White Paper "Transforming the Arctic future with Artificial Intelligence: A Norwegian Perspective"

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Preamble

This white paper is the first in which the members of the Artificial Intelligence and Data science for the Arctic (AIDing Arctic) steering committee present their views on addressing the future of the Arctic with the help of artificial intelligence. This originates from two-day discussion sessions[1] with academia, government, and engaged citizens held during 2021. Herein and below the term 'artificial intelligence' includes machine learning (deep learning, predictive analytics), natural language processing (translation, classification and clustering, information extraction), speech recognition (speech to text, text to speech), expert systems, planning scheduling and optimization robotics, vision (image recognition, machine vision). We invite all Arctic stakeholders including the public in general and any interested party to react to the opinions below and contribute to shaping future research priorities.

Big picture

Artificial intelligence (AI) has many practical and useful applications such as recommender systems in retail, chatbots, IBM chess-playing expert system, map routing, search technology, home controllers, radiology readers, mobile apps with situational awareness with big investments on autonomous driving, financial advisory, drug discovery, scientific knowledge compilation, automations of tedious task in manual operations, planet-scale digital twins to model climate and other complex phenomena[2], and more. The global AI software market is experiencing massive growth, with revenues increasing from around 9.5 billion U.S. dollars in 2018 to an expected 118.6 billion by 2025[3]. We are now witnessing the global update of a digitalization trend which sees a steady move of the use of AI and data science tools in research and engineering fields. This is now starting to be not only in data domains and for narrow problems (e.g., finance, telecommunications, travel booking, gaming) but also in areas that are product intensive (e.g., fisheries, environmental monitoring and modelling). Instead of jobs being replaced, high value jobs are being created e.g., in automation (digitalization). At the same time, human society is in danger from the accelerating decline of the Earth's natural life-support systems, and the Arctic region plays a key role in it. Currently, this region is most affected by the ongoing climate change, the Arctic

[1] The discussions with academia, industry, government, and engaged citizens took place online on 6th May and 29th of September 2021 with financial support from the Research Council of Norway through the grant no. 312173.

[2] https://nvidianews.nvidia.com/news/nvidia-announces-digital-twin-platform-for-scientific-computing [Accessed 25.04.2022]

[3] OpenPR 2020. Artificial intelligence market analysis industry trends. Press Releases from Digits N Markets: 01-15-2020

Amplification[4] – estimated to generate €8 trillion cumulative damages by 2050[5]. Some of the most important environmental issues that can cause a cascade of ecological changes and other impacts in the Arctic system can be itemized as follows:

- Reduction of cryosphere (sea-ice, glaciers, and permafrost) due to climatic change. Glaciers receding, the sea ice cover is getting younger, thinner, and smaller in extent.
- Atlantification (more warm water is penetrating into the Arctic), and the Arctic Ocean is indeed a "mediterranean" water, surrounded by huge terrestrial systems with a lot of rivers. It is a smallest Ocean (only 1 % of the total body of Oceans) and getting almost 10 % off total riverine discharged with human impact (i.e., pollution) through rivers from Asia to North America.
- Permafrost thawing regarding the release of CO2 and more importantly CH4 as well as draining of land-based sediments into the ocean.

Norway is a maritime nation managing ocean areas that are five to six times larger than its terrestrial areas, and has global responsibilities for sustainable development of its ocean space, including the Arctic and taking the natural environment into account. According to the Research Council of Norway (RCN) survey[6] at least 1,000 people in Norway are engaged full-time in polar research across 38 research units. In recent years, the volume of Arctic-related research has increased with a focus on improved scientific understanding of natural phenomena, security, and safety of human operations (ref. e.g., the Center for Sustainable Arctic Marine and Coastal Technology), improved monitoring and forecasting (ref. e.g., the Center for Integrated Remote Sensing and Forecasting for Arctic Operations). At the same time, there are several AI centers and research groups in Norway: Norwegian Artificial Intelligence Research Consortium (NORA), Cluster for Applied AI, Norwegian Open Artificial Intelligence Lab (NAIL), Artificial Intelligence Research Centre (CAIR), just to name a few. Many science- and engineering-oriented applications in the Arctic regions can draw on value created by Arctic data and can benefit from cross-disciplinary expert knowledge. There are extreme challenges unique to the Arctic, from scientific challenges (physical, social, economic) to geopolitics and data sharing. Data collected from the Arctic regions are growing exponentially and we expect this growth will continue in future with more data coming from industry, business, and the public sector. Currently, key challenges driving AI and data science in the Arctic are related to the increased number of highly distributed observations from Arctic and large volumes of heterogeneous data returned by the Arctic observing systems.

