A Multimodal Robotic Communication System for Students with Profound and Multiple Disabilities

Elmunir M. Elgajiji
Faculty of Information Technology
Misurata University
Misurata, Libya
eelgajiji@misuratau.edu.ly

Abstract - **Different researches claim that using a robot to play with students with profound and multiple disabilities might be a valuable tool to increase the learning curve of those students. Robots in schools and in other educational environments is a growing research field and it seems that it is time for technology to transform the education with people of special needs similarly to how technology affected mainstream education. The project focuses on using different switches plugged in a joybox to send signals to NAO Robot. Each switch caries a certain behavior. JoyBox contains eight numbered connectors and four direction connectors to move the robot. The paper implements client server communication to connect to the robot and be able to send signals to the robot via the switches connected to the JoyBox. Using the switch enables the users to communicate to NAO independently. This gauntness a deep level of engagement with the robot, since the robot moves based on the singles received from the switches. The paper describes the setup of the client server communication, and the robot knows which behaviour to implement next. This study implements a case study evaluated by only four researchers and staff from Oakfield school to evaluate the software .This study hopes to be able to assess the needs of school staff to improve communicational methods for students with profound and multiple disabilities.**

Index Terms - **Young Students, Learning disabilities, Human-Robot Interaction, Robotics, Profound and multiple learning disabilities.**

I. INTRODUCTION

Human-Robot Interaction is an emerging scientific field which comprises many technological, educational and health applications. Robots can mimic human's actions and behaviors, to work together or separately with humans in dealing with tasks and give satisfactory outputs. Robotics with advanced computer programming, can have the ability to "provide feedback, process information and give instructions to students with sophisticated and multiple disabilities to coordinate their attention to basics school tasks" [1]. Robotics can provide repeatable, accurate and customized involvement services to young students with learning disabilities. The robot does not get tired of repeating same information multiple times, and allows students to make as many mistakes as they like. Also, some real world tasks can be customized within which the task could be performed, so the students become more familiar with the tasks and then apply it in real world.

Human-Robot Interaction is not considered a threat to young students, but can increase the learning engagement of students with learning difficulties. However, the field of Human-Robot Interaction (HRI) is still at its very first stages, and more researchers from computer science, robotics, psychology, social sciences, and other fields need to collaborate to provide research on how robotics can improve learning and engagement for young students with learning disabilities.

The aim of this project is to develop a multimodal dialogue between the Humanoid-Robot Nao H25, (pronounced now), and young students with profound and multiple learning disabilities (PMLD). NAO is 58 centimeters high and weighs of 4.3kg and has many sensors and actuators, which makes it appealing to the young students to interact with and learn from it [2].

Usually, students with profound and multiple learning disabilities have complex health needs such as "great difficulty in communicating, learning disability, physical disabilities, and mental health difficulties" [2]. The combination of these needs demands a special and high level of support in providing adequate education.

"In the UK around 25 people in every thousand have mild or moderate intellectual disabilities and about four or five per thousand have severe intellectual disabilities [3]. These disabilities are often combined with additional impairments (e.g., mobility or fine motor control and additional sensory impairments) and help will often be needed with almost every aspect of daily living [4]. People with intellectual disabilities often face a lack of control and opportunity in their everyday lives [10], with less than 10% having jobs and few living in their own homes or having real choice over who cares for them [3].

Received 25 January 2015; revised 10 February 2015; accepted 24 March 2015.
Available online 29 March 2015.

It is however, the intention of current policy [3] to enable people with intellectual disability and additional impairments to have as much choice and control as possible over their lives, be involved in their communities and to make a valued contribution to the world at work. Several major reviews have recognized that this can only be achieved via appropriately designed educational courses that equip them for independent living, and that also develop communicational skills [5]".

