FUTURE E- BUSINESS OPPORTUNITIES WITH COMPANION ROBOTS

Thitipong Nandhabiwat[1] and Chun Che Fung[2]

[1]Department of Information and Communication Technology, Rangsit University International College
[2]School of Information Technology, Murdoch University

ABSTRACT

Computers, Internet, mobile phones and many new devices have changed the modern living significantly. In particular, the development has opened up many new businesses both online and offline. A few decades have also passed since the first generation robots have been put to work. Today, technological advancement in robotics has once again opens the door leading to new ways of living with *personal companion robots*. In addition to services and work, it is believed that the new generation of robots will be able to play and be a companion, entertainer, teacher and even as a life-saver. Not only will this generate revenues and investments in the robotics industry, this predicted future will also create many new e-business ventures. This paper presents a preliminary study of companion robots from the technical aspects and proposes the concept of future e-business opportunities with companion robots.

Index Terms— Companion Robot, Human-Robot Interaction, Human-Robot Social Interaction

1. INTRODUCTION

In human history, major technological breakthroughs have contributed to the improvement and changes in living conditions, ways of work, and how people are entertained. This is witnessed in the use of fire, printing, steam engines, electricity, transport systems, films, radio, television and many other examples. During the last few decades, computer and communication technology have brought major upheavals in how the society and individuals are connected, how works are carried out, and how businesses are conducted. In particular, the maturity and acceptance of E-business are mainly due to the advancement of the computer, network, and Internet technology.

At this point of time, it is believed that another major breakthrough is going to occur in the near future, following the similar patterns of the personal computers (PC) and Internet development. It is expected that intelligent, autonomous, humanoid robots will play the roles of personal assistant, teacher, entertainer, and companion for their "buddy", or, owner. This paper gives a description of the initial phase of such development and in particular, the E-business opportunities are also considered in this discussion.

For decades, robots have played a vital role in the modern society. Industrial robots are found in factories as basic units of assembly lines and manufacturing processes. They are also used extensively in industrial projects, surveillance, medical and military missions, Robots have been used in the entertainment industry such as movies and stage shows. Robotics competition tournaments are also conducted all over the world as intellectual challenges and for academic pursues. While robot technologies are relatively matured in most industrial applications, they are not yet available to provide affordable, practical and useful services in a human-centered environment on a one-to-one basis.

In a way, this is similar to that of the history of computers. Computers once were expensive equipment mainly used by government departments, universities and major corporations. Since the development of microprocessors and PCs over 30 years ago, computers have now truly become "personal" as most citizens in the developed world are able to possess one or more at work and at home. Similar can be said about the Internet and networking technologies which once were only accessible by the military, research and academic inner-circles. Knowledge on data communication and network was once considered as highly specialized skills possessed only by a few. Nowadays, accessibility to the Internet and establishment of networks (both wired and wireless) are affordable and relatively easy. This is mainly due to the rapidly reducing communication and hardware costs, and the ongoing development of the network infrastructures. The Internet today can provide every individual with a wide range of personalized services ranging from finance, life-style, games, social, education, and all forms of entertainment. The question is, "Will robot technology follow the same footpath?" The answer from the authors is arguably, "Yes!" It is proposed that the next generation robots are distinguished from the earlier generation of industrial robots in that they are providing one-to-one services and companionship instead of narrow and dedicated functions.

One of the drivers of the extension of robot applications from factories to human and domestic environments is due to the aging population in most industrialized countries. This is in association with the desire for relief from common daily tasks, and the lack or high cost of local human labors

[1]. In addition, due to the uncertainty associated with services provided by unknown strangers, the need of safety and dependability are the other reasons for the introduction of robots into human environments. In order to promote the use of personal robots in everyday life, issues such as cost, content generation, technical functionality, safety and dependability have to be addressed [2]. Today, such studies are focused in a rapidly developing field known as "Human-Robot Interaction", or HRI.

