Survey on context-aware tour guide systems

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Abstract: As a result of the pervasiveness of smartphones and improvement of context-aware systems, developers have designed and implemented a variety of context-aware tour guide systems. These systems focus on tourist attractions and provide services for tourists in order to support them before, during and after the trip. This survey aims to summarise, classify and investigate these systems from three standpoints of general, design and context-awareness, each of which consists of some parameters. Afterwards, the existing projects are categorised according to the proposed framework. Finally, concluding remarks as well as new trends are discussed in order to illuminate future research directions.

1 Introduction

Nowadays, tourism is regarded as one of the biggest and most efficient economic activities [1, 2]. It has a high capacity for progress and could result in economic, social and cultural development in many countries [3, 4]. Estimations of the World Tourism Organization indicate that the number of the world's tourists will reach 1.8 billion people in 2030 and they will spend beyond 2 trillion dollars that will be mainly absorbed by the developed countries [5]. As the tourism industry has a high extent of wealth and job opportunities creation, it has been considered by governments and researchers, and many applications have been developed in order to help the tourists. Recent advances in smartphones efficiency [6, 7] and inclusion of new sensors (e.g. GPS, accelerometer, NFC etc.) along with the pervasive provision of wireless and telecommunication networks [8], make smartphones an attractive and popular platform for assisting the tourists. In the past, tourism and travel-related applications had the 7th rank of frequent services among all mobile applications downloaded by users [9].

Traditionally, tourists have used human resources, maps, brochures or tour agents in order to gain information about their destination. After the advent of the Internet, it influenced various aspects of human life including tourism. As a result, E-tourism has emerged, which aimed to digitise the processes related to tourism, as much as possible [10]. However, mainly it was useful in achieving E-reservation and E-payment, as well as providing static information to users. After the advent of ubiquitous computing, Ubi-tourism has emerged, which aimed to provide context-aware [11] services to tourists anytime and anyplace [12] through their available mobile devices [13]. In fact, context-aware services obtain contextual information implicitly from the environment and perform the proper operation, accordingly [14]. This idea has been further extended to smart tourism, in which users expect to get value-added and intelligent services by leveraging the available smart infrastructure. In summary, in the smart tourism era, tourists expect smartphones to provide smart, context-aware and value-added services to them anytime and anywhere [12].

Today, smart cities provide the required platform for developing smart tourism. In fact, in the smart city and Internet of things paradigm, smart sensors and hardware are embedded in the infrastructure of the city. This smart infrastructure is exploited to increase the quality of services for users, which could be either citizens or tourists. In particular, as a result of deploying a smart city, tourist attractions become equipped with a smart infrastructure that provides an essential platform for developing smart tourism services. Hence, the realisation of smart cities yields to the evolvement of smart tourism [15]. In fact, smart tourism is one of the aspects of the smart city paradigm [16].

Previously, researchers and program developers have designed and implemented a variety of context-aware and smart tour guide applications [17, 18]. Providing information and pictures, as well as searching points of interest, are some well-known services of these applications [19, 20]. The main role of context-awareness is that the information, as well as services provided to tourists, have the most adaptation with their situation and interests, and the redundant information is filtered [21, 22]. Previously, some surveys have been published in the area of tour guide. Primarily, we could refer to the survey by Schwinger et al. [23], which investigates web-based tourist guide mobile applications from the perspective of context and adaptation. In another research, Grun et al. [24] categorise mobile tourist services and investigate different aspects of the services including service delivery, customisation and initiation. Kray and Baus [25, 26] review the mobile guide area with some common criteria including adaptation, user interaction and architecture. They also have investigated map-oriented tour guide services. Kenteris et al. [27] extract designing principles used by the developers of tour guide mobile applications and review the projects regarding architecture and network infrastructure, positioning technologies, input and outputs modalities and information models.