II. Background

Students with profound and multiple learning disabilities (PMLD), if provided with the right environment, will be able to continue to enhance their learning skills. However, we need to take into consideration that learning for students with (PMLD) is likely to take a longer time and the speed of learning is slower for the majority of the students. "Children with intellectual disabilities are often denied real world experiences, which for the non-disabled child provide the opportunity to acquire skills that will later allow them to become independent of their parents. As adults, acquiring or maintaining these skills through practice is difficult for the same set of reasons."[6]. Also, "As a group, they are considered to be poor at generalizing skills learnt in one setting to another." [7].

Supporting the learning needs of students with profound and multiple learning disabilities (PMLD) requires also a focus on developing their communicational skills [5]. Most PMLD students use "facial expressions, body language and simple symbols to communicate with others" [8,9,2]. Each student is different and this is especially the case for PMLD students forming a heterogeneous population, and any system designed to promote communication must strive to understand the "context in which the communication takes place".

The NAO Humanoid robot can promote the engagement of PMLD students in learning activities [2] and "Engagement is the single best predictor of successful learning for children with learning disabilities"[10] "Without engagement, there is no deep learning" [11], "effective teaching, meaningful outcome, real attainment or quality progress "[12]. Since students are not afraid of getting engaged with the robot [9], it can be used as a facility of engagement in education learning to communicate with students in the class.

To have successful multimodal human-robot communication, interaction between the students and the robot should be conducted in a natural manner. The robot needs to know the location of the students; the robot uses a set of web-cameras and sensors for "perception", and a microphone for "voice command". The methods for interaction between the students and the robot is via verbal dialog and visual communications. Through perception, the robot recognizes people and reacts to voice commands, and uses expressive gestures to communicate. Some of the tasks that can playing with a Red ball with the students and the use of its voice recognition system to respond back to the student. This combination of different modalities of communication provides an effective two-way dialogue between a human and the robot [9,1]

III. Aims and Objectives

To research, develop and evaluate a prototype multi-modal robotic communication system for students with profound and multiple disabilities. The objectives of this are:

1. To assess the needs of school staff to improve communicational methods for Students with (PMLD).
2. To investigate whether the NAO robot can potentially be used as a communicational learning tool, especially regarding its voice and object recognition system.
3. To map the development of the multimodal communicational system onto the 'Engagement Profile and Scale for students with Complex Learning Difficulties' to "prompt student-centred reflection on how to increase the learner's engagement leading to deep learning" (http://complexld.ssatrust.org.uk/project-resources/engagement-profile-scale.html) in a communicational context.
4. To evaluate the project and present the prototype in a precise and logical manner, in ecologically valid environments

Some further requirements of a multimodal robotic communication system may include (but not limited to the following):

1. Students need be able to interact with NAO in the ways they naturally communicate in the real world with their parents, teachers and peers, e.g., natural speech, signs, symbols, assistive technologies and gestures.
2. The robotic system also uses simple game-playing strategies to develop communicational skills with the students.
3. The robotic system should encourage the students to work collectively and collaboratively in developing their communicational skills.

The robot will have different ways of communication which could include some of the following:

- Expression of emotions such as: happy/sad or angry/calm based on different scenarios.
- Speaking expression associated with short term states: teaching, laughter, crying.
- Getting student's attention and applying interaction prompts.
- Sound imitation: siren sounds, and animals sounds.

- Responding to natural speech, gestures, signs and symbols.

Since it may not be feasible to apply all the goals mentioned above, applying some of them should provide us with a good perception of how to improve communicational skills with students with profound and multiple learning disabilities (PMLD).

IV. Review of Relevant Methodologies

In order for our robot, NAO, to communicate with the students in a Peer-To-Peer approach, it needs to do that autonomously and that implies "multimodality, personality, adaptively, learning ability, cooperativeness, and reactivity" [13, 8]. To accomplish all these skills, certain requirements need to be implemented to resolve Human-Robot Interaction.

Understanding context: This component of our model needs to be programmed to adopt context, objects and humans in a certain effective way to accomplish proper interaction. This is called a "formulation process", which is giving a meaningful definition to the environment of interaction.