In this paper, a preliminary investigation of an off-the-shelf robot from the Speecys Corp. of Japan has been carried out. The robot is SPC-101C and it is further developed into a companion robot named "iCHEER". This stands for intelligent Companion Humanoid Entertainment and Education Robot. Unlike many sophisticated, highly complex and very expensive humanoid robots, SPC-101C is much cheaper and affordable. The degrees of freedom (DOF) and communications channel are sufficient for most the tasks required in the project so far. The tentative outcomes have shown a promising future and the possibility of leading to new E-business models for the personal companion robots. If the prediction is fulfilled, the future of such personal robots will generate much revenues and commercial values from developed applications. This could lead to the development of robotics industries, big, medium and small enterprises, and many other businesses both online and offline.

This paper is organized in the following format. Section 2 gives an overview of robots and the background of Human-Robot Interaction and Human-Robot Social Interaction. Section 3 is a technical description of SPC-101C. Section 4 discusses the implementation of iCHEER as a first step towards a companion robot. Section 5 proposes a new business model. Section 6 provides the discussion and conclusion from the work so far.

2. BACKGROUND

It is expected that robots will be used as extensive as PC sin human-centered environments in the near future [3]. John Intini [4] recently predicted that by 2017, robots will care for the elderly, cars will drive themselves, and houses will talk. In 2004, a survey by the United Nations (UN) [5] reported that "robots are set to become increasingly familiar companions in homes by 2007 and there will be almost 2.5 million entertainment and "leisure" robots in homes which compares to 137,000 in 2004. Moreover, the UN 2002 robotics survey [6]grouped robots into three major categories which are primarily defined through their application domains. They are classified as Industrial robots, Professional Service Robots, and Personal Service robots.

Industrial robots have historically represented the vast majority of robotic development, with many deployed in the automotive industry, beginning with the entire automation of a Nissan plant in the 1990s. Moreover, the average cost of an industrial robot has decreased by 88.8% between 1990 and 2001. At the same time, U.S. labor costs increased by 50.8% [6]. These opposing trends continue to open up new opportunities for robotic devices to be used in tasks previously handled by human. However, industrial robots tend not to interact directly with people. Interface research in this field focuses on techniques for rapidly configuring and programming these robots.

Professional service robots are the subject of a much less practiced field, but the field is growing at a much faster pace than industrial robotics. Just like industrial robots, professional service robots manipulate and navigate their physical environments. Professional service robots assist people in the pursuit of their professional goals, largely outside industrial settings. Some of these robots operate in environments inaccessible to people, such as robots that clean up nuclear waste or navigate in abandoned mines. Others assist in hospitals, such as the surgical robotic system, used for assisting physicians in surgical procedures. Robot manipulators are also routinely used in chemical and biological labs, where they handle and manipulate substances (e.g., blood samples) with speeds and precisions that people cannot match. Most professional service applications have emerged in the past decade. According to the UN[6], 27% of all operational professional service robots operate underwater, 20% perform demolitions, 15% offer medical services, and 6% serve people in agriculture industry. The amount of direct interaction with people is much larger than in the industrial robotics field, because service robots often share the same physical space with people.

Personal service robots have the highest expected growth rate. They were estimated to grow from 176,500 in 2001 to 2,021,000 in 2005 – an 1,145% increase[6]. Personal service robots assist or entertain people directly in domestic settings or in recreational activities [7]. Examples include robotic vacuum cleaners, lawn mowers, receptionists, robot assistants to elderly [8] and people with disabilities, wheelchairs, and toys [7]. Many robots interact with people who have no special skills or training to operate the robot. These robots support humans in the house such as NEC PaPeRo [9].

2.1. Human-Robot Interaction

Many researchers in the robot disciplines now recognize that Human-Robot Interaction plays a pivotal role in personal service robotics [10]. There are many definitions of HRI, some are broad and some are comprehensive. For example, while Fong et al. [11] defined HRI as the study of humans, robots, and the ways they influence each other, Goodrich and Schultz [12] defined it as a field of study dedicated to the understanding, design, and evaluation of robotic systems for use by or with humans. Interaction, by definition, requires communication between robots and humans. Communication between a human and a robot may take

several forms, but these forms are largely influenced by whether the human and the robot are in close proximity to each other or not. Thus according to Goodrich and Schultz, communication and interaction can be separated into two general categories. *Remote interaction-* the human and the robot are not collocated and are separated spatially or even temporally. For example, the Mars Rovers are separated from earth both in space and time. *Proximate interaction-* The humans and the robots are collocated. For example, service robots may be in the same room as humans.

