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CACHE: Contextual Approach for Cultural Heritage Enhancing

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ABSTRACT

In the panorama of Italian coastal tourism, there are many unique and unexplored places. These places, which suffer from the lack of government investment, present the need to be promoted through low consumption systems and widely used distributed applications.

The present work aims to develop innovative solutions to support citizens and tourists to offer advanced services, highly customizable, able to allow, through the use of new technologies, a more engaging, stimulating, and attractive use of information than the current forms. The developed system is based on graph-based formalisms such as Context Dimension Tree and Bayesian Networks, representing the context through its main components and react to it anticipating users' needs. Through the development of a mobile app, it was analyzed a case study applied in the area of Amalfi Coast (in Italy). Finally, an experimental campaign was conducted with promising results.

1. Introduction

Nowadays, Italian coasts represent one of the most characteristic and priceless tourist places globally, i.e., offering users an important cultural heritage. Unfortunately, not all sites receive the attention or financial support necessary to bring out their uniqueness. Thanks to the advent of new technologies and the smart cities phenomenon, these places could finally be protected and promoted. In fact, the adoption of Future Internet (FI) technology and its most challenging components, such as the Internet of Things (IoT) [1] and the Internet of Services (IoS) [2], can provide the foundation for progress towards unified platforms that offer a variety of advanced services. Besides, the constant use of mobile devices to form interactive and participatory sensor networks, which allow users to collect, analyze and share local knowledge, can contribute to developing the smart city paradigm where the citizen is called to play an active role [3]. One of the sectors that could potentially benefit the most is tourism [4]. In such a scenario, places and objects such as sculptures, buildings, etc. can be brought into contact with users in a completely new and stimulating way [5]. In particular, data, which represents a significant added value, can be processed to enrich further the system's ability to relate man and machine. In this regard, one of the main problems is to model the awareness of the context. This problem can be solved through the Context Dimension Tree: a graph formalism representing all possible contexts [6]. The next step is to predict the possible scenarios to model the proposals to each user's needs. This further problem can be addressed through the use of Bayesian Networks [7]. Bayesian networks represent graph formalisms able to predict specific events when some variables (in our case, contextual variables) change [8].

This paper intends to propose a system based on a "Content/API Economy Platform", characterized by a strong awareness of the context. The designed system allows the content-generating actors (Institutions such as Museums, Communities or companies, and individuals) and the content user actors (the Institutions themselves, the service companies and, above all, the end-users) to operate through a platform-broker that, through the automatic composition (orchestration) of services, is able to activate in a controlled way they access and consumption of the information contained in

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the Knowledge Base. In fact, the operating modes include the entire life cycle of the Knowledge Base that provides for the collection, storage, classification, and availability of the contents accessible through simple mobile applications oriented to provide tourists with richer visiting experiences [9].

In particular, through the identification and processing of the context of use in which the user operates, it is therefore essential to define flexible methods, i.e., to dynamically recommend data and services that best meet users' situational needs. When necessary, this approach can tailor the information extracted to offer the user what may be useful at a given time.

2. Background

2.1 Context Awareness

The analysis of the context in which we do something is often more important than what we are doing [10]. This concept represents why search engines are increasingly trying to understand the real meaning of individual "keywords" and the context they are placed and, therefore, the user's intent. For example, if a user is searching by typing the keyword "Japanese", is the user looking for a sushi place in the area, or is looking for language lessons?

In this regard, context-aware computing is used to indicate the use of computer technology to collect and analyze data about the reality that surrounds us. The idea is to create devices and applications that are aware of their surroundings and analyze the data to create new exciting use cases [11].

Our smartphones have been collecting contextual data for years over the network or using their sensors, such as gyroscopes, or detecting movement. They use location-based data to power many of the apps we use daily, from Google Maps to the more recent Uber [12].

Part of the challenge is that non-uniform data from heterogeneous sources can be challenging to process in a single system. In fact, data can be stored in various formats or use a different syntax that can create disambiguation problems, which could lead to misinterpretation. Fortunately, while we have access to and create more data than ever before, we also can use tools such as artificial intelligence (AI) and machine learning that can help us process this data [13].

