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MODERN INTELLECTUAL TECHNOLOGIES IN COMPUTER TOMOGRAPHY

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ABSTRACT

In this article, an approach for the enhancement of computer tomography imaging by integrating modern technologies, including photon counting and dual-source CT, along with the application of the Ai-rad principles in Siemens Computer Tomography systems, is presented. The study proposes and empirically assesses the impact of these technologies on image quality and radiation safety. The architecture of dual-source CT and the photon-counting technique are explored, showcasing their role in improving diagnostic precision. Moreover, the article elaborates on the implementation of artificial intelligence through the Ai-rad approach, aimed at optimizing the scanning process and image analysis, while ensuring radiation doses are kept as low as reasonably achievable. The advantages of these contemporary technologies in addressing current challenges in CT imaging are presented. The results indicate that the synergy between advanced hardware capabilities and intelligent software algorithms leads to enhanced image resolution, reduced exposure to radiation, and overall improved clinical outcomes. This multi-faceted approach exemplifies the potential of modern innovations to set new benchmarks in the field of medical imaging.
Keywords: Dual-Source CT, Photon Counting, AI-Rad, myNeedle, Diagnostic Precision, Radiation Safety.

Introduction

Computer tomography (CT) stands as a testament to the extraordinary strides made at the intersection of medical science and technology. This non-invasive diagnostic technique has the unique capability to produce cross-sectional images of the body with a clarity that was once unimaginable. Using computer-processed combinations of X-ray measurements taken from different angles, CT scans create detailed pictures of structures inside the body, slicing through the traditional limitations of imaging [1].

Computer tomography (CT) is a vital instrument in the medical diagnostic arsenal, offering an unparalleled ability to peer inside the human body to detect and study disease. The versatility of CT imaging allows clinicians to confront a broad spectrum of ailments across various fields of medicine.

CT scans are crucial in detecting cerebral hemorrhages, skull fractures, brain tumors, and vascular malformations [2]. They're often the first line of imaging used to evaluate stroke patients, allowing for rapid intervention that can save brain function. CT angiography is utilized to assess the heart and blood vessels, providing clear images of the coronary arteries to detect blockages that can lead to heart attacks [3]. It can also identify aneurysms and calcifications within the

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vascular system, as well as evaluate the effectiveness of surgical interventions like stent placements. In the lungs, CT scans can reveal pulmonary embolisms, pneumonia, tuberculosis, fibrosis, and lung cancer [4]. They are particularly useful in the early detection of small lung nodules that may represent early-stage lung cancer.

Physicians rely on CT to diagnose appendicitis, diverticulitis, kidney stones, and gallstones. It's also instrumental in identifying and staging cancers of the liver, pancreas, kidneys, bladder, and reproductive organs [5]. CT is adept at visualizing bone fractures, particularly those involving complex structures such as the spine and pelvis [6]. It can also diagnose joint problems and bone diseases like osteoporosis by providing detailed images of bone density and structure. In cases of trauma, CT scans can quickly identify injuries to internal organs, supporting bones, and other structures, guiding the triage and treatment process [7]. CT imaging helps to locate abscesses and track the progress of severe infections, distinguishing between fluid accumulations that require drainage and solid masses that may need biopsy or further evaluation [8]. Chronic conditions like Crohn's disease or ulcerative colitis can be monitored using CT imaging to assess the extent of bowel inflammation and to check for complications like strictures or fistulas.

Computer tomography (CT) represents a blend of physical science, sophisticated technology, and advanced computational power [9]. At its core, a CT scanner produces a beam of X-rays that rotates around the patient. These X-rays are attenuated to different extents as they pass through the body's tissues, with denser structures like bone absorbing more X-rays than softer tissues like muscle or fat. The attenuated X-rays are captured by detectors, which then convert the varying intensities into electrical signals [10]. These signals are relayed to a Data Acquisition System (DAS) that digitizes them for image reconstruction. The image reconstruction process, traditionally based on algorithms such as filtered back projection (FBP) and increasingly by iterative methods, generates two-dimensional image slices from the raw data [1]. The reconstruction algorithms transform the raw data into a visual format by solving complex mathematical equations that map the X-ray beam's attenuation as it passes through the body. The mechanical components of the scanner, including the gantry and the patient table, are engineered for precise movement [2]. The gantry rotates smoothly around the patient while the patient table moves through the gantry in measured steps. The synchrony between the gantry's rotation and the table's advancement is meticulously controlled to ensure high-resolution images. Managing the radiation dose is another critical aspect, involving calculated modulation of the X-ray beam and careful timing to protect patient safety while obtaining the necessary diagnostic information [3]. This task is managed by automatic exposure control (AEC) systems that adjust the radiation dose based on the patient's size and the specific imaging task, ensuring the dose is kept as low as reasonably achievable. Supporting these processes is a powerful computer system tasked with handling and processing the high volume of data generated during a scan [4]. Software plays a pivotal role, not just in image reconstruction, but also in post-processing to enhance the visual clarity and diagnostic utility of the images. This includes the creation of three-dimensional reconstructions and other advanced visualization techniques. Once the images are processed, they are integrated into healthcare information systems, such as Picture Archiving and Communication Systems (PACS), which are essential for storing, retrieving, and distributing the digital images [5]. The seamless transfer and integration of this data require secure and efficient communication protocols to ensure they can be accessed by healthcare professionals within the clinical workflow. Routine calibration and maintenance are necessary to maintain the CT scanner's performance, which involves both mechanical servicing and software updates [6]. These procedures ensure that the system remains compliant with regulatory standards and continues to provide reliable and accurate images for clinical use. The operation of a CT scanner, therefore, is far from straightforward [7]. It encompasses a wide range of complex and precise processes, all geared towards converting X-ray measurements into detailed visual representations of the body's internal structures. These processes reflect the profound capabilities of CT scanning in modern medicine, offering an indispensable resource for clinicians in the diagnosis, treatment planning, and monitoring of various medical conditions [8].

Technologies in computer tomography

Let's look at the technologies used in Computer Tomography. Innovations have continuously advanced CT technology, enhancing the diagnostic capabilities while increasing speed and improving safety for patients. Dual-Source CT uses two sets of X-ray sources and detectors concurrently, which allows for faster scanning times, capable of capturing clear images of moving organs, like the heart, with reduced motion artifacts. This technology also enables better image quality and the potential to lower radiation doses.

Photon Counting is another breakthrough that distinguishes individual photons as they strike the detector, increasing the sensitivity and specificity of the scan. The resulting images are of higher resolution and contrast, offering the possibility to reduce the radiation dose because of the higher efficiency in X-ray detection. Artificial intelligence has found its place in CT imaging with AI-driven image reconstruction. AI algorithms process the raw data to reconstruct images, reducing noise and enhancing image quality at potentially lower doses. These sophisticated algorithms can also streamline the reconstruction process, making it faster and potentially allowing for real-time imaging capabilities. The myNeedle Companion technology by Siemens Healthineers is an innovative system designed to enhance CT-guided interventions. It integrates advanced features such as laser guidance, image fusion, and multiple needle path planning, along with a unique combination of hardware and software. This technology simplifies both simple and complex image-guided needle procedures, ensuring precision and efficiency in interventions while improving patient outcomes.

Diagnostic precision in CT imaging has reached new heights due to technological advancements, offering greater resolution and enabling clinicians to detect even the smallest of abnormalities. Early and accurate diagnosis is crucial for many conditions and can significantly influence treatment decisions and outcomes.

Radiation safety is a critical aspect of modern CT scanners, which now come with a range of built-in features designed to safeguard patients. These include automated exposure control systems that adjust the dose based on the specific examination and patient characteristics, as well as the use of protective measures to shield non-targeted areas from unnecessary exposure. Together, these technological advancements have made CT scans one of the most indispensable diagnostic tools in healthcare, providing detailed and precise images that allow for the early detection and management of various diseases. As technology progresses, it is likely that we will see even more improvements that will continue to enhance the utility and safety of CT imaging.

Dual-source computer tomography

Dual Source CT employs a setup with two X-ray tubes and detectors, operating concurrently within a single machine. As they orbit the patient, they collect data at double the rate of single-source machines. This dual mechanism has brought a new dimension to CT imaging, offering richer diagnostic data, mitigating issues related to the patient's heart rate, and maintaining or even lowering radiation doses.

The benefits of Dual Source technology when compared to conventional CT systems are numerous. It offers enhanced temporal resolution, thanks to its twin X-ray tubes and detectors operating independently. The improved temporal resolution is marked, with the latest systems achieving 75 milliseconds, just a fraction of a typical 0.28-second gantry rotation time. Furthermore, Dual Source CT provides a heightened level of precision. The technique known as "spectral dual energy imaging," which emanates radiation from two X-ray sources at different energy levels, permits a more nuanced differentiation between various substances in the body such as tissues, bones, and medical implants. This technology also excels in energy separation, leveraging the capability to apply distinct filters for each X-ray source. This aids in optimizing the energy spectrum for each beam. Another advantage is the integration of automated tube current modulation, which enhances the efficiency of Dual Source systems without compromising the speed of the gantry.

Siemens Healthineers, a prominent provider, has incorporated Dual Energy CT scanners that synchronize advanced scanning technology with automated processes to deliver seamless operations. Such Dual Energy spectral imaging is crucial in aiding physicians with precise diagnostics and informed decision-making, rooted in the exclusive insights that Dual Energy provides (Fig. 1).

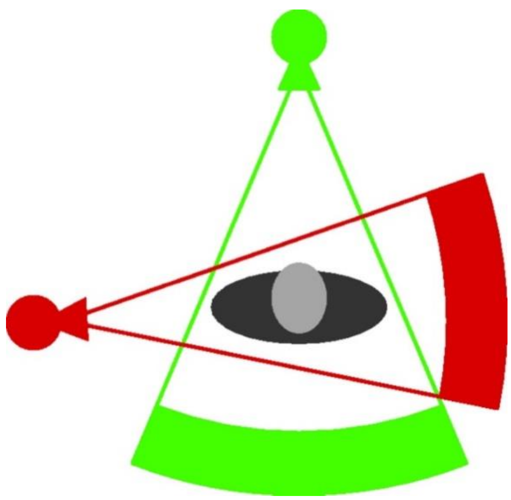

Figure 1. Dual Source technology in Computer Tomography

While visuals that directly compare Dual Source technology with traditional CT scans may not be readily available, the superiority of Dual Source technology is evident. It stands out for its advanced temporal resolution, precision, optimal energy separation, and sophisticated automation of tube current modulation. detection and management of various diseases. As technology progresses, it is likely that we will see even. Dual Source CT technology represents a significant leap in medical imaging, offering superior temporal resolution and precision compared to traditional CT systems. It excels in differentiating various body substances through spectral dual energy imaging and optimizes efficiency with automated tube current modulation. These advancements aid in precise diagnostics and informed medical decision-making, marking a new era in disease detection and management.

Photon counting technology

Siemens Healthineers has introduced a groundbreaking photon-counting CT device, the Naeotom Alpha, representing a significant leap in the field of medical imaging. Photon counting CT represents a departure from traditional CT imaging by using detectors that can count individual photons of X-ray, allowing for the creation of highly detailed and clear three-dimensional images from the data obtained through a patient's body. This innovative device surpasses traditional imaging benchmarks across key image quality parameters such as spatial resolution, contrast resolution, and the capability to capture high-quality images at reduced doses. The Naeotom Alpha delivers high spatial resolution CT data free from electronic noise, providing a superior contrast-to-noise ratio, all achieved with a lower radiation dose and enriched with intrinsic spectral information.

On the Siemens Healthineers website, there are comparative images showcasing how photon counting technology distinguishes itself from conventional CT imaging. These images illustrate the stark improvements in terms of spatial and contrast resolution, as well as the capacity for low-dose imaging. They also demonstrate the technology's ability to differentiate between various materials more precisely in the body, enhancing the precision of diagnostics.

In essence, photon counting technology reshapes the expectations of medical imaging, with Siemens Healthineers at the forefront through their Naeotom Alpha device. This technology enables the extraction of more detailed information from CT scans by singularly identifying X-ray photons to produce three-dimensional images of unprecedented detail and clarity. The comparative visuals available underline the enhancements in image quality, emphasizing how photon counting technology achieves these advancements while simultaneously reducing exposure to radiation (Diagram 1).

The flowchart describes an algorithm for a photon counting detector (PCD) used in CT scans. The PCD emits a signal for each photon detected, marking the beginning of the imaging process. This detector directly converts X-rays into electrical signals, bypassing the limitations of traditional detectors. It has the unique ability to measure each X-ray photon against multiple energy thresholds, providing intrinsic spectral sensitivity and enhanced image detail. Constructed from a semiconducting material, the PCD facilitates the direct conversion of X-ray photons to electrical signals. This allows for individual photon counting, leading to more accurate signals and clearer images. Additionally, the energy level of each photon is quantified, yielding high-quality spectral information for improved tissue characterization. The technology's potential for various applications is generating excitement in the medical imaging industry. Furthermore, advancements in detector technology, coupled with AI algorithms and imaging reconstruction techniques, are expected to continue revolutionizing CT imaging and precision medicine.

Siemens Healthineers' Naeotom Alpha marks a revolutionary advancement in medical imaging with its photon-counting CT technology, offering unprecedented image clarity and precision while reducing radiation exposure. This technology, showcased through striking comparative visuals, significantly enhances diagnostic accuracy by precisely differentiating materials in the body and improving tissue characterization. It represents a major leap forward in precision medicine, fueled by ongoing innovations in detector technology and AI algorithms.

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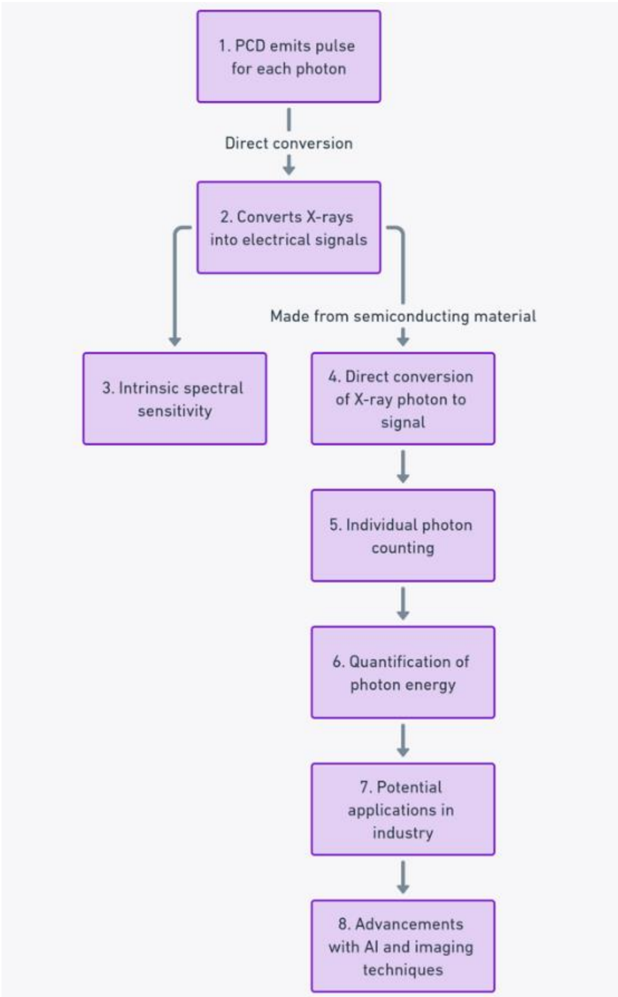

Diagram 1. Photon counting technology's working principle in algorithm.

Myneedle companion technology

The myNeedle Companion, developed by Siemens Healthineers, is a technological aid utilized in computer tomography (CT) to assist in the planning and execution of CT-guided interventional procedures. This tool is crafted to bolster the confidence of healthcare professionals by offering real-time guidance during these procedures. It is seamlessly integrated with the SOMATOM X.ceed, a high-end single-source CT scanner known for its superior image quality and low-dose imaging capabilities. This integration ensures smooth communication between the scanner and the myNeedle Companion software, facilitating real-time visualization and assistance during interventions.

Additionally, myNeedle Companion is a component of the broader myExam Companion interface, which leverages artificial intelligence to simplify and standardize the use of the scanner across different users. The myExam Companion interface intelligently directs operators throughout CT scan procedures, aiming for consistent and reliable results.

The combination of myNeedle Companion with the SOMATOM X.ceed scanner enhances the ability of medical professionals to conduct various interventional procedures, such as biopsies, drainages, and ablations, with increased accuracy and efficiency. The scanner's rapid rotation and scanning speeds, along with its high resolution, contribute to better-informed decision-making during interventions (Diagram 2).

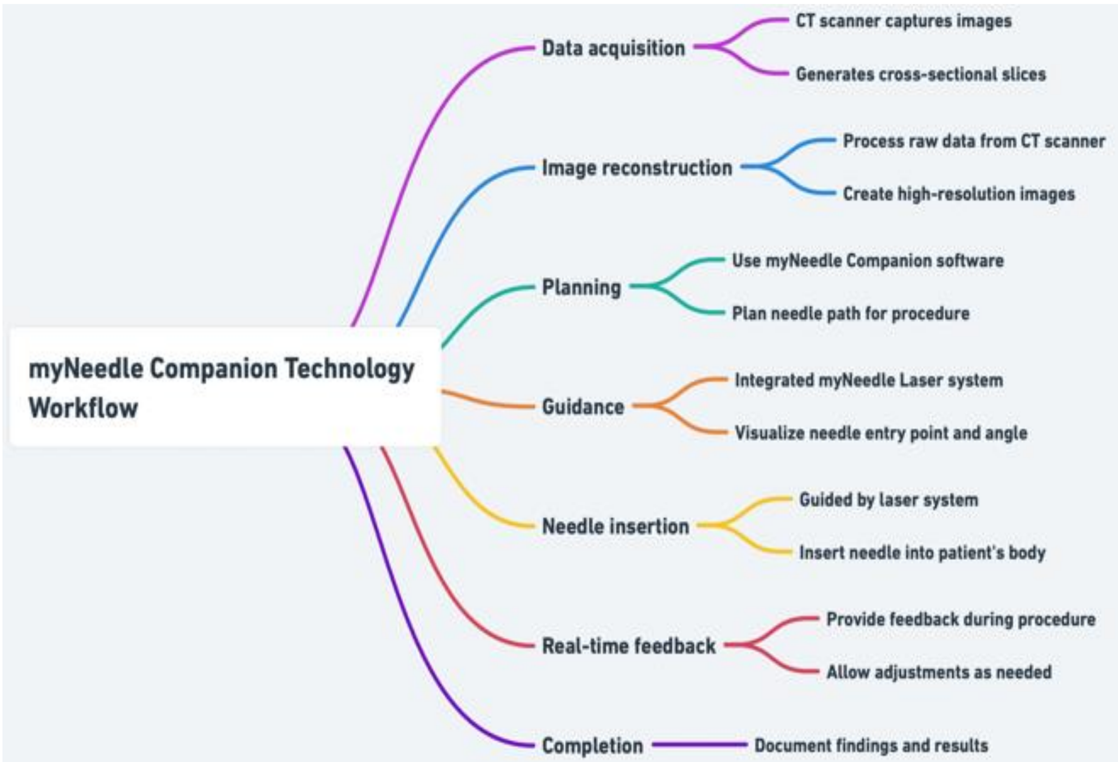

Diagram 2. myNeedle Companion technology workflow.

The mind map for the myNeedle Companion technology workflow begins with the data acquisition stage, where a CT scanner captures images of the patient's body, generating cross-sectional slices for detailed internal views. This is followed by image reconstruction, where the raw data from the CT scanner is processed to create high-resolution images of the patient's anatomy, crucial for the next stages. Next, the planning stage involves using the myNeedle Companion software to plan the needle path for the interventional procedure, ensuring precision. The guidance stage then comes into play, utilizing the integrated myNeedle Laser guidance system to visualize the needle's entry point and angle, aiding the healthcare professional in accurate placement. The needle insertion step is guided by the laser system, where the healthcare professional inserts the needle into the patient's body, a critical step that benefits from the precision offered by the guidance system. During the procedure, the myNeedle Companion technology provides real-time feedback, allowing the healthcare professional to make necessary adjustments, enhancing the procedure's effectiveness and safety.

Upon completion of the procedure, the technology is used to document the findings and results, vital for patient records and future reference. This comprehensive workflow enhances the efficiency, accuracy, and safety of interventional radiology procedures using the myNeedle Companion technology. The myNeedle Companion, in conjunction with Siemens Healthineers'

SOMATOM X.ceed CT scanner, marks a breakthrough in precision and safety for CT-guided interventional procedures. By providing real-time guidance and integrating artificial intelligence, this technology significantly enhances the accuracy and efficiency of medical interventions. Ultimately, it represents a pivotal step in advancing patient care and elevating the standard of medical imaging practices.

AI-RAD companion

The AI-Rad Companion is a software developed by Siemens Healthineers that uses artificial intelligence to assist radiologists with CT imaging. It helps to speed up and refine the diagnosis process and the documentation of findings. The software is equipped with advanced algorithms that are updated and distributed to users upon release. The platform offers several advantages, such as the ability to automatically detect and measure various structures in CT images, which aids in providing detailed clinical images with measurements of important parameters. It integrates smoothly into existing workflows, enhancing radiologists' efficiency and productivity. The AI-Rad Companion also delivers real-time analysis and reporting, which contributes to high-quality diagnostic decisions. It supports a variety of applications for different CT imaging needs, such as chest CT and organ-specific imaging, and is useful in radiation therapy planning. Additionally, it can be combined with other Siemens Healthineers technologies, like the SOMATOM X.ceed CT scanner and Medicalis systems, to improve overall imaging processes and patient care. The AI-Rad Companion is part of Siemens Healthineers' initiative to transform radiology by making CT image interpretation and reporting more efficient, accurate, and standardized.

The flowchart describes an algorithm integrating CT imaging with the AI-Rad Companion, a tool enhancing radiological analysis. The process starts with a CT scanner capturing detailed cross-sectional images of the patient's body. These raw data are then processed into high-resolution images, providing a clear view of the patient's anatomy. At this stage, the AI-Rad Companion uses advanced algorithms to automatically analyze the CT images, identifying and measuring various anatomical structures, including organs and lesions. The platform further enhances the clinical images by highlighting critical areas and quantifying relevant parameters, such as tumor size or blood vessel stenosis. Once the analysis is complete, the AI-Rad Companion promptly provides the results to the radiologist for review and potential inclusion in the final report. This system is designed to seamlessly integrate into the existing workflow, supporting radiologists by improving productivity and easing their daily workload. The AI-Rad Companion by Siemens Healthineers dramatically transforms radiological diagnostics by integrating AI into CT imaging, enhancing accuracy and efficiency. This innovative software streamlines radiologists' workflows and improves patient care, embodying the cutting-edge of medical imaging technology (Diagram 3).

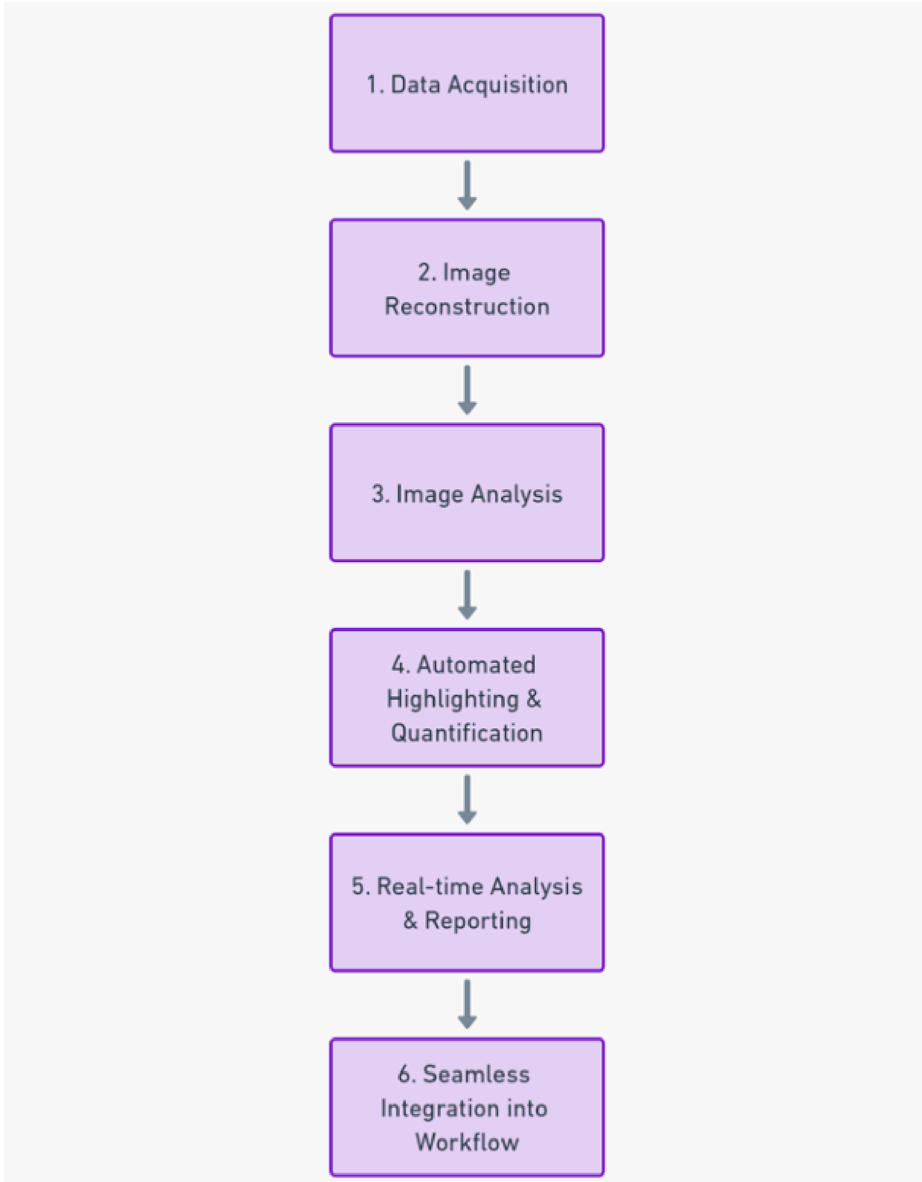

Diagram 3. AI-Rad technology's algorithm of working principle

Siemens Healthineers has been at the forefront of revolutionary advancements in CT imaging technologies, each contributing significantly to the field of medical diagnostics and patient care. The Dual Source CT technology, with its dual X-ray tubes and detectors, offers a remarkable improvement in temporal resolution and spectral imaging, enabling more precise diagnostics and substance differentiation in the body. This is further complemented by the Naeotom Alpha's photon-counting CT technology, which brings unprecedented image quality, enhanced spatial and contrast resolution, and reduced radiation exposure, setting a new benchmark in medical imaging.
The integration of artificial intelligence in radiological imaging, as seen in the AI-Rad Companion, marks another leap forward. This AI-driven software automates the detection and measurement of structures, fitting seamlessly into existing workflows and significantly enhancing

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diagnostic efficiency and accuracy. Similarly, the myNeedle Companion, used in conjunction with the SOMATOM X.ceed CT scanner, revolutionizes CT-guided interventions by providing real-time guidance and feedback, increasing precision and safety in procedures like biopsies and ablations. These technologies by Siemens Healthineers underline new opportunities in CT imaging, showcasing how advancements in technology, AI integration, and innovative imaging techniques can transform medical diagnostics, improve patient care, and promise even more significant developments in the future. [9,10]

Conclusions

The integration of advanced computer technologies in medicine, especially in computer tomography (CT), has significantly transformed medical diagnostics. Innovations like Dual Source CT, Photon Counting, the myNeedle Companion, and AI-Rad Companion, primarily developed by Siemens Healthineers, have revolutionized medical imaging. These technologies have enhanced the precision, efficiency, and safety of diagnostic procedures. Dual Source CT offers improved resolution and speed, while Photon Counting technology provides higher quality images with lower radiation doses. The myNeedle Companion aids in precise, real-time guidance for CT-guided interventions, and the AI-Rad Companion leverages artificial intelligence to streamline radiological analysis and reporting. Collectively, these advancements underscore the critical role of computer technology in advancing medical diagnostics, improving patient care, and paving the way for future innovations in healthcare.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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HARNESSING MEDICAL INNOVATION: THE IMPACT OF ROBOTIC SIMULATORS AND VIRTUAL REALITY (VR) IN IMPROVING THE QUALITY OF MEDICAL EDUCATION

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ABSTRACT

Medical education stands at the cusp of a transformative revolution, driven by the integration of cutting-edge technology. This article explores the profound impact of robotic simulators and virtual reality (VR) in enhancing the quality of medical education. Traditional medical education methods have their limitations, often constrained by a lack of hands-on experience and patient safety concerns. In response to these challenges, robotic simulators and VR have emerged as powerful tools, offering realistic, immersive, and safe learning environments for aspiring medical professionals. We delve into the world of robotic simulators, dissecting their mechanisms and outlining their versatile applications across various medical disciplines. These simulators provide aspiring medical professionals with hands-on experience, bridging the gap between theory and practice while eliminating the risks associated with real patient interactions. In the realm of virtual reality, we explore the innovative applications of VR in medical education. VR's immersive environments offer a unique platform for medical students and professionals to practice, learn, and refine their skills, all within a controlled and safe setting. We present case studies and learning activities that illustrate the efficacy of these technologies in teaching safety competencies, reducing medical errors, and improving patient outcomes.
Keywords: Simulation-Based Medical Education, Virtual Reality, Robotic Simulators, Artificial Intelligence, Patient Safety, Healthcare Technology, Healthcare Innovation, Medical Simulation, Education Technology.

Introduction

In the evolving landscape of healthcare, patient safety emerges as a paramount concern, necessitating a reevaluation of educational methodologies and the integration of advanced technologies [1]. The complexity of modern healthcare systems poses significant risks to patient safety, drawing attention to the medical-legal liabilities faced by healthcare professionals. This has led to the incorporation of patient safety into healthcare curricula, mirroring strategies employed in fields like aviation, where simulation plays a crucial role in preparing teams for real-world challenges [1]. Simulation-based medical education (SBME) offers a unique opportunity for healthcare teams to hone their skills and navigate complex scenarios in a controlled environment. This approach is pivotal in reducing errors and enhancing patient care. In simulated settings, mistakes transform into learning opportunities, fostering competencies that significantly lower the incidence of adverse outcomes. İn this article delves into the methodologies of simulation-based education, exploring international standards in clinical simulation and the intricacies of human factors in patient safety [2]. It underscores the evolving role of educators and the challenges in training healthcare professionals, particularly physicians and nurses, who are at the forefront of patient care [2]. The urgency for a paradigm shift in medical training is universally acknowledged. The core of clinical competence lies in the effective management of critical events, necessitating a cohesive team of healthcare providers (HCPs) with a unified approach. Traditional didactic medical teaching is giving way to problem-based learning (PBL) and repeated protocol-based training, aiming to minimize errors in emergency situations. This shift is crucial in environments like battlefields, highways, or emergency rooms, where rapid and accurate response is critical [3]. The increasing perception of health as an industry has brought greater emphasis on accountability, transparency, and quality assurance, demanding more stringent professional regulation and monitoring of healthcare delivery at all levels [3]ю However, the availability of suitable patients for training and the ethical implications of delaying treatment for educational purposes present challenges. This has spurred the exploration of new methods like SBME, which seeks to instill the correct attitude and skills in HCPs for competently handling real-life critical situations without compromising patient rights [4]. The recent shift towards technology in medical education, accelerated by the COVID-19 pandemic, marks a significant transition from traditional face-to-face teaching to digital education. Social distancing measures necessitated by the pandemic have catalyzed the adoption of digital technologies in medical training. Digital education, encompassing a wide array of modalities from e-books to virtual reality (VR), offers innovative solutions to the challenges posed by reduced physical interactions [4].

VR has emerged as a powerful tool in medical education. Defined as a technology that creates a 3D environment for interactive learning, VR encompasses various applications, including surgical simulators, 3D anatomical models, virtual dissection tables, and mobile VR [5] These tools have proven effective in developing technical skills, such as those required for endoscopic surgery, and in providing immersive experiences for understanding complex anatomical structures. Moreover, VR's application extends beyond technical competencies to soft skills like empathy and communication, often using avatars in virtual environments to simulate patient interactions [5]. The integration of VR into medical education represents a significant advancement, offering diverse applications from surgical training to the development of 3D visualization skills and emergency response training. The wide range of skills that can be taught using VR, combined with its accessibility and flexibility, positions it as a transformative tool in the realm of medical education [5]. In conclusion, the combined approach of SBME and VR in medical education is a testament to the evolving landscape of healthcare training. It reflects a commitment to enhancing patient safety, improving professional competencies, and embracing innovative educational methodologies [6]. This chapter aims to contribute to the knowledge in the fields of clinical simulation, patient safety, and safe nursing care, emphasizing the necessity for clinical teams and healthcare students to acquire these competencies in today's challenging healthcare environment [6].

Technology in medıcal educatıon

The infusion of technology into medical education has become indispensable, particularly in the ever-evolving landscape of healthcare. In the intricate field of medicine, where challenges are multifaceted and the demand for proficient healthcare professionals is ever-growing, technology stands as a critical enabler of innovative pedagogical approaches.

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In addressing the complexities of medical training, robotic simulators emerge as transformative tools. They provide a secure and controlled environment for medical students and professionals to hone their skills across a spectrum of procedures. In the context of the challenging and high-stakes field of medicine, where precision and expertise are paramount, robotic simulators offer a unique advantage. Aspiring healthcare practitioners can engage in realistic simulations, from surgical procedures to specialized interventions, allowing for a meticulous and error-tolerant learning process before encountering real patients.

Virtual Reality (VR) complements this paradigm shift by immersing medical learners in simulated environments mirroring actual clinical scenarios. This three-dimensional, interactive experience transcends traditional teaching methods, enabling users to navigate and grapple with the intricacies of medical challenges in a risk-free setting. Particularly in the difficult fields of medicine, where decision-making is complex and the margin for error is minimal, VR provides a transformative platform for honing critical skills.

Beyond simulated practices, technology facilitates the exploration of intricate anatomical structures and medical concepts through 3D modeling and virtual dissection tables. These tools not only enhance understanding but also bridge the gap between theoretical knowledge and practical application. In the contemporary era of digital education, technology ensures the continuity of medical learning, an aspect underscored by the imperative imposed by the COVID-19 pandemic. This transition, from e-books to mobile learning and other digital modalities, underscores the adaptability and resilience of medical education in difficult times. In essence, technology has become an indispensable ally in the difficult field of medicine, offering innovative solutions to bridge educational gaps and prepare healthcare professionals for the intricacies and challenges of modern healthcare. This section explores the multifaceted role of technology in reshaping medical education, acknowledging its pivotal importance in navigating the complexities inherent in contemporary medical practice. The evolving landscape of hospital patient profiles and heightened societal expectations have intensified medical accountability, leaving minimal room for errors. The Heinrich's Model of Accidents, originally depicting major injuries following a cascade of minor injuries and no-injury accidents, is mirrored in medical accidents. Heinrich's ratio, often cited in medical errors, illustrates that for every 600 non-reportable incidents, there are 30 reportable incidents, 10 accidents, and one fatal accident. In response to this heightened accountability, safety measures must be proactively implemented to prevent both minor incidents and severe accidents. Medical errors, following a similar pattern, necessitate a comprehensive approach to reduce incidents and subsequently accidents. Notably, physicians have been identified as lacking in clinical skills, problem-solving, and the application of information to patient care, especially in unexpected situations, despite possessing a solid foundational knowledge. To address these challenges, medical education transitioned to a system-based core curriculum with learning objectives spanning cognitive, psychomotor, and affective domains. The aim is to instill persistent behavioral changes, acquired skills, and attitudes, emphasizing Problem-Based Learning (PBL). However, critical and uncommon events often cannot be effectively taught on real patients, presenting ethical and legal challenges regarding patient consent for participation in teaching programs. İn figure 2.1 shown Modified Heinrich ratio for medical errors.

Figure 2.1. Modified Heinrich ratio for medical errors.

Enter simulation education a transformative approach that mitigates these challenges. Simulation provides a controlled and risk-free environment where healthcare professionals can practice and refine their skills, enhancing their preparedness for unexpected situations. Simulation education has proven effective in reducing medical errors, ultimately contributing to a decrease in fatalities. This approach not only addresses deficiencies in clinical skills but also aligns with ethical considerations by ensuring patient consent is genuine and not prompted by fear or inducements.
In summary, simulation education emerges as a pivotal strategy in the contemporary medical landscape, reducing mortality rates associated with medical errors and enhancing the overall competency of healthcare professionals in challenging and critical scenarios.

Robotıc sımulators
Healthcare is undergoing a transformative shift towards a proactive model guided by the principles of medicine a discipline characterized by predictiveness, personalization, prevention, participation, and precision. This patient-centric approach is heavily reliant on cutting-edge technologies like artificial intelligence (AI) and robotics, playing crucial roles in diagnosis, decision-making, and treatment. This article delves into the evolving landscape, showcasing the pivotal contributions of AI and robotic systems in this paradigm shift through various illustrative use cases.
Our exploration categorizes these systems along several dimensions, considering factors such as system type, degree of autonomy, care setting application, and specific areas of implementation. Noteworthy advancements have been made, exemplified by the successful prediction of sepsis or

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cardiovascular risk, continuous monitoring of vital parameters in intensive care units, and the emergence of home care robots. Despite these strides, the integration of AI and robotics into real-world healthcare settings faces limited adoption.

Overcoming barriers to adoption requires a comprehensive approach. Safety, security, privacy, and ethical considerations must be addressed to ensure the responsible deployment of these technologies. The detection and elimination of biases that may lead to harmful or unfair clinical decisions are paramount, as is the establishment of trust and societal acceptance of AI in healthcare. This article explores the transformative role of AI and robotics in the healthcare evolution, emphasizing the need to navigate challenges and pave the way for their widespread implementation.

The realm of AI and robotic systems in healthcare can be systematically classified based on three key dimensions use, task, and technology (refer to Figure 1). In the "use" dimension, a finer distinction can be made by considering the application area or the specific care setting. The "task" dimension revolves around the level of autonomy exhibited by the system. Lastly, the "technology" dimension takes into account both the degree of intrusion into a patient and the type of system employed. It's important to note that this classification, illustrated in Figure 1, represents a simplified and aggregated framework. For instance, AI algorithms themselves will not be physically situated within a patient. This structured classification system provides a clear and organized framework for understanding the diverse landscape of AI and robotic systems in healthcare. In figure 2.2. shown Categorization of systems based on AI and robotics in health care.

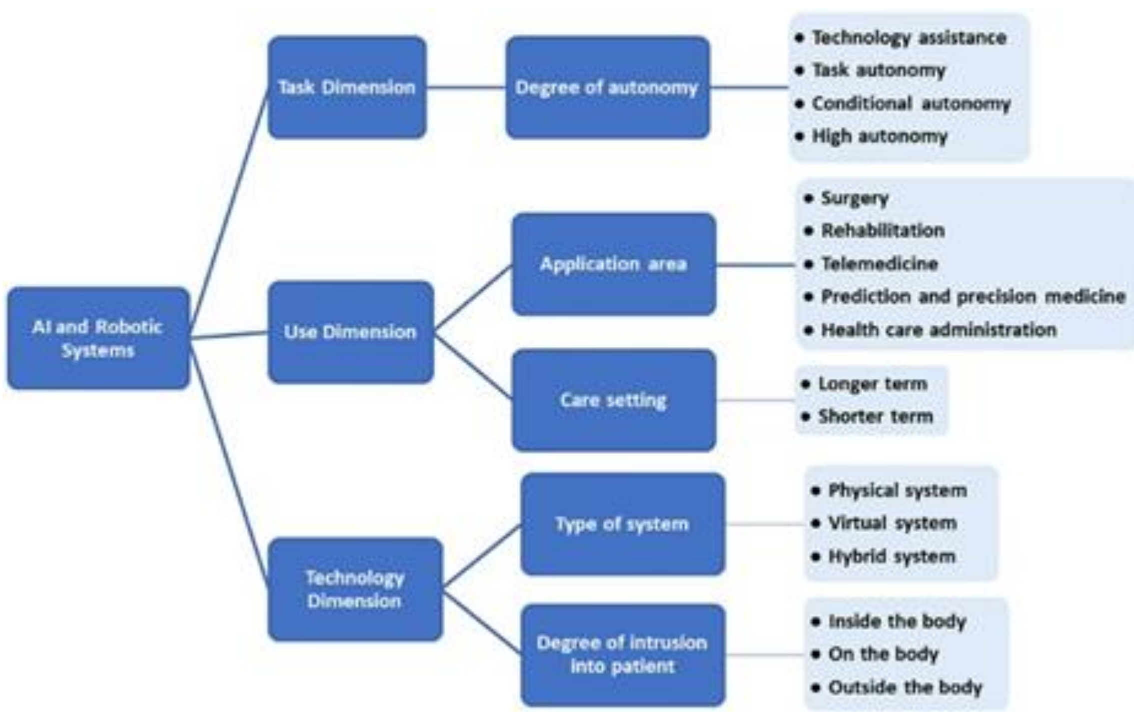

Figure 2.2. Categorization of systems based on AI and robotics in health care

Classification Based on System Type

The categorization of these systems can be delineated into two primary types: virtual and physical.

• Virtual Systems: These are aligned with AI applications and encompass a spectrum ranging from electronic health record (EHR) systems and text/data mining applications to systems dedicated to supporting treatment decisions.

• Physical Systems: This category is associated with robotics and includes a diverse range of entities such as robots aiding in surgical procedures, smart prostheses designed for individuals with disabilities, and physical aids tailored for elderly care.

Additionally, there exists a hybrid category amalgamating AI and robotics, featuring systems like social robots engaging with users or microrobots designed for drug delivery within the body. All these systems leverage enabling technologies rooted in data and algorithms (refer to Figure 2). For instance, a robotic system may gather data from various sensors—visual, physical, auditory, or chemical. The robot's processor then manipulates, analyzes, and interprets this data. Actuators within the system facilitate diverse functions, encompassing visual, physical, auditory, or chemical responses. This comprehensive classification underscores the diverse nature of systems in healthcare, highlighting the intricate interplay between AI, robotics, and enabling technologies. In figure 2.3. shown types of AI-based systems and enabling Technologies.

