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Context Modelling for Just-In-Time Mobile Information Retrieval (JIT-MobIR)

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ABSTRACT

Mobile users have the capability of accessing information anywhere at any time with the introduction of mobile browsers and mobile web search. However, the current mobile browsers are implemented without considering the characteristics of mobile searches. As a result, mobile users need to devote time and effort in order to retrieve relevant information from the web in mobile devices. On the other hand, mobile users often request information related to their surroundings, which is also known as context. This recognizes the importance of including context in information retrieval. Besides, the availability of the embedded sensors in mobile devices has supported the recognition of context. In this study, the context acquisition and utilization for mobile information retrieval are proposed. The "just-in-time" approach is exploited in which the information that is relevant to a user is retrieved without the user requesting it. This will reduce the mobile user's effort, time and interaction when retrieving information in mobile devices. In this paper, the context dimensions and context model are presented. Simple experiments are shown where user context is predicted using the context model.

Keywords: Context recognition, mobile information retrieval, just-in-time information access

INTRODUCTION

It is common now for people to address their information needs by using the web search in mobile devices. Since mobile users are connected to the Internet almost every minute, accessing information has become much faster than years before mobile Internet was introduced. However, performing information retrieval (IR) on mobile devices is rather complex because mobile browsers are implemented without considering the characteristics of

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mobile information retrieval (mobile IR). Besides, the characteristics of mobile IR are quite different from the traditional IR frameworks.

One notable characteristic of mobile IR is the physical limitations of mobile devices. Mobile devices are built physically small for ease of portability. This makes it challenging for mobile users to operate with the mobile device when they are on the move. Besides, adopting desktop browser to fit the size of a mobile devices screen forces them to spend more time selecting and reading the right information in small font and crowded text (Church *et al.,* 2002). Mobile users also need to put extra attention when using mobile devices because they can easily get distracted by other things going on around them (Sohn *et al.,* 2008). On the other hand, the evolving smart-phone technologies have enabled researchers and developers to exploit the embedded sensors in smartphones to sense users' surrounding information (Lane *et al.,* 2010). The user's surrounding information is also known as context. Context, in general, can be used to overcome the problem of IR systems retrieving too much information that may not be relevant in the user's current situation and also to minimize their involvement in interaction particularly on a mobile device. The embedded sensors on the smartphones make them ideal devices to capture users' context because these users always carry the devices.

The inclusion of context in the IR frameworks has become increasingly important particularly for the implementation of mobile IR. The problem with the current IR systems is that these systems retrieve all relevant information in response to a query without considering the representation of the query. These systems do not have any knowledge about user's preferences, or why the user submits a particular query or what is the user's intention when submitting that particular query. As a result, the relevant information retrieved by the IR systems is too generic and is not within the right user's context, and the user needs to spend time finding the desired information. In order to improve the retrieval results, the implementation of context in the IR frameworks is employed in one of the following retrieval phases: (a) query reformulation, (b) document re-ranking, and (c) document retrieval (Tamine-Lechani *et al.,* 2010). However, in mobile IR, apart from improving the retrieval results, minimizing the user interaction is also a key to increase the user's experience when using the mobile IR. Smartphones can react and adapt to the context to minimize user's interaction and use context as information trigger to pro-actively present information to the user. This is also known as Just-In-Time Information Access system (Leake *et al.,* 1999). For this research, the system is named as Just-In-Time Mobile Information Retrieval (JIT-MobIR). JIT-MobIR works by monitoring context, predicting user's information needs in any given context and proactively providing the user with relevant information with the aim to reduce user's interaction. Thus, the effectiveness of JIT-MobIR is measured both in the capability of the system to understand the context and in the ability of the system to retrieve information that satisfies user's information needs in that particular context.

The motivation of this research is to construct, understand and apply context for developing JIT-MobIR. However, very little work has been done on utilizing context in mobile IR because of the complexity of constructing and generalizing context. Context, by nature, is always changing particularly when a user is on the move. This makes context extremely complex to be identified (Schmidt *et al.,* 1999). How context can be identified and captured by using a smartphone is explained in this paper. In specific, the paper is organized as follows: In the next section, work related to the current study is presented. The context modelling in JIT-MobIR is introduced subsequently. Then, the implementation of JIT-MobIR is described in detail, with a discussion on the results, followed by conclusion and future work.