Human-Robot Interaction: Is defined as "the study of humans, robots, and the ways they influence each other". In order for young students to feel comfortable with a robot as a learning tool, students need to have the sensation they are interacting with their "Personal Robot" [8, 13]. The robot needs to be friendly and remember students names/faces and their preferences. In addition, the robot should behave naturally to display the information in a most effective way.

The architecture of human interaction needs to be shown in how the robot is interacting with (PMLD) students. According to [8, 13], proper human communication uses three elements for a complete natural dialog. Syntax to analyze the probabilistic language properties. Semantic so both the students and the robot implicitly agree on the meaning of the message. Pragmatic to ensure messages have a suitable effect on both party's behaviors.

This process of this interaction requires time parameters where the robot can detect the student's actions or when someone is speaking. In this case, there is a need to provide our robot, NAO, and the students with a clear model/prototype of each other. The time parameters assist the robot to study different attitudes, behaviors and motivations and follow the behavioral norms to respond correctly to all of these reactions [13].

Multimodality: The modes of interaction vary from visible expressive, touching, speaking, and visualizing based on the stage of the communication. These forms of movements mimic humans' interactions and of course helps to achieve more effective and natural communication [13]. Visible expressive could be either body language or using the body, or part of the body in the communication. For that to happen, the system in the robot needs to overcome the challenges of a gesture expression model and gesture recognition when implementing a human gestures model.

As for touching mode, NAO responds to commands by being touched on either its head or its hands.

Table: Walking Parameter for Robot NAO

Parameter	Straight
Threshold for walk forward	0.280000 m/s
Threshold for walk backward	0.150000 m/s
x- velocity along X-axis Use negative for backwards. [-1.0 to 1.0]	0
y- velocity along Y-axis	0
Use negative for right. [-1.0 to 1.0] **theta** : negative for clockwise [-1.0 to 1.0]	0
Frequency	10

Prototypes sensors are located on top of its head in three sections and on its hands. The robot can detect where its being touched and take that touch as a "command" to respond with an action [9, 13].

Speaking Mode: This mode is considered one of the most important multimodality sets that the NAO robot uses for human-robot communication. The robot reading text-to-speech and automatic-speech-recognition to support the communication of students with learning disabilities. Also, shows capability of recognizing a complete sentence or just few words in the sentence. Also, the robot can find the speakers' location and move its direction to face them. This gives the impression that the robot is more human-like and responsive to its environment. Thus, mastering this interface leads to smother and clearer communication.

V. Design Implementation

The system is design to allow students to interact with NAO in natural manner to stimulate their curiosity about learning and to provide meaningful engagement to increase learning. The main focus of the design is to create four different scenarios (behaviors) using Choregraphe software. Each behaviors is trigged by a switch box connected to a JoyBox through which a client server protocol is implemented. These scenarios are a suggestion of one of the senior staff at Oak Field School and Sports College to assist them to focus on the student's level of engagement in class.

Also, these scenarios apply engagement profile and scale developed by SSAT in (http://complexld.ssatrust.org.uk/project-resources/engagement-profile-scale.html).

A survey was conducted to ask teaching and research staff what type of students they think might benefit from working with NAO. The result of these questionnaires is presented in another chapter.