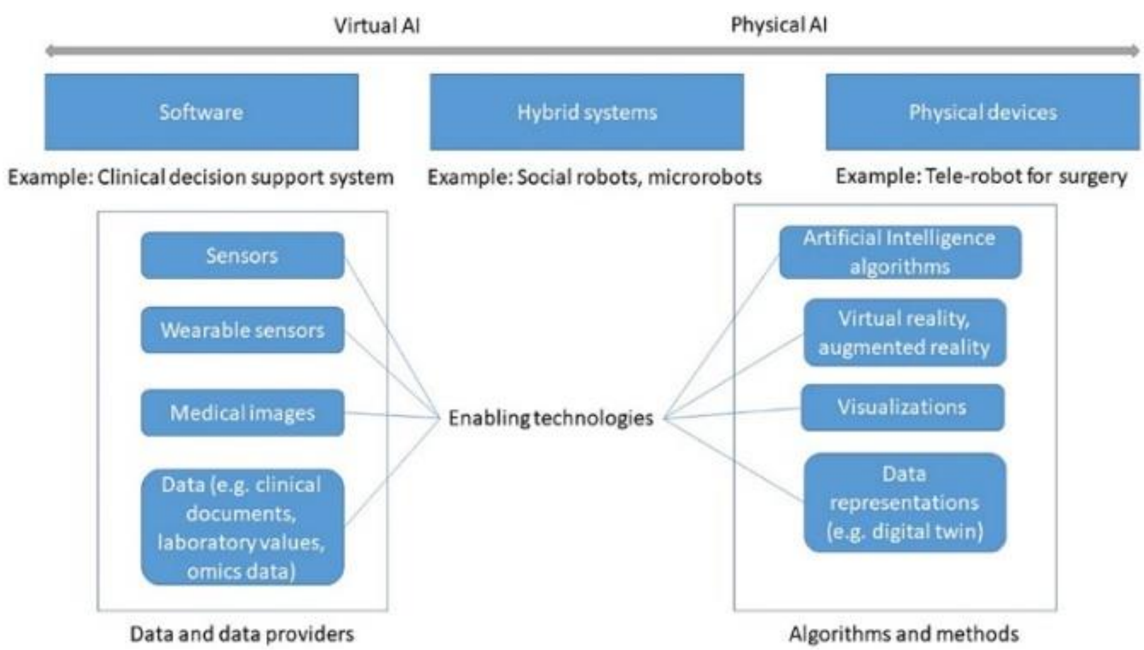

Figure 2.3. Types of AI-based systems and enabling technologies.

Data

Two essential categories of data are integral to the functioning of AI systems: data that encapsulates the knowledge and experience acquired by the system through diagnosis and treatment, often facilitated by machine learning; and individual patient data, which AI can scrutinize and analyze to generate informed recommendations. This data can be sourced from physical sensors (both wearable and non-wearable), biosensors [7], or other information systems like Electronic Health Record (EHR) applications. Digital biomarkers, derived from collected data, offer a foundation for AI analysis and interpretation. AI employs specialized algorithms and methodologies for data analysis, reasoning, and prediction. It encompasses various subfields, including machine learning (comprising supervised, unsupervised, and reinforcement learning), machine vision, natural language processing (NLP), and more. NLP empowers computers to comprehend and process natural language, whether written or spoken, while machine vision or computer vision extracts information from images. Despite the absence of a definitive taxonomy for AI, several standards bodies are actively addressing this classification challenge.

AI methodologies can be broadly categorized into knowledge-based AI and data-driven AI [8].

• Knowledge-based AI models human knowledge by soliciting input from experts, capturing the concepts and knowledge they employ to solve problems. This knowledge is then formalized within software—an approach closely aligned with the original expert systems of the 1970s.

• Data-driven AI, on the other hand, starts with extensive datasets, processed through machine learning methods to discern patterns applicable for predictive purposes. Utilizing virtual or augmented reality, along with various visualization techniques, aids in presenting and exploring data, facilitating a deeper understanding of relationships among relevant data points crucial for diagnosis.

2.2. VR ın medıcal educatıon

In the present day, virtual reality (VR) has gained widespread recognition owing to its diverse applications across various domains. Particularly notable is its role in enhancing 3D visualization for educational purposes, providing an innovative avenue for interactive engagement with the patient's soft tissue. This technology has found considerable traction in the medical field, garnering increased acceptance among the masses. Both students and medical professionals can now virtually explore the intricacies of the human body, leveraging VR headsets to immerse themselves in holographic images, thereby enhancing their learning experience.

The popularity of VR technology continues to soar with advancements in both hardware and software. Its utility extends to surgical procedures, where it facilitates harm-free operations. In emergency scenarios, Intensive Care Unit staff can efficiently practice procedures within tight timeframes, offering a valuable solution for studying and addressing challenging medical issues. The application of VR technology contributes to building trust and aiding in informed decision-making, particularly in the realm of neuropsychological treatments.

Moreover, VR proves to be a valuable tool in pain management, effectively reducing discomfort during treatment. Its applications are expanding to address phobias, allowing patients to confront their fears in a virtual environment. The technology offers a sophisticated platform for virtual surgery, enabling doctors to practice and refine their skills in a risk-free setting, ultimately minimizing errors during actual surgeries. The healthcare industry is increasingly embracing VR technology to enhance patient treatment, providing a safe environment for learning new skills. This includes training new medical professionals in anatomy, surgical practices, and infection control, leading to more confident and skillful healthcare practitioners. The contemporary benefits of virtual reality in the medical field are illustrated in Figure 1.

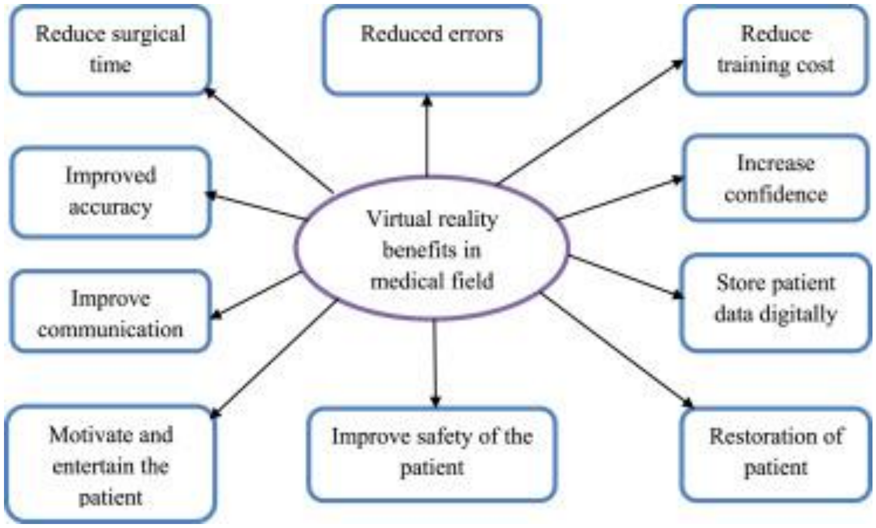

Figure 2.4. Virtual reality benefits in the medical field

The adoption process of virtual reality (VR) in the medical sector involves leveraging its applications to accelerate training procedures devoid of fear and risk. Its extensive use spans a wide array of diseases, significantly enhancing the performance of the medical field. This technology proves to be both useful and practical, contributing to heightened satisfaction levels among trainees and patients alike. The systematic application of VR in the medical domain presents a viable solution, as depicted in Figure 2.

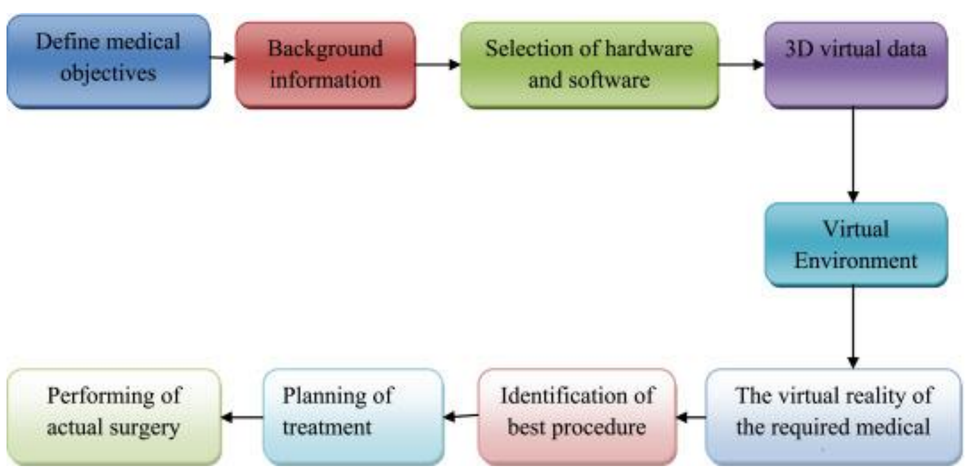

Figure 2.5. Process used for VR in the medical field

Virtual reality (VR) stands as a crucial technology within the development process, relying on tailored and sophisticated software and hardware. The initial step involves delineating the precise objective for the necessary treatment and gathering pertinent background information. Diverse hardware and software tools are then employed to generate 3D virtual data, crafting a comprehensive 3D virtual environment. The virtual representation of the required medical data is meticulously created and defined through optimal procedures. This approach proves instrumental

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in planning the treatment, ultimately aiding in the execution of the actual surgery.

Learnıng actıvıtıes to teach safety competencıes wıth sımulatıon

Incorporating simulation-based learning activities into medical education is instrumental in cultivating safety competencies among healthcare professionals. The immersive nature of simulation enables learners to engage in realistic scenarios, fostering hands-on experience in a controlled environment. Here are key learning activities designed to impart safety competencies through simulation:

1.Scenario-Based Simulations: Develop realistic scenarios that mimic challenging and critical situations encountered in healthcare settings. Integrate safety-focused challenges within the scenarios, requiring learners to navigate and apply safety protocols effectively.

Provide immediate feedback and debriefing sessions to discuss decision-making processes and safety measures.

2. Team-Based Training:Emphasize the importance of effective communication and collaboration within healthcare teams during simulation exercises. Create scenarios that necessitate teamwork to address safety challenges, promoting a culture of shared responsibility for patient well-being. Debrief as a team to analyze communication dynamics and identify areas for improvement.

3.Emergency Response Simulations: Simulate emergency situations, such as cardiac arrests or trauma cases, to enhance competencies in rapid and coordinated responses. Integrate safety protocols and emphasize the significance of maintaining a calm and organized approach during crises. Evaluate individual and team performances to reinforce safety measures in high-stress scenarios.

4.Interprofessional Simulations: Facilitate simulations involving various healthcare disciplines to enhance interdisciplinary collaboration. Emphasize the importance of understanding each professional's role in ensuring patient safety. Encourage open communication and mutual respect among different healthcare professionals during the simulation.

5.Technology Integration: Utilize advanced technologies like virtual reality (VR) and augmented reality (AR) to create realistic and immersive simulation environments. Integrate technology to simulate complex procedures and equipment handling, emphasizing safety protocols and precautions. Provide opportunities for learners to interact with cutting-edge medical technologies in a risk-free setting.

6.Patient-Centered Simulations: Develop simulations that focus on patient safety, considering aspects such as medication administration, infection control, and fall prevention. Emphasize empathetic communication and patient engagement to instill a patient-centered approach to safety. Analyze and discuss simulation outcomes to refine practices that prioritize patient well-being.

7.Continuous Improvement Exercises: Implement regular simulation sessions to reinforce safety competencies and address evolving challenges in healthcare. Encourage reflective practice among learners, prompting them to identify areas for personal and collective improvement. Establish a culture of continuous learning and adaptation to enhance overall safety awareness. By integrating these learning activities, simulation-based education becomes a dynamic platform for instilling safety competencies, preparing healthcare professionals to navigate the complexities of real-world patient care with a steadfast commitment to safety and excellence. Below, we present the constructed model based on the units overseeing the integration projects of simulation. This is noteworthy, particularly because the initial unit is an outcome of a curricular initiative.

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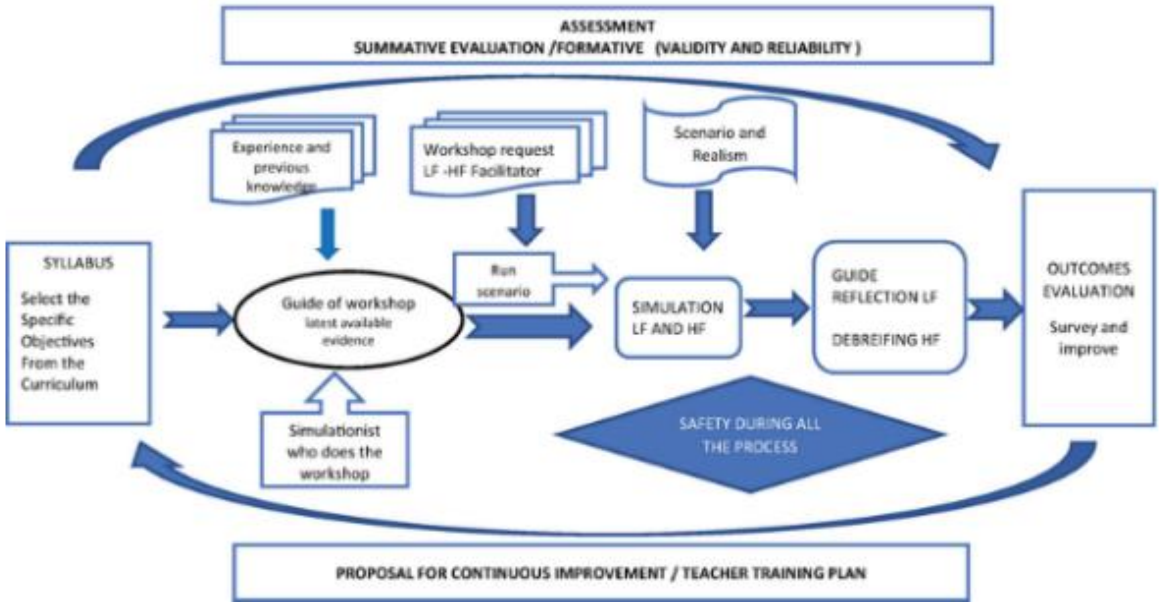

Figure 2.6. Education frame simulation based education.

Conclusıon

In the dynamic landscape of healthcare, the convergence of Simulation-Based Medical Education (SBME) and Virtual Reality (VR) with advanced technologies like Robotic Simulators represents a groundbreaking shift. These innovations address the challenges of medical training, enhancing skill development in a controlled environment.

Technology, including AI and robotics, contributes to predictive diagnostics and personalized treatments, although widespread adoption faces hurdles like safety and ethical considerations. Simulation-based learning activities, augmented by VR and Augmented Reality (AR), play a crucial role in cultivating safety competencies among healthcare professionals.

The chapters on SBME, VR in Medical Education, and AI and robotics integration underscore the industry's commitment to adapting to transformative tools, emphasizing patient safety, continuous improvement, and interdisciplinary collaboration. In embracing these innovations, healthcare education aligns with the evolving demands of the field, ensuring professionals are adept and prepared in the complex realm of medicine.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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cooperation and openness have significantly contributed to the depth and richness of the research findings.

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RESEARCH ON THE VARIATIONAL METHOD OF PROCESSING SIGNAL VARIABILITY OF HEART RHYTHM

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ABSTRACT

This article consists of an introductory section, a materials and methods section, an analysis focusing on heart rate variability, a conclusion, and a reference list.
This article discusses the variational method of processing heart rate variability signals for diagnosing the state of the cardiovascular system. The variational pulsemetry method is based on the analysis of the statistical distribution of R-R intervals, which are considered as random variables.
The analysis of heart rate variability is provided, along with examples of rhythmograms, histograms, and scattergrams. By analyzing the data, information is obtained about the influence of heart function on the autonomic nervous system, as well as various humoral and reflex characteristics.
An analysis was conducted of pulsating changes in the waveform of arterial pressure, to get an idea about the state of the cardiovascular system and General health. By analyzing the obtained information about the influence of the heart on the autonomic nervous system, as well as the number of humoral and reflex characteristics.
Keywords: Variational pulsemetry, adaptation, cardiovascular system, pulsegram, cardio interval, scattergraph.

Introduction

One of the main methods for analyzing electrocardiogram (ECG) is the analysis of heart rate variability (also known as cardiointervalography or rhythmography) - this study investigates the variability of the sequence of cardiac cycles. The duration of consecutive cardiocycles of a normal rhythm changes over time. The magnitude and rate of these changes determine the values of heart rate variability indices. Analysis of heart rate intervals allows determining parameters of heart rhythm, heart rate variability, and other characteristics related to the functional state of the heart and blood vessels [1].
Methods for assessing the functional condition of the cardiovascular system based on heart rate intervals include various approaches and algorithms for data processing. They rely on the mathematical analysis of temporal and frequency characteristics of heart rate intervals, as well as the study of their changes in response to various physiological and pathological conditions.

Material and Methods

The purpose of this study is to review the variational method of assessing the functional condition of the cardiovascular system.

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Noninvasive methods for assessing the functional condition of the cardiovascular system based on cardiointervals:

1. Analysis of heart rate variability
2. Classification of methods for assessing the functional condition of the cardiovascular system
3. HRV signal processing by variational methods

The term "heart rate variability" is widely used to describe changes in R-R intervals or heart rate. When studying heart rate variability, the complex processes of interaction of various circuits that regulate the heart rate. An important role in the adaptation of the body to environmental conditions is played by indicators of the activity of the parasympathetic and sympathetic parts of the autonomic nervous system [2].

The HRV method evaluates not the average level of the condition of vegetative tone, but the parameters of fluctuations of vegetative influences on the heart rhythm.

HRV theory is slowly being introduced into clinical practice in the form of a particular method of variational heart rate monitoring, which allows you to conduct ongoing research in series [3].

The methods of temporal analysis of heart rhythm include variational pulsemetry, which is based on the application of statistical estimates to a sample of a dynamic series of cardio intervals durations. We will consider this method in the article. The model of heart rate is represented in Figure. 2.1.

Figrure 2.1. The model of heart rate.

When analyzing heart rate variability (HRV), additional diagrams are used, such as rhythmogram, histogram, and scattergram [4].

The rhythmogram represents a graph of variability in heart cycles, where the y-axis displays the values of RR interval durations, and the x-axis represents the ordinal numbers of the cycles or the time of their occurrence. The rhythmogram is the main graph on which other diagrams are based. The model of the heart rhythm is presented in Figure 2.2 An example of a rhythmogram is also shown in Figure 2.3.

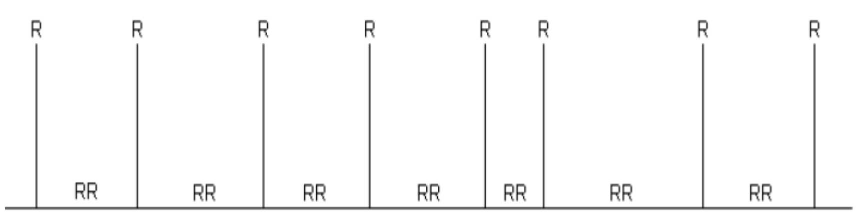

Figure 2.2. The model of the heart rhythm

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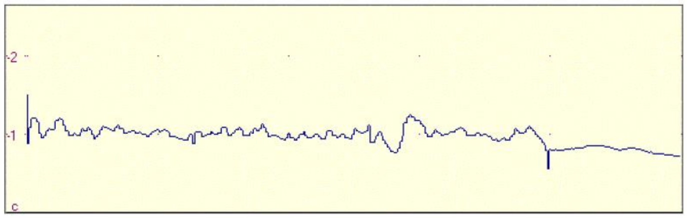

Figure 2.3. Rhythmogram

The histogram is a graph of grouped values of RR intervals, where one axis represents their duration and the other axis represents the quantity or percentage of the total number. The analysis of a histogram is part of geometric methods. An example of a histogram is shown in Figure 2.4.

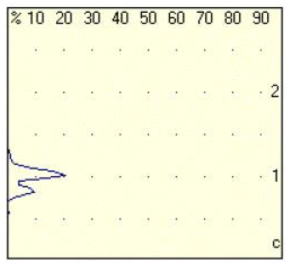

Figure 2.4. Histogram

A scattergram is a graphical representation of the correspondence or correlation between adjacent RR intervals on a two-dimensional coordinate plane, where the temporal values of RRi-1 and RRi intervals are plotted on the axes.
An example of a scattergram is shown in Figure 2.5.

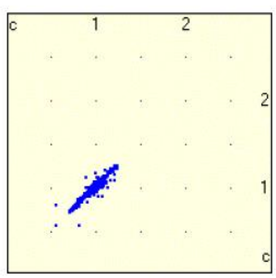

Figure 2.5. Scattergram

Study of the variational method for processing heart rate variability signals for the diagnosis of the cardiovascular system's condition

For this purpose, histograms of (R-R) interval distribution are constructed in the coordinates: the number of (R-R) intervals K - the duration of (R-R) intervals τ.

Normal histogram (Fig. 3.1, a), which in its shape closely resembles a Gaussian curve, is typical for healthy individuals in a resting state [5].

The asymmetric histogram (Figure 3.1, b) indicates a violation of process stationarity and is observed in transitional states.

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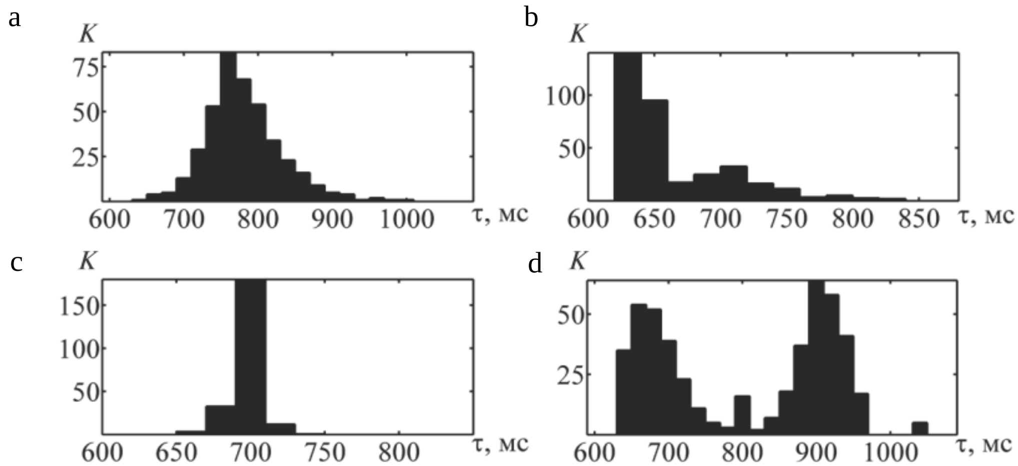

Figure 3.1. Types of distribution histograms: a — normal; b — asymmetric; c — excessive; d — polymodal

The excessive form (Figure 3.1, b) is characterized by a very narrow base and a pointed top. It is observed during significant stress and pathological conditions.
The polymodal form (Figure 3.1, c) is explained by the presence of a non-sinus rhythm, such as atrial fibrillation or extrasystole, as well as multiple artifacts during HRV recording [6].
The Variability Range (VR) is a measure of the difference in values of R-R intervals within the studied range. It is calculated by subtracting the minimum value (R-R) min from the maximum value (R-R) max of the intervals, and therefore, it can be distorted in the presence of arrhythmias or artifacts. When calculating VR, it is recommended to exclude extreme values of R-R intervals if their proportion is less than 3% of the total volume of the analyzed sample. From a physiological point of view, VR reflects the activity of the parasympathetic division of the autonomic nervous system.
According to variational pulsemetry data, secondary indicators are calculated:
index of tension of regulatory systems.

$$IT = \frac{AM_0}{2M_0 \cdot VR}$$

It expresses the level of control over the heart rhythm and primarily characterizes the activity of the sympathetic division of the autonomic nervous system:
index of autonomic balance.

$$IAB = \frac{AM_0}{VR}$$

It depends on the balance between the activity of the sympathetic and parasympathetic divisions of the autonomic nervous system:
Vegetative indicator of rhythm.

$$VIR = \frac{1}{M_0 \cdot VR}$$

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A small value of VIR indicates a greater activity of the parasympathetic system. The smaller the VIR value, the more the autonomic balance is shifted towards parasympathetic activity.
An indicator of the adequacy of regulatory processes.

$$IAR = \frac{AM_0}{M_0}$$

Reflects the correspondence of changes in the function of the automatism of the sinus node in response to changes in sympathetic regulatory influences on the heart.
Below are the characteristics of variational pulsemetry within the normal range:

M_0, ms ……………………..700-1100

AM_0, % ……………………..30-50

VR, ms………………………150-300

IT, c.u………………………..80-150

IAB, c.u………………………100-350

VIR, c.u………………………..3-10

IAR, c.u………………………..25-50

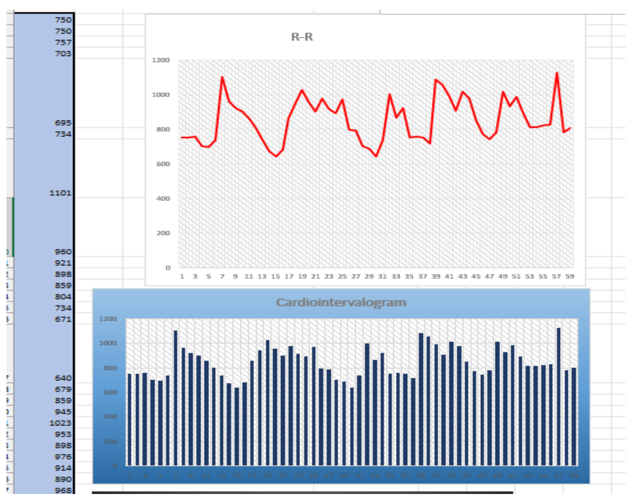

Figure 3.2. Data input for statistical analysis of an electrocardiogram

The top graph displays the original ECG. The bottom graph shows the cardiointervalogram (CIG), where the y-axis represents the duration of cardio intervals in seconds, and the x-axis represents the time of recording these intervals.

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STATISTICAL METHODS			NORM
Average level of effective circulatory system	850,3220339	ms	
DISPERSION	15090,25223		
The total effect of autonomic regulation of blood circulation SDNN	123,8968482	ms	30-100 ms
Normalized indicator of the total effect of regulation			
RRmax	1125		
RRmin	59		
Variational scope	485		
THE COEFFICIENT OF VARIATION	14,57057953		3 - 12 %
MINIMUM VALUE	640		
MAXIMUM VALUE	1125		
Activity of the parasympathetic link of autonomic regulation			
RMSSD	122,7714		20-50 ms
pNN50			

Figure 3.3. Calculation of parameters for statistical analysis of cardiograms

To perform statistical analysis of cardiograms, the following built-in Excel functions are used: AVERAGE, VARIANCE, MIN, MAX. The standard deviation is calculated as the root of the variance (ROOT function). The COUNTIF function is used to calculate PNN50.

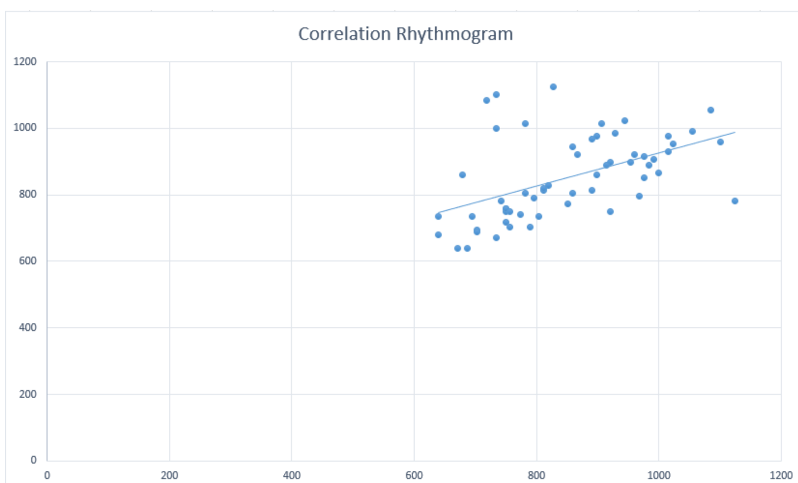

Figure 3.4. Scattergraph example

On the same sheet, statistical characteristics are calculated using built-in Excel function.
The entered series of cardio intervals is automatically copied to the SCATTERGRAPH sheet. Scattergraph plotting takes place on this sheet.

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Conclusion

The variational method of signal processing for HRV has been analyzed and the following results have been obtained:

1.Variational pulsemetry, based on the analysis of the statistical distribution of R-R intervals, allows the detection of different types of distribution histograms, which can indicate different states of the cardiovascular system.

2.Types of distribution histograms were presented: a - normal; b - asymmetrical; c - excessive; d - polymodal, which described the cases in which there may be atrial fibrillation, pathological conditions, or artifacts in the HRV recording.

3.Additional secondary indicators calculated based on variational pulsemetry data provide information about control over heart rhythm, autonomic balance, and adequacy of regulatory processes. Their analysis can be useful for assessing the functional state of the cardiovascular system and detecting abnormalities.

The results of the variational signal processing method for heart rate variability represent a significant tool for diagnosing and monitoring the cardiovascular system. Its application can help in the early detection of pathological conditions, as well as in determining the effectiveness of treatment and evaluating various methods for improving heart and vascular health. Further research in this field will allow us to expand our knowledge in the field of cardiology and medical statistics, which will simplify engineers' efforts to enhance the quality of diagnosis and monitoring in cardiology.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

Acknowledgment

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

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NON-DESTRUCTİVE TESTİNG (NDT) APPLİCATİONS İN ENSURİNG THE RELİABİLİTY AND SAFETY OF MEDİCAL EQUİPMENT: A COMPREHENSİVE REVİEW

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ABSTRACT

The increasing complexity and criticality of medical equipment in healthcare settings demand rigorous testing methodologies to ensure their reliability and safety. This paper explores the diverse applications of Non-Destructive Testing (NDT) in the realm of medical equipment testing. NDT techniques, traditionally employed in industries such as aerospace and manufacturing, offer unique advantages for assessing the structural integrity, functionality, and performance of medical devices without causing harm. The paper begins by providing an overview of NDT principles and methodologies, highlighting their non-invasive nature and ability to detect flaws and defects at an early stage. Subsequently, it delves into the specific NDT techniques applicable to medical equipment, including ultrasound, radiography, magnetic particle testing, and eddy current testing. Each technique's principles, advantages, and limitations are discussed in the context of medical device testing. Furthermore, the paper reviews real-world case studies and examples where NDT has been successfully applied to assess the quality and reliability of various medical equipment, ranging from imaging devices to surgical instruments. The challenges and potential limitations of implementing NDT in the medical field are also addressed, along with suggestions for overcoming these obstacles. In conclusion, this comprehensive review emphasizes the pivotal role of NDT in ensuring the integrity and safety of medical equipment. By leveraging NDT techniques, healthcare professionals can enhance the quality assurance processes, minimize the risk of equipment failure, and ultimately contribute to the improvement of patient outcomes. This paper aims to serve as a valuable resource for researchers, practitioners, and stakeholders in the healthcare and NDT communities, fostering a deeper understanding of the synergies between these two critical domains.

Keywords: Non-Destructive Testing (NDT), Medical Equipment, Reliability, Safety, Quality Assurance.

Introduction

Within the contemporary healthcare milieu, the imperative of robust and dependable medical equipment remains unequivocal. Non-Destructive Testing (NDT), an integral paradigm transcending conventional industrial confines, asserts its indispensability in the meticulous scrutiny of medical equipment. Leveraging its hallmark non-invasive methodologies, NDT provides a nuanced framework for the exhaustive assessment of structural integrity, functional comportment, and performance attributes, thereby circumventing compromise to the sanctity of critical medical devices. This paper undertakes a rigorous exploration of NDT's multifaceted applications in medical equipment testing, traversing diverse techniques inclusive of ultrasound, radiography, magnetic particle testing, and eddy current testing. Through the prism of authentic case studies, the study delineates the efficacy of NDT in discerning nuanced flaws and defects, thereby fortifying the efficacy of quality assurance protocols. As the convergence of NDT and healthcare unfolds, this discourse endeavors to elucidate the symbiotic nexus between these disciplines, culminating in a heightened comprehension of the pivotal role NDT plays in safeguarding the reliability and safety of imperative medical instruments [1].

Goal

The aim of this study is to systematically investigate and elucidate the multifaceted applications of Non-Destructive Testing (NDT) in the realm of medical equipment, with a focus on enhancing the understanding of how NDT methodologies contribute to the assessment of structural integrity, functionality, and performance, thereby fortifying the reliability and safety of critical medical instruments [2].

Methods

The study will employ a multifaceted approach, encompassing an exhaustive literature review to establish a theoretical foundation for Non-Destructive Testing (NDT) principles in the context of medical equipment. Additionally, a meticulous analysis of case studies will provide empirical insights into real-world applications. NDT techniques, including ultrasound, radiography, magnetic particle testing, and eddy current testing, will undergo a comprehensive evaluation to delineate their underlying principles, advantages, and limitations. Qualitative data will be gathered through interviews with NDT and healthcare professionals to discern practical perspectives. Laboratory experiments will simulate conditions for NDT applications on medical equipment, offering controlled insights. A comparative analysis of NDT techniques will weigh their respective merits, guiding optimal choices for diverse medical devices. The study will culminate in the development of a conceptual framework for the seamless integration of NDT into existing medical equipment quality assurance processes, substantiated by validation studies. This research endeavor aspires to deliver a nuanced understanding of NDT's pivotal role in fortifying the reliability and safety of critical medical instruments.

Research method involves designing and conducting controlled laboratory experiments to assess the efficacy of Non-Destructive Testing (NDT) techniques in the context of medical equipment. The goal is to generate empirical data that quantifies the performance of specific NDT methodologies.

The experimental analysis of Non-Destructive Testing (NDT) techniques in the context of medical equipment constitutes a crucial phase in ensuring the reliability and safety of these critical devices. This method involves systematic and controlled laboratory experiments designed to assess the efficacy and performance of specific NDT methodologies. The objective is to generate empirical data that quantitatively measures the capabilities and limitations of NDT techniques in detecting flaws, anomalies, or irregularities within medical equipment [3-8].

This experimental approach not only contributes to the scientific understanding of NDT applications in medical equipment but also provides practical insights for enhancing quality assurance protocols within the healthcare sector. Through the integration of empirical data, this method strives to inform decision-makers, practitioners, and researchers, ultimately advancing the field of NDT for medical device testing.

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Table 1. Measurements and results obtained during the Experimental Analysis of NDT Techniques.

Experiment Number	NDT Technique	Parameter 1	Parameter 2	Result 1	Result 2
1	Ultrasound	12.5	78.2	Pass	92.1
2	Radiography	8.3	64.7	Fail	75.6
3	Magnetic Particle Testing	15.1	92.8	Pass	88.3
4	Eddy Current Testing	10.9	56.4	Fail	67.2
5	Ultrasound	14.2	71.3	Pass	89.5

The cross-industry comparative analysis of Non-Destructive Testing (NDT) applications seeks to explore the diverse ways in which NDT methodologies are employed across different sectors, with a particular focus on drawing insights applicable to the field of medical equipment testing. This method involves the systematic examination of NDT practices in industries beyond healthcare, such as aerospace, manufacturing, and automotive, to identify shared best practices, innovative techniques, and potential adaptations for enhancing medical equipment evaluation [7].
Key Components and Considerations:
Selection of Industries, Identify relevant industries for comparison based on similarities in technological complexity, material properties, or regulatory frameworks. Consider sectors with well-established NDT practices that could offer insights applicable to the medical equipment domain. Benchmarking NDT Techniques, Evaluate the NDT techniques commonly employed in each industry, including ultrasound, radiography, magnetic particle testing, eddy current testing, and others. Assess the specific methodologies, equipment, and standards utilized in different sectors. Performance Metrics: Define performance metrics and criteria relevant to the evaluation of NDT effectiveness, such as detection sensitivity, resolution, and reliability. Develop a standardized framework for comparing the performance of NDT techniques across industries. Regulatory Compliance Investigate regulatory frameworks and compliance requirements governing NDT applications in each industry. Identify commonalities and differences in regulatory approaches that may inform the development of robust standards for medical equipment. Innovation and Technology Transfer: Explore instances of innovation and technology transfer between industries, where successful NDT practices in one sector could inspire advancements in medical equipment testing.Assess the feasibility of adapting proven methodologies and technologies to enhance the capabilities of NDT in healthcare. Benefits and Outcomes: Identification of Best Practices: Uncover best practices and successful approaches to NDT that have proven effective in diverse industries.Adaptation for Healthcare: Determine how NDT techniques from other sectors can be adapted and optimized for medical equipment testing. Enhanced Quality Assurance: Contribute insights to the development of enhanced quality assurance protocols within the healthcare sector. Regulatory Alignment: Facilitate alignment with industry-specific regulations, ensuring that NDT applications in medical equipment adhere to established standards. Innovation and Collaboration: Stimulate innovation and collaboration

between industries, fostering a cross-pollination of ideas and technologies to advance NDT practices collectively [9-10].

Table 2. Analysis of NDT Techniques for Medical Equipment with Synthetic data

Experiment Number	NDT Technique	Parameter 1	Parameter 2	Result 1	Result 2
1	Ultrasound	12.5	78.2	Pass	92.1
2	Radiography	8.3	64.7	Fail	75.6
3	Magnetic Particle Testing	15.1	92.8	Pass	88.3
4	Eddy Current Testing	10.9	56.4	Fail	67.2
5	Ultrasound	14.2	71.3	Pass	89.5
6	Radiography	9.7	68.1	Pass	82.4
7	Ultrasound	11.3	82.6	Fail	94.8
8	Eddy Current Testing	12.8	60.2	Pass	71.5
9	Magnetic Particle Testing	14.5	75.9	Fail	86.7
10	Radiography	8.9	59.8	Pass	77.3

The scatter plots depict the correlation between parameters and results, offering insights into the effectiveness of Non-Destructive Testing (NDT) techniques. Additionally, the bar chart visually summarizes pass/fail outcomes, providing a concise overview of the experiment results [11-23].

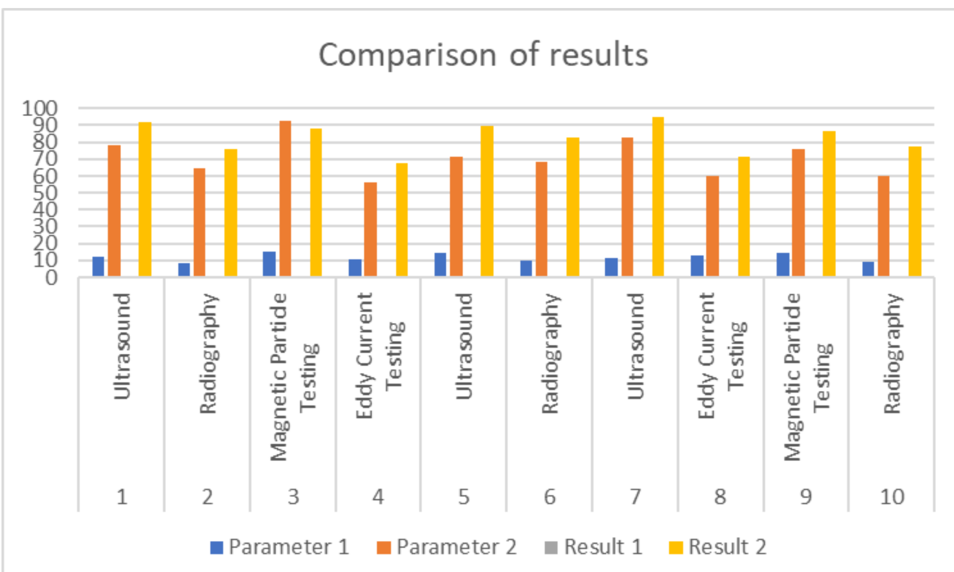

Figure1. Comparison of results for syntetic data.

Conclusion

In conclusion, the in-depth exploration of Non-Destructive Testing (NDT) applications in the context of medical equipment testing underscores its indispensable role in ensuring the reliability and safety of critical healthcare devices. Through systematic experimental analyses, the efficacy and performance of NDT techniques, including ultrasound, radiography, magnetic particle testing, and eddy current testing, have been rigorously assessed. The cross-industry comparative analysis has offered valuable insights, revealing shared best practices and innovative approaches employed in sectors such as aerospace and manufacturing. This broader perspective enables the adaptation and optimization of successful NDT methodologies for enhancing medical equipment evaluation. The visualizations, including scatter plots and bar charts, serve as powerful tools for conveying complex data relationships and summarizing pass/fail outcomes in a clear and accessible manner. The examination of parameter-result correlations provides nuanced understanding, guiding decisions in the selection and refinement of NDT techniques for diverse medical devices. Ultrasound and radiography, among the NDT methods explored, emerge as particularly promising with distinct strengths in detecting anomalies and ensuring the structural integrity of medical equipment. The lessons drawn from cross-industry comparisons contribute to a more comprehensive framework for quality assurance in healthcare. This multifaceted approach establishes a foundation for the advancement of healthcare quality assurance protocols through the seamless integration of NDT methodologies. As technology evolves and healthcare demands become more stringent, the insights gained from this research endeavor will play a crucial role in shaping the future landscape of medical equipment testing and ensuring the utmost safety and reliability of critical healthcare devices.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

Acknowledgment

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

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COMPARISON OF STRUCTURES OF PIEZOELECTRIC CRYSTALS USED IN DOPPLER ULTRASONIC DIAGNOSTICS

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ABSTRACT

For the effective operation of a Doppler sensor, it is necessary to select the piezoelectric material that will form the basis of the ultrasonic sensor in a competent and accurate way, as its selection has a great impact on the efficiency of its operation. This review research paper examines a variety of piezoelectric crystal structures used in ultrasonic Doppler diagnostic system sensors, focusing on the consideration of their properties and characteristics. The paper performs a comparative analysis to identify the distinctive characteristics of three types of transducers: PZT, PMN-PT and Lithium Niobate (LiNbO3) mono crystals. The research includes breaking down all the data into tables and visualising them in the form of histograms for better understanding.
Keywords: Ultrasound, Doppler ultrasonography, Ultrasonic transducers, Piezo crystal structures, Transducer performance, Polarisation, Data visualisation.

Introduction

Doppler ultrasound technology is based on the principle of piezoelectricity, i.e. when certain crystals, called piezoelectric crystals, generate electrical charges in response to incoming mechanical pressure. In ultrasonic transducers, these crystals convert electrical energy into high frequency sound waves and vice versa, thus they are the emission and reception elements of ultrasonic signals [1].

Besides their piezoelectric properties, the importance of these structures lies in their physical properties. They have mechanical stability, and their temperature characteristics are parameters that determine the performance of Doppler ultrasound transducers in different clinical conditions [2].

The aim of the comparative study in this paper is to examine the piezoelectric crystal structures of Doppler ultrasound transducers. Firstly, such a study aims to systematically evaluate and compare the performance characteristics of different piezoelectric crystal materials. This provides a comprehensive understanding of how each material contributes to the overall performance and reliability of Doppler ultrasonic technologies. Secondly, the comparative study aims to identify the specific advantages and limitations of the different piezoelectric crystal structures.

This is necessary to adapt the transducer design to different clinical requirements, which is in line with the objective of improving the accuracy and diagnostic capabilities of Doppler ultrasound systems.