Context-awareness is an important characteristic of the applications of the smart cities as well as smart tourism, which enables them to yield a better understanding of the situation of the user and environment. This understanding yields to the autonomy and intelligence of these applications. This paper investigates context-aware tour guide systems by focusing on context-awareness. For a systematic review, a framework with three dimensions is proposed. The first dimension investigates the projects from a general viewpoint and categorises them according to the parameters of the type of environment and service. The second dimension reviews the projects from a system design standpoint, which consists of three parameters, including architecture, communication type and action pattern. Finally, the third dimension is specific to the context-awareness. It surveys the projects according to the type of utilised contextual information as
The most significant contribution of this paper that makes it distinct from the previous surveys is comprehensiveness and focusing on context-awareness.

For a systematic selection of related projects, we have used the keywords of ‘tour guide’ plus ‘Context-aware’ in the Google Scholar as the most comprehensive paper indexing search engine. Afterwards, retrieved results have been filtered out in two steps. At first, papers published by unknown or unpopular publishers have been rejected. As Google Scholar is a keyword-based search engine, the papers have been conceptually considered in the second stage and unrelated papers to the subject of the survey have been eliminated. The outcome of the survey helps researchers to evaluate available systems according to these domains. It particularly concludes the level of realising context-awareness in these systems.

The paper is organised as follows: after this introduction, the proposed reviewing framework is introduced, and the projects are investigated from the general viewpoint in the first dimension. In Sections 3 and 4 the projects are reviewed regarding system design and context-awareness dimensions, respectively. Finally, the concluding remarks and open directions of research are discussed in the last section.

2 Proposed framework

The proposed framework consists of three dimensions of general, system design and context-awareness. Fig. 1 shows these dimensions as well as their aspects.

2.1 General

In this dimension, the projects are generally investigated via the parameters of the type of environment and service. Table 1 introduces the reviewed projects. Name of the university or institution where the research has been performed, the type of publication of the article, and the project status regarding implementation are provided in this table. Although there are other related papers, projects are selected based on correlation with the research subject, i.e. the mobile tour guide systems that are context-aware. The aim is to highlight the tutorial aspect of this research and to increase the quality of the content.

Alongside the academic tour guide systems, real systems are also introduced in this table. Corfu is a tour guide system developed for planning the visit of the tourists of the Corfu Island in Greece [47]. It helps tourists to find and reserve various types of accommodation (e.g. hotel, flat and villa) as well as surfing tours, to plan different types of boating, to participate VIP services and to rent vehicles. Smart Travelling [48] is an application, which supports more than 30 touristic cities mainly located in North of America and Europe. It maintains a comprehensive database including hotels, restaurants, shopping centres, points of interest etc. It helps tourists in finding and navigating the intended places. ImogI [44] is an early context-aware mobile museum guide system, which has been used in the Gallo-Roman Museum of Tongeren to elaborate the information of exhibits. Finally, WAM [45] is a mobile tour guide application, which shows images and information of nearby points of interest to the user. It exploits image hosting websites to retrieve related images.

Table 1 summarises the studied projects as well as their name and reference(s). In the text of the paper, the projects will be referred only by name. In the following, the projects are investigated regarding two parameters of the type of environment and service.

The environment indicates the scope of the area where the tour guide system could provide services to the user [49]. In this regard, EWALLET, TAPIR and
UbiqMuseum systems are developed for providing services in the museums’ indoor area.

- **Closed outdoor**: It refers to a geographical area with a completely determined scope. For example, the deSCribe system presents various information to the visitors at the University of Southern California. In addition, MTGS helps the tourists inside a historical garden in India called Ram Bagh, for finding information about their favourite places.

- **Open outdoor**: These systems support users in an absolutely open environment with an extensive geographical area. Most of the projects including CATIS, VISIT, COMPASS, PTG, PSiS Mobile, CorfuAR, CARS, IMTG and RAR are placed in this category. Among these projects, CARS is developed for guiding tourists in the city of Jaen, Spain. Similarly, others are developed for various cities around the world in order to provide services to tourists. The second column of Table 2 summarises the environment type of the projects.

