NAOCared: Intelligent and Communally Humanoid assistive robot for elderly care support

Ahmad Hoirul Basori[1*]
abasori@kau.edu.sa
[1]Faculty of Computing and Information Technology Rabigh, King Abdulaziz University, Jeddah, Saudi Arabia

Summary
The study of humanoid robot or bipedal robot has risen significantly over the past years. The robot has become more matured in term of appearance and behaviour. Various sophisticated sensors such as sonar, vision, tactile and gyroscope are helping robot to walk and behave like a human. Conversely, a growing number of elderly steer new problem in healthcare, primarily how society can provide their daily living needs. This research introduces an innovative solution by providing a humanoid assistive robot that can respond toward the voice and gesture command. Elderly might use the robot as assistant or support for medication, feeding or even cleansing activity in their daily life. The implementation was carried out by demonstrating robot named as NAOcared walked toward the subject to grasp an object. While other case has shown the robot respond toward the command to find and hold an object. The simulation was carried out through several tests and find out some angle divergence during the walking test. However, based on the logistic regression approach, the NaoCared likely will be succeeded in completing the task with a percentage of nearby 87%. A lot of improvement can be carried out for future research especially on complex task and route to asses total functionality of the robot.
Key words:
Humanoid robot, elderly Care, Walking trajectory

1. Introduction

The statistic in the United Kingdom has mentioned that elderly with age more than 65 years will experience half of their future life with a bodily and psychological wellbeing problem[1]. Therefore, the demand for supporting elderly for maintaining their daily activities indeed growth significantly over the past years. Around 15 years from now (2035), the requests of elderly support care are predicted will probably reach almost third[2]. This situation will become a great challenge for humanity to provide excellent facilities for taking care of them. World Health Organization(WHO) also highlight the issue of elderly care support that might become an enormous challenge in future society[3]. The recent study that released from English Longitudinal Study of Ageing (ELSA) found that 50% of elderly which experiencing difficulty of their Activity of Daily Living(ADL). They didn't receive any support, either formal or informal, to assist their condition[4]. The challenge of a robot for supporting daily care of the elderly such as feeding, bathing or even perform medication still debatable. Whether they are used as a supplement or replace the professional care giver[[5-8]. This research study is divided into several segments. Segments 1 focused on investigating elderly difficulty to perform their ADL and how the robot can support them. Afterwards, section 2, discuss the previous work of robot as assistive daily life support, then followed segments 3, which is a research method. Part 4 presents the result of research, and lastly, section 5 does the conclusion of the overall investigation..

2. Related Works

Previous research stated that population for the elderly might reach doubled in 2050 that will steer the cause of high demand for elderly support and care[9]. The need for first-class support care will rise significantly. It argued that Social assistive robot might become a key solution in fulfilling the high demand for elderly care support. Robotics technology has been expected widely to preserve and improvise the quality of elderly care over the world[10, 11]. The home care support is essential, including serving their daily activities such as serving food, medication, etc. The other researcher focused on providing the robot for helping elderly bathing activity, as shown in Fig.1[12].

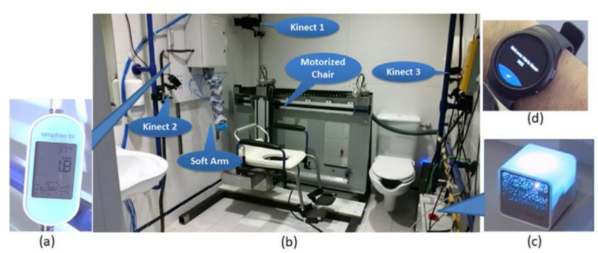

Fig. 1 The setup of I-support system for elderly bathing, a) water and temperature sensor, b) chair with motor, kinect camera and robotic arm, c) air temperature and humidity sensor,d) smartwatch. Image courtesy of Zlatinsi, et al.[12]

Fig.1 shows the complex setup of i-support that focused mainly on handling elderly bathing process, and it can adjust the water temperature, humidity and even the scrubbing procedure. The improvised version of bathing support system is presented by Werner, C. et al. by focusing

Manuscript received April 5, 2020
Manuscript revised April 20, 2020

the gesture interaction as the central controller for bathing equipment as shown in Fig.2.

