Exhibition Area Digitalization Using IoT Sensorics and Application to Smart Tourism Services

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***Abstract*—Mobile devices in Internet of Things (IoT) can accompany human (or robot) when moving on the area. Many e-tourism platforms exist to collect data on points of interests located in some exhibition area. Artificial Intelligence (AI) provides methods to derive knowledge on recognize human activity and to recognize person's interests in exhibition area space. In this paper, we propose to apply AI methods to IoT-enabled sensed data in respect to the observed human activity. The research goal is to elaborate possible smart extends to e-tourism platforms. Our case study is the CycleAdvisor system. We introduce a concept model of a smart tourism recommender system that uses human-accompanying IoT-devices to sense the human activity. From the sensed data person's interests are recognized and then used for constructing recommendations.**

I. Introduction

The tourism industry occupies a leading sector on the world service market, see reports [1-3]. For some countries, tourism is the key income stream. Other countries use tourism as an additional income stream, attracting guests to the country and making the image in the World. The tourism industry is now called "hybrid industry" due to the high level of information and communication technology (ICT). The digitalization moves towards e-tourism. The e-tourism product basically has an information flow and as a result a physical service, but the ratio, at the planning stage, of physical participation and the information component exceeds towards information support and services. Thus, ICT is becoming an important aspect of the formation of the tourism industry in general.

The ICT-enabled digitalization in tourism grows very rapidly [4]. Various mobile devices in Internet of Things (IoT) start accompanying human or robot when moving on the area. Such IoT devices are considered smart [5], [6]; they can sense the area and situation, recognize knowledge related both to the area and situation, and provide the knowledge on exhibition area space and its visitors' interests, either indoor or outdoor.

Many Internet-enabled platforms exist to collect knowledge on points of interests (POI) located in some exhibition area. In our previous work, we showed that the knowledge can be delivered to users as e-tourism services [7]. For indoor areas the class of such systems forms "smart museums" or "smart cultural heritage spaces", where the services provide information about exhibits [8]. For indoor areas the class of such systems forms POI knowledge bases, where the services provide information on POIs available in the area and possible routes to visit interested POIs [9].

Artificial Intelligence (AI) provides promising methods to recognize knowledge on human activity and interests in exhibition area spaces. Previously, knowledge on person's interests is constructed by expert observation or by analyzing user's opinions. In this paper, we propose to apply AI methods to IoT sensed data reflecting the observed human activity. Such methods are now progressing in collaborative robotics for comfort and safe interaction of people and machines [10, 11].

We consider the e-tourism platform CycleAdvisor developed in ENI CBC KS1305 "BizCycle" project (https://cycleadvisor.org/). The platform supports services to connect tourists and business in South-East Finland and North-West of Russia. The knowledge base collects data on cycle routes, POIs, and objects of tourist infrastructure

The goal of our research study is to elaborate possible smart extends to e-tourism platforms, using CycleAdvisor as a case study. We introduce a concept model of the recommendation system that uses human-accompanying IoT-devices to sense the human activity in the exhibition area with many POIs. From the sensed data the person's interests can be recognized and then used for constructing recommendations. We describe the knowledge conversion system of CycleAdvisor and its e-tourism services. Then we propose several smart extends where knowledge on person's interest enables smart services that can be implemented in CycleAdvisor.

From the application point of view, we focus on an individual client, who has a number of personal characteristics, receives from her/his environment the recommendations about holidays and plans for tourist activity. This encourages the producers of tourist services to find out the real needs of the consumer on their own, and try to satisfy them so that the potential client will not want to go to competitors or to organize a trip by themselves. In this regard, the most relevant task in the tourism field is the creation of personalized services and tools that allow client to customize and select individual tourist routes and services, as well as compile a list of cultural and historical sites or make recommendations on them.

The rest of the paper is organized as follows. Section II introduces existing methods of IoT sensorics that we apply in exhibition area digitalization. Section III considers the CycleAdvisor System for provision of smart e-tourism services. Section IV shows the proposed concept model for integration the recommendation system to CycleAdvisor based on IoT-devices to sense the human activity in the exhibition area. Section V summarizes the key results of this study.

