

Affective Computing for Enhancing Affective Touch-Based Communication Through Extended Reality

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Abstract. Nowadays, affective computing (AC), especially affective touch, plays a significant role in the next generation of human-computer, computer-computer and human-human communications. This is because it allows more senses in human communication to be included simultaneously and interactively, enabling innovative communications both between computers and humans, and between humans and humans. In this paper, we discuss applications and methodologies that researchers, including the author, have recently achieved by utilizing affective computing, affective touch, and extended reality (XR). Our purpose is to review our research work experience and other state-of-the-art results and propose a line of research to use these results in a future work or application. To begin with, we give an overview of extensive works using affective computing and emotion recognition systems for social media. After that, we explore some recent interesting research works about affective touch. Next, augmented reality (AR)-based applications using affective touch communication and affective computing are presented. Then, we review recent virtual reality-based systems using affective touch communication and affective computing. By understanding these approaches for extended reality-based applications with affective touch communication and affective computing presented recently by leading researchers, we believe that it will encourage sustainable advancements regarding human interactions in an integrated cross-disciplinary area.

Keywords: Extended reality · Augmented reality · Virtual reality · Force Jacket · Affective computing · Affective touch communication · Multimodal communication

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S. Misra et al. (Eds.): ICCSA 2019, LNCS 11620, pp. 351–360, 2019.
https://doi.org/10.1007/978-3-030-24296-1_29

1 Background

In this decade of 21st century, there are quick growth of internet as well as emergence and diffusion of smartphones that allow us to effectively deal with a large amount of unstructured data like images, audio and video. Cooking different types of data together is one of the core concepts in extended reality in order to obtain the most realistic or virtualistic user experiences. Recently, extended reality (XR) has become an extremely emerging field in computer science, computational science, and emotion recognition. Extended reality itself refers to the whole spectrum of reality-virtuality continuum, consisting of the core features regarding two majorly immersive technologies named augmented reality (AR) and virtual reality (VR). At the same time, emotion is a mental state and fundamental to human multimodal communication, human experience, and influencing cognition. It is very important for human to communicate. Therefore, affective computing (AC) for recognizing emotional information and human multimodal communication is recently an important research field in computational science, cognitive science, and neurosciences, from human perception of affect to robot perception of affect [1]. This is because it is able to recognize, interpret, and simulate human affects in many uniquely ways, including affective touch communication. At the same time, extended reality is an emerging development referring to all computer-generated environments that mix the real and virtual worlds created by machine and wearables or create an entirely immersive experience for the user interactively. Generally speaking, extended reality includes augmented virtuality (AV), augmented reality, virtual reality, and everything in between real and virtual worlds [2]. In recent years, it has experienced tremendous growth enhancing today's neighboring-fields, including affective computing. In fact, there are recently existing literature reviews on the topic of affective computing [3–5]. For example, Wu et al. [3] surveyed, in 2016, affective computing works in education for understanding the correlation between motivation, emotion, and learning performance. Moreover in 2017, Poria et al. [4] reviewed affective computing methods for unimodal affect analysis, focusing on the use of vision, text, and audio data. They surveyed affect recognition-based techniques for fusing information from various modalities. Also in 2017, recent literature review of the mobile affective computing was done by Politou et al. [5], focusing on affect recognition domain based on mobile-phone gained data. These are mobile-phone usage and mobile-phone embedded sensors. They discussed the exciting research trends towards affective computing on affect recognition from mobile-phone modalities. However, to our best knowledge, most existing literature reviews lack a detailed explanation of state-of-the-art in recent extended reality-based applications enhancing with affective touch communication and affective computing, which this survey aims to contribute and address.

In this paper, we discuss recent methodologies that researchers have presented extended reality-based applications enhancing with affective touch communication and affective computing. The aim of ours is to review our research work experience and other state-of-the-art results and present a way of research to use these results in a future application. This paper is divided into three parts. First, we review existing works of affective computing and emotion recognition systems applying in several

related-fields, such as social media and affective touch. Second, we introduce augmented reality-based applications using affective touch communication and affective computing technology. Also, in this main part, virtual reality-based systems that relate to deliberately influence affective touch communication, emotion and affective phenomena are discussed. Finally, we give a proposal for enhancing affective touch-based communication through extended reality.

