Affective Computing: SMART Interactions of Machines with Humans

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***Abstract*—Today people spend lot of time in interacting with computers and machines. Due to which day to day interaction between human and computer has huge expectations like machines can learn from their environment and hence could interact well with people more naturally. Recent advancement in the field of affective computing has developed as a result of these endeavours. The aim of this article is to highlight the concept of affective computing, recent trends and its applications. The literature review is showing that emotions may serve as a powerful vehicle for enhancing or inhibiting learning and there are optimistic expectations towards affective computing among researchers. Hence by large affective computing systems are expected to have positive impacts in various fields like learning, gaming, entertainment, etc. It is anticipated that in the coming future, affective computing will be a standard features for computer user or to HCI technology. This paper will discuss this emerging field along with few potential concerns also.**

Keywords— **Affective computing, Human computer interaction (HCI), Emotion, Privacy Concerns.**

I. INTRODUCTION OF AFFECTIVE COMPUTING

Affective computing is a relatively new field of research which adds an emotional capability in the computing machines. Affective computing emphasizes on the importance of emotions in decision making, learning, memory and virtually all the cognitive processes. With advancement in computers, sensors, algorithms, and data processing techniques machines can analyse emotions as effectively as human being. According to Picard [1], 'affective computing' describes the computing that relates to, arises from or influences emotions. Machines should be able to interpret the emotional state of humans and respond appropriately. Therefore the system can be friendlier to the user. Emotion-enhanced human computer interfaces is expected to acquire a higher rate of acceptance and range of applicability. The challenge of researchers is to figure out how these affective systems can be constructed and how they can be combined with abilities to form fully intelligent and truly personal. Machines have undoubtedly come a long way towards human intelligence in the past half a century. Today we live in an "experience culture" where emotional intelligence and emotional management are seen as critical to working life, commercial enterprise and products ([2], [3]). Users expect not just functionality as a factor of usability, but also experiences matched to their expectations, emotional states, and interaction goals. End user feel is thus the decisive factor for usability of systems which continuously opens up a lot of new challenges in the area of human computer interaction (HCI). The major concern of HCI now is the need to improve the interactions between humans and computers through justifications and explanations. Thus we observe a significant growth of new forms of 'natural' and 'indirect' interfacing, other than the traditional form, like keyboard and mouse. Using natural interaction means allowing people the ability to communicate with machines in ways similar to how they communicate with other people. This includes both verbal communication (speech and non-speech vocalization) and nonverbal communication (body gesture, gaze, movement, and facial expression). At present HCI is experimenting with multimodal input mechanisms through speech, gesture, posture and facial expression, etc. to substitute the largely impersonal devices such as a keyboard and a mouse, for a non-tech savvy. One of the significant ingredients which could enhance the interaction between human and computer is emotions. Literatures illustrate various examples where emotions play a vital role in communication among human beings. However so far, emotions have not played a substantial role in HCI. Incorporating the emotions in HCI is a challenging task, but desirable in several applications. We are all familiar with utilities such as the tip of the day, birthday reminders, etc in computer systems. While these are useful in a normal working scenario but when one is in a hurry to complete a quick piece of work, these are distractions. Similarly, when you are in a hurry, it would be nice if the booting process would delay the detailed check of its file system, and not force it just because some counter has reached a specific value. These are simple examples of how HCI can improve with the ability to recognize and use end users affective state more effectively. There are lots of situations where man machine interactions could be improved by understanding the user's affective states, more so, in those situations where computers act as a social agent. The objective of this paper is to understand the importance of affective computing.

This article brings many recent advancement and relevant applications in the field of HCI along with various challenges faced by researchers. Affective computers are not a substitute for affective humans. But with a hope that affective computing will helps people in their day to day activities in more creative ways, the importance and usefulness of related technologies in various fields have been mentioned.

II. RECENT TRENDS AND ADVANCEMENT IN AFFECTIVE COMPUTING

Over the few decades of existence in the field of HCI, human interface to computers have seen tremendous progress. However, the quest of being able to interact with a computer, with the same degree of comfort and ease as in interacting with other humans, is still a fairly distant dream. This section illustrates recent advancements in HCI as the ultimate goal is to make user interfaces more effective and efficient for people to use.

