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User Interface Design of Humanoid Robot at Library: Case of Chemnitz University of Technology

Gantogoo Oyunbat
Faculty of Computer Science
Chemnitz University of Technology
Chemnitz, Germany
gantogoo@hotmail.com

***Abstract*— The university library is one of the key places for students at higher education institutions. Some universities support their students with their literature search and research with humanoid robots. The Chemnitz University of Technology (CUT) is one of pioneer universities where a humanoid robot will assist at the university library. This paper describes user interface requirement and its programming, testing and implementation of humanoid robot at the university library. The programmed humanoid robot should support students and visitors with useful guidance and hints in finding materials they need for their research and study. For programming of the robot, the programming language Python was used and the implementation was tested with limited number of users due to the pandemic situation.**

***Keywords*— Humanoid robot, Pepper robot, CUT, robots, library, Chemnitz**

I. Introduction

The term "humanoid robot" is not alien to many of us. However, the real implementation of humanoid robots in everyday situation started only recently. And it is true that the majority of the general public have heard of or seen the robots through the media but most of them have never experienced or interacted with a humanoid robot [1].

Various scientists from different fields have been researching the interaction between human and robot as well as their importance and acceptance in modern society [2]. It is assumed that robots will move from their initial settings for industries to more education and everyday oriented settings and will support public and technical services in libraries [3], [4]. The robot "Pepper" is one of the well-known representors of the humanoid robots and will be discussed in this paper.

II. Motivation

Library search systems are complicated depending on the person using it. Staff who work at a library, experienced student or regular library user might have no problems finding a book whereas non-regular users or new visitors of the library would still have some issues finding the book they need. Not being able to find the book they are searching for is a common occurrence for visitors with no prior knowledge about how to effectively find their research related article from the vast amount of literature. In such cases, a robot, especially a humanoid robot can assist these people by educating and informing them about crucial functionalities of the library. By entrusting this duty to a humanoid robot called "Pepper", which the Chemnitz University of Technology (CUT) already possesses, the burden of repetitive explanation would be lifted off from the library staff.

III. State of the Art

A. Brief History of Robots

There are many definitions for the word "Robot". The British Department of Industry defines robot as "A programmable, multi-functional manipulator device". The word "Robot", which came from robota, a Czech word, means forced labor or labor and it was first mentioned in a play named Rossum's Universal Robots written by Karel Capek in 1921, which tells a story about machines resembling humans defy their human lords and take over the world [5], [6]. In 1942, Isaac Asimov wrote a short story "Runaround" depicting robots as helpful servants of man. There he defined the "Three Laws of Robotics". These are:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

The concept of using mechanical devices in labor has been around even before the definition of a robot. In the late 1940s, a maze-solving mouse was built by Claude Shannon. The maze consisted of 25 square checkerboards with removable aluminum walls. And a motorized carriage below the maze-floor provided power to the mouse through magnetic coupling. Simple relay circuits were used for logic and memory needed for exploring the maze and remembering the path. Then in the late 1970s, with the help of development of integrated circuits, computer-controlled robots, termed as industrial robots became an essential part of manufacturing systems [7].

B. Development of Humanoid Robots

Humanoid robot is a sub-category of the term "Robot", which came to fruition from the human beings' desire to create their replica. In 1960s the Zero-Moment-Point stability theory was introduced by Miomir Vukobratovic. Around the same time the first humanoid statically balanced robot WABOT was developed by Ichiro Kato in Waseda University, Japan [8]. Fig.1 shows development history shortly in time frame.

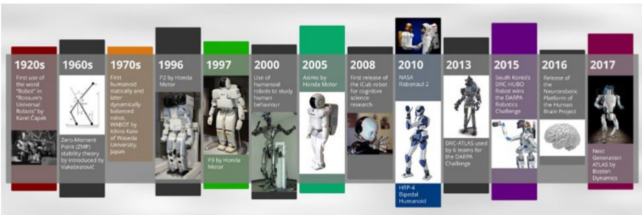

Fig. 1. Some of the key milestones in development of humanoid robots [8].