II. IoT Sensorics in Exhibition Area Digitalization

Recognition AI methods for IoT sensorics are widespread used in robotics, e.g., autonomous robot movement requires real-time situation analysis and decision making [11]. Let us consider another important problem domain when recognition is used to construct tourism-related knowledge on visitors' interests in exhibition area space. The sensorics is implemented using various IoT devices that accompany people. AI methods support sensed data mining to recognize person's interests. Then recommendations can be constructed based on the collected knowledge to advise POIs and routes to visit them.

A. Human-Accompanying IoT Devices

Smart tourism can be considered a logical progression from e-tourism laid with the extensive adoption of ICT and connecting the physical and digital worlds by taking advantage of 12 'smart key concepts' [17]. Among the concepts the IoT concept plays the crucial role. For sensing the data containing person's interest the following IoT devices can be used.

The IoT concept supports two types of accompanying devices to human [7]. They sense human activity and surrounding situation.

- Carried devices. A person carries such devices with her/himself.
- Surrounding devices. Such devises are installed in the digital environment in which a person is immersed.

Camera for video capture is used for multi-person human activity tracking in the area (e.g., trajectory construction). A typical case is camera as a surrounding device. Nevertheless, a camera can be carried based on a smartphone or augmented reality (AR) helmet.

AR helmet provides a carriable system with multiple sensors and computing devices. Such a system is used for individual human activity tracking in the area (e.g., location in respect to other objects and area map construction).

Thermal imaging camera is used in the popular case nowadays–temperature check when a person enters to the area. More advance case is regular temperature monitoring for people in the area. The information augments the area map with constructed trajectories of human movement.

Audio recorder is used for speech and other data sensing. Such a device can be integrated to smartphone or AR helmet. The sensed data are transformed to text or events retrospective sequences (e.g., emotional states).

B. Recognition of Person's Interests

Visiting the exhibition area space, a person behaves differently from other people. Let us consider which person's interests can be recognized as knowledge hidden in IoT sensed data. The sensed data are multimodal (video, audio, time-space, text, etc.).

Recognition of human activity in trajectory construction. The exhibition area space map is augmented with information on trajectory of movement, stop points, and other information on the person's movement.

Recognition of points of human attention focus (interest). Based on human activity the following knowledge can be recognized.

- The time the person spent for observing an object (e.g., exhibit or POI).
- Nearby objects that can be interested to the person based on her/his previous activity.
- Emotional and health state of a person when observing an object.
- Notes (stories) from people about observed objects.

The recognized person's interests provide knowledge that augments POIs. The knowledge is collected as user's opinions. As a result, collaborative ranking can me used to construct recommendations to the users. Other advanced methods for constructing recommendations can be found in [17].

III. The CycleAdvisor System

The CycleAdvisor system (free access at https://cycleadvisor.org) is a public platform that provides smart e-tourism services for ecotourists and entrepreneurs from Southeast Finland and Northwest Russia. The platform and its services are developed in ENI CBC KS1305 "BizCycle" project. In this Section, we evaluate CycleAdvisor as a promising use case for integrating the recognition AI methods with IoT sensorics, discussed in Section II above. The methods support adding knowledge to the collection and using the knowledge to make recommendations as e-tourism services.

A. Platform

The CycleAdvisor platform collects digital knowledge and resources through which tourists and businesses meet and find each other. The collected knowledge includes cycling routes, information about POIs and tourism infrastructure elements, and recreational security. The resources are provided as a simple and convenient digital tool for small and medium-sized businesses in the field of promoting goods and services in the tourism industry.

The latest version of the platform covers the Leningrad region (Vyborgsky, Priozersky, Vsevolozhsky districts) and the regions of southeastern Finland (Kotka, Hamina). Placing information on the site allows visitors to learn more about local attractions and POIs (historical, cultural, archaeological, natural sites) as well as about available services. The digital knowledge representation also provides information about the tourist infrastructure of the region: hotels, hostels, restaurants and cafes, bicycle rental and sale points, bicycle workshops and service centers with a detailed description of prices, terms of service and photographs.

The collected knowledge is oriented to making recommendations to cyclists and other categories of ecotourists moving at low speeds in the exhibition area. Along the way, the tourist receives information about nearby facilities and is able to dynamically update the route. Cyclists and hikers are more dependent on the environment than motorists. They need planning in advance. Combining all the information is a complicated procedure if well-known existing applications are used. The problem is to take into account the weather, route features and sights along the way. The advantage of CycleAdvisor is a smart semantic core that regularly update this information in the web portal where trips are planned.

