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Document Version
Accepted author manuscript

Published in:
HCI in Business, Government and Organization

DOI:
10.1007/978-3-319-58481-2_10

Publication date:
2017

License
Unspecified

Citation for published version (APA):
Qin, X., Tan, C. W., & Clemmensen, T. (2017). Context-awareness and Mobile HCI: Implications, Challenges and Opportunities. In F. F.-H. Nah, & C.-H. Tan (Eds.), *HCI in Business, Government and Organization: Interacting with Information Systems* (Vol. 1, pp. 112-127). Springer. https://doi.org/10.1007/978-3-319-58481-2_10

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Journal article (Accepted version)

CITE: Context-awareness and Mobile HCI : Implications, Challenges and Opportunities. / Qin, Xiangang; Tan, Chee Wee; Clemmensen, Torkil. In: *HCI in Business, Government and Organization: Interacting with Information Systems*. ed. / Fiona Fui-Hoon Nah; Chuan-Hoo Tan. Vol. 1 Cham : Springer, 2017. p. 112-127.

Context-Awareness and Mobile HCI: Implications, Challenges and Opportunities

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Abstract. Context-awareness endows mobile devices and services with the capability of interacting with users in an efficient, intelligent, natural and smart fashion. Consequently, context-awareness makes a significant difference to mobile HCI. However, the challenges brought by context-awareness to users of mobile devices are rarely examined in depth. In this paper, previous conceptions of context and their contribution to context-awareness in mobile HCI is scrutinized and a preliminary context-computer interaction (CCI) model is advanced to illustrate the interaction characterized by mobile context-awareness. Furthermore, the paper examines the limitations of information processing models and review alternative models of context. We also address user experience challenges related to the enablement of mobile context-awareness and highlight avenues for future research issues. Specifically, we found that context-awareness has been employed broadly in developing applications and services on mobile platform, has had a huge impact on mobile user experience, and has altered the interaction between humans and computers by giving the latter a more active role to play. The significance of context-awareness in the usage of mobile systems calls for systematic and in-depth appreciation of its impact on mobile HCI.

Keywords: Context-Awareness, Mobile HCI, User Centric

1 Introduction

Since the term "context-aware" was first proposed to describe the computing ability "of a mobile user's applications to discover and react to changes in the environment to discover and react to changes in the environment they are situated in" [1], it has received extensive scholarly attention across the fields of ubiquitous (or distributed and pervasive) computing, ambient intelligence, artificial intelligence, internet of things and user interface [2, 3, 4, 5, 6, 7]. More recently, due to advances in computing capabilities and sensor technologies, the concept of context-awareness has also found its way into a diversity of industrial applications like healthcare, mobile advertising, mobile learning, museum and tour guides, recommender system and virtual reality [8, 9, 10]. For this reason, Mobile Context-Awareness

adfa, p. 1, 2011.

(MCA) and its implications for context-driven service innovations has been acknowledged as a promising future in Human Computer Interaction (HCI) [11].

1.1 General Challenges of Mobile Context-Awareness(MCA)

Despite the optimism surrounding context-awareness, developers are confronted with challenges on how to capture, interpret, fuse and present contextual information in order to realize context-aware applications and services. Because smart phones yield rich contextual information through the facilitation of interactions with humans, the definition and categorization of context is very much dependent on the research objective, application domain and use cases, differing substantially from one situation to another. The forms of context-awareness also vary because the interaction between humans and computers is not yet clear with regards to the role of the former (active/passive) [12], the way of display contextual information (implicit/explicit)[13] and the level of automation. Furthermore, mobile context-awareness (MCA) also bring about challenges to user experience. These challenges to user experience (e.g., absence of control, distracting interruption, inappropriate feedback and privacy) not only constitute theoretical conundrums, but they also affect the actual user experience in practice [14].

1.2 Challenges for User-Centric MCA

MCA is a rapidly growing topic of interest for both academics and practitioners due to the increasing dynamism and richness of contextual information afforded by smart devices. Although context-awareness is intended to address issues in user experience caused by small screen size and ever-shifting context in smart devices, it is accompanied by its own side effects such as distracting interruptions, loss of control and privacy risk [14]. Consequently, there are calls for an in-depth appreciation of how user experiences (UX) are shaped by mobile context-aware systems.