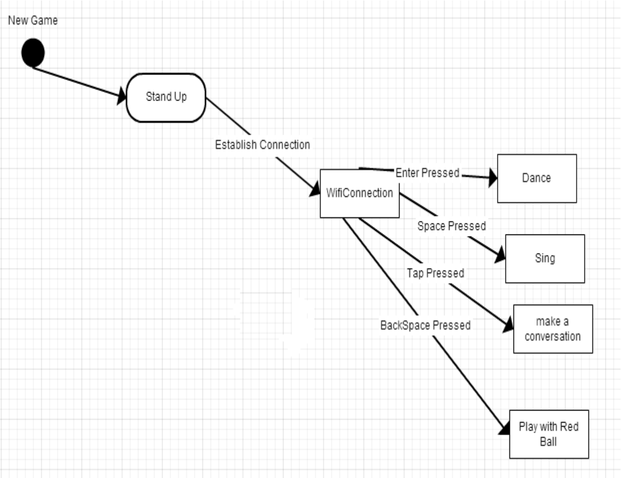

Figure 1. Four scenarios

VI. Client Server communication

There are two scripts need to be created to have a straightforward client server connection in python. One script is for the server to create a socket and a port and the other script is to run the client to connect to that port and host IP. The connection is between one server, (computer) and one client (Nao robot). The server allows the use of different switch boxes connected to a JoyBox to emulate space, enter, backspace and tab keyboard. The joyBox input method is used to control which scenario is implemented based on which switch box is pressed. This is experiment applies the concept of socket programming in networking.

This experiment also uses a module called TKinter that supports creating a user interface of the server side. The interface is very simple and it has a button for broadcasting the connection between the server and the client. The IP Address of the computer and port are already hardcoded behind the broadcast button.

VII. Server Side

Once the interface broadcast button is clicked the server starts broadcasting a connection and listen for a client to connect to .TCP domain sockets is implemented using the socket.socket() from socket library to provide classes for handling the message transports. The socket function available in socket module is used to initialize a socket object in the server. A socket object is then used to call bind function to Set up the socket on local IP address and selected port.

VIII. Client Side

In order to set up the client side (NAO), the IP address of the server side (computer) needs to be entered along with the port that it is broadcasting on. Choregraphe software on the server needs to be configured by editing script box which contains an IP address and port fields. To have a successful connection, the IP address the robot is connected to should be the IP address of the server and the port number should be the same value on the server.

The client side opens a connection by the socket function which has the hardcoded IP Address and the given port as its argument .The function opens a TCP connection to hostname on the port and reads any available data from the socket, then receives data from the connection. The client side then checks if data received is equal to string “enter” sent by the server.

This process gives it the functionality to trigger the enter output in the Choregraphe. Creating an enter output starts with editing box dialog in the script box by choosing Edit box option. In the Inputs / Outputs / Parameters section of the dialog type is always “bang” and the natural is “puntual” as there is no need to transfer data.

IX. Scenarios

Scenario 1: Play with red ball

This behavior is programmed to make NAO track a red ball and trigger different two behaviors once the robot reached the ball at a specific position. After reaching the ball with the distance between the left foot and the ball is 3 centimeters, NAO asks weather to kick the ball or grab it from the ground. The robot is programmed to track/kick/grab the RedBall with 2.25 centimeters radius, however this can be changed to smaller size if needed. NAO in this application reacts to motion and sound which promotes a human interaction while playing with the Red Ball.

It starts looking for the red ball by loading ALRedBallDetection module into the system and stiffness of the head, both arms and both legs must be set to default. It tracks the red ball by using a built-in library in Trackers WB Tracker box. This permits creating a bridge between the target (RedBall) and motion to make NAO use the middle camera to keep viewing the target. NAO moves the face only to look for a red ball by using the following WB Tracker module and returns 3 dimensions position of the target.

A. Walking

To make NAO walks, Aldebaran robot provides ZMP based walk engine built in ALMotion module. Throught this engine, NAO is controlled follow the pattern generated by the ZMP walk engine. There are four parameters for the walk engine implemented in the module. Different parameters values are used to control the movement of NAO when walking straight and walking side walk. The parameters we used for walking are shown in Table 1.

B. Wording

Once NAO reaches 3 centimeters from the target, NAO asks the user you what to do. Here is what they can say:

- To perform a strike:kick / shoot / strike.

- To grab from the ground and throw it: grab/take/grasp.

To apply full speech recognition, users need to use the front head sensor to communicate with the robot. If NAO does not hear or cannot understand what it has been said, it decides on its own what to do and it is set to kick the red ball in this situation.