In the late 1990, Dr. Cynthia Breazeal from MIT began work on Kismet ([4],[5])–a robot equipped with cameras and microphone that gave it an artificial sense of vision and hearing. It could also detect motion and uses its four cameras to estimate the distance of an object in its visual field. It is a sociable robot that engages people not only to communicate and interact with them, but also to promote its ‘‘well being” and could identify five different emotions-approval, prohibition, attention, comfort and neutral-from speech. For the robot to do the things at the right time in the right manner, the emotion system and the expressive motor system must work in concert. Kismet- once touted by the Guinness Book as the ‘World’s Most Emotionally Responsive Robot’ – is now an exhibit at the MIT Museum in the US.

Kirobo [6], a Japanese robot, blasted off for the International Space Station on August 2013. The robot, which can speak and recognize faces, is going to space with the primary mission of keeping astronauts company. The ability to process the natural language and respond to different facial expressions should also serve to make conversations more natural. Another of Kirobo’s mission aims is to see how or indeed if, machines like this can be a source of emotional support for people isolated over lengthy periods of time. Japan’s aging population means its citizens are living increasingly solitary lives and so researchers believe robots that can interact and show emotion could prove invaluable in the future [6]. On 6th September, 2013 (as per Times of India, Mumbai) Robot, Kirobo makes its first speech from the International Space Station during a session to check the success of its out-of –the-world journey.

Scientists have developed an interactive life-sized robot that acts as a stand-up comic and has already garnered many laughs from the audience during its unique performance in London, reported in article at Times of India, Mumbai on August 2013 [7]. The humanoid has been developed for human interaction as an interactive, customizable robot that can be programmed to communicate or entertain. Healey and Katevas[11] put the robot on a stage in London as an experiment in audience interaction - with a robot engaged in comedy. As the audience watched the robot tell jokes, cameras tracked facial expressions, gaze and head movements of the audience. These human reactions to the robot's performance were compared to responses to two human comedians that had performed before the robot went on stage. Hence evidence indicates that lots of new advancements have been considered for the interactive engagement of humans with computers in different forms.

The world’s first personal robot capable of understanding emoitions, Pepper is a pro-active robot with algorithms that allow it to understand his surroundings and react accordingly (DNA newspaper, Mumbai 16th June, 2014). Founder and CEO of Aldebaran, Mr. Bruno Maisonnier believed that the role of robots will be as kind and emotional companions to enhance our daily lives. To address further the role of HCI in various domains, following section has been devoted.

III. APPLICATION OF THE AFFECTIVE COMPUTING

The HCI design studies a human and a machine in conjunction, therefore it is socio-technological and involves how people both as individuals and in groups, are affected by the computer and how they use the computer and other communication systems [8]. HCI is used in many spheres of our daily lives. Some domains are discussed below:

A. For Disable People

HCI plays a very important role in assisting and addressing the needs of the disabled. A special kind of interface is required for them when compared to ordinary people. Major attributes of such interfaces include user friendliness, efficient and more effective ways to interact using gesture, voice, facial expressions, and head movements [9]. Many other devices could provide the special interface. The term interface, from the user’s viewpoint refers to “the whole system.” For example, the virtual keyboard is an on-screen representation of a standard keyboard and as long as the person can control a mouse, trackball, or other pointing device, he/she can mimic keystrokes for virtually any application. Similarly, webcam-based devices could track facial features to gather the user’s motion and do not need any headset for the users, resulting in minimal third party assistance ([10], [11]). Eye tracking is used frequently for usability analysis purposes [12]. An eye tracking system consists of one or more cameras that focus on one or both eyes and record the users’ eye movement. The facial mouse [11] is a mouse emulator system based on the facial movement of the user. A webcam is placed in front of the user, focusing on the user’s face. A motion extraction algorithm, which is user independent, is used to extract the facial motion from the respective recording. This motion is used to move the mouse pointer that is controlled relatively similar to standard mouse devices. The use of affective computing plays an important role in understanding the individual needs and providing accessibility to the disabled for participating in substantial life activities.

B. IN E - LEARNING

In the past decade, e-Learning has evolved from Computer Aided Instruction, through Intelligent Tutoring System, to Smart Classrooms, and to Mobile Learning (e-Learning with mobile devices). Today, e-Learning becomes heavily learner-centered, emphasizing pervasive and personalized learning technologies [13]. The influence of emotions on learning is still a new area. Recently literature ([13], [14]) has begun to espouse the central role of emotion to any learning endeavour and outcomes, especially in online learning. Continuous and increasing exploration of the complex set of parameters surrounding online learning reveals the importance of the

emotional states of learners and especially the relationship between emotions and effective learning [14]. So both put together seem to be a good model for e-learning, as negative emotions like boredom and anger reduce cognitive effort and in consequence hinder the achievement of learning goals. These findings underscore the important effects of emotions on learning.