In classifying the architecture of context-aware systems into five layers, [15] discovered that the bulk of research (237 articles in total) published between 2000 and 2007 tends to concentrate on layers associated with concept and research, network, middleware and application. A mere 6.7% of the published articles touch on user infrastructure and only 1.5% (3) discussed usability issues. Even though the few studies, which have examined the issue of UX for MCA (device and application), have put forth general guidelines for designing mobile context-aware systems (i.e., avoiding unnecessary interruptions, ensuring user control, guaranteeing system visibility, incorporating contextual settings, preventing information overflow, securing user's privacy, selecting an appropriate level of automation and tailoring content to match individual needs) [12],[14], there is a dearth of research that has been devoted to a dedicated scrutiny of how such systems can be designed from a user-centered perspective [16].

We begin the paper with the application developers' perspective on context-awareness, and gradually move towards a more holistic understanding of MCA that includes the user's perspective on MCA.

2 General Overview: Context and Mobile HCI

2.1 Context in HCI

Context either simplifies or enriches human-human interaction in different situations. Humans could predict the intention or behavior of another human based on contextual information (i.e., gender, culture and interaction experience). However, harnessing contextual information to enhance human-computer interaction remains an elusive challenge. Indeed, smart phones yield a diversity of contextual information from multiple sources, including those captured by sensors (e.g., brightness, gravity and direction), generated by users (e.g., activity logs, interactive behavior, sign-up information, sign in/out status and tags), inferred by computers (activities, hobbies, preferences). Although capturing contextual information via sensors has made significant strides over the past decade, providing users with meaningful and valuable contextual information on the basis of fusion, interpretation and adaption of raw information is still an uphill task. A common barrier in the appropriation of contextual information stems from the fact that there is no common, reusable model for context across these environments [17].

In its formative years, the notion of context is either conceived with select elements (e.g., location, time, people and objects in environmental, physical or social states) or described in general terms like situational information [18]. A widely acknowledged definition of context was put forth by Abowd et al. [18], who asserted that context entails "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". This implies that any information that characterizes the situation of a human in an interaction can be regarded as context. A number of studies have investigated the concept of context and refer to it as comprising location, identities of neighboring objects and users, environment characteristics such as season and temperature, date and time, user's emotional state, focus of attention, objects and people in the user's environment [1],[19,20].

Although contextual information is promising in enabling smart phones to communicate with humans in implicit and intuitive ways, context is an underutilized source of information in our computing environments. The interaction between smart phone and users is still below expectation due to the impoverished ability of users to provide contextual input to smart phones and the inability of smart phones to take full advantage of the interactive context. As a consequence, we have a limited understanding of what context is and how it can be employed in developing HCI systems.

To render contextual information more usable for developers of mobile applications and services, they are organized into various categories and levels. From our review of extant literature, we realize two predominant trends governing past conceptions of context. One is that the definition of concept varies considerably depending on the types of applications and/or services. Another is that most definitions tend to categorize context according to the entity that is relevant to the interaction between an application and a user, be it human factors, location (or place), application (or object) and physical environment [21].

The inclusion of communal activity, social context and user tasks in the definition of context [22] indicates that contextual information can also be produced through interactions between humans and computers (Fig.1.). Compared with the three well-recognized categories of context, interactive contexts are either created by users as inputs to HCI systems or need to be reasoned by computers as output of HCI systems. Given that the context associated with the utilization of smart devices fluctuates over time, we hence subscribe to an *interactional* view by treating the scope of contextual features to be dynamic so much so that the relationship between activity and context becomes cyclical in nature. In this sense, we depart from the *representational* view that assumes context to be a form of static information, which is independent from the underlying activities [10].