2 Affective Computing Systems

In this section, it is divided into two subparts. The first subpart is affective computing and emotion recognition systems in social media platforms. The second subpart is about affective touch.

2.1 Affective Computing in Social Media

In recent years, with the rise of social media (e.g., YouTube, Facebook, and Twitter) for online digital marketing and political views, affective touch communication and affective computing works have progressively developed from existing unimodal analysis to more complicated types of multimodal analysis. Therefore, extracting sentiments and emotions from conversations and writings published online in social media is useful for many reasons such as preventing the spread of "false news", sometimes so called "fake news". But it is not easy for recognizing emotions in the context of the text from any social media platforms. According to Kratzwald et al. [6]'s work from ETH Zurich and National Institute of Informatics which was presented recently in 2018, they developed an affect computing system using deep learning technology in social network platforms. They used bidirectional long short-term memory networks (LSTMs) that are able to predict using the data from texts of different lengths, so they can classify news into non-factual and factual for decision support. Thus, by utilizing affective computing and identifying highly polarizing language, their method can help and support people to recognize the spread of "false news" in social media platforms. Furthermore in 2018, Zhao et al. [7] presented a research work for predicting and assuming the individual image emotion perceptions for every viewer in social media platforms. By using rolling multi-task hypergraph learning (RMTHG), they can integrate the elements that possibly influence individual emotion perceptions of images into a learning algorithm for optimization automatically. Their experimental results illustrated that individual emotion classification can be achieved. In addition, Dai et al. [8] proposed an affective computing technique for emotion recognition on vocal social media, focusing on WeChat, based on a LS-SVR (Least Squares SVR) model. They aimed to turn the propagation characteristics of emotions and affective computing into a PAD (Position–Arousal–Dominance) value estimation exercise in three dimensions.

2.2 Affective Touch

Affective touch, especially human affective touch, brings a very great amount of data about distinct emotions in affective computing field. There are recently interesting research works about affective touch. For instance, in 2018, Masson et al. [9] built a space of observed socio-affective touch experiences in many dimensions, called the Socio-Affective Touch Expression Database (SATED). This representational space contained a large range of complicated non-social and social touch interactions. They computed neural similarity values in different eighteen regions of interest (ROI) from following regions: pain, motor, the theory of mind, somatosensory, and vision regions using correlational multivariate pattern analysis algorithms. Pain, the theory of mind, somatosensory, and vision regions represent the socio-affective touch. Next in 2018, Heraz and Clynes [10] studied detection and recognition of various emotions. These emotions included awe, anger, love, desire, laughter, fear, hate, grief, and even no emotion. They then conveyed by affective touch through force-sensitive screens using feature selection and machine learning methods. In this way, they can recognize emotions for precision, calibration, and normalization from the coordinates of person' fingertip touches, number of touches, amount of force, and skin region for affective touch. In addition, affective touch communication can convey uniquely messages-is inexistent in a new form of digital media and interactive digital multimedia applications, as discussed by ours in [11]. According to the concept of touch communication in interactive digital multimedia, an affective tele-touch haptic device was built in 2017 by Cabibihan and Chauhan [12] from Qatar University and National University of Singapore for sending affective touch from a user to another one remotely and entertaining people who are watching movies or films at home. Figure 1 illustrates this overall concept of affective tele-touch haptic device. Therefore, several commands for warmth, tickle, and vibration were transferred remotely to this tele-touch device with a galvanic skin response sensor and a heart rate monitor at the subjects' forearm, while a user is watching emotion-eliciting film. According to our discussion about the research works of affective touch in this section, it is possible to integrate the affective touch into other new technologies such as augmented reality. Therefore, in the next section, we will discuss about extended reality-based applications using affective touch communication and affective computing technology.

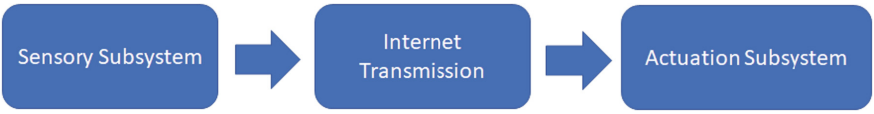

Fig. 1. An overall concept of an affective tele-touch haptic device developed by [12] from Qatar University and National University of Singapore in 2017.