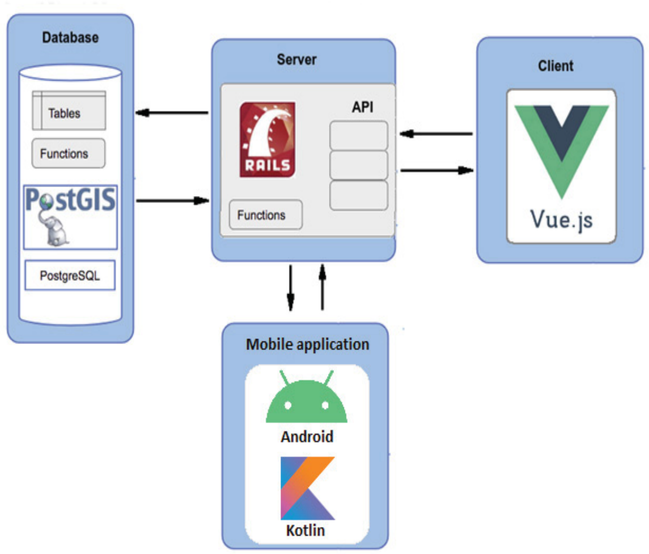

Fig. 1. The basic parts in CycleAdvisor platform

The platform is divided into the following two large parts (see Fig. 1), based on the well-known client-server model for web and mobile applications.

- A server to host the database with dynamically maintained knowledge for constructing e-tourism services as information assistants to tourists.
- Web clients and mobile applications on the user side to access the e-tourism services constructed using the consolidated knowledge.

The web client interacts with the user, processes her/his requests, detects and acts on explicit or hidden person needs, and provides the user with relevant services for the trip. The web client is primary used for resources management, planning the trip, and post-trip memories management.

The mobile application provides onsite assistance to the user during the trip. The application simplifies access to the available information based on user's preferences. The preferences are managed in user's profile. Offline services are also supported (without Internet connection), including access to information about the preferred routes and POIs. Third-party services can be used for navigation, which is an effective and comfortable solution for the users. Installation instructions and user guidance are provided on recommended applications that can be installed by the user. Only a registered user is supported, since access is needed to the user's profile and her/his preferences.

The server side is responsible for searching and extracting relevant information from the database, smartly process the data and deliver the result as a service to the client side. Interaction between the client and server parts is implemented using the application programming interface (API).

The typical scenario of interaction between the web client and the server is as follows. The user sends some inquiry (request) for preferred information from the web client. The client side calls the API at the server side with a set of parameters that corresponds to user's request. The server is processing the received request using local database and data processing tools and then packaging the result to the required target format. Then the server sends the prepared response to the client side. The client receives the response, transforms it into a human-readable form, perform required post-processing when needed, and displays result to the user.

Implementation of the client side uses the Vue.js framework. Modern design patterns are used to make nicer user-friendly interface for interacting with the application. The framework provides efficient application development using the predefined architecture patterns. The application is developed in a way to work on all popular desktop and mobile browsers. In addition, Vue.js supports such properties of the application frontend as the simplicity and maintainability.

Implementation of the server part uses Ruby on the Rails framework. The framework supports implementing the convenient interface for interaction between the server and client parts. The PostgreSQL database is used for implementing the information storage. The PostGIS extension is used for implementing geo-data representation and storage.

Currently, CycleAdvisor version 1.016 is published and available with open code for free use. The platform updates are published regularly, once every 3 weeks. The next major update (and change to version 2.0) is scheduled for April 30, 2022 (just in the beginning of the next bike season).

B. *Knowledge Conversion Properties*

The CycleAdvisor system recognizes and transfer tourism-related knowledge about the exhibition area and its POIs to the database. The knowledge is about local POIs (historical, cultural, archaeological, natural objects and services). The following properties can be achieved by applying existing knowledge conversion methods.

Big Data: one of the main opportunities in tourism industry for analytical exploitation of information [12]. Big Data can shape experiences of smart travel. Big data opens the doors to various opportunities for developing the modern knowledge or changing our understanding of this scope and support decision-making in tourism. In particular, the knowledge on behavioral patterns of tourist can be discovered and collected in the CycleAdvisor database.

