A Context-Aware Mobile Solution for Assisting Tourists in a Smart Environment

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Abstract

The cultural heritage of the italian territory is an impressive breadth of resources, unfortunately still little known today. Such a cultural heritage should be valued for the purpose is to better understand the Italian citizens their cultural identity, is to make known to the citizens of other nations the history of the place, with its story and its characters, and the life of the inhabitants, with their own traditions and customs.

In this paper, it is introduced an adaptive Context-Aware app able to collect not-structured data, belonging to heterogeneous sources and develop tailored recommendations for the user, in order to support a tourist inside a town. The solution found takes advantage of information technologies, like Internet of Thing and Internet of Services and the objective is reached through the use of a system of description of the context through a graphical formalism named Context Dimension Tree.

The system described was implemented in the city of Salerno in Italy and the results of a questionnaire distributed to the users show great appreciation.

1. Introduction

The Italian towns have a cultural heritage that often does not succeed in being completely enhanced. The natural, artistic and cultural resources present in the Italian towns, above all the smallest ones, many times remain hidden and are not enjoyed by the tourists. This problem becomes even more important when the tourist has few hours to visit a town: let us think, for instance, about some passengers of a cruise who in few hours have to visit an unknown place. The problem arises also for those people who, for work, live an experience in a town that they can visit in little time. Where eating? What seeing? How moving? These are the typical questions that such a user makes when he/she is in a station, an airport or a harbor. If in the big towns there are pre-constituted itineraries that can be easily followed by the tourists, this is not always true in towns of little or medium dimension that, even if they have a sure interesting cultural heritage, often risk of not enhancing it completely.

On second thoughts, information necessary for the enhancement of the resources of a town are, in many cases, already present on the web: the social networks have much information about the resources present in a town. On the other hand, also the public institutions, usually, develop some contents in support of the cultural resources present in the territory, but not present in places not easily reachable by the tourists, above all the foreign ones. Moreover, often, there are also services that can be useful for a tourist who unlikely knows where finding them. Therefore, it is necessary to create a framework that can integrate contents and services to support a user inside a certain territorial context.

The adoption of Future Internet (FI) technology and of its most challenging components like the Internet of Things (IoT) and the Internet of Services (IoS), can constitute the basic building blocks to progress towards a unified ICT platform for a variety of applications within the large framework of smart cities projects [1].

In addition, recent issues on participatory sensing, where every day mobile devices like cellular phones form interactive, participatory sensor networks enabling public and professional users to gather, analyze and share local knowledge [2] [3], seem to fit the smartness requirements of a city in which also people have to play an active role. Eventually, the cloud computing technologies provide a natural infrastructure to support smart services [4].

As previously said, one of the fields that can take great advantage from such technologies is Tourism [5]. In this scenario, people (citizens, tourists, etc.) and objects (cars, buildings, rooms, sculptures, etc.) equipped with appropriate devices (GPS, smart-phone, video cameras, temperature/humidity sensors, etc.) constitute a particular social network in which all the mentioned entities can communicate [6][7].

Exchanged and produced data can be exploited by a set of applications in order to make the system "smart". From a more general point of view, the social network can be seen as composed of a set of Single Smart Spaces (S3) (indoor museums, archaeological sites, old town centers, etc.), each needing particular ICT infrastructure and service that transforms the physical spaces into useful smart environments. Here, one of the most challenging and interesting research problem is to model context-awareness in a S3 and design context aware applications able to provide useful data and services depending on the current context occurrences [8][9].

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Context is not just a simple profile that describes the surroundings of data. Rather, context is better described as any piece of information that can be used to characterize the situation of an entity such as a person, a place, or any other relevant object/aspect in the interaction between a user and an application. In this paper, we try to give an answer to the problem of the context representation using the Context Dimension Tree (CDT) formalism [10][11].

The objective of this work is to indicate an approach for the realization of a Context-Aware engine that can allow the dynamic supply of contextual contents, adaptable to the needs and the behaviors of the users.

In order to give an innovative technological solution to the Context Awareness, the main contribution has been to exploit the CDT to represent the context and access not-structured data, belonging to different and heterogeneous sources.

On the basis of what has been previously described, this work will be organized in this way: in the following paragraph, we will describe the concept of context and how it can be declined in a modern way thanks to the use of new technologies. Then, we will introduce a context-based approach able to give, inside a little town, services and contents useful for the user. Some experimental results will be presented in the last part of this paper.

2. Motivating example

In this section, we describe a typical application in the Tourist domain in order to better understand the main features of the proposed system. In particular, we consider a tourist who during his/her vacation in Campania desires to visit Salerno, a beautiful town located in the South of Italy. To be considered smart for a tourist, our environment related to the town of Salerno should provide a set of smart services for:

- suggesting the visit of the most important cultural places in Salerno
- having information about the restaurants in Salerno
- accessing proper multimedia guides describing the main artworks that are in Salerno
- recommending special visit paths (trekking paths, bicycle tours, …)
- monitoring the weather condition
- showing the timetable of the transport services located in Salerno
- saving the visit in a multimedia album
- accessing information about public services in Salerno (post office, pharmacy, …).