DEFINITION OF CONTEXT

According to the Free Online Dictionary of Computing (FOLDOC), context is defined as "*that which surrounds, and gives meaning to, something else*". However, the definition of FOLDOC is too broad and vague, and for this reason, many researchers defined the context according to their own understanding that is influenced by their research observations (Dey & Abowd, 2000; Schilit *et al.,* 1994; Schmidt *et al.,* 1999). Schilit *et al.* (1994) proposed the definition of context based on location awareness. However, Schmidt *et al.* (1999) disagree when context is treated merely as a location as past researchers always do. They describe that context has many aspects in three dimensions: Environment, Self and Activity. Nevertheless, Dey and Abowd (2000) argue that those two definitions of context are experimental oriented and difficult to be applied. They also argue that one aspect of context is not important from others since these aspects will change from one situation to another. Thus, context according to Dey and Abowd (2000) emphasizes that any information will be considered as context when this information helps a user to interact with an application. However, if the information is no longer relevant to the user's interaction, then it is no longer a part of the context. This definition does not restrict where the context is coming from as long as that context helps the user's interaction. Dey and Abowd's (2000) definition of context is "*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 definition is widely recognized as a formal definition of context by current researchers. The definition also emphasizes that context has several dimensions which can clarify the situation of an entity.

DIMENSIONS OF CONTEXT

Previous works on context awareness usually used location as an approximation of context. Although location is one of the dimensions of context, relying solely on it does not explain the entire context of a user. Schilit *et al.* (1994) explained that context should exploit the changing aspects of the environment. They further summarized the environments as: (a) *Computing environment*, such as network connectivity, communication costs, and nearby resources such as printers and workstations; (b) *User environment*, such as location and user's profile; and (c) *Physical environment*, such as lighting and noise level. However, according to Schmidt *et al.* (1999), the computer environment and the physical environment overlap with each other. They proposed a hierarchical context model where context is divided into general categories of *human environment* and *physical environment*. Beyond these general categories, each of them is further divided into three sub-categories where a set of relevant features is identified. The value of these features will determine the overall user's context. Based on those two works, researchers began to propose their own dimensions of context by expanding, reducing the dimensions or proposing new general models of context according to their own works (Bierig & Göker, 2006; Brown & Jones, 2002; Korpipaa *et al.,* 2003; Raento *et al.,* 2005; Razzaque *et* *al.,* 2006). However, some researchers often incorporate too many dimensions of context which make the context models too complex to be implemented in smartphones. On the other hand, a few dimensions of context make context models unable to understand the whole context.

CONTEXT AND INFORMATION RETRIEVAL

IR system is dependent upon how efficient a user formulates his information needs into a form of a query to retrieve relevant information. Mizzaro (1998) discusses how the user's actual needs are inadequately represented by the queries. Besides, the retrieval process in the current IR frameworks does not consider any external information other than the queries. This external information is also known as a context. The role of context in the IR frameworks has been discussed by many researchers (see for example, Brown & Jones, 2001; Fuhr, 2005; Jones & Brown, 2004) and also cited as one of the long-term challenges in IR (Allan *et al.,* 2004). According to Fuhr (2005), the definition of IR generic task does suggest the need of IR systems to be user specific and to have the necessary knowledge about the user. This indirectly indicates the importance of including context to the IR frameworks. Meanwhile, Brown and Jones (2001) proposed that a query could be constructed by user's current context on behalf of user in context-aware retrieval framework. The query would be specific to a user and understand that user's situation and information problem. In order to simplify mobile user interaction, Jones and Brown (2004) also suggested the IR system to behave autonomously and pro-actively in retrieving and presenting information to a user with the implementation of context. This would make mobile IR, in some sense, intelligent because information is retrieved and presented to a user without much effort from the user.

CONTEXT MODELING IN JIT-MobIR

Contextual retrieval by definition is application specific (Fuhr, 2005). Since context plays an important role in this research, we need to acquire a complete interpretation of user context. Thus, we proposed our own dimensions of context. These dimensions were created by studying the dimensions proposed by different researchers and mapping it with the embedded sensors in Apple iPhone. Details of our dimensions of the context are described below:

- **User's Profile** – this dimension stores any information about the user. Information such as who the user is and habits are saved in this dimension.
- **Time** – this dimension stores timestamp of every change to other context dimensions. This dimension contains the date, the days, the hours, and the minutes of change dimensions.
- **Location** – this dimension stores the information about where the user is.
- **Sounds** – this dimension identifies the surrounding sounds where the user currently is.
- **Activity** – this dimension identifies and stores user's activity.
- **Agenda** – this dimension contains user's driven data on user's future activities.
- **Speed** – this dimension indicates any change in speed if the user is on the move.
- **Heading** – this dimension updates user's heading in order to recognize if the user has the possibility of visiting previous location in his context.

