A Survey of mobility Prediction in ubiquitous Computing

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***Abstract*— Mobility prediction; as context parameter; has been receiving significant consideration in the last years. This information is very useful in pervasive/ubiquitous system, it permit to prepare services to offer to the user in advance, therefore the system will be proactive.**

This work presents a survey of mobility prediction. It analyses and compares the different mobility prediction techniques and approaches.

Keywords - component; Mobility prediction; Context; ubiquitous Computing; Context prediction

I. Introduction

Mark Weiser was the first who introduced the concept of ubiquitous / pervasive system. He expected that "*In the twenty-first century the technology revolution will move into the everyday, the small and the invisible. The impact of technology will increase ten-fold as it is imbedded in the fabric of everyday life. As technology becomes more imbedded and invisible, it calms our lives by removing annoyances while keeping us connected with what is truly important*" [1]. Supported by technological evolution, Mark Weiser's vision becomes more and more concrete. Today we are witnessing of an exponential advancement of technology that become available anywhere and at any time.

Current technological advances led to the design of computer systems increasingly powerful. Enabling a user to get on his hand a range of small devices such as smartphones and personal digital assistance, their use is part of daily lives. These devices facilitate access to information for anyone, anywhere and anytime. Users can exchange data easily, quickly, effortlessly and regardless of their geographical location. Here we are talking about pervasive / ubiquitous systems.

These systems are proactive, without the involving of the user; they are capable to anticipate services since they are equipped with a certain autonomy and a certain capacity of decision-making.

Implementing these ubiquitous, proactive and intelligent systems still raises many challenges to ensure context-sensitive proactivity and adequate to the user's needs.

In this paper, we present a survey concerning the context prediction and especially the mobility prediction of the user as an important context parameter.

The rest of this paper is organized as follows: Section 2 describes our motivation. Section 3 presents review for ubiquitous applications. Section 3 discusses the literature survey of the location prediction, and we conclude the paper in Section 5.

II. Motivation

Context prediction is a relatively new problem in the ubiquitous computing field. Any system, in order to be proactive and to act before the change of the context, should predict the future context. For this reason, this paper gives a motivating overview of past and current research works concerning the prediction of the user mobility.

III. Ubiquitous computing

A. Definition

In the dictionary, the word "ubiquitous" is defined as "seeming to be everywhere and especially at the same time" [2]

The ubiquitous computing is the way which computing become imbued in the world around us [3]. It provide all functionalities of computing anywhere and anytime. Using any device, Ubiquitous computing [4] can ensue, at any time, in any format and in any location.

1. Constituent of ubiquitous computing

Combining the aspects: distributed, mobility and intelligence, pervasive computing gradually embodies an ambient intelligence framework where technology becomes invisible and offers a proactive adaptation to assist users in their daily activities.

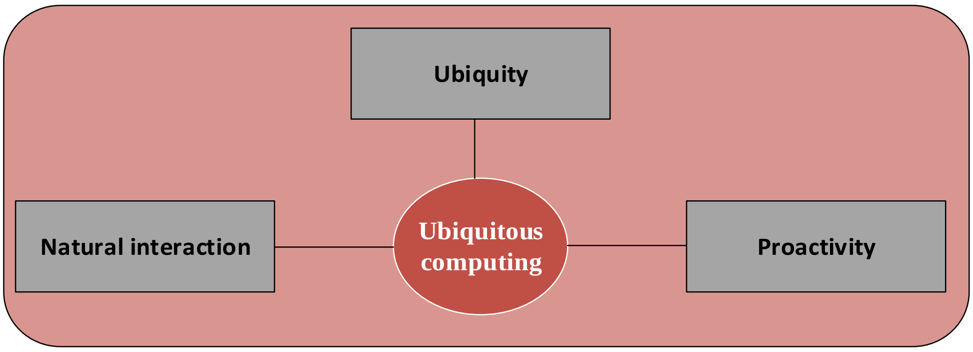

Figure 1 Constituent of ubiquitous computing

The Figure 1 summarize the main constituent of ubiquitous computing. As shown, the ubiquitous computing is the combination of ubiquity, natural interaction and proactivity.

