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Importance of Appearance, Behaviour and Personal Features in Social Robots. Is there Really any Uncanny Valley?

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Abstract – **In house use of robots imposes a number of challenges to design its behavioural, interactive and collaborative capabilities, appearance and learning abilities etc. for it to be welcomed in human social environments. A phenomenon called "Uncanny Valley" has been suggested by researchers to limit the human likeness in appearance of robots to a certain level to avoid negative response from human. However some researchers oppose this phenomenon and support the human likeness in robotic design. This paper presents a study of views from robotic researchers about human likeness and other challenges in robotic design. A survey was conducted to obtain and analyze the responses of people towards some humanlike robots presented in China Robot Exhibition 2006. The paper also presents and discusses the results of this study of human responses towards humanlike robots.**

Index Terms—**Human-Likeness in Robots. Human-Robot Interaction, Social Robots, Uncanny Valley**

I. INTRODUCTION

Robots now have started serving in the domestic environments, in hospitals, in museum etc. where they have to face and deal with human directly. Robots are also expected to serve as companion/caregivers to elderly and children[1] and/or personal assistant, to prevent children accidents [2], for Robot Assisted Activities (RAA) and Robot Assisted Therapies (RAT) as a substitute for Animal Assisted Activities and Therapies (AAA/AAT) [3,4, 5, 6] etc. It will be usefull for robots serving in these scenarios to utilize available human cooperation to perform the tasks more efficiently [7]. Human will feel more comfortable, pleasant and supporting with systems which (at least to some extent) possess ethical beliefs matching that of their own, do not make a decision or perform an action that is harmful to their moral values, and honour their basic social values and norms [8]. Thus where interaction with human is desired, the robots are desired to behave as social machines. Because of various level of social capabilities, social robots can be classified in four classes namely *socially evocative robots*, *socially communicative robots*, *socially responsive robots* and *sociable robots* [9].

Recently the role of humanlike appearance is claimed to be as important as its behavior for the robot to be recognized as a social identity and to elicit more natural response from human [10, 11, 12]. Having a humanlike face provides the benefit of universally recognized facial expressions, an understood focal point of interaction etc. Some researchers suggest that an iconic/minimal face to be sufficient as it provides a sense to project one's own emotions and expressions, and to apply their own identity to the robot whereas the completely realistic face may increase false expectation in users [13]. Experimental results from Hinds et. al [10] presented in (section III) also agree with these expectations. Researchers thus are now focusing to develop human likeness in both appearance as well as in behavior of robots [14, 15]. Such machines are also expected to serve the studies in psychology and cognitive sciences to perform controlled experiments to understand the human-human interaction [16, 17, 18], which are rather not as easy with human beings. Results from research performed for human robot interaction have suggested hypothesis not only for the human-robot interaction but also for the human-human interaction [19, 20]. The work however is very preliminary and needs much more to be explored.

Fig. 1. Our under development robot.

We are working towards the development of a humanlike robot (fig 1). Since the role of humanlike appearance has been questioned among the researchers and developers and there are groups of people both in favour and against the extreme humanlike appearance, we wished to analyze human response towards such machines. For this we conducted a survey at the China Robot Expo 2006 where various robots with humanlike appearance were presented for the visitors to interact with.

Following this section of introduction this paper present views about Human-Robot Interaction (HRI) in Section II. Various possible issues in HRI and evaluation of HRI are then presented in sections III and IV respectively. Section V discusses the

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humanlike appearance in robots and the concept of uncanny valley. Section VI describes the conducted experiment and section VII presents and discusses the results. Finally conclusion is presented in section VIII followed by description of our future work in this regard in section VIII.