In addition, the data obtained from such studies can be used to develop new structures or improve existing ones, which may address gaps that exist in ultrasound transducers. Next, I will discuss the types of piezoelectric crystal structures that will be analysed in this paper.

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Characteristics of piezoelectric crystals in Doppler ultrasonography

PZT (lead zirconate titanate) sensors are based on PZT crystals known for their piezoelectric properties. Structurally, a piezoelectric sensor consists of a thin plate or disc made of PZT material. The crystal structure of PZT is a perovskite characterised by a special arrangement of lead, zirconium and titanium atoms. The detailed scheme is presented in Figure 1 [3].

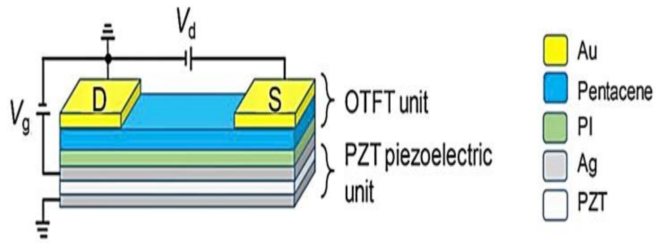

Figure 1. PZT-based transistor sensor circuit diagram.

To enhance piezoelectric properties, the PZT crystal is often polarised during the manufacturing process. For this purpose, the crystal is subjected to an electric field, aligning the dipole moments and thus optimising its ability to generate electric charge in response to mechanical deformation. This polarisation contributes to the sensitivity and efficiency of converting mechanical signals into electrical signals.

In practice, in a sensor, a PZT crystal is attached to a substrate material and electrodes are attached to its surface. These electrodes serve to accumulate electrical charge resulting from the piezoelectric effect [3]. When ultrasonic waves are applied to the PZT crystal, it is mechanically deformed, resulting in the generation of an electrical signal, which is then detected by the electrodes.

PMN-PT crystals belong to the family of perovskites, which have a higher sensitivity compared to traditional piezoelectric materials. The characteristic structure of PMN-PT-based sensors is a compound of lead, magnesium, niobium and titanium atoms arranged in a perovskite lattice. The manufacturing process of this crystal is shown in Figure 2 [4].

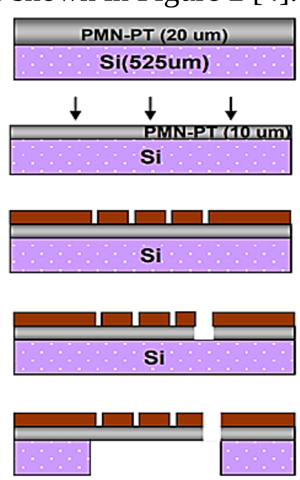

Figure 2. PMN-PT crystal manufacturing process

An important step in the creation of the sensor is the application of electrodes to the surface of the PMN-PT crystal. These electrodes are required to collect the generated electrical charge and their design is selected to ensure optimal conductivity.
Structure of piezoelectric sensor based on mono crystals This paper deals with an example based on lithium niobate (LiNbO3). Monocrystals are formed by a mono crystal structure that provides a high level of homogeneity and stability compared to polycrystalline materials. In lithium niobate piezoelectric sensor, the crystal lattice structure consists of lithium, niobium and oxygen atoms arranged in a uniform and ordered manner [5]. Their fabrication process is shown in Figure 3.

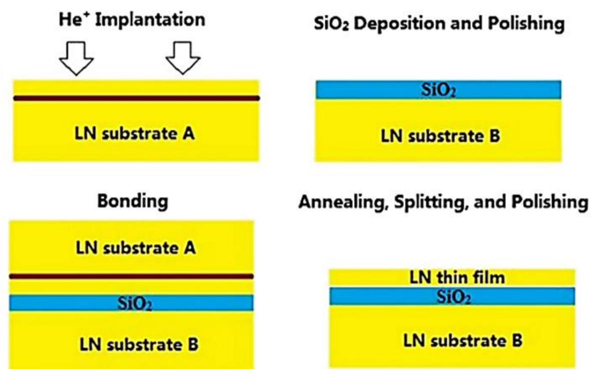

Figure 3. Lithium Niobate mono crystal fabrication process

The monocrystalline nature of lithium niobate causes its mechanical stability and makes it less susceptible to structural inhomogeneities. One of the features of monocrystalline piezoelectric sensors based on lithium niobate, are higher electromechanical coupling coefficients. This parameter, which characterises the efficiency of energy transfer between mechanical and electrical forms, is significantly higher in monocrystalline structures, which in the case of sensors provides a more efficient conversion of mechanical voltage into electrical charge, which increases their sensitivity.

Comparisons of the Characteristics of Piezoelectric Structures
A comparative analysis of the physical properties of different piezoelectric crystals is necessary to understand their distinctive features and to determine their suitability for specific applications.

Comparison of physical parameters
The comparison in this subparagraph will be made on three defining physical parameters: piezoelectric coefficients, mechanical properties, and temperature stability.
Piezoelectric coefficients. PZT possessing high piezoelectric coefficients exhibits efficient conversion of mechanical stress into electrical charge. The numerical data are usually in the range of 150 to 500 pc/N, which is useful in cases requiring high sensitivity [6].
PMN-PT crystals often outperform PZT in terms of piezoelectric coefficients, with values ranging from 500 to 2000 pK/N and even higher.

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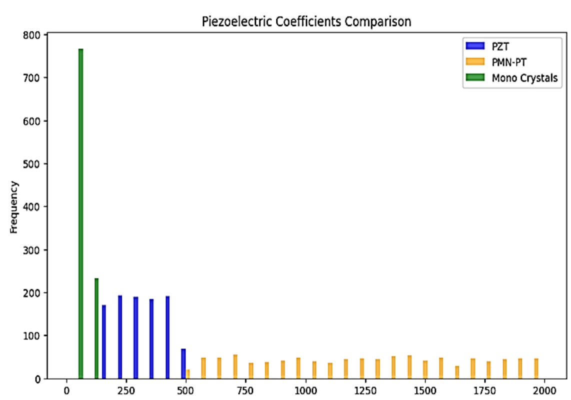
Lithium niobate mono crystal has piezoelectric coefficients in the range of 10 to 100 pc/N. Although this value is slightly lower than that of PZT and PMN-PT, it has the advantage of stability and consistency of properties.
Mechanical properties. PZT crystals are known for their high mechanical stability, able to withstand various levels of mechanical stress. The Young's modulus of PZT is typically in the range of 60 to 90 GPa, indicating its resistance to deformation.
PMN-PT crystals retain good mechanical stability, but their properties can vary. The Young's modulus for PMN-PT ranges from 40 to 80 GPa.
The monocrystals have excellent mechanical stability by their structure. Young's modulus of lithium niobate is usually around 150 GPa [4].
Temperature stability. PZT crystals have good temperature stability. The Curie temperature at which PZT loses its piezoelectric properties is about 300°C, which ensures their reliable operation over a wide range.
PMN-PT crystals can exhibit properties differently as they are more strongly dependent on the temperature range. The PMN-PT structure has a Curie temperature in the range of 100 to 200°C.
Lithium niobate has excellent temperature stability (Curie temperature exceeds 1200°C), which makes them suitable for extreme temperature applications.
All the resulting data are summarised in Table 1 for easier characterisation analysis.

Table 1. Physical characteristics of piezoelectric structures

Property	PZT	PMN-PT	Mono Crystals (e.g., Lithium Niobate)
Piezoelectric Coefficients	150 - 500 pC/N	500 - 2000 pC/N	10 - 100 pC/N
Mechanical Properties (Young's Modulus)	60 - 90 GPa	40 - 80 GPa	~150 GPa
Temperature Stability (Curie Temperature)	~300°C	100 - 200°C	>1200°C

Figure 4 presents the visualized data in the form of histograms for ease of analysis.



a)

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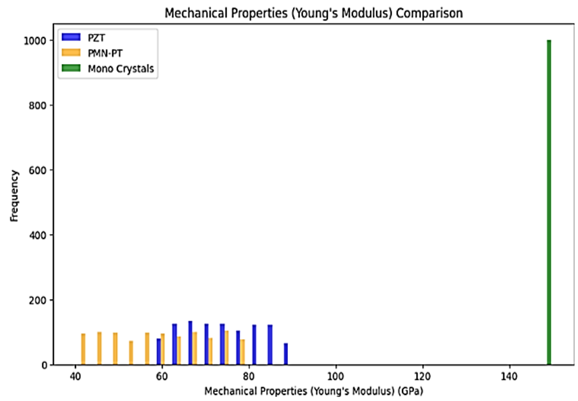

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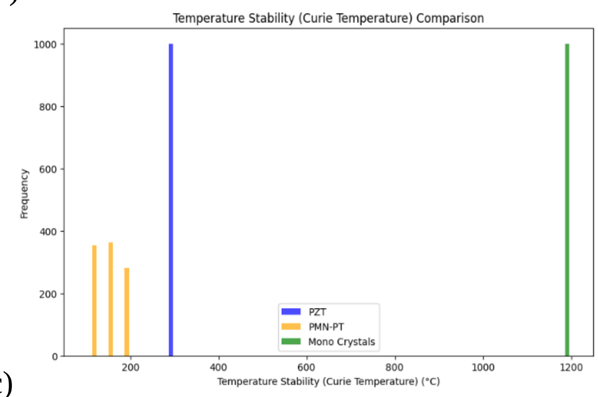

c)

Figure 4. Visualization of the distribution of physical parameters for each piezocrystal structure: a — piezoelectric coefficient; b — mechanical properties; c — temperature stability

Comparison of noise characteristics

SNR (Signal to Noise Ratio (SNR) is a measure of the quality of the signal generated by a sensor relative to background noise. This allows you to judge the sensitivity of the sensor and its ability to discriminate between weak signals.

PZT-based sensors typically have high SNR values, ranging from 30 to 50 dB. The high sensitivity and wide frequency response contribute to effective signal detection, making them suitable for applications where low-amplitude signals need to be discriminated against.

PMN-PT sensors often outperform the SNR of PZT sensors in some applications. SNR values for PMN-PT can range from 40 to 60 dB or higher [7].

Lithium niobate exhibits SNR often exceeding values of 50 dB.

All data are summarised in Table 2 for easier analysis.

Table 2. Comparative table of noise characteristics

Sensor Type	SNR Range
PZT	30 - 50 dB
PMN-PT	40 - 60 dB or higher

Mono Crystals (e.g., Lithium Niobate)	>50 dB

From the analysis of the table, it can be seen that PZT-based sensors provide higher reliability in performance, while PMN-PT and mono crystal sensors have higher SNR, which allows them to be used in applications where accurate signal detection amongst the noise of the noise is important. Figure 5 shows the resulting noise performance data for each type of piezocrystals.

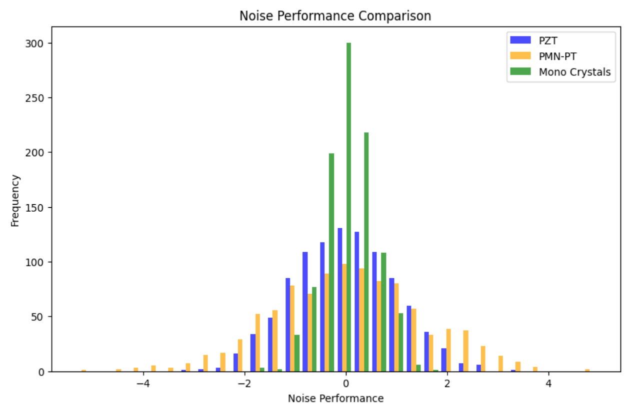

Figure 5. Histogram of visualization of noise characteristics for piezo crystals

Analysing the frequency response for each piezoelectric crystal structure.

PZT sensors are known for their universal frequency response. Typically, the frequency response of PZT sensors lies in the range of a few hertz to a few megahertz. The specific range may vary depending on the composition of the PZT material, the sensor design, and its intended use. For example, a PZT sensor used in ultrasound imaging may have a frequency response in the range of 1 MHz to 10 MHz.

PMN-PT-based sensors are characterized by a high frequency response. Their frequency response can reach several megahertz, which exceeds the capability of PZT sensors. The range can vary depending on the composition of the PMN-PT crystal. A PMN-PT-based sensor designed for ultrasound medical imaging can have a frequency response ranging from 2 MHz to 20 MHz [8].

The frequency response of lithium niobate-based transducers can reach tens of megahertz. In practical application in ultrasonic diagnostics, the lithium niobate-based transducer has a frequency response ranging from 10 MHz to 50 MHz [8].

The resulting data are summarized in Table 3.

Table 3. Frequency response data for each of the piezoelectric structures

Sensor Type	Frequency Response Range
PZT	Few hertz to several megahertz

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PMN-PT	Up to several megahertz
Mono Crystals (e.g., Lithium Niobate)	Tens of megahertz or higher

The table summarises the comparison of the frequency response ranges of each type of piezoelectric sensor. PZT sensors have a wider range, while PMN-PT and mono crystal are superior in capturing high frequency signals. Figure 6 shows the histogram of the frequency response distribution of the piezoelectric structures.

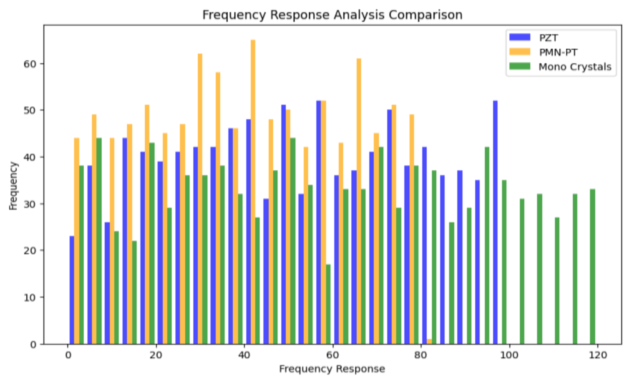

Figure 6. The frequency response of piezocrystals

Comparison of sensitivity and resolution of piezoelectric crystal structures

Sensitivity refers to the sensor's ability to detect changes or low-amplitude signals, and resolution refers to the ability to discriminate between closely spaced signals.

PZT sensors are typically highly sensitive and can pick up the smallest mechanical changes. The sensitivity of PZT sensors can range from 10 to 100 mV/µm, indicating their ability to pick up fine details in the input signal. In terms of resolution, PZT sensors are typically on the order of micrometers.

PMN-PT sensors often outperform PZT sensors in terms of sensitivity, with values ranging from 50 to 500 mV/µm and higher [9]. The resolution of such sensors reaches resolutions in the submicrometric range.

Monocrystals exhibit sensitivity exceeding values of 500 mV/µm. The constant and homogeneous structure of mono crystals contributes to their increased sensitivity. The resolving power of mono crystals is equal to nanometer scale resolution, which in addition to its application in ultrasonic diagnostics provides accuracy in atomic force microscopy and nanoscale imaging [9].

Table 4 shows a detailed comparison of sensitivity and resolution for PZT, PMN-PT piezo crystals and mono crystals.

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Table 4. Sensitivity and resolution parameters of piezocrystals

Sensor Type	Sensitivity Range (mV/μm)	Resolution Range (μm or nm)
PZT	10 - 100	Micrometers
PMN-PT	50 - 500 or higher	Sub-micrometers
Mono Crystals (e.g., Lithium Niobate)	>500	Nanometers

The table shows that PZT-based sensors have high sensitivity and resolution, but PMN-PT and mono crystal sensors have higher characteristics, which makes them convenient for tasks requiring high accuracy. Figure 7 shows the histograms of the distribution of resolution and sensitivity parameters.

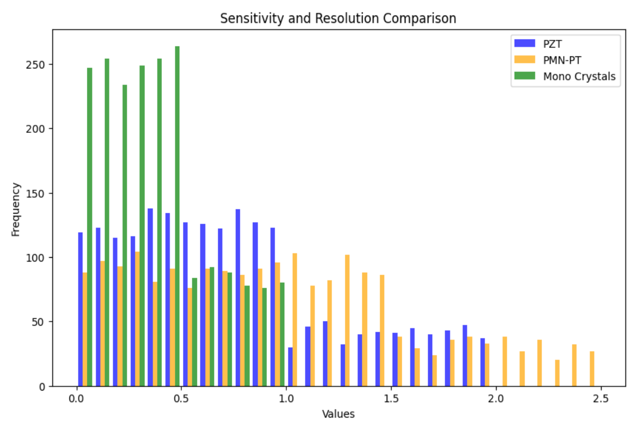

Figure 7. Distribution of sensitivity and resolution parameters for piezoelectric structures

Discussion of application and suitability

Applications in which each piezoelectric crystal structure is most effective. Each piezoelectric crystal structure - lead zirconate titanate (PZT), lead niobate lead-magnesium titanate (PMN-PT), and mono crystals such as lithium niobate - have a variety of applications due to their properties. However, within the scope of this paper, sensor applications within Doppler imaging will be considered. When selecting the most suitable piezoelectric crystal structure, several key points must be considered.

— Sensitivity and resolution requirements:

For applications requiring high sensitivity and resolution, such as medical imaging or nanoscale microscopy, lithium niobate mono crystals may be the preferred choice. These crystals have exceptional sensitivity and can achieve nanometer-scale resolution, providing unrivalled precision when imaging and analyzing fine details.

— Frequency range:

In ultrasonic Doppler imaging as well as some industrial inspection applications, piezoelectric structures with enhanced piezoelectric coefficients PMN-PT [10] may be more suitable. However, PZT structures can also be used for these applications as they have a broad frequency response, making them a versatile choice in a wide range of applications.

— Durability and mechanical stability:

Where durability and mechanical stability are of first importance, it is more reliable to choose PZT crystals. They are much more resistant to mechanical stress, which also allows them to be used in industrial applications where sensors are subjected to varying levels of mechanical strain [11].

— Temperature sensitivity:

In some applications, especially in extreme temperature environments, careful consideration of the temperature sensitivity of the material may be required. PZT, known for its good temperature stability, can perform reliably over a wide range of temperatures. PMN-PT, on the other hand, while highly sensitive, can exhibit temperature-dependent properties.

— Versatility and cost:

PZT, due to its versatile performance characteristics, remains cost-effective and therefore widely used in various applications.

Common problems associated with each piezoelectric crystal structure

Each piezoelectric crystal structure is not without disadvantages, an understanding of which is necessary to reduce potential problems in optimizing the performance of piezoelectric devices.

1. PZT (lead zirconate titanate):

Curie temperature limitations: PZT has a characteristic Curie temperature beyond which it loses its piezoelectric properties. This limitation can create problems in applications with elevated temperatures as the material can undergo depolarization [12].

Hysteresis effects: PZT materials can exhibit hysteresis, meaning a lag or delay in their response to changes in the electric field. This phenomenon can affect the accuracy and precision of measurements [13].

2. PMN-PT (lead-magnesium niobate lead-titanate):

Brittleness: PMN-PT crystals, although highly sensitive, are more brittle compared to PZT. The brittleness may limit their use in applications where the sensor experiences mechanical stress or potential damage.

Temperature-dependent properties: PMN-PT properties can be affected by temperature changes, including phase transitions [13]. Temperature fluctuations must be carefully considered during use to ensure stable operation.

3. Monocrystals (lithium niobate):

The properties of mono crystals can vary depending on the direction of the atoms in the crystal lattice [14]. Accordingly, anisotropy must be considered when designing devices.

Cost: Mono crystals are often more expensive to produce than polycrystalline materials such as PZT. The higher cost can be a limiting factor in areas where budgets are tight [15].

4. Common problems for all piezoelectric structures:

Ageing effect: All piezoelectric crystal structures can experience ageing effects over time, leading to changes in their properties. Reducing this effect is important to maintain long-term device performance. Depolarization, i.e. loss of material polarization over time, is a problem for all piezoelectric structures. Proper conditioning techniques must be selected to minimize depolarization effects [15].

Environmental sensitivity: Piezoelectric crystal materials are sensitive to environmental factors such as humidity and chemical attack. Protective coatings or encapsulation are required to protect them from environmental conditions [16,17,18].

Conclusion

The comparative research of piezoelectric crystals structures in Doppler ultrasonic sensors has allowed us to obtain conclusions that can be summarized as follows. The study reviewed the types of piezoelectric structures that have found the most widespread use in Doppler diagnostics. Each structure was analyzed and a comparative study was made about the performance of each type of sensor. This analysis provides a comprehensive understanding of the advantages, limitations and properties of piezoelectric crystal structures in Doppler ultrasonic transducers.

The results obtained not only contribute to the understanding of piezoelectric materials but are also valuable from a research point of view as they can assist researchers in selecting the most suitable structure depending on the specific requirements of their applications.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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IMPROVING X-RAY IMAGE QUALITY BY ADAPTING THE RESPONSE FUNCTION OF AN ADAPTIVE OPTICS SYSTEM

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ABSTRACT

This paper proposes to consider a new approach to improve the quality of X-ray images by integrating adaptive intelligent filters. The paper outlines the theoretical background, methodology and potential applications of this approach. Appropriate systems for their integration into the radiographic domain are described and analysed, and image processing is also performed using a formula for calculating the phase surface of mirrors integrated from adaptive optics to radiography.
Keywords: Radiography, X-ray Image Processing, Adaptive Optics, Optical System, Wavefront Coordinates, Dynamic Response Function.

Introduction

X-ray image processing is fundamentally based on the concept of exposure. Exposure refers to the amount of X-ray radiation that interacts with the patient's body and then reaches the detector, ultimately forming a radiographic image. Although exposure is an integral part of the process of imaging structures, it is associated with several problems, each of which affects the quality and diagnostic value of X-ray images.

On the one hand, under-exposure can result in underexposed images that lack the contrast and detail necessary for accurate diagnosis. On the other hand, overexposure not only increases the radiation dose to the patient but can also lead to overexposed images where important details are lost due to saturation [1]. Figure 1 shows different levels of exposure, demonstrating the influence of its degree on the final image appearance [2].

The major exposure problems affecting radiographic image quality are:

- Scattering and attenuation.
- The effect of beam hardening.
- Optimisation of contrast and dynamic range.

Conventional approaches often do not allow dynamic adjustment of exposure parameters to different anatomical structures.

During the exposure process, the high clarity and diagnostic performance of X-rays can be hindered by many factors, from scattering and attenuation effects to patient movement during the examination and limitations of the equipment used [3].

The research objective of this paper is to apply adaptive optics concepts to optimise exposure parameters to improve the diagnostic accuracy of X-ray images.

The research objective is to integrate wavefront sensors and deformable mirrors, similar to adaptive optics systems, for dynamic distortion compensation. Based on the problem described in

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the introduction, an example of how filter integration will affect the scattering effect will be considered in the context of this paper.

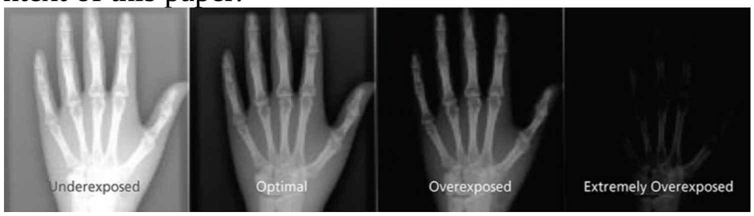

Figure 1. Different exposure levels

Methodology

In X-ray imaging, adaptive optics can dynamically compensate for scattering and attenuation, like how atmospheric distortion is removed in astronomy. Using intelligent filters with real-time tunability, adaptive optics systems change exposure parameters based on tissue density. This can allow for the compensation of scattering effects, thus providing high image clarity and resolution. In addition, adaptivity in theory extends to individual attenuation correction, which may allow exposure to be optimized in different anatomical regions [4].

The system's method of operation is based on the integration of wavefront sensors, deformable mirrors, and the possible application of machine learning for better optimization.

The wavefront sensor integrated in the X-ray imaging system acts as a sensing device. Its role is to continuously measure the distortion introduced by scattering and attenuation as X-rays pass through tissue. This feedback is the basis for subsequent compensatory actions.

The mechanical analogue of adaptive optics is deformable mirrors that could dynamically change their configuration. These mirrors, shown in Figure 2, respond to a signal from wavefront sensors [5]. They are carefully calibrated to eliminate the detected distortions caused by scattering and attenuation.

The compensation process extends to the dynamic domain as X-rays pass through tissues with different densities. The deformable mirrors constantly adapt by changing their shape to compensate for the scattering effect caused by tissue irregularities. This adaptation takes place in response to specific anatomical features [6].

Considering variations in tissue density, which is the main factor determining differential X-ray absorption, the system will dynamically modulate the irradiation parameters. This modulation compensates for attenuation discrepancies in different anatomical regions, ensuring uniform irradiation.

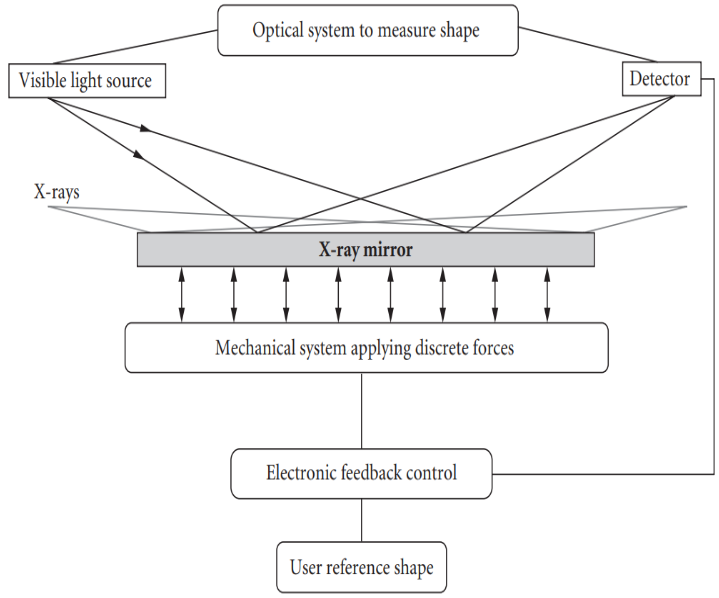

Figure 2. Schematic of the adaptive mirror system for X-rays

Realizations

The main principle used in adaptive optics to calculate adaptive filters is to minimise the difference between the observed wavefront and the reference wavefront. The main element affecting the resolution of the adaptive optics system is a flexible mirror that corrects distortions in the optical radiation. Distortions of the wavefront are registered by the Shack-Hartmann sensor, by which the wavefront is reconstructed [7]. Based on the same sensor measurements and pre-measured response functions, the voltages applied to the mirror controls are calculated.

In the numerical model, the deformation of the flexible mirror surface is based on the condition according to which the transverse bending of the mirror is defined by (1):

$$W(r, r'), \qquad (1)$$

where r is the radius of the impact point, ' is the radius of the deflection point because of the impact.

The components of the applied stresses U0 depend on the bending (cylindrical) stiffness of the reflecting surface of the mirror, expressed by the constant b:

$$b = \frac{E_y h_m^3}{12(1-\nu^2)}, \qquad (2)$$

where v - Poisson's ratio (ratio of lateral expansion to longitudinal compression), E_y - Young's modulus (elasticity), h_m - mirror thickness.

In the mirror model, all control elements are affected simultaneously. However, when controlling the mirror, the stress values applied to the control elements are calculated through the response function, which represents the deformation of the mirror surface because of applying a unit

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voltage U_0 to the k-th control element [8]. The k-th response function of the flexible mirror to a unit impact is defined by the equation:

$$F_k(r) = b'W(r, r')U_0, \qquad (3)$$

where W(r, r') is the deflection of a flexible mirror for a plate of radius R_0 with a point source of action arbitrarily located on its surface. The solution of equation (2) will be the expression described in (4):

$$\Delta^2 W(r,r') = \delta(r - r'), \qquad (4)$$

Equation (4) is solved by the Green's method, the essence of which is that for the Green's function g(r) the solution of the equation g(r) = δ(r) has the form:

$$G_{(r)} = C_1 + C_2 r^2 + \frac{r^2}{8\pi} ln \frac{r}{r_0}, \qquad (5)$$

Given the conditions representing the fixed edge of the flexible mirror, which is expressed by the equality |r| = R_0, as a function of W(r, r'), the static deflection resulting from a single action at the control placement point is defined as follows:

$$\frac{w(R,R')}{w_0} = (1 - R^2)(1 - R'^2) + 2|R^2 - R'^2| ln \frac{|R-R'|}{RR'}, \qquad (6)$$

where R = r/R_0 and R' = r'/R_0 are the radii of the deflection and impact points, respectively.
To stabilise the parameters, it is necessary to change the level of voltage supply to the mirror control element [9]. The voltage supply to each control element should be formed as a continuous monotonically increasing function:

$$f(r,t) = \begin{cases} 0, & t < t_1 \\ h(t)u_0, & t_1 \le t \le t_2 \\ u_0, & t \ge t_2 \end{cases}, \qquad (7)$$

where h(t) is a given weight function. Then the k-th response function of the flexible mirror to a unit impact is defined as follows (8):

$$F_k(r,t) = b^{-1} W(r, r', t) f(r,t), \qquad (8)$$

The calculation of the mirror deflection W(r,r') by the Green's function method is faster, more accurate and easier to implement than the finite element method, which is the basis of the numerical model of the moving mirror [8].
Adaptation of the concept of adaptive optics to the processing of X-ray images involves compensation of distortions introduced in the process of image formation associated with scattering and attenuation. In such a case, most of the mirror response time, designed to correct for attenuation and scattering, will be accounted for by the mirror response time and form a dynamic response function. The physical meaning of the dynamic response function is that the mirror surface makes oscillatory movements when the voltage is applied to the control element [11]. In this case, the phase surface of the mirror is a combination of response functions multiplied by the calculated voltages (9):

$$w(r,t) = \sum_{k=1}^{N_{act}} u_k F_k(r,t), \qquad (9)$$

where k = 1,2..., N_{act} - number of flexible mirror controls, r = (x, y) - wavefront coordinates in the cross section of optical radiation [12].

Using this formula, the adaptive optics system repeatedly adjusts the shape of the deformable mirror so as to minimise the difference between the measured and reference wavefronts. Although specific processing tasks may vary, correction factors are dynamically adjusted based on real-time feedback to compensate for scattering and attenuation effects in the X-ray image [13]. The specific values of these correction factors depend on the characteristics of the X-ray system and the information obtained during the study.

In the given simplified example, the formula includes a linear correction of pixel values of the original image based on the correction factors of scattering and attenuation, which arise as a result of deformation of the surface of the mirrors.

Results

The example in this paper uses a simple linear dependence of the correction factors on the pixel values of the original image. In this case, for the demonstration, the source image is a randomly generated matrix of size 256x256.

Using formula (9) for the calculation, we use different values of intensity readings x to demonstrate how the phase surface of the mirror affects the intensity and distribution of pixels in the image. The form of the formula used can be retained, but a substitution must be made, considering the course of our further operation (10).

$$I(r,t) = \sum_{k=1}^{N} U_k F_k(r,t), \qquad (10)$$

where r is respectively expanded as r=(x,y).

To adapt the dynamic optics formula for image processing, we reproduce the following substitution. In this case, the parameter I(r,t) represents the processed image, N the number of parameters or filters applied in image processing, r the coordinates of a pixel in a two-dimensional image, U_k represents the filter intensity factor, for the calculation we will consider a constant value of the quantity, F_k is the response function, r = (x, y) is the coordinates of the wavefront in a section of optical radiation, in image processing this can mean the coordinates of a pixel in a two-dimensional image [14].

For the convenience of structuring, we will create Table 1, where numerical values and changes before and after application of the formula will be indicated.

Table 1. Pixel intensity readings before and after application

r = (x, y)	U_k	F_k values	$I(r,t)$
120	1.2	120	144
180	1.2	180	216
90	1.2	301,75	108
200	0.8	76,67	160
150	0.8	150	120
…	…		…

We start with the calculation for k = 1.

$$I(r,t) = \sum_{k=1}^{N} U_k F_k(r,t), \qquad (11)$$

The sum sign indicates that we should sum the terms for each value, but in the case where k=1, the sum becomes a single expression:

$$I(r,t) = U_k F_k(r,t), \qquad (12)$$

Substituting the values into formula (12) we obtain the following form:

$$\mathrm{I}(120,\mathrm{t}) = 1{,}2 * \mathrm{F}_1(120,\mathrm{t}), \qquad (13)$$

F (120,t) represents the response function for the given wavefront coordinates, for the value k=1 it has the value equal to U1. Performing multiplication we obtain the result (14).

$$I\ (t) = 144, \qquad (14)$$

Similar calculations were performed for the other values and their results are presented in Table 1. Figure 4 shows four variants of the function I(t), which form different models depending on the value of the plate bending stiffness r:

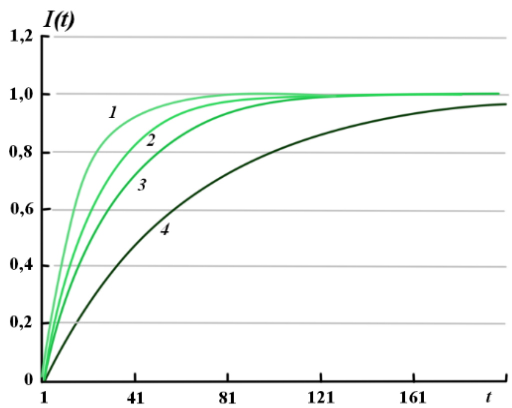

Figure 4. Functions describing the time transformation of control voltages for mirror models with different wavefront coordinates:

1 - 120; 2 - 180; 3- 90; 4 – 200

Figure 5 shows the algorithm according to which the images are processed.

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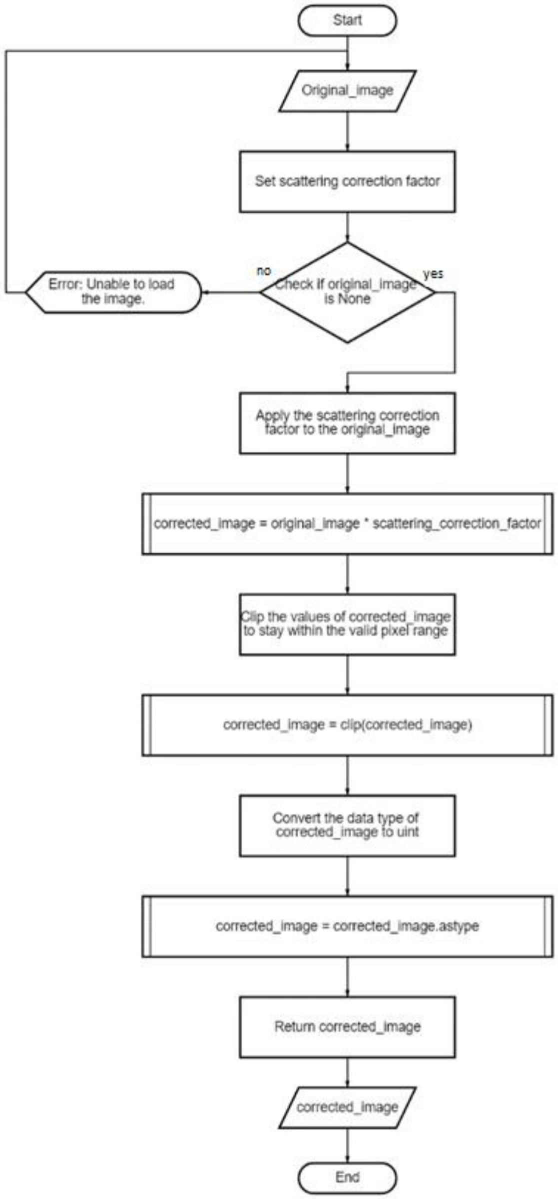

Figure 5. Algorithm for realising image processing by using the response function of an adaptive filter

The description of the algorithm is as follows:
The first step is to start the algorithm.
Then the image to be processed is loaded (in the example of processing the original image is presented)
This is followed by setting the spread of the correction factor to an appropriate value, in this case the value is 1,2.
The conditional algorithm checks whether the original image has a weight value.

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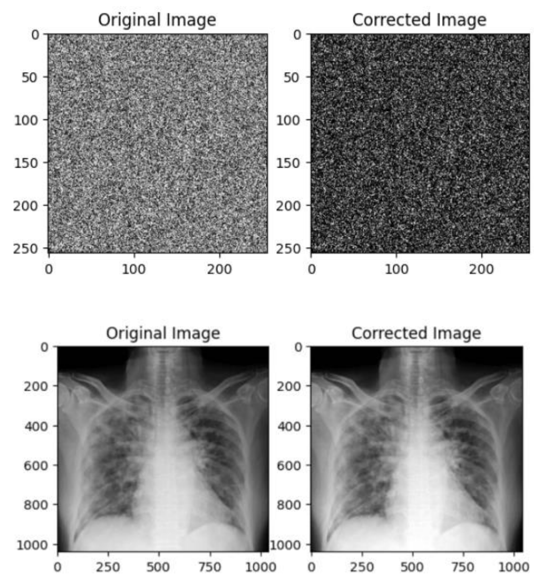
If it does not, then an error about the inability to load the image is displayed and the image needs to be re-loaded. If the image has a weight value, then further processing is done.
A scattering correction factor is applied to the original image.
The values of the corrected image are constrained to remain within the acceptable pixel range (0-255) [15,16,17].
The data type of the corrected image is converted to uint8 (as type is represented as uint8), since an 8-bit integer is used for the pixel range 0-255).
The output is the corrected image after applying the adaptive filter.
Figure 7 shows the result before and after image correction after applying the response function.



a) b)

Figure 6. Image processing result before and after applying the response function. a) example of application on a black and white image; b) X-ray image processing before and after applying the filter

Conclusion

This paper presents a method that has been borrowed from astronomical adaptive optics and used as a basis for developing an adaptive system in radiology. By integrating the systems, it minimizes the distortion caused by scattering and attenuation during X-ray irradiation.
The difference between wavefronts that affect the performance of optical mirrors has been studied. Using example equations, it is shown how deformable mirrors compensate for scattering and attenuation, and how a dynamic mirror can be used for X-ray imaging. The example of linear correction of pixel values presented in the computational part clearly demonstrates the adaptability and potential effectiveness of the method proposed in this paper using an adaptive intelligent filter.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

Acknowledgment

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

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FİNİTE ELEMENT ANALYSİS OF THE OUTER TUBE PART OF THE ENDOSCOPE

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ABSTRACT

Even after cleaning and disinfecting the endoscope, the possibility of contamination is high and can adversely affect the health of patients. The US Centers for Disease Control report that there are approximately two million infected victims each year, and approximately 20,000 people succumb to the infection. In recent news, several deaths at UCLA Ronald Reagan Medical Center have been linked to bacterial contamination of endoscopes. Hence, there is a need to design an endoscope that will reduce or eliminate the chances of these deadly bacteria entering the body. In this article, we will look at the finite element analysis of the outer tube part of a newly designed disposable endoscope. The finite element method (SEM) is a popular method for the numerical solution of differential equations arising in engineering and mathematical modeling. Traditional areas of structural analysis include typical problem areas related to heat transfer, fluid flow, mass transport, and electromagnetic potential.
Keywords: endoscope, outer tube, finite element method, mathematical modeling, analysis.

Introductıon
Endoscopy is a non-surgical procedure used to examine the digestive organs in the human body. An endoscope is a medical device specially designed for this procedure. This article discusses different models of endoscopes. By applying the finite element method, the analysis model is established for various tests, and the boundary conditions are discussed accordingly. The results of the analysis performed using the finite element method are examined in this paper.

Purpose
Finite element analysis of the outer tube part of a newly designed disposable endoscope

Method
Analytical analysis, comparative analysis, and the finite element method were mainly used in the research for the article.

Main part
In this article, the external tube design is an alternative design for the ERCP endoscope. This tube design can be rotated 90° and helps the doctor guide the endoscope to the intended location. It can also be used to compress in a single position using balloon-like plugs. The outer tube design is similar to the cylindrical endoscope design. It has cylindrical bonds connected by gaps. The inner diameter is 17 mm, which is slightly higher than the outer diameter of the endoscope. Figure 1 shows the 3D model of the outer tube [1].

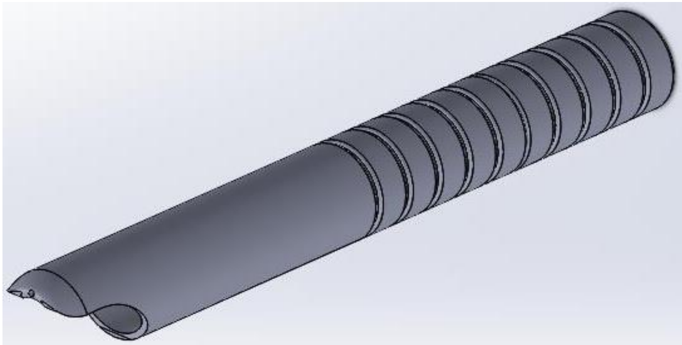

Figure 1. 3D model of the outer tube

This model tip can be bent, and I have shown the bent tip design in Figure 2. The designed end is controlled by a thread. When the string is pulled, the end is bent 90 degrees, as shown in the figure below.

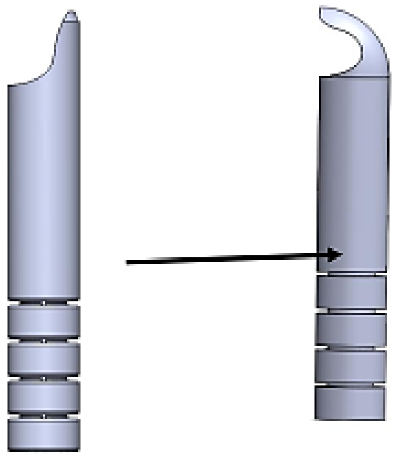

Figure 2. Model of bent tip

An external tube and endoscope are passed through the gastrointestinal tract. A typical outer tube and endoscope assembly is shown in Figure 3.

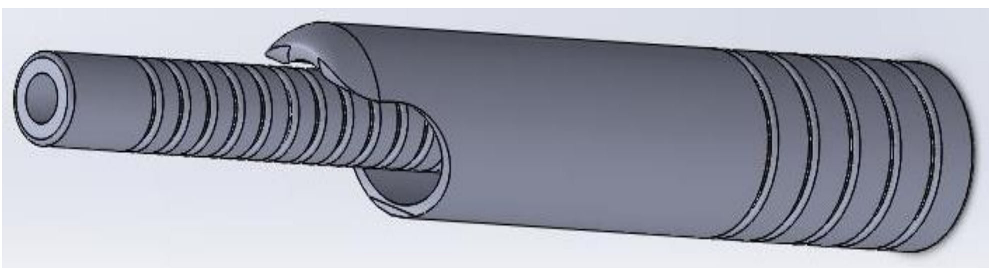

Figure 3. Outer tube assembled with endoscope

The balloon occlusion technique is used to compress the upper tube in one position. After inflation, a balloon puts pressure on the organ and closes the upper tube in this position. Figure 4 shows the top tube with an inflated balloon around it.