In recent years there has also been much talk about augmented reality (AR). The resounding success of Pokémon Go has shown us how powerful this technology can be when applied correctly. In this regard, context processing will probably have a knock-on effect on the field of AR development because it provides access to new types of data that developers can exploit [14]. A consequence could be the possibility for the user to have a digital "sixth sense" available. After all, this will allow us to increase our understanding of the world around us and our possibilities, such as the quality of the air we are breathing or our speed.

The most interesting thing is that context-aware applications have led to devices that learn to know ourselves better and anticipate our moves. Google Now, for example, is specifically designed to provide information to users by predicting what they want, based on historical and contextual data [15]. As said, our smartphones are able to detect a range of information from available sensors to detect both our position (GPS) and our movements (accelerometer). To them are added wearable devices such as Fitbits, which lead, of course, to a further increase in useful information. At this point, an analysis of the data can predict when we will be hungry and how much we should eat to compensate for our activity or indicate what we probably like and what our budget is.

One of the most relevant potentials that come from contextual processing is how it can help us build artificial intelligence that speaks and can understand the environment and interact with the "senses" in a similar way to humans. Of course, we are still far from this goal. We will need a continuous joint development of machine learning and deep learning technologies to continue to progress together with context-aware computing [16]. All the data produced and available will be useless and counterproductive if we cannot process them. Context-aware technologies are based on both hardware to collect data and software to make sense of them.

Thanks to their virtual assistants, current leaders in this field are companies like Google, Apple, and Amazon. Google, Siri, and Alexa are always listening and using what they grasp to provide context-aware services. After all, if they are not listening to instructions, they cannot react to commands, so they are equipped with a certain amount of built-in contextual computing. In addition to listening to our instructions, devices like Google Home, Apple HomePod, and Amazon Echo monitor our home environment [17]. They can turn on the lights when we enter the rooms and adjust the temperature according to the weather conditions.

Ultimately, the main thing to remember is that new context-aware technologies can make our lives more comfortable, operating in an environmentally friendly way. However, it is the way we use them to offer added value in society, visible even in the long term.

2.2 Context-Aware Computing for Tourism

In the world of tourism, the advantages of using context-aware applications lead to an inevitable enhancement of cultural heritage [18]. This opportunity is linked to visitors' enormous flow, whose management is not easy and is closely related to the proper development of the tourism chain. The latter involves both public and private operators who together are able to organize the processes necessary to achieve the objective in economic and social terms.

First of all, tourists express the need to have explicit, updated, and exhaustive references to enjoy a complete cultural heritage experience with all the necessary services (for example, local transport, catering, accommodation, information, and guides). On the other hand, the agencies and public administration want to increase the economic and social weight of the cultural heritage of their pertinence through the increase of presences and services. Finally, operators in the sector express the need for greater economic returns from interaction with the flow of visitors interested in the enjoyment of cultural heritage through engagement and relationship mechanisms dedicated to this segment of customers.

In general, the considerable amount of existing material on cultural heritage, which far exceeds the physical space available in museums or archaeological sites, and the growing interest in collections accessible to a wide audience have led institutions and professionals to increasingly adopt web-based and mobile tools to present their collections and services, meeting the needs of interested visitors [19].

Currently, with the convergence of the Internet, wireless technology, and the growing adoption of the Web as a platform for publishing information, the visitor is able to take advantage of services and material related to cultural heritage before, during, and after the visit, having different purposes and requirements at each stage. Therefore, cultural heritage exploration becomes a continuous process, starting the visit before reaching the place of interest and, ideally, never-ending. In fact, the user is able to plan and anticipate his or her travel itinerary, visit the site in person, and then revisit the places of interest using the material shared online.

It is clear that the enormous amount of information available must be filtered, customized, and contextualized to allow the individual user to access it easily. The contextualization of data and services related to cultural heritage requires a system that can model the user (for example, based on his/her interests, knowledge, and other personal characteristics), as well as contextual aspects, thus selecting the most appropriate content.