II. Human-Robot Interaction (HRI)

Interaction can be classified as active or passive interaction [21]. The most important factors to be considered to implement while designing an interactive robot are its capabilities to establish and maintain *Engagement, Trust* and *Motivation* with the user [22, 23]. S*eamlessness, adaptivity, redundancy* and *flexibility* are also considered as important attributes of human-robot interaction [10]. Interactive robot design requires work from other research fields [24, 16] such as physiology, social psychology, artificial intelligence, and computer science in general and some other area specifically related to the application such as bariatrics, nutrition and behavior changes [22, 23]. The robots need further capabilities like initial contact, negotiating a collaboration, checking that other is still taking part in interaction, deciding to continue interaction or to end it etc. [25, 26].

A broader scenario of HRI is the human-robot collaboration in joint activities to achieve common goals. This requires to maintain mutual beliefs, share relevant knowledge, coordinating actions, demonstrating commitment to do one's own part, helping the others to do their parts, avoiding from preventing others to complete their parts and completing the shared task, to communicate to establish and maintain a set of shared goals and beliefs and to coordinate their actions to execute shared plans [27]. Hinds et. al. presented the first systematic controlled experiments in this area [10]. It has been reported that human subjects although not too much, but comparatively rely more and feel less responsible while collaborating with a more humanlike robot than with a machinelike one. Also it is reported that people attribute less credit and more blame to robotic supervisors and subordinates as compared to robot peer. Finally it is claimed that the people feel more responsibility and attribute less credit or blame to robotic partners having machinelike appearance than those having humanlike appearance.

Human often use nonverbal cues to communicate to one another. Such communication has been termed as *implicit communication* by Breazeal et. al [28]. Implicit non-verbal communication is helpful to understand the mental state, direction of attention on one another and to alter the behavior accordingly and to utilize the affective knowledge of one another. Thus the nonverbal information through social cues can improve the human-robot interaction and the efficiency to perform collaborative tasks [29]. From their experimental results Bruce et. al. [30] have also presented the hypothesis that face to face interaction is the best model for interface in human-robot interaction. Based upon their results they concluded that having an expressive face to provide non-verbal cues from expressions and indicating attention with movement both make a robot more compelling to interact with.

An interesting demonstration of intuitive human-robot interaction was presented by Atienza and Zelinsky [31] where a robot through its active vision after detecting a human face follows the gaze of its human subject, picks up the object the human subject is looking at and hands it over to the subject. This way it fulfills the user's desire which is implicitly communicated to the robot through nonverbal communication by the gaze direction of user and not provided to the robot verbally.

To interact simultaneously with more than one person is also a challenging task for the interactive robots. While during the human-person interaction involving only one human faces the challenges of speech recognition, sound localization, tracking the human face, posture/gesture and expressive and cognitive capabilities, multi-person conversation puts further requirements of finding the current speaker and the addressee and to reply if the robot itself is the addressee, the information flow, appealing the intended interaction, the intended next speaker and focusing towards the speaker in time, attending interruption to its speech and to interrupt others smoothly [32, 33].

III. Issues in Human Robot Interaction

Various *social, moral, ethical* and *legal issues* are expected to arise with the increased sophistication of conscious machines [34]. Calverley J.D suggested that a starting ground can be taken from animal rights as basis to build moral and social rules for such machines. According to Robins et. al. [35], interaction can be enhanced by appropriate context suggesting more interacting activities but this can also increase the expectations of user thus a balanced context must be designed for interactive robot. In addition to the conventional modalities of interaction (speech, gesture, haptics etc.) the physical activities and performance of robots should also be carefully designed to match the moral values (mutual distance for example) of the user interacting with it [36]. Breazeal and Kidd [37] have presented the issues such as *relationship issues, personality issues, cultural issues, quality issues, naturalness issues, user expectation issues* and *comparative media issues* desired to be addressed by HRI studies. According to Thomaz et. al. [38] timing is also very important in human-robot interaction. Along with possessing high quality expressive behavior capabilities it is also important to express these behaviors at right time in a right manner [25]. Larger delays in a shared attention mechanism may introduce errors in attribution of others in the robot.