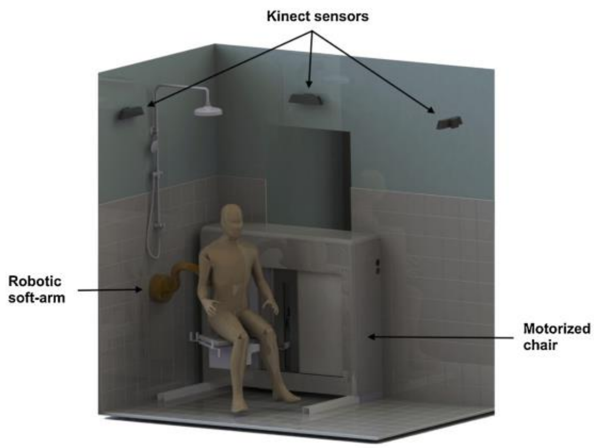

Fig. 2 I-support improvisation system rendering with gesture interaction, Image courtesy of Werner, C. et al.[13]

Some elderly need even more attention due to the lack of social life communication with others. Elderly need companions for sharing their burden with simple chitchat[14-16]. Therefore, the researcher developed a therapeutic robot pet known as SNOWY (refer to Fig.3) that able to provide social interaction with human[16].

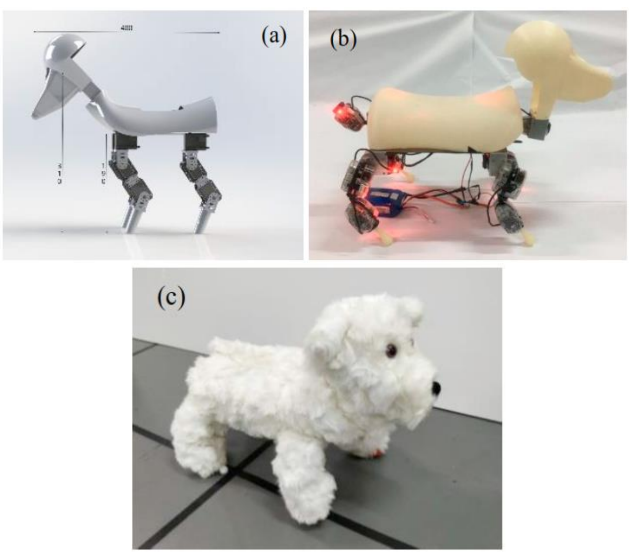

Fig. 3 SNOWY Pet robot Design. a)CAD design of SNOWY,b)Meachanical structure of robot and SNOWY in fur cover. Image courtesy of J.K Sheba, et al.[16]

The snowy robot uses an inverse kinematic model for its leg movement which is shown in Fig.4.

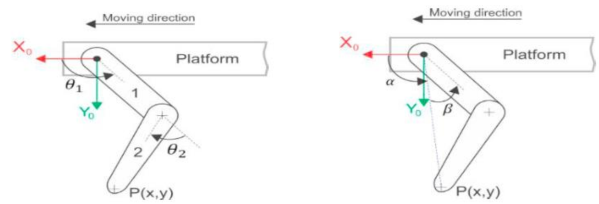

Fig. 4 Snowy robot leg movement, Image courtesy of J.K Sheba, et al.[16]

The geometric method for controller computation model of robotic leg by cosine theorem is depicted in equation 1 [16].

$$P_x^2 + P_y^2 = l_1^2 + l_2^2 - c\cos(\pi - \theta_2)\ldots\ldots\ldots\ldots\ldots(1)$$

Where, Px and Py are the end point of P; l1 value(link1):45mm while l2=85mm. The angle of joint rotation of joint 2 is represented by θ2. While the walking model of the humanoid robot also introduced by another researcher [17-20], by considering bipedal robot type.
The assistive robotic for social interaction with multi-party setting also introduced by Quan, W. et al. (2011). They focused on developing robot based on the archetypal Japanese day-care system[21].

Fig.5 Experimental setup of non verbal behaviour with robot, Image courtesy of Quan W. et al[21]

They train their robot to analyze the daily activities of human and correspond to their feedback during social interaction. The non-verbal behaviour, including eye contact, is being tested to the participant. When eye contact has been made, then subject need to raise their hand[21], refer to Fig 4 for their experimental setup.
Besides, to increase the social interaction of human, researcher also provides sport assistance toward for them. Coaching or tutoring human toward exercise for home sport might bring the potential for keeping the fitness of human in the future[22]. Additionally, the robot can be used as

walking provision inside the house, or even taking care of garbage inside house[23]. Fig.5 shows the robot helping elderly walking inside their home by giving walking provision[23].