A service expresses the facilities and information the application gives to the users based on their needs and requests. When a tourist uses a context-aware application, s/he expects it to meet her/his needs in different situations. These needs might be presenting information about the history of a historical place or the ability to search or reserve restaurants. After reviewing the projects, the following services are recognised, which are discussed subsequently:

- **Exploratory**: The ability to explore tourism attractions and determine their geographical position on the map is called exploratory. It is the most popular service among the projects, which enables users to observe the position of all tourism attractions on the map and make the best decision. Among the projects, the MTGS system has the ability to determine the geographical position of tourism attractions in Ram Bagh. PSiS Mobile system enables the user to explore restaurants and tourism places. In addition, SMARTMUSEUM enables the

### Table 1: Projects overview

| Project name | Reference | Organisation | Year | Publication type | Project state |
|--------------|-----------|--------------|------|------------------|---------------|
| VISIT        | [28, 29]  | University of Ulster (Ireland) | 2012, 2013 | conference | designed |
| CATIS        | [30]      | Aware Networks Inc (USA), Northwestern University (USA) | 2003 | conference | designed |
| PTG          | [31]      | University of Tehran (Iran) | 2008 | journal | designed |
| COMPASS      | [32]      | Telematica Instituut (Netherlands) | 2004 | conference | designed |
| EWALLET      | [33]      | Institute for Information Industry (Taiwan) | 2005 | conference | designed |
| CARS         | [34, 35]  | University of Jaén (Spain) | 2012 | journal | implemented |
| RAR          | [36]      | iMinds-Ghent University (Belgium) | 2014 | journal | implemented |
| MTGS         | [37]      | Dayalbagh Educational Institute (India) | 2015 | journal | implemented |
| PSiS Mobile  | [38]      | Porto Polytechnic Institute (Portugal) | 2011 | conference | partially implemented |
| TAPIR        | [39]      | Korea Advanced Institute of Science and Technology (South Korea) | 2014 | conference | implemented |
| SMARTMUSEUM  | [40]      | University of California (USA), Aalto University (Finland) | 2013 | journal | implemented |
| CorfuAR      | [41]      | Ionian University (Greece) | 2015 | journal | implemented |
| IMTG         | [42]      | St. Petersburg Institute for Informatics (Russia) | 2013 | conference | implemented |
| deSCribe     | [43]      | University of Southern California (USA) | 2010 | conference | implemented |
| Corfu        | [25]      | Corfu Tourist Services (Greece) | 2019 | website | deployed |
| smart travelling | [26] | Smart travelling (International) | 2019 | website | deployed |
| ImogI        | [44]      | Limburgs Universitair Centrum, Gallo-Roman Museum of Tongeren (Belgium) | 2004 | conference | deployed |
| WAM          | [45]      | Petrozavodsk State University (Russia) | 2012 | conference | deployed |
| UbiqMuseum   | [46]      | Polytechnic University of Valencia (Spain) | 2006 | journal | implemented |

### Table 2: Environment and service type of projects

| Project name       | Environment type | Service type |
|--------------------|------------------|--------------|
| VISIT              | Indoor          | *            |
| CATIS              | Closed Outdoor  | *            |
| PTG                | Open Outdoor    | *            |
| COMPASS            | Exploratory     | *            |
| EWALLET            | Tour Guide      | *            |
| CARS               | Navigation      | *            |
| RAR                | Social          | *            |
| MTGS               | Entertainment   | *            |
| PSiS Mobile        | Commercial      | *            |
| TAPIR              |                 | *            |
| SMARTMUSEUM        |                 | *            |
| CorfuAR            |                 | *            |
| IMTG               |                 | *            |
| deSCribe           |                 | *            |
| Corfu              |                 | *            |
| Smart travelling   |                 | *            |
| ImogI              |                 | *            |
| WAM                |                 | *            |
| UbiqMuseum         |                 | *            |
tourist to search for different places such as museums, parks and universities etc. and locate them on the map. In IMTG application, there is the possibility for the user to search the location of stores, cultural centres, stadiums and hospitals based on the current situation.