AI could be a game changer for the Arctic. There is a strong need to direct AI applications and to attract interest of the AI experts towards solving Arctic challenges as we see them and that are important for the world, and for the socio-economic development of the local communities. Artificial intelligence and data science applications in the Arctic science and engineering domains have received relatively less attention in comparison to the fields of finance, logistics, medicine, advertisement, etc. This trend is seen not only in Norway but also worldwide and may be attributed to the data quality, availability and the expertise that is needed to process these data, national AI and Arctic policies, geopolitics, etc. In contrast to open-source AI algorithms, Arctic data from industry and businesses are not always easily accessible, or limited in coverage to lower latitudes, (an example is satellite-acquired Automatic Identification System data from

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[4] Serreze, M.C., and Roger G. Barry. Processes and impacts of Arctic amplification: A research synthesis. Global and planetary change 77.1-2 (2011): 85-96

[5] Calel, R., Chapman, S.C., Stainforth, D.A., and Watkins, N.W. Temperature variability implies greater economic damages from climate change, Nature Comms. (2020).

[6] Norwegian Polar Research: An Evaluation, The Research Council of Norway (2017).

vessels). Not all Arctic countries are willing to openly share their knowledge and experience, and for the openly shared data, the data quality and understandability is a concern. There are open data that are of poor quality, either though being incomplete or not having sufficient quality control, and(or) are difficult to comprehend. Hence, it is vital that similar experiences, challenges are shared and discussed with the relevant shareholders (e.g., data providers and strategy makers) and future efforts are directed toward improving Arctic data availability, quality, and interoperability in support of AI applications.

In 2021 through the series of AIDing Arctic workshops, we brought together representatives from academia, industry, government, and engaged citizens (approximately 50-100 attendees) to discuss the future of AI and its sustainable development for Arctic applications. This White Paper presents the thoughts on transforming the future of the Arctic with artificial intelligence.

No strategy for AI in the Arctic

Despite there being several international AI strategies and agreements, the Norwegian Artificial Intelligence Strategy document[7] says nothing about the Arctic as a region. Furthermore, the Norwegian Government's Arctic Policy[8] has no mention of artificial intelligence. It is interesting to note that both Norway's National AI Strategy and Arctic Policy mention sustainable development, however neither takes a detailed approach to addressing sustainability in detail to any great extent. One of the important questions is: how could we proceed to make a political strategy for sustainable use of AI and data in the Arctic (when? where? who?). Currently sustainability is completely missing from action. Investments/priorities (e.g., in Arctic shipping, tourism, fishing, resource exploration) are placed to ensure the outcome. Other important questions are: How to ensure responsible development of technology and minimize misuse of AI? How to regulate/steer the technology in the right direction? Regulations lag behind the technology and still have a long way to go. The European Space Agency is a good example of how one can collaborate across different spaces.

Data is an asset not a liability

Today most Arctic data, related to research are stored on a variety of distributed systems. Efforts are ongoing to keep data under control, make them discoverable, and enhancing them to align with the FAIR and CARE principles (SAON, DataOne, SIOS, Polar View, Arctic Data Portal, Geo Cold Regions Initiative, CCADI, ASTD, Arctic PASSION just to name a few) but it is hard for individuals to compete with the AI giants (e.g., Google Deep Mind). The real technical challenge is a lack of interoperability between distributed national and international Arctic data networks due to the custom metadata structures (e.g., for in-situ data), custom vocabularies, lack of machine-readable access, difficulties to understand data translation from vocabularies and semantics, human culture). Polar Data Discovery Enhancement Research (POLDER) has recently launched a pilot where users can search for datasets about Earth's polar regions. In future, more Arctic data (including codes, libraries) will be captured and managed as an asset. Today we are moving from simple structured data (what, when, where, how, who) to complex unstructured data (What is near? How things are related? What is next? What is the uncertainty/confidence level? What is the accuracy? What is the research state of an algorithm, can it be implemented into operation?). There is a need to find a way to quantify data uncertainty (beyond the sensor uncertainty) as well as to capture and manipulate unstructured data in an economic and effective way. AI expect data in certain formats, so the

[7] National Strategy for Artificial Intelligence, the Norwegian Ministry of the Local Government and Modernization (2020)

[8] The Norwegian Government's Arctic Policy, Norwegian Ministries (2021)

challenge will be to make sure it is convenient to understand and leverage the data quickly from Arctic observing networks and the devices working at the edge of these networks. Despite the recent policies[9] and frameworks, in most RCN's research-projects related to Arctic, data is currently still an after-thought and quickly become a mess. In Norway, it is not enough incentives[10] to share the data and methods, and this makes it difficult (if impossible) to reproduce (or verify) research findings and to use the data in AI applications.