For improving their effectiveness, these services and contents have to be furnished to the user in the right context and at the right timing. Therefore, the context awareness of the framework and the opportunity to use it by mobile devices is important [12]. Another essential feature of the system is the ability to suggest resources that usually are not considered as mainstream.

In order to give the most suitable contents to the users, in this paper we introduce a context aware system able to tailor data and services depending on the context and the users' needs. For example, if the user declares as preference the use of the transportation when he/she is close to a bus stop, the timetable will be automatically downloaded on his/her smartphone. The same will happen when the user is close to restaurants: if he/she loves food based on fish, only this kind of restaurant or menu will be proposed.

Data about resources and services are collected from a knowledge base built by a group of experts and collecting information from the various social networks.

In the next paragraphs, more details about the system architecture and the application of the proposed approach in real context will be furnished.

3. Context Awareness and ICT

The human being has always used the concept of context, which belongs to that kind of concepts known by the majority of people, but that are difficult to describe with words. In [13], there is the first attempt to describe the relation between the context and the context-awareness in the field of information technologies. The three main aspects of the context are: 'where you are', 'who you are with' and 'what resources are nearby'. If we put together the three just mentioned sentences, we realize that they can be seen as a first definition of context based on some observable characteristics. Another definition of context has been proposed in [14] where the context is defined as a series of environmental features (environment), such as, for example, the place, the temperature and the considered user's identity. The definition of context that usually is taken into account is the one proposed by [15]: '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.' Directly linked to the definition of context, there is that of context-awareness applications: applications that in some way are aware of the context where the user is and the capability to detect and react to the changes in the environment where it is located [16]. Again in [15], there is a definition of the context-aware system: 'A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.' In practice, a system can be defined context aware when it takes advantage of the context to give important

information and/or services to the user, where the importance depends on the user's request and features. If we wanted to classify the context-aware applications, we could consider the ones presented in [13]:

1. Proximate Selection, which literally means 'selection of proximity', is an interfacing technique that considers that the user gets close to a particular place to receive some relevant information and/or to make elaborations, both on request and automatically.
2. Automatic contextual reconfiguration is the process of addition of new components, removal of already existing components or alteration of the connection among the components of a system. In actual fact, there is the change of the system according to the context. Typically, the components can include: driver modules directly downloadable by the user, modules of programs.
3. Contextual information and commands: often the operations that people make can be predicted. In fact, usually, there are some recurring operations made in particular places (e.g. universities, libraries, offices, etc.). The applications that use this kind of 'contextual information' are made to accomplish certain orders (contextual commands) in place of the user according to the context.
4. Context-triggered actions are those applications that automatically carry out an operation when there is a particular condition (trigger) in the context.

Although, as time goes by, new classifications have been introduced, the previous ones are still valid. It is important to precise that a context-aware application has not to necessarily belong to one of the listed categories, but it is possible to have some 'hybrid' applications that have features belonging to more categories.

What are the context-aware applications for? For some years, more and more often we hear talking about smart environments aimed to the improvement of the quality of life, both in domestic environment (domotics) and in city environment. In particular, there is an expression that recurs a lot in the several mass media: 'smart city'. The smart cities are the so-called intelligent cities. This subject is interdisciplinary and encompasses all the fields: from the energy saving, to the improvement of life and the fastest and more natural access to information. It is exactly in these two latest fields that the context-aware applications insert themselves. In fact, in the future cities, there will be more and more smart spaces (domestic and not), which will take care of the users making easier and more immediate their access to information and, under determined conditions, will be able to foresee the user's desires and therefore to anticipate some operations on behalf of the user. As an example of smart environment, we can think of a room that has the capability of automatically regulating the temperature of the environment according to the user's preferences, or, through a centralized stereo system, it can change music according to the user's tastes. And moreover, we could think to a public park where people, by tagging, can leave their own messages on a virtual wall, so that in the future the users of this same park can take advantage of the advices of who has been previously in that place. A further example could be that of a smart shopping center, where, when a user enters a shop, he/she directly receives information about the products on sale that he/she could be interested in. This processing can be made on the basis of the previous purchases and/or of a series of indications given by the same user (for example, through an electronic questionnaire made available by the shopping center). This kind of applications can become very important also in the field of the improvement of disabled people's life. In fact, it is possible to study some areas that change according to the specific need. For example, let us consider a blind person that enters a smart public building, this environment, after having received context information about the user, has to be able to guide him/her towards his/her destination using audio messages.

In the following paragraph, we will present an approach to the management of the context and its associated services to make the previously introduced approaches concrete.