Table 1 classifies the most frequent types of interactions for the home and edutainment application domains among other major ones. For many of these domains, current research patterns exhibit a trend away from remote interactions toward proximate interactions, and away from operator roles toward peer or mentor roles [12]. This could be considered as one of the essential characteristics of the companion robots.

Moreover, personality is another key factor in HRI and that the robot personality should match that of the human user [13].

Also, in a study by Lund [14], he pointed out that many robot systems put less artificial intelligent (AI) capabilities than their entertainment functionality. This renders the robots as toys instead of useful beings. This observation correlates with the fact that most off-the-shelf robots are lack of advanced AI capabilities for the fulfillment of being a useful personal service robot.

Pransky [15] has provided an interesting perspective on the different profiles a future robot companion should take. The proposal also listed the advantages and weaknesses of such a future companion. The 'Robotic Nanny' can on the one hand play with children and feed them. On the other hand, it could make a child being deprived of human interaction and viewing robot interaction as the 'norm'. A 'Robotic Assistant/homework companion' would be able to organize meetings, research, and track documents. But this could lead to the feeling that robot interaction is easier than human interaction. Finally, the 'Robotic Butler/Maid' could do all the housework, but they may cause relationship difficulties at home by being too efficient and making one feels being redundant.

2.2. Human-Robot Social Interaction

Human-Robot Social Interaction (HRSI), also known as Socially Interactive Robotics (SIR) or Social Robotics, is a subfield of HRI. In recent years, HRSI has attracted considerable attention by the academic and the research communities [16]. Fong et al. [17] described SIR as ones *"for which social interaction plays a key role . . . [in order] to distinguish these robots from other robots that involve 'conventional' human-robot interaction, such as those used in tele-operation scenarios"* with some indications by describing their characteristics as *"A socially interactive robot may express and/or perceive emotions, communicate with high-level dialogue, learn and/or recognize models of other agents, establish and maintain social relationships, use natural cues (gaze, gestures, etc.), exhibit distinctive personality and character, and learn or develop social competencies."*

In addition to the definition of HRSI or SIR, Feil-Seifer and Matarić [18] further expanded HRSI or SIR to include Socially Assistive Robotics (SAR) to better understand the key unique challenges of this growing field. SAR focuses on aiding through social rather than physical interaction between the human user and the robot. Moreover, SAR is the intersection of SIR and Assistive Robotics (AR). SAR shares with AR the goal to provide assistance to human users, but it specifies that the assistance is through social interaction. Because of the emphasis on social interaction, SAR has a similar focus as SIR. In SIR, the robot's goal is to develop close and effective interactions with the human for the sake of interaction itself. In contrast, the SAR robot's goal is to create close and effective interaction with a human user for the purpose of giving assistance and achieving measurable progress in convalescence, rehabilitation, learning, etc.

Table 1. Examples of roles and proximity patterns that arise in major application domains.

Application Domain	Interaction Type	Role	Example
Search and Rescue	Remote	Human is supervisor or operator	Remotely operated search robots
	Proximate	Human and robot are peers	Robot supports unstable structures
Assistive Robotics	Proximate	Human and robot are peers, or robot is tool	Assistance for the blind, and therapy for the elderly
	Proximate	Robot is mentor	Social interaction for autistic children
Military and Police	Remote	Human is supervisor	Reconnaissance, de-mining
	Remote or Proximate	Human and robot are peers	Patrol support
	Remote	Human is information consumer	Commander using reconnaissance information
Edutainment	Proximate	Robot is mentor	Robotic classroom assistant
	Proximate	Robot is mentor	Robotic museum tour guide
	Proximate	Robot is peer	Social companion
Space	Remote	Human is supervisor or operator	Remote science and exploration
	Proximate	Human and robot are peers	Robotic astronaut assistant
Home	Proximate	Human and robot are peers	Robotic companion
	Proximate	Human is supervisor	Robotic vacuum
Industry	Remote	Human is supervisor	Robot construction