IV. Evaluating Human Robot Interaction

According to Brian Scassellati [39] social machines can be evaluated through the same principles and criterion as applied to the normal human beings and autistic children with only eye direction detection and intentionality detection systems. Kidd and Breazeal [40] have proposed measures to evaluate human robot interaction including *"Self-Report Measures"* using questionnaires, *"Physiological Measures"* such as galvanic skin and *"Behavioral Measures"* using data obtained from observations during HRI experiment. All three types have their own merits and demerits and to obtain reliable results a well balanced combination of three types of measures may provide the best evaluation measure. Haeussling and Burghart [29] have also suggested a network concept based sociological multilevel framework to evaluate the interaction at the levels of *Interaction Context, Interaction/Cooperation, Activity of Actors* and *Nonverbal Actions and Emotions*.

V. Human Likeness and the Uncanny Valley

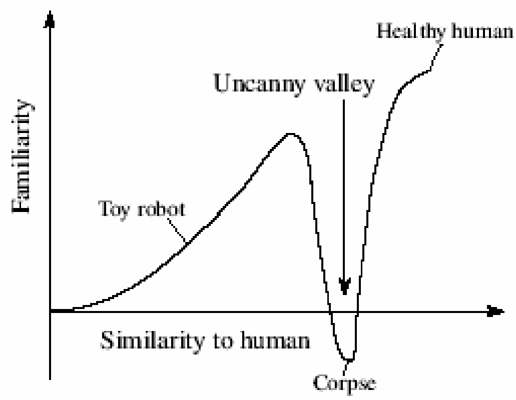

Fig. 2. The Uncanny Valley

Most of the researchers have been using robots with mechanical appearance [41] and have rarely considered the human likeness of appearance in robots. The fear of falling into the uncanny valley hypothesized by Mori [42] in 1970 has restricted the developers of humanoid robots to avoid achieving this height of designs. Japanese robotist Mori has hypothesized that as the designer tries to improve the human likeness, there comes the situation when the person interacting with the robot becomes conscious enough that little distances from human likeness give rise to eerie feelings. This negative behavior is named as the *Uncanny Valley* in the relation plotted between familiarity and human likeliness of the design as shown in fig 2. The eerie sensation generated in human by humanlike robots is supposed to be due to a reminder of mortality from the robots [17]. The effect has been suggested for both appearance and movement of the robots and that the overall response of human towards the humanlike entities can be obtained by combining their response to the movement (behavior) and that to the appearance[43]. Personal attributes such as age, gender, personality etc. of human user may also influence the depth and shape of the uncanny valley [44, 16, 45].

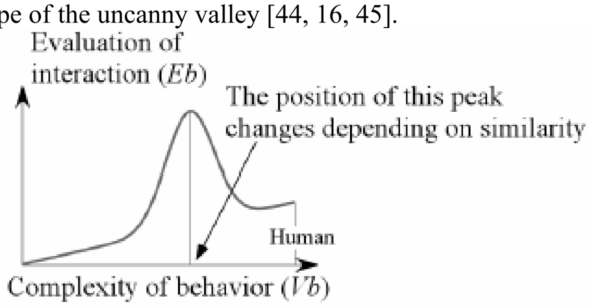

Fig. 3. Synergy Effect

Minato et al. [44] suggested that for different appearances the same behavior of the machine may elicit different response from human. Minato also presented a combined *"Synergy Effect"* at the point of matching of behavior and appearance (shown in fig 3) and suggested that by synthesizing the uncanny valley and synergic hill the uncanny effect caused by the appearance of robot can be reduced through its behavior(fig 4).