In 1996 and 1997, the robots P2 and P3, developed by Honda Motor, were introduced at the IEEE (Institute of Electrical and Electronics Engineers). In 2005, the robot ASIMO (Advanced Step in Innovative MObility) surprised the general public with its human-like movements, and the ability to balance itself, move up and down stairs. ASIMO is one of the most developed humanoid robots but is also one of the most expensive ones. The price of a single ASIMO costs 2.5 million US Dollars [8].

C. Robots in Libraries

Robots were initially implemented in jobs, mostly in industries or factories, that were hot, heavy and hazardous for human workers. Today, robots can be seen working, not only in industries, but in many different fields. The general public is not able to directly interact with such robots in everyday situations and places. Library is one such place where people could meet robots.

1) KoRo: Guidance robots for library use are being developed in Japan, for example at the library entrance of Konan University, the robot "KoRo" developed by Masahiro Tanaka was placed in 2016 [4]. "KoRo" could talk with people and display various videos or show floor maps on the screen beside it. If the visitor wanted to talk to the staff, KoRo could arrange a meeting in another room [4], [9].

2) NAO: NAO is one of the most sold humanoid robots and was developed by Aldebaran Robotics (currently Softbank Robotics Europe) in 2006 and was introduced to the academic market in 2009. The robot is 58cm tall, weighs 5kg, and has two legs, two arms, torso and a head. The physical appearance of NAO has smooth texture to it, making it friendly looking and easy to interact [1], [10]. The robot has been implemented in many distinct fields but mainly in the field of education. In the library setting, NAO can be seen working in public libraries of Frankfurt, Cologne, Wildau and Reinickendorf, Germany, in Westport Library, USA, and in Noosa Library, Australia.

3) An-San: Konan University also has another service robot called "An-San" originally developed by Prof. Dr. Tomohiro Ametani in order to study tactile sensations of human fingers. Thus, An-San does not have pre-programmed automatic answers to questions, but is tele-operated by the library staff from a distance [4].

4) Sota: Library of University of Electro-Communications introduced an interactive robot "Sota", which provides information regarding the library and how to use certain functions of it [4].

5) Uta-San: A rabbit-type robot "Uta-San" guides the visitors of Oyama City Central Library to the bookshelf containing a book which the visitor is looking for. The purpose of implementing this robot was to motivate grade-school children to read more books and visit the more often library. An experiment conducted reported a great success [4].

6) HAL and THOUZER: The robot suit "HAL" (Hybrid Assistive Limb) helps library staff of the Tsukuba City Central Library carry heavy items and reduce their burden on their back. HAL can sense a signal sent from the brain to a muscle and assist the person. It is estimated that the suit reduces the back pain caused from lifting heavy objects up to 40% [4]. Tsukuba City Central Library also has a transportation robot "THOUZER", which can carry weight up to 120kg.

7) Pepper the Humanoid Robot: The humanoid or semi-humanoid robot "Pepper" (Fig. 2) was developed by Softbank Robotics in cooperation with Aldebaran Robotics in 2014 as the successor of NAO robot. With its 120cm height and big eyes Pepper looks like a slightly tall child [1], [11]. Pepper is an emotional robot which can communicate with humans on a wide range of issues by utilizing its autonomous behaviors, speech and emotion recognition functions [12]. The robot has various sensors in its head, chest, hands and legs, cameras, microphone and a touch-tablet on its chest, weighs 28kg and moves with omni-wheels [9], [11], [13].

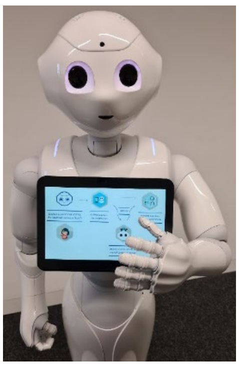

Fig. 2. Pepper robot.

