Pervasive Social Computing: Augmenting Five Facets of Human Intelligence

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Abstract - **Pervasive Social Computing is a novel collective paradigm, derived from pervasive computing, social media, social networking, social signal processing, etc. This paper reviews Pervasive Social Computing as an integrated computing environment, which promises to augment five facets of human intelligence in physical environment awareness, behavior awareness, community awareness, interaction awareness, and content awareness. Reviews of related studies are given and their generic architectures are derived. The resulting architecture for Pervasive Social Computing is presented. A prototype is developed and examined in order to investigate the characteristics exhibited by Pervasive Social Computing.**

Keywords: **Pervasive Computing, Social Computing, Pervasive Social Computing**

I. INTRODUCTION

Recently, a new topic - Pervasive Social Computing is rising and attracting researcher's attentions. In [1] Kellogg from IBM thinks that social computing systems are likely to contain components that support and make visible social features such as identity, reputation, trust, accountability, presence, social roles, expertise, knowledge, and ownership. In [2] Jamison from Microsoft enumerates social computing examples such as social publishing (Wikipedia [3], etc.), personal publishing (Blogs, YouTube), social networking (Facebook, LinkedIn), social feedback (ratings/comments, e.g. Amazon, TripAdvisor), social tagging (Folksonomy), social bookmarking. In [4], Wang argues that social computing is a new field with a long history; its research crosses two schools of information technology and human and social studies; it is born for addressing new situations and challenges in the age of integrated cyber and physical worlds. In [5] Vinciarelli et al. argue that next-generation computing needs to include the essence of social intelligence – the ability to recognize human social signals and social behaviors like turn taking, politeness, and disagreement. In [6] Ben Mokhtar et al. argue that pervasive computing is moving towards Pervasive Social Computing with the pervasiveness of handheld devices and the enormous popularity of social networking websites. Pervasive Social Computing aims to take advantage of human social relationships, expressed as social networks, to enable the fulfillment of users' tasks on the move, ultimately promoting social interactivity. In [7] Dryer et al. use the term social computing to refer to the interplay between person's social behaviors and their interactions with computing technologies. In [8] Parameswaran et al. review social computing platforms such as Blogs, Wikipedia, P2P networks, file sharing networks, YouTube, etc. and observe that all of them share a high degree of community formation and user level content creation.

What is Pervasive Social Computing? Is it social networking for forming communities on the Internet? Is it social signal processing for recognizing human social behavior? Is it an evolution of pervasive computing only taking advantage of social networks? What is the journey towards Pervasive Social Computing? What are essential traits characterized by Pervasive Social Computing? Motivated by addressing those issues, we argue that each topic of social networks, social signal processing, pervasive computing represents one direction to Pervasive Social Computing; Pervasive Social Computing integrates the above dimensional computer intelligence to enhance people social experience in the capabilities of physical environment awareness, behavior awareness, community awareness, interaction awareness, and content awareness. This paper aims to provide a multiple view of Pervasive Social Computing and investigates their salient characteristics by examining prototypes.

The remainder of the paper is organized as follows. Section 2 presents notations related to Pervasive Social Computing. Section 3 overviews earlier studies related to Pervasive Social Computing. Section 4 presents a resulting architecture for Pervasive Social Computing. Section 5 examines a prototype for further investigating characteristics of Pervasive Social Computing in augmenting multiple human intelligence.

II. NOTATIONS TOWARDS PERVASIVE SOCIAL COMPUTING

Fig. 1 shows a logical view of Pervasive Social Computing. Five dimensional researches of social signal processing, multimodal Human Computer Interaction (HCI), social networking, social media, and pervasive computing converge at the point of Pervasive Social Computing. Its relevant notations are given as follows:

Pervasive computing changes the way people thinks about computers. According to [9, 10], pervasive computing makes computers vanish into the background. Pervasive computing allows computers available throughout the physical environment but making them effectively invisible to the user [11]. In the future, pervasive computing system must be everywhere, live in our real world, allow users to move around freely, and respond to

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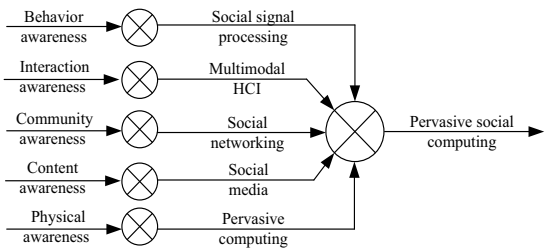

Fig. 1. A logical view of Pervasive Social Computing

changes in user requirements and operating conditions [12]. The early definition by Mark Weiser has been altered by different researchers. A common feature in pervasive computing is to compute physical context to enable the user to adapt to physical environment, e.g. location-based applications [13] [14].