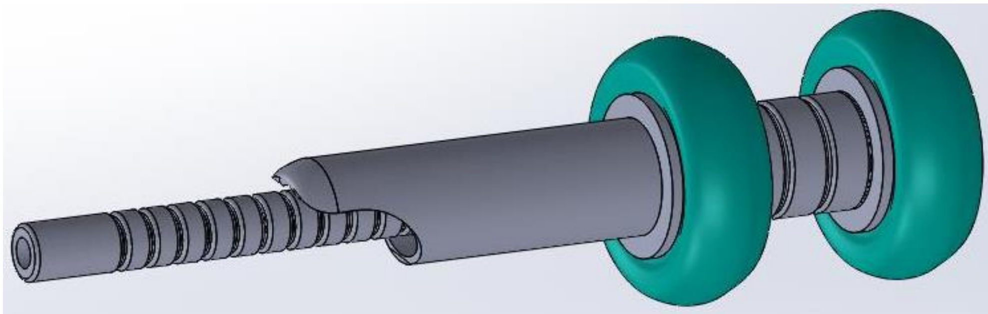

Figure 4. Top tube with inflated balloon

Developing a smart outer tube that can act as an elevator in the ERCP procedure may be a promising approach to avoid the problem of superbug infection. The outer tube model could be a potential solution to the superbug problem. With an external tube, we can use an anterior view instead of an ERCP scope. The outer tube is disposable, and the preview area can be cleaned by a standard process. The outer tube design is a potential alternative to the elevator section in the duodenoscope or the entire duodenoscope [2].

Finite element method and analysis

The finite element method (SEM) approximates boundary conditions based on boundary conditions. Finite element analysis is a process in which a design is discretized into smaller elements. The process of forming these small elements is called meshing. Finite element analysis is a tool used to simulate practical situations without producing a design or manually testing it. After 3D modeling in SolidWorks, the model is meshed in the same software. The model is discretized into small elements such as tetrahedral elements or hexagonal elements. Figure 5 shows the discretized model. This procedure is also called design preprocessing [3].

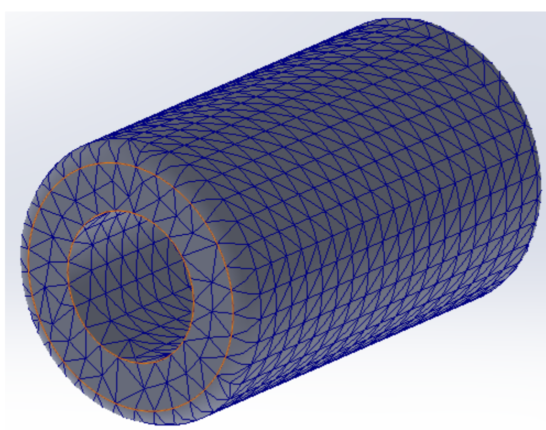

Figure 5. Mesh tip of the endoscope

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After meshing in SolidWorks, the design is analyzed for various conditions. We use a postprocessor such as SolidWorks Simulate to perform the analysis. This solver is a finite element analysis solver.

Material Properties and Meshing

The material properties of the 3-D-printed material are assumed to be similar to those of natural rubber. The material properties of the 3-D printed materials were calculated using uniaxial testing and are like those of natural rubber. The natural rubber material in the SolidWorks program has the following properties [4].

Table 1. Material properties of natural rubber

Characteristics	Value (unit of measure)
Modulus of elasticity	12000 Pa
Poisson's Ratio	0.4
Mass density	960 Kg/$m3$
tensile strength	20000 KN/m2
Thermal conductivity	0.2256 $W/(m.\ k)$
Specific heat capacity	1386 J/(Kg. k)

Figure 6 shows a mesh endoscope model. The tip and cylindrical joint are connected using 4-node tetrahedral elements. The tip has a 4 mm, 0.3 knot element. Critical areas such as voids and holes have a finer mesh with a cell size of 0.01 mm. The total number of nodes in this mesh endoscope is 104151. The total number of elements in the endoscope is 56,738.

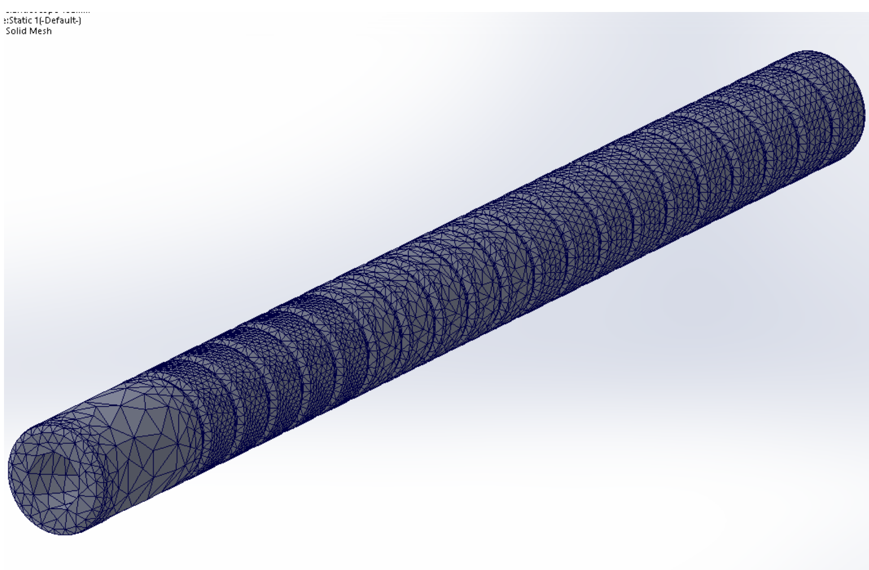

Figure 6. Design of the endoscope after mesh installation

Boundary condition

Boundary conditions are defined to apply constraints and loading conditions to our design. The results provided by the FEA are highly dependent on the accuracy of the boundary conditions. A small change in the boundary conditions can cause the final result to change by orders of magnitude. Thus, the accuracy of the boundary conditions plays a very important role in the accuracy of the final FEA solution. The end connection of the endoscope is considered a fixed support. The nodes in this connection are fixed, with no movement in all six degrees of freedom.

When the endoscope is pushed in the direction of travel, it slides over a wall. A force of 1 N is applied to the tip of the endoscope to test the deflections and stresses in the model. Surface-to-surface contact between various components is established at the contact and tip interfaces and at the contact interface. The design shown in Figure 7 is a simplified version of the endoscope. It does not show any wires or other components in the assembly [5].

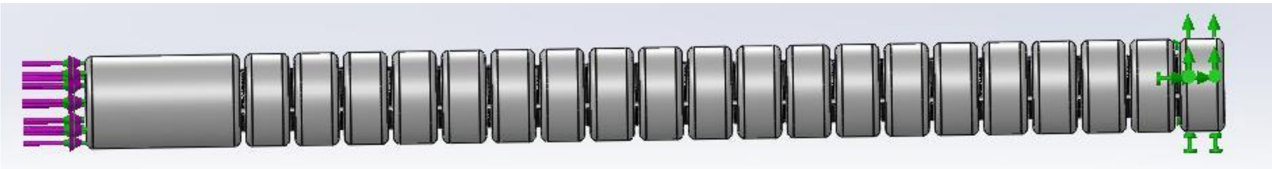

Figure 7. Boundary condition for tension and bending test

The design parameters of the model are shown in Figure 8. All design parameters are compared to Olympus' base model with dimensions shown in Table 3.

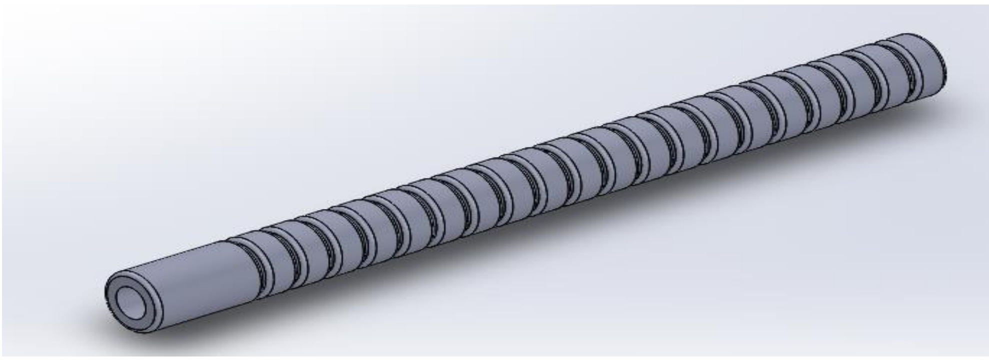

Figure 8. Construction parameters in the model

Table 2. Design parameters of the basic model and 3D model.

	Length(mm)	Thickness(mm)	Diameter(mm)
Lens	20	2	16
Bend tip	150	3,5	15
Follower	350	3,5	16
Camera unit	20	N/A	4
Routing wire	500	N/A	0,5

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Stress analysis and loss of stability

Stress calculations for the model were performed using SolidWorks software. A structural analysis was performed to investigate the stresses in the design. This study allows for checking the regions of high stress concentration in the design. Figure 9 shows the resulting displacement contours for the boundary condition in the basic model. A displacement of 1,522 mm is observed at the distal end of the endoscope [6].

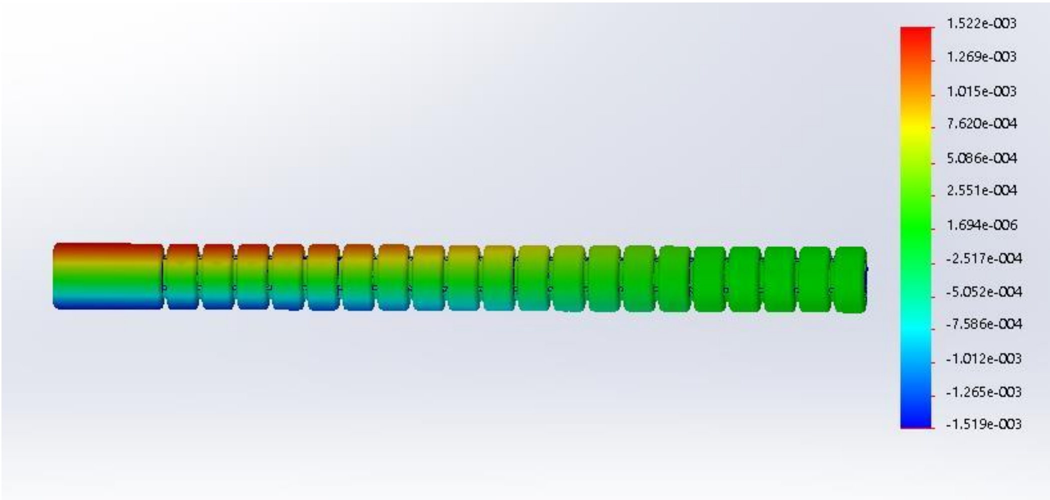

Figure 9. Displacements of the endoscope

Figure 10 shows the stress distribution of the endoscope model. A maximum Von Mises stress of 2.958 MPa is observed in the spacer region of the assembly. The endoscope is assumed to be manufactured from natural rubber and has a yield stress of 12 MPa. High stress results are observed in the spacer regions. This is due to the sudden displacement of wires and holes. However, the stresses are five times below the yield limit [7,8,9,10].

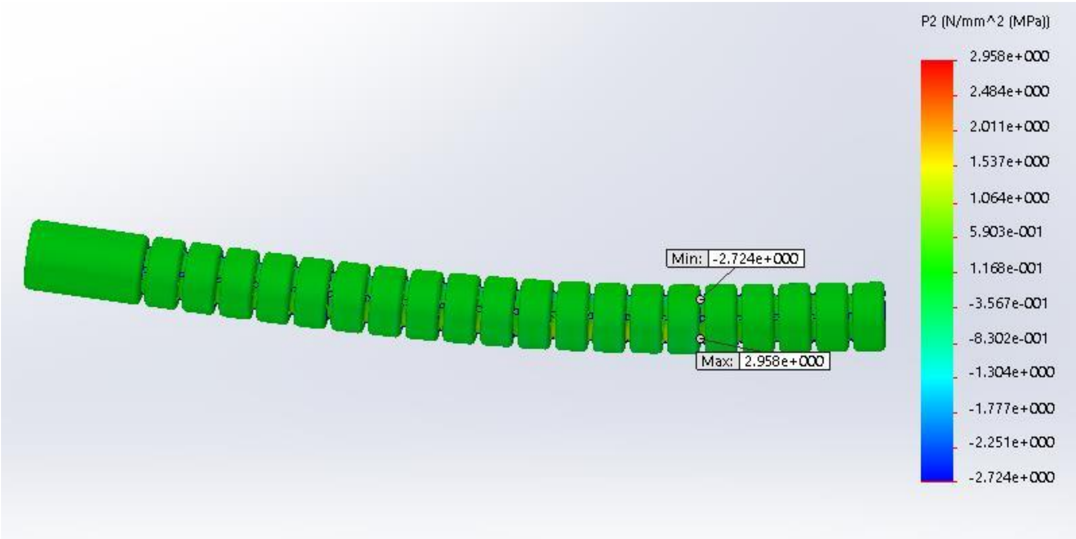

Figure 10. Stress contours in Mpa

Buckling analysis shows the bending frequencies. Boundary conditions for bending are similar to stress calculations. Figure 11 shows the four modes of bending.

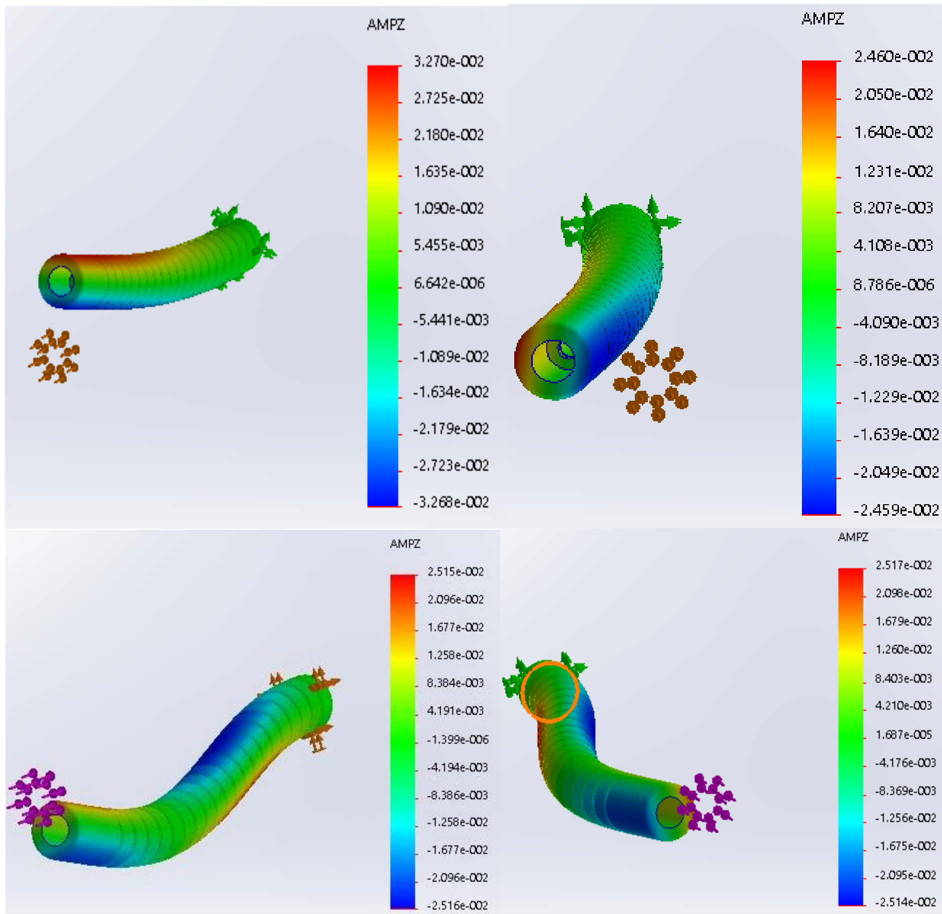

Figure 11. Bending modes in Hz.

Frequency (module) analysis

The resonance frequency is the natural vibration frequency determined by the physical parameters of the vibrating object [11]. Most structures can be made to vibrate resonantly, that is, with a high vibrational motion. Resonance is one of the causes of vibration and noise problems in structures and running machinery.

Modal analysis is a common method for determining the vibration modes of a structure. The modal regimes are determined by the material properties (mass, force, and stiffness) and the boundary conditions of the structure. A multiple degree of freedom system can be described by the following equation [12,13]:

$$Mx(t)+Cx(t)+Kx(t)=f(t)$$

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where M is the mass matrix, C is the damping coefficient matrix, K is the stiffness matrix, x is the displacement, and f is the external force matrix. Figure 12 shows a mesh model of the endoscope. Modal analysis calculates the natural frequencies of the endoscope design. Shows different modes of vibration and their corresponding frequencies. The natural frequency of the design is very low. It has a frequency of 7,683 Hz.

Table 3. Frequency response of the model.

Mode type	Cylindrical model (Hz)
1st bend	15,59
2nd bend	30,26
1st twist	11,14
2nd twist	13,48
Natural Frequency	7,69

Table 3 shows the combined result of different vibration modes. This is illustrated in Figure 12. Figure 13 shows the CAD modal analysis with 4 vibration modes.

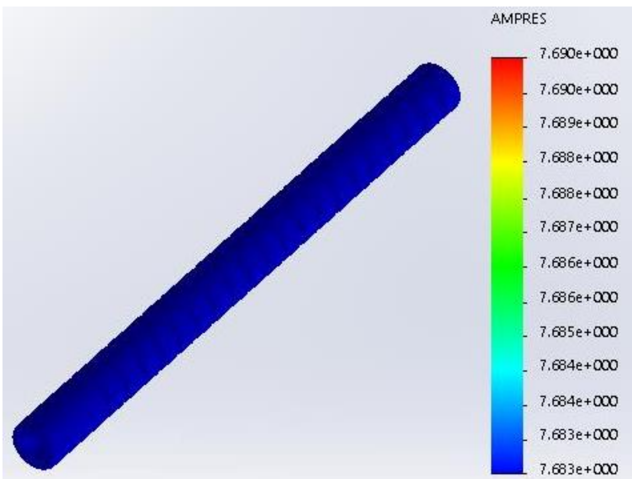

Figure 12. Natural frequency of the 3-D Model

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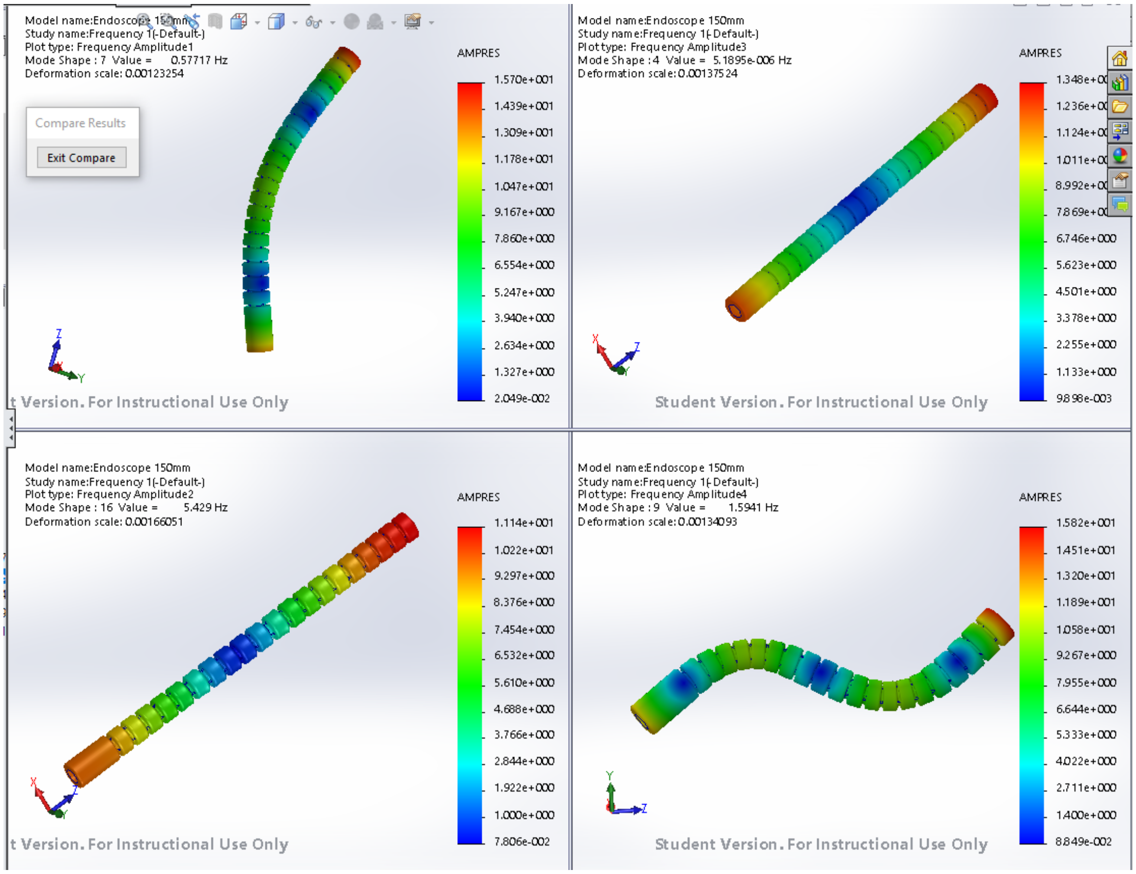

Figure 13. Hz-də 3-D modelin tezlik reaksiyası

Conclusion

In this article, diameter, thickness, etc. optimization for individual design parameters was investigated one by one. In this paper, the displacement of the distal tip of the endoscope was observed to be 1.5 mm for a compressive load of 1N. The maximum stresses observed were 2.5 MPa, well below the rubber yield stress. The frequency response for the design shows a natural frequency as low as 7.8 Hz and is considered safe. Among the design parameters, material properties play an important role in determining endoscope displacement and performance.

The tip of the endoscope can be optimized to achieve the requirement of improved surgical performance. The true optimal design can be achieved by specifying the functional parameters and changing all the design parameters at the same time. At the same time, functional parameters can be minimized by keeping the maximum voltage and frequency response within the permissible range.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

Acknowledgment

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

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INVESTIGATION OF ANTI-CANCER PROPERTIES OF COMPONENTS EXTRACTED FROM POLARMICROALGAE

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ABSTRACT

Cancer is irregular cell division that can be inherited or occur under environmental factors. Due to mutations in DNA, damage occurs in the cell division mechanism and cells divide uncontrollably [1]. Natural compounds are widely preferred in the treatment of cancer, which is the second leading cause of death. Microalgae have a great role in cancer treatment because they have rich bioactive components and high efficiency [2,3]. Microalgal biomass has many uses in a wide variety of fields, thanks to its potential for rich bioactive compounds and its ability to be used as a sustainable bio- product source. It provides benefits [3]. Therefore, research on microalgae is increasing as biotechnology advances.

Bioactive compounds derived from microalgae are a natural, safe, and renewable resource and are research subjects for nutraceutical and pharmaceutical applications due to their potential therapeutic properties [4]. These bio-actives also have drug delivery, wound healing, and antioxidant, anti-oxidant, anti-inflammatory, neuroprotective, and anti-carcinogenic properties [5]. There is a lot of research done on microalgae. And these studies continue to increase. This study aims to determine the content of microalgae obtained from the polar regions and to investigate their anti-cancer properties, thus adding new information to the knowledge in the literature.

Microalgae has been proven to have anti-cancer properties due to its bioactive properties. While microalgae exhibit natural killer cell activity against cancer cells, they also activate the immune system. There are no studies in the literature regarding the anticancer effects of polar microalgae. This project aims to extract the contents of various polar algae species and analyze these contents, then examine their anticancer properties through cancer lines and offer an alternative way to treat this disease. After investigating the properties of the produced polar microalgae, the substance obtained through extraction will be applied to cancer cells to study its anticancer activity. The primary field contribution of this project is to examine the anti-cancer activity of polar microalgae in various types of cancer and to pave the way for the production of polar algae-based biotechnological drugs. Therefore, one of our main goals is to fill the gaps in the literature and pioneer other studies.

Keywords: Polar Microalgae, Biotechnology, Neuroprotective, Anti-inflammatory, Anti-carcinogenic.

Eigen value

Cancer is a health problem that is responsible for 21% of deaths worldwide and ranks second after heart disease. Although much research has been done on the disease, according to the information published by the World Health Organization, cancer-related deaths are increasing year by year [6]. As seen in Chart 1, one of the most common types of cancer today is breast cancer. Additionally, the incidence of prostate cancer is also quite high. For this reason, research will be

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conducted on these two types of cancer in our study. Cell line diversity will be provided to examine the carcinogenic effecton the cells that are in our department and will be serviced.

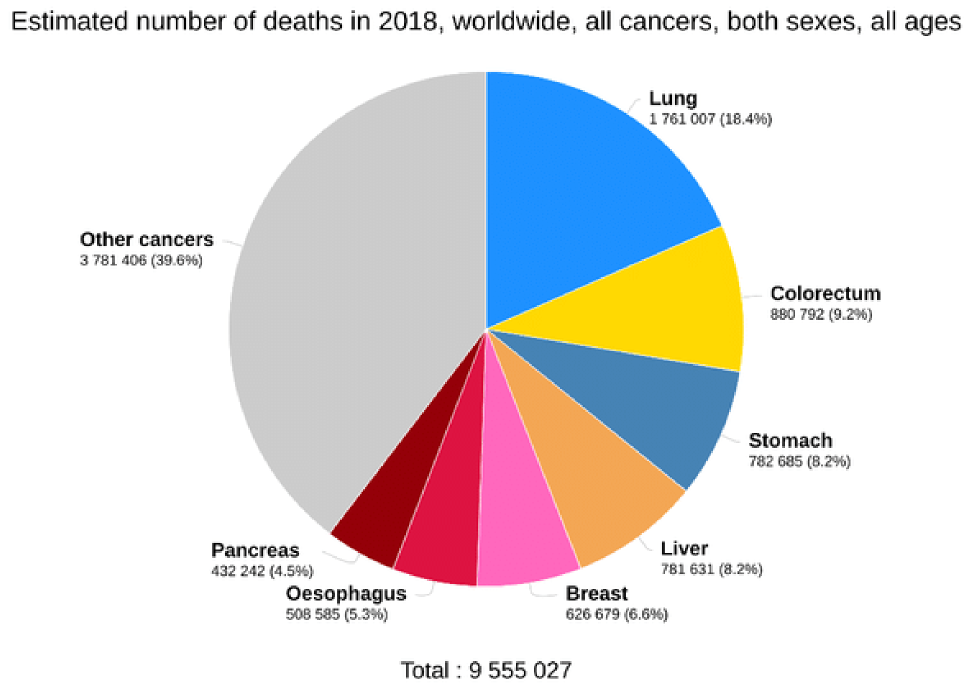

Figure 1. Statistical data on various cancer types around the world [7]**.**

Microalgae are single-celled organisms with photosynthetic properties and are widely found in aquatic environments [8]. Microalgae attract great attention in fields such as biotechnology and energy production due to their advantages such as high nutritional value, rapid production of biomass [8], andthe ability to use biochemical components in various industrial applications [9]. It is known that micro aggregates are used in pharmaceutical production, the cosmetics industry, and biodiesel fuel production [10]. Figure 1 shows the microalgae isolated from the poles.
Its usage is simply demonstrated. Additionally, the relationship of microalgae with cancer is also being investigated [11]. Some studies show that microalgae have anti-cancer activities and can inhibit the growth of cancer cells [11]. In particular, microalgae that can survive in extreme living conditions, such as arctic microalgae, are thought to be a potential source in the fight against cancer. However, it is important to note that research on this topic is still in its early stages and more work needs to be done. For this reason, we will use polar microalgae species in our research to examine their anticancer effects and the contents of their extracts and will contribute to the literature.
The uncontrolled division of cancer cells, their ability to metastasize, and their heterogeneous structure [12] make cancer diagnosis and treatment methods difficult. Problems such as side effects of traditional treatments and drug resistance have negative effects on patients. Therefore, the searchfor alternative treatments with fewer side effects is increasing. Microalgae stand out due to the rich bioactive components they contain. Studies show that microalgae may have anti-cancer properties inmany types of cancer [9,10].

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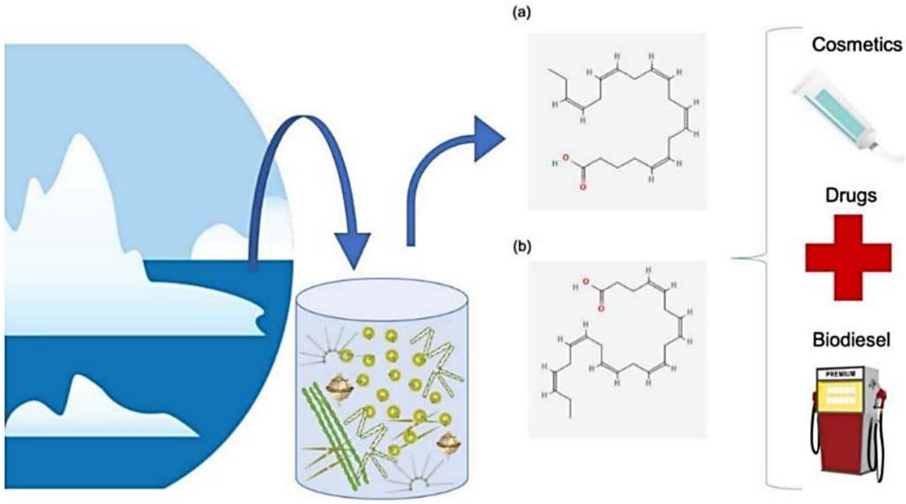

Figure 2. Summary of the conversion of microalgae isolated from the poles into products [10] (a) Eicosapentaenoic acid (EPA) and (b) Docosahexaenoic acid (DHA)

In this study, microalgae isolated from the Chlorella variabilis species obtained from Antarctica will be used. These polar microalgae are thought to have different biochemical content than other microalgae due to their adaptation to harsh environmental conditions. There are no detailed studies on the anticancer effect of arctic microalgae, and their effects on selected types of cancer have not been examined in the literature. This study will provide important data on the effect of microalgae extracts on cancer and fill the gaps in the literature. At the same time, polar microalgae will be characterized, and together with the determination of their bioactive substances, new data for the use of polar microalgae in other areas will take their place in the literature. Examining the anticancer properties of extracts obtained from Antarctic species is another important aspect of the project.

Goals

Nowadays, microalgae are used in many areas such as medicine, food, cosmetics, and biofuel, and are becoming an increasingly popular raw material. This popularity is due to the increasing demand for products produced with microalgae, since microalgae are natural. In the proposed project, it was aimed to examine the contents of algae species, as they have rich bioactive products that have adapted to harsh conditions such as polar regions, and to investigate the anti-cancer properties of these examined contents. In line with the information obtained for this purpose, an alternative method that is effective and has fewer side effects on cancer can be created.

Microalgae are frequently used in the field of biotechnology due to their wide range of bioactivities, including anti-cancer, antioxidant, and anti-inflammatory, and their rich content [13]. It has been suggested that many microalgae have anti-cancer properties [9,14]. In this proposed project, the anticancer activity of arctic microalgae in various types of cancer will be investigated and the obtained data will be reflected in the literature. Based on these data, an effective alternative cancer treatment based on natural and sustainable raw materials, with fewer side effects than synthetic drugs, is presented. During the project process,

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- Studies will be carried out for the production and biochemical analysis of microalgae species.
- The anticancer activity of microalgae species obtained within the scope of these studies will be investigated on various types of cancer.
- Additionally, based on the results of the research, experiments leading to anticancer research such as protein determination, carbohydrate and fat efficiency will be carried out.
- If the data obtained in this graduation project yields positive results for cancer treatment, it is aimed to take an important step towards the production of biotechnological drugs from polar microalgae extracts with determined anticancer activity and to contribute to studies on cancer.

Method

This project consists of four work packages:
Work Package 1: Production of microalgae isolated from polar regions, their biochemical analysis and drying and storage to be used in products, extraction by Soxhlet method, substance determination of the resulting microalgal oil, content determination by GC/MS and HPLC methods.
Work Package 2: Obtaining polar microalgae in different forms (Nano capsule)
Work Package 3: Growing cancer cell lines in the Cell Culture laboratory and performing cell viability analysis with the obtained cell lines.
Work Package 4: Investigation of the anticancer effect of cultivated polar microalgae
The aim is to produce, biochemically analyze, and dry and store the isolated polar microalgae for use in products in WP 1. Microalgae will be grown in a medium containing agar cultures to create a stock culture and then transferred to conical flasks with a 10% (volume: volume) inoculum amount. Microalgae will be grown in suitable media for growth in a shaking incubator at 150 rpm under continuous illumination at 25°C. Growth monitoring will be done on a spectrophotometer withabsorbance measurements at a wavelength of 680 nm.
Microalgal biomass obtained from production will be harvested using a Sigma brand refrigerated centrifuge (5000 rpm, 15 minutes). Then, the resulting biomass will be solidified by incubation and lyophilization processes and will be stored for use in biochemical analyses and anticancer studies.
Additionally, since the algae content to be obtained from TÜBİTAK-MAM-KARE is currently unknown, the algae cell will be investigated and appropriate parameters will be evaluated. In the appendix, several types of algae commonly introduced from the poles are visually indicated.

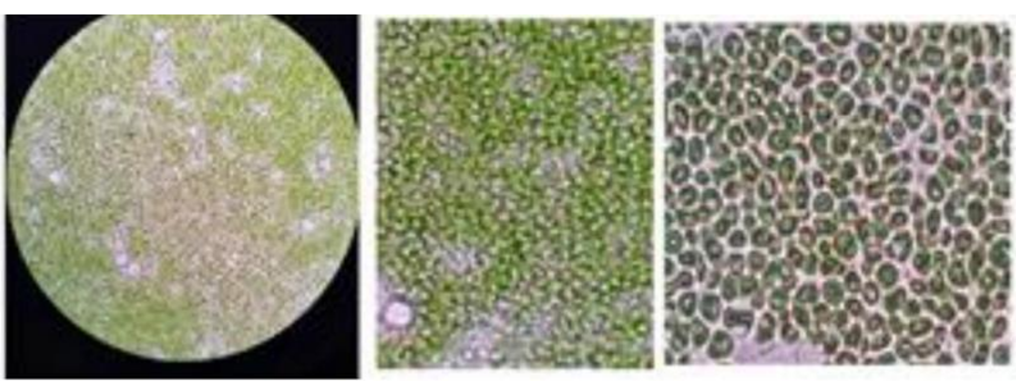

Figure 3. Representation of two microalgae species (Chlorella variabilis and Auxenochlorella pyrenoidosa) from Antarctica.
https://www.yok.gov.tr/Dergi/YOK_Dergi_Sayi_15/index.html#page/73

Determination of carbohydrate content

The total carbohydrate content in microalgae will be determined by the phenol-sulfuric acid method. In this method, phenol reagent is prepared at a concentration of 80% (g/g). The reagent is created by adding 80 g of phenol to 20 g of distilled water. Glucose is used as a standard for analysis and 0.05 ml of phenol reagent is added to glucose solutions prepared at different concentrations in tubes to create the standard curve. Then 5 ml H_2SO_4 is added. After the tubes are left at room temperature for 10 minutes, the absorbance values of the samples are measured in the spectrophotometer at a wavelength of 490 nm, and the carbohydrate content of the microalgae cultures is determined.

Determination of protein content

Modified Lowry Method will be used to determine protein content. This method is used to determine low amounts of protein. Samples taken in certain amounts from the standard BSA solution are placed in glass test tubes and standards in the range of 70-140 mg protein/L are created by adding distilled water and 1 N NaOH solution. 1 N NaOH is added to the samples taken from the cultures and kept in a 100°C water bath for 5 minutes. The tubes are then placed in a cold water bath to cool rapidly. Reagents C and D are added and mixed quickly by the vortex. It is incubated at room temperature for 30 minutes, and at the end, the absorbance values at 750 nm wavelength are measured and read with a spectrophotometer.

Determination of oil content

For the determination of oil content, total lipids from microalgal biomass will be extracted using the modified Bligh and Dyer (1959) method. The process will be carried out through the following steps:

1. Lipids will first be extracted with a chloroform-methanol (2:1, v/v) mixture.
2. Then, the chloroform and aqueous methanol phases will be separated by adding methanol and water so that the chloroform: methanol: water ratio is 1:1:0.9.
3. The chloroform layer will be washed with 20 ml of 5% NaCl solution and then evaporated to dryness.
4. In the last step, the total lipids obtained will be measured gravimetrically.

This method is used as an effective method for the extraction and quantification of lipids.
Determination of oil content of microalgae: Gas chromatography (GC) will be used to determine the oil content of microalgae.
GC analysis is a widely used method to separate and identify the components of oil samples.
Analyzes will be performed on a gas chromatography device. In this method, oil samples are passed over a special column, allowing the separation of their components. A flame ionization detector (FID) is usually used in the analysis. For easy comparison and identification, methyl heptadeconate (C17:0) will be used as an internal standard. Samples are made ready for analysis by mixing them with internal standards and appropriate solvents. During analysis, the column temperature program is used. Starting at a low temperature initially, it is increased at a certain rate.

This program allows the separation and analysis of components to be optimized. The results will be detected by the detector and analysis results will be obtained.

will be done. This method of analysis is a reliable tool to determine the amount and distribution of components contained in microalgae oil.

Antioxidant Activity Analysis: Total antioxidant activity analysis of the algal extract will be performed using the 1,1-diphenyl-2-picryl hydrazyl (DPPH) free radical scavenging method. In this method, the method developed by Brand-Williams et al. will be applied.

DPPH radical scavenging activity will be calculated by the following formula: DPPH Radical Scavenging Activity (%) = [(A0 - A1) / A0] x 100

A0: Absorbance value of the control

A1: Absorbance value of the sample or standard

For spectrophotometric pigment analysis, 5 ml of sample will be taken into sample tubes and excess water will be removed by precipitation in a centrifuge. Then, 5 ml of acetone will be added and homogenized in an ultrasonic bath for 5 minutes.

The resulting sample will be kept at 50-60°C for 5 minutes and mixed using vortex. The extract will be separated by centrifugation again. The liquid remaining on the samples coming out of the centrifuge will be read on the spectrophotometer at 666 nm and 475 nm wavelengths and the amount of chlorophyll-a and beta-carotene will be calculated.

HPLC analysis: The content of bioactive substances in the extracts of polar microalgae will be determined. The appropriate column will be selected and used for this analysis and the sample injection volume will be 20µl. Two different eluents will be used: (A) water: methanol (1:4, v/v) and (B) acetone: methanol (1:1, v/v). By determining the gradient of mobile phases, carotenoids will be separated and detected with absorbance values in the range of 360-700 nm. Calibration lines will be created using concentrations of standards of bioactive substance ingredients associated with anticancer activity.

WP 2. Obtaining polar microalgae in different forms (Nano capsule)

In this work package, microalgal extracts will be encapsulated using the electrospray method. With this method, extracts rich in bioactive components obtained from microalgae will be transformed into nano-sized structures and the anticancer effects of these products will be investigated. PVA and sodium alginate will be used for encapsulation.

First, PVA solutions of different concentrations will be prepared. PVA solutions will be mixed in a magnetic stirrer until completely dissolved in distilled water at 90°C. Alginate solution will be prepared in 2% (w/v) distilled water. After the solutions are cooled, PVA solution with a final concentration of 20% (v/v) will be added to the alginate solution. In addition, a homogeneous solution will be obtained by adding 1% (w/v) microalgal oil and 1% (w/v) Tween 20 solution. Although electrospraying is a bettermethod here, Double emulsion or double emulsion method will be preferred within the possibilities of our school. It is a double emulsion (water-in-oil-in-water) method. Here are the steps to create nanocapsules with this method:

1. Preparation of water-containing internal emulsion: Prepare the water phase containing the water solution, the targeted ingredient, or active ingredients.
2. Oil phase preparation: Prepare an oil solution or an oily phase. This phase may contain an oily substance or polymer that will form the exterior of the nanocapsule.
3. Dispersing the inner emulsion into the outer emulsion: Mix using a suitable mixing method to disperse the inner emulsion in the outer emulsion. This will disperse the water phase into the oil phase and form the double emulsion structure.

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4. Nanocapsule formation: After the inner emulsion is well mixed in with the outer emulsion, nanocapsules are formed. In this step, the water phase is ensured to become spherical capsules withinthe oil phase.
5. Nanocapsule hardening: A suitable method is used to harden nanocapsules. This hardening process may vary depending on the type of material or polymer used. For example, a chemical hardener or thermal treatment may be used.

This method is easier and less costly than the electrospray method. However, the size and distribution of nanocapsules may vary depending on the emulsion mixing method and hardening steps used. Therefore, it must be optimized by trial and error to obtain the desired nanocapsule properties.

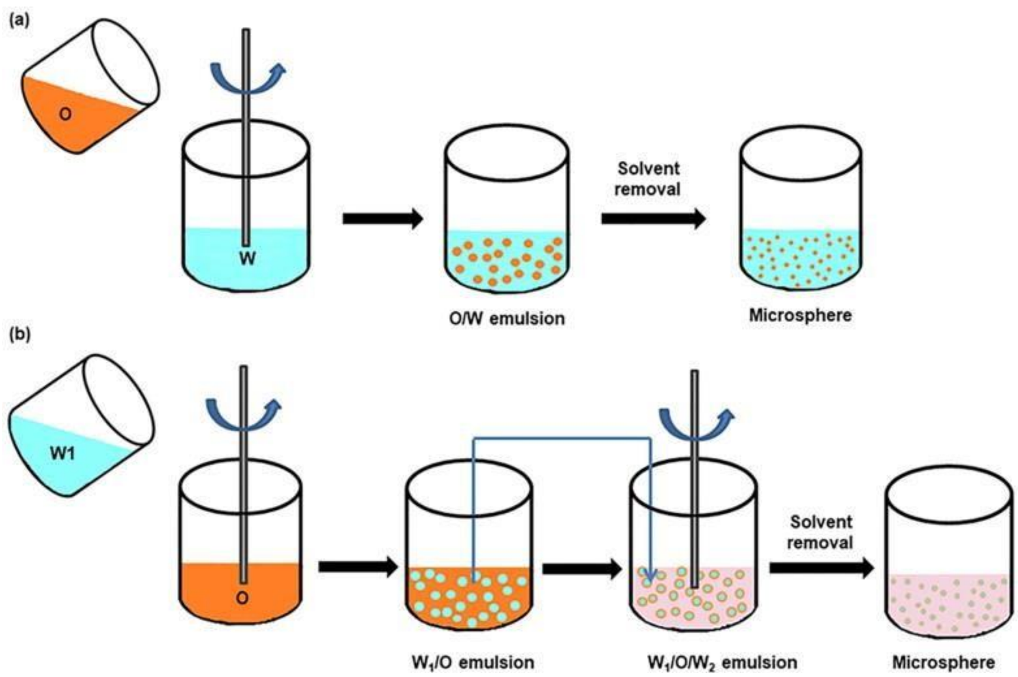

Figure 4. An example binary emulsion method illustration. Doi: 10.1007/12_2011_150

WP. 3. Growing cancer cell lines in the Cell Culture laboratory and performing cell viability analysis with the obtained cell lines.
In this work package, cell lines that we have in stock, such as the MCF7 Breast cancer cell line and DU145 prostate cancer cell line, will be used. The process steps will be as follows.