Technology enthusiasts who want to educate themselves in robotics may start with LEGO-Mindstorm or basic programmable toys, but this approach is not particularly practical, as it does not have many real-life applications. On the other hand, there are industry-level platforms, which are very complex. The gap between these two is filled by Pepper, as it has its own Python-based operating system and a dedicated software and programming platform Choregraphe [13]. Depending on the manufactured year, Pepper has two versions. Versions manufactured before 2019 have Python based operating system (NAOqi 2.5) which runs Choregraphe whereas the versions after 2019 have Android-based operating system (NAOqi 2.9) Pepper [1]. Both versions have their advantages and disadvantages. NAOqi 2.5 is more fit for advanced robotics programs, on the other hand NAOqi 2.9 is easier to use for interaction-based applications [14].

Studies showed that people show favorable interest in robot, when the said robot used gestures during the interaction [15], [16]. The robot Pepper is implemented in libraries around the world. For example, in Japan Pepper has been working in libraries since 2015. Few of these very first libraries that accepted Pepper as an assistant to their team are Yamanaka Public Library, Library of Kitami Institute of Technology, Yamato City Library, Edogawa City Library, and libraries in the area of Tokyo [4].

In Germany, Pepper has been implemented since 2016 in the University Library of Wildau. There, Pepper helps the library visitors by answering questions, locating books, and leading the way to location of the book and supports the staff. Shortly after the City Central Library of Dusseldorf followed with their own Pepper robot [1], [11], [17]. Pepper is also active in an education field other than libraries in Germany. The humanoid robot Pepper works as an assistant in lectures at the University of Marburg [1], [18].

D. Problem Statement

Relaying information is not an easy undertaking, especially for a robot. Everyone has their own opinions regarding humanoid robots. And these opinions differ greatly from person to person thus making the robot interaction extremely unpredictable which in turn makes the interaction seem unnatural or uncomfortable [19]. To achieve relatively comfortable interaction, the robot Pepper performs following tasks for the workshop at the university library (Fig. 3):

- A start button, indicating that the robot is ready to begin the interaction should be shown on its tablet. The button will appear when a person appears before it. When the start button gets pressed, or the keyword “start” is said by the person in contact, the workshop will start.
- Workshop starts by Pepper explaining the general concept of the main topic. The topic is divided into four modules.
- The modules are shown on the tablet. Pepper explains what to expect from the modules.
- When a module is initiated, Pepper first gives an insight on the topic of the module and allows the user to decide whether to end the module and go back to the main menu or to continue with the module.
- If the user decides to continue, Pepper explains further in detail about the topic of the module, while using gestures to emphasize parts of the dialog. The corresponding pictures, videos or websites will be shown on the tablet during the speech.
- After the explanation, Pepper asks topic related questions from the user to clarify the topic. For example: Would you like to clarify your understanding of the topic?
- If the user is able to answer the questions, Pepper will compliment them. If not, Pepper encourages them and gives the right answer.
- After that the user can ask topic related questions from Pepper. Pepper answers the questions or tells them to seek library staff for deeper explanation.
- The module ends and the main menu is shown on the tablet. And the process repeats itself.

If the user ends the workshop but stays in the near proximity of Pepper, the user will be asked whether they want to start the workshop from the beginning. It is important to note that every humanoid library assistant robot is individually unique as the majority of the libraries around the world do not implement humanoid robots.

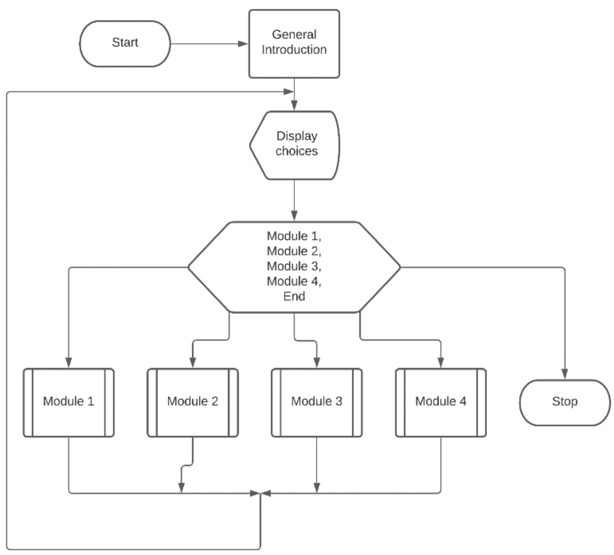

Fig. 3. General structure of the program [19].