Fig. 2. Our integrated system [15] using augmented reality and enhancing affective touch communication for helping and assisting people with disability.

3 Extended Reality Systems with Affective Computing

Since extended reality refers to all real-and-virtual combined environments, including augmented reality and virtual reality, this section is divided into two subparts. The first subpart is augmented reality with affective computing and affective touch. The second subpart is about virtual reality with affective computing and affective touch.

3.1 Augmented Reality with Affective Computing and Affective Touch

Augmented reality is the blending of interactive digital elements to augment the real world, sometimes called physical world. In recent years, there are emerging research works about augmented reality-based applications enhancing with affective computing and affective touch communication. For example, a real-time system was built by Roberts [13] in 2018 utilizing affective computing for proxemic interactions in augmented reality (called it in their paper as mixed reality (MR), a largely synonymous term). Using Magic Leap One as the interface interactively, this augmented reality-based system can be controlled by indicating emotions, which are compatible with affective integrations of tonal analysis and facial micro-expressions. This user interface visualization element of this system can leverage the features of augmented reality by identifying a spatial component to interactive interfaces. Also, in 2017, Datcu and Rothkrantz [14] presented interfaces that can help creating emotional awareness and situational awareness for car driving simulation using augmented reality and affective computing. Their research contribution is to solve some specific problems regarding integration of affective computing and augmented reality for supporting vehicle driving. By using augmented reality, situational awareness can be created. At the same time, by using affective computing, they can build emotional awareness. By integrating these two technologies, it can allow affect-driven remote collaboration for car driving simulation in augmented realty. In addition, in our previous research work [15] in 2016, an integrated application using augmented reality enhancing affective touch communication was built to assist disabled people. By using augmented reality, a cardboard

glass, Google Glass-like, was developed to support disabled people with hearing impairment to have a good immersive experience for geometric visualization. As depicted in Fig. 2, by using affective touch communication, a hugging wearable tool, called T.Jacket, was utilized to support people with disability for hugging their loved one from different locations using airbags, 3x Teensy 3.6, computer, arbotiX, serve motor, and air compressor. This affective touch communication can be done by reproducing a touch sense between two people remotely, though artificially. In this case, it is about hug. By combining augmented reality and a wearable jacket for affective touch communication, this can allow disabled people having a new human-computer interaction experience. Nevertheless, this integrated concept is not only limited to utilize in only augmented reality-based applications, but it also can use in virtual reality-based applications. We will discuss this issue in the next subpart.

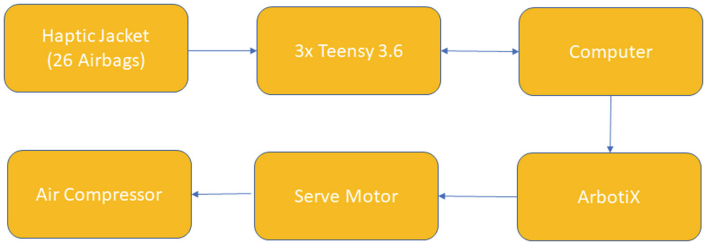

Fig. 3. A technical concept of the Force Jacket developed by Delazio et al. [16] from Disney Research and MIT in 2018 through affective touch

3.2 Virtual Reality with Affective Computing and Affective Touch

While augmented reality is an interactive experience of a real-world environment where the real-world objects are augmented by some immersive information in the virtual world, virtual reality is an interactive experience taking place within a totally immersive virtual world. Similarly to ours [15] in some issues, although presented more recently, Force Jacket was developed by Delazio et al. [16] from Disney Research and MIT in 2018 for the multimodal communication techniques through affective touch using virtual reality technology to help people in communication and entertain people interactively. Figure 3 shows some examples of virtual reality games of the Force Jacket. This pneumatically-actuated jacket was built from an array of airbags and force sensors for haptic experiences. After wearing this jacket, it can directly give force and vibrations energetically to the upper part of body by reproducing an artificial hug, an artificial punch, and an artificial snake moving feeling across the user's body while wearing this pneumatically-actuated jacket. By integrating affective touch communication into virtual reality, it can enhance new immersive experiences and entertain people with virtual reality games.