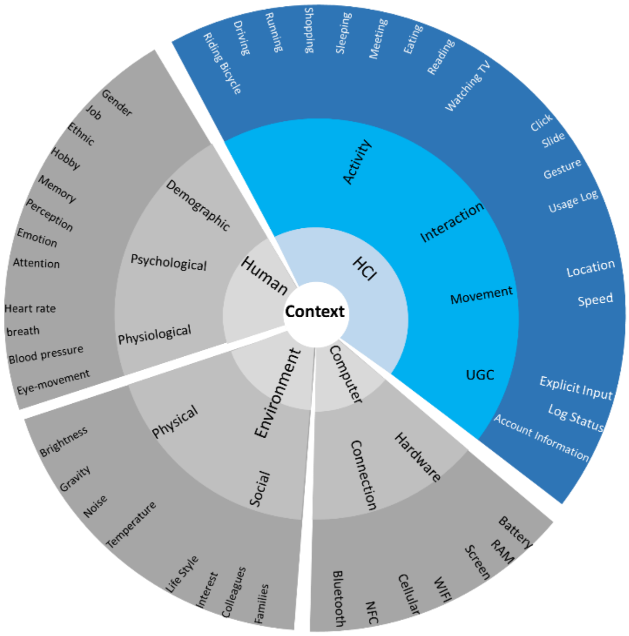

Fig. 1. The Contextual Information from HCI Perspective

2.2 Level of Context

In addition to efforts in categorizing context by entity, context can also be categorized according to hierarchical levels in HCI. [23] defined contextual information with three levels, namely low-level context (sensed), high-level (inferred) and situational relationships (presumed). Contextual information captured by sensor are considered as low-level context that is directly referred to a raw data. A sensor in context-aware applications is described not only a physical device, but also a data source that could be useful for context representation. Furthermore, sensed context can be split into three types, that is physical, virtual and logical sensors [23]. Higher level of context are abstract and usually inferred by fusing multiple lower level contexts [6, 7, 8, 9, 10].

According to predominant viewpoint of depicting HCI as a closed ‘information processing loop’, an appropriate conceptual basis for studies of HCI at different levels of context (cultural, organizational and social context) is absent for modelling the contextual information in HCI systems [24]. Alternative theoretical models are required to interpret, design and develop HCI systems by deploying contextual information in an effective and efficient manner (this issue will be discussed in greater detail later in the paper).

2.3 Model of Context

Due to difficulties in theorizing the dynamism of context, researchers have turned their attention to the construction of context meta-models. A context meta-model is a generic description of the contextual environment on a meta-level that is not tar-geted towards a particular system [21]. Context-meta models thus serve as the theoretical foundation for deriving context-specific models for adaptive systems, guiding system developers in determining what contextual variables to take into account for a given context-adaptive system. While context-specific models denote relevant context for a given context-adaptive system, context meta-models express context on a generic meta-level and are not bound to any particular system.

Existing context meta-models are differentiated by their degree of abstraction from the real world context [21]. Although seven meta-codes are identified, there are still approximately 20% of variables not covered by any of the analyzed context meta-models. With the boom in smart phones and the diversity of mobile scenarios, contexts might emerge that cannot be covered by contemporary context meta-models.

From the perspective of HCI, a successful context meta-model should interpret the role of contextual information in HCI systems. Different levels and categories of contextual information should be integrated into HCI systems to support developers in making decisions about what contextual variables to include in a given context-adaptive system [21]. Specifically, context meta-models have to address the following issues:

- Contextual information consists of inputs that are captured by sensors and/or generated by users, thereby giving rise to issues of fusing different types of contextual information as input to make it meaningful for users as output.
- Contextual information as computer outputs involving both low-level (battery life, data connection and CPU speed) and high-level (activities such as running, sleeping and shopping, demographics such as gender, age and occupation and psychological status such as fatigue, happiness and depression) contexts, thereby giving rise to issues of inferring and gauging high level of contextual information based on their low level counterparts.
- Diverse modalities and types of contextual information are acquired through interactions between humans and computers (e.g., haptic, speech and vision), thereby giving rise to issues of integrating multiple modalities of contextual information in the design of HCI systems.