Social media is considered as means of aggregating various media source via the Internet used to efficiently exchange and distribute information via social networks.

Social networking makes individuals into groups on the Internet. When it comes to online social networking, websites are commonly used. These websites are known as social sites. Social networking websites function like an online community of internet users, in which members can share common interests in hobbies or others. Social networking services allow users to manage, build and represent their social networking online [15].

Social context is the culture that people studies or lives in, and through this context people can contacts with each other easily [16]. In the given social context, members of the same social environment will often think in similar styles and patterns even when their conclusions differ. Social context has three major components [17]: societal structures (shapers), social processes (perceptions, attitudes, values), and common patterns of social behavior (social realities).

Social Computing is early defined to describe any type of computing application in which software serves as an intermediary or a focus for a social relation [18]. Dryer et al [7] uses the term to refer to the interplay between persons' social behavior and their interactions with computing devices. More recently, it has been defined as applications and services that facilitate collective action and social interaction online with rich exchange of multimedia information and evolution of aggregate knowledge [19]. Traditionally, social Computing is briefly described as computer aided group collaboration.

We define Pervasive Social Computing as a collective computer mediated means for augmenting multiple human social intelligences by detecting human social context, recognizing human social intentions, and further presents human with desired computations during the course of his interaction with the cyber and physical environments. Those social intelligences are categorized into physical environment awareness, behavior awareness, community awareness, interaction awareness, and content awareness. Ultimately social computing enriches and enhances human social experience.

Behavior awareness detects participants' behaviors, recognizes their behavior intentions, and presents the user desired services. Community awareness detects, searches and extends the user's social community based on his personal information. Community awareness extends users' social experience by presenting the user with all types of information interested by the user. Interaction awareness detects the patterns used by the user to interact with cyber and physical environments, and adapts to an appropriate interaction way to communicate with the user. Content awareness enables the user to aggregate media content so that it extends and enriches the user's social experience. Physical environment awareness detects contextual information on physical environment so that the interaction between the user and the computing system becomes pervasive and invisible.

III. Reviews towards Pervasive Social Computing

A. Behavior awareness

In [5] Vinciarelli et al. regard social intelligence as an indispensable and perhaps the most important facet of human intelligence. They argue that next-generation computing needs to include the essence of social intelligence - the ability to recognize human social signals and social behaviors like politeness, and disagreement in order to become more effective and more efficient. They survey recent advances in machine analysis of relevant behavioral cues like blinks, smiles, crossed arms, laughter, and design and development of automated systems for social signal processing (SSP).

We categorize social signal processing intelligence into behavior awareness. Human behavior is one major social signal which can be used to understand the social behavioral patterns of human. Behavior awareness is one method through which social signals can be effectively analyzed by machines in order to implement social computing. Behavior awareness can be classified into verbal behavior awareness and nonverbal behavior awareness. Verbal behavior awareness involves voice recognition systems, e.g. analyzing languages and prosodic cues, pitch, intensity, duration, laughter and voice quality. Nonverbal communication conveys all the messages other than words that people exchange in interactive contexts [5]. The contribution of these expressions to the understanding of what is being communicated is given in [20]. A generic architecture for social signal processing is derived as Fig. 2.

Behavior awareness can be modeled as a three-layer architecture. The upper layer uses sensors and other methods to capture verbal and nonverbal behavioral signals and pass them to the middle layer. The middle layer carries out classifying these signals into basic verbal and nonverbal classes. Nonverbal signals are further classified into facial signals, hand movements, posture, etc.

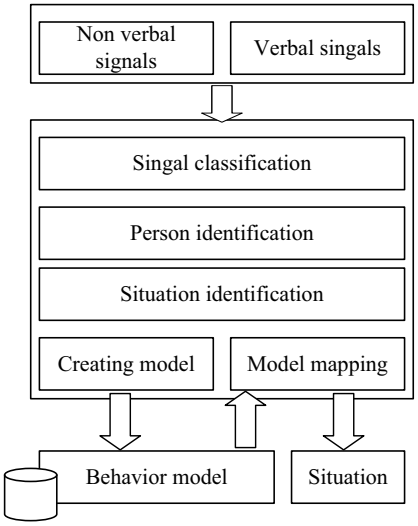

Fig. 2. A generic architecture for behavior awareness

The lower layer carries out identification of situations through model mapping and outputs the behavior situation. Situation examples are like argument and discussion. For example, the architecture first captures the nonverbal signals of a person, identifies it as hand movement signals, then it retrieves hand signal models from behavioral model archive. By comparing with these models it identifies that this person is in a discussion. The architecture outputs 'discussion' as the situation.

