Human-Computer Cloud for Decision Support in Tourism: Approach and Architecture

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Abstract—**Tourism is one of the most dynamic and fastest-growing economic sectors, where on-the-fly information and decision support are more actual than ever. Tourist decision support systems today leverage a variety of technologies both machine-driven (GIS or knowledge-based inference) and human-driven (recommendation systems). This paper applies a novel concept of human-computer cloud as an architectural approach to building decision support systems in tourism (both from the tourist's perspective, and from destination management organization's perspective). This concept serves as a unifying basis for using human-based resources, allowing to virtualize them much like "ordinary" computing resources. Particularly, the paper identifies the list of typical decision support tasks in tourism domain, and then maps them to a multi-tiered conceptual architecture of cloud services. The proposed architecture is illustrated by the discussion of two scenarios – one for tourist perspective and one for destination management organization.**

I. INTRODUCTION

Tourism has become one of the largest and fastest-growing economic sectors in the world. According to the World Tourism Organization (UNWTO) report, international tourist arrivals doubled in the last two decades (from 527 million in 1995 to 1186 million in 2015). International tourism receipts earned by destinations worldwide have surged from US$ 415 billion in 1995 to US$ 1260 billion in 2015. The number of domestic tourist arrivals is even higher and is estimated to be between 5 and 6 billion. In the long term forecast, UNWTO expects that the number of international tourist arrivals worldwide would increase by an average of 3.3% a year over the period 2010 to 2030, reaching approximately 1.8 billion in 2030 [1].

At the same time, there are some structural and behavioral changes in tourism highly connected to the development of Internet and Information Technologies. The increasing use of ICTs in tourism services allows tourists to take a more active role in the production of tourism products, being no longer satisfied with standardized products. The "postmodern tourist" with differentiated life-styles, individual motives and specific interests demands products tailored accordingly to stated preferences [2].

Besides, social sciences research reveals the importance of decision support systems in tourism, caused by large number of aspects that need to be paid attention to: tourist mobility, high risk and uncertainty in unfamiliar environment, distributed nature of information sources and several other factors [3].

All that makes the problem of tourists' information and decision support more actual than ever. Therefore, services that can help in collecting information about the trip being planned and provide tourist with information needed during the trip are becoming more and more popular.

There is also another perspective in information and decision support in tourism. Not only tourists travelling in an unfamiliar environment need support, but also destination management organizations (DMOs) need a tool (or a suite of tools) that would help to make decisions about what should be done to make destination more attractive for tourists, to develop a sustainable and profitable tourist economy.

Information technology is extensively used in tourism, and that even resulted first in the appearance of an e-Tourism concept [4], and further in the introduction of a smart tourism. The latter is defined as *tourism supported by integrated efforts at a destination to find innovative ways to collect and aggregate/harness data derived from physical infrastructure, social connections, government/organizational sources and human bodies/minds in combination with the use of advanced technologies to transform that data into enhanced experiences and business value-propositions with a clear focus on efficiency, sustainability and enriched experiences during the trip* [5]. Most of the features listed in this definition are also discussed in smart city discourse. Therefore, smart city infrastructure can be viewed as an enabler for smart tourism.

Tourist information (and decision) support systems today use a wide spectrum of technologies, including GIS, knowledge-based inference, information retrieval, social network processing and various recommendation systems. It can be seen, that this spectrum includes both machine-driven (solely computational) technologies like GIS or knowledge-based inference and also human-driven ones like recommendation systems.

The aim of the ongoing research is to develop a (human-computer) cloud environment for decision support in tourism. The distinguishing characteristic of the cloud environment being developed is the fact that it treats human effort as an additional (to traditional storage, computing, networking) kind of resource. The rationale is that currently each system that relies on human in the loop (recommendation systems, review aggregators, participatory sensing systems, etc.) needs to form its own pool of users, which can take long time and require some advertising effort, and that is one of the factors that hampers the use of human computation technologies. Cloud computing technology allows to abstract computational resources and decouple them from application services in a system, allowing, in turn, to dynamically use the required amount of the resource, on the pay-per-use basis. Current implementations of cloud technology deal with conventional computational resources (like computing, storage, networking), however, some recent works adapt this concept for sensors and Internet of Things (IoT) systems in general. Treating human effort as another kind of resource would obviate the need to collect the significant number of users/contributors for human-in-the-loop applications and streamline the process of developing and deploying this kind of applications. In this sense, our research is elaborating the ideas of [6] and [7], and applying them to the domain of smart tourism.

Besides usefulness of abstraction, the impact of cloud computing on the decision support systems area and the potential uses of the cloud in decision support systems are discussed, for example, in papers [8] and [9]. Common point is that conventional cloud computing is mostly useful in decision and information support systems in these cases: (a) system deals with large volume of data (structured and unstructured) [8]; (b) in particular, spatial decision support systems where large volumes of common geographic (and spatial) data are needed; and spatial data processing is often very computer intensive [9]; (c) users are spatially dispersed and mobile. These characteristics are relevant for tourism scenarios with geographically dispersed constantly moving users.