• **Network** – this dimension indicates if the user is connected to the Internet.

• **Preferences** – this dimension refers to user's interest in some particular topics.

The information on this part will be updated over time since it can be influenced by many factors. These dimensions use only the sensors that are embedded in iPhone in order to identify and capture user's context. The work by Lane *et al.* (2010) discusses in detail the lists of Apple iPhone sensors. However, the extracted sensors data do not represent the whole information of user's context. For example, GPS sensor only specifies user's current location but it does not indicate why the user is at that location. Thus, the sensor data need to be interpreted to understand user's context. Consequently, we developed our own context interpretation model to translate sensors data into the description of user's context. This model consists of four different levels of context interpretation, as depicted in Fig.1.

The levels on this context model are:

• **User's scenario**: situations encountered by a particular user.

• **High-level** context: a description of user's current context. User's current context is characterized by interpreting multiple context dimensions.

• **Context dimensions or low-level context**: a characterization of multiple sensors data into meaningful information. It is recognized that one dimension of a context is a subset of high-level context.

• **Sensors data:** any information collected from embedded sensors in the smart- phone and information from user's interaction with the mobile applications.

In this model, context dimension is regarded as low-level context whereby it interprets and describes information collected from sensors data. The context dimension addresses the basic questions like who the user is, where the user is, what the user does, and many more.

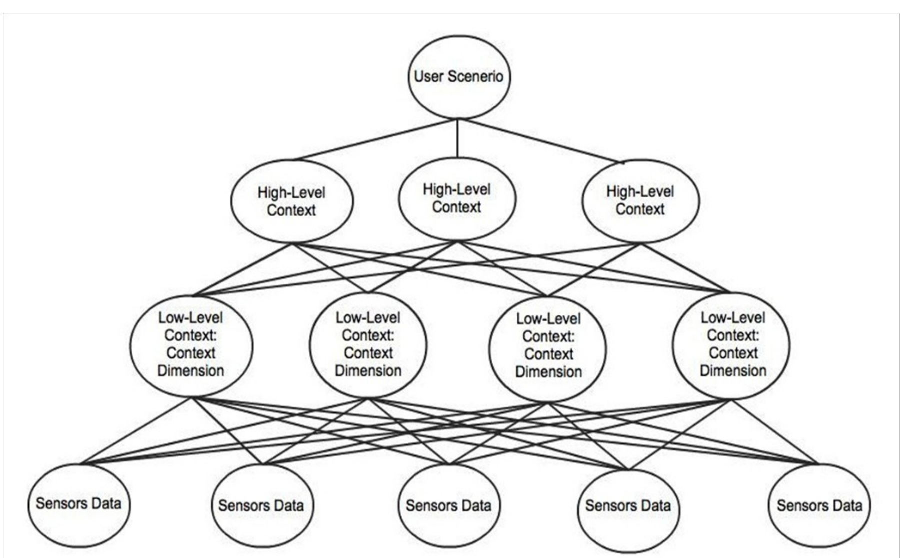

Fig.1: Four levels interpretation of context model

Each context dimension in this model is treated as a subset of high-level context, which is more abstract and difficult to characterize. Besides, the high-level context deals with the semantic relationships between the low-level contexts.

IMPLEMENTATION OF JIT-MobIR

The context model in the previous section is implemented by using the Apple iPhone. The aim of this study was to recognize user's context by using the data from iPhone embedded sensors. The implementation relies solely on iPhone embedded sensors and any external sensor that is not included in the process of acquiring user's context. The conceptual architecture of JIT-MobIR is depicted in Fig.2. In the JIT-MobIR conceptual architecture, the system has two important functions. The first function of the system is to recognize user's context and to infer the user's information needs. The second function is the retrieval system, where it provides two different approaches (pro-active retrieval and query-based retrieval). The pro-active retrieval uses user's information need in context to retrieve relevant information to the user and present it without a request from the user himself. For query-based retrieval, the query submitted by the user is re-formulated by enhancing it with context before it is used to retrieve relevant information. The user's information needs in context and query re-formulation are processed in the server where the contexts are saved. In this architecture, the retrieval process will use a common IR framework and the mechanism will remain unchanged.