2.4 Active and Passive Roles of Human and Computer in Interaction

The MCA systems can be categorized into two types depending on whether computers play an active or passive role in executing inferred actions [13], [15]. For active MCA systems, computers execute inferred actions automatically and implicitly on the basis of contextual information. Conversely, for passive MCA systems, the sensed information and inferred actions will be presented to users explicitly, giving the latter an opportunity to decide on whether to execute the actions or not..

From the perspective of HCI, a core discrepancy between active and passive CA systems resides in the mode of interaction. Active CA systems adapt implicitly to users' activities by altering system behavior whereas passive CA systems explicitly presents novel or updated contextual information to users, allowing the latter to make decision on whether the system should continue or abandon the execution. In this sense, active CA systems are characterized by the implicit input and output of computers whereas passive CA systems are characterized by the explicit output of computers. While explicit interaction contradicts the idea of invisible computing, implicit interaction might be helpful in realizing the vision of ubiquitous computing in delivering intuitive interaction [13]. For example, implicit interaction happens when a smart phone activates mute mode automatically for a meeting event in the calendar. Conversely, an example of an explicit presentation may take the form of a smart phone prompting a user with information about the calendar event, thereby enabling the user to decide whether to mute the phone or not.

Although implicit and explicit interaction are well recognized as a method for categorizing CA systems from the perspective of HCI, attitudes towards them tend to diverge [12]. Active CA systems are deemed to be much more interesting as a sign of computing capability while passive CA systems permit users to control the interaction with computers.

3 Computing centric view of MCA

As a defining characteristic of ubiquitous (ambient, pervasive) computing, context-awareness is developed to acquire, decipher, fuse, infer and utilize the contextual information of a device in order to provide services that are appropriate (how) to select people (who), place (where), time (when), event (what) and intention (why)[15]. Consequently, much scholarly attention was paid to dealing with computing issues about concept and research, network, middleware and application of MCA [25, 26].

3.1 Value of Context-aware for Computing

When humans interact with humans, contextual information is usually deployed to help us effectively and efficiently convey thoughts and emotions to one another and react appropriately. Contextual information plays a pivotal role in helping humans to sense, decipher, reason, infer and predict one another in social networking [18, 19]. This ability of humans to acquire situational awareness was introduced into the field of computing to allow computers to easily sense and decipher the world of ubiquitous computing.

Supposedly, context-awareness enables computing devices to interact with humans in natural, implicit, intelligent, automatic and sophisticated ways like human-human interaction [18]. Context-aware computing promises a smooth and intuitive interaction between humans and computing systems. However, interaction between humans and computers fails to achieve that goal until the last ten years with the widespread penetration of smart devices.

3.2 Context-Awareness Application Development for Mobile HCI

"One of the most ubiquitous tools in the progress of context awareness has been the mobile device. Its enormous popularity and permeation into daily life—coupled with increasingly sophisticated hardware—has greatly increased the potential for context awareness in the world."[18]

Over the past decade, mobile devices, especially smart phones, have been widely adopted by a vast user population across the world. In many countries, more than 50 percent of population are mobile phone users. Nowadays, mobile phones are equipped with miniaturized sensors and enhanced computing capability, enabling smart phones to interact with humans in implicit, intelligent and human-like ways.

Technological advancements have transformed smart phones into a powerful tool with tremendous capacity for context-awareness. Firstly, human perceptual ability is extended with a variety of sensors like brightness, proximity, infrared and gravity, to name a few. Secondly, the diversity of smart phone usage generated dynamic, rich and complicated contextual information that is valuable for context-awareness [27]. Context-awareness is reflective of the 'smart' side of mobile phone and adopted commonly in mobile services and applications to enhance the user experience. To help developers harness contextual information, Google even released express API for context-awareness to facilitate the development of mobile applications and services based on Android platform.

3.3 Issues for MCA Computing

The major objective of technical efforts of MCA is to make sure that mobile devices could be aware of their contexts and automatically adapt to the changing contexts [15]. Technical efforts made to realize that vision include modeling, monitoring, capturing, filtering, processing and reasoning context, together with detecting inconsistency and resolution [25, 27].