4. A Context Dimension Tree based approach for contents and services contextualization

A key element in the design of a contextual application and a Context Aware System is the representation and management of the context itself.

To better understand formal concepts, it has been carried out in the paper an example based on a simplified citizen domain, on which it is now being developed a Context Aware System that assists residents and tourists in their activities.

The goal is to provide a mechanism of dynamic and automatic invocation of services considering the context through the Context Dimension Tree [17].

CDT is a tree composed of a triad <r; N; A> where r indicates its root, N is the set of nodes of which it is made of and A is the set of arcs joining these nodes.

CDT is used to be able to represent, in a graphic form, all possible contexts that you may have within an application.

Nodes present within CDT are divided into two categories, namely dimension nodes and concept nodes. A dimension node, which is graphically represented by the color black, is a node that describes a possible dimension of the application domain; a concept node, on the other hand, is depicted by the color white and represents one of the possible

values that a dimension may assume. Each node is identified through its type and a label. The children of the root node r are all dimension nodes, they are called top dimension and for each of them there may be a sub-tree. Leaf nodes, instead, must be concept nodes. A dimension node can have, as children, only concept nodes and, similarly, a concept node can have, as children, only dimension nodes. In addition to nodes, you can use other elements: the parameters, which may arise both from a dimension node (graphically represented by a white square) and from a concept node (white triangle), submitting them to particular constraints. In fact, a concept node can have more than one parameter, while a dimension node can have only a parameter and only in case it has not already children nodes. The introduction of parameters is due to their usefulness in shaping the characteristics that can have an infinite or very high number of attributes. For example, a node representing cost dimension risks having a high number of values that should be specified by as many concept children nodes. In a similar case, it is therefore preferred to use only one parameter, whose value will be specified in each case. Leaf nodes, in addition to concept nodes, can also be parameters. In general, each node has a parameter corresponding to a domain, dom(nP). For parameter nodes connected to concept nodes, the domain can be a set of key values from a relational database, while in case of parameter nodes connected to dimension nodes, the domain is a set of possible concept nodes of dimension.

In figure 1, it is shown a general designed CDT, called Meta CDT, which is the starting point for the design of a specific CDT that can be exploited in contextual applications. You may note six top dimensions, which correspond to the questions of the 5W1H method: Location (WHERE), Role (WHO), Time (WHEN), Situation (HOW), Interests (WHAT) and Utilization (WHY). In particular, there are two types of users and eleven categories of interests.

A context element is defined as an assignment $d\_name_i = value$, where d_name_i indicates a possible size or undersize of CDT (it is the label of a dimension node), while *value* may represent the label of one of the concept nodes that are children of the considered dimension node or the value of a parameter referring to one of these concept nodes or the value of a parameter referring to the considered dimension node.

For example, these assignments are possible context elements: Interest = tourism, Location = LocationID (ID = 3), Role = user, Utilization = holiday.

A context is specified as: $\wedge$ (d_name_i = value).

It is defined as an **"and"** among different context elements. Several context elements, combined with each other by means of an **"and"**, damage, therefore, the origin of a context.

For example, a possible framework that can be obtained from the previously seen CDT, through the context element that we have listed, is:

C = (Location = locationID (ID=3)) $\wedge$ (Role= user (ID=15)) $\wedge$ (Time = now) $\wedge$ (Situation = routine) $\wedge$ (Interest = tourism) $\wedge$ (Utilization = holiday)

The context is defined as a user, interested in tourism, who uses the contextual app on vacation, in a called place.