Fig. 6 In building walking provision

3. Research Method and Material

The main contribution of our paper is the improvement of the robotic assistance functionality by marker recognition and walking trajectory precision, as illustrated in Fig.6.
The process commenced with data gaining, that come from eye-tracking using Nao camera and voice receptor sensor. Our system using voice command and gesture tracking. The marker tracking is part of finding the destination of the robot where they will pick up and deliver the items to the elderly. Finally, object grasping focus on how NAO measure the object size and grasp it gently.

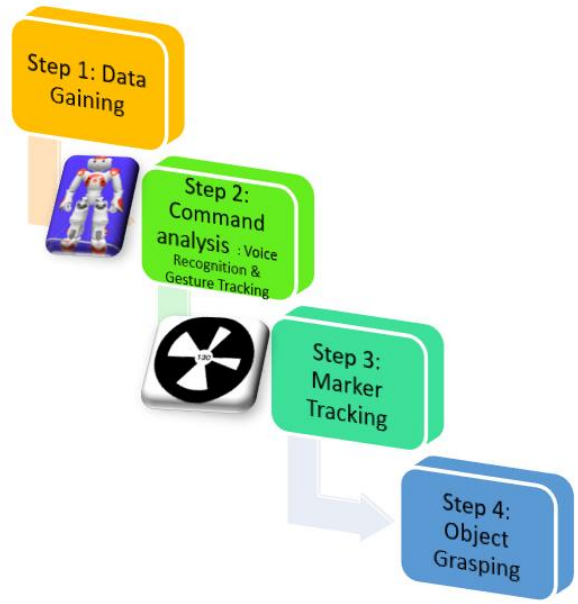

Fig. 7 Research Methodology for NAOCared

The full functionality of the proposed system is illustrated in use case diagram depicted in Fig.7.

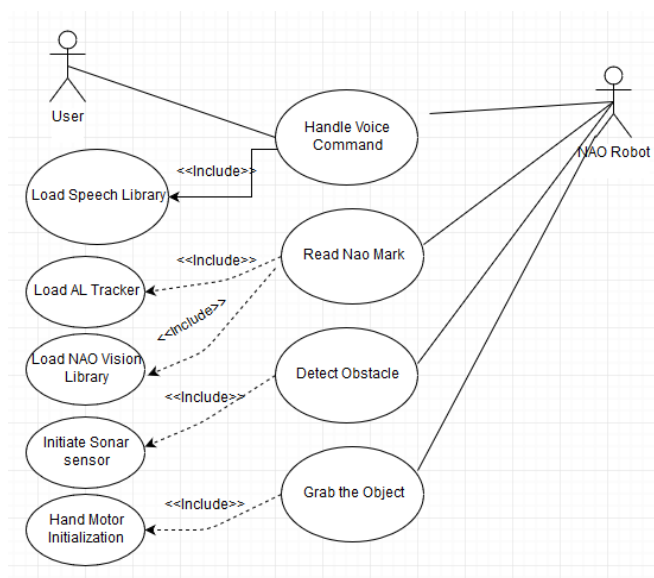

Fig. 8 Use case diagram of NAOCared

The use case diagram in Fig.7 illustrates the whole process of NAOCared system. User will use voice command and robot will respond to the instruction.
The robot will read Nao Mark as the landmark of destination. During the journey, robot will detect obstacle mainly using two sensors: Sonar sensor for long-range,

while closed range object using a tactile sensor on their feet. Once the object within range, the robot will grab the object by initiating command to hand motor. The algorithm of the robotic assistance is depicted in Fig.8.

```
Algorithm
Initiate Robot
ALNavigation
ALProxy ("MEMORY")
ALProxy (TRACKER)
Set TARGET ("LANDMARK")
Recall AL
while target not reached do
Navigate;
Tracking
end
stop Tracking;
Grasp Object
```

Fig. 9 Algorithm for target tracking

The architecture diagram in Fig.9 of NaoCared involved several libraries such as object recognition library: NAOVision & AL Tracker. Nao Driver handle the communication between Nao robot and computer through a wireless connection, while Nao SDK focused on providing the library for programming to control the robot, all this library is bundled in one package software called as choregraphe.