1. Thawing the cells in the cryotube: The cryotube removed from the cryobank will be kept in a 37°C water bath for thawing. Cells will be transferred with DMEM/F12 medium containing 10% (v/v) Fetal Bovine Serum (FBS) and 1% (v/v) penicillin-streptomycin.
2. Centrifugation process: Cells will be centrifuged for 5 minutes at 1000 rpm. This process is done to sediment the cells and remove excess medium.
3. Sowing process: After centrifugation, the cells will be planted in T25 flasks with fresh medium. Passaging will be performed when the cells reach 70-80% density in the flask.

4. Passaging process: During passaging, cells will be washed with sterile Phosphate Buffered Saline (PBS) solution, then treated with 0.25% Trypsin/EDTA solution and lifted from the surface.
5. Centrifuge process and cell counting: The flasks will be kept in an incubator containing 5% CO_2 at 37°C for 5 minutes and the cells removed from the surface will be transferred to sterile falcons. After centrifugation, the supernatant will be discarded and for cell counting, 1 µl of cells will be taken from the pellet and stained with 49 µl of trypan blue. Cells will be counted under an inverted microscope using a Thoma slide.

Cell transplantation: Then, cell transplantation will be done with 1.5×10^5 cells in each flask. Transplanted cells,

It will be cultured in an incubator containing 5% CO_2 at 37°C.

These process steps aim to make the cell lines ready for use by thawing them, multiplying them, and culturing them under appropriate conditions.

WP. 4. Investigation of the anticancer effect of cultivated polar microalgae

The following formula is used to calculate cell viability using the MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) test:

Cell Viability (%) = [(Sample absorbance - Background absorbance) / (Control absorbance - Backgroundabsorbance)] x 100

1. Sample absorbance: The measured absorbance value of MTT formazan in the well to which polarmicroalgal extracts were added.
2. Background absorbance: The measured absorbance value in the well containing only MTT solution.
3. Control absorbance: The measured absorbance value of the MTT solution in the control well withoutextract.

This formula is a calculation method used to determine cell viability with the MTT cytotoxicity test.

Calculated cell viability values will be compared between the experimental groups and the control group and statistical analysis will be performed. Additionally, half maximum inhibitory concentration (IC50) values will be calculated and used to determine the anticancer effect.[15]

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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PRODUCTION OF T7 RNA POLYMERASE ENZYME WITH RECOMBINANT DNA TECHNOLOGY

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ABSTRACT

T7 RNA polymerase is an enzyme that performs RNA synthesis using the DNA template. RNA polymerases carry out the process of RNA synthesis using the template of DNA, while T7 RNA polymerase is an enzyme found in the genome of the T7 bacteriophage [1]. T7 RNA polymerase is an enzyme used especially in in vitro (extracellular) transcription experiments. This enzyme initiates RNA synthesis from the DNA template and creates the RNA molecule. T7 RNA polymerase is known for its high specificity and efficiency. It can synthesize RNA more quickly and effectively compared to other RNA polymerase enzymes. An important feature of the T7 RNA polymerase is its low requirement for additional protein factors. While some RNA polymerase enzymes require the presence of various protein factors for RNA synthesis, T7 RNA polymerase is less dependent on these factors. This featureenables T7 RNA polymerase to be used more simply and quickly [2,3].

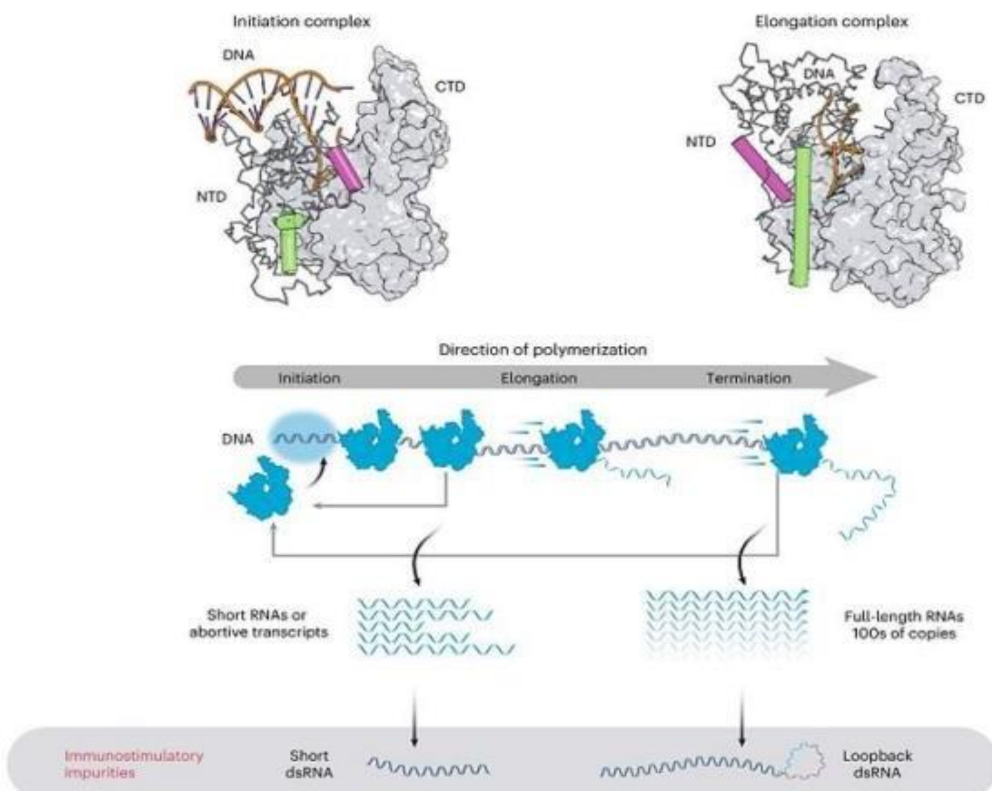

Figure 1. Illustration of the T7 RNAP transcription cycle [4].

The T7 RNA polymerase enzyme requires fewer additional protein factors than other enzymes because it has one subunit. Thanks to this feature, it requires less additional factor use during RNA synthesis. In addition, the stability of the enzyme is high, which ensures that it maintains its activity over long- term use. It is thought that T7 RNA polymerase enzyme, mRNA vaccine technologies, and therapeutic mRNAs may be important tools for potential research in the treatment of genetic diseases and diseases associated with protein deficiency. This enzyme can be used in gene laboratories and pharmaceutical research centers to help unravel the structure of proteins, investigate the function of RNA, or examine RNA-virus interactions. Additionally, it is thought that these studies may be the beginning of discoveries and inventions [5].
In this study, we aim to produce T7 RNA polymerase enzyme in high purity, high activity, high stability, and low cost in the E. coli expression system using the pTOLT vector system. This domestic production method may contribute to the widespread use of the T7 RNA polymerase enzyme and make research more accessible.

Keywords: T7 RNA polymerase, Recombinant DNA Technology, mRNA Vaccine Technology, Therapeutic mRNA

Eigen value

T7 RNA polymerase is a derived enzyme of the T7 bacteriophage and catalyzes RNA synthesis from DNA in the 5'→3' direction. It is highly specific compared to other RNA polymerase enzymes and initiates transcription by tightly binding to the T7 promoter, which is its double-stranded promoter sequence. T7 RNA polymerase, unlike other RNA polymerases, recognizes and transcribes the T7 promoter more efficiently [6]. Therefore, it is only capable of synthesizing transcripts from the T7 promoter and cannot effectively recognize other promoter sequences or DNA templates. T7 RNA polymerase is a DNA-dependent enzyme with a single subunit and can transcribe without the need for additional protein factors. This means that it has a simpler working mechanism, unlike other RNA polymerases. T7 RNA polymerase can rapidly produce large and complex RNA molecules and can synthesize long RNA sequences from the DNA template [7,8].
T7 RNA polymerase is a useful tool in many fields, such as gene expression studies and recombinant protein production. Additionally, transcribing cloned DNA into vectors containing different phage promoters is widely used in biotechnology applications such as selective RNA synthesis, homogeneous single-stranded RNA production, mRNA and sgRNA synthesis, mRNA vaccine technologies, and gene expression studies [9]. However, T7 RNA polymerase has some disadvantages. For example, it can produce oligoribonucleotide impurities as a result of unsuccessful initiation events and cause undesirable immunological responses by creating dsRNA. Additionally, read-error transcription has the possibility of causing errors in base pairing and incorrect bases in the synthesized RNA sequence. These factors can cause problems in situations where a sensitive and accurate RNA sequence is required [10]. Therefore, when working with T7 RNA polymerase, it is important to pay attention to factors such as optimized template DNA sequence, promoter selection, modified nucleotide usage, and purification steps to reduce unwanted immunological responses in mRNA synthesis. Studies on the domestic production and efficiency of T7 RNA polymerase will increase the potential of this enzyme to provide support to research laboratories and other laboratories in our country. In addition, its high purity and low-cost production in E. Coli bacteria using recombinant DNA technology will make its use more widespread in mRNA vaccine studies and other biotechnology applications.

Goals

This project covers gene expression, production, purification, and characterization of the T7 RNA polymerase enzyme to achieve various goals. The main goals of the project are:

- Synthesizing the gene expression of the T7 RNA polymerase enzyme in the appropriate plasmid vector: To ensure the integration of the T7 RNA polymerase enzyme into the genetic material, a suitable plasmid vector will be selected and the enzyme gene will be cloned into this vector.
- Producing the T7 RNA polymerase enzyme recombinantly with E.coli: The cloned T7 RNA polymerase gene will be transferred to E. coli bacteria using recombinant DNA technology and the enzyme production will be carried out by the bacterial cells.
- Purification of T7 RNA polymerase enzyme: The produced T7 RNA polymerase enzyme will be obtained in high purity by using appropriate purification methods. This step will ensure that the enzyme is separated from other components and retains the desired activity.
- T7 RNA polymerase enzyme activity measurement tests and characterization: The purified T7 RNA polymerase enzyme will be subjected to measurement tests and characterization analyses will be performed to verify its activity. These analyses will include experimental studies to evaluate the performance and functionality of the enzyme.

After ensuring sufficient purification, activity tests, and characterization of the T7 RNA polymerase enzyme, the resulting enzyme will be made available to scientists. Additionally, thanks to recombinant DNA technology, desired modifications can be made to the enzyme. These modifications may include improvements to reduce immunological responses. Thus, the obtained T7 RNA polymerase enzyme can be used as a powerful tool in mRNA vaccine technology and other research fields. The goal of this project is to facilitate access to this technology in our country by producing the T7 RNA polymerase enzyme with domestic resources and to contribute to scientific and academic studies.

Method

Selecting the Target Gene

The gene sequence encoding the T7 RNA Polymerase enzyme will be obtained from the NCBI database by conducting the necessary literature review. By performing codon optimization on the gene (https://www.novoprolabs.com/tools/codon-optimization), the gene will be synthesized in a suitable expression vector.

Expression of T7 RNA polymerase protein

E. coli BL21 pLysE strain will be used for protein expression. After the cells are made chemically competent, the transformation process will be applied and they will be allowed to grow in an environment containing appropriate antibiotics. Then, the growing cells will be taken and inoculated into a liquid medium to obtain higher cell density. After incubation at 37 ºC overnight, samples will be taken from the liquid culture and measurements will be made using a spectrophotometer. When the
O.D value reaches approximately 0.6, the induction process will be carried out by adding 1 M IPTG and the media will be incubated at 37 ºC for 3-4 hours [10].

Purification of T7 RNA polymerase

After the cells are separated by centrifugation, they will be dissolved in phosphate buffer (pH: 8.00) and lysed by sonication. Then, hydrophobic proteins and other hydrophobic cell materials will be precipitated by ultra-centrifugation at 30000 rpm for 1 hour. Afterwards, T7 RNA Polymerase protein will be purified by affinity chromatography method. Tris/HCl buffer containing Ni-NTA agarose resin and imidazole will be used for this purification process. In the elution step, each fraction from the column will be sampled for SDS-PAGE analysis [10].

Purified T7 RNA polymerase Activity

One of the most commonly used methods to measure T7 RNA polymerase activity is in vitro transcription assays. In these experiments, T7 RNA polymerase carries out RNA synthesis from a DNA template. Measuring this synthesis may be an indicator of T7 RNA polymerase activity.

Materials to be used in T7 RNA polymerase activity test

- T7 RNA polymerase enzyme
- DNA template (containing T7 promoter)
- Nucleotide triphosphates (ATP, GTP, CTP, UTP)
- Buffer solution (T7 RNA polymerase buffer)
- Radioactive or fluorescently labeled nucleotides (optional)
- Reaction inhibitor (e.g. EDTA)

Method of T7 RNA polymerase activity test

A general T7 RNA polymerase in vitro transcription assay protocol has a flowchart as follows.

1. Preparation of DNA template: A DNA template containing the T7 promoter will be prepared. It can generally be obtained using PCR or DNA synthesis methods. The DNA template must code for RNA thatwill be transcribed by T7 RNA polymerase.
2. Preparation of the reaction mixture: T7 RNA polymerase enzyme, nucleotide triphosphates, and buffer solution will be mixed in a reaction tube. Prepare the reaction mixture for T7 RNA polymerase activity.

It will be adjusted by the conditions under which it will be measured and the experimental protocol. The following conditions are generally used:

T7 RNA polymerase buffer (10x), DNA template (e.g. 1 μg), nucleotide triphosphates (0.5 mM each), T7 RNA polymerase enzyme (usually 1-5 units).

3. Optionally, using labeled nucleotides: You may want to monitor RNA synthesis by adding labeled nucleotides (radioactive or fluorescent). This facilitates the detection of synthesized RNA. The concentration and ratio of labeled nucleotides should be adjusted according to the experimental protocol.
4. Initiating the reaction: Incubate the reaction mixture at a certain temperature (usually 37°C) and T7 RNA polymerase will be allowed to perform RNA synthesis from the DNA template. Incubation time may vary depending on the experimental protocol and measurement purpose. Generally, an incubation period of 1-2 hours will be used.
5. Stopping the reaction: After the specified time, a reaction stopper will be added to stop the reaction. An inhibitor such as EDTA will usually be used. This will terminate RNA synthesis by stopping T7 RNA polymerase activity.
6. Isolating RNA: An appropriate method will be used to isolate the resulting RNA. This will

allow the RNA to be separated from other components. For example, phenol-chloroform extraction or commercial RNA isolation kits can be used.
7. Analyze the RNA: An appropriate method will be used to analyze the isolated RNA. Generally, gel electrophoresis, spectrophotometry, or other analysis methods can be used. Gel electrophoresis is a frequently used method to determine the size and density of RNA.

Declarations
The manuscript has not been submitted to any other journal or conference.

Study Limitations
There are no limitations that could affect the results of the study.

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IMPROVING ULTRASOUND IMAGE EDGE ENHANCEMENT WITH AADFP METHOD

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ABSTRACT

Image processing is a constantly evolving field that is actively seeking innovative solutions to improve the quality and accuracy of image analysis. Smoothing the edges of ultrasound images using filters is a common processing method that reduces noise and improves image clarity. The choice of filtering method and its parameters depends on the specific clinical or research requirements and the nature of the ultrasound images being processed. However, traditional image processing approaches, especially smoothing, have their limitations. An example is medical imaging, where the preservation of clear anatomical image structures is of paramount importance. Excessive smoothing in such cases leads to the erasure of important anatomical details, potentially affecting diagnostic accuracy. In "computer-aided imaging", excessive smoothing of the edges of the investigated objects may prevent their accurate recognition, which is particularly important when the object is characterised by a variety of features. Due to the limitations of traditional methods, the introduction of better approaches is required to address this problem. The AADFP (Adaptive Anisotropic Diffusion with Feature Priority) method is a technique for improving the quality of ultrasound images, which allows a new approach to their processing, by simultaneously smoothing edges and reducing noise, while preserving important anatomical features. The method is based on adaptive anisotropic diffusion, which adjusts the diffusion process depending on image filling, combined with the integration of features previously extracted from a database of annotated ultrasound images. The use of AADFP allows to significantly improve image quality by selectively smoothing out areas with noise while preserving the main structures in the image.
Keywords: Ultrasound image processing, AADFP Method, Image Processing, Medical Imaging, Filtering methods, Feature recognition.

Introduction

Ultrasound imaging is a versatile and non-invasive technique that plays a key role in modern medicine. Ultrasound, also known as ultrasonography, is a widely used medical imaging technique that works on the principle of acoustic waves. High-frequency sound waves, typically in the range of 2 to 18 megahertz (MHz), enter the body and interact with various tissues and structures. The resulting echo signals are recorded by a transducer and converted into a visual image called an ultrasound image. One of the most characteristic features of ultrasound is the ability to obtain images in real time [1]. Unlike many other imaging methods, ultrasound allows dynamic, live images of internal organs and tissues, making it invaluable for studying physiological processes. The absence of ionising radiation, typical of methods such as X-ray and CT scanning, makes ultrasound safe for repeated use, especially during pregnancy.

The quality of an ultrasound image depends on several parameters that determine the clarity, accuracy and diagnostic value of the image [2]:

- Resolution: Resolution, both axial and lateral, determines the ability of the image to distinguish closely spaced structures and accurately reproduce details. High resolution is particularly important when visualising small anatomical structures.
- Depth of penetration: The depth of penetration of ultrasound waves into the body is determined by their frequency. High-frequency waves provide better superficial visualisation, while low-frequency waves provide visualisation of deeper structures.
- Frequency: Ultrasound transducers operate at different frequencies to meet different clinical needs. Higher frequency transducers provide higher image resolution, making them suitable for imaging superficial structures, while lower frequency transducers are ideal for imaging deeper organs.
- Gain and Time Gain Compensation (TGC): Gain parameters control the overall brightness of the image. HGF, often used in cardiac and abdominal imaging, allows you to fine-tune the brightness level over the depth of the image, ensuring optimal visibility of structures located at different depths.
- Frame rate: Frame rate affects the nature of real-time ultrasound imaging by determining the number of frames acquired per second. High frame rates are necessary to visualise fast-moving structures or dynamic processes such as heart activity.
- Artifact Management: Artifacts such as reverberation, shadowing, or speckle noise can distort ultrasound images. However, proper management and correction of artefacts is essential to obtain diagnostically accurate images.

Methodology

Edge portion of the ultrasound image

The edge of an ultrasound image, often referred to as its boundary, is an object of interest to medical professionals, diagnosticians, and researchers for several good reasons.

First and foremost, the edge allows the shape, size, and contour of structures within the body to be assessed. This is very important for differentiating normal and abnormal objects, as it allows doctors to detect abnormalities such as tumours, cysts or other lesions. The edge of the ultrasound image serves as a reference point for anatomical localisation. By visualising the boundaries of an organ or tissue, the doctor can accurately determine its position in the body, which is especially important when planning surgical procedures. Ultrasound image boundaries facilitate accurate measurement and quantification of any body structure [3]. For example, in obstetrics, the boundary where the infant's head falls is critical for assessing fetal biometry and growth. In cardiology, the edge of the image is important for measuring chamber dimensions and heart wall thickness. Also, thanks to the edges of ultrasound images, differential diagnosis of various diseases can be made.

For example, the distinction between benign and malignant tumours is often based on the evaluation of their edge characteristics such as roughness, spiculation or well-defined borders. Given the presence of staining and the manifestation of different textures, two categories of edges can be distinguished in the image, which are referred to as RG-edges and RT-edges [4]. RG-edge is the boundary between two adjacent areas with different average colour shades (in uzi grey images), and RT-edge is the boundary between two adjacent areas with different textures. As an example, two images are shown in Figure 1, showing that the RT-edge is located along the lower boundary and the RG-edge is located on the upper boundary.

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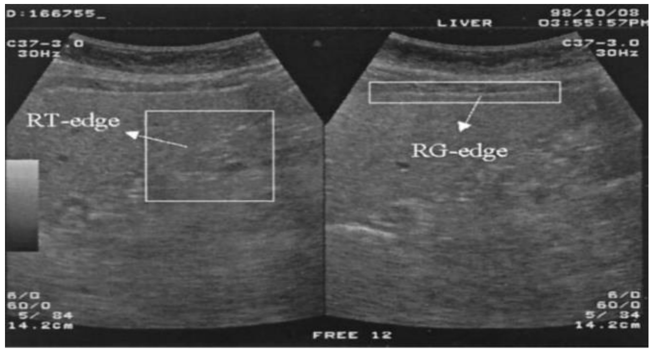

Figure 1. Ultrasound image showing the difference between the RG edge (left) and RT edge (right)

The complexity of segmentation of such images is primarily due to the need to detect both types of edges simultaneously. In this paper, we consider the example of RG edge processing, as methods for detecting and processing RT edges are at an early stage of research [5].

Although the edge of an ultrasound image is of great importance, there are gaps that can affect its quality and diagnostic value. Noises and artefacts common to ultrasound imaging can have a pronounced effect on the image edge as well. Due to the presence of noise and artefacts, problems such as incomplete segmentation or the absence of a significant portion of the desired edge for examination may occur when examining image edges.

Noise at the edge: Noise, especially speckle noise, can introduce a grainy and uneven effect at the edge of the image. This can lead to a loss of edge definition and make it difficult to recognise the noise and the actual anatomical features of the object under study.

Edge artefacts: Artefacts such as reverberation, edge shadowing and refraction artefacts are particularly common near edges due to abrupt changes in tissue characteristics. These artefacts can distort the edge image and mislead clinical interpretation.

Significance of edge artefacts: Edge artefacts can be diagnostically significant. For example, an edge shading artefact may indicate the presence of a strongly attenuating structure behind the edge, and a reverberation artefact may indicate the presence of air or gas near the edge.

Artifact Correction: Correcting edge artefacts is necessary to maintain image quality and preserve the diagnostic accuracy of the edge. This often requires adjusting equipment settings and optimising sensor placement.

To summarise, the edge of an ultrasound image is a diagnostic key that contains a wealth of information for clinical decision making and research. However, understanding existing influences, including noise and artefacts, is essential to optimise ultrasound imaging and ensure accurate clinical assessments.

The essence of image edge smoothing

Before proceeding to the new processing method proposed in this paper, it is necessary to understand the main purpose of edge smoothing. Essentially, this process aims to improve image quality by suppressing high-frequency components that often appear as noise or artefacts and interfere with visual interpretation. Traditional filtering techniques, honed over time and having made significant contributions to image processing, have long been used to achieve this goal. Each method has its own prince of operation and a number of advantages, but also has inherent limitations. Some of the classical methods include:

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2.1 Gaussian smoothing. The Gaussian filter is one of the main tools for processing ultrasound images and is often used for edge enhancement and smoothing. Its working principle is based on convolution, where the image is processed using a Gaussian kernel [6]. The main objective of this filter is to reduce noise and sharpen edges by emphasising pixel intensity variations. However, uniform blurring across the entire image can inadvertently affect fine details, and in particular the edge of the image. The Gaussian normal distribution formula (1) reflects how it works.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}, \qquad (2.1)$$

where, σ is the standard deviation of the normal distribution; x is the horizontal offset from the centre of the convolution kernel; y - vertical displacement from the centre of the convolution kernel.

Figure 2 shows two normal or Gaussian distributions corresponding to different measurements with the same X values and different σ values.

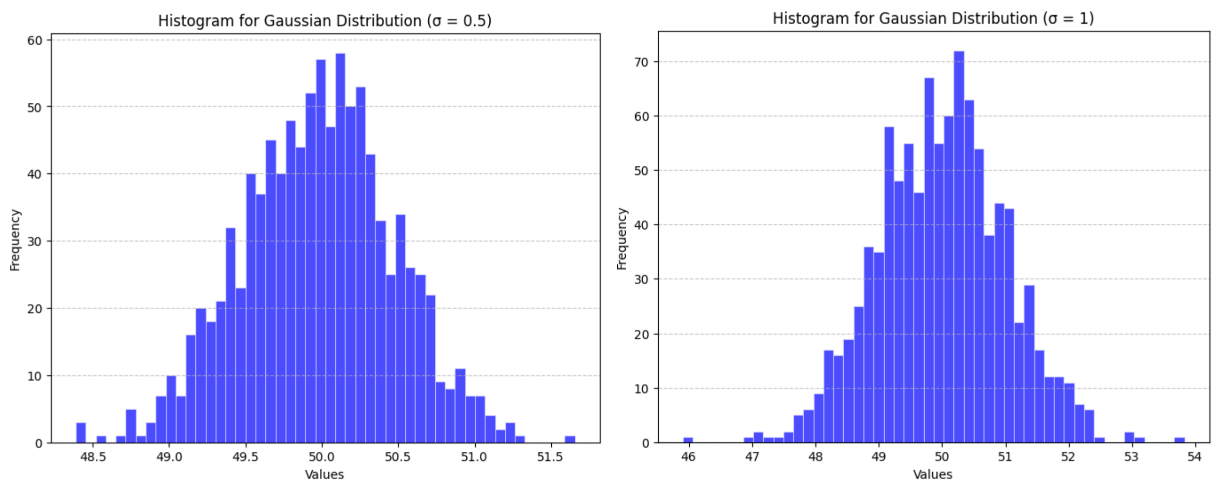

Figure 2. Gaussian distribution for σ = 0.5, X = 50 and σ = 1, X = 50

In the first case X = 50, σ = 0.5, in the second case X = 50, σ = 1. The value of σ in the denominator of the exponent provides for a narrower distribution a greater height at the maximum. In the case of the Gaussian distribution, the expected mean value for a large number of measurements can be calculated using the standard formula.

2.2 Median filtering. Median filter is another traditional method that is designed to reduce noise, particularly speckle noise, while preserving edge detail in images. The filter works by replacing the pixel value at each point with the median value from a given neighbourhood of pixels. However, this can result in blocky artefacts in the processed image, especially if it is over-applied.

2.3 RMS filtering is a sophisticated filter particularly well suited for noise reduction and edge enhancement of ultrasound images. This method is based on an iterative decomposition of pixel intensities. While it reduces noise, it also tends to smooth edges and small structures, which, however, can potentially degrade image quality [7].

One of the main limitations of traditional methods is their homogeneity. Gaussian and median filtering apply a single level of smoothing to the entire image. This homogeneity can lead to blurred edges and unintentional smoothing of important image elements and structures. In addition, traditional methods lack adaptability. They cannot distinguish noise from critical image elements, nor can they distinguish areas where fine details and edges should be preserved from areas where noise should be reduced. Median and RMS filtering, while effective at reducing noise, can result in block artefacts. By replacing pixel values with median or average values in local neighbour-hoods, this method can lead to loss of texture and detail, ultimately resulting in an unnatural looking processed image. Traditional methods can also unintentionally smooth edges. In the noise reduction process, these methods can dull the sharpness of edges, making them less distinct and less representative of the original image structures [8].

Due to the limitations of existing edge filtering methods for ultrasound images, this paper proposes to consider a new approach: Adaptive Anisotropic Diffusion with Feature Priority (AADFP). AADFP is an edge smoothing technique that aims to address the shortcomings of previous methods, providing improved noise reduction while preserving image edge quality. Table 1 summarises the characteristics of each of the described filter types and also shows the characteristics of the proposed AADFP filtering method for comparison.

Table 1. Comparative table showing the difference in basic parameters between filtration method.

Parameter	Median Filter	Gaussian Filter	Anisotropic Filter	AADFP Filter
Filter Type	Non-linear	Linear	Non-linear	Non-linear
Operation	Pixel replacement by median value	Convolution with a Gaussian kernel	Diffusion-based edge-preserving	Adaptive anisotropic diffusion
Purpose	Noise reduction	Smoothing	Edge-preserving and noise reduction	Edge-preserving and noise reduction
Edge Preservation	Limited, not specifically designed	Limited	Strongly preserved	Strongly preserved
Noise Reduction	Effective for Median noise	Effective for Gaussian noise	Effective for random noise	Adaptive to various noise types
Adaptability	Fixed parameters	Fixed parameters	Parameters need tuning	Adaptive parameters for each pixel
Applicability	General-purpose	General-purpose	Edge-preserving applications	Edge-preserving applications
Computational Complexity	Low Simple	Effective smoothing	Strong edge preservation	Adaptive

The table allows for a complete analysis of the filtering methods and from it, conclusions can be drawn as to why the method proposed in this paper should potentially be better.

The advantage of AADFP is that it uses prior feature estimation to optimise the noise reduction, thus effectively dealing with speckle noise without compromising edge clarity. In addition, AADFP excels in preserving fine edge details, ensuring the clarity and accuracy of edge structures, which is essential for accurate diagnosis. AADFP adapts to the specific characteristics of the ultrasound image, providing a customised approach to noise suppression and improved edge clarity. In the next chapter of this paper, the principle of this method will be discussed in more detail.

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Results

Implementation of the Adaptive Anisotropic Diffusion method with Feature Prior and algorithm of the method operation

The AADFP (Adaptive Anisotropic Diffusion with Feature Priority) method is an extended version of the Adaptive Anisotropic Diffusion (AAD) method. This method uses the principles of AAD with the inclusion of an additional step of integrating features extracted from a database of annotated ultrasound images.

Traditional methods such as Gaussian filtering or anisotropic diffusion do not have the accuracy required to recognise complex diagnostic scenarios. As mentioned above, AADFP is based on the principles of anisotropic diffusion, which involves controlled dispersion of pixel intensity to reduce edge-preserving noise. A distinctive feature of AADFP is its adaptive nature. It uses a priori characteristics, a priori information about the image, to make informed decisions for noise reduction and edge preservation [9]. In essence, AADFP detects and adapts to image features, allowing diffusion to be selectively applied to regions requiring smoothing while avoiding critical edge details. Fig. 3 is a schematic diagram illustrating the algorithm of the filter using the AADFP method. The circuit model is more simplified and illustrates the basic principle of the method.

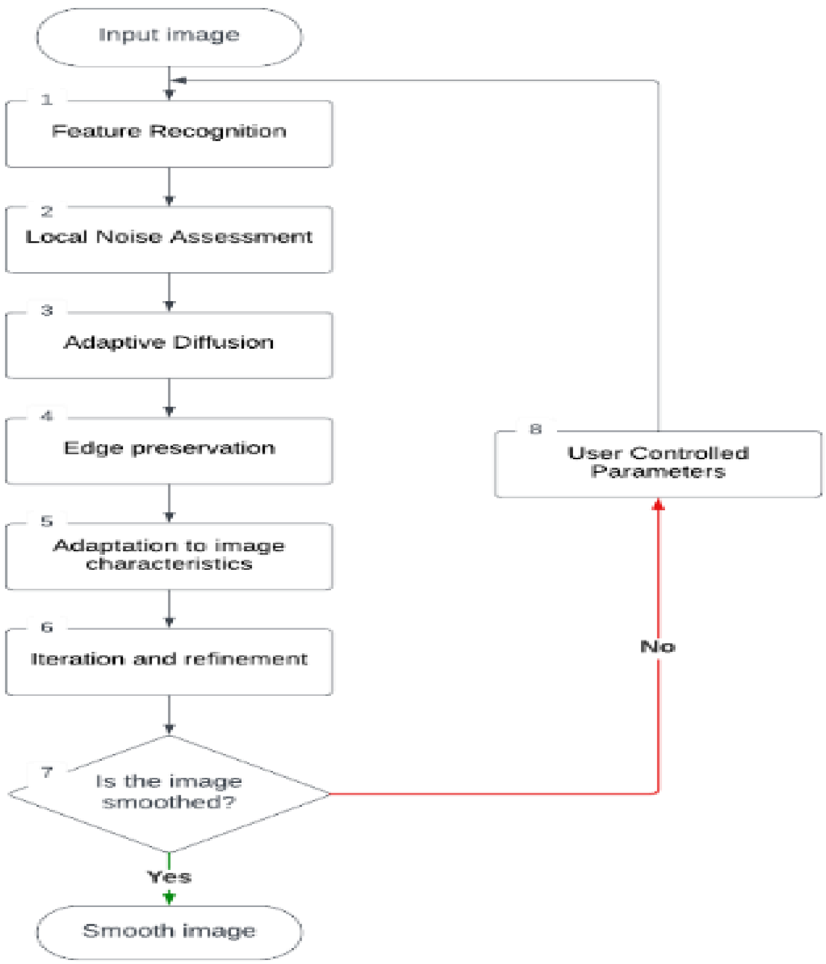

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Figure 3. Block diagram of the algorithm of the proposed method for edge processing of ultrasound images

Pre-processing the ultrasound image and preparing it for further processing steps consists of the following steps.

1. Feature Recognition: The AADFP begins its work by recognising features in the ultrasound image. It identifies areas where there are significant differences in pixel intensity, indicating the presence of edges or thin structures. These features are critical for diagnostic accuracy and must be preserved.
2. Local Noise Assessment and Suppression: This assessment helps the method to determine the level of noise reduction required. AADFP is good at suppressing noise, especially speckle noise which is common in ultrasound images. By selectively diffusing the pixel intensity in non-critical regions, it effectively reduces noise without affecting the clarity of the image.
3. Adaptive Diffusion: AADFP selectively applies anisotropic diffusion to regions that are considered less important in terms of edge information. This method distributes pixel intensity in a controlled manner, effectively reducing noise in these regions.
4. Edge preservation: By applying diffusion, AADFP protects the edges and subtle structures of the image. Instead of clutter smoothing, it protects edges and fine structures by limiting diffusion in these regions using an adaptive approach.
5. Adaptation to image characteristics: AADFP evaluates the image characteristics and adapts its diffusion programme accordingly. Areas with complex structure are prioritised for edge preservation and smoother areas are prioritised for noise reduction.
6. Iteration and refinement. To improve edge smoothing, the algorithm iterates frequently. Iterations allow for more accurate propagation, resulting in better image quality.
7. In the conditional block, the image is comparatively analysed. If the image quality reaches the required level, the image is transferred for output to devices or for recording. If the image quality is unsatisfactory, control passes to block 8 for parameter adjustment.
8. User Controlled Parameters: User Interaction: AADFP provides user interaction by allowing customisation of parameters. It allows user-defined parameters, providing a flexible balance between noise reduction and boundary preservation. Users can adjust the sensitivity of the method depending on image features and the degree of diffusion.

Final Image Output: The AADFP algorithm is completed by generating the final image and outputting it for further processing.

Mathematical formulas defining the method operation and results of ultrasound image processing

Creating precise formulas for the AADFP (Adaptive Anisotropic Diffusion with Feature Prior) algorithm is a complex task, as it involves various mathematical notations, equations, and functions to perform detailed edge processing of ultrasound images. Below, I will provide an overview of some of the key mathematical components that constitute the AADFP algorithm:

1. Anisotropic Diffusion Equation:

The core of AADFP is the anisotropic diffusion equation, which controls the diffusion of pixel intensities while preserving edges. It is represented as:

$$\frac{\partial I}{\partial t} = \nabla \cdot (c(|\nabla I|)\, \nabla I), \qquad (3.1)$$

where ∂I/∂t represents the rate of change of pixel intensity over time, ∇· denotes the divergence operator, |∇I| is the gradient magnitude of the image intensity and c(|∇I|) is a function of the gradient magnitude that controls the diffusion, emphasizing or reducing diffusion based on edge strength [10].

2. Feature Priors and Edge Recognition:

Feature recognition and edge preservation in AADFP involve complex criteria. Feature recognition can be represented as:

$$F(x, y) = \frac{\nabla I(x,y)}{|\nabla I(x,y)|}, \qquad (3.2)$$

where F(x, y) is a measure of feature strength at pixel coordinates (x, y), ∇I(x, y) is the gradient of image intensity at (x, y) and |∇I(x, y)| represents the magnitude of the gradient.

This measure identifies regions with strong edges or fine details.

3. Local Noise Estimation:

The estimation of local noise in the image is critical for AADFP. This involves calculating the local standard deviation (σ) using a defined neighborhood:

$$\sigma(x, y) = \sqrt{\frac{1}{(2N)\sum[I(I,j) - \mu(x,y)]^2}}, \qquad (3.3)$$

where σ (x, y) is the local standard deviation at pixel (x, y), N represents the size of the neighborhood, I(i, j) is the pixel intensity at coordinates (i, j) within the neighborhood and μ(x, y) is the local mean intensity [11].

4. Adaptive Diffusion Coefficient:

To control diffusion, AADFP utilizes an adaptive diffusion coefficient (c) based on feature strength and local noise:

$$C\,(|\nabla I|, F, \sigma) = c0 \cdot f(|\nabla I|) \cdot g(F) \cdot h(\sigma), \qquad (3.4)$$

where 0 is the baseline diffusion coefficient, f(|∇I|) is a function of gradient magnitude, g(F) is a function of feature strength and h(σ) is a function of local noise level.

These functions together determine the degree of diffusion based on edge strength, feature recognition, and noise.

5. Final Anisotropic Diffusion Equation:

The complete anisotropic diffusion equation for AADFP with feature priors is given by:

$$\frac{\partial I}{\partial t} = \nabla \cdot (c\,(|\nabla I|, F, \sigma)\, \nabla I), \qquad (3.5)$$

where ∇· denotes the divergence operator, c(|∇I|, F, σ) is the adaptive diffusion coefficient and ∇I represents the gradient of the image intensity [12].

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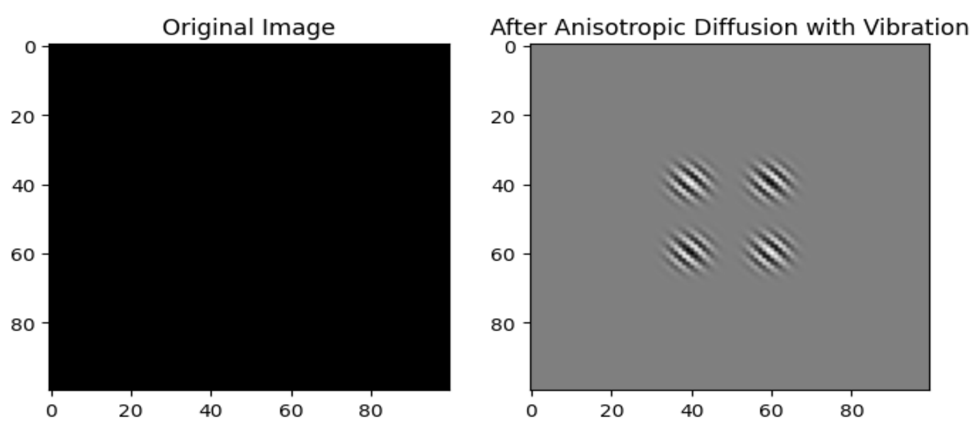
The anisotropic diffusion equation (1) is based on the diffusion of pixel intensities, which selectively smooths out changes depending on the magnitude of the image gradient. This is done by means of a diffusion coefficient that adapts depending on the image characteristics. The feature detection function (2) identifies areas with significant changes in pixel intensity, such as edges and fine structures. This preliminary feature detection function allows prioritising the preservation of these important areas during smoothing. The local noise estimation (3) allows us to determine the noise level in the image, which is further taken into account in the diffusion process. Adaptive diffusion coefficient (4) is the most important component that combines feature recognition, gradient magnitude and local noise level. It allows adaptive control of diffusion in different regions of the image, prioritising edge preservation in areas where it is necessary and allowing more aggressive noise suppression in non-critical areas. All these formulas used in the AADFP (Adaptive Anisotropic Diffusion with Feature Priority) method work in concert to collectively form an image processing system (5). These equations represent a simplified mathematical scheme of the AADFP used for demonstration in the paper.
To visualise the behaviour of the anisotropic diffusion equation (1) described by the AADFP method, simulations can be performed using a simple image or synthetic function [13]. For more practical understanding, let us consider an example with a hypothetical image intensity function, which is an extension of formula (6).

$$I(x,y) = A\sin\left(\frac{2\pi x}{\lambda}\right)\cos\left(\frac{2\pi y}{\lambda}\right), \qquad (3.6)$$

Here, A is the amplitude of the intensity, λ is the wavelength, and x and y are spatial coordinates. Now, let's calculate the diffusion of edge intensity using this function:
To visualise the behaviour of the anisotropic diffusion equation (1) described in the AADFP method, we will perform simulations using a simple image.
We use a two-dimensional grid representing the pixel intensity on which we will model the change with time in a particular region. In this case, we will model a vibrating region in the center of the image [14,15,16,17]. Then by applying anisotropic diffusion we will show how this will affect the vibration and edge preservation of the investigated image. The results can be seen in Figure 4.



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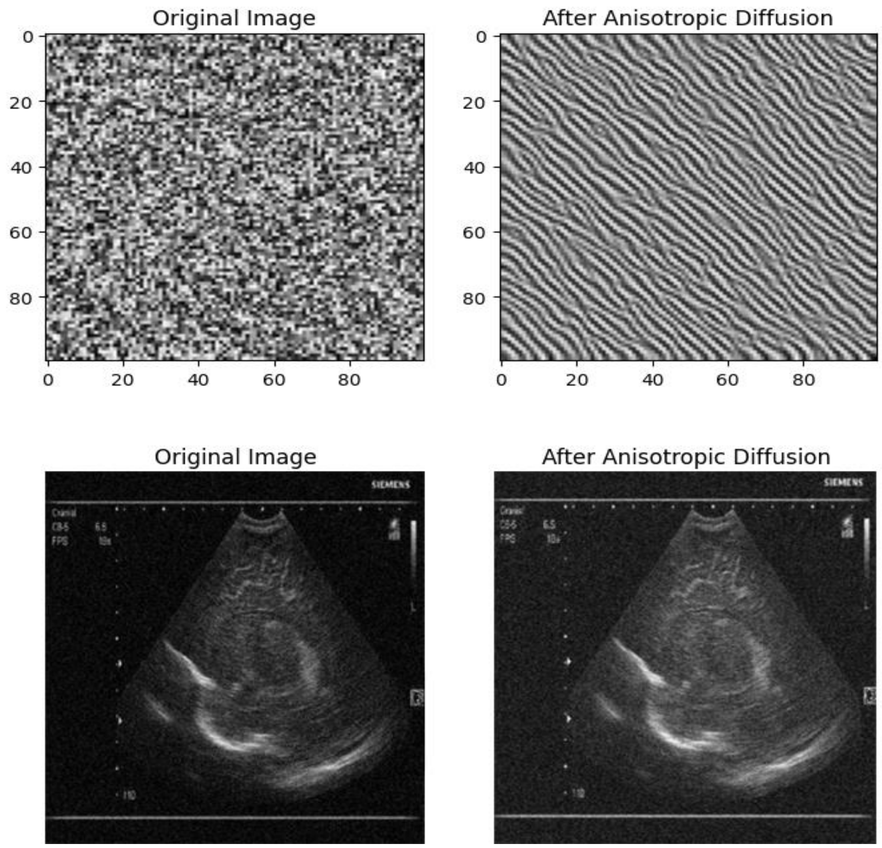

Figure 4. Ultrasound images at different processing stages: (a) Synthetic image before and after application of anisotropic feature; (b) Vibration image before and after application of anisotropic feature; (c) Original ultrasound image and after processing.