- **Tourism attraction guide**: This type of service presents information about the tourism place or attraction in the form of multi-media, such includes text, picture, video or audio. Many of the projects support this service type. For instance, MTGS sends a notification to the user when s/he approaches the tourism attraction in Ram Bagh. Afterwards, the user could observe or listen to a multimedia file (text, picture, or audio) about that attraction. In SMARTMUSEUM application, the tourist can receive information about the objects in the museum (e.g. tableaux), after reaching the intended place. deSCribe allows the tourist to point to every building in the University of California via his/her smartphone camera, to receive information about the building. In IMTG, some information about museums, parks and clubs etc. are presented regarding the tourist's selected location.

- **Navigation**: The ability to display the direction and guide the user from the current location to the destination is called navigation. In a typical navigation service, the movement direction is displayed dynamically in every moment, while the correct direction is presented so that the tourist could easily arrive at his/her intended destination. For example, CorfuAR is able to display the direction to the intended PoI (Point of Interest) on Google Map. Furthermore, it is able to compute and display the distance of all directions to this place.

- **Social**: This service type allows the tourist to share their thoughts, beliefs, criticisms, suggestions or photos. By using it, the user could exchange information about their trip experiences with others in order to gain more information about specific places [50]. Among the projects, PSiS Mobile provides a social network in which the users can share their comments or photos taken during the trip with each other. Moreover, in EWALLET and CorfuAR projects, the tourist is allowed to discuss their trip experiences with others in the same PoI visit, and make suggestions to them. In the VISIT application, the user is able to connect to the Twitter network and share their comments.

- **Entertainment**: Providing news broadcasting, recreational and gaming services to the user are called entertainment. Many applications organise and refine user's location, conditions and priorities play an important role in promoting the application's service. For instance, when a tourist is going to travel to a cold region, a context-aware tour guide system gives some advice related to the region's weather. As another example, if the user requests the nearest restaurant, the system suggests the restaurants based on time, location and user's favourite food and interests. Actually, these applications organise and refine an extensive volume of information for the user [52–54]. Context-awareness dimension includes two parameters of the type of the used contextual information and context gathering method. The required contextual information depends on the type of application and the services it provides. So far, several categories have been proposed for contextual information. Ryan et al. categorised the types of context into location, identity, environment and time [55]. Schilit et al. categorised the context types as 'where' you are, with 'who' you are, and 'what' objects are near you; therefore, they only considered location and identity [56]. The most common classification introduced location, time, identity and activity as the most important types of context, and named them as the primary context types. Primary context types are used in order to obtain other contextual information which is called secondary context [57]. According to the unique nature of tour guide area, none of the aforementioned general categorisations is appropriate for this field. In the tourism domain, common context information includes time, user's location, priorities and speed and direction of movement.

Context acquisition for a tour guide system is a critical issue. Several types of context information such as user's location and speed have become available by hardware inventions in the area of sensors and wireless communications [58, 59]. Furthermore, part of the application's required contextual information are gathered via sensor networks from the smart environments including museums, exhibitions, gardens and parks. The projects are reviewed regarding the context-awareness dimension in Section 4.

### 3 System design

In this section, the introduced projects are technically investigated regarding the system design dimension. In each subsection, the projects are reviewed and classified based on a parameter, which is totally summarised in Table 3.

#### 3.1 Architecture

Context-aware tour guide systems are generally categorised into three groups based on the structure of system architecture:

- **Stand-alone**: Some systems have only one component which is located on the user's device. These systems are considered as stand-alone. TAPIR, deSCribe and MTGS systems are in this category. Stand-alone applications have the limitations of a smartphone's storage and computation; hence, they cannot perform massive computations or use a large amount of information.