IV. CONCEPT DEVELOPMENT

The main concept of the workshop is to explain the users about the literature search and research processes in the university library of CUT in an interactive manner. In order to do that the tasks mentioned above were carried out. The corresponding topic is based on the publication of Ms. Dagmar Hesse [20]. The topic discussed in the workshop is under-categorized in four modules. These four modules are:

- Module 1: Catalogue Search
- Module 2: Database Research
- Module 3: E-book Search
- Module 4: E-Archives

These modules are structured in a similar manner to one another. Pepper starts a module with a welcoming gesture and gives the user a short insight on the module content and displays it on its tablet. During this brief insight the user can decide whether to continue or to end the module. If the user wants to continue the module Pepper goes on to give the user further detailed information regarding the chosen module. Pepper will also demonstrate module specific literature search and research for the user on its tablet. During this process, Pepper will deploy lively gestures, movements, and interesting sounds to make the information flow more interactive. When the explanation and demonstration part ends Pepper goes on to ask questions regarding the explained module from the user, which builds a dialog between Pepper and the user and waits for an answer. If the user answers right, Pepper compliments the user and asks the next question. Else if the user answers wrong or does not answer the question for a certain amount of time, Pepper encourages the user to think of an answer and asks the question one more time. If even then the answer is wrong or no answer was given to the robot then Pepper says the right answer and moves to the next question. This process repeats itself until all the pre-written questions from the robot site is finished. At the end of the module, the user gets to ask questions, if the user needs clarification for some parts of the process. Pepper will answer the question if the question was anticipated by the programmer. Else, Pepper will advise the user to seek out library staff and ask them for more information [19].

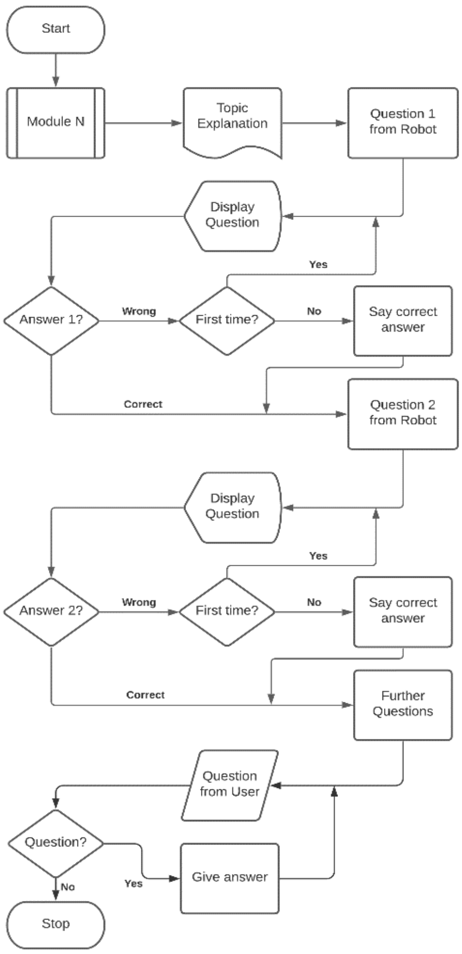

Fig. 4. Algorithm flow of a Module [19].

Module ends when the user has no further questions. Pepper will then thank the user for their cooperation and will automatically go back to the main module displaying the four choices of topics. Basic algorithm is shown in Fig. 4.

V. IMPLEMENTATION

The concepts established above were first tested on a virtual robot then implemented on the real Pepper. For this paper, Python-based Pepper with NAOqi 2.5.10.7 which the CUT had was programmed using the platform Choregraphe. As there is currently no universal way of programming a humanoid library assistant robot, each robot that is implemented in a library is programmed according to its working environment and requirement.