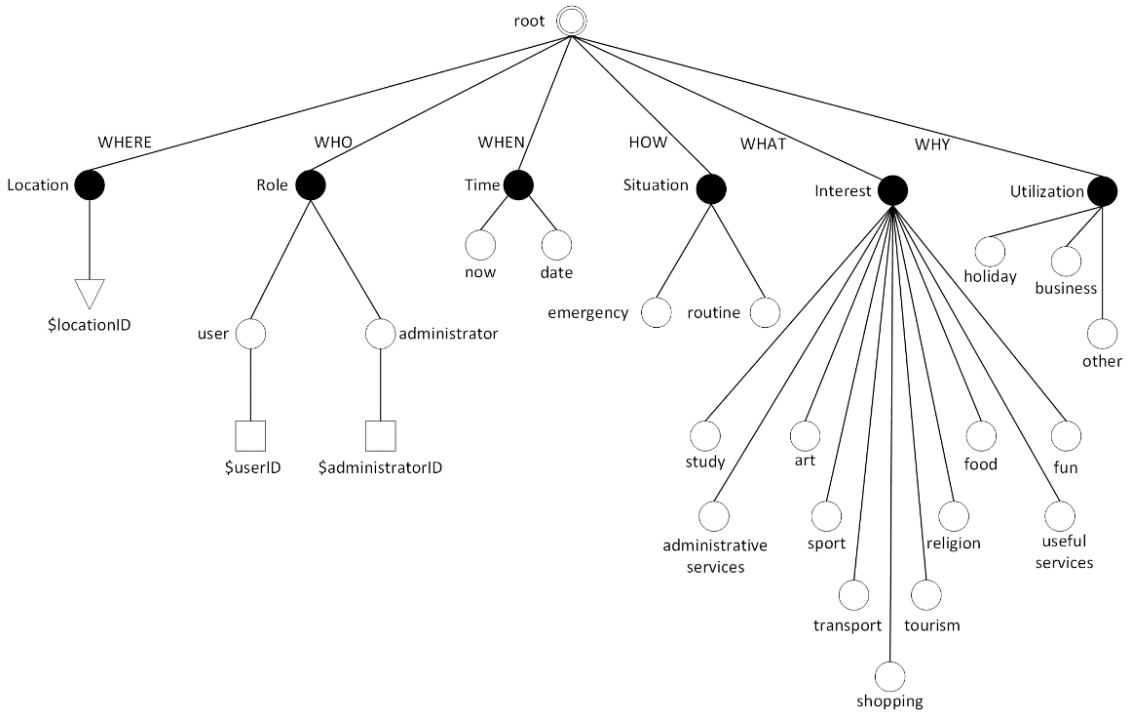

Figure 1. Meta CDT for contextual applications

Therefore, through the Context Dimension Tree, it is possible, after analyzing the domain of application, to express the size characteristics and values they can take in a graphical way by, respectively, dimension nodes and concept nodes or parameters. The assignment to a dimension of one of its possible values is a context element. The context element can be considered the main feature of the application, by which a context can be decomposed. The moment you make the formulation of the context, you must specify all the context elements that are part of it and that enable its creation. Any context is expressible by an **"and"** combination of the context elements to which they are peculiar.

There are some ties that have not to be violated when the context is defined through the CDT. In fact, the designer has to define some rules in order to avoid meaningless or senseless contexts, such as for example a user, in a situation of emergency, interested in the shopping. By definition, you can begin to understand how you will create views based on data relating to each context; in fact, they will be built starting from the portions of the database and then from the partial views, associated to the context element that takes part into context information.

The advantage of this approach is to have the possibility to access and use not-structured data, coming from different sources, treating them in the same way and enriching our knowledge base. Through the CDT, in order to identify a suitable context and therefore to supply contextual contents, you will be able to use immediately data coming from the network, in particular from very known platforms such as TripAdvisor, Facebook, Google Places. The use of this multiple platforms has made possible to find a big amount of information concerning the details of the places of interest, as the effective opening of a pub or the telephone number to reserve a table, as well as the ones related to the user's profile, in order to personalize the found contents.

In the two following subsections, we will describe the methodology to obtain the contextual services and the total architecture of the system.

4.1. Methodology and phases to obtain contextual services

The methodology, shown in figure 2, has been realized in order to manage the database and to carry out reductions of their content based on the context.

The purpose is to help the designer in the definition of all contexts relevant to the considered application and, later, in the association to each context of the portion of the database containing the relevant data about the context.

The methodology consists of three main phases, which we will see in detail later: design phase of the Context Dimension Tree (CDT), definition phase of partial views and composition phase of global views.

1. Design phase of the Context Tree: in this phase, the Context Dimension Tree is designed to identify significant context elements for the considered application. In fact, it focuses on the definition of contexts and on the elements that compose them. These contexts must be identified and shaped, indicating particular elements that characterize each of them. As it has been said, it is available a special tool called Context Dimension Tree (CDT) to make context design. Three CDT were made for specific environments in order to represent and manage a multitude of different contexts and in order to identify, represent, preserve and make available cultural points for each type of user.
2. Definition phase of partial views: after the definition of all the contexts and their context elements, in this step a different portion of the database is associated to each context element, containing the relevant data for it. In practice, the goal is to find the appropriate value for a given dimension, in order to obtain, by means of the values of all the dimensions, a valid query and specific to the context in which the user is located. A partial view could be related to dimension "Role": once logged in, the application is able to recognize the user and to know more precisely whether he/she is, for example in tourist areas, a resident or a tourist. Thus, the value "tourist" of dimension "Role" is a partial view for the current context: using this knowledge, you can exclude certain services, not suitable or useful to the tourist role. Furthermore, Location, Time and Situation dimensions are automatically obtained by the system, while Role, Interest and Situation are information that the user needs to provide manually, but also automatically updated by accessing him/her data from social networks.
3. Composition phase of global views: this is the phase where you have the automatic generation of views associated with each context, which is made starting from partial views associated with context elements. After the creation of the global views of the contexts, the answers to questions that will be asked to the system will be developed from these views and, in particular, from the view associated with the context in which you are located when the query is performed. In particular, once defined the values for each dimension, you can use all the information obtained in order to identify the right context and offer data and services customized for the user.