- **Centralised**: In this type of architecture, the main component of the tour guide system is located on a centralised server. In this architecture, most of the information is saved and processed on the centralised server. If the server crashes, the whole system may be stopped. CARS consists of two servers; GIS and Recommender server. GIS server is responsible for managing the user's requests, presenting maps and managing advice. The recommender server is responsible for giving suggestions and advice to the user. Actually, each of these servers implements
the intended service in a centralized way. Finally, CorfuAR, RAR, IMTG and UbiqMuseum systems use a centralized information server.

- **Distributed**: In a distributed architecture, the system's main components are distributed on several servers and the service will be provided even if one of them crashes. Many of cloud and web servers are implemented in a distributed way; therefore, we consider these servers as distributed. For example, PSiS Mobile is based on information available on a web Tomcat server. Moreover, the architecture of SMARTMUSEUM, VISIT, CATIS, PTG, COMPASS and EWALLET is distributed.

### 3.2 Communication type

The development of internet and telecommunication networks leads to the development of online applications. In general, the investigated projects are categorized into two groups regarding communication:

- **No-communication**: These systems thoroughly run on the user's smartphone and they have no communication with the outside. Among the projects, MTGS and deScRibe are of this type. These systems create a database on the user's smartphone during installation, which maintains their required data.
- **Mobile-to-InfraStructure (M2I)**: Some projects use wireless data exchange between the user's mobile phone and the infrastructure servers. This M2I communication can be realized through wireless, Bluetooth, Wi-Fi or telecommunication connections. Typically, M2I communication is utilized to address the limited resources of smartphones or the need for interaction with other entities. Most of the investigated projects utilize M2I communication. Some of them further elaborate on the type of communication, which are shown in Table 3.

### 3.3 Action pattern

After investigating the projects, they are classified into three groups regarding their action pattern:

- **User-initiated**: These systems act and provide services upon user's request. For example, deScRibe provides the required information from the University of California, when the user points out by mobile camera to the interested building. In addition, the action pattern of CorfuAR, SMARTMUSEUM, IMTG, COMPASS, PTG, UbiqMuseum and EWALLET projects is also initiated by the user.
- **Periodic and background**: Some applications act in a continuous or periodic manner. Among the projects, CARS, RAR, VISIT and PSiS Mobile are categorized into this group. The CARS system continuously monitors the moving user to download new parts of the map that are required because of his movement. Subsequently, new advice is given about the restaurants available in the determined region. Similarly, the RAR system continuously monitors the user and recognizes his activity during the day to give some suggestions, accordingly.
- **Event-based**: These systems are automatically activated whenever a special event takes place. Among the projects, MTGS, TAPIR and CATIS are classified into this group. In MTGS, whenever the user's location changes, the application reacts to guide him in reaching the destination in that region. In the TAPIR system, whenever the visitor approaches a work of art, the sound signal is received and the appropriate audio file is presented. In the CATIS system, some suggestions are automatically given to the user in specific times and without any explicit request. For instance, the list of restaurants is suggested to the user in the noon and in accordance with current time and location.

### 4 Context-awareness

Ubiquitous computing and context-awareness have found their way in new computing models [60, 61]. Context-aware tour guide systems are based on using tourist contextual information. These applications could provide related services to the user and restrain hisbewilderment. According to the two parameters of this dimension, the projects are investigated, subsequently.