In particular, it should be remembered that museum visitors differ from each other. Their visiting to the museum is made up of the physical, personal, and socio-cultural context and aspects related to identity. Therefore, they can enormously benefit from systems that take into account personal and contextual characteristics. Moreover, visitors' behavior may not remain constant during the visit, requiring an ongoing adaptation. Besides, since tourism is a social activity, adaptation to individuals is not enough, and groups and communities also need to be shaped and supported, taking into account mutual interests and previous everyday experiences.

The challenges faced by researchers and developers of context-aware applications concern how to model and represent the user and the context of the visit and how to retrieve the available information [20]. In fact, extensive Web-based collections are difficult to identify and carry the risk of overloading users. As said, visitors are extremely heterogeneous and require different types of information and different levels of detail. Finally, in general, users of cultural heritage and tourists are often, and for a short time, visitors to a place unknown to them. On the one hand, this means that they have a constant need to find the relevant information; on the other hand, providing them with adequate answers is challenging since their interests and needs are not known from the beginning.

In this field, context-aware computing techniques can guide the selection of data and services based on the context and interests of the user or groups, protecting them from information overload [21]. Besides, contextualization and customization can be used to adapt the presentation of information on the device, thus facilitating its exploration.

However, for these purposes, heritage information must be represented, through the use of ontological models, in a format that can be interpreted by a processing system (computer, smartphone, etc.) that can be combined with the interests, preferences, and, in general, the recipient's current context [22].

3. Motivating Example

The system aims to recommend a wide range of services, which can help users during a travel experience. The system is able to help users manage the time and all the resources at his disposal in the best possible way, i.e., revealing what is around him and satisfying current and future needs.

The intention is to improve a tourist's experience and quickly project him/her into the new world in which he/she lives. It is crucial, in fact, for a person who is in a place to visit, to have the opportunity to orient themselves among the points of interest that place offers, and to know its history in order to have a conscious vision of the cultural attractions present. As soon as he or she arrives in a new place, therefore, a tourist will need to know, in general terms, the characteristics of the place and the reasons why it is worthy of interest. Through the services provided, they can immediately obtain a description and then go into all the details. Moreover, a trip does not always allow tourists to have the right time to thoroughly visit the chosen destination. In these cases, the tourists are faced with the difficult selection of the attractions that will then actually be visited. In this scenario, the tourist will be able to take advantage of the knowledge acquired previously to visit the most important historical points and visualize the impressions that these have left in other visitors, automatically detected by, for example, Sentiment Analysis techniques. Another classic situation is to be faced with the planning of one's activities and visits; in this case, through the proposed system, tourists will be able to obtain dynamic itineraries based on their tastes and the parameters related to the current context: during the planning of the itinerary, the system must always adapt to dashboards measuring the resources that the user has made available (for example, time, budget, number of members of the visiting group, age, etc.). This system will be able, therefore, not only to perceive the whole context but also to react to it, giving appropriate answers to the user in terms of services. Imagine, for example, that the weather for the entire duration of the trip is terrible. In this case, the system has the ability to discard a priori the attractions that are outdoors and propose only "indoor services.

In this tourist scenario, the platform can be declined in mobile applications of type "Trip Designer", which build a travel itinerary by collecting from predefined folders the various steps of which the itinerary itself is composed, or through a chatbot, which maintains, through techniques of natural language processing and context recognition, a logical discourse with the user in order to respond to specific tourist needs [23]. The platform will not only have to provide a simple list of the data found on that place but will have to present them in such a way that the user can be an active part of it in order to scrutinize its past, present, and future, behaving like a modern tourist guide, also taking advantage of social networks, for years now an integral part of everyday life and containers of immense information. For all these reasons, it must enclose the set of functionalities oriented to the construction of an ecosystem to share and consult content describing the tourist/cultural heritage, exploiting, as said, a Knowledge Base.

4. System Architecture

As highlighted above, we want to propose a system for the automatic selection of services adaptive to the context and its users' needs.