A variety of context models are proposed to represent patterns representing the object of context, such as key-value, markup, graphical, object-oriented, logic-based, domain-focused and ontology-based context model. New solutions about multi-sensor data fusion is employed extensively to merge data collected by heterogeneous sensors to improve the accuracy of probabilistic inference systems by including context information. Event-driven and query-based paradigms of context-awareness were proposed to depict different kinds of context-aware. Usually sensors are employed to capture the physical contexts (e.g., light and vision, audio, movement and acceleration, location and position) while image recognition, machine learning and data mining are utilized to capture the virtual contexts (e.g., user preferences, emotions and satisfactions) [25, 28]. To preprocess and filter out the noise intrinsic to the original contextual information, centralized, distributed and hybrid paradigms are formulated [25].

Despite extensive scrutiny of the technical issues of MCA computing, there are still many issues worthy of further exploration, such as how to acquire novel types of contexts that may enable applications to be more adaptive to changeable contexts, eliciting contexts from user behavior and communities as well as incorporating schemas for detecting and resolving contextual inconsistencies [25].

4 User Centric View of MCA

A computing-centric view of MCA focuses on how to capture contextual information efficiently, decipher context accurately and adapt to the context automatically. To this end, mobile devices tend to play a more proactive and intelligent role in the interaction with users. Nevertheless, concerns over the role of humans in HCI, as characterized by MCA and relevant user experience issues, have also been raised [29].

4.1 Implicit and Explicit Interaction

An abundance of intricate contextual information are exploited in human-to-human communication, such as eye contact, facial expression, hand gestures, body language and even more profound social attributes like culture and religions. Implicit interaction helps humans to understand situations of different human beings in an efficient and effective way. Unlike human-to-human communication, the traditional human computer system lacks the ability to detect implicit information as humans normally do in face-to-face interaction [30, 31]. Consequently, conventional interactions between humans and computers are constrained by the latter's computing power and number of embedded sensors in harvesting and harnessing contextual information.

Context-aware systems are able to adapt their behaviors to given contexts without explicit user intervention, thereby leading to increased efficiency and effectiveness by taking environmental context into account [4]. Thus, context-awareness systems also modified traditional modes of HCI through the introduction of implicit interaction. Implicit human computer interaction (iHCI) is originally defined by Schmidt [31] as" *the interaction of a human with the environment and with artefacts which is aimed to accomplish a goal. Within this process the system acquires implicit input from the user and may present implicit output to the user*."

Capturing and making sense of contextual information is essential for the success of designing interactive systems that run on MCA devices [18]. Contextual information is captured implicitly, intention of user is reasoned and potential options are presented to users subsequently. Mobile context-awareness is changing the interaction between humans and computers in several aspects. Firstly, the interaction is shifting from *explicit* to implicit ways. Secondly, information sources are much more diverse, comprising both human and computer inputs [15]. Thirdly, computers (or smart phones) are shifting from a *passive* role of accepting, processing and displaying information to a more *active* role of acquiring, deciphering, inferring, recommending information and at times, executing action automatically. Fourthly, context-aware systems can sense other computers and users in surrounding situation that enables smart phones to facilitate cross-device and social interaction.

Changes brought by mobile context-awareness to HCI might lead to the following challenges: How can users be aware of the implicit contextual information inputted and captured by smart phones? How to exploit and integrate contextual information in multiple models? Should smart phones be more active in executing actions that are undertaken by human traditionally? How should human beings deal with an intelligent and emotional device with social networking ability?

4.2 Active and Passive Roles of Human and Computer in Interaction

The MCA systems can be categorized into two types by the passive/active role of computer in executing the inferring actions [30, 31]. In passive MCA system, the sensed information and inferring actions will be presented to user explicitly and user make decision on whether to take execution or not. In active MCA, computer execute inferring actions automatically and implicitly on the basis of contextual information and inference of potential actions of user.