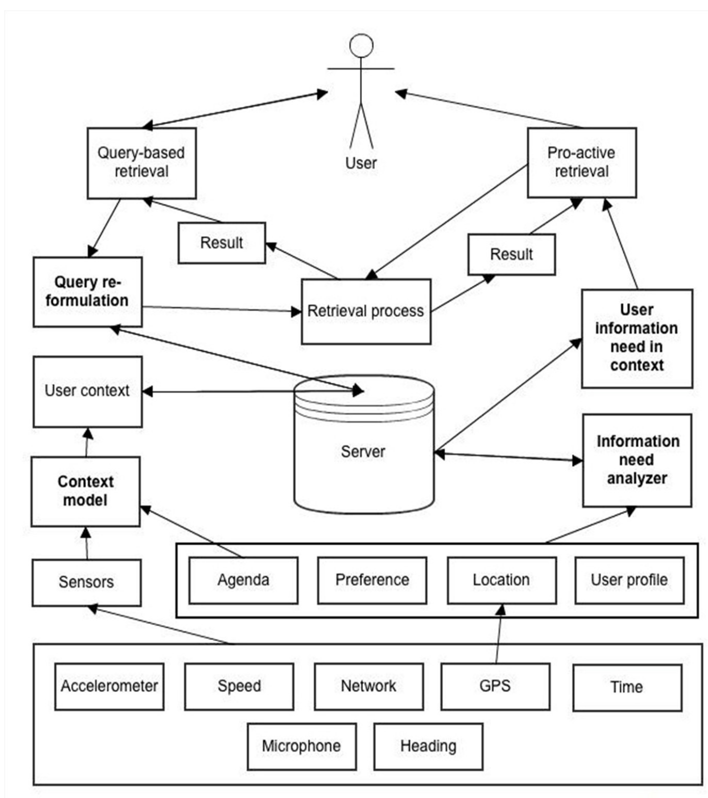

Fig.2: JIT-MobIR conceptual architecture

In order to recognize user context, context model obtains sample data from the embedded sensors. These sample data are classified into low-level context and combined in order to identify high-level context. User's agenda is also extracted in order to recognize if user's context is influenced by the agenda. The system also needs to recognize if the user's current context is a repetition of the user's previous context. If the new user's context is not a repetition of user previous context, the agenda will be examined to determine if it affects the new user's context. Conversely, simple description of the user's context is provided if there is no indication that the context is not a repetition of the user's previous context or the context is affected by agenda. Next, the system infers user's information need in context based on the user's current context and the information need analyzer. However, user's information need in context may fail to infer user's information need. If this happens, the system could predict user's information need through: (a) acquiring the context from different users that are closely similar to the current user's context, or (b) arranging information related to the user's location, preference, and context. The information retrieved based on these approaches may not be required by the user but by presenting the information to the user, the system can update user's preference based on the information selected by the user.

RESULTS

The initial result of recognizing user's context is presented in this section. Since the sensors can be interpreted in various ways, the sensors interpretation in this study is restricted to information that is required by JIR-MobIR, as presented in Fig.3. The sensors data are assigned to the proper dimension with several interpretations. Some of the interpretations are rather straightforward. However, some of the dimensions require a prior pattern in order to distinguish the dimensions value. For example, a prior walking pattern of accelerometer data is required before the context model can recognize it. Thus, initial experiments are conducted to collect these prior patterns where the application captures several users' activities and sounds. The collections of these prior patterns are analyzed and used to automatically interpret the

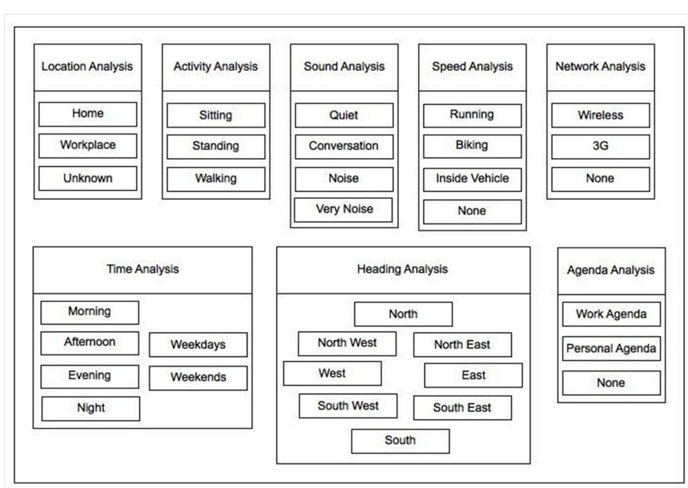

Fig.3: General sensors analysis for the context dimensions

particular dimension. Besides, these patterns need to be general and consistent in interpreting the dimension when implemented in a later stage.