#### 4.1 Context type

Every system relies on a set of contextual information for providing its services. Generally, context elements in the tour guide area could be categorized into three classes as follows:

- **Local entity context**: The information that describes a local entity such as the user or her mobile phone is categorized into this group, which is the most frequent type of contextual information in tour guide systems. All projects (except TAPIR) utilize user's location. In addition, a group of local contextual information such as time, user's profile and speed has been used in most of the projects. Moreover, some specific local context elements are utilized including movement direction in CATIS and CARS projects, direction in deScRibe, phone status (battery status, internet connection and GPS activation) in PSiS Mobile, device type in UbiqMuseum, device features (screen size properties, picture support and browser type) in CATIS, trip distance and user's rating to the restaurants in CARS, and battery status, acceleration, proximity, user's appointments, physical activity and behaviour in RAR.
- **External entity context**: The information that describes an external entity such as the user or her mobile phone is categorized into this group, which is the most frequent type of contextual information in tour guide systems. All projects (except TAPIR) utilize user's suggestions (Pol sentiments) are used as the external entity context. Moreover, the external entity context of EWALLET includes friends' current location.
- **General**: Other general contextual information is categorized in this class, which is further classified into the following subgroups:
  - **Related to tourism**: This subcategory refers to the general contextual information that is related to the tourism domain. In this subclass, we can mention Pol location in CorfuAR and PTG as well as the ID of exhibit and information of the artistic work in AMARTMUSEUM, UbiqMuseum and TAPIR. Besides, COMPASS uses information about restaurants’ menu. Finally, in PSiS Mobile the information about Pol timetable, and in RAR general information about Pol are used.

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**Table 3** Review of projects regarding system design

| Project name    | Architecture     | Communication     | Action pattern       |
|-----------------|------------------|-------------------|----------------------|
| VISIT           | distributed      | M2I               | periodic & background|
| CATIS           | distributed      | M2I (SOAP)        | event-based          |
| PTG             | distributed      | M2I               | user initiated       |
| COMPASS         | distributed      | M2I (GPRS, UMTS)  | user initiated       |
| EWALLET         | distributed      | M2I               | user initiated       |
| RAR             | centralised      | M2I (GPRS, UMTS)  | periodic & background|
| MTGS            | stand-alone      | No-communication  | event-based          |
| PSiS Mobile     | distributed      | M2I (Wi-Fi)       | periodic & background|
| TAPIR           | stand-alone      | M2I               | event-based          |
| SMARTMUSEUM     | distributed      | M2I (Wi-Fi)       | user initiated       |
| CorfuAR         | centralised      | M2I               | user initiated       |
| IMTG            | centralised      | M2I               | user initiated       |
| deScRibe        | stand-alone      | No-communication  |                      |
| Corfu           | distributed      | M2I               | user initiated       |
| smart travelling| distributed      | M2I               | user initiated       |
| Imogl           | distributed      | M2I (Bluetooth)   | event-based          |
| WAM             | distributed      | M2I               | user initiated       |
| UbiqMuseum      | centralised      | M2I (Bluetooth)   | user initiated       |
Table 4  Context type utilised in projects

| Project name | Local entity context | External entity context | General Related to tourism | Unrelated to tourism |
|--------------|----------------------|-------------------------|---------------------------|----------------------|
| VISIT        | location, time, user profile | Pol Sentiment | — | weather |
| CATIS        | location, time, user profile, device features, user’s speed, movement direction | — | — | — |
| PTG          | location, time, user profile | — | Pol location | — |
| COMPASS      | location, time, user’s speed, user profile | — | — | menu of restaurant |
| EWALLET      | user location, time, user profile | friends location | — | — |
| CARS         | location, movement direction, user’s speed, user profile, time, user rating of restaurant, travel distance | — | — | — |
| RAR          | location, battery status, acceleration, proximity, user’s speed, time, user’s appointments, physical activity, user behaviour | — | information about PoIs | weather |
| MTGS         | Location | — | — | — |
| PSIS Mobile  | location, time, phone status, user profile | — | ID of exhibit | weather |
| TAPIR        | — | — | ID of exhibit, Information about exhibit | — |
| SMARTMUSEUM  | location, user profile | — | ID of exhibit, Information about exhibit | — |
| CorfuAR      | location, time, user profile | — | Pol location | — |
| IMTG         | location, time, user profile | — | — | weather, traffic situation |
| deSCribe     | location, orientation | — | — | — |
| Corfu        | number of adults and children | — | hotel location, hotel reservation date, tour location, Tour reservation date, tour category | — |
| Smart travelling | Location | — | Information about hotels, restaurants, shopping centres and Pols | — |
| ImogI        | Location | — | exhibit information | — |
| WAM          | Location | — | images and information of nearby Pols | — |
| UbiqMuseum   | user profile, user language, device type | — | exhibits’ information | — |