From the perspective of human-computer interaction, one of the key differences between passive and active CA system exist in the way of interaction. Active CA implicitly adapts to a user's activity by changing the system's behavior, where passive CA explicitly presents the new or updated context to the user and let the user make the decision whether the system should continue or stop the execution. Passive CA system is characterized by explicit output of computer and active CA system is characterized by implicit input and output of computer. While explicit interaction contradicts the idea of invisible computing, disappearing interfaces and natural interaction, implicit interaction might be helpful in realizing the vision of a Ubiquitous Computing which can offer natural interaction [30]. A simple example of implicit interaction is the mobile phone that changes its profile to mute mode automatically in a meeting event of calendar. In the corresponding explicit context-aware application, the mobile phone prompts the user with information about the calendar event and lets the user decide whether the phone should be muted or not.

4.3 MCA and Intelligent/Adaptive User Interface

Context-awareness is also widely deployed in designing intelligent/adaptive user interface in order to circumvent problems caused by the increasing complexity of mobile human-computer interaction [32, 33]. Contextual information and inferred intentions of user are utilized to adapt user interface to users' behavior and actions. The screen of mobile phone might switch between landscape and portrait mode as user rotate the mobile phone, the layout of interface might also change accordingly. In this case, the gesture of mobile phone is sensed by gravity sensor and gyroscope and then utilized to adapt the user interface to the gesture.

5 Dominant Theories of user-centric MCA

Theory is critical to HCI as a research field [34]. It is generally accepted that the lack of an adequate theory of HCI is one of the most important reasons why progress in the field of HCI is relatively modest [24]. In contrast to the general agreement that current attempts to apply cognitive psychology to HCI are not very successful, there is little agreement on the most promising theoretical alternative.

Although the “information processing loop” proposed by the dominant theory of cognitive point of view provides a coherent description of the whole system of human computer interaction within the information processing framework and structures the problem space of HCI in a helpful way, its ecological validity is questionable for its inability to take into consideration the context that exist outside this loop [24]. Human computer interaction can only be understood within a wider context and any HCI model needs to provide an appropriate conceptual basis for studies of computer use in its cultural, organizational and social context.

Therefore, efforts in developing a solid and widely accepted theoretical foundation for HCI are related to context more or less [35, 36]. These approaches model use-context as yet another source of information that can be formalized and transmitted to computers [36]. As alleged by Clemmensen [34], “HCI researchers need to know more about the sociocultural contexts of other researchers’ use of theory, in the same way that designers need to know users’ context of use in order to design systems and products for them”.

5.1 Situated Action and CA

Situated action places emphasis on environmental context and stresses how the environment provides context for actions [37]. According to situated action theory, the goal for interaction is to support situated action and meaning making in specific contexts, and the questions that arise revolve around how to complement formalized, computational representations and actions with the rich, complex, and messy situations at hand.

Situated action analogize interaction as phenomenological situated and accentuate the significance of constructing meaning on the fly and in specific contexts and situations, designing interaction moves from attempting to establish one correct understanding and set of metrics of interaction to studying the local, situated practices of users. Interaction is seen as an element of situated action in the world, the deciphering or construction of the situation is the core of the design [36].

MCA can help address some of the challenges by capturing, understanding, structuring and modeling the specific contexts and then provide individualized and customized interactions. MAC is especially valuable in providing local, situated and context-dependent interactions by adapting the mobile phone actions to the specific contexts.

5.2 Activity Theory and CA

Activity theory is originally proposed by the Russian psychologist Alexey Leontiev [34], it argues that human mind emerges, exists, and develops within the context of human activity as a whole, and therefore analysis of object-oriented activities should be considered as a necessary prerequisite for comprehending the human mind. Activity theory was introduced to HCI in the late 1980s-early 1990s and has established itself as one of the most influential theories in HCI [34].

Activity theory proposes that the activity itself is the context. What takes place in an activity system composed of object, actions, and operation, is the context. Con-text is constituted through the enactment of an activity involving people and artifacts.

Activity-awareness means that the HCI system can actively construct and update a model of the ongoing activity by sensing, communicating, and interpreting changing conditions, resources and processes [32].