Fig.4 shows the accelerometer axes. The axes are influenced by gravitation force. By examining this force, the orientation of the iPhone can be detected. Then, by collecting the force value over time, the user's activities can be recognized by analyzing the iPhone orientation. For this experiment, iPhone accelerometer and microphone data are collected and analyzed to collect a prior pattern that recognizes the user's activities and the surrounding sounds.

The initial results of recognizing the user's activities are presented in Fig.5, Fig.6 and Fig.7, and the result of analyzing the surrounding sounds is depicted in Fig.8. In this experiment, the iPhone is always placed inside the front pocket of the user's trousers because most of the users often place their smartphones inside the trouser front pocket. The accelerometer data are collected when the user is doing simple activities like sitting, standing and walking. These accelerometer patterns will be used as a reference to automatically recognize the context dimensions of the user's activity in this research.

Fig.5 shows the pattern for recognizing the sitting activities. The x, y, z axes of the accelerometer indicated the orientation of the iPhone. If z axis is equivalent to -1, the screen of the iPhone is facing up and if z axis is equivalent to 1, the screen of the iPhone is facing down. Since the user is sitting, the values of the x and y axes indicate that the user is practically not making any movement.

Fig.6 indicates the pattern when the user is standing. The graph indicates when the user is standing and the user will somehow move a little bit, as indicated by the x and z axes. The orientation of the iPhone is in portrait orientation when y axis is equivalent to -1 or portrait upside down when the y axis equal to 1.

On the other hand, a pattern of accelerometer data when the user is walking is shown in Fig.7. The accelerometer axes are greatly fluctuating and unstable compared to the graphs when the user is sitting and standing. When the user is walking, the user's steps cause the accelerometer to record greater gravitation force as shown in the y axis. Besides, the user's steps when walking also cause the iPhone to receive a vibration, as suggested by the values from the x axis. Hence, the system can automatically distinguish these activities by recognizing the fluctuating pattern of the accelerometer axes. This process will not require too much processing power, which can be implemented inside the iPhone without draining its battery life.