Ubiquity: it is the fact of appearing everywhere or of being very common [5]; this is done by using mobile, ambient devices and networks.

Natural interaction: the user will use his natural modalities in communicating or exchanging information with applications. Permitting natural and efficient interaction between man and machine [6]. Therefore, the system should be embodied, multimodal and implicitly controlled.

Proactivity: the system must be able to predict the future and anticipate services [7]. This is include activity detection, behavior modeling, context-Awareness and especially the context.

IV. LITERATURE SURVEY

A. Overview of the context

In this section, an overview of the context is presented. We will present the definition, characteristics, dimensions and the context modelisation.

1. Definition

Before introducing the concept of context prediction, we firstable define the context. The first definition of the context is introduced by [8] and [9]. They defined the context as enumeration of different types of information that are considered pertinent about the user or the environment. They mention that the most important aspect of the context is to answer to the following questions: “where is the user? “, “who you are with” and “what are the nearby resources?”

[10] and [11] have extended the concept of the context. The context is no longer limited only to the user who has performed an action or his location but extended to the socials information, physical information (weather, time, location, etc.) and organizational information.

The most recent definition of context is presented by [12]. They defined the context as "**Any entity undergoing a spatiotemporal variation and that may lead to a change in the service or the quality of service in the short or long term**“ [12]. *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*

There to define better the context we should answer to the following questions:

- **Who?** To identify the current user and others in the environment;
- **What?** is the user doing?
- **Where?** is the user? Home? Work? Bathroom? Familiar coffee shop?
  - Location context, the most widely used type of context
- **When?** What time is it?
- **Why?** Why is the user performing a certain task?
  - Motivating context, one of the most difficulty type of context
- **How?** To describe how the activity takes place.

2. *Dimensions*

Classifying the context elements into a set of dimensions is useful for managing context quality. There are many dimensions of the context. The most significant dimensions that we can cite are:

Spatial dimension: here we are talking about the time. The time is an important element to establish or to manage the context history. For instance, the duration of an event, ect.

User context: The user's context is based upon the user profile.

Environmental context: The values of the environmental context parameters are sensed using sensors and interpreted accordingly

System context: The system context is detected using the computing device that the user is currently using as well as necessary computing resources parameters such as the current available bandwidth, the network by which the computer is connected, the computer's available memory, battery and processor and its activities.

Spatial dimension: here we are talking about the location, which is detected through the use of a sensor (i.e. GPS). This dimension brings together physical location, such as absolute position (geographical address), place (at work, at home, etc.), GPS coordinates, as well as the virtual location for instance the IP address.

3. *Context modelisation*

B. Context prediction

Ubiquitous computing [13] touches on a wide range of research topics, including distributed computing, mobile computing, location computing, sensor networks, human-computer interaction, artificial intelligence and context-aware.

The context-aware [14] is considered the most essential part of the ubiquitous computing. Context awareness has become an important research topic in computer science specially the context prediction. By definition, the context mean "any entity undergoing a spatiotemporal variation and that may lead to a change in the service or the quality of service in the short or long term" [12].

Many research has focused on prediction in many types of applications, such as healthcare [15], [16] and [17], failure in wireless network [18], failure in software [19] , survival after extracorporeal membrane oxygenation for severe acute respiratory failure [20], etc.

Among these research works focused on context prediction [21], [22] and more specifically on the prediction of future location of the user.

Studies on contextual models have shown that a user's location, identity, time, and activity are the most important parameters determining the type of service to provide [23]. A user's location can be determined accurately. Environmental, system, and user information are susceptible to change depending on the user's location; Furthermore, the user periodically occupies well-defined locations, such as "at home" (nighttime), "at work", or "at school" (daytime) etc...