B. Physical environment awareness

Information related to the physical environment provides very important context for easing human daily activities. Derived from pervasive computing, physical environment awareness makes it possible to capture information related to the physical environment. For example, it is possible to obtain information like the temperature, lighting, noise level and humidity of a room through sensors. This contextual information can be used in an application which makes the user adaptable to a physical environment. In situations where environment is dynamic, user can carry a device which is aware of physical environment and make the environment aware of the presence of the user [17]. Traffic control is another example, in which traffic lights change dynamically by sensing the coming vehicles on the road.

In physical environment awareness, identification of features of physical environment can be done by using different sensors. For example, weather information can be measured through sensors. Since certain parameters in physical environment are static in most of the occasions, we can use pre-defined set of data to define characteristics of environments. Maps are kind of predefined data set commonly used for navigation purposes. A generic architecture for physical environment awareness is illustrated in Fig.3. Physical environmental aware applications can be broken down into three layers. They are physical environment sensing layer, physical analysis and computation layer and presentation layer. The analysis and computational layer structures contextual information and reasons them about answering 'where it is? what it is?'. Finally the resulting decision and data is presented to the presentation layer. Physical environment aware systems help human to concentrate on their daily life by diluting all kinds of the dominant techniques and letting computer technology fadeout of the user's vision.

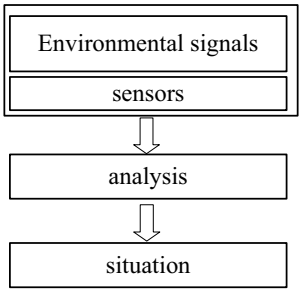

Fig.3. A generic architecture for physical environment awareness

C. Community awareness

Community awareness focuses on being aware of ongoing activities in communities [21]. A community can be defined as a group of people belonging to a particular physical area or a similar kind of interest group. Community awareness can be defined in two different ways. (1) Community awareness is about the degree that people generally know about each other, about social norms and people's different roles within the community and about issues that affect the community [22]. (2) Community awareness is about understanding the common interests of a community and providing applications that support these common needs.

One important characteristic of a community is sharing of common interests and preferences but not obvious goals [15]. Therefore community awareness is more general than awareness of a group. Community awareness is challenging because people in a community are neither organized as a group nor do they have any commonly identified goals. For computational purposes, community awareness can be interpreted in two different ways. (1) Facilitation of awareness among physically separated communities [22]. This type of applications use technology to bridge physically separated communities. '2nd Life' is one of the applications that recreate the real world inside the digital world. (2) Facilitating the needs of a community [15]. This is one of the challenging tasks in community awareness because it is necessary to find a way to collect data from the community before making any decision about the community. Current applications collect data by asking users to create their own profiles with their personnel information and interests. 'Tour Navigation' [15] is one good example

A generic architecture for community awareness is illustrated in Fig.4. It consists of three layers. In the upper layer, community-aware systems use user profiles as inputs. Based on user profiles they analyze and classify users into groups in the middle layer. Meanwhile necessary information on users is published among the user community. For example, if a person's interests are close to interests presented by group A, then this person is classified into group A and his/her information is published in group A. The lower layer carries out linkage of communities with social media and other user groups.

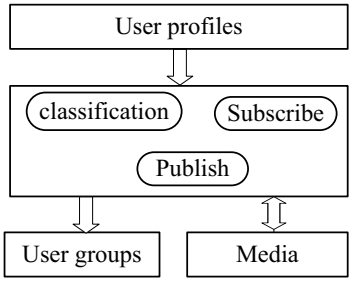

Fig.4. A generic architecture for community awareness

D. Content awareness

Social media websites have grown rapidly within the past few years [11]. This is mainly because web is rapidly shifting from content contributed by anonymous authors to a 'social' web in which almost all the content is linked to an author's name [12]. YouTube, Flickr, Myspace and Facebook are some of these famous social media websites. Social media provides a medium to present social computing. We categorize this kind of social computing into context awareness because social media websites are mostly used to host user generated content.