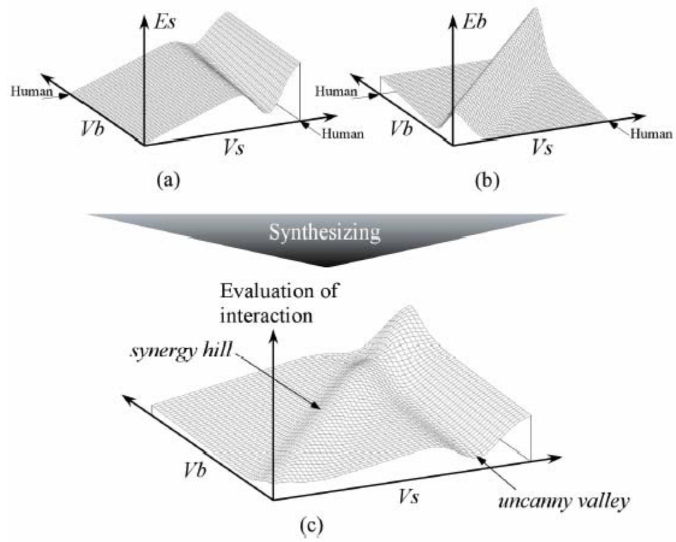

Fig. 4. Synthesizing the Uncanny Valley and Synergic Hill

The uncanny valley however lacks sufficient experimental data in its support and is a question challenged nowadays. There are also researchers who do not believe in it at al claiming that humanlike machines can be appealing or disturbing at any level of similarity to real human. In contrast another theory called *"Path of Engagement"* has been proposed [46, 47].

The data both in support and opposition of uncanny valley is not sufficient enough to decide whether any such phenomenon exists or not. Another problem is that there is no universally defined method for quantitative evaluation of how much humanlike an imitation is so as to find its location on the similarity axis of fig 2. A possible solution to compute human-likeness of humanoid robot has been suggested in [48]. Once such a scale is defined and human-likeness is computed, the response the robots elicit in human can be used to examine the existence of uncanny valley.

VI. Experiment

We conducted an uncontrolled experiment at the China Robot Expo 2006 held in Beijing last year. Various humanlike robots from commercial companies and universities were presented in the exhibition. We collected the response of people towards these humanlike robots presented to the visitors who were allowed to interact with these robots freely. The human subjects included people of both genders from almost all over the world almost including Americans, Asians, Europeans and others, and all were well grown adults of age group ranging from 20 to 40 years of age. However majority of them belonged to China. They included students as well as professionals from various backgrounds like technology, management, business and fine arts etc. We prepared a questionnaire to be answered by the visitors. The questionnaire consisted of 10 questions related to their experience, feelings and desires with such robots.

Fig 5 shows the three robots we considered useful for our purpose. The first is our own head robot capable of generating few facial expressions and interaction with users through voice and facial expression but is not very fine in its appearance. The second is the female singing doll which presented different songs to the users with constant facial expressions and the third is the android designed to copy a real human appearance. This robot performs some humanlike movements in his hands and head/face and also interacts with people through voice.

(a) (b) (c)

Fig. 5. Robots Presented at Chine Robot Expo 2006.

There were also other humanoid robots presented with iconic appearance but since our interest was in interrogating the uncanny valley, we selected these three robots with different levels of humanlike appearance. We prepared the questionnaire to focus the response of people towards these robots. The first two questions were about which of these robots the subjects liked most of all and what was its most remarkable feature for them. The next three questions were regarding there feelings with first look, during and after interaction with these robots. Next two questions were related to possible length of time and frequency the subjects will like to have for the interaction with these robots. Subjects were asked to express their desired enhancement or addition of features and capabilities in next question. The ninth question asked the subjects for possible place of such robots in their lives and the last question was regarding the gender the subjects may desire in humanlike robots.

VII. Results

1. Appearance/Behavior: 53% of the visitors liked the third robot (the most humanlike) whereas almost 30% of them liked the singing robot. 11% visitors liked the least realistic but still much humanlike one (fig 5-a) whereas 6% could not decide. Nearly 45% of the visitors found the appearance of these robots to be the most attractive feature, almost 42% of them suggested the robots behavior during interaction while the rest 13% considered both appearance and behavior to be equally important. However as the answer to what features they desire to be added or enhanced in these robots, only 12% suggested the appearance whereas 88% of subjects responded as the behavior to be the feature of these machines needing enhancement.