This paper is based on the previous work of these authors in e-Tourism (Tourist Assistant TAIS [10], ridesharing [11] and attraction recommendation services [12]) and elaborates the earlier ideas on the basis of human-computer cloud.

Contribution of this paper is twofold. First, it presents a human-computer cloud platform that provides virtualization of both human and machine resources and facilitates building of systems that require both types of resources. Second, it proposes an architecture of a tourism decision support system – both for tourists and DMOs – that is based on human-computer cloud platform. The paper identifies the spectrum of decision support tasks in tourism and maps them to a multi-tiered conceptual architecture of cloud services. The paper also discusses what benefits could this mapping bring to all the stakeholders: tourists, developers of tourist applications, and tourist destination management organizations.

The rest of the paper is structured as follows. Section II discusses typical problems of decision support in tourism extracted from literature, Section III introduces the concept of human-computer cloud and related extensions of cloud concept, Section IV discusses a conceptual architecture of cloud services for decision support in tourism, and Section V provides a brief description of two scenarios that can be implemented using the proposed environment.

II. Decision support in tourism

There are two different perspectives in the analysis of decision tasks (and, therefore, their support) in tourism: tourist's perspective, and DMO's perspective. Tourist usually deals with decisions about where to stay, how to travel, what points-of-interest (POIs) and in what sequence to attend and the like. The aim of a DMO is to be responsible for the planning and marketing of the tourist destination and to have the power and resources to organize infrastructures, local stakeholders and their relationships. There are many definitions of a tourist destination, but informally, every place to visit may be considered as a destination. Hence, as a result of DMO's activity, destination offers a combination of tourism products and services under a brand of the destination [13].

Usually, these perspectives are discussed separately. There are papers focused on tourist decision support (e.g., [14], [15], [16]), and there are papers focused on decision support for DMO (e.g., [17]). That makes sense, because types of decisions taken by these groups are completely different. However, the information that is taken into account by these groups of users largely intersects. For example, both groups are interested in visiting statistics – but the kinds of decisions taken based on this statistics are different: tourists find the most popular places that are "must see", but DMOs use this information to identify places that need promotion and some marketing actions. Another example of information used by both groups is visitor opinions. Therefore, there are some low level functions (such as data collection and processing, opinion monitoring) that are useful for both groups. In this paper, we build a multilevel cloud-based decision support concept that provides common infrastructure for decision support in both perspectives.

It must be noted however, that these perspectives are not the same as the list of actors/stakeholders involved in decision support system. The perspectives represent two general points of view on tourism, each corresponding to significantly different set of goals and functional requirements. However, there may be different categories of actors that mostly share the same perspective. For example, tourist perspective is shared by tourists (obviously) and tourism agencies. Although e-Tourism and smart tourism concepts are, in the long run, powered by a belief that a tourist can do everything without the help of tourist agencies, relying only on the help of automated smart environments, agencies still exist and in some sense serve as a proxy in the task of tour planning, matching tourists requirements and wishes with the available opportunities. More detailed discussion of various actors/stakeholders can be found in Section IV.

In the rest of this section, functional requirements to both perspectives of decision support in tourism are discussed, based on the literature review.

A. *Decision support for tourists*

Tourists' experience basically comprises three phases: trip preparation, trip implementation, and trip evaluation. In [15] this triad is extended to more specific four phases:

1) Trip elaboration. Tourist elaborates the concept of the trip, identifying restrictions and analyzing available

information to draw up the list of possible attractions to visit.

2) Trip planning. During this phase, the specific itinerary is composed, taking into account available means of transportation.
3) Trip execution. In this phase, actual trip is made, implementing the decisions taken before. This, however, may include elements of trip planning as a response to some unexpected events.
4) Post analysis. In this phase, tourist mostly analyses the facts and impressions of the trip and structures them in some way, optionally sharing via social networks.

Most decisions are taken by the tourist in the first three stages, decisions in the third stage are usually less numerous, but have stronger requirements for response time and availability, as situations when a tourist needs some replanning during the trip in the uncommon environment might be stressful.

In [18] CIDSS framework is proposed to structure tourism related decision support requirements. The framework consists of following activities: personalized data and model management, information search and navigation, product/vendor evaluation and recommendation, do-it-yourself travel planning and design, community and collaboration management, auction and negotiation.