Social media can be grouped based on the different granularity of content creation and control [12]. There are three basic levels of granularity for social media, they are (1) Fine - Users have control over minimal units of media; (2) Medium - Users have indirect control over units of media; (3) Coarse - Users have limited control over particular blocks of content like photos.

When social media, i.e. content awareness, is integrated into objects of a society then it becomes Pervasive Social Computing. Content awareness can be modeled as a three layer architecture (Fig.5). The upper layer involves inputting various types of content such as multimedia, informative content, reviews, tags, etc. to the system. The middle layer carries out the classification of content. For example if you input a video file then it can be classified under the 'Sharing' category. Then the lower layer involves publishing content based on its category. For example, a video classified under "Sharing" will be published in multimedia websites such as YouTube.

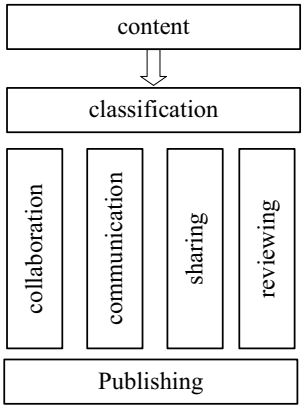

Fig.5. A generic architecture for content awareness

E. Interaction awareness

There are different human computer (machine) interaction techniques. Interaction awareness makes interaction between human and computers more intelligent. Interaction-aware applications need information about the user's interaction interests and should present the user with a desired interaction mode. Interaction awareness aims to grab and recognize the type of interaction-related information and adapt itself to the desired user's needs in interaction. A list of interaction types is given as follows.

- Visual based interactions will respond to human appearance in front of it. UBI-hot spot provides one example of visual interaction awareness [23]. In the applications, the large display alternates between a passive broadcast mode and an active mode based on face detection and other mechanisms.
- Gesture based interactions are gaining popularity nowadays. The project "6th sense" by MIT presents a good example [24]. Gesture based interaction enables natural hand movements to trigger actions in a computer [25].
- Touch based interactions enables the user to interact with the computer through touch screens or touch panels intuitively [26].
- Speech based interactions carry out voice recognition to analyze speech based instructions. Speech based interactions are considered to be more secure because this technique makes use of the creature character of human body to carry out identification. Since every body's creature character is unique and stable in a certain period, they are different from others and difficult to be imitated [27].
- Tag based interactions allow the user to interact through RFID tags. The UBI-hot spot uses RFID tags to trigger transitions between passive and active modes in large displays [23].

Different types of sensors can be used to capture those above physical interactions so that the computer system can adapt to the desired interaction modes. A generic architecture for interaction awareness is modeled into three layers (Fig.6).

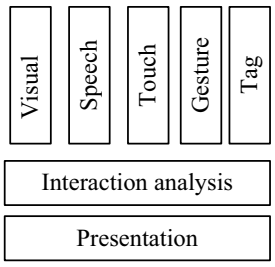

Fig.6. A generic architecture for interaction awareness

The upper layer consists of sensors to capture the interaction patterns. The middle layer carries out the interaction pattern analysis and determines appropriate presentations to the user. This layer can make the above five kinds of interaction analysis. The lower layer is the

application and presentation layer which provides the user with the customized interface to the context of the recognized interaction. For example, if a user interacts with a computer through a touch panel, the display may change its view to the touch-based interaction mode, and so on.

IV. Resulting architecture for Pervasive Social Computing

We defined Pervasive Social Computing as collective computer intelligence, targeting to augment multiple human social intelligences by detecting human social context, recognizing human social intentions, and further presents human with desired computations during the course of interacting with the cyber and physical environments. The desired computations consist of behavior-awareness, community awareness, interaction awareness, content awareness, and physical environment awareness (Fig.7). Those computer mediated awareness enhance the following five human intelligences.