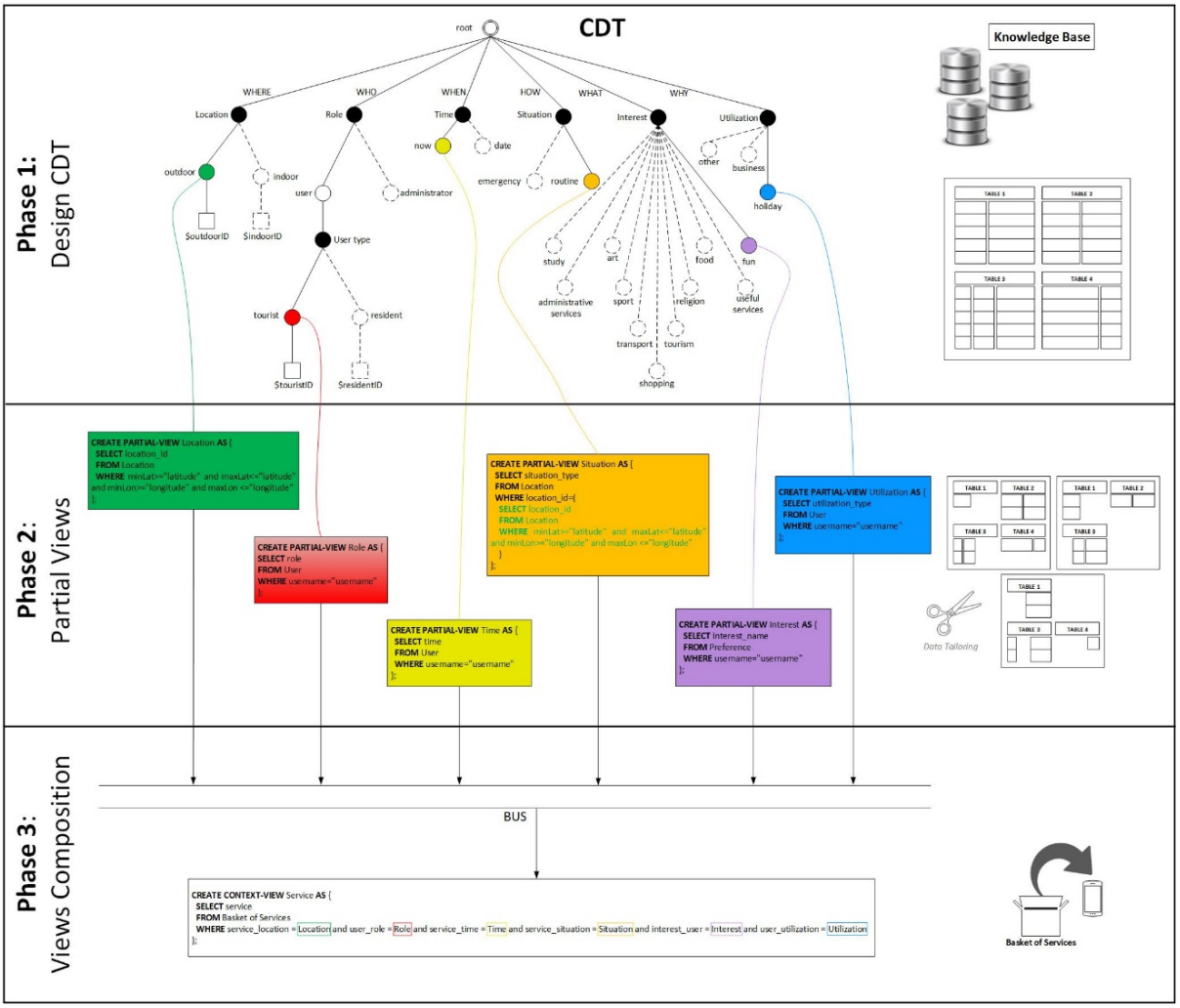

Figure 2. General System Workflow

It is assumed the example of a tourist who is walking near a beach who gets initially a notification of his/her proximity. Later, he/she needs to deepen such notification. Therefore, it will propose him/her services that he/she might be interested in, such as the site of the nearest beach, where he/she can get the price list. In case it is not possible to know the values for one or more dimensions, anyway the system will make queries to the knowledge base, considering all the admissible contexts for the known dimensions.

4.2. System Architecture

We have made a Context Aware System, whose architecture is shown in figure 3, able to adapt useful data and services to users based on the context. Context awareness of interaction is particularly important in ubiquitous systems and mobile applications for groups of users. In fact, given the ever-increasing variety of interaction devices (fixed and mobile) and application use contexts, it becomes increasingly necessary to develop Context Aware systems that manage information that makes unique and distinguish each human-machine interaction.