C. IN AUTOMOBILES INDUSTRY

As per a news piece in DNA, Mumbai, (dated 6th August, 2013) it is known that the total size of global industrial automation market has reached $152 billion and there is a 6% annual growth in the automation industry since 2003. In this industry, machine interfaces are becoming smarter each day, like, they offer not only support to drivers as navigation aids and collision avoidance alerts, but they also compete for drivers' attention with potentially tragic consequences in sensing the driver's state of mind like when he is frustrated or drunk or wants to a take nap so, HCI could enhance his interactions in real time platform for safety critical domains. Google's self-driving cars [16] which are more automated and self-sufficient than all other cars are a good example of a smart interface. The technology takes the form of a modular kit that can be integrated into any vehicle. It is capable of autonomous navigation, and uses radar and laser beams to measure the vehicle's surroundings, allowing it to navigate almost autonomously. Obviously, this is not an easy task; even the best GPS system isn't enough to pilot a driverless car 24*7. When it's the autonomous vehicle's turn to drive, it compares the data it is acquiring from all those sensors and cameras to the previously recorded data and helps it differentiate a pedestrian from a light pole. It comes with some limitations as well, like driverless cars can't handle heavy rain and can't drive on snow-covered roads "because the appearance and the shape of the world changes. It can't figure out where to go or what to do" and how to handle "rare events" like encountering a stalled vehicle over the crest of a hill or identifying debris, in the middle of the road [17]. This is to be noted that human factors and HCI need to address these rare events in order to achieve goal of safety, efficiency and enjoyment to deal with capabilities and limitations of drivers [18]. Innovations of this kind will come to fruition, in the coming decade, and will form the foundation of another technological revolution [16].

D. ROBOT DESIGN

Robots are now no longer confined to the class of heavy industrial machines operated by skilled technicians in structured factory environments for welding and assembly operations. Robots are now beginning to function in unstructured, dynamic and uncertain environments such as homes, offices, hospitals, and museums. In such environments they need to interact with humans and modify their behaviour accordingly, in real-time. They may also be required to identify and track human position, respond to questions, display text information, and travel on command avoiding obstacles. Also, they will be expected to interact not just with skilled robot professionals but with people from all walks of life including children, housewives, hospital workers, etc. so that they can carry out social as well as physical and intellectual tasks without an expertise in robot operating skills [19].

For example, robots like AIBO [20], ASIMO [21], Keepon [22], AUR [23], 'Improv' Robots [24] are entertainment robots. AIBO (Artificial Intelligence RoBOt) referred to as the Entertainment Robot, marked a turning point for the world of entertainment in 1999 in Japan, when Sony introduced this electronic robot [20]. Another example is the mentor robots like 'Basketball Coach' [25] and 'Chips' [26]. A robotic basketball coach as described by Liu et al. [27] monitors the physiological signals (heart rate and galvanic skin response) of people while they shot baskets. Depending on how anxious people seemed to be, the robot altered the game's level of difficulty. The researchers found that the style of interactive robots has an essential role in many ways like entertainment, engagement, etc. Therefore the field of affective computing plays an important role in the process of designing interactive robots.

E. SMART COLLABORATION AND ENVIRONMENT FOR BUSINESS

The next example belongs to the business arena where a smart environment is the prerequisite of dynamically changing business. Smart environment refers to physical spaces that encourage and enable better collaboration, more creative thinking, quicker decision making, and increased productivity. These environments will be equipped with a number of physical devices such as: large group displays, high-end analyst workstations, multi-touch tables, digital dash boards and ambient displays, telepresence and video conferencing equipment, multiple cameras and microphones, room and people sensors (motion detectors, acoustic analyser, body tracker, eye-tracker), room controls (software controllable lights and speakers) and biometric authentication. A few applications of intelligent and smart systems used in Naval Space and Warfare (SPAWAR) Systems, Navy Command Center of the Future (CCoF) ([28], [29]) are Smart Video Conferencing [30] and Intelligent Homes and Offices [31].