Syrdal et al. [19] mentioned in order for a robot to operate successfully in human-centered environments, it needs to be able to behave in a manner that is socially appropriate. Furthermore, Fong et al. [11] emphasized the human interaction and the robot's autonomy are key functions that can spread the use of the social robots in human daily life. Nowadays most of the available robots can interact only with their creators or with a small group of specially trained individuals. The long term goal of the most of robotic research is to develop a social robot that can interact with humans and participates in human society. In this case, the human roles during the interaction process will be evolved from being operator or supervisor to being a peer in form of teammate. Such type of robot must have effective and natural interfaces with high level of robot's autonomy by which the robot will be able to survive in different situations. This interaction can be social if the robots are able to interact with human as partners if not peers. In this case, there is a need to provide humans and robots with models of each other. Sheridan [20] argues that the ideal would be analogous to two people who know each other well and who can pick up subtle cues from one another (e.g., musician playing a duet). In addition, an adaptive personalized robot companion [21], must also be capable of adapting to the individual needs and preferences of its users. Salichs [22] viewed a social robot as *"having attitudes or behaviors that take the interests, intentions or needs of the humans into account."*

As an interdisciplinary field, HRSI integrates synergically robotics, artificial intelligence, cognitive science, psychology and other fields like linguistics and ergonomics, in order to improve the naturalness of human-robot interaction [16]. Many robotic platforms have been built with different design considerations and capabilities to study HRSI. A Robota, for example, is a sophisticated educational toy robot designed to build human-robot social interactions with children with motor and cognitive disabilities [23]. All these projects pretend to develop robots that function more naturally and can be considered as partners for the human not just as mere tools. These robots need to interact with human (and perhaps with each other) through similar ways by which humans interact with each other. To achieve this goal, many novel interfaces have been currently developed in order to allow humans to move seamlessly between different modes of interaction, from visual to voice to touch, according to changes in context or user preference [16].

Robots which are currently commercially available for use in a domestic environment and which have human-like interaction features are often orientated towards toy or entertainment functions [24]. In the future, a robot companion which is to find a more generally useful place within a human orientated domestic environment (e.g. sharing a private home with a person or family) must satisfy the following two main criteria [25], [26], [27]:

Technical Capabilities: It must be able to perform a range of useful tasks or functions.

Social Abilities: It must carry out these tasks or functions in a manner that is socially acceptable, comfortable and effective for people it shares the environment with and interacts with.

The technical challenges in getting a robot to perform useful tasks are extremely difficult, and many researchers are currently researching into the technical capabilities that will be required to perform useful functions in a human inhabited environment (E.g. navigation, manipulation, vision, speech, sensing, safety, integration, planning etc.) [24]. The second criterion is arguably equally important, because if the robot does not exhibit socially acceptable behavior, then people may reject the robot if it is annoying, irritating, unsettling or even frightening.

It is possible to conceive of a robot which is very sociable, but not very effective or useful (or vice versa). For example, Kanda et al. [28] studied a robot which exhibits social cues so that people have the impression that it listens and understands them as they ask for route directions. However, the robot did not comprehend speech, so the human users did not actually gain any useful help from their questions.

The study of socially interactive robots is relatively new and experimenters in the field commonly use existing research into human-human social interactions as a starting point. In a recent HRI study, Walters [24] believed that *"Robots are perceived by humans in a social way and therefore that humans will respond to robots in a social way. There may be some similarities with the ways that humans respond socially to a pet, another human, or a child or infant. However, while the aim of many robot designers is to create robots that will interact socially with humans, it is probable that humans will not react socially to robots in exactly the same way that they would react to another human. It is probable that a number of factors including robot appearance and behavior, proximity, task context and the human user's personality will all potentially affect humans' social perceptions of robots. However, as a practical necessity for the first stage in the experimental research, the number of factors under investigation were limited."*