The architecture of our model is composed of: the Context Aware Module (CAM), which is the main engine and considers the context in reference to the obtained data (contextual information), in particular position (GPS location), interests and role (obtained during registration) of each user; the Knowledge Base Module, a special type of relational database, where data is processed by a server, for the management of knowledge and information: in particular “Users”, representing all users of the application, “Services”, which describes all the services of every possible application context, “Resources”, which forms all the points of interest and “Events”, which describes all events; and finally the Management Module (MM), used both by the administrators of the app and the users themselves. This module deals with some important issues, including: POIs management, where the insertion can be done directly from map, manually or by search of interests, interacting in the last two cases with Google Maps; services, comments and events management, interacting with TripAdvisor and Facebook/Twitter API.

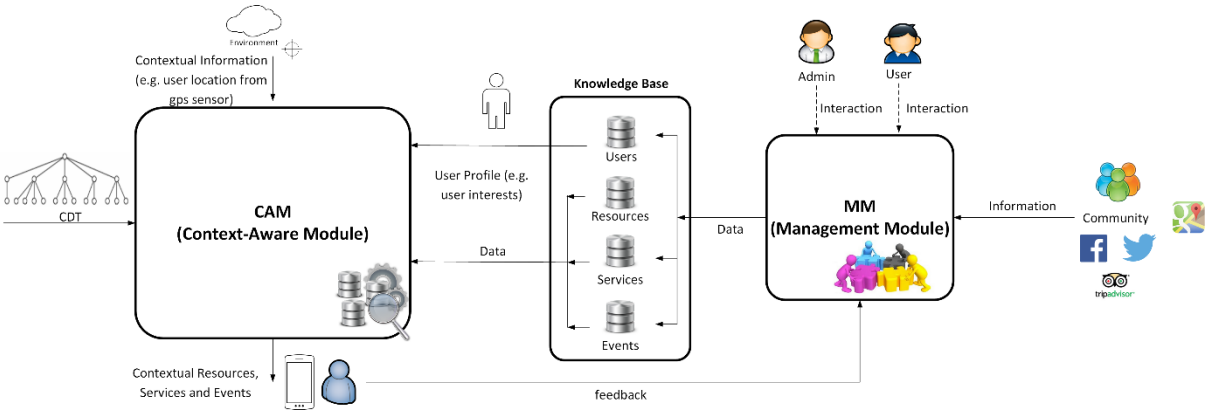

Figure 3. System Architecture

In figure 4, for a greater immediacy, it is shown a deepening of the realized architecture: the set of user profile, such as preferences and interests, of user context, such as his/her GPS location, of CDT, which provides the rules and allows the representation of the specific context in which he/she is located, of data, including the points of interest and services, allows obtaining the contextual resources tailored for the user, through the use of a contextual application.

On this subject, for the different environments described, we have realized hybrid mobile applications, both in Android and iOS, with many features, some of which are shown in figures 6 and 7: contents, including descriptions, images and services, tailored to interests, profile and location users, planning a route based on user's interests and his/her preferences of travel, exploration of the surroundings from the current position, custom QR Code reader, weather and news on the site, search and insertion of events, comments section, display position and points of interest on the map, with integration of the GPS on the smartphone to reach specific ones.

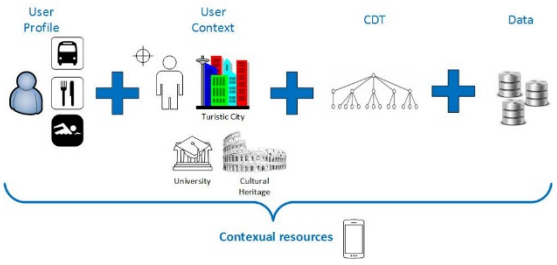

Figure 4. Contextual resources as final result of App

5. SmartApp Salerno: A Context Aware App for e-Tourism

In this section, we will present SmartApp Salerno, a contextual app designed and implemented according to what was described previously. In particular, we have thought to apply the approach to the context of the town of Salerno, a municipality in Campania (Italy) of about 135.261 inhabitants and with an extension of 59,85 square km. Along with the Municipality of Salerno, a reference CDT has been designed. In this phase, we have collected the potentially useful services and contents for the citizens and situated them on the map defining the activation zones (figure 5).

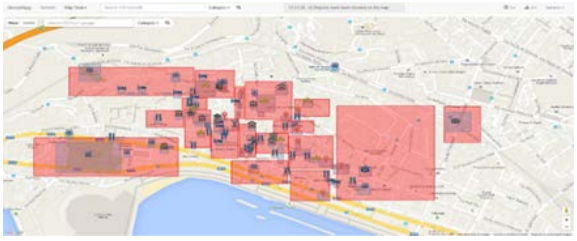

Figure 5. Definition of the activation areas of services and contents.