As a conclusion after applying the anisotropic diffusion equation, the histograms of the pixel intensities of the ultrasound image edge image before applying the anisotropic diffusion equation and after applying the above formula are shown in Fig. 5 shows the histograms of pixel intensity of the edge image of the ultrasound image before application of the anisotropic diffusion equation and after application of the above formula.

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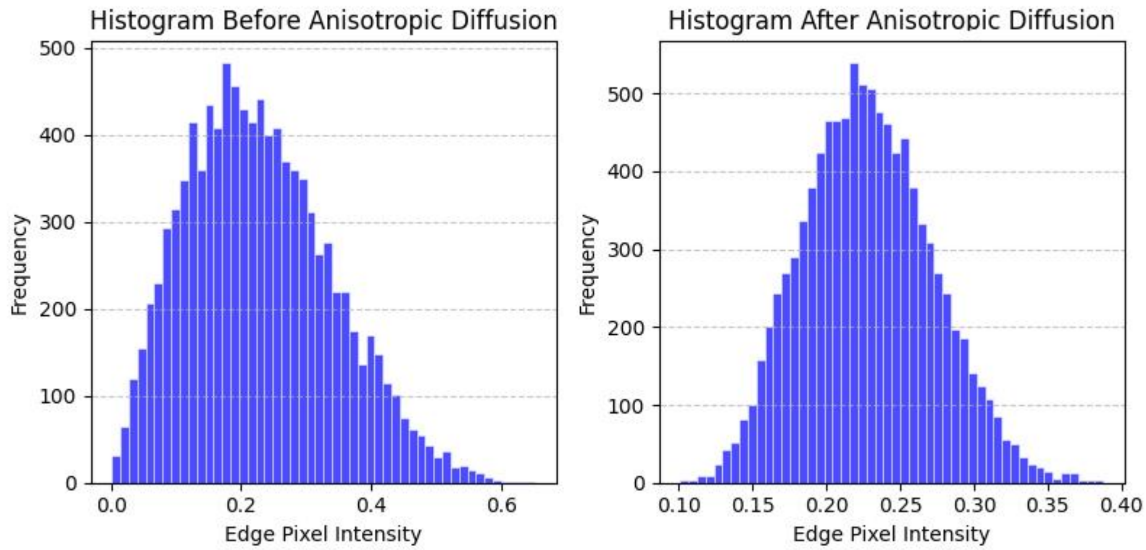

Figure 5. Difference in pixel intensity before and after applying the anisotropic function

Conclusion

The AADFP method proposed in this paper is a new variant of ultrasound image processing. It provides a harmonious use of noise reduction and edge enhancement techniques, thus helping to unlock the full diagnostic potential of ultrasound images. An important parameter such as adaptability makes it a good addition to the toolbox of those seeking to improve the quality of ultrasound images for more accurate diagnosis and comprehensive studies.

The AADFP method is a promising approach in the field of imaging. It paves the way for better patient examinations and a better understanding of the complex medical conditions represented on ultrasound images.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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QUANTITATIVE ANALYSIS OF PET IMAGING VIA THE FOUR COMPARTMENT MODEL FOR LUNG CANCER ASSESSMENT

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ABSTRACT

Lung cancer is a life-threatening disease that requires early detection for effective treatment. Positron emission tomography (PET) imaging has been instrumental in diagnosing and monitoring lung cancer, but it has some limitations. To overcome these limitations, the four-compartment model has been developed, which provides a more accurate representation of the cancer's metabolic activity. This model incorporates the vascular volume and tracer delivery rate into the traditional two-compartment model, resulting in improved diagnostic accuracy and treatment planning. Recent studies have shown that the four-compartment model outperforms conventional PET scans in predicting tumor response to treatment and differentiating between active and inactive cancer cells. The four-compartment model holds great promise in revolutionizing the diagnosis and monitoring of lung cancer, offering improved outcomes and renewed hope for patients worldwide.
Keywords: Lung cancer, PET imaging, four-compartment model, metabolic activity, diagnosis, monitoring, limitations, vascular volume, tracer delivery rate, accuracy, treatment planning, tumor response, active cancer cells.

Introduction

Lung cancer remains one of the most prevalent and deadly diseases worldwide, with a staggering number of lives claimed each year. Early detection and accurate diagnosis are critical factors for successful treatment and improved patient outcomes. In recent years, medical imaging techniques have played a pivotal role in the detection and monitoring of lung cancer, aiding in the identification of malignant cells. One such technique that has shown immense promise is Positron Emission Tomography (PET) imaging. PET imaging allows for the visualization and assessment of metabolic activity within tissues, providing valuable insights into the presence and behavior of cancerous cells [1].

Traditionally, PET imaging has been used as a powerful tool for identifying areas of increased glucose metabolism, characteristic of cancerous growth. However, as the field of medical imaging advances, limitations within existing techniques come to light. Differentiating between healthy and cancerous tissues, as well as identifying clustered cancer cells accurately, have remained challenging with conventional PET imaging methods.

To address these limitations, researchers have developed advanced models, such as the four-compartment model, to provide more precise information regarding the metabolic activity of lung cancer. This model surpasses the constraints of conventional PET imaging by incorporating additional parameters, including vascular volume and tracer delivery rate, into the analysis. By

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doing so, the four-compartment model offers enhanced diagnostic accuracy and improved treatment planning capabilities, ultimately leading to better patient outcomes [9].
In this article, we delve into the advancements made in the field of lung cancer diagnostics, with a particular focus on PET imaging. We explore the significance of metabolic activity visualization in identifying cancerous cells and understanding their behavior. Furthermore, we emphasize the necessity of advanced models, like the four-compartment model, in overcoming the limitations of conventional PET imaging for more precise and sophisticated diagnostics. By leveraging these new approaches, medical professionals hold a renewed potential to provide early and accurate diagnoses, thereby positively impacting patient care and treatment outcomes [2,16].

Understanding PET Imaging in Lung Cancer Diagnosis
PET imaging is a groundbreaking diagnostic technique that allows doctors to detect and visualize the metabolic activity within tissues, including cancerous cells in the lungs. Understanding the principles behind PET imaging is crucial to grasp its role in lung cancer diagnosis. At its core, PET imaging involves the use of a harmless radioactive tracer that emits positrons, which are positively charged particles. These tracers are injected into the patient's bloodstream and are specifically designed to accumulate in areas of increased metabolic activity, such as tumors [13].
To capture the emitted positrons, a PET scanner is used. The scanner consists of multiple rings of detectors that surround the patient. As the positrons collide with electrons present in the body, they annihilate, resulting in the release of two photons in opposite directions. The PET scanner detects these photons, and the data is analyzed to produce detailed images of the metabolic activity within the body. Areas with higher tracer accumulation indicate areas of increased metabolic activity, which can be indicative of cancerous tissue. Figure 2 shows the scheme of PET [4].

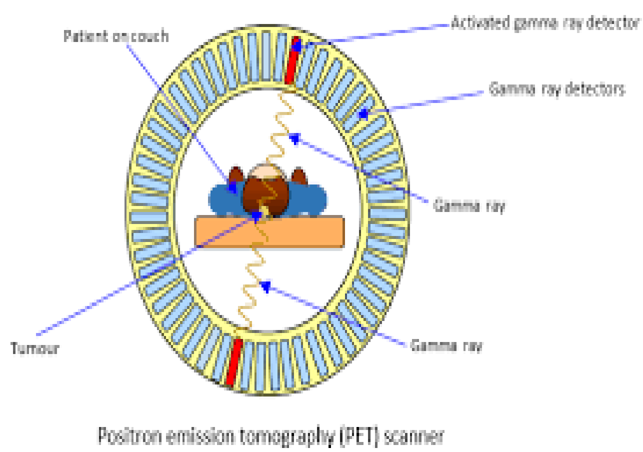

Figure 1. PET scanner

To better understand this process, let's imagine a patient with suspected lung cancer undergoing a PET scan in Figure 2. After the radioactive tracer is injected, it circulates throughout the body and accumulates in areas of increased metabolic activity, such as a lung tumor.

Figure 2. Pet scan of a lung tumor

As the patient lies on the PET scanner bed, the detectors in the scanner detect the emitted photons resulting from the annihilation of the positrons. By capturing the paths and timing of these photons, a computer generates a three-dimensional image, illustrating the distribution of the tracer within the lung tissue [3].

These PET images provide valuable information about the size, location, and metabolic activity of lung tumors. They help doctors differentiate between cancerous and non-cancerous tissue, identify the extent of tumor spread, and determine the most appropriate treatment plan for each patient. Significance in PET Analysis:

- Quantification: The model helps in quantifying the rate of transfer of the tracer between compartments, providing insights into biological processes.
- Understanding Uptake and Retention: It helps understand how much tracer is retained in the target tissue versus what's cleared from the body.
- Drug Development: In pharmaceutical research, this model assists in understanding the behavior of potential drugs in the body.

By understanding the principles and visualizing the process, patients and medical professionals can appreciate the remarkable capabilities of PET imaging in diagnosing lung cancer. These imaging techniques have revolutionized the way we detect and monitor this deadly disease, ultimately leading to improved outcomes for patients [5,9].

The Four-Compartment Model: Basics and Significance

The compartmental modeling approach is a method used in pharmacokinetics and various biological sciences to understand the dynamics of substances within a system. It involves dividing the system into distinct compartments based on the movement and distribution of substances (like drugs, tracers, or nutrients) between these compartments. Compartmental modeling provides a valuable framework to understand and predict the behavior of substances within biological systems, aiding in drug development, understanding disease mechanisms, and interpreting experimental data [12].

Structure of the model

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The Four-Compartment Model is a fundamental concept in Positron Emission Tomography (PET) analysis used to understand how a radiotracer behaves in the body. This model breaks down the process of tracer kinetics within the body into four compartments or regions. Let's break down each compartment with annotated diagrams. Figure 3 shows diagram of the 4-comparment model [6,11]:

Compartment 1. This compartment represents the tracer initially injected into the bloodstream. The tracer enters the body's circulation and is transported through the arteries. slightly lower than that of PZT and PMN-PT, it has the advantage of stability and consistency of properties.

Compartment 2. This compartment represents the tracer in the tissue that is freely exchangeable with the blood. It's the region where the tracer can move in and out of the bloodstream.

Compartment 3. This compartment represents the tracer that specifically binds to the target of interest, such as receptors or proteins within the tissue.

Compartment 4. This compartment represents the tracer that non-specifically binds to other elements within the tissue, not related to the target of interest.

These compartments aid in developing mathematical models that describe how the tracer concentration changes over time, helping researchers interpret PET scan data to draw conclusions about physiological processes or disease states [7].

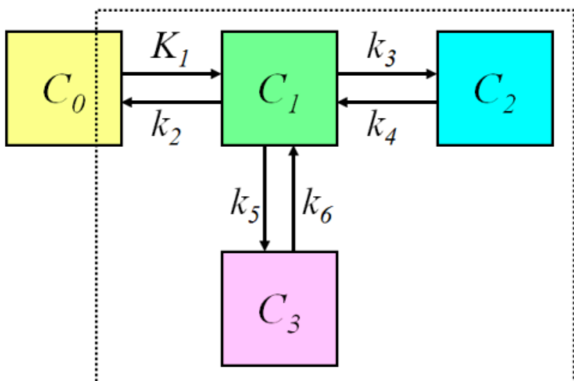

Figure 3. Diagram of 4-compartment model

Let's look at the compartments more detailly:

Mathematical representation of the model

For mathematical representation we use ODEs. For each compartment we define one ODE, rate influx and efflux, and metabolism rates within compartments [8].

Each compartment has its own variables:

Compartment 1: Bloodstream (Central Compartment)

- Rate of Drug Influx (from intravenous administration): k_{in}
- Rate of Drug Efflux to Well-Perfused Tissue: K_1
- Metabolism Rate within the Central Compartment: k_{met1}

Compartment 2: Well-Perfused Tissue (Intermediate Compartment)

- Rate of Drug Influx (from the bloodstream): k_2
- Rate of Drug Efflux to Less-Perfused Tissue: k_3

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- Metabolism Rate within the Intermediate Compartment: k_{met2}
Compartment 3: Less-Perfused Tissue (Intermediate Compartment)
- Rate of Drug Influx (from well-perfused tissue): k_4
- Rate of Drug Efflux to Tumor Tissue: k_5
- Metabolism Rate within the Less-Perfused Tissue: k_{met3}
Compartment 4: Tumor Tissue (Peripheral Compartment)
- Rate of Drug Influx (from less-perfused tissue): k_6
- Rate of Drug Elimination from Tumor: k_{out}
Now, let's build differential equations according to these variables:
For the bloodstream (central compartment):

$$\frac{dC_0}{dt} = k_{in} - (K_1 + k_{met1}) * C_0.$$

For well-perfused tissue (intermediate compartment):

$$\frac{dC_1}{dt} = k_2 - (k_3 + k_{met2}) * C_1.$$

For less-perfused tissue (intermediate compartment):

$$\frac{dC_2}{dt} = k_4 - (k_5 + k_{met3}) * C_2.$$

For tumor tissue (peripheral compartment):

$$\frac{dC_3}{dt} = k_6 * C_3 - k_{out} * C_3.$$

Software and libraries used to build model.
Building the Four-Compartment Model using MATLAB involves creating a system of differential equations that describe the dynamics of the tracer in each compartment over time. While MATLAB doesn't have specific libraries for compartmental modeling, you can use its built-in functionalities for differential equation solving and optimization. [8]
Here's a general guideline on how you might approach building this model in MATLAB:
1. Define the Differential Equations:
Define a set of differential equations that describe the rate of change of the tracer concentration in each compartment.
Use parameters such as transfer rates, volumes, and initial conditions for each compartment.
2. Solve the Differential Equations:
MATLAB's ODE solvers (e.g., '**ode45**', '**ode23**') can solve systems of ordinary differential equations (ODEs).
Define a function that computes the derivatives of tracer concentrations with respect to time for each compartment.

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Use the chosen ODE solver to integrate these equations numerically and simulate the tracer kinetics over time.

3. Parameter Estimation and Optimization:

If experimental data is available, use optimization techniques (e.g., '**lsqcurvefit**', '**fmincon**') to estimate model parameters by fitting the model to the experimental data.

Optimize parameters such as transfer rates or volumes to minimize the difference between model predictions and actual data.

We use the following toolboxes in MATLAB:

1. SimBiology Toolbox: This toolbox provides functionality for modeling and simulating dynamic systems, including pharmacokinetic and pharmacodynamic models, which could be adapted for compartmental modeling.
2. Curve Fitting Toolbox: Useful for parameter estimation and optimization when fitting the model to experimental data.
3. Optimization Toolbox: Provides various optimization algorithms that can be used for parameter estimation and fitting the model. [5]

Building the MATLAB code

The MATLAB code of the 4-compartment model for lung cancer:

```
% Define the four-compartment model ODEs
odefunc = @(t, y) [
   kin - (K1 + kmet1) * y(1);              % dC1/dt
   k2 * y(1) - (k3 + kmet2) * y(2);        % dC2/dt
   k4 * y(2) - (k5 + kmet3) * y(3);        % dC3/dt
   k6 * y(3) - kout * y(4)                 % dC4/dt
];

% Initial conditions for C1, C2, C3, and C4
C1_0 = 0;  % Initial drug concentration in bloodstream
C2_0 = 0;  % Initial drug concentration in well-perfused tissue
C3_0 = 0;  % Initial drug concentration in less-perfused tissue
C4_0 = 0;  % Initial drug concentration in tumor tissue

initial_conditions = [C1_0; C2_0; C3_0; C4_0];

% Define the time span for the simulation
tspan = [0 10]; % Change the end time as needed

% Define the kinetic parameters
kin = 0.5;      % Rate of drug influx into the central compartment
K1 = 0.2;       % Rate of drug efflux from central compartment to well-perfused tissue
kmet1 = 0.1;    % Metabolism rate within the central compartment
k2 = 0.3;       % Rate of drug influx into well-perfused tissue from the central compartment
k3 = 0.2;       % Rate of drug efflux from well-perfused tissue to less-perfused tissue
kmet2 = 0.05;   % Metabolism rate within the well-perfused tissue
```

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```
k4 = 0.4;       % Rate of drug influx into less-perfused tissue from well-perfused tissue
k5 = 0.3;       % Rate of drug efflux from less-perfused tissue to tumor tissue
kmet3 = 0.04;    % Metabolism rate within the less-perfused tissue
k6 = 0.2;       % Rate of drug influx into tumor tissue from less-perfused tissue
kout = 0.3;      % Rate of drug elimination from the tumor tissue

% Solve the ODEs using ode45
[t, y] = ode45(odefunc, tspan, initial_conditions);

% Extract drug concentration data from the solution
C1 = y(:, 1); % Drug concentration in bloodstream
C2 = y(:, 2); % Drug concentration in well-perfused tissue
C3 = y(:, 3); % Drug concentration in less-perfused tissue
C4 = y(:, 4); % Drug concentration in tumor tissue

% Plot the drug concentration in all compartments over time
figure;
subplot(2, 2, 1);
plot(t, C1, 'b', 'LineWidth', 2);
xlabel('Time (minutes)');
ylabel('Concentration in C1 (Bloodstream)');
title('Drug Concentration in Bloodstream');

subplot(2, 2, 2);
plot(t, C2, 'r', 'LineWidth', 2);
xlabel('Time (minutes)');
ylabel('Concentration in C2 (Well-Perfused Tissue)');
title('Drug Concentration in Well-Perfused Tissue');

subplot(2, 2, 3);
plot(t, C3, 'g', 'LineWidth', 2);
xlabel('Time (minutes)');
ylabel('Concentration in C3 (Less-Perfused Tissue)');
title('Drug Concentration in Less-Perfused Tissue');

subplot(2, 2, 4);
plot(t, C4, 'm', 'LineWidth', 2);
xlabel('Time (minutes)');
ylabel('Concentration in C4 (Tumor Tissue)');
title('Drug Concentration in Tumor Tissue');

% Display the final drug concentrations
final_C1 = C1(end);
final_C2 = C2(end);
final_C3 = C3(end);
```

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```
final_C4 = C4(end);

disp(['Final drug concentration in C1 (bloodstream): ' num2str(final_C1)]);
disp(['Final drug concentration in C2 (well-perfused tissue): ' num2str(final_C2)]);
disp(['Final drug concentration in C3 (less-perfused tissue): ' num2str(final_C3)]);
disp(['Final drug concentration in C4 (tumor tissue): ' num2str(final_C4)]);
```

Results of the model

The following Figure 4 shows graphs of change of the concentrations in tissues (in model each compartment assigned to one tissue).

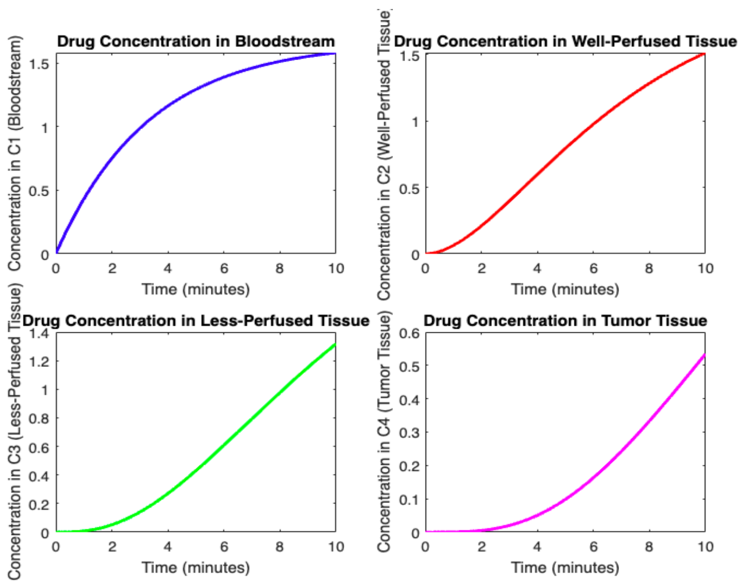

Figure 4. Concentration changes in different compartments over time

By solving the differential equations using numerical solvers in MATLAB, we can simulate how the drug concentrations change in each compartment over a specified time-period.

The simulation provides concentration-time profiles for each compartment, showing how the drug distributes, moves between compartments, and undergoes metabolism.

Analyzing the simulated concentration-time profiles helps understand how the drug behaves within the body.

It allows us to assess how variations in parameters (such as influx rates, efflux rates, metabolism rates) impact drug distribution and concentration in different compartments.

This simulation aids in drug development, dosage optimization, and understanding drug kinetics in various tissues or compartments within the body. Adjusting the model parameters allows for studying different scenarios and their effects on drug concentration changes in compartments.

This model aids in better understanding the drug's interactions within diverse tissues, enabling differentiation between drug uptake by cancer cells and instances of excessive drug consumption across various conditions [16,17,18].

Conclusion

In conclusion, the development and utilization of the four-compartment model in the context of PET imaging for lung cancer assessment marks a significant advancement in enhancing diagnostic precision and treatment efficacy. By addressing limitations inherent in conventional PET imaging, this model has demonstrated notable improvements in capturing the metabolic intricacies of lung cancer. Its integration of vascular volume and tracer delivery rate provides a more comprehensive understanding of cancer activity, offering superior prognostic value and treatment guidance.

Recent investigations showcasing the four-compartment model's superior predictive capabilities for treatment response and its ability to discern between active and dormant cancer cells underscore its potential as a transformative tool in lung cancer management. With its promise to refine diagnostics, personalize treatment strategies, and potentially improve patient outcomes, the adoption of the four-compartment model represents a beacon of hope in the realm of lung cancer care [4,15].

This model's ability to revolutionize diagnosis, treatment planning, and monitoring processes highlights its pivotal role in fostering renewed optimism and improved prognoses for individuals affected by lung cancer worldwide. As ongoing research continues to validate and refine its utility, the four-compartment model stands poised as a cornerstone in reshaping the landscape of lung cancer assessment and management.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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CARDIO-ONCOLOGY: A COMPREHENSIVE OVERVIEW AND INNOVATİVE APPROACHES

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ABSTRACT

Cardio-oncology is a rapidly evolving field that focuses on the management of cardiovascular complications in cancer patients and survivors. As advances in cancer treatment continue to extend the lives of cancer patients, there is a growing need to address the cardiovascular consequences of cancer therapy. This essay provides a comprehensive overview of cardio-oncology, highlighting the challenges and innovative methods in the field. It discusses the impact of cancer treatment on the cardiovascular system, strategies for risk assessment and prevention, and the emerging techniques and technologies that are transforming the practice of cardio-oncology.

Cancer and cardiovascular diseases are two of the leading causes of death worldwide. While advances in cancer treatment have significantly improved cancer survival rates, some of these treatments can lead to cardiovascular complications. Cardio-oncology is an interdisciplinary field that seeks to address the complex relationship between cancer and cardiovascular health. This field is essential in ensuring that cancer patients receive optimal care while minimizing the potential cardiovascular side effects of cancer therapies.

This essay provides an in-depth exploration of cardio-oncology, beginning with an overview of the impact of cancer treatment on the cardiovascular system. It then discusses strategies for risk assessment and prevention before delving into the innovative methods and technologies that are revolutionizing the practice of cardio-oncology.

Keywords: cardio-oncology, cancer therapy, cardiovascular system.

Introduction

The Impact of Cancer Treatment on the Cardiovascular System:

Cancer therapies, such as chemotherapy, radiation therapy, and immunotherapies, have revolutionized the treatment of cancer. However, many of these treatments can have adverse effects on the cardiovascular system. Understanding the mechanisms by which cancer therapies affect the heart and blood vessels is crucial for the development of effective cardio-oncology strategies [1-4].

1. Chemotherapy-Induced Cardiotoxicity:

Chemotherapy drugs are a cornerstone of cancer treatment, but they can lead to cardiotoxicity, which can manifest as acute or chronic heart damage. Anthracyclines, such as doxorubicin, are known to cause dose-dependent cardiotoxicity by generating free radicals and impairing the heart's contractility. Trastuzumab, a monoclonal antibody used to treat breast cancer, can cause cardiotoxicity by interfering with signaling pathways in cardiac cells. [1,2,3,4,5,6,7,8,9,10]

2. Radiation-Induced Cardiovascular Damage:

Radiation therapy is a vital component of cancer treatment, especially for solid tumors. However, radiation can damage the heart and blood vessels, leading to conditions like radiation-induced heart disease. The pathophysiology involves inflammation, endothelial dysfunction, and fibrosis of the affected tissues. Cardiologists must be vigilant in monitoring radiation therapy patients for cardiovascular side effects. [5,6,7,8,9,10,11]

3. Immunotherapy and Checkpoint Inhibitors:

Immunotherapies, such as immune checkpoint inhibitors (e.g., pembrolizumab, nivolumab), have revolutionized the treatment of various cancers. While these therapies enhance the immune system's ability to target cancer cells, they can also lead to immune-related adverse events, including myocarditis, pericarditis, and arrhythmias. The exact mechanisms behind these complications are still being investigated.

II. Strategies for Risk Assessment and Prevention in Cardio-Oncology:

Early identification of cancer patients at risk of cardiovascular complications is a critical aspect of cardio-oncology. Risk assessment and prevention strategies aim to reduce the impact of cancer therapies on the heart and vascular system.

1. Risk Assessment:

a. Baseline Cardiovascular Assessment: Before starting cancer treatment, it is crucial to perform a baseline cardiovascular assessment to identify preexisting cardiovascular risk factors. This includes evaluating the patient's medical history, family history, physical examination, and baseline cardiac imaging [12,13,14,15,16,17].

b. Cardiac Biomarkers: Cardiac biomarkers, such as troponin and brain natriuretic peptide (BNP), can help identify early signs of cardiotoxicity. Elevated levels may warrant further evaluation and potential modification of cancer treatment.

c. Advanced Imaging: Echocardiography, cardiac MRI, and nuclear imaging are powerful tools for assessing cardiac function and detecting early structural and functional changes in the heart

2. Prevention Strategies:

a. Cardioprotective Medications: In certain cases, cardioprotective medications like angiotensin-converting enzyme (ACE) inhibitors, beta-blockers, and angiotensin receptor blockers (ARBs) may be prescribed to mitigate the risk of cardiotoxicity associated with cancer treatments [18,19,20].

b. Lifestyle Modification: Encouraging patients to adopt a heart-healthy lifestyle, including regular exercise, a balanced diet, and smoking cessation, can help reduce cardiovascular risk.

c. Individualized Treatment Plans: Tailoring cancer treatment regimens to the patient's cardiovascular risk profile can help minimize the impact on the heart while still effectively treating the cancer.

III. Innovative Methods in Cardio-Oncology:

The field of cardio-oncology has witnessed remarkable advancements in recent years, thanks to innovative methods and technologies. These innovations have improved risk assessment, monitoring, and the overall management of cardiovascular complications in cancer patients.

1. Cardiovascular Imaging:

Advanced imaging techniques, such as cardiac MRI and strain imaging, have provided a more detailed and sensitive assessment of cardiac function. These tools allow for the early detection of subtle changes in cardiac structure and function, enabling timely intervention.

2. Biomarker Discovery:
Ongoing research is focused on identifying novel biomarkers that can predict cardiotoxicity. For example, genetic testing and proteomic profiling may help identify patients at higher risk of cardiac complications. These biomarkers could lead to more personalized treatment strategies [21,22,23,24].
3. Artificial Intelligence (AI):
AI and machine learning algorithms are being employed to analyze large datasets of cardiac imaging and biomarker information. These AI systems can aid in the early detection of cardiotoxicity, allowing for timely intervention and treatment modifications.
4. Telemedicine and Remote Monitoring:
The COVID-19 pandemic accelerated the adoption of telemedicine and remote monitoring technologies. These tools are especially valuable in cardio-oncology, allowing healthcare providers to monitor patients' cardiovascular health during cancer treatment and survivorship, reducing the need for in-person visits.
5. Cardiac Rehabilitation Programs:
Cardiac rehabilitation programs are being adapted for cancer patients to improve their cardiovascular health and reduce the risk of cardiovascular complications. These programs combine exercise, dietary counseling, and psychological support to enhance the overall well-being of cancer survivors [25,26].
6. Targeted Therapies and Precision Medicine:
Advances in targeted cancer therapies and precision medicine have allowed for more effective cancer treatment with fewer cardiovascular side effects. Tailoring cancer treatment to the individual patient's genetics and tumor characteristics can reduce harm to the cardiovascular system.

Conclusion

Cardio-oncology is an essential and evolving field that addresses the complex interplay between cancer and cardiovascular health. As the landscape of cancer treatment continues to evolve, so does the need for innovative approaches in cardio-oncology. Early risk assessment, prevention strategies, and advanced technologies have the potential to minimize the impact of cancer therapies on the cardiovascular system and improve the overall quality of care for cancer patients and survivors.

In this essay, we have highlighted the impact of cancer treatment on the cardiovascular system, strategies for risk assessment and prevention, and the innovative methods and technologies that are transforming the practice of cardio-oncology. As our understanding of this field grows, cardio-oncologists, oncologists, and cardiologists will continue to work together to ensure that cancer patients receive the best possible care while protecting their cardiovascular health.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

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ECHOCARDIOGRAPHY AS AN INITIAL DIAGNOSTIC TOOL FOR RARE EXTRA CARDIAC DIAGNOSIS- IDIOPATHIC ACHALASIA

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ABSTRACT

Transthoracic echocardiography (TTE) is a noninvasive initial imaging modality in evaluating the anatomic structure and function of the heart. Although the diagnostic coincidence rate of TTE is slightly lower than that of computer tomography (CT) and magnetic resonance tomography (MRT), TTE has certain diagnostic value for extra-cardiac lesions. We report about a very rare and interesting finding observed using TTE study. Our case shows the role of TTE in identifying extra cardiac structure leading to the new important diagnosis and deferent treatment strategy.
61-year-old male patient was admitted to the hospital with main complaints: chest pain, dyspnea, cough, also he had dysphagia and weight loss. First of all, cardiologic examination has been done, TTE revealed left atrial (LA) compression by an inhomogeneous mass and accelerated flow in LA. TTE provided useful information of the location, size, echogenicity of the extra cardiac structure and its relationship with the heart. Esophageal pathology was suspected, the patient had been subjected to X-ray examination with barium and then an endoscopy. The result of which was confirmed diagnosis of idiopathic achalasia.
Our case shows the role of routine TTE in identifying extra cardiac structure – esophageal achalasia, leading to important extra cardiac diagnosis and indication for further surgical intervention.
Incidental echocardiographic extra cardiac findings in the clinical case presented by us led to a new diagnosis, referral of patients to surgeons and, accordingly, changed the treatment strategy.
Thus, it is very important to train, improve knowledge, focus on extra cardiac manifestations on echocardiography and establish appropriate guidelines for conducting a comprehensive study.
Keywords: Achalasia; Transthoracic eechocardiography; Extra cardiac manifestation.

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Introduction

Transthoracic echocardiography is a noninvasive primarily initial imaging modality in evaluating the anatomic structure and function of the heart. With widespread availability, portability, low cost and safety TTE presents a mainstay of cardiac imaging. In some cases, it may also present as a diagnostic tool to identify different non-cardiac structures within multiple anatomical areas [1, 2]. Incidental extra cardiac findings (INCF) are chiefly investigated and described by cardiac computed tomography and magnetic resonance imaging. The literature in this field about the role of TTE is very sparse. The majority of incidental findings are clinically insignificant; however, some may cause symptoms or require further investigation and management [3, 4].

Our case shows the role of routine TTE in identifying extra cardiac structure – esophageal achalasia, leading to important diagnosis and indication for further surgical intervention.

Achalasia is a motility disorder of the esophagus, characterized by impaired peristalsis and inadequate relaxation of the lower esophageal sphincter. Patients most commonly experience dysphagia with solids and liquids, regurgitation, and intermittent chest pain with or without weight loss. Using high-resolution manometry, three subtypes of achalasia have been identified that differ in pressure and contraction patterns. Important diagnostic signs are endoscopic findings of saliva residues with folds at the esophagogastric junction or findings of a dilated esophagus with a bird's beak [13-15].

Achalasia is one of the most studied esophageal motility disorders. In this guide, we discuss the diagnosis, treatment, and general management of adult patients with achalasia. This guidance includes recommendations, key concepts and a summary of the evidence. Each recommendation statement is accompanied by an assessment of the quality of the evidence and the strength of the recommendation based on the GRADE (Grading of Recommendations Assessment, Development and Evaluation) process. Key concepts are statements that do not meet the requirements of the GRADE process due to the structure of the statement or the available evidence. In some cases, key concepts rely on the extrapolation of evidence and/or expert opinion. Although the nature of the symptom may influence clinical judgment, it may be difficult to determine which of these causes is affecting the patient. Therefore, additional diagnostic testing is necessary unless the patient is experiencing heartburn and a PPI is attempted. High-resolution manometry allows you to assess the integrity of the myotomy, as well as determine the presence of spasmodic contractions after treatment; However, it is not possible to accurately determine bolus delay and assess the contribution of GERD, and the procedure can be difficult due to obstruction and abnormal anatomy [16-19].

Many patients with refractory achalasia or terminal achalasia, characterized by a barium-like esophagus with severe dilation (>6 cm in width) and complex anatomical deformity (concha trap), experience severe symptoms and complications. potentially fatal. Therefore, measures should be taken to prevent aspiration and malnutrition. And the dead. Unfortunately, esophagectomy is associated with a high complication rate and a real risk of death. Additionally, quality of life is reduced after esophagectomy, so this approach should be considered a last resort, and most patients and doctors prefer a more conservative treatment attempt. For patients in whom PD and POEM methods have failed, attempting Heller myotomy may still be reasonable before resorting to esophagectomy, given the number of cases in which severely terminally ill patients may respond to surgery. You should know that the success rate still remains much lower than that of patients with a more favorable anatomy and without prior radical treatment. A comprehensive evaluation including assessment of esophageal anatomy with barium, upper esophageal

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endoscopy to assess for esophagitis and strictures, and possibly manometry or FLIP to assess LES function may provide evidence that a disease-targeted level of WIS therapy can be effective. Patients with severe anatomy, significant bolus delay, and evidence of complete myotomy may be referred for esophagectomy, while patients with evidence of incomplete myotomy may undergo Heller myotomy. Ultimately, this decision is extremely complex and this approach requires careful assessment and informed discussion, focused on risks and benefits. Patients requiring esophageal resection should be referred to specialized centers with a large number of patients, because the results directly depend on the number of patients and their experience [20-23].

Patients with symptoms suggestive of achalasia should undergo upper gastrointestinal endoscopy to ensure the absence of other pathologies and to rule out possible pseudo achalasia. Heart rate management and timed barium swallows should be used to confirm the diagnosis. The choice between treatment modalities depends on the manometric subtypes of achalasia, patient preference, and institutional experience. PD, HM and POEM are good choices for people with achalasia type I and II. PD should be performed gradually, starting with the smallest balloon (3.0 cm), except in young men (<45 years) who require one initial 3.0 cm to 3.5 cm balloon or surgical myotomy. Patients who do not respond to Parkinson's disease should undergo surgical myotomy. Individual CM or POEM can be used in patients with type III achalasia. If patients are not suitable for radical treatment due to comorbidities, treatment with botulinum toxin and smooth muscle relaxants should be offered. To maximize patient outcomes, all definitive treatments should be offered in centers of excellence with sufficient capacity and experience. Patients should be monitored for recurrence of GERD symptoms and complications after the procedure. CE and endoscopy can be complementary in assessing disease recurrence versus inflammation or stenosis associated with reflux. Repeat PD, CM, or POEM may be performed in individuals with recurrent disease, and antacid therapy should be offered to individuals with symptoms due to GERD. People with a dilated esophagus (more than 8 cm) and an unsatisfactory response to the initial myotomy may require an esophagectomy [24-26].

Cardiac achalasia, a form of dynamic esophageal disorder, is a relatively rare primary esophageal movement disorder characterized by loss of function of ganglion plexus cells in the distal esophagus and lower esophageal sphincter. Loss of distal and lower esophageal sphincter ganglion cell function is a major cause of cardiac achalasia and is more common in older adults. Histological changes in the esophageal mucosa are considered pathogenic; However, research has shown that inflammation and genetic changes at the molecular level can also cause cardiac achalasia, leading to dysphagia, reflux, aspiration, chest pain and weight loss. Current treatment options for achalasia aim to reduce the resting pressure of the lower esophageal sphincter, which helps empty the esophagus and relieve symptoms. Treatment options include botulinum toxin injection, inflatable dilatation, stenting, and surgical myotomy (open or laparoscopic). Surgical procedures are often controversial due to concerns about their safety and effectiveness, especially in older patients. Here, we review clinical, epidemiological, and experimental data to determine the prevalence, pathogenesis, clinical presentation, diagnostic criteria, and treatment options for achalasia to aid clinical management [28-30].

As an important part of the digestive system, the esophagus plays an important role in transporting nutrients. Diseases of the esophagus can be classified into anatomical lesions of the organic cavity (e.g.: digestive or eosinophilic stenosis) or severe dysphagia with progressive injection of the digestive tract (e.g.: severe dysphagia of neurological origin or cardiac achalasia). Esophageal achalasia is a form of dynamic esophageal disorder (DED). It refers to obstruction of

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the esophageal outflow tract due to impaired relaxation of the lower esophageal sphincter (LES) and loss of esophageal motility or spasmodic contraction when the esophageal body or esophagogastric junction (EGJ) is not structurally blocked. There are primary and secondary types of achalasia. Cardiac achalasia is characterized by a loss of functional muscle ganglion cells in the distal esophagus and LES. Although histological changes in the esophageal mucosa have long been considered part of the pathogenesis of cardiac achalasia, recent studies have shown that inflammation and genetic changes may also contribute to achalasia at the molecular level. Currently, achalasia is an incurable chronic disease. Different subtypes of achalasia respond differently to medications and surgery, after which some patients develop submucosal fibrosis. This may recur and require additional treatment [32-34].

Background

Achalasia symptomatic consequence the motility disorder is the classic form of solid-liquid dysphagia associated with regurgitation of soft undigested food or saliva. Substernal pain while eating, associated with dysphagia, weight loss, and even heartburn, can accompany symptoms that often lead to achalasia being misdiagnosed as gastroesophageal reflux disease (GERD). Achalasia should be suspected in individuals with solid-liquid dysphagia and in those with ineffective regurgitation after the first use of proton pump inhibitor (PPI) therapy. Endoscopic evidence of retention of saliva, fluids and food into the esophagus without mechanical obstruction due to stenosis. or the mass should arouse suspicion of achalasia. In contrast, other diseases can mimic achalasia both clinically and manometrically. These include pseudoachalasia due to tumors of the gastric cardia or tumors infiltrating the myenteric plexus (adenocarcinoma of the gastroesophageal junction, pancreatic, breast, lung or hepatocellular carcinoma) or secondary achalasia due to external processes such as anterior dense fundoplication or laparoscopic adjustable gastric banding [36-38].

Achalasia is a primary movement disorder of the esophagus, characterized by lack of peristalsis and insufficient relaxation of the lower esophageal sphincter. Given new advances and developments in the treatment of achalasia, there is a growing need for comprehensive evidence-based guidelines to assist clinicians in treating patients with achalasia. Achalasia is a relatively rare primary esophageal motility disorder characterized by loss of function of the ganglion cells of the distal esophageal plexus and the lower esophageal sphincter. Histological changes in the esophageal mucosa are considered pathogenic; However, research has shown that inflammation and genetic changes at the molecular level can also cause cardiac achalasia, leading to dysphagia, reflux, aspiration, chest pain, and weight loss. The aim of this review article is to provide a comprehensive overview of the literature and to present the current state of knowledge on the subject of achalasia.

Currently, the etiology and pathogenesis of cardiac achalasia remain unclear; However, it is generally accepted that histological changes in the esophageal mucosa caused by loss of esophageal nerve cell function play a fundamental role in the pathophysiology. Autoimmune attack on the esophageal intermuscular nerves by cell-mediated mechanisms and possibly by antibodies can lead to inhibition of esophageal smooth muscle, resulting in loss of nerve function and degeneration of nerve fibers.

Several pathological mechanisms have been proposed as possible triggers of this immunodeficiency process, including underlying viral infections, idiopathic autoimmune triggers, and genetic predisposition. Herpes zoster virus, herpes simplex virus, measles virus, and human papillomavirus may influence the regulation of functional esophageal movement and control of LES in patients with achalasia , but not in all patients with viral infections. Many patients with achalasia have varicella-zoster virus DNA in their saliva. Limited evidence suggests that eosinophils and mast cells may play a role in the development of achalasia and obstructive esophageal motility disorders. Aggregation of eosinophils and mast cells in the esophagus leads to increased levels of inflammatory cytokines; This leads to fibrous remodeling of the esophageal wall, which ultimately leads to esophageal dysfunction and associated symptoms. Dysphagia (solid or liquid) is a common symptom in patients with achalasia. Initially, this symptom appears sporadically; However, as the disease progresses, the esophagus enlarges significantly, resulting in burning and decompensation of the sigmoid colon with corresponding clinical symptoms. Additionally, patients with achalasia may experience chest pain [5]. There is also a risk of long-term aspiration pneumonia and esophageal squamous cell carcinoma [17]. A study using UK hospital and primary care databases found that patients with achalasia had high morbidity and mortality from oesophageal cancer, aspiration pneumonia and lower respiratory infections [37] Additionally, other studies have shown that patients with achalasia suffer from acute respiratory failure and hemodynamic instability. The final stage of achalasia with hypertrophy of the thoracoesophageal region can manifest as an acute illness. Achalasia often presents insidiously, with many subclinical features before a definitive diagnosis is made, which can result in a delay between symptom onset and diagnosis.

Currently, cardiac achalasia is mainly diagnosed by high-resolution manometry (HRM), endoscopy, and barium meal examination. Temporary barium swallow esophagography or functional luminal imaging probe (FLIP) is only used if achalasia cannot be diagnosed.

Manometry plays an important role in the differential diagnosis of dynamic esophageal diseases. Human resources management is the gold standard in the diagnosis of achalasia cardiaca. HRM typically involves performing a pressure test using a minimum of pressure sensors distributed throughout the catheter. Each pressure sensor is spaced 1 cm apart to obtain baseline values at rest. The probe enters through the nose and passes through the esophagus into the esophagus, allowing the entire esophagus to be examined. In fact, HRM can not only confirm the diagnosis of achalasia, but also identify specific subtypes demonstrating significantly different therapeutic outcomes. Correct diagnosis of intraoperative HRM can help guide therapeutic approaches and predict therapeutic outcomes. Endoscopy is necessary in patients with digestive disorders, although it is not very sensitive to achalasia. Studies have shown that only a third of patients can be diagnosed with achalasia via endoscopy. Endoscopy is commonly used to evaluate patients with gastrointestinal symptoms and to exclude luminal neoplasms of the esophagus and proximal stomach.