- **Unrelated to tourism**: Other general information that is not related to tourist area is categorised in this group. For example, PSIS Mobile, VISIT, IMTG and RAR use weather information, and IMTG uses road traffic status.

Table 4 summarises the utilised context types of investigated projects.

### 4.2 Context gathering method

The investigated projects make use of five methods for gathering contextual information, which are described as follows:

- **Mobile sensors and wearable devices**: Many of the context elements are extracted by the user’s smartphone sensors, and generally, by mobile sensors. As an example, in most projects, user location and speed are obtained from smart phone’s sensors. In addition, movement direction, proximity, acceleration, device features, battery status and phone status are acquired in this way. Finally, in TAPIR the information about user’s profile is obtained by reading RFID tags.

- **Web service**: Part of contextual information is provided by web services through the Internet. VISIT, PTG, COMPASS, EWALLET, RAR, PSIS Mobile, CorfuAR and SMARTMUSEUM projects make use of this method in order to obtain part of contextual information. Examples of these contextual information include weather, Pol information and location, friend’s location, restaurant’s menus as well as the information about the works of art. Although user location is typically acquired from GPS of the mobile phone, it is also obtained by using telecommunication networks (GSM, UMTS etc.) in the places without access to GPS.

- **Static infrastructure**: The static infrastructure of smart places is a rich source for contextual information. Among the projects, the identity of artistic work in SMARTMUSEUM and TAPIR is obtained by this mechanism. In TAPIR, the identity of the artistic work is received by the mobile phone through some sound waves (which cannot be heard by human) that are scattered periodically by the sound tags installed on the exhibits. Therefore, the information about the exhibit is retrieved from the smartphone database and is displayed, when the user approaches an artistic work. In SMARTMUSEUM, this identity is obtained by reading RFID tags.

- **User interface**: A part of contextual information is explicitly entered by the user through the graphical user interface. Most of the projects including VISIT, CATIS, PTG, COMPASS, EWALLET, CARS, PSIS Mobile, SMARTMUSEUM, CorfuAR, UbiqMuseum and IMTG use a graphical user interface for obtaining part of contextual information, especially the user’s profile. Besides, CARS receives the user rating to the restaurant as well as trip distance explicitly through a user interface.

- **Inference component**: High-level context elements could not be measured directly by any sensor. These elements are usually deduced from low-level contextual information through an inference component. Among the projects, RAR uses this mechanism in order to obtain user’s activity and behaviour. It uses a classification scheme for classifying activity into one of the classes including standing, walking, running and cycling. For this, the acceleration in three axes has been extracted and
given to the SVM classifier. Afterwards, a framework is proposed to further infer user behaviour by utilising user location, velocity and activity, weather condition, time, smartphone status, etc.

Table 5 summarises the mechanisms of collecting contextual information in different projects.

### 5 Conclusion and future research directions

Context-aware tour guide systems relieve tourists from referring to and depending on old resources for obtaining information. Recently, personalised services for the tourists in tour guide systems have grown, enormously. In this paper, previous research on context-aware tour guide has been investigated according to the proposed framework, which includes three dimensions. Each dimension aims to investigate the projects from a specified standpoint, which in turn consists of a few parameters. Reviewing the projects according to these parameters reveals that:

- The extensive investigation of exploratory, guidance and navigation services in different projects highlights the importance of these services for tourists. On the other hand, providing social and entertainment services for tourists is in the beginning stages as a few projects have considered them and also their service scenarios are elementary. For example, the main social service that has been provided is the possibility of sharing information and experiences. However, a group of tourists need higher-level social requirements such as scheduling social trips in order to optimise the satisfactory level of members who may have different interests.
- Because of limitations of mobile phones and to provide online services, most of the applications are not stand-alone; they are rather in communication with internet or infrastructural servers. In a few projects, cloud computing has been utilised to support mobile applications; however, it does not support real-time or interactive applications, because the communication cost and delay between mobile devices and cloud is high. As a result, fog computing can be investigated as a solution for implementing real-time and interactive tour guide systems.
- Although various context elements have been exploited, nearly all applications utilise location and time. Despite the usefulness and importance of high-level contextual information in providing intelligent services, these contexts such as user behaviour, activity etc. have been utilised in only one project. This indicates that the whole potential of context-awareness has not been used because of challenges in acquiring high-level context elements. Hence, context-awareness in the tourism domain is in an elementary stage. Fully context-aware tour guide systems could provide highly customised services.

An area for future research is investigating health tourism. Nowadays, health tourism is not only restricted to natural resources (e.g. mineral water for curing diseases), every trip for curing diseases is called health tourism. Likewise, paying attention to the issues of travelling to untouched areas is a necessity. These systems

#### Table 5 Context gathering method of projects

| Project name     | Mobile sensor                        | Context gathering method                        | User interface | Inference component |
|------------------|--------------------------------------|-------------------------------------------------|----------------|---------------------|
| VISIT            | location, time                       | location, weather, Pol sentiment                 | user profile   |                     |
| CATIS            | location, time, device features, user's speed, movement direction | —                                          | user profile   |                     |
| PTG              | location, time                       | Pol location                                    | user profile   |                     |
| COMPASS          | location, time, user's speed         | location, menu of restaurant                    | user profile   |                     |
| EWALLET          | user location, time                  | friends location                                | user profile   |                     |
| CARS             | location, user's speed, movement direction, time | —                                          | user profile, travel distance, user rating to restaurant |                     |
| RAR              | location, time, user's appointments, battery status, acceleration, proximity, user's speed | location, weather, information about Pols      | user activity, user behaviour                     |                     |
| MTGS             | location                             | —                                               | —              |                     |
| TAPIR            | location, time, phone status         | weather, Pol timetable                          | user profile   |                     |
| SMARTMUSEUM      | location                             | information about exhibit                       | —              |                     |
| CorfuAR          | location, time                       | Pol location                                    | user profile   |                     |
| IMTG             | location, time                       | weather, traffic situation                      | user profile   |                     |
| deScribe         | location, orientation                | —                                               | —              |                     |
| Corfu            | —                                    | hotel location                                  | number of adults and children, hotel reservation date, tour location, tour reservation date, tour category |                     |
| smart travelling | location                             | information about hotels, restaurants, shopping centres, and PoIs | —              |                     |
| Imogl            | location                             | —                                               | —              |                     |
| WAM              | location                             | images and information of nearby PoIs           | —              |                     |
| UbiqMuseum       | —                                    | —                                               | user profile, user language, device type         | —                   |

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should be able to guide and introduce those areas, plants and animals and lead the tourists to beautiful places for creating memorable experiences. Finally, one of the concerns of the World Tourism Organization is the incidence of contagious diseases in some regions and tourists. Tour guide systems should give necessary advice and information as well as health notes about the outbreaks in the local region to the tourists.

Finally, today’s tourism is a major area, which is based on several technologies including Internet of things, social networks, augmented reality and fifth generation cellular network (5G). It aims to invent innovative approaches to upgrade the tourism industry in terms of sustainability, resource management efficiency, and user experience. In this regard, user’s profile, comments and reviews on social networks (in particular tourism social networks such as TripAdvisor) are a rich source of data that can be processed by powerful inference technique to dynamically infer their hobbies, preferences etc. in the tourism domain. This information can fulfill the smartness of the infrastructure to provide intelligent personalized services to them.

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