Confidence: Dependencies and their critical role in fostering user acceptance in pervasive applications

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Abstract— **Pervasive computing offers new scenarios where users are surrounded by invisible and proactive technology making smart spaces. Although the utility and power of solutions developed using this computer paradigm are proved, there are unresolved problems that hinder their acceptance and inclusion in our private life. Users have problems understanding the operations of a pervasive computing solution, and therefore they should trust that the solution works properly and according to their expectations. Nevertheless, the concept of trust is already framed in a specific use within the ecosystem of applications that can populate a smart space. To take this concept of trust to the whole space, we propose to study and define the concept of confidence. In contrast to the concept of trust, confidence has deeper psychological implications.**

Keywords-component; Confident Computing, eHealth, Telemedicine, Pervasive Computing, Technology Acceptance.

I. INTRODUCTION

Pervasive and mobile computing present new scenarios in which a significant increase in computing capacity is often accompanied by increased complexity due to the high number of technological elements integrated into the environment. Such scenarios provide a customised view of the physical world [1] and thus offer interesting options for developing and implementing new interactive services to assist people in performing daily tasks.

The interaction model offered by pervasive computing is of particular interest in the definition of intelligent environments used to promote personal autonomy or to provide telemedicine services and e-health solutions [2]. In particular, pervasive computing is being studied as a new concept of development in the field of telemedicine and homecare because it enables prevention and early detection and facilitates the patient's treatment in their usual environment [3]. It also provides other socio-economic benefits that must be considered, such as the reduction of costs in chronic patient management and the possibility of establishing a more direct relationship between primary and specialised care [4].

However, although trends in health care and the needs of today's society justify the inclusion of sophisticated technology in the development of new types of health services [5], [6], there are unresolved issues that prevent the final implementation of solutions based on these models. The sensors and actuators used in defining intelligent or sophisticated spaces represent a vague and strange concept that hinders its acceptance by inhabitants in such environments. Researchers encounter serious complications when trying to deploy this technology in real homes, mainly due to the difficulty in understanding its operation by its users, i.e., the inhabitants [7].

For this reason, we propose the concept of *confidence* to model the final acceptance of pervasive technological solutions applied to critical contexts such as telemedicine.

This work aims to discuss the concept of confidence and its differences with trust. To achieve this objective, we present a definition of the concept and therefore suggest a way to characterise it.

II. THEORETICAL FOUNDATIONS

From the beginning of pervasive computing, authors such as Tennenhouse [8] remarked on the need to study in depth the role of users in the new world made up by this technology. Other authors such as Norman explained the need to apply other types of method to design services and applications, putting attention on the activity instead of the user [9], as he argued that design based on considering what to do is more effective than development following the capabilities of the technology and the abilities of the users. These two requirements are highly evolving and could prove difficult for adapting the development to new needs.

However, if researchers and developers forget the user needs or assign the users a passive role, the final solution will most likely not be accepted and used. A study of the related literature shows specific models for predicting the acceptance of technology by potential users. These models try to conclude whether certain elements will be accepted and therefore used based on a set of factors. One example is the Technology Acceptance Model (TAM) [10]. This model defines indicators related to the feelings of a user in relation to a specific technological element, noting the perceived usefulness and the perceived ease-of-use. The TAM has evolved with the inclusion of social aspects (TAM2) and user capabilities (TAM3) in the model. Researchers have also tried to adapt the TAM to pervasive computing solutions through the Pervasive Technology Acceptance Model (PTAM) [11]. PTAM tries to model user acceptance of solutions defined based on the ubiquitous computing paradigm (including smart spaces and, by extension, the digital home). To complement the TAM with

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ubiquitous computing features, PTAM considers new criteria to. One such criterion is trust.

Because of the difficulty of understanding the operations of a pervasive computing solution, users should trust that the solution works properly and according to their expectations. Nevertheless, the concept of trust is framed in a specific use within the ecosystem of applications that can populate a smart space. To extend this concept of trust to the whole environment, we propose to study and define the concept of confidence. Confidence has deeper psychological implications than the concept of trust [12] because it does not refer to a single service or space but to feeling comfortable in a space that is aware of your actions at any time. The idea is to extend the concept of trust as applied to a complete environment that, by definition, is changeable and adaptable to the needs of its users and where the users' feelings and perceptions play an important role in their final acceptance.

III. CONFIDENCE IN PERVASIVE COMPUTING

In general, researchers in the field of Computer Science and Information Technologies use the terms trust and confidence interchangeably. Although these terms are related, several authors set forth key differences, which show us the need to treat them separately. Luhmann explained in [12] that trust is only developed if one knows the risks related to some action, whereas confidence is only possible if you do not consider alternatives. In this way, Mayer *et al*. in [13] argued that trust is only present in case of risk, uncertainty and the need for interdependency with another person.

A. A lexical and stipulative definition

The Collins English dictionary defines the concept of confidence as *"a feeling of trust in a person or thing; belief in one's own abilities; or trust or a trustful relationship"*. The Cambridge dictionary explains confidence as *"the quality of being certain of your abilities or of having trust in people, plans, or the future"* in British English or "*a feeling of having little doubt about yourself and your abilities, or a feeling of trust in someone or something*" in American English.

Additionally, depending on the context in which we apply the concept of confidence, we look for different stipulative definitions. For example, in the case of economics, confidence refers to states where the relationships between entities can be satisfactorily developed [12], i.e., we can control and manage everything that happens in this state. In the specific field of medicine, confidence refers to the relationship between doctors and patients [15]. Thus, doctors represent trustworthy entities because patients accept them as people who can understand situations that we could not. In both cases, experts, as people with a high level of knowledge, generate the state of confidence.