Arctic is a small data problem

Data is a necessary enabler of practical AI applications, so it is important to make sure the data is captured and managed as an asset. Except satellite data, the hype (paradigm) "Big data all around us" does not match the Arctic reality. Arctic in-situ data is expensive and is not everywhere and is not on relevant scales (e.g., physical, and biological scale of relevance, undisturbed by noise and light). The Arctic is a system in change. There are many areas we don't know much about. For example, baseline data for biology and chemistry during winter is scarce, not to mention data on communities and food web interactions. In future it will be important to secure access to good data and the data from businesses. The latter will require additional incentives for businesses to share the data for research. Autonomous vehicles can be used to deliver data from under the ice, at night, understand new species that arrive, thus strengthening observation networks. It should also be noted that AI as a technology has own limitations, and more data – may not give us more understanding of scientific problems in contrast to the myth "more data – better learning". Current AI tools can do a lot with "reasonable" amount of data (ref. for example a 'data-centric AI' approach[11]). One doesn't necessarily need MEGA data amounts, also one may have reasonable about of data but only some labels. AI can work in those situations with techniques called semi-supervised learning. Both compositional pattern-producing networks (CPPNs) and spiking neural networks are very interesting and certainly CPPNs give good results in restricted domain. There is hope that some approaches (e.g., evolutionary approaches) can make a comeback. Right now, it is mainly the powerful, not-evolving deep learning systems (without spikes) that are dominant.

Responsible and Fair AI for the Arctic

There is a possibility to explore the Arctic region at the AI forefront. Opportunities for AI and data science in the Arctic include but are not limited to (1) environmental monitoring and mapping, (2) interoperable data infrastructures in support of AI applications, (3) autonomous vehicles, (4) application of AI and data science in Arctic remote sensing, (4) smart sensors in harsh environments, to support arctic operations, (5) in-situ data analysis, (6) task automation, (7) use of ML to support data mining, pattern recognition in Arctic settings, and data-driven modelling, (8) augmented reality - (AR) and virtual reality (VR) technologies for human-AI collaborative discoveries.

The most advanced community when it comes to AI applications is a remote sensing group. Currently, remote sensing is a key to understand what is happening to the earth. Although AI is applied to sea ice applications, remote sensing of that medium still has the challenges of sensor characteristics and limitations to overcome.

[9] The Research Council Policy for Open Science, in effect from 2020.
[10] Rewards that are given to researchers and/or organizations if they participate in sharing their raw data, including codes (e.g., government funding based on Open Science Badges).
[11] https://arxiv.org/pdf/2110.03613.pdf

No-one can predict the future of computer science. However, some think an AI winter[12] is coming. Deep learning is amazing so perhaps it will stay, improve, and will combine with other fields. Currently there a gap between AI (statistical mechanics) and how the humans think. In future, we may see more neural networks run side by side along physical and logic systems with importance given to explainability and transparency. We will witness more applications of AI for the environment (e.g., AI applications that contribute to biological diversity and can help avoid further biotic crisis), AI surveillance. At the same time, we should remember that most digital infrastructures are not running on renewables, and AI is an energy sink. It consumes a lot of energy when is e.g., used to mine data. In one possible future scenario we might see more energy-efficient computations, own AI chips, and less people to be depended on the cloud computing to make the work done moving toward computing on edge devices (e.g., processing information on the satellite level). We will be looking at intertwined research dependencies in the use of AI as a part of larger ecological systems.