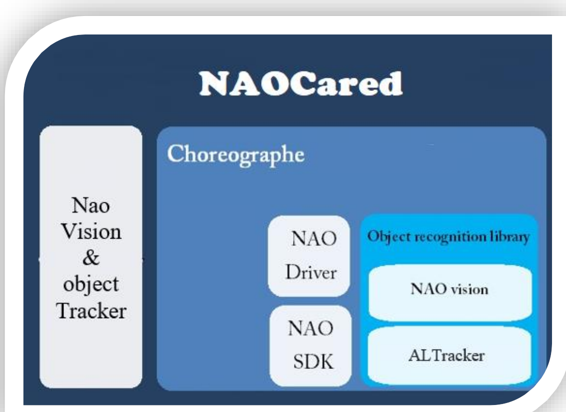

Fig. 10 NaoCared Architecture Diagram

4. Result and Discussion

Choreghaphe software is an SDK that supports visual/block programming. It consists of several built-in functions that can be used to control the robot. Fig.10 show some of Choreghaphe standard function.

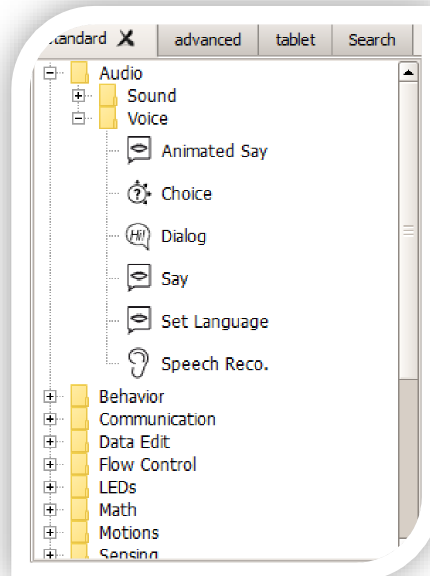

Fig. 11 NaoCared Architecture Diagram

Each block has its specific function, for example, the voice, "**Animated say**" capable of producing a welcoming voice message "Hello". The detail inside this block programming is shown in Fig.11.

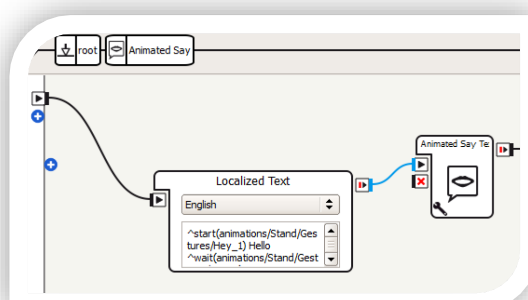

Fig. 12 Welcoming message "hello" with animated say function

We can display the result of this block programming toward the real robot of NAO, or through virtual robot inside choregraphe software. Fig.12 shows the robot expression when it's programmed to say "**hello**".

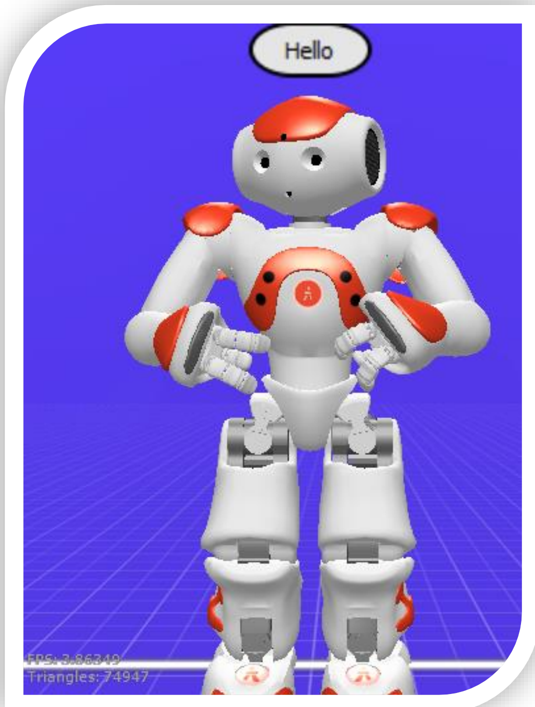

Fig. 13 Welcoming Message of **"Virtual robot"**

The block of welcoming message is supported by built-in phyton programming that controlling the behaviour of the blocks as depicted in Fig.13.

```
import time

class MyClass(GeneratedClass):
    def __init__(self):
        GeneratedClass.__init__(self, False)
        self.animSpeech = ALProxy('ALAnimatedSpeech')

    def onLoad(self):
        self.bIsRunning = False
        self.ids = []

    def onUnload(self):
        for id in self.ids:
            try:
                self.animSpeech.stop(id)
            except:
                pass
```

Fig. 14 Phyton code fragment for welcoming message.