3. SPEECYS SPC-101C

Speecys SPC-101C is a 33 cm. high humanoid robot weight 1.5 kg. and it has a total of 22 DOF, which can provide a high degree of mobility for SPC-101C. There is a 270,000 pixel video camera mounted in the head which can be used to capture video images and to be sent to a receiver. The camera can be panned using the head servo and moved up and down by tilting the torso at the waist. Dual stereo speakers are built into the torso sides. There are LED arrays in the hand and chest which can be used to display characters, text, or robotic emoticons (block graphics). The

robot uses Futaba Corp. RS301CR servos and RPU-50 CPU robot controller, powered by a 7.4V 780mAh Futaba Corp. LiPo battery. It also has a miniSD slot for extended programming in addition to 64 MB of RAM and 64 MB of Flash memory. The robot can also be operated while plugged into the charger. SPC-101C runs the NetBSD operating system. Its operations and communications are carried out through a WiFi connection, allowing it to extend its operations over the Internet and it can support its own IP address. Hence, SPC-101C is IP-enabled and can be operated remote via the Internet. Moreover, itsprograms can be downloaded via Internet servers as shown in Figure 1.The Robot Transaction Markup Language (RTML) makes content handling easier by allowing the transfer of service requests or responses with HTTP protocol. Using simple HTTP protocol, SPC-101C can easily communicate with servers independent of network characteristics[29].

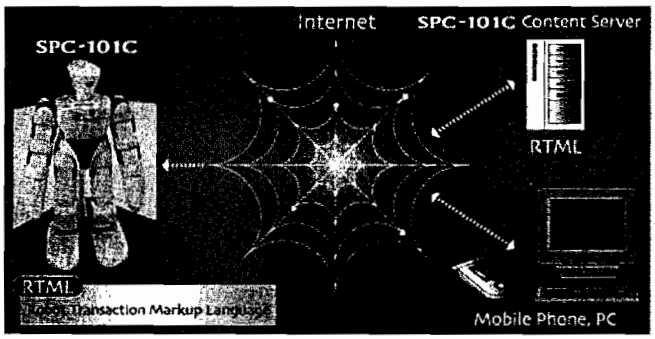

Fig. 1. SPC-101Cand its interaction environment.

In terms of programming ability, this off-the-shelf robot allows users to customize series of movements using the bundle software called "Motion Editor". Advanced users may customize their applications in Visual Basic, C#, Java, or any other development languages. The Speecys Corp., designer and manufacturer *of SPC-101C,* has released the open source software SDK named "Open Roads", which facilitates the use of a wealth of well established, proven application libraries. For example, the Microsoft .NET 3.0 System Speech libraries can be used to add voice recognition and synthesized speech to the robot. Video capture, object recognition and tracking and other advanced functionality can also be added using the same approach. This can be noted that SPC-101C offers the potential to utilize the large amount of resources from the library [29].

4. IMPLEMENTATION OF ICHEER

One of the first applications being developed and tested for the iCHEER is to send the robot a voice command over the Internet by using a computer or an Internet-enable mobile device such as an Apple iPhone used in this project. A user issues a voice command by talking on the iPhone. Then the voice command is sent to the robot within seconds. The command then activates a set of instructions and movements. For example, when using an iPhone from any location, the robot can be activated to monitor a house and capture a video motion on detection of motions. The video captured will then be transferred over the Internet to store on a designated computer. The next application developed for iCHEER is a cheerleading performance with an actual Cheerleading team as a prop in the beginning of the show. The dance sequence and music are stored in the robot and the performance is activated by voice command using the iPhone. Another application developed is to have iCHEER teaches Yoga to a person who would like to spend his/her private time alone training from the robot. Again voice activation is required in order learn each exercise. The latest application currently being developed is to have iCHEER teaches an elderly to exercise. This exercise is not just any exercise, but it is the standard exercise that has formerly been carefully designed by health care experts in the area.