Increasing role of digital literacy and ethics

It takes a lot of time to manually analyze Arctic data (including metadata). As more data will be collected in future it will be important to train scientists to use AI for time-consuming trivial tasks. For example, researchers could use more images/videos from the field operations and have AI helping in processing the images. It is important to distinguish between tasks that are easy for us but hard for computers and vise versa (e.g., object recognition, speech recognition, high-dimensional regression). Humans e.g., are better in understanding other humans. Strength of AI is to help us to find hidden observation patterns. Quality of AI has improved since 90s including robotics. A lot of tools that are used today are from 1980s and it is important to find ways of teaching young generation/communities to develop resources to help with data as well as to use AI tools in a responsible way while understanding AI limitations. Ethical responsibility both ways. Citizens are also responsible for AI development, not only the scientists.

Collaboration is the key

Arctic science is borderless, but there are country borders. There is need to broader aligning the efforts (around the world) on principles of data reporting and sharing (shared vocabularies, protocols, best practices, also for codes) and miniating continuity and scalability in view of generation gap, cultural differences (e.g., strong self-determination of indigenous people). This also includes non-arctic countries aligning resources to make data available.

Issue of disciplinarities

Interdisciplinary work is not sufficiently developed for AI in Norway (we still need to pick sides: social science vs natural science vs engineering). This can also be traced throughout research portfolios and the way research results are registered in the Current Research Information System in Norway. More efforts should be placed on bridging the gap between science and applications, between problem solvers and problem owners. Citizen science initiatives[13] and AI techniques are often used in isolation, the Arctic is not an exception. There is a recognized need for greater recognition of the benefits offered by combining

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[12] a period of reduced interest and funding in the field of AI
[13] https://polarcollective.org/

citizen science and AI[14].In this view, interdisciplinary facilitators[15] and (or) knowledge brokers could play a key role in improving inter/trans-disciplinarity and cross-sectoral work/collaborations in the Arctic.

Disciplinarities (intra-, cross-, multi-, inter-, trans-) should be much developing in the future (e.g., social climate-variables), domain experts, working side by side data scientists and technology providers. An issue such as links between citizens – government – user has to be tackled. Not all the ministries are fully aware of the potential of the remote sensing data. Remote sensing community has achieved a lot of progress in using AI, and now it's time to include people from other disciplines. There is a need for politicians who are interested in technology (AI) and engaging. One standing challenge is complex methodologies (e.g., deep learning) and their communication between science, policy, and citizens in view of the geographical differences (Arctic community in Norway vs other places).

Summary remarks

The Arctic region is a great place to start a concerted shared effort towards thinking about sustainability and AI, especially considering disastrous consequences of climate change that can be seen unfolding around the world. We have looked at AI as an Arctic technology (a tool) while mainly focusing on remote sensing and briefly considering other domains. Currently, what drives AI and data science in the Arctic are the increased number of highly distributed observations and large volumes of heterogeneous data returned by the Arctic observing systems. It's time to push the AI technology (explore it) but try to escort it to our needs, and if not, to reverse what should happen.

While there are numerous benefits offered by exploring AI and data science applications in the Arctic, complexities do exist and can be summarized as follows:

- There is a need for even better alignment between national AI and Arctic strategies and policies.
- There are seemingly little (if at all) tested[16] incentives (for Arctic researchers and(or) organizations) that promote scientific data sharing (methods and codes included).
- There is a need to secure access to good data and the data from businesses (when possible) as well as to align the efforts (around the world) on principles of data reporting and sharing.
- There is a great need to attract interest of the AI elite towards solving Arctic challenges.
- There is a need for a dedicated communication channel(s) (e.g., on Discord, Slack) for the AI and Data Science for the Arctic community.
- An even greater efforts should be placed on training the next generation thinkers while focusing on digital literacy, T-shaped skills[17], ethical use of AI, etc.

Note AI is not going to solve all problems in the Arctic and change the world, neither AI is to replace humans by robots but rather is taking robots out of humans. We invite all Arctic stakeholders including public in general and any interested party to react to the opinions presented and contribute to shaping future research priorities.

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[14] McClure E.C., Sievers M., Brown C.J., Buelow C.A., Ditria E.M., Hayes M.A., Pearson R.M., Tulloch V.J.D., Unsworth R.K.F, Connolly R.M. Artificial Intelligence Meets Citizen Science to Supercharge Ecological Monitoring. Patterns, (2020).
[15] individuals with depth knowledge in overlapping several fields (e.g., glaciology and applied AI)
[16] Documented effectiveness for increasing Arctic data sharing and data re-using rates
[17] https://en.wikipedia.org/wiki/T-shaped_skills

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