5.3 Distributed Cognition and CA

Distributed cognition intends to introduce computer technology into the workplace by remedying the shortcomings of the information-processing model in that it lacks cosiderations for real-life action, work environment and user interaction [37]. It is a branch of cognitive science and considered as complementary to the information processing model that is devoted to the investigation of: (1) knowledge representation both inside the heads of individuals and in the world; (2) knowledge propagation between distinct individuals and artifacts, and; (3) transformations which external structures undergo when operated on by individuals and artifacts [35]. Distributed cognition emphasizes interaction over individual in HCI systems by construing the latter as a distributed collection of interacting people and artifacts.

In the vision of ubiquitous computing, context is spatially and temporally distributed in a ubiquitous computing environment. Distribution has a significant role and is central to the realization of context-awareness system in Ubiquitous Computing [31]. In a Distributed HCI system, MCA are capable of easing the sharing of contextual information, seeing and having access to context information that is around an application and distributing the contextual information within the HCI system spatially and temporally.

6 Challenges and future research directions of user-centric MCA

6.1 MCA and HCI

One of the significant changes that CA brought to the field of HCI is the roles of users and computers in interacting with each other. In traditional HCI systems, users are active and computers are passive when interacting with each other. In most cases, computers are simply waiting for user input and then executing the computing tasks as required. By contrast, computers tend to play a more active and even proactive role in context-aware HCI systems. Computer can sense, capture, decipher and reason about the contextual information of HCI and then execute certain actions based on the computing results of context-awareness. Despite progress in relevant technology and applications, attitudes towards active and passive context-awareness are divided by emphasis on CA computing capability of computers or users control over computers [7]. Although automatic execution of CA action and adaptation to con-textual information are critical metrics of MCA systems, the implicit interaction might lead to non-awareness of users over what's happening and unable to know what is required for users to do before s/he is required to do it [38]. High quality of MCA systems need to improve both the capability of computers and users at the same time by providing information to users at the right time and letting users control the interaction.

Furthermore, a novel theoretical framework of HCI is required to explain and structure the interaction characterized by context-awareness. We proposed a preliminary model named Context-Computer Interaction (CCI, Fig. 2.) to embody the above mentioned changes that context-awareness brought to HCI. CCI differs from traditional HCI as below:

- Human is not the only source of input any more but creates a context pool together with computing devices and environmental factors. This implies that computers are not interacting solely with humans, but as a whole contextual system in which humans are but one form of constituents and the three units interact with each other dynamically.
- Computer approaches the contextual system, captures the contextual information, deciphers the meaning behind, predicts plausible actions and executes actions proactively rather than waiting for the explicit input and command from users.
- Computers might predict and execute actions implicitly to improve the efficiency and unfetter human from selecting, judging and executing some apparent and predictable actions. The computer itself has a closed loop of information (context) processing characterized by executing behaviors implicitly.

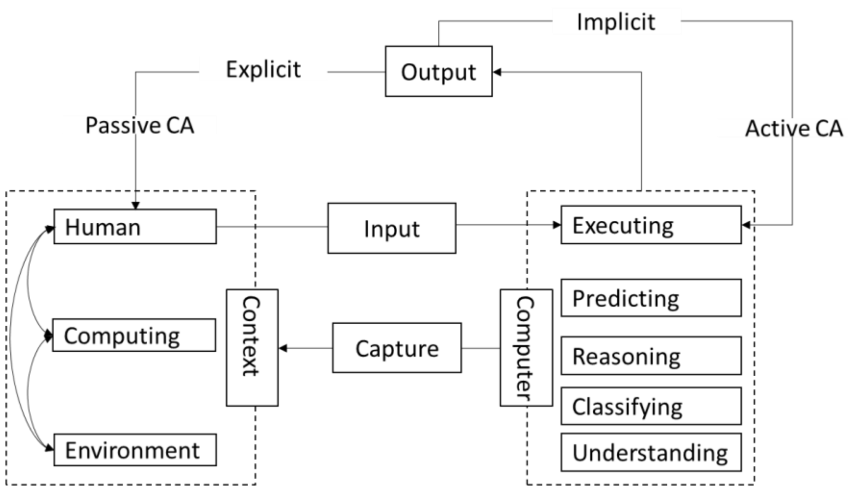

Fig. 2. Context Computer Interaction（CCI）

6.2 Non-instrumental User Experience and MCA

Much of the ongoing efforts to apply context-awareness to the interaction and interface design of mobile applications or services focus on improving the efficiency of HCI systems [3, 4], [16]. Context-awareness is valuable in improving the instrumental or pragmatic user experience of mobile application and services by sensing, deciphering, interpreting and adapting to the contextual information automatically. However, users of mobile applications might expect more from interacting with mobile phone than improvements to efficiency.