The walking balancing of the robot is based on Zero Moment Point (ZMP) that introduce by Vukobratovic, M and Borovac, B. This method shown in Fig.14.

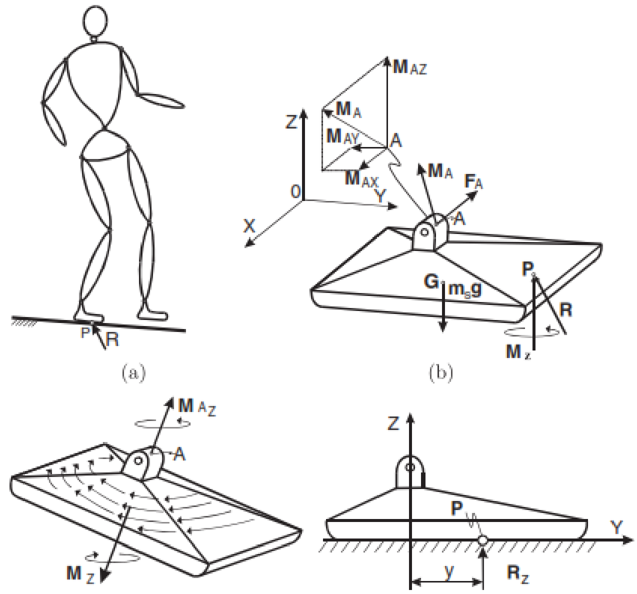

Fig. 15 Humanoid machinery of bipedal walking robot, image courtesy of Vukobratovic, M.[24]

The equation for the bipedal robot to calculate force R is depicted in Equation 2 and 3[24].

$$R + F_A + m_s g = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\overrightarrow{OP} \, x \, \overrightarrow{R} + \overrightarrow{OG} \, x \, m_s g + M_A + M_z + \overrightarrow{OA} \, x \, F_A = 0 \ldots\ldots\ldots (3)$$

There two main scenarios of robotic assistance, first, the robot need to approach user and take an object, during the second scenario robot obliges to find target and bring to user..

❖ First Scenario

The robot will receive a voice command from a person asking to approach him/her to take an object. Afterwards, the robot will walk toward the user. We use a predefined location where robot walks in a straight path and stop in front of the target, as shown in Fig.15.

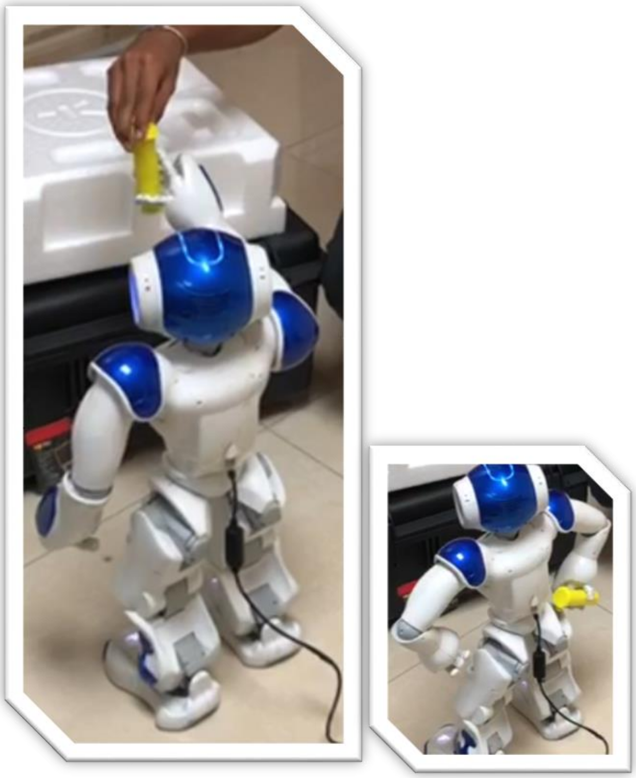

Fig. 16 NaoCared reach destination and grasp the object

❖ Second Scenario

The second scenario, NaoCared, must track the destination based the nao mark. Each nao mark, represent a unique id that represented by a number and symbol black and white as depicted in Fig.16.