The characteristics of the proposed architecture (Figure 1) mainly concern the information content that is available to end-users through the orchestration of services, proposing three different points of view:

- Representation of the Context;
- Data Management and Organization;
- Inferential Motors.

4.1 Context Representation

First of all, it is intended to convey to different categories of users, at a specific time, useful information in a given context; in practice, it is intended to create a system with a high degree of Context-Awareness. Knowledge of the context in which the user finds himself allows, in fact, to offer a wide range of services that can help the user during daily, work or private life, managing the time and resources at disposal, revealing what is around and satisfying their needs. The real-time knowledge of the context in which the user finds himself, through its representation in the form of graphs, allows, therefore, to offer highly personalized services ("tailored") able to take into account countless aspects as well as, for example, the mood of the user through an analysis of Affective Computing. For this reason, the application fields can be the most diverse: cultural heritage, tourism, e-learning, etc.

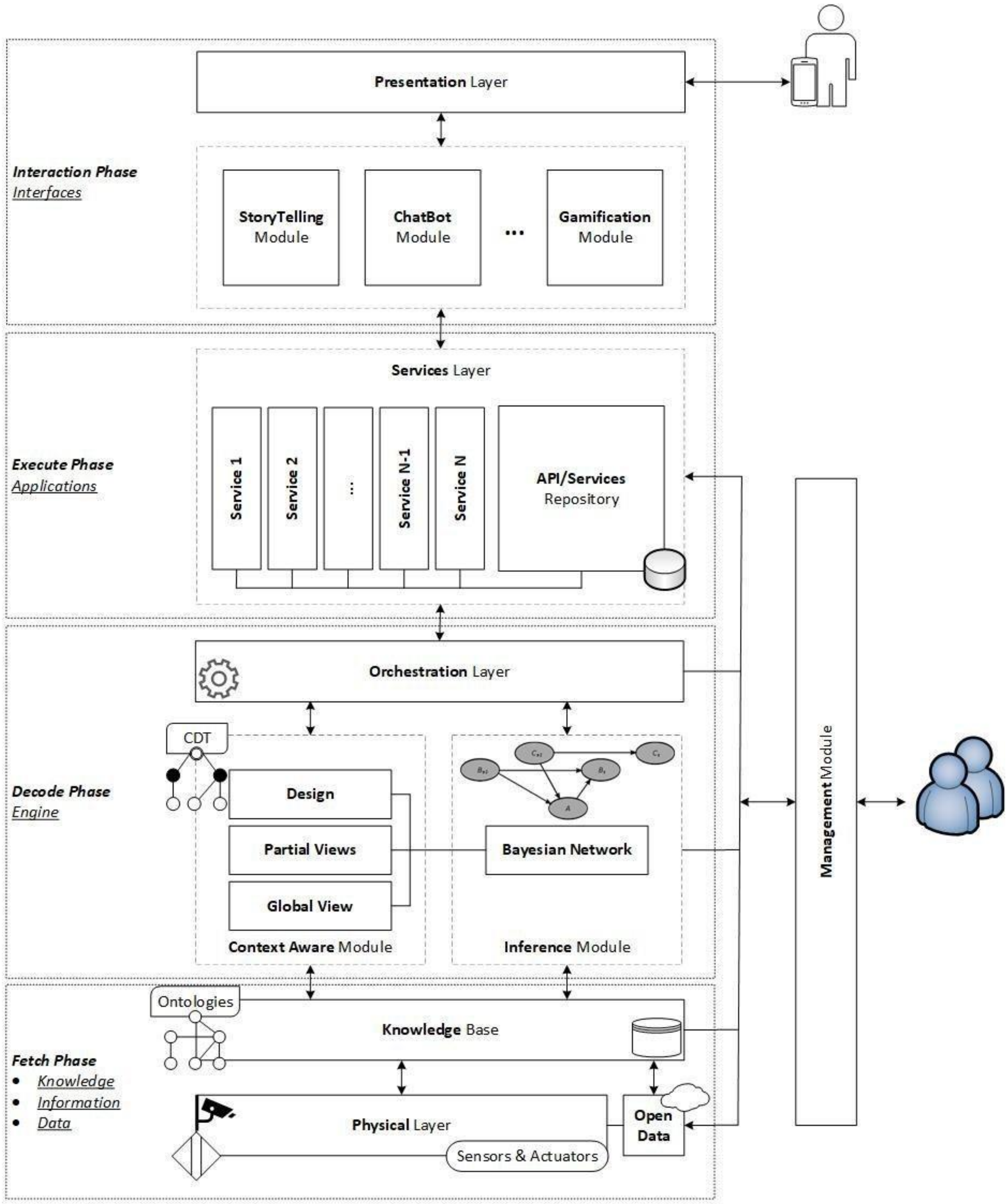
Context Awareness must be understood as a set of technical features able to give added value to services in different application segments. Context-Aware Computing applications can exploit, in our case, these features to present context information to the user or to propose an appropriate selection of actions [24]. In order to obtain a better representation of the various features, therefore, context representation formalities will be adopted, able to define, in detail, the needs of the user in the environment in which he is acting, through an approach such as: Where, Why, When, How. Everything will be declined through the state-of-the-art technologies present in the sector.