Ambient Intelligence: IoT-enabled knowledge conversion can use artificial intelligence in the form of Ambient Intelligence (AmI) [7]. Various IoT devices become data sources for recognition of new knowledge to add to the system. Such agents are assisting agents that accompany the user.

Geospatial Data: An essential part of knowledge about the exhibition area. Location based and geo-context aware e-tourism services can be constructed with the use of this knowledge [13]. IoT provides an infrastructure to uniquely identify and link physical objects with virtual representations. As a result, a physical object has virtual reflection in the service space. This gives an opportunity to replace actions on physical objects by operations on their virtual reflections, which is faster, cheaper and more comfortable for the user.

Recommendation as a Service: Implementation of smart assistance of the users. For instance, the mobile application from [14] uses a recommendation system that suggests POIs the tourist is interested. Recommendation construction is based on her/his previous preferences and the current situation in the region. Landmarks, their descriptions and images are taken from available Internet sources (such as Wikipedia, Wikivoyage, Panoramio). They are ranked by the application's special recommendation service. Recommendations are based on collaborative ranking by the tourists themselves.

Personalized User Experience: Smart e-Tourism services can be personalized by enhancing traditional user experiences with digital content [15]. The backend system is integrated with typical end-user IoT devices like cell phones, tablets, and smart glasses. Automatic recognition of 2D images (like book pages, paintings, murals, etc.) and adding the corresponding digital content (audio, video, text, links, etc.) can significantly enhance user experience. Further integration with 3-D object recognition, IoT, digital maps, and GPS services could also be used to prepare specialized tours, and even allow a self-service where end-user is allowed to create such tours from predefined elements.

C. *Information Represenation and Services*

In CycleAdvisor services, information is represented in the form of a package of offers for tourists. It leads to more active using of local services by tourists. The service makes it easy to put together a package with tourist routes, combining various attractions with a wide range of services provided by local businesses.

Services are oriented to geospatial data. Users can pre-set certain route parameters, such as difficulty, type of road surface (asphalt, dirt road and so on), suitability for families with children or people with disabilities, and others. Points on the map are classified according to these characteristics. Semantic technologies allow to perform flexible search, including requests in natural language, which will ensure that correct data is provided. The system will build a route in accordance with the request, offering a number of options. These technologies support the customer to provide targeted information to a person depending on the content.

In particulars, the Cycle Advisor platform operates with the following types of knowledge about local POIs.

1) description of the cultural object;

2) information about the location of the cultural facility and its opening hours;

3) photographs of a cultural object;

4) comments of tourists who visited this object;

5) object rating (scores, ranks);

6) number of object card views;

7) information about the associated routes, which includes this object.

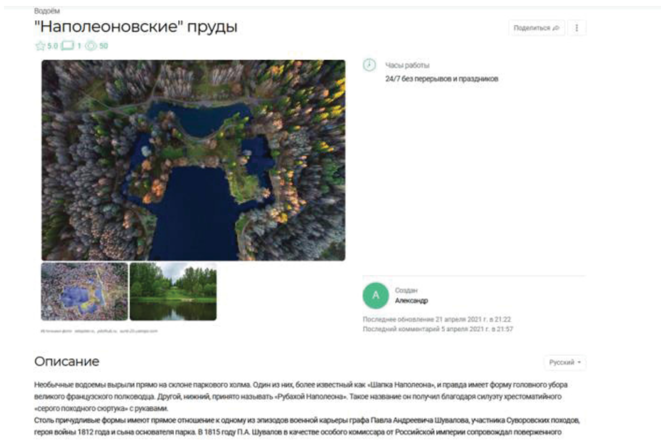

Fig. 2. Example card: Digital representation of a cultural-hisorical POI (in Russian)

An example card of a cultural-historical POI is shown in Fig. 2. Based on such descriptions, the following types of services are constructed.

Route construction: The sequence of geospatial objects in respect to available local services. Such a route can be dynamically updated based on the current situation and changes in the user context.

Selection of top-interesting POIs: Augmenting the route with possible POIs to visit. The selection is based on user's preferences such that personalized recommendations are constructed.

User opinions and evaluation: Feedback with user experience along the route. The information is further used for collaborative collection of user-related knowledge about the exhibition area and its local POIs. The recommendations constructed from this knowledge are useful for local business.