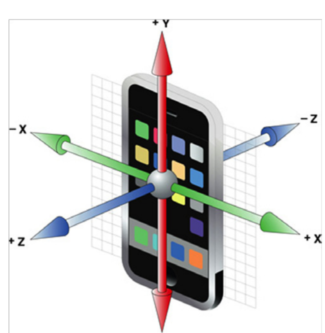

Fig.4: The iPhone accelerometer axes

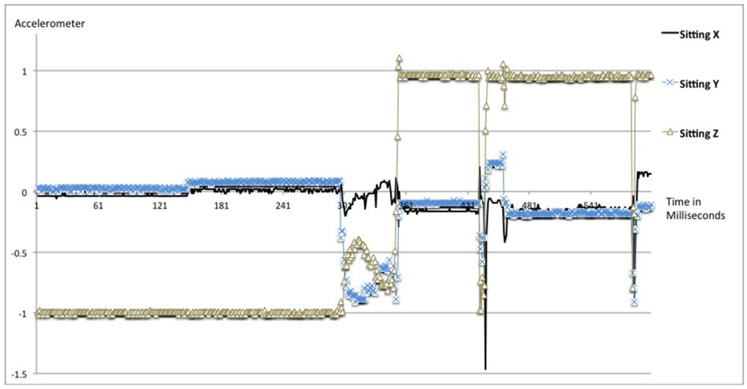

Fig.5: Accelerometer pattern for the sitting activity

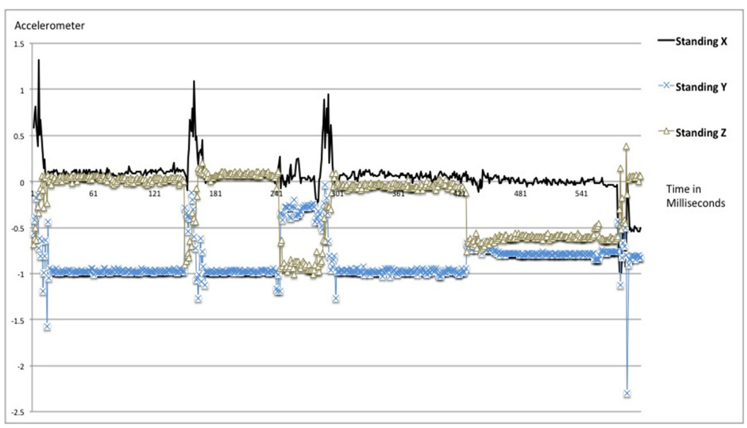

Fig.6: Accelerometer pattern for the standing activity

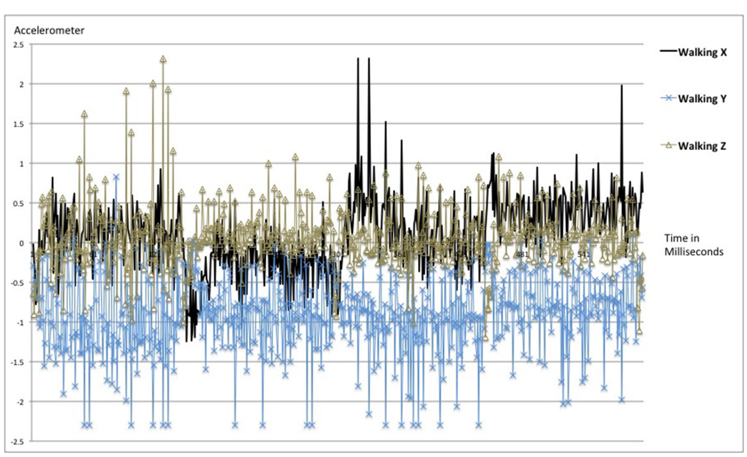

Fig.7: Accelerometer pattern for the walking activity

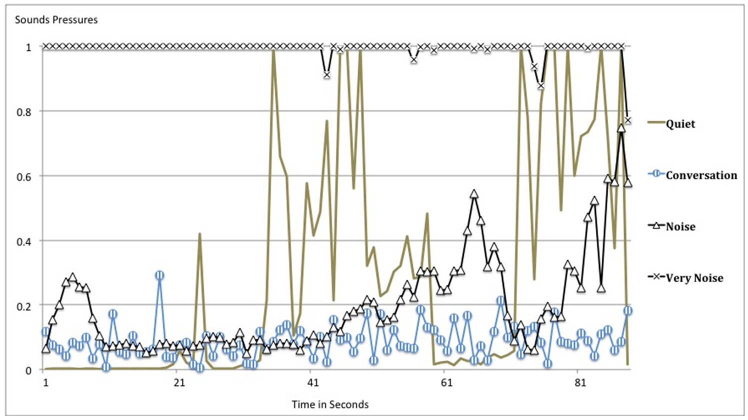

Fig.8: Sound patterns

Fig.8 indicates the patterns of different sound categories. These patterns captured the sound pressure power or decibel from the microphone instead of using sound recognition. There are four sound patterns captured in this experiment, which are: “quiet”, “conversation”, “noisy” and “very noisy”. The “quiet” pattern is probably difficult to capture because the consistently quiet surrounding sound is not easy to obtain. The “conversation” pattern shows that the lowest decibel almost reaches zero decibel because while people are conversing, there are moments when people are silent for brief seconds. The “very noisy” and “noisy” patterns can be differentiated by identifying the lowest and the highest decibels.

CONCLUSION AND FUTURE WORK

The results presented in this paper have shown how context could be identified and captured by using embedded sensors in smartphone. The results collected in this paper will be used as prior patterns to automatically recognize context in a later development without using complex recognition algorithm. This could ensure that smartphone can be used to identify context without draining its battery life.

The next development in this research focuses on context interpretation, context utilization in JIT-MobIR and user’s verification of the JIT-MobIR. The current implementation in this study emphasizes on identifying and capturing user’s context based on the analysis of the embedded sensors. In order to develop a feasible JIT-MobIR system, three different studies are outlined, and these are:

1. Generating context interpretation, where user’s context is automatically interpreted by using the patterns collected in this paper.
2. User’s validation, where the system is employed in real situation and the user’s validation of his context is collected.
3. Relationship between context and queries, where the system needs to understand how queries can be substituted by context.

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