A. Programming Tool: Choregraphe

Chooregraphe is a graphical programming platform developed by Aldebaran Robotics for its robots. With Choregraphe one can create animations, behaviors and dialogs for Pepper, test the written programs on a virtual robot, observe and control the robot, and refine behaviors with python codes [1], [13], [21]. The user interface of the platform is structured similarly to a flow diagram. Each action of the robot can be programmed in python and the resulting python scripts can be put into small boxes which the programmer can easily connect to another box via mouse click. These boxes with the codes inside them can be moved around and modified without any difficulty per drag-and-drop motion. An original behavior can be assembled from these boxes. If needed, the assembled behavior can be tested on a virtual robot, although some features do not work in simulation mode, it is still a helpful component [1], [13], [21].

B. Programming stage

For this paper six independent behaviors were created, four of which corresponding to the four topic related modules, one designated for the main module, and one for the general testing. A general testing behavior was needed because changing a few lines of code or dialog and running the whole module to see whether the change was made successfully or not was eventually time consuming and ineffective [19].

Following the general structure of the workshop, shown in Fig. 3, the programming began with the main module containing the introductory part and module selections. For the programming of the main module, employing the predefined boxes by bringing them in certain orders through the medium of connecting their inputs and outputs, it was possible to duplicate the general flow. But it was necessary to include HTML, CSS, JavaScript and Python scripts for some of the tablet related events of Pepper. It was necessary to do so as the operating system of the tablet and the robot were different for Pepper version implemented in this paper. In order to assist with the use of tablet on the robot, Aldebaran has made a template, and the template was adjusted to the workshop [19], [22]. The dialog of the robot was written in script language QiChat. Difficulty with this approach was to predict every possible user input during the interaction. A module insight is shown in Fig. 5.

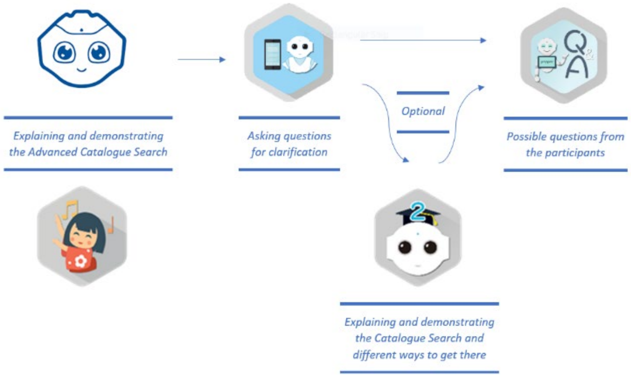

Fig. 5. Module insight [19].

As discussed in concept development part, when the module is chosen Pepper explains in detail about the chosen topic while demonstrating certain actions. These actions can be, for example, choosing between different databases, borrowing loanable books, doing normal and advanced catalogue search, and doing interlibrary loan, if a specific document is not found within the library.

C. *Experimenting and Debugging*

These experiments were conducted during the pandemic period where the access to the university was restricted. Therefore, the first test had to be done on the virtual robot. From tests conducted, it became apparent that the tablet related functions as well as autonomous life function of the robot were not available on the virtual version. Thus, making the virtual tests mainly dialog oriented. For the same reasons, only the module one was largely tested virtually. Most of the dialog related issues could be debugged in this manner. When tested on the real robot, tablet related issues were found. One such issue was that although the tablet was fully functional it still lacked speed when loading images. The length of these lags was random, and sometimes the images did not appear at all. This was solved by loading the images beforehand and calling them at the wanted moment. Additionally, dialog specific movements and action had to be added, as random movements would not correlate with the speech which would distract the human interacting with Pepper. In case of the speech recognition ability of the robot fails, the tablet was integrated to get user text input for communication.