F. GAME DESIGN

Gaming industry has recognized the important role of emotions while developing engaging games ([32], [33], [34], [35]). Current focus in affective gaming is primarily on the sensing and recognition of the players' emotions, and on adapting the game responses to these emotions such as to minimize frustrations and manage their anxiety levels ([36], [37]). Consequently, there is an increasing interest in approaching game studies from the perspectives of HCI. Some researchers investigated novel forms of interaction to encourage collaboration and techniques of gathering user needs for designing educational games [38]. While other studies focus on the human behavior and physiological responses such as frustration [39] in order to better understand the interface design toward building affective computer through the study of computer game play. In terms of research in Game Usability researchers [40] attempted to generate Heuristics and usability guidelines for the creation and

evaluation of fun in video games by working closely with game developers. Literature findings ([41], [42]) reported that in computer game design for children, it is important to design games in such a way that the user has the freedom to explore, and the game should therefore be controlled using spontaneous, self - initiated and self-regulated act.

Many applications exist from the HCI perspective. As we create new forms of input, we need to consider whether these will replace well-established methods of interaction or not. Traditional interaction forms may be superior in terms of performance and may be preferred by users, or may produce a better experience, while new forms may provide additional capabilities for kids and disabled people. But there are certain potential concerns using affective computing.

IV. Potential Concerns with Affective Computing Technologies

As discussed, affective technologies enable a wide variety of interesting new and beneficial applications; however, technological power to sense, measure, monitor, communicate, influence, and manipulate emotion could also be used for harmful or otherwise undesirable purposes. But unfortunately every technology almost has a darker side and so does affective computing. This raises quite a few questions related to social, ethical, and philosophical concerns like:

A. *Human Privacy*

Emotional lives are highly personal and need not be concerned with the professional life. Hence affective information should be treated with full respect and with confidentiality and there are possibilities of misuse of this affective information. For example, a driver might like to have the car navigation system to sense and adjust accordingly its voice to his mood, which can increase driving safety; however, this may not be a good idea to share this data to the insurance company or for medical claim, who might raise the price of the person's policy if they find out that he frequently gets behind the wheel when angry. This scenario [15] explores the possibilities that people, in general do not want to disclose their affective states, and if a computer was expected to show its internal state constantly then it could become very annoying. The question that arises is -What is the best balance for expressing affective state and on what factors does this balance depend? Making the computer decision making process use emotion is a delicate matter. A balance should be found where the positive effects can be utilized without slipping into irrational behaviour.

B. *Inaccuracies and False Impression*

Another concern is the accuracy with which humans interact with the machine, which depends on many parameters like context in which end user is working, state of mind, working environment, etc. Sometimes an end user can expect that a machine will probably never be perfect at knowing whether or not you are lying or what is your exact state of mind? Manipulation of emotions, and moods could be possible by using some external stimuli or may be in the form of social constraints or by having drinks, or chocolates, etc. Controlling the internal feeling may be ethical as per the norms of the society but by understanding the exact state of mind of the end user while interacting with the computers and getting access to their affective state, there is a possibility that system (intelligent interface having emotional capability) might try to control them.

C. *Expectations from End Users in Interfaces*

The notion of computers adapting their behaviour according to the perceived emotional state of the user is something new to most people. Many find it difficult to relate to this notion, given the notion of a computer as a pure machine. In order to get a feel of this space, including people's perception of such a development a survey was conducted. The survey focused on the aspect of "set of behaviour cues you would expect from your computer system at any point of time assuming it can recognize your emotional state when you are reading or composing a mail, when you are browsing the net, etc ". This survey had four sections. The first section captures the demographic profile of the respondent. The second section deals with his/her usage pattern of computers and the internet in day to day activity. In this category, options related to type of applications being used on daily basis are given to the respondents so that they could select from the list. The third section of the questionnaire comprises the 'frustrating experiences and problem people (end user) encounter while interacting with the computer'. In this part of the survey we want to know about "anything that frustrates end user while interacting with the computers". The last section of the survey is based on the type of expectations of the end user from the system. The interest is to know that if the system (computers) were able to recognize the emotional state and mood of the end user while interaction and to understand the expectations of the end users from the system (computers). Survey was held among 104 people consisting of students and employees of varying background. 24% (of the total) is female and remaining 76% (of total) are male candidates. The age profile of 82% (of total) belongs to the range in between 16 to 30 years. 52% (of total) are from technical background while remaining 48% (of total) are from academics and others. It is seen that many people use computers at their workplaces and their homes on a daily basis. The same is true with the Internet usage. The fig. 1 shows the detail of the same and fig. 2 shows the complete distribution of usage pattern.