C. Kicking the red ball

NAO starts this behavior by standing up and initialize that it is ready to look for a red ball. It then moves the head around to find the red ball and localize itself in the direction of the ball. When the ball is found, it walks up to the ball until it is about 3 centimeters away from the target, then it takes one step to the side to line up with the ball, and finally kicks it. To kick the Red Ball, NAO raises one foot up while balance itself on the other foot to keep balanced. It directs the raising foot according to the location of the ball and then kick it. After kicking happens, the robot puts the lifted foot back to the ground and balance the body using both feet.

This scenario uses a static implementation of kicking the ball which means it uses key frame techniques mentioned in [15]. It is very straight forward approach to implement and can be configured easily .However, this approach is not capable to extend the move to be dynamic where there is more complex motions passing a ball in football game with other robots.

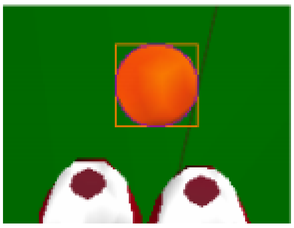

Figure 2. Three Centimetres Away from RedBall (http://www.cs.utexas.edu/~AustinVilla/?p=nao)

D. Grabbing the red ball

Nao get to pick the red ball as required from the user. To ensure precision, he/she picks up the ball by using left hand. NAO gets down to grab the ball by bending his both legs inward while his right arm lean on his right knee to make him prop himself so that the other one could grab the ball. After he reaches the ball, he stops for few seconds to make sure that he got the ball between his three fingers. Furthermore, Nao spreads his legs and lifts his right leg a bit which is important for getting up again. The series of images from 4.3 to 4.10 shows every single keyframe of this animation.

The robot holds the Red Ball firmly while lifting his foot up and balancing his body relying on the other foot. This step is very complicated and NAO can easily loses his balance and fall. The robot is not always accurate in picking the ball for two reasons. First, the Red Ball we are using for the experiment is 3.5 centimeters radios. NAO's hand has three fingers and they can go as wide as 2.5 radios. To solve this issue, a smaller ball is replaced when the robot goes down to pick up the target from the ground. The second issue is with the new smaller ball. NAO's three fingers are soft and the ball slips away. This is really issue since a human assistance is required each time it goes to pick the ball.

Scenario 2: NAO asking questions

NAO Starts this behavior by waving and introducing him/her-self to the audience. This is done by open both hands and rising the right hand up to wave .NAO then asks the user to repeat what they hear. NAO uses The ALTextToSpeech module to permit the robot to speak. It transmits a text-to-speech engine, and authorizes also voice customization. The voice of the NAO can be customized through voice set parameters of the say Text.

To have voice recognition systems, NAO open framework called NAOqi is utilized using a sequences of predefined behavior boxes programmed into Choregraphe. We have used the component Set Speech Lang box onto Flow Diagram panel. NAO has Choice box component built i-n to do speech recognition when the user repeats after the robot. ALSpeechRecognition module needs to have a lists of words that are correct. SpeechDetected module is then utilized to detect the element of the list that best matches what is heard

NAO response to the correct answer by moving the head to both sides and get hands close to each other. Also a recorded sound of people cheering gets called to indicate the correctness of the solution. NAO moves to a new word and keeps repeating the same steps each time the user says it correct. In the case the user provides incorrect answer, the robot moves to a new word. At the end, the robot asks for high five from the user to finish this scenario.

Scenario 3: Dancing

Dancing NAO is a very common behavior and been developed many times for different research studies. However, It is very important action that young students enjoy watching and participating. The robot stands up inviting others to dance, play the recorded music and dance Macarena and then sits down.

Since it is repetitive setting, the technology used to develop the dance is no longer unique. Yet, it is still useful for the report to have entertainment level to encourage students to engage in the case study. NAO starts this move by asking others to dance with him. Since the moves of the Macarena dance are not very complicated, NAO appears to do the move in a very humanoid manners. To have the robot dancing for longer time, copying Macarena box in the framework will make NAO dance for longer time. The code of the Macarena dance is in Appendix.