VI. Results and Evaluation

A survey was prepared in order to get the user's impression after interacting with Pepper. As a consequence of the ongoing pandemic, it was not possible to get quantitative amount of data for the survey. To determine the outcome of implementation, the workshop needed to be evaluated in this manner only. Due to the limited number of applicants, a qualitative research method and short survey techniques for evaluation were applied. As the length of the workshop was relatively short compared to normal workshops, the number of questions asked in the survey were limited to two rating questions, three dichotomous questions, and one open-ended question resulting in total of six questions [19], [23], [24]. The survey questions asked were in English and the participants had to fill in the survey after interacting with Pepper. Participants of the survey were not explicitly recruited. No personal information from the participants were collected or stored.

Due to the pandemic situation during which this thesis was written, the number of participants were drastically small. In total, data from seven applicants were collected in the survey (Fig. 6). In response to the dichotomous questions, when asked "Have you worked with Pepper before?", only one person answered "Yes" while the others had "No" prior experience working with Pepper. To the question "Would you be willing to work with a robot?", all seven participants answered "Yes". The last dichotomous question "Was the content presented by Pepper easy to understand and follow?", three people chose "Yes" whereas four chose "No". The main aim of the rating questions was to get the satisfaction rate of the participants after conversing and communicating with Pepper. Surprisingly, the evaluation result of the rating questions was very positive. There were no one who felt "Very Bad" from the interaction. That means the general satisfaction level of the participants was good enough to accept the service given by Pepper.

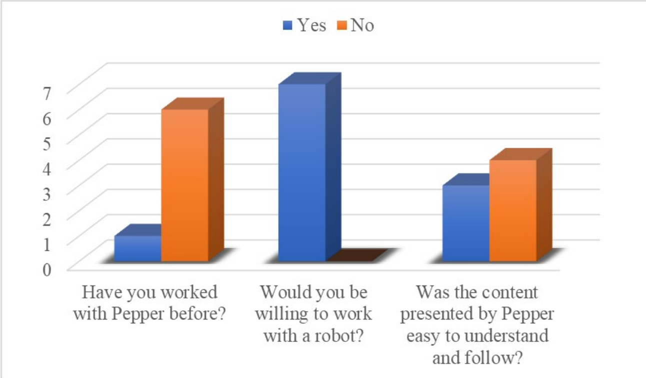

Fig. 6. Results of dichotomous questions [19].

Purpose of the dichotomous questions was to receive feedback from the users regarding their experience with getting content from Pepper. Only one person from the seven surveyed had previous work experience with Pepper, for the other six it was their first time interacting with the humanoid robot. The focus of the open-ended question was to hear the opinions of the applicants to the workshop. Six people expressed their thoughts which confirms their interest in such projects. Two people wrote that the explanations and answers from Pepper should be shorter and more interactive. Others stated that the speed of the speech was still relatively fast for non-native English speakers and it needs to be louder. All these comments from the participants need to be considered in the future development of the workshop.

VII. Conclusions

Technology has advanced to a new height in the last three decades. It was made evident especially in the last two years where a pandemic covered the entire world urging the people to immediately change from analog to digital in the shortest time. Of course, this process did not occur without any problem. Nevertheless, the transition happened in this short, given time. The initial idea of making the humanoid robot Pepper do a small workshop about literature search and research was achieved. However, improvements still need to be done on certain points. We are of the opinion that the workshop can be developed further for better service and interaction. There were some uncertainties regarding the acceptance of the robot. But then again, the evaluation results showed that people are ready to accept and interact with the relatively new form of technology.

The robot Pepper is one of the well-known representors of the humanoid robots. Pepper had been globally implemented in numerous different fields. One such field is in education, especially in libraries. We believe, if this goes on as anticipated, it will not be long when everyone can meet a humanoid robot in a library. In regards to the survey results, the general satisfaction of the interaction was good enough for the objectives to be classified as successfully reached. The fact that the second part of the survey with polar questions showed the majority of the survey participants were new to the experience. Limited amount of data could be collected due to the present situation and the restrictions that follow. Therefore, a qualitative evaluation method was used. Based on the evaluation results we conclude that the implementation of the demonstration workshop as successful. The users were satisfied with the interaction with Pepper and the service offered by the user interface was accepted. There were and are certain points that need to be improved for better service in the future.

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