Moreover, we have defined the different typologies of citizens (elementary school's students, users with kids at school, university students, …) associating them to a previously established set of services and contents. Having the town a series of artistic contents, we have developed services and contents in support of them too. A series of services and contents considered transversal, such as the opening hours of the City Hall, the Library, the Cemetery, the pharmacies, have been made available to all the typologies of users. All information about places of worship and shops has been uploaded, for any building or area of potential. The App has been developed with hybrid technologies (Cordova and PhoneGap) to allow an easier publication both in Android and Apple environment (figure 6).

The App has been presented to various tourists in December 2015 and January 2016 during 30 workshops.

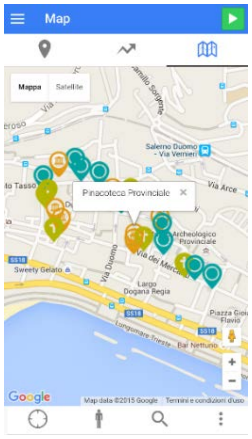

Figure 6. Screenshot with some features of contextual application.

The occasion has been given by a Christmas event, called *Luci di Artista* (Artist's Lights), which every year is held in Salerno and that involves hundreds of thousands of tourists. They have been involved overall about 3000 tourists between 18 and 50 years old. During each workshop, the app has been installed on the mobile devices of the tourists. For each of them the system has started to supply personalized itineraries (figure 7). They can be saved earlier than the visit that the tourist will do and then loaded and run offline in the time of need.

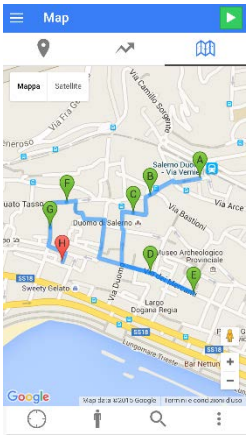

Figure 7. Example of Adapted Path for a user

After a week the system has given a questionnaire of 5 sections to 100 spot-selected tourists. To every question present in the section, 5 possible answers have been associated: I totally agree (TA) – I agree (A) – Undecided (U) – I disagree (D) - I totally disagree (TD). The questionnaire in detail is the following:

- *Section A: SmartApp Salerno – Context*
- A1. SmartApp gives the user tailor-made contents and services
- A2. SmartApp allows the user to know several points of interest of the Old Town Center of Salerno
- A3. SmartApp supplies contents and services in the right place
- A4. SmartApp supplies services according to the interests selected in the user profile
- *Section B: SmartApp Salerno – Usability*
- B1. SmartApp is immediate to understand and use
- B2. The registration is quick to do and non-invasive
- *Section C: SmartApp Salerno – Further aspects*
- C1. Information about each point of interest is very useful
- C2. I do not know other applications like SmartApp
- C3. The contents, such as descriptions and images, are of high quality and represent one of the strong points of SmartApp
- C4. The services associated to the points of interest allow a higher immediacy than a classic research on the Internet
- *Section D: SmartApp Salerno – Functionality*
- D1. The map is very useful and well curated
- D2. The plan itinerary service allows easily realizing an itinerary in the Old Town Center of Salerno according to the user's preferences
- D3. The explore surroundings service is very useful to know what there is nearby and eventually reach them
- D4. The functionality of research of points of interest by category of interest is intuitive and practical
- D5. It is useful to know if a certain point of interest is open or closed
- D6. The functionality of QR code in inner environments can be well used
- D7. The tutorial effectively allows learning the main characteristics of SmartApp
- D8. The weather forecast and the news are two very useful services
- *Section E: SmartApp Salerno – Future developments*
- E1. It would be interesting to have a higher integration with the main social networks
- E2. It would be interesting to insert the available time in the plan itinerary service

Table 1 presents a synthesis of the answers of the participants to each declaration.

Likert Scale	Answer	TA	A	U	D	TD
Context	**A1**	35	53	7	3	2
	A2	49	35	7	6	3
	A3	24	72	3	1	0
	A4	48	38	7	5	2
Usability	**B1**	33	46	17	3	1
	B2	49	34	11	3	3
Further aspects	**C1**	21	74	4	1	0
	C2	28	31	30	8	3
	C3	28	50	15	5	2
	C4	42	32	20	4	2
Functionality	**D1**	33	62	2	2	1
	D2	50	38	6	4	2
	D3	36	49	10	4	1
	D4	30	55	11	3	1
	D5	45	35	14	3	3
	D6	25	49	17	5	4
	D7	27	51	14	7	1
	D8	47	34	13	6	0
Future developments	**E1**	24	67	6	2	1
	E2	40	38	9	9	4

Table 1. Experimental results

As shown in this table, of the 100 participants who have interacted with the application, many agree and/or strongly agree that the system gives appropriate contextual information about the place, it is immediate to understand and use, further aspects and functionality are very useful and future developments are interesting. Instead, only in few cases, the participants do not are particularly satisfied. In figure 8, we can notice in graphic form, the results obtained from the proposed questionnaire and, in figure 9, the positivity of the answers with respect to the total. Then, users show great appreciation for the app: in general, they have appreciated the proposed contents and services.