Drugs are usually prescribed to patients who cannot undergo or refuse endoscopic or surgical treatment, as well as to those in whom endoscopic or surgical treatment has failed. Calcium channel blockers, nitrates, and proton pump inhibitors are commonly used to control acid reflux; However, they provide only short-term relief and are less effective [31].

In the early stages of the disease, dysphagia may be very subtle and may be misinterpreted as dyspepsia, poor gastric emptying, or stress. Heartburn due to stagnant food can increase this confusion. As the disease progresses, difficulty swallowing solid and liquid food usually occurs. Dysphagia affects solid foods more than liquids. To facilitate the flow of food, patients usually change their eating habits: They eat more slowly or resort to certain maneuvers, such as raising their arms or arching their backs. The most common misdiagnosis of achalasia is GERD, as many patients misinterpret regurgitation symptoms as reflux.8 It is important to ask about dysphagia or shutdown symptoms and to be alert to the possible diagnosis of achalasia in patients whose condition does not improve. . Treatment with PPIs after initial suspicion of GERD.

In this section, an algorithm for the individual treatment of patients with achalasia is presented. Symptomatic patients with achalasia who are good candidates for surgery should be provided with information about the risks and benefits of equally effective treatment options such as MP and myotomy. The choice between procedures should depend on patient preference and facility experience. However, to achieve maximum results for patients, both procedures must be performed in centers of excellence with sufficient size and experience. PD should be performed gradually, starting with the smallest balloon (3.0 cm), except in younger men (<45 years), in whom initial placement of a 3.5 cm balloon or surgical myotomy may be beneficial. Patients who do not respond to PD should undergo surgical myotomy. Surgical candidates with poor indications should initially inject botulinum toxin into the LES and be aware that retreatment is often required. Other treatments based on nitrates or calcium channel blockers may be offered if there is no clinical response to botulinum toxin injection. Individuals with a dilated esophagus (>8 cm) and a poor response to the initial myotomy may require an esophagectomy.

Achalasia is a relatively rare disorder of esophageal motility. The main clinical manifestations are dysphagia, reflux, chest pain and weight loss; They can significantly affect the patient's quality of life. Treatment for achalasia cardiaca is primarily aimed at relieving symptoms, as there is no cure for the disease. POEM is expected to be an ideal treatment for cardiac achalasia due to its effectiveness and safety. Individual treatment should be carried out taking into account the clinical characteristics of each patient. Currently, clinical studies on cardiac achalasia suggest the possibility of infectious events associated with certain genetic factors triggering the autoimmune mechanism. However, further research is needed in related areas to determine optimal treatment regimens [11,25].

The clinical care of patients with achalasia has changed significantly in the past decade under influence of new developments such as high-resolution manometry, per-oral endoscopic myotomy and studies providing new insights regarding achalasia subtypes, cancer risk and follow-up. Given the substantial growth of knowledge in the past years, there is need for a comprehensive, evidence-based European guideline covering all aspects of the disease. This multidisciplinary guideline aims to provide an evidence-based framework with recommendations on the diagnosis, treatment and followup of adult achalasia patients. Chagas disease and achalasia secondary to other disorders, as can be seen after fundoplication, bariatric surgery, sarcoid infiltration, opiate usage or malignancy, is not covered by this guideline. This guideline is intended for clinicians involved in their management, including gastroenterologists, endoscopists, radiologists, gastrointestinal surgeons, dietitians and primary care practitioners [12,29,36].

The diagnosis of achalasia should be considered when patients present with dysphagia associated with other esophageal symptoms and when upper gastrointestinal endoscopy can exclude other conditions. Barium esophagography may reveal the classic bird's beak sign, esophageal dilation, or free fall. Esophageal manometry is the gold standard for diagnosing achalasia; A diagnostic sign is incomplete relaxation of the VOC, expressed by an increase in integrative relaxation pressure in the absence of normal peristalsis. The use of high-resolution manometry (HRM) has led to the classification of achalasia into three clinically relevant groups based on esophageal contractility patterns.

Malignant pseudoachalasia is a condition in which a patient is initially diagnosed and sometimes even treated for achalasia, but is later found to have a malignant disease as the underlying cause. This may occur with submucosal adenocarcinoma of the cardia, locally advanced pancreatic cancer, submucosal metastases, or anti-Hu-producing small cell carcinomas (most commonly lung carcinoma). All Patients diagnosed with achalasia should under no circumstances undergo additional tests such as: B. undergo a CT scan or endoscopy. Ultrasound to exclude malignancy. Interpretation of temporary barium esophagus. In a patient with achalasia, radiographs were taken at 0, 1, 2, and 5 minutes in the left posterior oblique position after ingestion of 100 to 200 ml of low-density barium suspension. Measurement of the height and width of a barium column measured from the OGJ to the barium-foam interface. A barium height > 5 cm at 1 minute and > 2 cm at 5 minutes indicates achalasia. The time is lost if malignant disease is not recognized at an early stage. Only two studies have addressed the question of how to identify patients with malignant pseudoachalasia. significant duration of weight loss and aging. A study by Ponds et al. also identified difficulties inserting the endoscope into the stomach, which endoscopists identified as a risk factor. A model was developed in which the presence of fewer than two risk factors did not increase the risk of malignancy, whereas the presence of two or more risk factors increased the risk [14,18,26,35].

Idiopathic achalasia is a primary esophageal motor disorder characterized by loss of esophageal motility and inadequate relaxation of the lower esophageal sphincter in response to swallowing. Patients with achalasia often complain of solid and liquid dysphagia, mild regurgitation that often does not respond adequately to proton pump inhibitors, and chest pain. Many, but not all, patients experience weight loss. Although the exact etiology is unknown, it is often thought to be an autoimmune disease, viral immune disease, or neurodegenerative disease. Diagnosis is based on history, barium esophagus, and esophageal motility studies. To exclude malignancy, endoscopic evaluation of the gastroesophageal junction and gastric cardia is necessary. New diagnostic techniques such as high-resolution manometry help predict treatment response in achalasia based on esophageal pressure topography patterns that identify three achalasia phenotypes (I-III), and studies of Results show improved treatment response in Types I and II compared to Types III. Although achalasia cannot be completely cured, excellent results are obtained in more than 90% of patients. Modern medical and surgical treatments (pneumatic dilatation, endoscopic and surgical myotomy and pharmacological agents) aim to reduce the pressure of the LES and facilitate emptying of the esophagus under the influence of gravity and hydrostatic pressure of food debris and liquids. Staged pneumatic dilatation or laparoscopic surgical myotomy with partial fundoplication is recommended as initial treatment, depending on the patient's age, gender, preference, and local experience. The prognosis of patients with achalasia is excellent. Most patients who receive adequate treatment have a normal life expectancy, but the disease recurs and the patient may require periodic treatment.

The increased prevalence of circulating antibodies against the myenteric plexus in some patients with achalasia suggests that autoantibodies play a role in the pathogenesis of this disease. It has been suggested that these circulating antibodies are likely the result of a nonspecific reaction to the disease process rather than its cause. This idea was supported by the discovery of similar antibodies in patients without achalasia. Ultrastructural studies of esophageal tissue in patients with achalasia also revealed inflammatory infiltrates around myenteric neurons, whereas controls showed a normal myenteric plexus without infiltration. Several case-control studies have reported a significant association with HLA class II antigens in idiopathic achalasia. Patients with achalasia and its associated HLA allele were found to have a higher prevalence of circulating antimyenteric autoantibodies, suggesting an autoimmune etiology. HLA association also suggests immunogenetic susceptibility to idiopathic achalasia; However, this should be treated with caution since not all patients with achalasia have associated HLA antigens. Recent genetic association in patients with achalasia revealed classical HLA haplotypes and amino acid polymorphisms, suggesting immune-mediated processes in idiopathic achalasia [4,9,23].

The presence of familial cases may indicate that achalasia is, in some cases, a hereditary disease. Such familial cases have been observed mainly in children, between siblings and, in some cases, in identical twins. There are also reports of a parent-child association in achalasia.61 Although these data suggest an autosomal recessive mode of inheritance for this disorder, the rarity of familial occurrence does not support the hypothesis that genetic inheritance occurs in most cases. case. Case of achalasia. Instead, it is suggested that genetic predisposition in these individuals likely increases their susceptibility to acquiring achalasia following exposure to common environmental factors that may play a role in pathogenesis [28,35,38].

The treatment of achalasia is the result of an evidence-based approach and international interdisciplinary efforts. The guidelines provide advice on key aspects of the diagnosis and treatment of achalasia, as well as commentary based on the best available literature and the opinions of leading European achalasia experts. The main aim of these recommendations is to reduce variations in practice and improve patient outcomes in Europe. Careful and widespread dissemination of these recommendations is therefore necessary to ensure high compliance in clinical practice. It is important to promote counseling and education. Future well-designed clinical trials should address the knowledge gaps and unmet needs that emerged during the development of these guidelines.

Case report

A 61-year-old man with unremarkable past medical history presented to the hospital with a 6-month history of chest pain, dyspnea, cough, dysphagia and weight loss (about 15kg). Chest pain, dyspnea and cough were worsening in the postprandial period, with regurgitation of undigested food.

Physical examination revealed irregular heartbeat, without appreciable heart murmurs, clear lung sounds.

Electrocardiography showed sinus rhythm with supraventricular extra heart beats and nonspecific St Segment and T-wave changes in leads V3-6.

Echocardiography revealed mild hypertrophy of the left ventricle with normal systolic function, without regional wall motion abnormalities, diastolic dysfunction – grade I (abnormal relaxation), right ventricular systolic function was preserved; Estimated pulmonary artery systolic pressure (PASP) was normal of 28mm/Hg. The valves were without significant structural changes; 2D and color Doppler echocardiography revealed left atrial compression by an inhomogeneous mass in close relation to the pulmonary veins and accelerated flow in LA (Figure 1, figure 2).

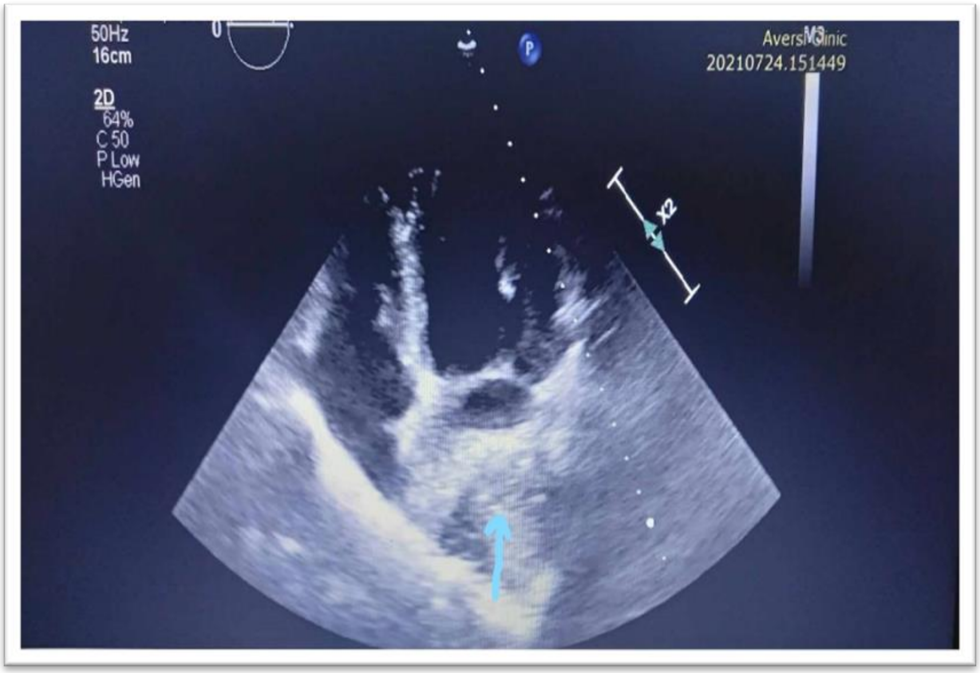

Figure 1. Apical 4-chamber view. Left atrial compression with extra cardiac structure (blue arrow)

Figure 2. Apical 4-chamber view with color Doppler. Left atrial and pulmonary vein compression with extra cardiac structure (white arrow)

Esophageal pathology was suspected and the patient was referred to the barium swallow study to confirm the diagnosis. The x-ray showed the typical "bird's beak" sign, esophageal dilatation with failure of normal peristalsis, incomplete lower esophageal sphincter relaxation that did not coordinate with esophageal contraction, stasis of barium in the esophagus (figure 3).

Figure 3. The x-ray shows the typical "bird's beak" sign, esophageal dilatation.

Endoscopy showed dilation of the esophagus with food remnants, whitish coating of the mucosa caused by adhesion of the remaining food inside of the esophagus and thickening of the mucosa. Endoscopy excluded esophageal and gastric cancer.
Secondary causes of achalasia, such as: esophageal malignancy and stricture, gastric carcinoma, Chagas disease, systemic sclerosis was excluded.
Coronary angiography was unremarkable and has been performed 1 years ago due to unexplained acute chest pain.
As soon as diagnosis was established, the patient was referred to the laparoscopic Heller myotomy with fundoplication, after which his complaints disappeared and the patient fully recavered.

Discussion
Idiopathic achalasia (IA) is a primary esophageal motility disorder characterized by aperistalsis and lower esophageal sphincter dysfunction, with an annual incidence of approximately 1.6 cases per 100,000 individuals and prevalence of 10 cases per 100,000 individuals [5].
IA results from inflammation and degeneration of inhibitory neurons in the esophageal wall that primarily release vasoactive intestinal peptide and nitric oxide. A localized decrease of these substances causes failure of lower esophageal sphincter relaxation and disruption of esophageal peristalsis [6]. The cause of the inflammatory degeneration of neurons in primary achalasia is not known [7]. IA is most frequently seen in middle and late adulthood (age 30 to 70 years) with no gender and racial predisposition.
Left atrial compression by achalasia is a rare presentation and may cause hemodynamic compromises [8].

Patients with achalasia may suffer symptoms for a long time before being diagnosed. The most common symptoms are dysphagia, regurgitation, chest pain, difficulty swallowing both liquids and solids and thus weight loss. Some patients may have a cough due to aspiration of food particles into their airways [9].

Laboratory studies don't play an important role to establish diagnosis of IA.

Several diagnostic tests are routinely utilized for the diagnosis of achalasia: Barium swallow, esophageal manometry, esophagogastroduodenoscopy, prolonged esophageal pH monitoring, endoscopic ultrasonography.

Because conservative treatment of achalasia is not curative, therapeutic success is determined by the improvement in symptoms as reported by patients. All available treatments are hence palliative [10].

Management of achalasia involves improving the esophageal outflow to provide symptomatic relief to patients [11].

The treatment modalities employed for this purpose included pharmacological therapy (e.g., Calcium channel blockers, long-acting nitrates), endoscopic interventions (e.g., botulinum toxin injection to lower esophageal sphincter, pneumatic dilation, paroral endoscopic myotomy) and surgical interventions (surgical myotomy, esophagectomy) [12].

Our case shows the role of routine TTE in identifying extra cardiac structure – esophageal achalasia, leading to important diagnosis and indication for further surgical intervention.

Incidental echocardiographic extra cardiac findings in the clinical case presented by us led to a new diagnosis, referral of patients to surgeons and, accordingly, changed the treatment strategy.

Conclusion

Thus, it is very important to train, improve knowledge, focus on extra cardiac manifestations on echocardiography and establish appropriate guidelines for conducting a comprehensive study.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

Acknowledgment

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VENTURE INVESTMENT IN INDUSTRY: WORLD TENDENCIES AND EXPERIENCE OF AZERBAIJAN

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ABSTRACT

The article analyses global trends in venture capital investment, highlighting the impact on Azerbaijan. Particular attention is paid to the dynamics and innovations in the industrial sector, as well as the diversity of venture capital in different regions. The role of venture capital investment in the development of Azerbaijan's economy is examined.
Keywords: Venture capital companies, investment trends, industrial innovation.

Introduction

In the ever-changing landscape of global finance, the venture capital industry stands out as a dynamic catalyst for innovation and growth. This article provides an overview of global trends in the industrial sector and their impact on Azerbaijan. The aim of this article is to analyse trends in venture capital investment, offering a dual perspective covering both the global scenario and the specific context of Azerbaijan. The growing interest in venture capital is not only evidence of its financial attractiveness, but also an indicator of paradigm shifts in business and technology. Through the study of regularities, shifts and emerging trends, the article not only reveals the trajectory of venture capital, but also identifies sectoral trends that herald a new era of industrial development.

Venture capital investing is an alternative approach to investment characterised by a high degree of risk and high returns. Over the past decade, this type of investment has gained popularity, becoming a significant force in the global economic arena. Although the industrial sector is not the market leader according to S&P Global Market Intelligence reports, it still holds a solid share of 20% at the end of 2022 [1]. This indicates confidence in the sector's innovative potential and significant return on investment.

Currently, the global venture landscape reflects a rich diversity of industries, from information technology and biotechnology to renewable energy and beyond. This diversity not only emphasises the adaptability of venture capital to different industries, but also its role in fostering cutting-edge innovation. It is worth noting that the nature of venture capital investment is not the same across different regions of the world. Each region has unique characteristics and trends influenced by its economic background, regulatory framework and technological maturity. In this context, Azerbaijan represents a unique example. Located at the crossroads of Eastern Europe and Western Asia, Azerbaijan has set a course to diversify its oil-dependent economy, and venture capital investment has become one of the most important tools in this process. Venture capital investment in Azerbaijan is in its infancy, characterized by government initiatives, growing entrepreneurial interest and increasing foreign investment.

This article attempts to provide a comprehensive overview of current trends in venture capital investment globally and, at the same time, to examine the specific dynamics that characterise Azerbaijan. By comparing these two trends, the article seeks to provide insight into how emerging economies such as Azerbaijan are navigating the complex world of venture capital and what this means for the future of global venture capital investment.

History of venture capital investment

Venture capital investment has travelled a relatively short but very significant path of development. The evolutionary history of venture capital investment reflects the path of innovation, adaptation, and economic growth. To better understand venture capital, it is necessary to highlight the milestones of its development:

Venture capital investing, which began its development in the early years of the 20th century, underwent significant transformations reflecting the trajectory of innovation and economic growth. The post-war period was characterized by an industrial explosion, but venture capital investment was then rare and industrial companies relied on traditional financing. By the end of the 20th century, venture capital began to invest heavily in the technology and medical sectors, with companies like American Research and Development Corporation and Kleiner Perkins at the forefront.

The development of new technologies led to venture capital opportunities in the fields of robotics and automation, with Modicon pioneering the field of programmable controllers. The 1980s and 1990s saw the integration of advanced technologies into industrial processes, with companies like General Electric and Autodesk in the role of innovators. As the 21st century began, globalization and a focus on sustainability provoked investment in clean technology, with Siemens and ABB Technology Ventures as success stories. The era of Industry 4.0 brought innovation in the form of the Internet of Things, artificial intelligence, and machine learning, with Cognex and Keyence, leaders in machine vision systems, confirming the importance of intelligent manufacturing in modern industry.

2020s - digital transformation and disruption

Pandemic has accelerated digital transformation in the industrial sector by emphasising remote operations and supply chain resilience. Current venture capital trends include investments in robotics, artificial intelligence-enabled manufacturing, autonomous systems, and integration of digital platforms into traditional industries [2, 3].

Companies such as Honeywell and Rockwell Automation have accelerated the development of digital solutions in response to COVID-19 around process automation, including monitoring and control of systems in petrochemical plants, pharmaceutical manufacturing, and other industrial plants. In the field of advanced robotics and artificial intelligence applications, startups such as Boston Dynamics and UiPath are iconic companies.

According to Table 1, of all the sectors, it is the energy sector that has increased investment in 2022 compared to the previous year. This may indicate a shift in investment preferences to the industrial sector.

Table 1. Trend of venture capital investments in 2022.

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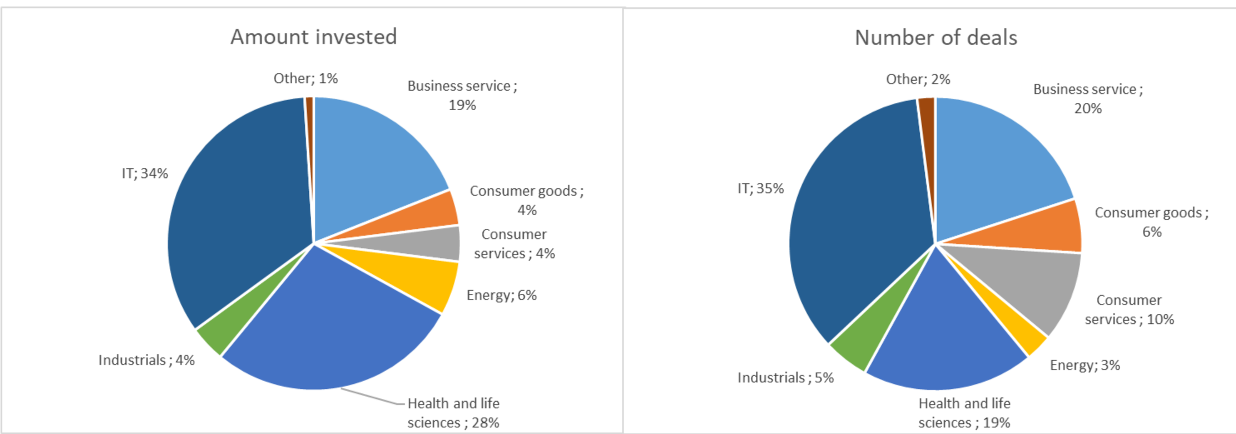
Sector	Trend of Venture Capital Investments in 2022 compared to 2021
Information Technology (IT)	Decrease of more than 35%
Business and Financial Services	
Healthcare	
Consumer Services	Decrease of 58%
Energy	Increase of 17%, with total funds of $12.6 billion

Source: compiled by the author based on [4]

In both charts, the industrial sector accounts for a relatively small share of other venture capital investment sectors.

Figure 1. Distribution of venture capital investment shares by sector for 2022.



Source: compiled by the author on the basis of [4]

In the "Amount of Investment" chart, the industrial sector accounts for 4% of total investment, which shows that although the sector attracts investors' attention, its share is smaller compared to more attractive sectors such as information technology (34%) and healthcare and research (28%).
In the "Number of Deals" chart, the industrial sector's share increases to 5%, which may indicate that although the total investment in the industrial sector is smaller, the number of individual deals is larger, which may suggest less investment per deal in the industrial sector compared to other sectors.
Overall, this data may suggest that the industrial sector has potential for growth and development within the venture capital investment space but is not currently a leading destination for investors compared to more dynamic sectors such as IT and healthcare.

Trends of venture capital financing in Azerbaijan.
In the growing sphere of Eurasian economic development, Azerbaijan represents an interesting case study in venture capital investment. Azerbaijan's unique geographical and cultural location at the crossroads of Eastern Europe and Western Asia creates a favorable ground for an in-depth study of its investment trends, opportunities, and challenges in the broader context of global economic shifts.

Attention to venture capital investment in Azerbaijan is still relevant today. As the country moves towards diversifying its economy beyond the traditional oil and gas sector, understanding the dynamics of venture capital becomes critical.

Despite the existence of a number of obstacles in Azerbaijan, to date the country has managed to accumulate experience in the creation of venture capital funds. By 2020, the country had two local funds fully dedicated to venture capital investments - Infipro and Khazar Ventures.

Infipro Venture Fund, founded in 2012, focuses on investments in the information and communication technology sector, especially in the early stages of internet services and software. Its main objective is to co-operate with entrepreneurs to develop new ideas and expand their businesses. The Fund focuses on innovative companies with high growth potential and has partnerships with the largest investment organizations in Azerbaijan (American Chamber of Commerce in Azerbaijan), international technology companies (Microsoft), other venture capital funds and associations (Russian Venture Capital Association). One of the most successful projects supported by Infipro is GoldenPay, the leading online payment company in Azerbaijan.

Khazar Ventures, a venture fund established in 2014 with the support of local private investors, also focuses on the initial stages of business project development. The fund takes an active interest in a variety of technological endeavors, supporting innovation in a wide range of areas such as web platforms, applications for mobile platforms and e-commerce.

Khazar Ventures is not limited to venture capital investments only. The fund also provides business development support and helps young entrepreneurs connect with partners and industry leaders. Since 2015, Khazar Ventures has helped "grow" more than 30 local startups. Since 2016, the fund has also invested in overseas startups, including projects in the US (Wetravel), Turkey (Shrippy, Emlaktown), Dubai (Cyclee, Maliyya, Wandafi) and Germany (TicketSetup, OrderHunt).

In addition to these funds, an agreement on the establishment of a joint venture fund between the Ministry of Transport, Communications and High Technologies of the Republic of Azerbaijan and DAAL Venture Capital was signed at the InnoFest innovation festival on 30 May 2019. Under the terms of the agreement, the fund will focus on investing in Azerbaijani startups, starting with financing four projects. By June 2019, the joint venture fund had already invested in two local startups, Nextsale and Paym.ese, according to the ministry's chairman.

Trends in the development of venture capital investment in Azerbaijan can be highlighted by the recent activities of local venture capital firms:

- Caucasus Ventures: Founded in November 2022, the Caucasus Ventures fund has invested $300,000 in 6 startups, with a minimum investment amount of $50,000 each. The fund is supported by the Ministry of Digital Development and Transport of Azerbaijan and PASHA Holding, which demonstrates government support and private sector interest in the development of the startup ecosystem [7];
- SABAH Investments LLC: An accelerator that has made 16 investments with an average deal size of $523k. Founded in 2021, it has around 11-50 employees and holds demo days for startups. SABAH Investments specialises in early-stage investments in Azerbaijan and aims to support startups through the stages of idea validation, MVP creation and fundraising [8].

This information provides an insight into the emerging venture capital industry in Azerbaijan, reflecting an environment that is increasingly supportive of start-ups and innovation, both at the public and private level.

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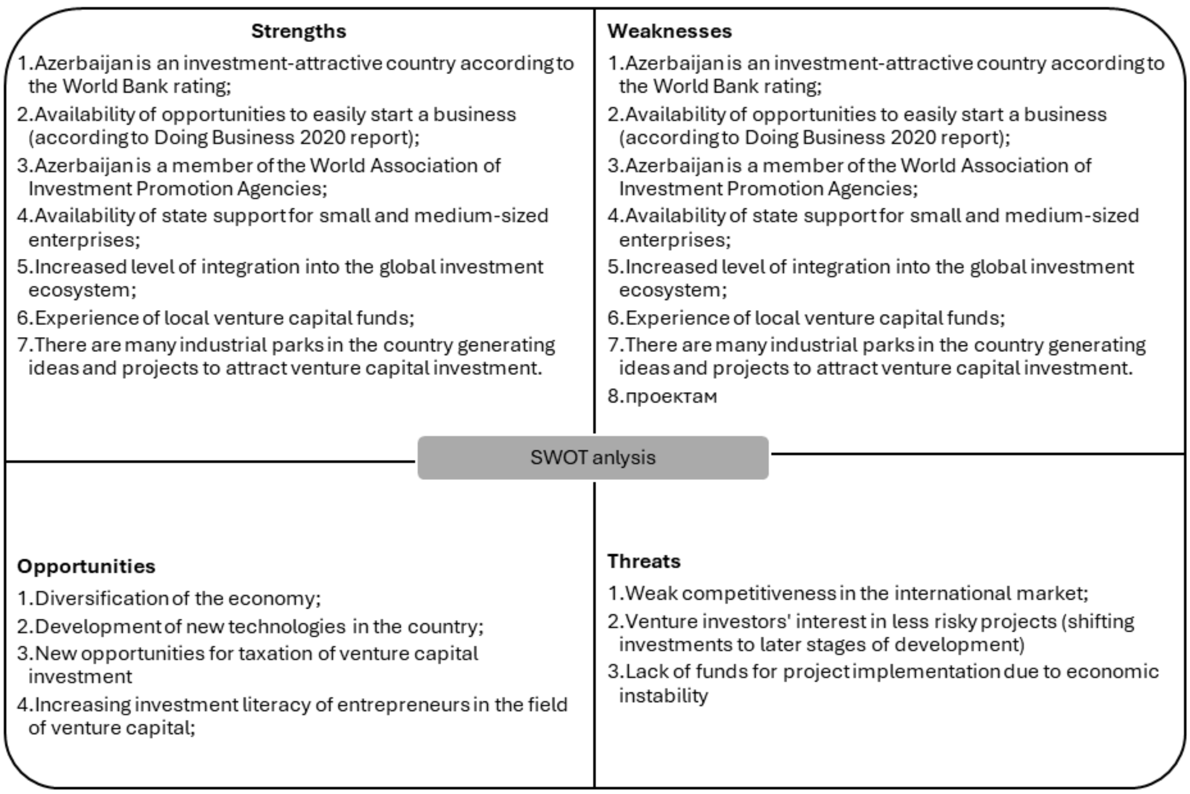
SWOT analysis of venture capital investments in Azerbaijan

In recent years, Azerbaijan's burgeoning venture capital sector has come to play a key role in the region's entrepreneurial landscape. The purpose of this analysis is to analyse the strengths, weaknesses, opportunities, and threats in this dynamic field. By scrutinizing these elements, a comprehensive understanding of the current state and prospects of venture capital investment in Azerbaijan will be gained. It will analyze how the country is progressing towards building a strong startup ecosystem by leveraging its unique geopolitical location, rich natural resources and growing emphasis on digital innovation.



Recommendations

Azerbaijan should consider following global venture capital trends for several reasons:

1. Diversification: Global trends often reflect sectors with high growth potential. By joining them, Azerbaijan can diversify its economy beyond the oil and gas sector.
2. Innovation and competitiveness: Investments in sectors such as Artificial Intelligence, clean technology and digital health can stimulate domestic innovation and improve Azerbaijan's position on the global stage.
3. Sustainable Development: Investments focused on sustainability are in line with global efforts to combat climate change and can lead to more sustainable economic growth.
4. Economic Transformation: Following global trends can help the economy transition to high-tech and knowledge-based industries.

Given Azerbaijan's current economic structure and growth potential, the clean technology and artificial intelligence sectors seem most suitable for venture capital investment:
- Clean Technology: Azerbaijan has begun to diversify its economy with renewable energy projects. Investing in clean technology can reinforce this momentum and contribute to sustainable development.
- Artificial Intelligence: due to the country's strategic position on the Silk Road, investments in Artificial Intelligence can improve various sectors such as logistics, fintech and e-commerce, facilitating regional trade and economic integration.

To improve the economic environment and support venture capital investment in Azerbaijan, the government can implement several strategies:

1. Improve legislation around venture capital investment.
2. Establishment of a state venture capital fund combining the resources of funds established by the Ministry of Communications and High Technologies for large investments in innovative companies at the initial stages. This experience can be borrowed from China and its Torch programme.
3. Holding educational events and masterclasses to enhance the skills of local investors.
4. Overcoming innovation passivity of large enterprises.
5. Phased dissemination of existing innovative institutions and sources of non-bank lending among young people.
6. Providing tax incentives for start-ups with legal liability for non-compliance.
7. Development of cluster strategies for territorial techno-zones.
8. Expanding access to financial instruments on the securities market and promoting IPOs.
9. Introduction of a "consumer to producer" approach based on the successful experience of the Israeli state programme Yozma.

Venture capital investment in Azerbaijan can attract different types of investors, including state funds, corporate venture capital investors from large local conglomerates, national and foreign private investors, commercial bank funds, multinational companies, as well as institutional investors including charitable foundations, insurance companies and credit unions.

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DISTRIBUTION REGULATIONS AND LIFE FORMS OF THE SPECIES OF THE BERBERIDACEAE JUSS. FAMILY WHICH ARE DISTRIBUTED IN THE NAKCHIVAN AUTONOMOUS REPUBLIC OVER ALTITUDE ZONES

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ABSTRACT

Nakhchivan Autonomous Republic, which is part of Azerbaijan, has unique physical and geographical conditions. The total length of the border lines of the autonomous republic, located in the south west of the Lesser Caucasus, is 398 km. The main plain of the Autonomous Republic, 2/3 of which is mountainous and 1/3 is plain, is Araz-Long Plain, which in turn is divided into Ordubad, Nakhchivan, Sharur, Sadarak and other small Plains. Due to the fact that the territory of Nakhichevan Autonomous Republic consists of mountainous and lowland areas, the vegetation cover was formed in accordance with these conditions. The north-eastern territories of the autonomous republic, being part of the high mountain belt, cover heights of more than 2500 meters, and the Alpine and subalpine meadows of the Zangazur and Daralayaz ranges included here cover large areas. Plants belonging to the family Berberidaceae Juss. are distributed mainly in the middle and lower mountain belts, sometimes in the upper mountain belt, Alpine and subalpine belts on dry slopes, clayey, salty soils, Stony-gravel areas, as well as in arable land, field and grounds. In the article berberidaceae juss. The distribution of plants belonging to the family in the height zones, life forms have been studied and it has been determined that the species belonging to this family are most common in the middle and low mountain zones.
Keywords: low mountain belt, barberry, height belts, shrub, Berberis vulgaris L., biological spectrum, distribution pattern

Introduction

The family Berberidaceae Juss is one of the few genera of the order Ranunculales-Buttercup of the dicotyledonous class, but is widespread. The most widespread genus of the barberry family is Berberis L. In its natural form, it grows in North Africa, temperate climatic regions of Eurasia, North, Central and South America. In our country, 4 species of this family are found in 11 genera. These are species included in the genera Epimedium L., Bongardia, C.A.Mey., Berberis L., Leontice L.. Species belonging to the two genera - Leontice L. and Berberis L. are found naturally in Nakhchivan AR.

Berberis L. - Barberry genus are evergreen shrub or small-sized tree plants that shed their leaves. Young Trunks are brown or reddish in color, located at an acute angle on the stem, older trunks are covered with gray, brown bark. Thin light-colored lines are noticeable on the bark. Its long shoots (3-10 mm) do not have scales or have short scaly shoots (1-2 mm). The leaves have been reduced from complex to simple, so 2-7 leaves are arranged alternately on the shortened stem and are located in the form of a ball. The leaves are ovate, reverse-ovate, scalpel-shaped, ellipse-shaped, oblong, less often oval and so on. In most species, the leaves have changed their shape

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and become thorns, which have 1-3-5 crossbars or spines. In the cluster flower Group, yellow flowers are located on short lateral stalks. It has 6 bowl leaves and flowers with 6 petals. The smallest and innermost petals, located in two rows, carry several large, fleshy, bright orange nectaries. The stamens are 6 and are located in two rows. 1 tooth has a short column and 2-5 ovules. The fruit is ellipsoid, ovoid, globular, oblong and other forms of bright red or black color, small berries reaching about 0.8-1.2 cm in length [Salmanova N.H., 2019 P.241-242].

Common barberry (Berberis vulgaris L.) Berberis L. - is one of the most common species of the genus barberry. Common barberry is widespread in all regions of Nakhchivan AR, from the high mountain zone to meadows, arid forests, stony-rocky areas. He can also be found at the same time, on forest edges, in River avalanches [Talibov T.H., Ibrahimov A.M., 2013 p. 60-77].

Discussions. In the poorly developed heights of the vegetation cover of the Nakhchivan Autonomous Republic, the species Berberis vulgaris L. belonging to the genus Berberis L. from the family Berberidaceae Juss., and its different forms can be found singly or in groups [Ibrahimov, A.M., Salmanova, N.H., 2019 p.115-119]. Berberis sphaerocarpa Kar et. Kir. - Tuberous barberry grows in subalpine meadows. All species of the genus Berberis L. can be found in the middle mountain belts. Along with the genus Berberis L., Leontice minor Boiss, the only species of the genus Leontice L., which grows in the Nakhichevan AR, grows in the low mountainous belts. Mountain xerophyte plants are characteristic of the lower mountain belts, of which Berberis siberica Stev.et Fisch. is common, forming formations with other species [Salmanova, N.H., 2019 p. 356-359]. In a word, barberry species participating in soil settlement, drought-resistant and preventing erosion are of particular importance among the plants of Nakhchivan AR [Babayev, S.Y., 1999 p.23].

Table 1. Berberidaceae Juss.- Distribution of plants in the barberry family in height zones, ecological environments.

Species name	Height belt	Ecological environment
1	2	3
Berberisvulgaris L.	From the lower mountain belt to the middle mountain belt, rarely the upper mountain belt	River edges, forest edge, chagilli-stony places, Meadow
Berberisiberica Stev.&Fisch.	Up to the middle mountain belt	Saline soils, Stony-gravel areas
Berberissphaerocarpa Kar.&Kir	Alpine and subalpine mountain slopes	Stony Mountain slopes, river terraces
Berberisintegerrima Bunge.	Lower and middle mountain belt	Dry slopes, hills, along the river
Berberisdensiflora Boiss. &Buhse.	Middle mountain belt	Forest edge, dry mountain slopes, thickets
Berberisorientalis C.K.Schneid.	Plain, from the middle mountain belts to the upper mountain belts	River edges, bushes, dry slopes, rocky places
Berberisthunbergii DC.	Middle mountain belt from upper mountain belt	In gardens and parks
Berberisturcomanica Karel.	Up to the middle mountain belt	On riverbanks, Stony slopes
Mahoniaaquifolium Pursh.	Low mountain belt	In gardens and parks
Leontice minor Boiss.	Low mountain belt	Dry, clayey slopes, stony soils, salty soils
Nandinadomestica DC.	Plain, middle mountain belt	In gardens and parks

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Epimediumpinnatum Fisch.in DC.	Low mountain belt	Shady mountain forests

Looking at the distribution table of species of the family Berberidaceae Juss by altitude zones, we see that the species is most common in the middle and lower mountain belts. It is found in the form of jungle on plains and mountain slopes, although it shows little distribution in Alpine and subalpine meadows. Most of the species included in the family are found in Riverside areas, dry, stony, rocky places (diagram 1).

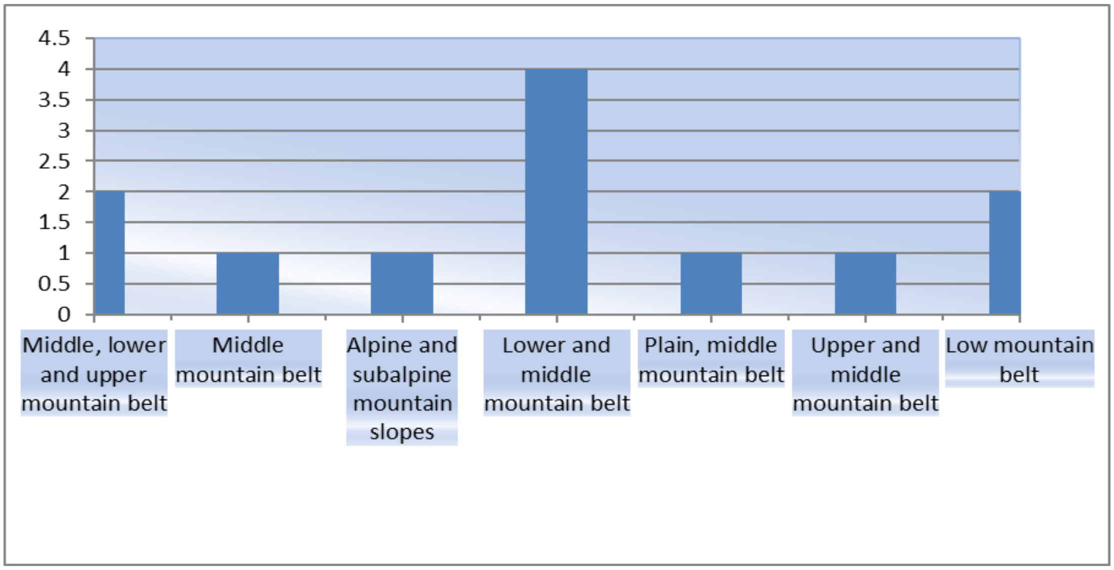

Diagram 1. Distribution of barberries by height belts.

The presence of these plants in the forms of shrubs and small trees, the transformation of the leaves into thorns, the presence of a strongly developing root system ensure their drought resistance and protection from unfavorable environments of the area. The amount of distribution of species in the height zones within the family in %of the total number of species is presented in the following table.

Table 2. The amount of distribution of species in height belts in %based on the total number of species.

№	Height belts	Number of species	Ratio in %relative to the total number of species
1	2	3	4
	Alpine and subalpine meadows	1	9,09
	Upper mountain belt	2	18,19
	Low mountain belt	3	27,27
	Middle mountain belt	1	9,09
	Middle and lower mountain belt	3	27,27
	Plain and foothills	1	9,09
	Total:	11	100

Life forms of species included in the family Berberidaceae Juss.

In the process of vegetation, plants have their own life forms. BC the ancient Greek botanist Theophrastus defined plants as trees, shrubs and herbs. This division, carried out based on the dependence of the morphology of plants on soil, climatic factors of the structure and growth of their stems, laid the foundation for the creation of various divisions and suggestions to subsequent scientists about their morphology. The German biologist A. Humboldt (1769-1859) first identified 16, and then 19 life forms, clarifying the issue of the differentiation of vegetation of different climates as well. The term life form was first coined by the Danish scientist E. Varming in 1884 and defined as the period of adaptation of the life form of a plant to the external environment for the entire vegetation period, starting from the seed form of the plant.

A. Grizebach has identified 9 life forms. Danish scientist K. Raunkier (1937) proposed 7 life forms of plants based on the way they spend their growing season in soil or water [Raunkier C.R.,1934, p.48-154]. K. Raunkier called the life forms of plant groups in the studied area a biological spectrum. Each territory has a unique biological spectrum. For the determination of life forms, K. Raunkier defined the life forms of plants as terophytes, hemicrophytes, chamephites, cryptofites, phanerophytes, halophytes and hydrophytes, taking into account the condition of the shoots of plants on the soil and their adaptation to unfavorable factors of the climate.

1. Phanerophytes (Ph) (Greek faneros - open) –these plants are plants whose shoots are located above 25 cm above the graund. This form, in turn, is divided into 4 subgroups:

- Megaphanerophytes - trees higher than 30 m;
- Mesophanerophytes - low-rise trees up to 8-30 meters high;
- Microfanerophytes - shrub plants;
- Honofanerophytes - low-rise bushes.

2. Hemicryptophytes - mainly dicotyledonous herbaceous plants, spread in temperate climates.

3. Chamefites include low-rise small shrubs and semi-shrubs. Those whose shoots that grow in areas with a cold climate are slightly above the ground surface belong.

4. Cryptofit refers to the type - plants that hibernate in winter and dry summer at the expense of six parts in the soil. This, in turn, is divided into 3 subgroups:

- Geophytes are rooted, bulbous, tuberous and other plants. They are steppe and semi-desert plants.
- Helophytes or limnophytes are swamp plants.
- Hydrophytes, on the other hand, are aquatic plants.