In particular, the representation of the context can occur through formal models of representation, such as the Context Dimension Tree (CDT). The latter is able to describe all the possible contexts that can be had within an application domain, through the definition of a tree consisting of a trio <r; N; A> where with r you indicate its root, with N you represent the set of nodes of which it is composed and with A the set of arcs that join these nodes. In detail, the nodes inside the CDT are divided into two categories, that of dimension nodes and that of concept nodes. The first type of node describes a possible dimension of the application domain; the second, vice versa, represents one of the possible values that a dimension can assume. The children of the root node, which constitute the top dimension, are all dimension nodes, and for each of them, a subtree may exist; the leaf nodes must be concept nodes. A dimension node can have, for children, only concept nodes and, in the same way, a concept node can have, for children, only dimension nodes. Defined, at this point, each "context element" as an assignment "dimension=value", a context will be indicated as a combination, through the use of an and, of different context elements.

Based on the use of this type of representation, the proposed methodology consists of three main phases:

- the design phase of the contexts tree, in which to identify the context elements that are significant for the application considered;
- the definition phase of partial views, in which to associate to each of them a different portion of data;
- the composition phase of the global views, in which to process the answers to the queries.

Figure 1: System Architecture



4.2 Data management and representation

In this scenario, therefore, data represent the key to building and enabling innovative services; therefore, we intend to create a Knowledge Base (KB) to collect, process and manage information in real-time. In this regard, as Knowledge Management Systems (KOS), we refer to some well-known schemes such as Taxonomies, Thesauri, or other types of vocabularies that, together with Ontologies, represent useful tools that allow modeling the reality of interest in concepts and relations between concepts. The resulting advantages are many: the use of Ontologies, for example, allows to fix a series of key concepts and definitions related to a given domain, which can be shared, providing the correct terminologies (collaborative knowledge sharing). Moreover, an ontology allows complete reuse of the knowledge encoded in it also within other ontologies or for their completion (non-redundancy of information) [25]. Electronic computers' interpretation enables the automatic treatment of knowledge, with considerable benefits (Semantic Web).

4.3 Inferential Engines

Finally, the system, designed to be in continuous operation, will have to continuously collect data from various sources and process them immediately to provide accurate services according to users and events. These, detected and analyzed, will have to be translated into facts associated with specific semantic values: it is necessary, therefore, to use an inferential engine able to conclude by applying some rules on the reported facts.

Summarizing, the need for a user can be solved in a given context by using the right services provided. The latter is characterized by innovative elements of recommendation based on the formal representation of the context, management, and organization of knowledge, inferential engines.

In particular, it is possible to define a need N_i through the following function:

$$s_i = F_{inference}(u_j, c_k)$$

Where:

$S = \{s_1, s_2 \dots, s_i\}$ represents the set of possible services that can be provided by the platform

$U = \{u_1, u_2 \dots, u_i\}$ represents the set of possible user features

$C = \{c_1, c_2 \dots, c_i\}$ represents the set of all possible contexts in a certain application domain.