Past studies have shown that users are aware of hedonic and non-instrumental qualities such as interactive aesthetics, privacy, stimulation and social status in long-term UX of mobile phones [39], although some of them (e.g., privacy) are already addressed [14]. Social, emotional or informational state were considered as parts of contextual information that should be employed in context-aware systems at the early era of relevant areas [20]. Mobile context-awareness is also widely adopted in developing and designing applications dedicated for social-networking, shopping, sharing and well-being as well. Any efforts of MCA UX should address both instrumental and non-instrumental issues instead of focusing on productivity.

6.3 Research, Evaluation and Design of HCI System in Context

Research and evaluation is considered as one of the major cornerstones of HCI. During the last decade, attention was paid to the pros and cons of lab and field evaluations in the wild, as well as how to balance research methods in natural, artificial, and environment independent settings [37], [41].

Traditional laboratory-based usability testing methods are questioned as they are often expensive, time consuming and fail to reflect real use cases [30]. It tends to measure the efficiency, effectiveness and satisfaction of products or services by constraining users in artificial usability test settings and getting them to complete predefined 'typical' tasks. Users' interactions with computers in this situation is distinct from the real scenarios given that the interactions is interfered by moderators and fragmented by discrete tasks. By contrast, there is a growing tendency to infer and extract user experience information implicitly from user interface events and behaviors in the field of HCI in order to fully experience and explore real world usage [41].

Exploring usage of mobile applications and devices is still challenging despite much attention being paid to this issue. Traditional issues associated with conducting HCI studies (e.g., incentives and recruiting) are confounded with the highly mobile, dynamic and complicated context that makes explorations in this area creepy [42]

Over the past decade, a range of methodologies have been adopted to evaluate mobile services and conducing HCI studies in non-intrusive and ecologically valid ways [42]. Amongst them, experience sampling is proposed as an ideal alternative of traditional research method. Conventional long-term ethnographic observation is too intrusive in certain domains, such as sleeping habits or bathing rituals [43]. Collecting data in the wild through sensor-equipped prototypes is considered as one of the optional approaches of conducting user studies in evaluating product or services. This form of data collection also allows researchers and developers of HCI systems to glean insight into activities and contexts where an observer might be an undesirable presence.

Involving users in the context of use in the design of mobile systems was proposed as “The Final Frontier in the Practice of User-Centered Design” [44]. New design methods were also proposed by utilizing an open contextual and experiential design approach that makes extensive use of varying kinds of knowledge [43]. These sort of methods try to explore how mobile context-aware technologies and applications can effectively support contextualized learning and the relationships among different aspects of context. Amongst them, Experiential Design Landscapes and Living Labs allow in-context experimentation and data collection “that put all stakeholders (e.g., designers, users, researchers, developers, officials, producers…).in context of using products and services”.

7 Conclusion

Context-awareness is playing an increasingly vital role in developing mobile HCI systems. Little attention was paid to the user-centric view of MCA in comparison to the extensive studies from the computing-centric point of view. Attitudes towards implicit/explicit interactions and active/passive roles of humans and computers are divided, influence of MCA on user experience and related measures are not clear enough in which both instrumental and non-instrumental user experience might be considered. Dedicated theoretical framework is required to structure and illustrate the interactions characterized by context-awareness in mobile HCI.

8 Acknowledgements

This study is part of the project *Mobile context-aware cross-cultural applications (MOCCA)* funded by Marie Skłodowska-Curie Action. The grant number is 708122

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