In order for iCHEER, a customizable off-the-shelf robot to fulfill the goal as an entertainment companion robot, two dance routines have been developed. The show was put forward to a group of audience during a press conference in Bangkok, Thailand. As for the development process, the initial phase involved the implementation of the dance patterns and sequence, in which "Motion Editor" was used together with the background music being integrated. The next phase is to incorporate voice recognition ability by using Microsoft Speech SDK 5.1 to allow iCHEER to be controlled through the Internet via a mobile phone such as the Apple iPhone. This will demonstrate the flexibility of the interface for controlling the performance of the robot. During the dance performance of iCHEER (see Figure 2) the audiences were observed to be amused and entertained. A snapshot of the occasion is shown in Figure 3.

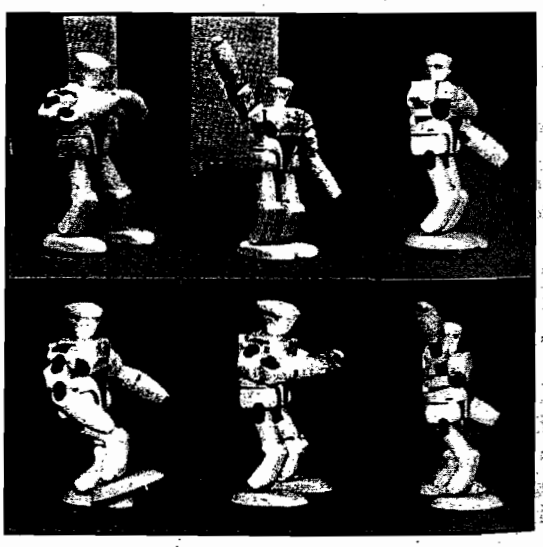

Fig. 2. iCHEER demonstrated dance routines.

Fig. 3. Audiences entertained by iCHEER.

5. BUSINESS MODEL

As robotics industry continues to evolve, it is expected that companion robots will become more popular and user-friendly. In times to come, it will be easy enough for users to generate their contents and the robots will be flexible enough to do the functions as required by its human partner. Learning from the history of PCs, internet, music and media industry, it can be expected that new business models associated with companion robots will definitely emerge. However, the content generation aspect currently remains a challenge. Most of the existing companion robots are still fall short of the requirements on ease of programming and flexibility of the functions. Even with the existing high-cost companion robots, they still require specialized skills to develop the content and software applications. Hence this paper has used iCHEER as example to illustrate the ability that a companion robot could download contents and software applications from a server through the Internet as seen in Figure 2. The content will have commercial and intellectual and this can adopt the similar concept of subscription based model such as Apple iTunes. Users to will be able to download contents and applications from the Internet with a fee. Other possibilities are specialized consultancy services for customization or adaptation of the robot hardware and software. These are just some possibilities of the future e-business models for robotics industry, following similar models at present. While the current research is concentrated on overcoming the shortcomings of current companion robots, iCHEER is only used as an example for illustration. It is believed that next generation commercial companion robot will be more cost effective, flexible and user-friendly in its programming and communication. It could be anticipated that they might appear in many families before the end of the next decade, along with the emergence of new e-business models.

6. DISCUSSION AND CONCLUSION

The ongoing objective of this research is to develop a framework for development of content and applications for off-the-shelf robots to be used in different applications including entertainment. Robot technologies have advanced rapidly in terms of movement, hardware/software architecture, communication and network supports. They are moving closer to become entertainer and companion. However, one of the main challenges observed from this research so far is the obstacle in software development. It is essential that new and appropriate content must be able to be added to the robot in order to maintain ongoing interest and meaningful purposes. The iCHEER so far has shown the ability to be a companion entertainment beyond the ability of normal off-the-shelf robots. It has also demonstrated that it is possible for users to generate contents for the robot, just like people can produce motion video for YouTube and applications for Apple iPhone. The long term value will be the need to generate useful applications to meet day-to-day requirements and be a "true" companion. Hence, the future e-business opportunities with companion robots is anticipated to be promising with the success of a companion robotics industry. This may fulfill the saying that, "We are not alone!"

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