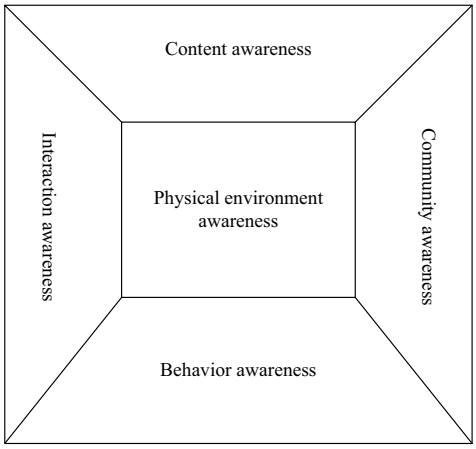

Fig.7. A conceptual Pervasive Social Computing architecture for augmenting five facets of human intelligence

A. Physical environment-oriented intelligence

People become more and more mobile. The surrounding environment changes quite often. User activities from a short tour in a foreign city to moving to a new place, becomes more time- and cost- consuming without a physical environment awareness. Through physical environment awareness, the user can get information on bus schedule, attracting city points, local news, etc. anywhere and anytime. In a business perspective, the user can access his/her desired devices indispensable involved in his/her activity course, e.g. available printers nearby, available displays nearby for showing pictures. State of the art of pervasive computing is making physical environment awareness real.

B. Behavior-oriented intelligence

Human behavior is one of the main ways of communication since old ages. But the computerized systems are still not able to capture these valuable set of data which adds quality and completeness to a conversation or an action. So the behavior oriented awareness aims to recognize behavior signals expressed by the user during his/her interactions with human or computers. For example, person's mobile song player can adapt to the users' current behavior pattern and can generate music suitable for user's current mood.

C. Community-oriented intelligence

The virtual community via the Internet plays an increasing important role in aggregating information. Community awareness is bringing the user community-oriented intelligence to extend his/her social networks in need of special help or in search of information.

D. Content-oriented intelligence

The Internet is moving towards Web 2.0 because it receives amounts of contribution by the user themselves [28]. Content awareness plays an important role in identifying and distributing the right content to the right users through content sharing websites.

E. Interaction-oriented intelligence

The link between computer and the user is the interaction. Typing on keyboard or working with mouse are the most common interaction methods to make human instructions understandable to computers. With the advancement of technology, interaction is no more restricted to keyboard or mouse. Interaction awareness brings the user intelligence for caring about various manners of interacting with advanced computer systems.

V. Prototype examinations

The SmartEye prototype [29] is examined in this section. It has been implemented by us at the writing time. We revisit it to investigate the characteristics exhibited by the Pervasive Social Computing architecture so that we deepen the understanding of Pervasive Social Computing. It is depicted as follows. Alice is on a business trip. Before she leaves for the trip she needs to secure her home. Also her sister Liza, might come to her place to spend couple of days. Alice decides to use SmartEye to solve all these problems. She first configures all the electronic appliances at her home to the system. And then she configures door sensors, door locks and security cameras to the system. After Alice leaves, Liza comes to Alice's house. At the door step the sensor detects Liza and sends an alert to Alice's mobile phone. Alice remotely sees Liza and opens the door and turn on the living room lights with her mobile phone.

Table 1 summarizes the resulting examination. SmartEye employs three social computing capabilities to relieve Alice of the trouble of safe guarding her home. SmartEye employs community awareness to enable Alice to group family members to share the configuration of home devices and view of the home plan. SmartEye also employs interaction awareness to enable Alice to do system configuration in her home computer and in her mobile phone. SmartEye also employs physical environment awareness to sense physical contextual information, e.g. sensing Liza's proximity to Alice's home so that it sends an alarm to Alice on time. The alarm can also broadcast to all family members in term of community awareness.

TABLE 1. PERVASIVE SOCIAL COMPUTING IN SMARTEYE

Awareness	Use cases	Explanation
community awareness	group-based home security, etc.	system broadcasts the alert to home members.
interaction awareness	mobile monitoring, home monitoring	system enables the user to use different HCI to interact.
physical awareness	home security,	system detects the presence of someone close to home.

VI. CONCLUSION

Many technologies are evolving into enhancing human intelligence. We generalize a collective term Pervasive Social Computing to describe this trend. That is, Pervasive Social Computing leads to augment five facets of human intelligence such as behavior awareness, physical environment awareness, interaction awareness, community awareness and content awareness. To have an explicit understanding of Pervasive Social Computing, we first analyze the advanced course of Pervasive Social Computing and its bonds with other emerging computing technologies. Then we review its associated computing technologies, each of which addresses one facet of Pervasive Social Computing. Their generic architectures are derived as well. The resulting architecture is given in the support of behavior, physical environment, community, content, and interaction-oriented human intelligence. One prototype is examined in order to investigate characteristics exhibited in Pervasive Social Computing.

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