5. Experimental Results

In order to provide a validation of the proposed methodology, a prototype was developed. The prototype is implemented through a hybrid mobile app and a server-side component implementation. The developed App is designed to support tourists (users) visiting Campania's coastal area (South of Italy Region). Only some user preferences and interests were considered in the first phase of methodology validation, and only the main services and points of interest have been identified. The experimental phase involved 60 volunteers aged between 21 and 55 who were unknown from the study's main purpose. The prototype was installed on the mobile device of each participant, and after an interaction phase, the system proposes a questionnaire covering several sections:

A. Presentation
B. Usability
C. Performance
D. Recommendation
E. Reliability

Each section presents two assertions associated with five possible answers according to the Likert scale: I totally disagree - TD, I disagree - D, undecided - U, I agree - A, I totally agree - TA. The answers to the questionnaire have been collected in Table 1.

Table 1: Questionnaire answers

Section	Answer				
	TD	D	U	A	TA
A	0	16	22	53	29
B	5	0	24	50	41
C	6	8	12	58	36
D	4	0	8	62	46
E	6	7	13	60	34

Table 1 shows that the users agree or strongly agree that the system provides a satisfying and reliable recommendation and contextual information and appropriate services on the site and its points of interest, meets the tourist's needs and experiences. Therefore, users show an excellent appreciation for the app: they appreciated the contents and services proposed in general.

Also, further analysis was conducted involving a smaller number of participants to evaluate the system's ability to recommend. In the first experimental phase, three pathways (P1, P2, and P3) and two activities (A1 and A2) were selected to be recommended to users. This experimental phase was divided into three steps. In the first phase, the users respond to an aptitude test. According to these tests, the users were divided into macro-groups for aptitude similarity. Subsequently, a training set was created, consisting of about 75% of the participants belonging to each macro-group. In the second phase, the training set users were able to experience the system's suggestions and interact with it. In this phase, the system could learn about the system. In the third and last phase, the users belonging to the test set group have brought to experiment with the prototype's suggestions and evaluate if the type of path or activity suggested by the system was inherent to the context presented. The results were collected in the form of a confusion matrix in Table 2.

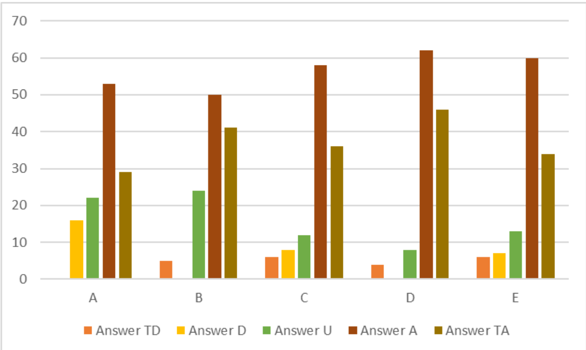
Table 2: Confusion matrix

Prediction \ Reference	P1	P2	P3	A1	A2
P1	58	8	2	7	1
P2	7	39	9	4	5
P3	0	6	45	5	7
A1	8	5	4	40	1
A2	0	6	3	4	51

Overall Accuracy : 71,69%

According to Table 2, the overall accuracy of the system is higher than 71%. This result is very encouraging and could improve over time, based on the increase of experimental data available.

Figure 2: Questionnaire answers trend



6. Conclusion and Future Works

This paper aimed to introduce a framework that can support tourists during each phase of the travel experience in the coastal area south of Italy. The system was designed to provide highly customizable and tailored services, making a tailored and unique experience. The innovation of the recommender system presented lies in the use of a high degree of context-awareness.

The proposed architecture could be used in several contexts and applications. The experimental results show that the system is able to recommend a high degree of reliability with results. In addition, the experimental campaign shows users positive feedback in-service presentation, usability, and performance shown. Future developments include improvements to the developed prototype and enlargement of the experimental campaign.

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