Also, Ontiveros-Hernández et al. [17] presented insights towards a model using virtual reality and affective computing inducing emotional states in human activities for improving training and learning. This affective computing work was further used to

develop the virtual reality-based intelligent tutoring work [18] of Pérez-Ramírez, presented in 2016, using in the classroom classes and camp training. Besides in 2017, Leon [19] proposed an affective distant learning model with the use of online illustrations in a virtual reality world, called avatars, with realistic facial emotional expressions. These expressions are compatible with the emotional state of the real user. Emotional facial expressions of the user are recorded and then analyzed beforehand. The affective user interface was built, and therefore this can utilize avatars as stand-in for users, such as learners and students, remotely by processing emotional facial expression. In addition, Ahmed et al. [20, 21] designed virtual reality-based affective symbiosis, the connection between the human and computer-generated affective virtual information, with biosensors, haptics, and emotive agents. In their virtual reality-based affective symbiosis, people can play an application of air hockey in a virtual world with affective agents. Their game included some features of haptic feedback and psychophysiological measurements. They then gathered the electrocardiography, heart rate variability, electro-dermal activity, and postural data and information for evaluating how these emotional things affected human behavior, physiology, and experience. Furthermore in 2018, Cooney et al. [22] recently identified possible pitfalls of affective computing in emotion visualization. They presented strategies for avoiding pitfalls of affective computing and minimizing the risks when misusing emotion visualization. Because affective computing can improve people's well-being by enabling computers to help making decisions and serving through awareness of people's emotions, by avoiding pitfalls of affective computing, their work can possibly enable emotion visualization to contribute to well-being of people which could solve several related-affective computing issues such as physical or psychological harm, disempowerment and miscommunication. Moreover in 2018, González-Franco et al. [23] from Microsoft Research developed a virtual reality-based system called "uncanny valley" using haptic stimulations. They generated an illusion of spatial touch for human perception of haptic feedback, and then they investigated human response to haptic stimulations of increasing fidelity using virtual reality as a perceptual testbed.

4 Future Directions for Affective Touch-Based Communication

As explained in the previous sections, it is quite clear that affective touch plays an essential role in the future of communications. This is since it allows more senses in human communication to be included simultaneously and interactively, enabling innovative communications both between computers and humans, and between humans and humans. At the same time, research about extended reality grows very quickly, as it effects and impacts on the daily lives of many people. Because of the overlapped areas of the affective touch-based communication and extended reality, we believe that future directions for affective touch-based communication would be indispensably linked to extended reality, especially augmented reality in the next decade. In the point of view of affective computing and emotion recognition, although virtual reality can also be connected to affective touch-based communication, augmented reality can be more profound in our opinion. This is because augmented reality

has a more unique capacity to amplify human performance than virtual reality, as suggested similarly by Apple CEO Tim Cook in [24]. A next possible reason is about virtual reality sickness which is about several symptoms of headache, nausea and even sometimes vomiting, when diving in a virtual environment completely and immersively. We also believe that our previous works about augmented reality [2], touch communication [15] and human hand tracking [25] could be more practical when applying in the context of affective computing and emotion recognition. Through this integrated cross-disciplinary context, it could be a big leap in human communication in the next decade to come.

5 Conclusions

Until today, the development of affective computing and extended reality-based applications is not a trivial task for computational scientists, psychologists, and cognitive scientists due to various complexities of artificial emotional intelligence and many challenges in using extended reality. This paper has discussed various state-of-the-art applications and methodologies that researchers, including the author, have recently achieved by utilizing affective computing, affective touch, and extended reality. We have given an overview of extensive works using affective computing and emotion recognition systems for social media. After that, we have explored some recent interesting research works about affective touch. Next, augmented reality-based applications using affective touch communication and affective computing have been proposed. Then, we have discussed recent virtual reality-based systems using affective touch communication and affective computing. We believe that, by perceiving the state-of-the-art concepts and methods for integrated extended reality-based applications with affective touch communication and affective computing achieved by leading researchers around the world, this would possibly advance the interactions that humans would have with modern innovations in an integrated cross-disciplinary area. Also, it will be of great value and good direction to the researchers in these related-fields of affective computing and extended reality.

Acknowledgments. This research presented herein was partially supported by a research grant from the Research Center, NIDA (National Institute of Development Administration).

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