X. Case Study : The Interview

The interviews are used to implement the questionnaires stated in (Appendix A2). The aim is to attain teaching and research staff opinion of using NAO in the classroom; and to discover the type of PMLD students who would benefit from learning from NAO. Also, what benefits would be gained if we have had PMLD students involved in this case studies? What barriers do the teachers face in engaging students in class? What can be done to overcome these barriers.

All four interviewees were members of staff recruited from Oakfield School, and researchers from Nottingham University. Staffs were recruited based on their level of experience working with PMLD students. The interviewees were requested to see the demonstration of the four scenarios first. They were given access to the four switches to select and move from one scenario to the other. Then they are requested to answer the questions in the questionnaires stating their opinion about the demonstration .

Another aim of the interview is to investigate the interest of school staff and research working with NAO. Based on the staff answers, it will be a lot clear to see if they can enjoy having NAO in their class. In general, having motive school staff is very important to make proper use of the NAO. It is believed that humanoid robot could be very useful as long as they staff are confident using it.

The results of this case studies will provide general ideas to assist OakField Collage and researchers to decide whether working with a robot is effective.

XI. Challenges During Implementation

A. The red shoulder of NAO

One issue we encountered during the implementation is NAO gets confused when looking at one of his/her red shoulder. This happens when NAO looks for the RedBall and move his head further to the left or right side. Since we are using the built-in library for a red ball, it is not possible at this point to change the color of the targeted ball. Luckily, this issue did not happen a lot. The only way to work around this issue was to place the red ball in NAO's vision range so it he/she does not need to move head to either sides.

B. Slipping out ball

NAO's fingers have a 2.5 range when they are widly open. This gives us two issues. First issue, the Red Ball we are using his 3.5 diameters which is bigger than the NAO's hands to grab. To work out this issue, a smaller Black ball was introducing when NAO picks up the target from the ground. Second, NAO's fingers are soft which allows the target to slip away. It is suggested by [16] to stick hook-and-loop tape onto Nao's finger tips to help holding of the ball. However, we decided to provide human assistance during grapping of the ball to avoid any damage to robot.

XII. Conclusion

Overall, human-robots are highly motivating, but there are not meant to replace human teachers, they are rather to provide additional teaching aids. It is vital for human-robot interaction to have the robot mimicking human behavior naturally. Joining all of "formulation processes" above provides a natural "intuition" to the robot which is useful in situations where the robot is able to determine by itself if, how and when it can intervene and help.

The ultimate objective of this study is to explore NAO robot capabilities to be used as a communicational learning tool, to support the needs of school staff to improve communicational methods for students with (PMLD) especially regarding its voice and object recognition system.

References

[1] M. Ali, S. Alili, M. Warnier, And R. Alami. (2009). An Architecture Supporting Proactive Robot Companion Behavior. SSAISB: The Society for the Study of Artificial Intelligence and the Simulation of Behaviour. 0 (0), p1-8.

[2] J. Hedgecock. (2010). Can working with a robot enhance learning in pupils with intellectual disabilities?. SCHOOL OF COMMUNITY HEALTH SCIENCES. 0 (0), p1-85.

[3] Department of Health. (2001). Valuing people: A new strategy for learning disability for the 21st century. London: HMSO.

[4] D. BROWN, D. MCHUGH, P. STANDEN, L. EVETT, N. SHOPLAND, and S. BATTERSBY, 2011. Designing location based learning experiences for people with intellectual disabilities and additional sensory impairments. Computers & Education, 56 (1), pp. 11-20.

[5] J. Tomlinson, (1997). Inclusive learning: the report of the committee of enquiry into the post-school education of those with learning difficulties and/or disabilities, in England 1996. European Journal of Special Needs Education, 12, 184–196.

[6] P. STANDEN, and D. BROWN, 2005. Virtual reality in the rehabilitation of people with intellectual disabilities. Cyber Psychology and Behavior, 8 (3), pp. 272-282.

[7] J. Cromby, P. Standen, and D. Brown (1996). The potentials of virtual environments in the education and training of people with learning disabilities Journal of Intellectual Disability Research 40:489–501.