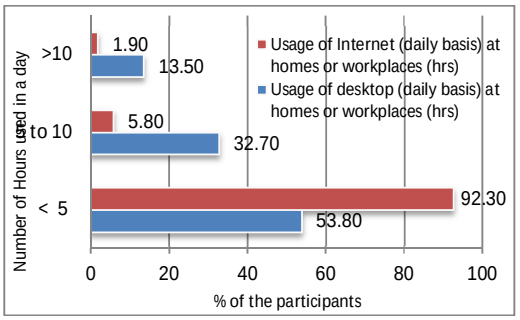

Fig. 1 % distribution of the usage of computers and Internet by people

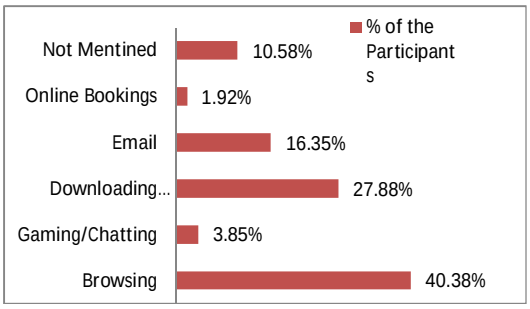

Fig. 2 % distributions of the usage pattern when People feel frustrated if any problem encountered

It is found that most of the times people use computers for email, Internet, word processing and presentation, chatting and for the development of applications. People found that sometime system does not respond the way it should be (it could be due to slow network, hanging various applications, non interacting or limited options, hardware and software problem, etc.), due to which they feel frustrated. Total of 40.38% people say that when they browse Internet they feel frustrated when any such problems occur and they can't proceed further. In such instances, how would the end user react?

Our survey says that 47% (of total) of the end users feel angry at their desktop when encountering such problems while interacting with computers (desktop). 51% (of total) feel helpless and 2% (of total) don't react at all if such problem occurs. The ability of the desktop to recognize end user's emotional state while interacting is the key area of our research. 61% of the respondents feel that the system (desktop) should have the ability to recognize their emotional state for enhancing their interaction. Only these respondents had any useful views regarding the behaviour cues and expectations from their computer system based on recognizing their emotional states and out of them hardly 1% could respond with anything practical.

Some of their views are given below:

While reading / composing a mail, the following options could be useful:

- Automatically rate which mail is the most important to read, according to the priority of end user.
- Play music according to end user's mood.
- Distracting pop-ups, scrolling text, moving graphics etc should be handled properly based on the emotional state of the end user.

While browsing Internet and based on the emotional state of the end user, the following options could be useful:

- If a page takes longer than the usual time to load, then a message could be displayed saying that it is taking unusual long time to load, needs to remain calm and patient.
- Page should either come as soon as end user click or it should give some beautiful pictures instead of giving boring error message.
- Study the end user preferences and show only relevant ads.

From the above discussions and findings, it seems that colour and typeface are among the syntactic properties that can be modified to suit the emotional state of the user. Use of audio and other cues in HCI can also be included in this. Level of detail in messages produced, prioritization of messages, nature of help that is relevant, etc. are some of the other aspects that can be tuned. This requires forming an abstraction of the HCI mechanism, and defining them with emotion as a parameter. Some of the respondents don't want the system to have the ability to recognize emotions and react accordingly. According to them interacting with the system has nothing to do with the emotional states of the users. In a way, these results are not surprising since most users currently treat a computer system simply as a machine and hence unable to visualize the possibilities arising out of emotion recognition. It is also possible that a behaviour that a human friend may show may be considered unacceptable or may not produce the same effect when expressed by a machine. A computer that can recognize people's frustration should have multiple strategies for responding. As mentioned by Picard, can it let the user to select from all these strategies the best one, or will the details of these strategies need to be hidden for them to work, so that user does not feel manipulated? Thus this is definitely an area for active experimentation and is a significant challenge in addressing these concerns.

V. Conclusion

The field of affective computing has developed significantly in recent years. There is evidence that emotions are an active part of intelligence, especially perception, rational thinking, decision making, creative thinking, etc. Many applications related to affective computing in learning, entertainment, social development, etc. are emerging. Giving computers affective abilities in the various fields is an effort to bring balance and reason to their logical skills. The known fact is that every technology seems to arrive with its pros and cons. This paper raised several concerns of affective technology which includes breaches of privacy, inaccuracies in recognizing affects and expectations from them. The demand of affective computing should pick up the shortcomings and it is anticipated that in the next future, this will be a standard features for computer user or to HCI technology. In this aspect Innovation, education, and research would provide holistic perspective and complete understanding of related disciplinary frameworks and paradigms. Affective computing might also widen the application spectrum of computers in general and make it more effective.

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