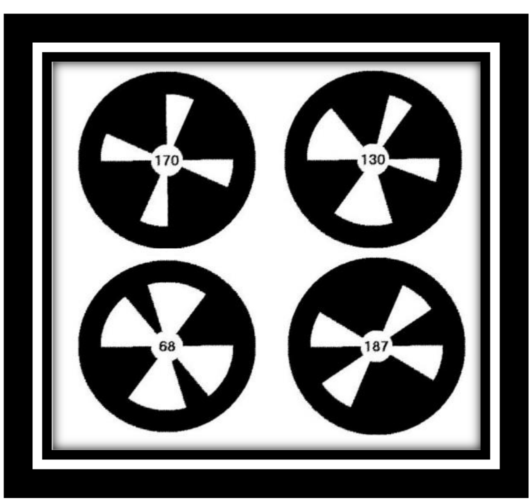

Fig. 17 Nao Mark Model from Aldebaran[25]

When the 2nd scenario started, Nao will keep wandering and searching for the nao mark as their destination. The Nao mark can be placed in different location to produce maze pattern so Nao robot can keep searching from marker to marker.

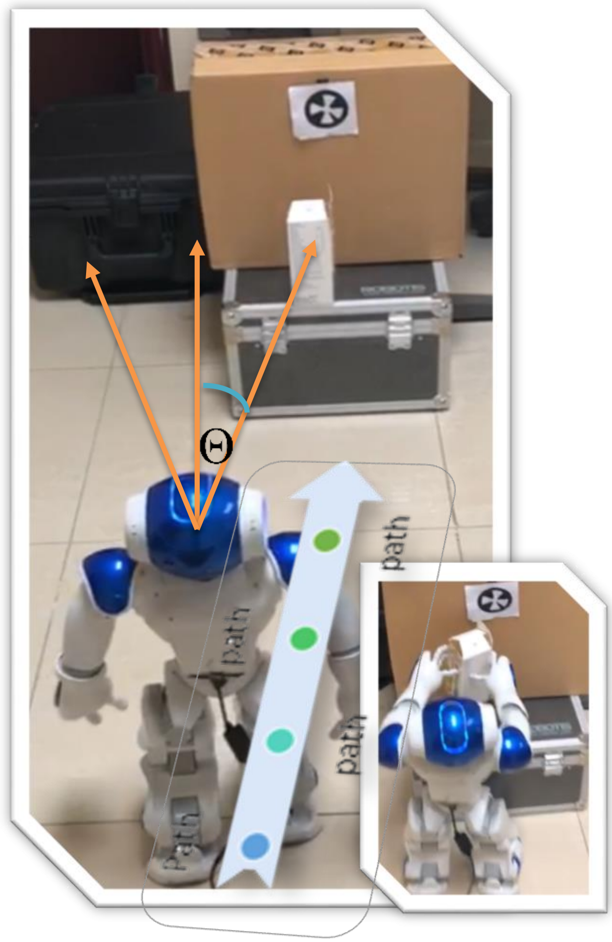

Fig. 18 NaoCared approaching target and grasp the object

Fig.17 demonstrates the NaoCared tried to find its target. The robot has plenty of distance and walks toward the marker. We dit put another tag to distract Nao robot. However, Nao keeps walk confidently then reach the target and grasp the object.

We did several simulation tests for the robot approaching the target and grasping the object, successful test and failure test also compared each other. The successful test means robot able to reach and grab the object, while failure means robot deviates from the intended path and walk toward a different route. The standard deviation of both cases imprint in Fig.18.

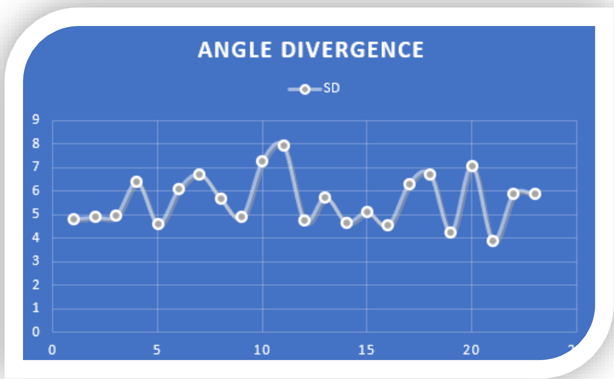

Fig. 19 Angle divergence for success and failure case

Further evaluation was carried out with logistic regression to determine both cases and based on our dataset, the accuracy of prediction around 87%, refer to Fig.19.

Evaluation Results

Model	AUC	CA	F1	Precision	Recall
Logistic Regression	0.962	0.870	0.870	0.874	0.870

Fig. 20 Logistic regression result

A further evaluation carried out by plotting the density of success case, is shown in Fig.20, between periods 10-12, it reaches the highest value for angle deviation while the smaller angle deviation reached between period 12-14.