5. Terophytes include annuals that dry out during the winter months. It includes steppe, desert and semi-desert plants that, wintering in the form of seeds, restore themselves in favorable conditions.

Currently, in the classification of plants according to their life forms, the system created by K. Raunkier and I. G. Serebyakov is most widely used.

The analysis of the life forms of the species of the Berberidaceae Juss. family, which grows in the Nakhchivan Autonomous Republic, which is our object of study, is presented in Table 3 with the classification system of K. Raunkier and I.G. Serebyakov.

Table 3. Life forms of plants included in the Berberidaceae Juss family.

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Species name		Life forms	
		According to I.G.Serebryakov	According to K.Raunkier
1	2	3	4
	Berberisvulgaris	Perennial shrub	Microfaneophyte
	Berberisiberica	Perennial shrub	Microfaneophyte
	Berberissphaerocarpa	Perennial shrub	Microfaneophyte
	Berberisintegerrima	Perennial shrub	Microfaneophyte
	Berberisdensiflora	Perennial shrub	Microfaneophyte
	Berberisorientalis	Perennial shrub	Microfaneophyte
	Berberisturcomanica	Perennial shrub	Microfaneophyte
	Berberisthunbergii	Small-sized Bush	Microfaneophyte
	Mahoniaaquifolium	Shrub or small-sized tree	Microfaneophyte
	Leontice minor	Perennial grass	Geofit
	Epimediumpinnatum	Perennial grass	Hemikriptofit

As can be seen from the table, most of the species of the family *Berberidaceae* Juss., distributed in the Nakhchivan Autonomous Republic, are shrubs.
I.G.Serebryakov (1964), on the other hand, considered the life form of a plant as a peculiar external appearance of groups of plants that accumulate in ontogenesis under certain environmental conditions, as a result of growth and development [Серебряков И.Г., 1964, с.146-205]. I.G. Serebryakov showed that vegetative organs are of decisive importance in life forms. In this regard, the modern classification of life forms of cover-seed and conifers was proposed by I.G.Serebryakov.
The Danish scientist K.Raunkier gave the classification of plant life forms based on the location of the aboveground shoots of plants on the soil surface, adaptation to an unfavorable environment and the nature of wintering.
The grouping of barberries by K. Raunkier is presented in Table 5:

Table 4. Grouping of life forms of the species of the barberry family according to K. Raunkier.

	Life forms	Number of species	% Quantity relative to the total number of species
1	2	3	4
	Microphanerophyte	9	73
	Hemicryptophytes	1	9
	Geofit	1	18
	Total	11	100

As can be seen from the tables, most of the plant species of the family Berberidaceae Juss are microfanerophyte species, 1 species is considered Geophyte.

Conclusion

The species of the barberry family spread in Azerbaijan, including Nakhchivan AR, are almost mainly shrub plants, and 3 species are perennial herbaceous plants. The influence of environmental biotic and abiotic factors plays a major role in the growing season of these plants. The spatial interpretation of each species is complex, therefore, the study of its cenopopulations requires special attention. As a result of our research, it becomes clear that barberries are mainly drought-resistant and soil-undemanding plants. It is adapted to the climate of the Autonomous Republic, which is very dry in summer and harsh in winter, and together with other species affects the formation of vegetation. Most of the species included here are xerophytic species, which grow on mountain slopes, in the middle mountain belts up to the upper mountain belts.

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ASSESSMENT OF ENTERPRISE EFFICIENCY AND EFFECTIVENESS BOTH ON DOMESTIC AND WORLDWIDE PRACTICE

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ABSTRACT

Enterprise effectiveness plays a major role in distinguishing companies' success and ability to present a better product rather than that of the competitors. Assessing this important factor is crucial to obtain organizational success and evaluate factors pertaining to that goal. It is important for organizations to directly comply strategies that center effectiveness and efficiency as one of its primary goals.
Nowadays a large aid arrives to this matter with addition of new technology and globalization. Many companies evaluate foreign experiences in constructing their organizational structure and company strategies around this essential factor of success. Many outcomes of technology such as the internet and social media, help companies both directly and indirectly to follow the desired outcomes.
In this study, we are going to analyze the current state and practice of enterprise efficiency followed by companies on domestic level as well as paths set on worldwide level led into practice by key players of international business communities.
Keywords: Efficiency, Effectiveness, Assessment, Enterprise, Worldwide, Domestic, Factors, Impact, Productivity, Ratio.

Azerbaijan is one of the currently fast-growing economies of Caucasus region. Growth is witnessed to progress in fulfilling due self-support and economic stability. This is also powered by country's vast non-renewable resources such as oil and gas which help to strengthen countries position on foreign export level and allow for foreign resources to enter strengthen countries financial standings. Big help is also pertained by growing employability and decrease of non-working percentage of the population.
Many working places as companies in Azerbaijan increase their competitiveness as shift from planned economy to rivaling strategy of market economy and powering factor of demand and supply. This one element is used by companies and due to high intake of labor power, companies need to potentially invest and forecast in strategic planning to grant factor of success and effectively use allocated resources. Therefore, companies try to deeply invest and take into matter strategic planning as major factor to highlight and concentrate on the product they can occupy the best and make use to modernize to use as competitive advantage against other companies with similar product and area of service. On par with resource planning companies need to seriously investigate its human resources and to allocate them effectively.
To produce such matter, organizational structure of the company should represent company's objectives and be as transparent as possible, represent best practices and primarily attention the

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company's interest, while reducing unwanted services that company does not plan to target or that does not suit companies' strategic objective not as primary or even as secondary role.
Clearly understanding goal of each department and strategically planning human resources in its best intentions is key priority for Human Resources Department of the company.
As well to the stated before, employee satisfaction is also a major factor concerning Human Resources of the company, and the biggest attention should be paid to this matter, although it should be carried out judgmentally based on input factors of the employee and his/her effectivity ratio based on the produced work output. Raising high motivation percentage of the employees is essential for raising effectivity ratio of the companies. Graph below is showing dynamics of labor cost per hour on which companies should center when developing their employee motivation and satisfaction strategies.

Table 1. Labour costs per 1 hour by economic activities in manat

Economic activity	2017	2018	2019	2020	2021	2022
On economy - total	4,21	4,36	5,06	6,15	6,00	6,83
Agriculture, forestry and fishing	2,09	2,26	2,99	3,51	3,64	4,13
Mining	24,46	24,17	24,55	27,94	27,04	26,70
Manufacturing	4,49	4,55	5,18	5,39	5,65	6,29
Electricity, gas and steam production, distribution and supply	4,43	4,69	5,10	5,70	6,47	7,21
Water supply; waste treatment and disposal	2,50	2,35	3,72	4,28	4,25	5,02
Construction	6,17	5,46	5,79	6,31	7,02	7,90
Trade; repair of transport means	2,92	2,98	3,63	4,27	4,28	4,48
Transportation and storage	6,03	6,46	7,04	7,43	7,93	9,37
Accommodation and food service activities	4,02	4,25	4,42	4,79	4,63	5,29
Information and communication	6,78	6,93	7,87	8,56	9,18	10,59
Financial and insurance activities	10,79	11,63	12,59	13,88	15,81	16,43
Real estate activities	2,75	3,38	4,41	4,97	5,43	6,51
Professional, scientific and technical activities	8,14	8,40	9,18	9,98	9,99	11,70
Administrative and support service activities	4,35	4,43	3,08	3,39	3,48	3,93
Public administration and defence; social security	4,22	4,74	6,30	7,66	7,82	9,56
Education	2,69	3,05	3,69	5,90	4,54	5,43
Human health and social work activities	1,79	1,93	2,84	4,25	4,65	5,86
Art, entertainment and recreation	2,12	2,34	3,33	4,52	4,31	4,94
Other service activities	5,05	5,03	5,13	5,94	6,39	7,93

On the other hand, companies should also orient themselves on global trends to increase competitiveness and bring innovation to already performed practices. Investment in digitalization will also heavily benefit the enterprise, since it will help to cut down costs on previously performed activities that included labor work and also production of supplementary materials i.e advertising.

Here as an alternative companies can rely on social media which will not only cut down their costs, but also grant them a wider audience since many countries connected to them and will effectively use it to find solutions to their existing needs.

Other factors which companies need to address it to develop and make use of many indicative factors, such as KPI' which stands for Key Performance Indicator and helps companies to view and grade productivity of its employees and services. Such underlying factors of it as punctuality, time management and production output are import part of the performance indication of the employees

One of the major parts of effective control of the enterprises lies in resource allocation which includes asset planning and long-term liability strategy of the company, as well as many outstanding factors of the company internal economics and planning. Such activities should be evaluated and performed effectively, and companies should not hesitate to approach world-famous international consultants and practices to improve and innovate their strategies.

Product diversification is another important factor where companies can innovate. By being able to present the consumer with a large spectrum of product and services, companies can find the niche market for targeting and further develop their product for the targeted audience. Here digitalization will provide a huge aid as an ability to view algorithms to analyze customer behavior, and if company invests in acquiring such sensual data and gets to possess it, it will give it competitive advantage over its competitors.

Above we stated important sectors that companies need to research to make their daily operations as smooth as possible. But external analyses are not possible to be the only key factor without internal adaptations. Company management needs to adapt its financial conditions to its desired outcomes to be able to increase its productivity. Such principals of the economics such as ROE (Return on Investment) and depreciation as well as other parameters should be followed to obtain optimistic future outcomes

EBITDA (Earnings before interest, taxes, depreciation, and amortization) is another important factor which displays initial financial gaining's from enterprise operations, an important factor to value in future calculations and plays financial role in economics of the company for future prosperity.

And of course, properly balanced and structured Cash flow statement will let companies view it assists and liabilities to better compare current and previous years activities and identify wheter company is being successful or there is room for further improvement.

Stated above graph 31.1 shows indicators of growth in fixed assets of different spheres of the economy, which is a positive note that indicated value added in assets to comply with companies' necessity to acquire more assets to cover its operations in respective manner.

Worldwide practices promote use of digitalization and outsourcing, which is also an important factor for companies to face when monitoring need for production output that they not able to perform locally. In such case companies tend to negotiate with foreign services in order to acquire the necessary assets (manpower, equipment and etc.) to realize necessary output at lower cost. This also results efficiently in company procedures and financial standings.

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Table 2. Fixed assets in the section of oil-gas and non oil-gas of economy, end of the year, current prices, million manats.

including:				
oil-gas sector	122 837,2	126 222,4	133 232,4	135 514,7
non oil-gas sector	104 383,4	114 471,6	126 042,5	128 201,7
including:				
Agriculture, forestry and fishing	8 379,9	8 524,0	9 230,3	10 118,4
Mining	342,2	360,1	369,3	200,2
Manufacturing	8 582,8	11 153,4	11 820,4	11 860,9
Electricity, gas and steam production, distribution and supply	12 312,7	13 657,6	16 431,5	16 994,3
Water supply; waste treatment and disposal	6 782,1	7 431,4	9 508,1	10 007,1
Construction	5 672,2	9 570,0	11 463,6	11 423,6
Trade; repair of transport means	2 221,6	2 266,8	2 393,2	2 396,8
Transportation and storage	15 695,5	15 704,6	17 260,9	17 363,4
Accommodation and food service activities	1 795,5	1 789,7	1 807,4	1 807,7
Information and communication	4 097,4	4 190,2	4 193,4	4 228,4
Financial and insurance activities	3 507,3	3 699,4	3 769,1	3 773,3
Real estate activities	10 803,6	11 585,3	12 795,8	13 088,8
Professional, scientific and technical activities	2 114,0	2 226,4	2 219,0	2 077,4
Administrative and support service activities	652,0	747,9	789,6	812,7
Public administration and defence; social security	10 480,8	10 498,3	10 884,3	10 926,7
Education	3 059,1	3 075,5	3 092,7	3 107,2
Human health and social work activities	3 930,6	4 007,4	4 010,7	4 012,5
Arts, entertainment and recreation	3 211,4	3 235,9	3 246,2	3 248,3
Other service activities	742,7	747,7	757,0	754,0
* Primary data				

Conclusion

Since transition to market economy, enterprises in Azerbaijan had taken a big step to adapt to modern challenges and take serious steps to implement new strategies in their day-to-day plan. We have witnessed wide use of today new technological tools and trends as vast usage of internet, social media. Digitalization is used actively to communicate with consumers and that makes companies more efficient and effective in providing their services.

Companies also partner with foreign consultancy companies that help to improve organizational structure of the companies located in Azerbaijan and adapt better to new global trends.

Outsourcing is widely seen in business activities, since production output of local enterprises mostly occupies lightweight operations, when relying on heavy production infrastructure, except oil and gas industry, companies mostly rely on services of foreign service providers.
Overall enterprises in Azerbaijan are able to catch attention of foreign investment, in regards of current sanctions against Russia, their position has become even stronger and obtain catchment area from new markets. This trend should further be enhanced and developed as now it proves to be effective for the companies, it can be developed even further to allow for more advantageous position, which as well careful management can adapt to make services provision more efficient.

Declarations
The manuscript has not been submitted to any other journal or conference.

Study Limitations
There are no limitations that could affect the results of the study.

Acknowledgment
The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

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ARTIFICIAL INTELLIGENCE, PROBLEMS AND PROSPECTS

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ABSTRACT

The article discusses the concept of "artificial intelligence", its problems and prospects.
Artificial intelligence is the property of artificial intelligent systems to perform creative functions that are traditionally considered the prerogative of humans. the science and technology of creating intelligent machines, especially intelligent computer programs.
The article discusses the main characteristics of artificial intelligence. Features and examples of the implementation of artificial intelligence technologies in the modern foreign educational space are shown.
The history of artificial intelligence as a new scientific direction begins in the middle of the 20th century. By this time, many prerequisites for its origin had already been formed: among philosophers there had long been debates about the nature of man and the processes of cognition of the world, neurophysiologists and psychologists developed a number of theories regarding the work of the human brain and thinking, economists and mathematicians asked questions about optimal calculations and the presentation of knowledge about the world in in a formalized form; finally, the foundation of the mathematical theory of computing - the theory of algorithms - was born and the first computers were created.
The formation of modern computer technologies has created a large number of cases that are related to:
• human speech, the ability to learn to recognize and synthesize it;
• development of technical vision mechanisms that will be able to recognize people's faces;
• the ability to teach cars to drive independently without human intervention, etc. [1].
Such systems that demonstrate and follow human behavior are called artificial intelligence. The study of artificial intelligence is an important direction in modern science.
Artificial intelligence is a technology that contains a set of tools that help a computer, based on the studied data, provide answers to questions, and also draw conclusions based on this.
Today, AI is essential for a wide range of industries, including healthcare, retail, manufacturing, and even government. But there are ethical challenges with AI, and as always, these options need to be out of options to ensure AI doesn't do more harm than good. Here are some of the biggest ethical challenges of AI.
Keywords: Artificial intelligence, computer, robot, thinking, awareness, personality, society, humanity, problems, prospects, future.

XÜLASƏ

Məqalədə “süni intellekt” anlayışı, onun problemləri və perspektivləri müzakirə olunur.
Süni intellekt süni intellekt sistemlərinin ənənəvi olaraq insanların səlahiyyəti hesab edilən yaradıcı funksiyaları yerinə yetirmək üçün mülkiyyətidir. intellektual maşınların, xüsusən də intellektual kompüter proqramlarının yaradılması elmi və texnologiyası.
Məqalədə süni intellektin əsas xüsusiyyətləri müzakirə olunur. Müasir xarici təhsil məkanında süni intellekt texnologiyalarının tətbiqi xüsusiyyətləri və nümunələri göstərilir.
Açar sözlər: Süni intellekt, kompüter, robot, düşüncə, şüur, şəxsiyyət, cəmiyyət, bəşəriyyət, problemlər, perspektivlər, gələcək.

Introduction

We have classifieds to train our AI programs, and you must sort through almost everything that comes in to remove bias in that data. For example, the ImageNet database has much more facial data of people with white skin than black skin. When we train our AI abilities to learn facial features using a database of the correct proportions of faces, the cleaner will not work as well on black faces and will create a bias that could have a huge impact.

Control and Morality of Artificial Intelligence

As we use more and more artificial intelligence, we are asking machines to make increasingly important decisions. For example, there is currently an international agreement governing the use of autonomous drones. If you have a drone that can potentially fire a rocket and kill someone, there needs to be a human in the decision-making process before the missile is deployed. So far, we have solved some critical control problems of AI with a set of rules and regulations like this [6].

The problem is that AIs are increasingly forced to make split-second decisions. For example, in high-speed trading, more than 90% of all financial transactions are now driven by algorithms, so there is no chance of giving control of decisions to a human.

The same goes for autonomous cars. If a child gets stranded, they need to react immediately, so it's important for the AI to check their status. This creates interesting ethical challenges around AI and control.

Security

Privacy (and consent) to use data has long been an ethical dilemma of AI. We need data to train AIs, but where does this data come from and how do we use it? We sometimes assume that all data comes from adults with full mental abilities who can make choices for themselves about the use of their data, but we don't always have that [4].

As we've seen a lot in the news lately, there are also many companies that collect data and sell it to other companies. What are the rules regarding this type of data collection and what legislation may need to be implemented to protect users' private information.

Humanity

Artificial intelligence will continue to automate more of our work. What will be our contribution as humans? I don't think AI will replace all our jobs, but AI will empower them. We need to get better at working with smart machines so that we can manage the transition with dignity and respect for people and technology. These are some of the key ethical challenges that we all need to consider very carefully when it comes to artificial intelligence.

As of now, artificial intelligence has become the branch of science and engineering that creates intelligent machines, especially intelligent computer programs. The main expectation is to develop algorithms that bring the characteristic features of human intelligence to computers and to develop systems that can produce solutions to problems by exhibiting human-like intelligent behavior [2].

Artificial Intelligence Capabilities. The power of artificial intelligence is gaining strength as a result of the internet of things, big data analysis and production of information. Ways are being opened for machines to talk to each other. It is fair to say that it is time to create a new language between human-machine-software. As of now, using artificial intelligence, the computer can beat humans in the game of chess. Expert systems, one of the basic technologies of artificial intelligence, can control a spacecraft. With speech recognition systems, people can talk to computers and machines (robots). Language translation can be performed automatically on websites. The developed machines are equipped with relevant software;

It can make comments, solve problems, establish relationships and make decisions (expert systems).

• Can learn (artificial neural networks and other machine learning techniques).
• It can produce solutions to complex problems that conventional computers cannot solve (genetic algorithms).
• Can understand words. It can perform operations based on words (fuzzy propositional logic).
• Can climb stairs, play ball, answer questions, communicate... (intelligent agents)
• Can read, interpret and teach texts (natural language processing)
• Can detect, prioritize, focus (computer vision) [3].

When the course of developments is followed, it seems that in the near future, perhaps within 5-10 years, robots and computer-based systems will be enriched with artificial intelligence technology;

• They will be able to talk to each other (information protocols).
• They can focus on the same goal (objective/sensor modelling).
• They will be able to socialize, help each other and support each other (emotional intelligence).
• They will be able to teach each other about events (intelligent teaching systems).
• They will be able to conduct R&D studies and act innovatively (modeling scientific discoveries).
• They will be able to do more than one job on their own (intelligent agents).
• They will be able to take part in management positions of businesses and serve as virtual managers (intelligent agents).
• They will be able to create personalized education/training systems (intelligent teaching systems)
• They can be very skillful in communicating with their interlocutors in their native language (natural language processing) [5].

It is possible to find many exemplary scientific studies on most of the subjects mentioned above. Practical applications of some of them have begun to be seen. There are even studies showing that robots can now act as doctors [6].

Dangers and Negative Effects of Artificial Intelligence.

One of the most curious topics regarding developments in artificial intelligence technology is how dangerous artificial intelligence can be. Artificial intelligence is a human structure. This issue needs to be understood very well. A person or a group can only create a system as intelligent as its own intelligence. If a person has good intentions, he will try to develop systems that will benefit

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society; if he has bad intentions, he will try to develop systems that will harm society. Ultimately, the problem is whether a person is good or bad. If there is danger, it is in humans. It is in human modeling ability. This is very clear. It is much easier to stop an evil robot than to stop a malicious human. The only condition is to raise the intelligence level above the intelligence level of the malicious system. Since it is human intelligence that makes it, a person or a group of people can produce the intelligence to take precautions. What needs to be done is to prevent people from behaving badly through education and to invest in systems that will monitor any bad behavior in society (whether it comes from a human or a robot) and take the necessary measures. Scientists especially have important duties in this regard.

Conclusion

Social and technological change in the world continues at a high pace. It should be well understood that the digital world can elevate business models and that businesses must be open to radical discoveries and be ready to detach themselves from routine thinking and behavior to find new and sustainable sources of income. Since this will definitely bring with it some risks, processes must be redefined, and special designs must be developed to eliminate risks. A sound innovation and competitiveness strategy should be determined, and these elements should be encouraged regularly. The developed strategy should be implemented very carefully. One should not remain indifferent to technological developments, especially artificial intelligence, and efforts should be made to intelligentize all operations throughout the system.

The state and business administrations need to provide close support to these developments. However, controlled development of artificial intelligence must be ensured. If left uncontrolled and left to its own devices, it can cause problems that are difficult to manage and solve in societies.

In order to be successful in artificial intelligence initiatives, taking the first step without delay and constantly measuring the results of the studies is an important requirement to experience a successful transformation process. If neglected, it will be almost impossible to catch competitors in the future. Because the pace of developments is very fast. While one system is in the design phase, another system may be released to the market and the designs may be meaningless.

Declarations

The manuscript has not been submitted to any other journal or conference.

Study Limitations

There are no limitations that could affect the results of the study.

Acknowledgment

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

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THE ROLE OF SOLAR AND ALTERNATIVE ENERGY IN DIRECTING OF THE BIOECOLOGICAL CHARACTERISTICS, CONSERVATION AND USE OF ESSENTIAL OIL PLANTS

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ABSTRACT

The main purpose of the research is to study the role of solar and alternativ energu in the direction of bioecelogical characteristics, protection and usage of essential oil plants. The huge food and technical importance of oil and essential plants are given in the article. The vegetable oils obtained from them are used in the food industry, in baking, in the preparation of various preserves, confectionery, margarines and oils, and from essential oils in the field of medicine, in the perfumery and cosmetics industry, etc. widely used. At the same time, it is used in the production of linoleum and stearic acids, lacquer-paint, weaving, soap-making, leather tanning, etc. these oils are used in industries. Oil crops include sunflower, soybean, sesame, groundnut (araxis), safflower, castor, poppy, white mustard, blue mustard, winter and spring rape, oilseed rape, lallemantia, perilla (sudza), oil tulip, radish, flax, etc. includes plant species. Among the vegetable oils produced for edible oil on a global scale, the first place is soybean, the second place is sunflower, and then peanut, cotton, rapeseed, olive, sesame, corn and safflower oils.
Most essential oils are found in free form in plants. Their amount in different types of plants varies greatly, from 0.001% to 22%. There may be a type of plant in which the amount and composition of the essential oil is negligible. This may mainly depend on the cultivated region, the age of the plant, the phase of development and other conditions.
It has been determined that plants accumulate more essential oil in dry and hot weather than in cold and humid conditions. The amount of essential oil in the plant is greater during the flowering and ripening period. A group of plants cultivated to produce essential oil are called essential oil plants. They contain volatile aromatic substances with different chemical composition. The amount of these oils in the seeds, flowers, leaves, branches and other organs of the plant varies depending on cultivation technology and soil-climate conditions. Essential oil plants include coriander, mint, cumin, basil, cloves, myrtle, etc. belong to plants. Essential oils are widely used in the food, medicine and perfume-cosmetics industry. The waste obtained after the processing of fruits and seeds is used as feed in livestock and poultry farming.
Solar energy from alternative energy sources is used in many countries of the world. In the process, solar energy is converted into useful energy and replaced by other forms of energy, such as biomass, wind or hydropower, and "drives" the weather on Earth. Most of the solar radiation is absorbed by the oceans and seas, as a result of which their water heats up, evaporates and falls to the Earth in the form of rain, "feeding" hydroelectric power plants.
Solar energy affects to the plants mainle the essentional oil plants, either. Most plants admit solar energy during the drying or feeding process.

Thus, we considered both the essential oil plants, especially the flax plant, and learned the advantages and disadvantages of alternative energy. We came to the conclusion that alternative energy has a role in the process of cultivation and protection of essential oil plants. Approaches and results can be different in the analysis of positive and negative sides in the fast developing era.

Keywords: essential oil, plants, solar energy, ecology, industry, flax, linseed

Introduction

Oily and essential plants have great food and technical importance. The vegetable oils obtained from them are used in the food industry, in baking, in the preparation of various preserves, confectionery, margarines and oils, and from essential oils in the field of medicine, in the perfumery and cosmetics industry, etc. widely used. At the same time, varnishing, weaving, soapmaking, leather tanning, etc. these oils are used in industries. Oilseeds are also a source of plant protein. 35-40% protein is left in the oil obtained from the seeds of oilseeds, which is a concentrated feed rich in protein and fat for livestock. Many of the oil and essential plants are good honey plants. Proteins in the fruits and seeds of various oil plants contain many essential amino acids (lysine, tryptophan, cysteine, arginine, etc.) that make them completely valuable. Oil crops include sunflower, soybean, sesame, groundnut (araxis), safflower, castor, poppy, white mustard, blue mustard, winter and spring rape, oilseed rape, lallemantia, perilla (sudza), oil tulip, radish, flax, etc. includes plant species. Among the vegetable oils produced for edible oil on a global scale, the first place is soybean, the second place is sunflower, and then peanut, cotton, rapeseed, olive, sesame, corn and safflower oils. Among the technical oils, linseed takes the first place, and castor oil takes the second place. In the world agricultural system, the cultivated area of oil crops is significant. Their cultivated area is more than 140 million hectares on earth. Oilseed crops are mainly cultivated in the USA, Canada, India, Brazil, Argentina, China, Pakistan, Russia, Moldova and Ukraine. Oil plants represent separate botanical genera and species of different families (Astra, Cabbage, Leguminous, Dalamaz, Milkweed, etc.). Vegetable oils are complex esters of trihydric alcohols, consisting of a ratio of glycerin and various fatty acids. Fats contain 75-79% hydrocarbons, 11-13% hydrogen and 10-12% oxygen.

The main part.

The seeds, flowers, leaves, branches and other organs of essential oil plants also contain essential oil containing various organic compounds: hydrocarbons, alcohols, phenols, ethers, aldehydes, ketones and organic acids. Most essential oils are found in free form in plants. Their amount in different types of plants varies greatly, from 0.001% to 22%. There may be a type of plant in which the amount and composition of the essential oil is negligible. This may mainly depend on the cultivated region, the age of the plant, the phase of development and other conditions. It has been determined that plants accumulate more essential oil in dry and hot weather than in cold and humid conditions. The amount of essential oil in the plant is greater during the flowering and ripening period. A group of plants cultivated to produce essential oil are called essential oil plants. They contain volatile aromatic substances with different chemical composition. The amount of these oils in the seeds, flowers, leaves, branches and other organs of the plant varies depending on cultivation technology and soil-climate conditions. Essential oil plants include coriander, mint, cumin, basil, cloves, myrtle, etc. belong to plants. Essential oils are widely used in the food,

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medicine and perfume-cosmetics industry. The waste obtained after the processing of fruits and seeds is used as feed in livestock and poultry farming.

Linseed oil plant. (Linum usitatissimum ssp. humile (Mill.) Czernom.).

History, origin and distribution. The linseed oil plant has been cultivated since ancient times. It is difficult to give an accurate opinion about his homeland. Linen was known in India, China, Egypt and Transcaucasia 4-5 thousand years before our era. It is believed that the homeland of linen is mountainous regions of India, China and Mediterranean countries (Transcaucasia, Anatolia, Western Iran). The flax plant easily transitions into wild form. It shows itself as a wild plant in many countries, including southern Russia. It passed from Asia to the territory of Russia.

Currently, flax is cultivated in the warm regions of Europe, Asia and North America, and in North Africa. To this day, there is no correct opinion about the origin of linen. However, several hypotheses have been proposed. In some of these hypotheses, it is shown that the narrow-leaved flax came wild from the territories of the Persian Gulf states to the shores of the Caspian and Black seas. Others suggest that the cultured linen first took its origin in the highlands of India. Here, archeological excavations provide information about the cultivation of flax 51 years before our era. Some say that the first cultivation areas of flax were the Middle East, Caucasus (Azerbaijan), European and Asian countries. Based on the remains of linen obtained as a result of archaeological excavations conducted in these places, scientists say that it was planted in the Stone Age. Cultivation of flax has been started in Russia since ancient times. In the III-V centuries, flax was cultivated in Yaroslavl and Kostroma regions of Russia. Already in the 10th century, cloth, thread, fiber and oil produced from linen in Russia were sold not only to meet the country's own needs, but even to foreign countries. More than 60% of the cultivated area of flax is concentrated in the CIS countries. Russia, Ukraine and Belarus have more arable land. Poland, Romania, France, Czech Republic, Netherlands, etc. the cultivated area is also significant in the countries. The cultivated area of the main fibrous flax in the world is 1.5 mln. more than one hectare, and that of oilseed is about 1 mln. is a hectare.

Oilseed crops are more abundant in Argentina, USA, Canada and India. The cultivated area in Russia is 200,000 hectares. The average fiber yield of flax is 0.4 tons per hectare, but the potential is 1.6 and more. Herodotus, who is considered the "father of history", shows that in Colchis, cloth products made of linen not only satisfied the domestic demand, but also exported them to many Eastern and Western countries. Herodotus notes that the ancient Scythians, who lived around the Dnieper and Dniester rivers, planted flax and hemp in addition to wheat, lentils, onions, and garlic, and wove excellent quality fabrics from them. These ideas of Herodotus are confirmed by the materials obtained as a result of archaeological excavations on the banks of the Dnieper River. They determined that in those times the peoples of today's Lithuania were also widely engaged in linen weaving. The Arab traveler Ibn-Faldan in 901, when he was in the Volga and Ural regions, came across people walking in clothes made of linen. Among the people, many legends and tales related to linen were invented, and special solemn holidays were celebrated. Every year on June 3, after collecting the harvest, they held a solemn holiday. Azerbaijan is also considered one of the ancient homelands of linen. However, after falling under the slavery of the empire, like many fields in Azerbaijan, linen weaving was forgotten. Now Azerbaijan has regained its state independence. Therefore, in the near future, it will be necessary to think about the development of linen in Azerbaijan in order to increase the production of thread and meet the demand of the republic.

Flax farming is developed to obtain fiber and oil. Long-fiber flax is used for fiber purposes, and curly or oily flax (Linum usitatissimum ssp. humile (Mill.) Czernom.) is used for oil purposes (color figure 1).

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Figure 1. (Linum usitatissimum ssp. humile (Mill.) Czernom.

Cultivated flax, sown or common flax (L. usitatissimum L.) is a self-pollinating annual herb with a height of 30-150 cm. It is taller in hot countries eg India. It branches only from the upper part. The main root (spindle root) is quite short, whitish in color, and produces several large lateral branches (roots). However, there are many tiny root strands. The main part of the stem is covered with a dull green waxy layer, which is erect and straight, thin, cylindrical, sometimes simple, branching only from the upper part. The body is hairless and almost hairless, i.e. covered with short hairs. The leaves are numerous, relatively sparsely alternate or spirally arranged, 2-3 cm long, 3-53 4 mm wide, linear or linear-lanceolate, relatively large lanceolate, finally pointed (sharp) sessile, light bluish in color, with a relatively weak wax layer. covered, smooth edges, 3-veined. Leaves covered with hairs or glabrous, margins entire. The flowers are gathered at the end of the stem in the form of a false umbrella (dikhazi). The flower group is sparse, curved, sometimes curled, and the inflorescence is lanceolate. The flowers are relatively few-membered, most of them are medium-sized or small, 1.5-2.4 cm in diameter, with rather long stalks, close together in the upper parts. Sepals 5-6 mm long, grass-like, ovate or ovate-lanceolate, oblong-ovate, pointed or short-pointed in the upper parts, 2-5 in most cases 3-veined, relatively wide inside, bordered with a white coating, the edges are jagged in the upper part , thinly ciliated. Petals 12-15 cm long, wedge-shaped, inverted ovate, a few obtuse or obtuse in the upper parts, full-margined, smooth or slightly wrinkled, blue or blue, with relatively dark veins, sometimes white, pink or red-purple , dried downwards is white, with a yellow vein at the base and falls quickly. The stamens are linear, white in color, and the upper part has a thorny blue stalk (veined). The stamen tube is short, ring-shaped. Anthers are oblong, mostly blue, and sometimes yellow or pink. The tooth consists of one, circular, five columns. The ovary (seed) is egg-shaped, green in color, the column has a wedge-shaped line, and the mouth changes from dark blue to purple. It blooms in June and July. Its flowers open early in the morning as soon as the first rays of the sun hit, and in the afternoon they begin to be washed and shed. It does not bloom on wet and rainy days. Fertilization takes place only through insects - cross-fertilization. The fruit is a five-slotted capsule, 6-8 mm long, 5.7-6.8 mm in diameter, flattened globose or globose-ovoid. There is a trace of a bowl on it. The upper part is slightly pointed, yellowish in color, the main part is not covered with anthocyanin color, sometimes weakly colored before ripening, non-cracked, false septate, hairless (smooth) and sometimes ciliated. The fruit ripens in July-August [Humbatov, Bashirov: 2016, p.53].

At this point, it is necessary to consider the types of solar and alternative energy sources that have a role in essential oil plants. Alternative and renewable energy sources are solar, wind and geothermal energy, small HPPs, sea swells and waves, and biomass energy.

Solar energy from alternative energy sources is used in many countries of the world. The use of solar energy falling on the roofs and walls of the houses significantly reduces the annual energy demand of the residents of these houses. At the same time, the use of solar and thermal energy is clean, simple and all its forms are obtained by natural methods. With the help of solar collectors, residential houses and commercial buildings can be heated and supplied with hot water. Solar energy collected by parabolic mirrors is used for heating. It is also possible to provide production with electricity from it. In addition, there is another method of energy production through the Sun - photoelectric technology. Photoelectric devices are devices that directly convert solar radiation into electric current. Solar radiation can be converted into useful energy using active and passive solar systems. Active solar systems include solar collectors and photovoltaic cells. Passive systems are obtained by designing buildings and choosing building materials to maximize solar energy.

In the process, solar energy is converted into useful energy and replaced by other forms of energy, such as biomass, wind or hydropower, and "drives" the weather on Earth. Most of the solar radiation is absorbed by the oceans and seas, as a result of which their water heats up, evaporates and falls to the Earth in the form of rain, "feeding" hydroelectric power plants.

One of the alternative energy sources is alternative fuel for transportation. Renewable energy sources are primarily biomass fuel.

During the Second World War, ethanol and gas obtained by gasification of wood were used in the United States, Brazil and many European countries due to difficulties in transporting oil. However, in the post-war period, the price of oil dropped and the interest in biofuel decreased when it was known that there were enough oil deposits, but today the situation in the oil market is completely different. The cost of fuel produced from exhaustible sources is increasing rapidly, thus opening the way to alternative fuels, mainly biomass.

Fuel consumption in transport is constantly increasing. In 1985, there were 375 million passenger cars and 109 million trucks worldwide, and in 2002, the world's passenger car fleet reached 530 million cars. In the United States, whose population is 5 percent of the world's population, a quarter of all cars used in the world were. According to experts' calculations, by 2020, a billion cars will be on the streets of the world.

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Our country has a wide range of alternative energy options.

There are wide opportunities for obtaining wind energy in Azerbaijan, especially on the Absheron Peninsula. Considering the rapid economic development of our country, serious steps will be taken in the use of alternative energy sources in the coming years.

There are opportunities for using wind energy in our republic. Here, the average wind speed varies from 3 to 7 meters per second during the year. This means that it is possible to purchase approximately 800 megawatts of wind energy in Azerbaijan per year. Currently, solar power plants are operating in about 70 countries of the world. The efficiency of solar power plants depends on the natural climate and geographical location of the countries. Note that the number of sunny days in Azerbaijan is 260-280 days a year.

The amount of solar energy falling on one square meter of surface in a year is 1500-2000 kWh in the USA, 800-1600 kWh in Russia, 1200-1400 kWh in France, 1800-2000 kWh in China, and 1500-2000 kWh in Azerbaijan. It is 2000 kw/h. As can be seen from here, there are great opportunities for using solar energy in our country. It is also possible to use the energy of thermal waters. Thus, thermal water reserves are large in the Greater and Lesser Caucasus, Absheron Peninsula, Talysh mountain-slope zone, Kura depression and Caspian-Guba region in Azerbaijan.

In the last hundred years, the rapid development of human activity in all areas of the economy and the extreme exploitation of natural resources have had a negative impact on the environment. As in most countries, the Republic of Azerbaijan attaches great importance to solving environmental protection problems and efficient use of natural resources. Therefore, in order to achieve results in the field of environmental health, the "State Program on the use of alternative and renewable energy sources in the Republic of Azerbaijan" was prepared and approved by the order of President Ilham Aliyev on October 21, 2004. On July 16, 2009, in order to speed up the implementation of issues arising from the State Program, the president signed a decree "On the establishment of the State Agency for Alternative and Renewable Energy Sources of the Ministry of Industry and Energy". After the establishment of the agency, a number of works have been started in this field.

The world is looking for new types of energy sources.

The search for new types of alternative energy sources continues around the world. So, NASA intends to use algae and cheap sewage treatment methods to produce fuel.

The space agency is preparing to grow algae for biofuel production in plastic bags filled with sewage floating in the oceans.

Jonathan Trent, lead scientist at NASA's California Research Center, says the research has three goals: to produce biofuels from small amounts of resources in a small area, to help clean up wastewater, and at the same time limit carbon dioxide emissions.

The process is very simple. First, the algae are collected in plastic bags called OMEGA - "coastal membrane covers for algae" - filled with runoff water. It should be noted that such packages were used by astronauts during long-term flights, and in this case, the membranes allow drinking water to escape, while at the same time preventing salt water from entering. After that, the algae grow rapidly due to nutrients from the runoff. The plant cleans water and produces lipids - fat molecules that are then used as fuel.

After that, oxygen and purified water flow through the membrane into the ocean. This does not require energy consumption. The pressure works itself out. Even if cracks form in the OMEGA package, the salty ocean water kills algae and prevents the spread of infectious diseases.

The shelf life of NASA's plastic bags is 3 years. After that, they are turned into plastic mulch or shredded to improve soil quality and retain moisture. Thus, it becomes possible to use such packages in three directions: production of final products - fuel and fertilizer, as well as wastewater treatment and reduction of carbon dioxide emissions.
Trent envisions a process that could cover all of America's airfield cover needs, which he says would require 21 billion gallons (63 million tons) of biomass per year. This means ten million acres - 40.5 thousand square kilometers (slightly less than the territory of Switzerland (41.5 thousand sq/km) or the Netherlands (41.3 thousand sq/km)) ocean area.
It seems huge to a person, but compared to the area of all the oceans, it is very small.
But there are also reasons that hinder the technology. So far, Trent and his colleagues have been searching for a plastic material that can withstand waves and low temperatures. And, of course, it's all about financial security. According to Trent, although there is no investment yet, the California Energy Commission plans to help them with this. The state will start giving the grant in August this year. And this grant should help Trent and his colleagues build the revolutionary system within a year [Valiyev F.: 2010, s.12].

Pros and cons of renewable energy sources.
In addition to all that has been said, it is necessary to mention the positive and negative aspects of renewable energy sources. The positive aspects of these energy sources are that all their types can be widely distributed everywhere and are environmentally friendly. Their operating costs are almost non-existent, because such energy sources are practically free.
The disadvantages of renewable energy sources are that their use covers a wider area and most of their types are time-varying. The first disadvantage forces the installation of power plants in a large area. This means that such devices require a large volume and, as a result, require a large investment. It is true that the high investment is later justified by the low operating costs, but at the initial stage it has a considerable impact on the pockets of those who use it.
More unpleasant cases are related to the change of such energy sources over time. Suppose that if the variation of the swell energy is strictly cyclical, then the solar energy input process, although generally subject to regularity, is to some extent dependent on the weather conditions.
Wind power, on the other hand, is more variable. As for geothermal installations, they guarantee constant energy production.

Conclusion
To sum up, we considered both the essential oil plants, especially the flax plant, and learned the advantages and disadvantages of alternative energy. We came to the conclusion that alternative energy has a role in the process of cultivation and protection of essential oil plants. Approaches and results can be different in the analysis of positive and negative sides in the fast-developing era.

Declarations
The manuscript has not been submitted to any other journal or conference.

Study Limitations
There are no limitations that could affect the results of the study.

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$$f(x) = a_0 + \sum_{n=1}^{\infty} \left(a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right) \quad (1)$$

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Single column	A4 (8.27” X 11.69”)	Top=1” Bottom=1” Left=1” Right=1”	Do not add anything in the header	So not add anything in the footer	
Font	**Article Title**	**Headings**	**Subheadings**	**Reference list**	**Text**
	Times New Roman, 16 pt, Bold, centred	Times New Roman, 11 pt, Bold, Left aligned	Times New Roman, 10 pt, Bold, Left aligned	Times New Roman, 8 pt, Justified	Garamond, 11 pt, Justified
Line Spacing	1.15	1.15	1.15	1.15	1.15
Page number	We will format and assign page numbers				

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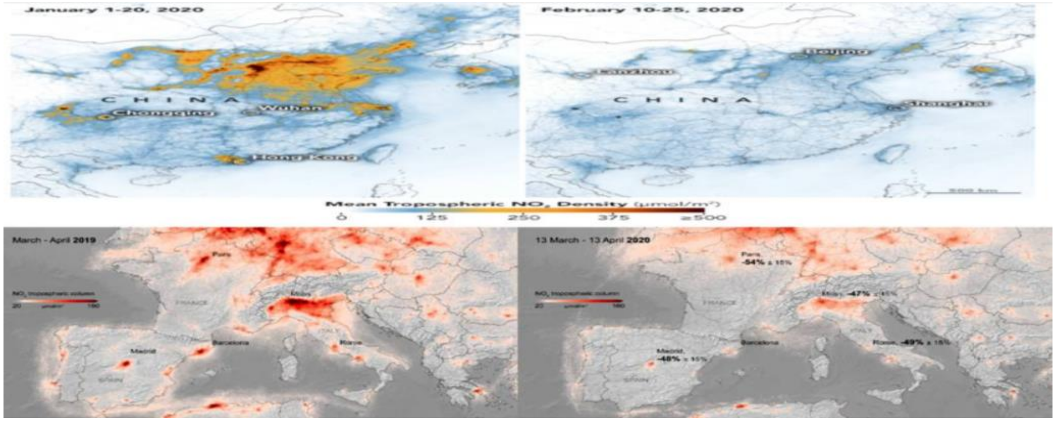

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