IV. Smart Extends to CycleAdvisor

The proposed extends are based on the following approaches, which are actively elaborated in smart robotized systems [10, 11] when moving on the exhibition area (see also Section II).

- Continuous sensorics based on mobile IoT devices.
- Recognition of person's interests in the sensed data.
- Construction of recommendations and their visualization.

In this Section, we introduce a concept model for development a recommendation system that uses IoT-devices to sense the human activity in the exhibition area with many POIs. From the sensed data of human activity, the person's interests can be recognized and then used for constructing recommendations and their visualization.

As it is studied in robotized system, sensing people movement on the exhibition area provides the following information to digital model (image) of the area.

1) Trajectories of visitors when moving on the exhibition area.

2) Viewing time of each exhibit by visitors (map of interests).

3) Objects of the visitor's attention.

4) Temperature control of visitors at the entrance to the exhibition area.

This kind of sensing is typically implemented based on IoT devices located in the area (e.g., video camera), so creating an AmI environment for the users [7].

In addition, accompanying IoT devices (associated with the visitors) can be used to sense the following information about person's interests. A typical example is user's smartphone or advanced gadgets.

1) Observable visitor's interests when she/he is viewing an exhibit (or other object).

2) Emotions detected when viewing an exhibit (elements of POI);

3) Explicit voice or text responses and opinions, e.g., the visitor likes dislikes the exhibit.

We expect that a promising extent to CycleAdvisor is a smart recognition system to evaluate voice and textual comments from the user. The system can be implemented as additional functions in the mobile application onsite. The user shares own experience and opinion to use in CycleAdvisor.

The collected knowledge on experience from multiple users and their opinions can be used for collaborative ranking of POIs, routes, and infrastructure elements in the exhibition area [14, 16]. Such ranks reflect current person's interests. That is, exhibits can be recommended that are similar in content or interests to the visitor. The ranking system is implemented on the server side of CycleAdvisor with collecting the user experience and collaborative ranks in the database.

The recommender system is based on the following data.

1. The features of paintings and exhibits that do not depend on the user:

- author,
- country of creation,
- year (years) of creation,
- genre (landscape, portrait, still life, etc.),
- style (impressionism, surrealism, etc.).

2. For each user the history of her/his viewing of POIs is stored (or history of traveling with the route). For each viewed POI, the following features are stored.

- time spent for viewing the POI,
- the emotion that the POI leads to,
- positive or negative evaluation of the POI obtained by recognizing the voice or text user's comments.

For each POI, a general vector of all features was compiled, and for those already viewed by the user, it was determined by emotion and voice response whether they liked it or not. The system constructs a recommendation to the visitor of the exhibition based on the accumulated information after viewing 5 objects.

The recommendation can be delivered to the user in a visual form, including representation of person's interest in the portfolio. We expect that a promising extent to CycleAdvisor is a user portfolio visualizer in the form of dashboard. The user can dynamically analyze:

- own history and current situation,
- evaluations of her/his interests,
- provided recommendations.

Therefore, we conclude with the proposal of the following directions to develop smart extends to CycleAdvisor.

1) Smart recognition system to evaluate voice and textual comments from the user based on smartphone and other smart gadgets.

2) Ranking system is implemented on the CycleAdvisor backend with collecting the user experience and ranks in the database.

3) User portfolio visualizer in the form of dashboard presented in the mobile application.

The proposal forms a concept model for development a recommendation system that uses IoT-devices to sense the human activity in the exhibition area with many POIs.

V. Conclusion

The paper introduced an approach to exhibition area digitalization based on advances in IoT sensorics and recognition AI methods, which have been successfully applied earlier in robotics, e.g., autonomous robot movement requires real-time situation analysis and decision making. The sensorics is implemented using various IoT devices that accompany people. AI methods support sensed data mining to recognize person's interests. Then recommendations can be constructed based on the collected knowledge to advise POIs and routes to visit them.

We elaborated the approach in respect to the CycleAdvisor system, where knowledge on person's interest and available resources to ecotourists are integrated. As a result, recommendations as services provided for tourists and businesses. A concept model is introduced for development a recommendation system that uses IoT devices to sense the human activity in the exhibition area with many POIs. Our further plan is to integrate such a recommendation system to the CycleAdvisor system.

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