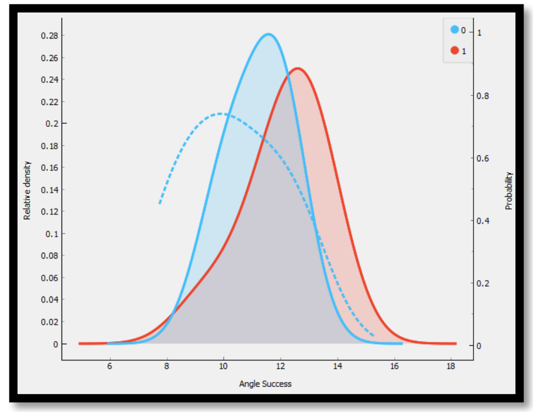

Fig. 21 Relative density of the success case

5 Conclusion

Robotic assistive for elderly become a vital demand in the future along with the growth of elderly number. Providing professional yet regularly service for elderly such as nursing, cleaning, or medication indeed become significant encounter for society. Many robot assistive care has been introduced. However, the accuracy of completing the given task remains a challenge for the robot. It involves the precision of sensor, tracking method and even the approach for training the robot. This study is presenting a humanoid model of assistive robot that might be used for elderly support. The combination of voice command, gesture and object tracking proven that robot able to accomplish a specified mission. Even though there is divergence on the angle during walking simulation, cause by kinematic of the biped robot. The logistic regression approach has demonstrated that 87% of NaoCared likely success in delivering the task. Future work can be focused on the more complex delivery task and route to perceive the full functionality of a humanoid robot.

Acknowledgements

This work was supported by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah Saudi Arabia. The authors, therefore, gratefully acknowledge the DSR technical and financial support.

References

[1] O. f. N. Statistic. (2017, 17 January 2020). Health state life expectancies, UK: 2014 to 2016, London.[https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/healthstatelifeexpectanciesuk/2014to2016]Last Accessed: 17 January 2020.

[2] Kingston, A. Comas-Herrera, and C. Jagger, "Forecasting the care needs of the older population in England over the next