2. Immediate and Delayed Effects: 68% of the visitors were positively surprised with their first look and 26% said that they were attracted immediately, thus overall positive response was 94%. Only 3% responded to avoid and an equal amount of 3% claimed to fear i.e. only 6% of human subjects showed negative feeling from immediate look. During interaction 88% of subjects said that they were attracted or amused with these robots whereas only 6% felt eerie. Remaining 6% were not clear about their feelings during interaction. When people were asked about any change in their feelings after having some time with these robots 56% of them said that the attraction was increased and the 6% who were afraid to attract said their fear reduced with attraction. 29% of people replied that there was no change in their feelings and there were 9% of them who got bored.

3. Frequency/Length of Interaction: When asked about how frequently they will like to have interaction with such robots 18% showed interest in frequent interaction whereas 44% said that they would like to interact only occasionally, 23% preferred rare interaction and interestingly 15% of them disliked to interact with these machines ever. Answering about expected length of interaction without getting bored 38% responded it to be up to only few minutes, 32% expected it to span over hours, 15% said over a day and 15% of the people thought it to be any length of time.

4. Possible Uses of these Robots: Interestingly about 48% of people considered best use of these robots as toys, 34% suppose them to be good companions, assistant or caregiver , 3% of them said to have no place of these machines in their lives and 15% could not decide in what place these robots can be accepted.

5. Gender: About 68% of people replied that any gender is acceptable in these machines. 26% desired female robot and 2/3 of these were males whereas 6% all of whom were females desired these machines to look like male human being.

Results showed that people are attracted with humanlike appearance and the response is more positive with increase in the closeness of imitation towards reality. On the other hand, humanlike behaviour is found to be equally almost important as the humanlike appearance. It is also evident from the fact that enhancements in behaviour were desired by 88% of people, in robots whose appearances are already much humanlike and one is almost indistinguishable from natural human being (fig 5-c). The immediate feelings with these robots have been found positive and attractive where as negligibly small ratio of people expressed negative feelings. Further the negative feelings seem to be reduced after interaction. A small fraction of people got bored with this interaction but that was just loss of attraction and interest due to habituation and there was no sign of increase in fear or disturbance.

Very interestingly, in spite of finding these machines attractive, a very small number of people showed interest in frequent and long interactions with these imitations of human and most of the replies supported only occasional and short interactions with them. Almost only one-third of the visitors suppose these machines to have an active place of caregiver, assistant or companion in their lives. A large proportion just thought these not to be more than toys whereas there were also people who were not ready to give any place to these robots in their lives although they were attracted with them.

Personal features of these robots found to be almost unimportant as most of the people were happy with any gender present in robots. Only a small ratio was interested in robots with appearance of opposite gender and even smaller who were only females showed interest in same gender. Interestingly none of the male subjects desired the machines with masculine appearance.

VIII. Conclusion

Role of humanlike appearance and behaviour appears to be equally important in humanlike machines. However machines lagging in some features of appearance or behaviour may cause disappointment when not fulfilling expectations but there are almost negligible feelings of fear or danger observed in humans interacting with these humanlike machines. Some people may avoid this technological achievement but it can not be considered as fear. Thus there is no support found for the concept of uncanny valley in the results of our study. However agreements to the hypothesis *"path of engagement"* presented in [39, 40] is supported from people's desire of improved behavioural skills in humanlike machines.

IX. Future Work

The experiment we conducted represents views from a small number of people from a vast geographical as well as cultural background. The results will be more comprehensive with a larger number of human subjects interrogated for their response/views. We are developing our own humanlike robot (shown in fig 1) to perform controlled experiments to further investigate the role of appearance and behavior during human-robot interaction. The robot is in its initial stages. Its physical structure is almost complete and we are working towards its behavioral enhancements. We desire to implement robot personality and emotions to develop humanlike social capabilities in it.

X. Acknowledgement

In the end we would like to acknowledge all those visitors at the exhibition who voluntarily took part in answering our questionnaire and their help made us able to obtain these usefull results for our study.

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