[8] V. Yu. Budkov, M. V. Prischepa, A. L. Ronzhin, A. A. Karpov. (2010). Multimodal Human-Robot Interaction. IEEE. 10 (4), P485-P488.

[9] B. Robins, F. Amirabdollahian, Z. Ji, K. Dautenhahn. (Sept. 12-15, 2010). Tactile interaction with a humanoid robot for children with autism: A case study analysis involving user requirements and results of an initial implementation. 19th IEEE International Symposium on Robot and Human Interactive Communication. 0 (0), P704-711.

[10] R. Iovannone, G. Dunlap, H. Huber, and D. Kincaid, (2003) Effective educational practices for students with autism spectrum disorders, Focus on Autism and Other Developmental Disabilities, 18, 150–166.

[11] D. Hargreaves, (2006) A New Shape for Schooling? London: SSAT.

[12] B. Carpenter, (2010a) Disadvantaged, deprived and disabled, Special Children, 193, 42-45.

[13] R. Barber. (2013). Multimodal human - robot interaction. Available: http://roboticslab.uc3m.es/roboticslab/topic.php?id_topic=12. Last accessed 3rd, May, 2013.

[14] A. Corrales; M. Malfaz; M. A. Salichs. Signage system for the navigation of autonomous robots in indoor environments. IEEE Transactions on Industrial Informatics. In press. Vol. 0. No. . pp.0-0. 2013.
[15] Y. Xu, and H. Mellmann (2010). Adaptive Motion Control: Dynamic Kick for a Humanoid Robot. Institut fur Informatik, LFG Kunstliche Intelligenz. 1 (1), p1-8.
[16] A. Jaime, S. Fabian, S. Norman, W. Daniel, (2013). CogSys-Project-B: Project Nao Final Version. cogsys.. 1 (1), p1-43.

APPENDIX

The main motive behind the project primarily came from reading online articles and coming across unknown terms, at which stage typically Human-Robot Interaction, NAO and learning disabilities were used to attempt to define the meaning or get a synonym. I started my dissertation by doing a general reading of academic articles browsing the famous search engine Google. I also used Wikipedia to get general ideas about robotics and Human-Robot Interaction. I found taking these steps was very helpful to clarify my thoughts and make sure that I know what is there for me about my research. A further search for dictionary applications on download.com brought up some more similar applications and their reviews were found again via Google search engine

I then attended the Victoria Boskett session at the Nottingham Trent library .The session with the librarian was very helpful to understand proper research techniques in my topic area. I learned how to select the right sources, how to manage the information and use the best search strategies. The librarian supported me of how to use NTU Library database to search for more solid academic articles.

After I decided what exactly I wanted to find out for my report, I started using precise keywords /questions /statements on NTU database search engine to generate e-books and academic articles. I started my research by using the words that define my research topic. Since my report is a very specialized topic, E-journals are important key sources for my literature search. It is because E-journals are updated with recent research and other sources and they rely on a particular implantations which is very important for my research.

After I have developed some ideas for my dissertation topic, I started to demonstrate the foundation of my study, to describe that the research context fits within my topic area. I summarized several articles regarding humanoid robotics and its application in everyday life. Category view was used is computer Science and Information technology. The search engines that I used for my research include:

- www.scholar.google.com
- Wikipedia
- Library One Search of University of Trent Nottingham
- Electronic journals available via NTU library
- Science-Direct
- University of Nottingham Library Online Catalogue
- IEEE Proceedings

I also watched YouTube videos of other researchers using NAO robot for different academic purposes. This was extremely helpful to understand the capabilities of NAO and be able to draw specific goals to be achieved in my implementation.

BIOGRAPHY

Elmunir Elgajiji holds a MSc from Nottingham Trent University in Computer Science and a bachelors degree from Carleton University, Canada with Honors in Computer Science. Worked with Adobe and RIM as a software developer. Currently, he is the head of information and documentation center at Misurata University.