20 years: estimates from the Population Ageing and Care Simulation (PACSim) modelling study," The Lancet Public Health, vol. 3, no. 9, pp. e447-e455, 2018.
[3] S. Abdi, A. Spann, J. Borilovic, L. de Witte, and M. Hawley, "Understanding the care and support needs of older people: a scoping review and categorisation using the WHO international classification of functioning, disability and health framework (ICF)," BMC Geriatrics, vol. 19, no. 1, p. 195, 2019/07/22 2019.
[4] A. Vlachantoni, "Unmet need for social care among older people," Ageing and Society, vol. 39, no. 4, pp. 657-684, 2019.
[5] P. Lehoux and D. Grimard, "When robots care: Public deliberations on how technology and humans may support independent living for older adults," Social Science & Medicine, vol. 211, pp. 330-337, 2018/08/01/ 2018.
[6] M. Shishehgar, D. Kerr, and J. Blake, "The effectiveness of various robotic technologies in assisting older adults," Health Informatics Journal, vol. 25, no. 3, pp. 892-918, 2019/09/01 2017.
[7] R. H. Wang, A. Sudhama, M. Begum, R. Huq, and A. Mihailidis, "Robots to assist daily activities: views of older adults with Alzheimer's disease and their caregivers," International Psychogeriatrics, vol. 29, no. 1, pp. 67-79, 2017.
[8] S. T. M. Peek, S. Aarts, and E. J. M. Wouters, "Can Smart Home Technology Deliver on the Promise of Independent Living?," in Handbook of Smart Homes, Health Care and Well-Being, J. van Hoof, G. Demiris, and E. J. M. Wouters, Eds. Cham: Springer International Publishing, 2021, pp. 1-10.
[9] J. Abdi, A. Al-Hindawi, T. Ng, and M. P. Vizcaychipi, "Scoping review on the use of socially assistive robot technology in elderly care," BMJ Open, vol. 8, no. 2, p. e018815, 2018.
[10] R. Bemelmans, G. J. Gelderblom, P. Jonker, and L. de Witte, "Socially Assistive Robots in Elderly Care: A Systematic Review into Effects and Effectiveness," Journal of the American Medical Directors Association, vol. 13, no. 2, pp. 114-120.e1, 2012/02/01/ 2012.
[11] S. T. Dahl and N. K. M. Boulos, "Robots in Health and Social Care: A Complementary Technology to Home Care and Telehealthcare?," Robotics, vol. 3, no. 1, 2014.
[12] A. Zlatintsi et al., "I-Support: A robotic platform of an assistive bathing robot for the elderly population," Robotics and Autonomous Systems, vol. 126, p. 103451, 2020/04/01/ 2020.
[13] C. Werner et al., "Improving gesture-based interaction between an assistive bathing robot and older adults via user training on the gestural commands," Archives of Gerontology and Geriatrics, vol. 87, p. 103996, 2020/03/01/ 2020.
[14] H. M. Do, M. Pham, W. Sheng, D. Yang, and M. Liu, "RiSH: A robot-integrated smart home for elderly care," Robotics and Autonomous Systems, vol. 101, pp. 74-92, 2018/03/01/ 2018.
[15] N. Ezer, A. D. Fisk, and W. A. Rogers, "Attitudinal and Intentional Acceptance of Domestic Robots by Younger and Older Adults," (in eng), Univers Acces, vol. 5615, pp. 39-48, 2009.
[16] J. K. Sheba, L. T. Phuc, A. A. Salman, S. Kumar, M. R. Elara, and E. Martínez-García, "Development of Rehabilitative Multimodal Interactive Pet Robot for Elderly Residents," Procedia Computer Science, vol. 133, pp. 401-408, 2018/01/01/ 2018.
[17] A. H. Basori, "Emotion Walking for Humanoid Avatars Using Brain Signals," International Journal of Advanced Robotic Systems, vol. 10, no. 1, p. 29, 2013/01/01 2013.
[18] S. A. Mohamed, M. I. Awad, and S. A. Maged, "Online Gait Generation For NAO Humanoid Robot Using Model Predictive Control," in 2020 International Conference on Innovative Trends in Communication and Computer Engineering (ITCE), 2020, pp. 205-209.
[19] W. S. Ki, B. K. Shim, W. J. Hwang, E. U. Kang, W. S. Lee, and S. H. Han, "A Stable Walking Control of Two – Legs Biped Robot," in Intelligent Robotics and Applications, Berlin, Heidelberg, 2013: Springer Berlin Heidelberg, pp. 265-273.
[20] J. Solis, "Development of a human-friendly walking assisting robot vehicle designed to provide physical support to the elderly," IFAC-PapersOnLine, vol. 49, no. 21, pp. 656-661, 2016/01/01/ 2016.
[21] W. Quan, H. Niwa, N. Ishikawa, Y. Kobayashi, and Y. Kuno, "Assisted-care robot based on sociological interaction analysis," Computers in Human Behavior, vol. 27, no. 5, pp. 1527-1534, 2011/09/01/ 2011.
[22] S. Schneider, M. Goerlich, and F. Kummert, "A framework for designing socially assistive robot interactions," Cognitive Systems Research, vol. 43, pp. 301-312, 2017/06/01/ 2017.
[23] N. Hendrich, H. Bistry, and J. Zhang, "Architecture and Software Design for a Service Robot in an Elderly-Care Scenario," Engineering, vol. 1, no. 1, pp. 027-035, 2015/03/01/ 2015.
[24] M. Vukobratovic and B. Borovac, "Zero-Moment Point—Thirty Five Years of Its Life," International Journal of Humanoid Robotics, vol. 1, no. 1, pp. 157-173, 2004.
[25] Aldebaran. (2020, 3 January 2020). ALLandMarkDetection, http://doc.aldebaran.com/2-1/naoqi/vision/allandmarkdetection.html, Last Accessed: January 2020 [Online]. Available: http://doc.aldebaran.com/21/naoqi/vision/allandmarkdetection.html.

Ahmad Hoirul Basori, received B.Sc(Software Engineering) degree from Institut Teknologi Sepuluh Nopember Surabaya in 2004 and the Ph.D (Computer Graphics) from Universiti Teknologi Malaysia, Johor Bahru, Johor, in 2011. In 2011, he has appointed as Assistant Professor with the Department of Computer Graphics and Multimedia, Universiti Teknologi Malaysia. In 2016, he is promoted to Associate Professor rank in Faculty of Computing and Information Technology Rabigh, King Abdulaziz University. He is the member of Editorial board of some international journal, and published more than 80 articles. He is also a member of professional membership IEEE, ACM SIGGRAPH, IAENG and Senior Member of IACSIT. His research interests include Computer Graphics, Facial Animation, Cloth Simulation, Medical Visualization, Haptic Interaction, Man Machine Interaction and Robotics.