The prediction of the location in outdoor spaces is the type of prediction most often investigated. A history of past observations serves as the basis for context prediction and for the prediction of general future behaviour of an individual in an outdoor space [24]. The prediction process is based on the deterministic assumption that future events are determined by past events and that whenever a situation is observed, the subsequent situation will be similar to previously observed behaviour. Daily and weekly routines are assumed to be well established, and the activities of individuals are characterised by a degree of regularity and predictability [25], [26].

In [27], based on the location history, they used a k-means approach to cluster the data to the adequate location. They define a first order Markov model to predict the future location.

In [28] they present their own data set created using a mobile phone of a user behavior. They create a pattern of cell that the user has visited before. Therefore, the proposed prediction approach took a sequence of recent cell transitions the find the most probable cell the user will enter next.

Many research works used the artificial neural network (ANN) to predict the future context (location prediction). The ANN is a computational model based on the structure and functions of biological neural networks [29]. As shown in Figure 2, the ANN is an interconnected group of nodes, each node represents an artificial neuron and each arrow represents a connection from the output of one neuron to the input of another.

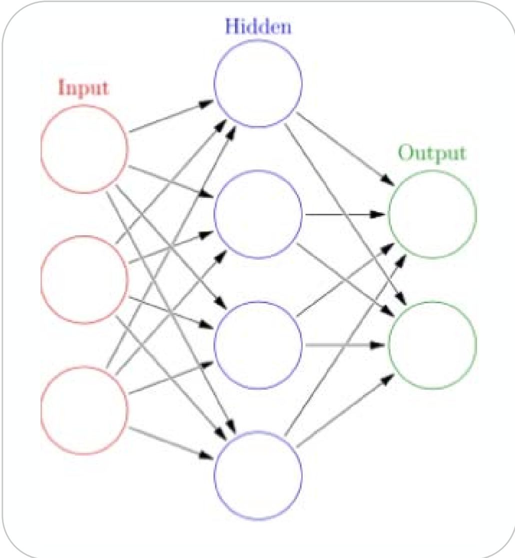

Figure 2 General structure of neural network [30]

Among the researches used the artificial neural network, we can cite the work of Mozar [31] and Vintan [32]. Mozer [31] was the first one who used the neural network to predict the future context (location prediction). To predict the context through the work of Mozer, neural networks have been used [31]. Authors in [31] described a smart environment with various services, such as space occupation models, estimates the consumption rate of the hot water. To predict the most probable location to visit by the user in a given environment, Vintan [32] used the same approach in [31] .

Bayesian networks [33], naïve Bayes [34], and dynamic Bayesian network [35] are probabilistic technics used for the location prediction. They are based on Bayes theorem. The dynamic Bayesian networks are an extension of Bayesian network that model a dynamic system that varies with time and they can represent the temporal properties of contextual information. Jan Petzold et al. have compared different location prediction algorithms [36] and have concluded that Bayesian Networks have the best prediction time. In [37] the same authors predicted the indoor location of a user using dynamic Bayesian networks and they have found that the prediction accuracy is comparable to the neural networks and state predictor.

In [38] and [39], the authors used Markov chains to predict the future location of the user. This technique provides an easily understandable view of the system and can be applied if the context can be decomposed into a finite set of non-overlapping states. The main idea of this technique is to calculate the transition probability from one state to another using the equation:

$$P_{ij} = P(S(t+1) = S_j | S(t) = S_i)$$

Where: $i, j \in [0..n-1]$

t=0,1,2, 3,….

Using this technique will determine the user's habits from the sequences of its history actions.

In [40], they present an approach to predict the next location of the user so the system can initiate several preparation routines to maximize comfort and minimize energy consumption. They demonstrate that the combination of SVM and RF (Random Forest) can significantly improve the accuracy of location predictions.

V. CONCULUSION

This research work presented a survey of mobility prediction research. We reviewed projects and research work related to mobility prediction. These research work, presented in the literature review, do not present a formal presentation of the prediction and only consider the current context to predict the future location, consequently these system are unidimensional.

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