6. Conclusions

In this paper, we have presented an app able to offer services and contents personalized for the needs of the user according to the context where he/she is. The app bases its 'contextual' functioning on the adoption of the CDT that is able to shape the context and the actions to implement. The app has been developed for the needs of a little Italian town and the first results have been satisfying. The following activities have as purpose the application of the proposed methodology to more complex environments, for dimension and number of potential points of interest to manage. A potential further future development relates to greater integration with other heterogeneous sources of information.

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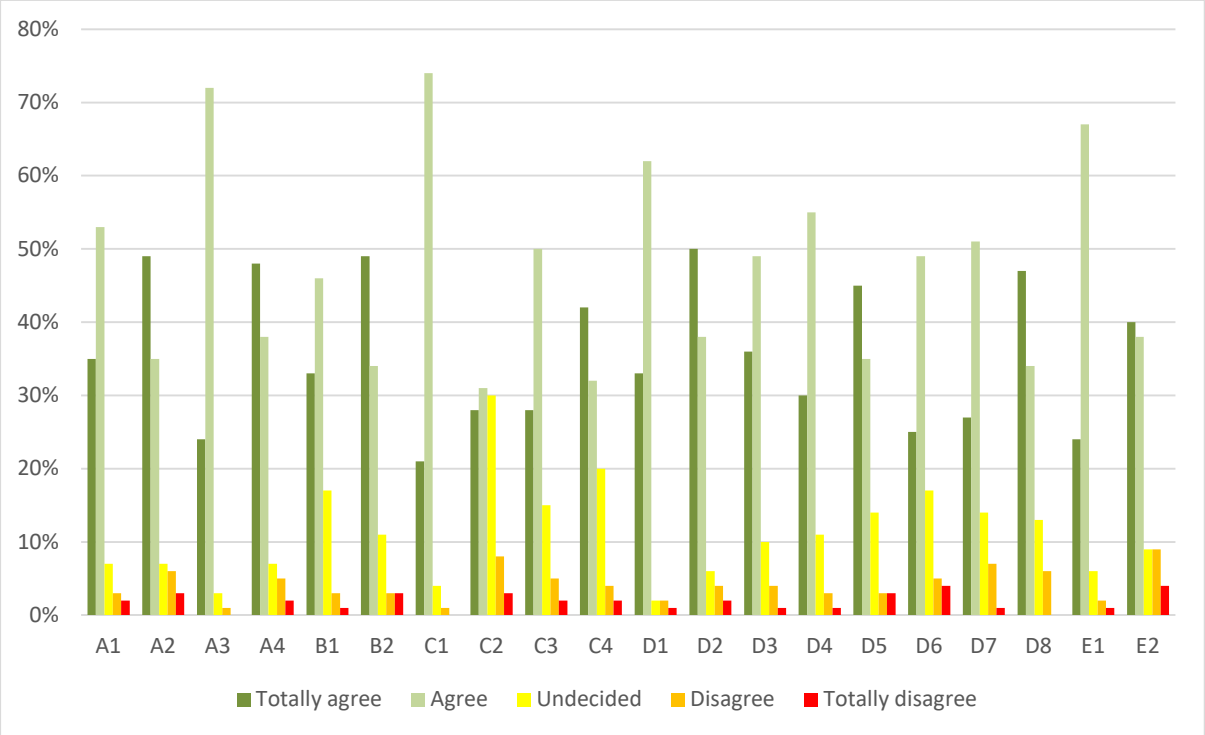

Figure 8. Analysis of Questionnaires

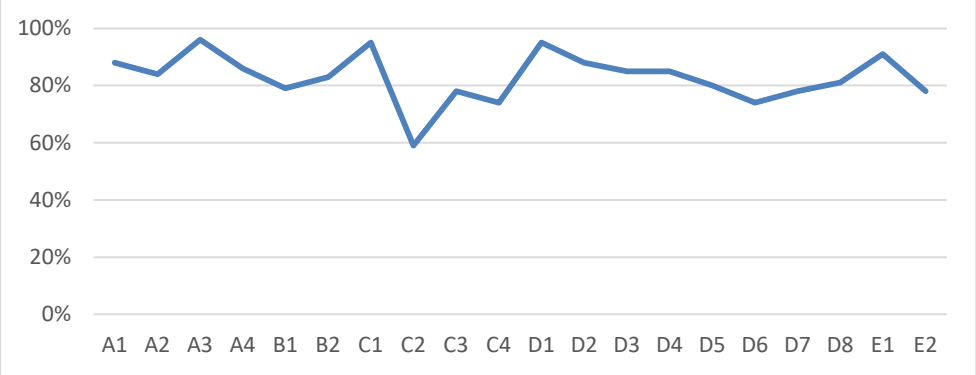

Figure 9. Positive feedback

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