As we mentioned before, pervasive computing offers new possibilities of interaction to the users and new spaces to deploy services and interact. In this sense, telemedicine is paying attention to the homes as a new space of intervention because of user proximity, reducing cost and enabling prevention. Homes are thus a new context in which to apply the concept of confidence, and therefore, the previous stipulative definitions are invalid. Additionally, the lexical definition seems unclear from the point of view of engineering because it is not possible to establish a measurement based on it.

B. An alternative definition of confidence for pervasive applications

We suggest a definition of confidence to apply in the field of pervasive computing and telemedicine. This definition considers the measurement principles, which are discussed later, in addition to the lexical definition. Thus, we define confidence as a positive psychological state in which people can establish trust relationships with every element that composes it, both human and technological. Confidence is a positive feeling because we seek the acceptance of a solution by people. Additionally, we focus on the relationships between humans and technology because telemedicine services involve people as physicians and patients in addition to pervasive elements.

Finally, with these considerations, we can provide a new and precise definition of the concept of confidence for pervasive computing and telemedicine:

"A psychological state of a person encouraged by a high level of control over and understanding of the behaviour of a system and the feasible relationships among all entities involved."

IV. A MEASUREMENT OF CONFIDENCE

From an engineering perspective, the measurement of confidence seems to be an interesting target. Measurement means that we can establish guidelines to define confidence accurately. By defining indicators to adjust the term, we minimise its ambiguity and vagueness. Therefore, we can establish a precise definition for the term confidence, beyond its lexical meaning, to employ in the field of the Computer Science.

We propose a first approximation to the measurement of confidence. To achieve this measurement, we divide the term into three indicators: control, understanding and intuitiveness. As we mention above, these indicators are derived from our experience and from a deep and systematic literature review.

These indicators mean that people only can be in a confident state if they understand everything that surrounds them and can control all interactions and relationships that can be developed throughout this state. A pervasive application often consists of a large number of devices, elements and instances, many of them imperceptible for the user, operating at a higher speed than human brain capacity, and the users have significant difficulty in making a mental map of this situation and therefore in understanding how it runs. Thus, human beings must be elevated to a higher plane in the computational process to conduct the supervision of all activities surrounding them in a simple and understandable way [8].

A. Understanding

Understanding is directly related to the user's expectations. Users understand some element, system or technology when they know its utility, function or objective. Therefore, a smart

space that is understood by users will do what the users expect, even if it is established by sophisticated technology.

B. Intuitiveness

In this way, understanding is closely related to the concept of intuitiveness. To apply this concept to interaction design, it is necessary that systems and elements of technology have affordance, or the capability to allow users to perform an action using them.

C. Control

Control is direct interaction of the users with the system or space. When a user has a situation under control, it is because the user's intention has a clear repercussion over all the system's results. The users control a system when they can act on the behaviour of the system directly or using a type of tool. Of course, certain interactions or uses can cause operation errors, and ideally the system must adapt itself to these circumstances. This capacity is called control with resilience.

V. Confident Technology

Currently, there are several technologies that have been studied as examples of confident technology. The main example of confident technology is the Digital Home (DH). DH represents a comforting environment in which the people feel safe and at ease. In this way, DH represents a suitable catalyst to deploy confident services.

Other technology that we can consider confident, because it seems extremely intuitive, is Smart Textiles. Smart textiles are currently gaining importance in the development of sensorised garments and their use in telemedicine services, such as patient monitoring and personalised healthcare [17].

Finally, there is another technology that, because of its significant penetration into our daily life, we can consider to be confident technology. This technology is smartphone and tablet technology, which most people have experience with on an everyday basis and know how to use. Additionally, these devices have powerful computational capabilities that can be used to deploy critical services.

VI. Discussion

The definition of *confidence* is based on observable properties, such as experience in developing telemedicine services for real homes and a systematic literature review (unpublished). In this sense, this definition is itself an hypothesis and also theory dependent. We have planned at least two user studies to verify this hypothesis. First, a qualitative study of how understanding and control model the sense of confidence about a pervasive service deployed into a real home has been defined (unpublished work in progress). Second, an experiment with smart toys to measure functional disorders in children is being conducted.

Another important issue to solve is validation, that is, definitive proof that the concept of confidence can be applied to actual implementations of pervasive and telemedicine applications. For this purpose, we are developing an architecture that allows the deployment of critical services in digital home environments. This architecture is based on Activity Theory and the Activity Centred Design method (Unpublished work in progress). Activity represents a concept close to human beings and therefore seems suitable for developing an understandable and intuitive service.

VII. Conclusions

Telemedicine systems and applications may benefit in several ways from the use of pervasive computing. However, to be accepted as valid solutions, these systems must solve challenges that have not been adequately covered yet. We must add to the typical challenges of telemedicine systems, often related to user acceptance, the challenges derived from the use of new technologies such as smart environments. This work has sought to analyse confidence, which, as one of the main aspects of Human Factors, is a key element in the acceptance of telemedicine solutions for home and smart home spaces. We propose understanding, intuitiveness and control as important indicators of such confidence.

This work shows that it is possible to adequately extend the definition of confidence to a computer science and information technology context. This definition differs from the concepts of reliability and trust in that it represents a complex psychological state that goes beyond specific relationships. Furthermore, indicators are provided to measure, quantify and manage this concept, making it precise and clear.

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