An important function of tourist decision support systems is recommendation of various objects, events and activities. It helps to match in an automated way the variety of leisure activities with the (implicit or explicit) preferences of a tourist. Different types of recommendation systems in a tourism domain are discussed, e.g. in [19]; there are recommenders for attractions, tourist services, routes and tours, and the techniques employed range from "classical" collaborative filtering to collaborative user-generated content and social networking services. In other words, in most recommendation system approaches, human feedback (either in the form of simple ratings or in the more elaborate form of reviews) is crucial.

Based on CIDSS framework [18] and extending it with recommendation functionality, the typical operations performed by tourists with a help of decision/information support systems are identified (with examples of papers and systems aimed mostly on the implementation of a specific function):

- To create and maintain personalized travel objectives, preferences, web pages, and evaluation criteria. It represents an explicit specification of tourist preferences, which can also be extended with an implicit specification, derived from actual tourist experience [18].
- To search and browse tourism-related (factual) information such as destinations and accommodations, attractions and features, package tours and travel agencies, etc. Information presentation technologies may range from simple web pages or application forms to virtual and augmented reality. Examples of systems focused mostly on this operation are [20] and [21].
- To browse analytical information about a destination or its parts. This analytical information may be extracted from statistical reports issued by government authorities or commercial organizations (e.g. [22], [23], [24]), or even it may be produced as a fusion of people's feedback (e.g. [25], [26]).
- To employ the evaluation and selection procedure using pre-specified criteria for choosing tourism products and vendors to match their needs with specified satisfaction level [18].
- To receive and browse recommendations of particular places of interest or events within the specified destination with respect to explicit and implicit preferences and context (type of the trip, weather, local traffic etc.). See, e.g. [19].
- To design personalized travel plans (itineraries) when no existing package tours pass the required satisfaction level. See, e.g. [27], [28], [29].
- To find and organize customers of similar interests to exchange ideas and collaboratively design and develop commonly accepted group trip plans. See, e.g. [30], [31].
- To negotiate with tourist operators [18].

B. Decision support for DMO

To perform their core activities, e.g. the planning, the development, the organization of products and services, and the management of infrastructures, DMOs need a wide spectrum of information gathered from many different sources: tourists, local environment, general economy, etc. [17].

In [32] the following functional structure of DMO decision support systems was proposed:

- Tracking current situation. Gathering basic data on the number of visitors, the amount of money spent, types of activities most commonly undertaken.
- Measuring travel motivators. Combining the visitation and expenditure numbers with data that explain why those customers came and what they liked about their experience.
- Gathering competitive intelligence. Provides information on the strategies and actions of competitors. It helps develop and appropriate response for actions of competitors and, in the same time act as a source of new and innovative marketing ideas.
- Recognizing new opportunities. Monitoring market trends would create opportunities by identifying areas of growing demand.
- Evaluating marketing activities. It is important to decide which programs to continue and in the same time it can give individual operators information which marketing programs they could participate in.
- Monitoring industry satisfaction. An ongoing interaction between DMO and tourism operators, measuring satisfaction with marketing and other tourism-related activities coordinated by DMO.
- Measuring return of investments. Estimating and economic effect of marketing activities.

In [17] this structure was extended by adding monitoring of the basic resources of the destination: physical environment, cultural resources, infrastructures and local social and economic conditions. In the technological point of view, authors of [17] underline the use of geographic information systems (GIS) and knowledge management technologies.

Significant part of the data required to plan and assess activities listed in [32] are collected by surveys and reviews. Currently, there are many social services in the Internet aggregating tourist reviews (e.g. TripAdvisor) and their role as a dominant feedback source is well acknowledged in tourism industry and academia [33], [34]. However, the analysis of only existing review sources makes it harder to control the feedback sample, selecting only several target groups of tourists. Therefore, analysis of existing social networking and review sites can be defined as exploring some “passive” opinion sources, and it should be conjoined with tools for active surveys, where respondent selection is fully controlled by the initiator (e.g. decision-maker representing DMO).

One of the outcomes of the analysis of the main decision support functions from the both perspectives is that human-based services play an important role in both of them. The most obvious, is that humans are a valuable source of information about current situation, thus making a solid contribution to situation awareness required for decision-making. Not that obvious is the fact that human contributors may also participate in the provisioning of some services other than simple feedback, for example, there are some experimental systems, where itinerary planning is performed with the help of human contributors (either in the form of user-generated content like in Mygola, Tripoto, TripHobo, or in the form of online real-time crowd activity as in [40]). However, these human-based services require different characteristics from a contributor (a human, providing a service). For various kinds of feedback and evaluation, a human should be a tourist, who recently interacted with an object, because that is the entire idea of recommendation – complex evaluation of an object by a person who is similar to you. From the point of DMOs it is also interesting how the destination (and its attractions and services) are evaluated by the consumers. For planning services or on-line help service local expertise is a primary requirement. It can be found either among local citizens, or among some experienced tourists. There also are services that do not require neither complex evaluation from the consumer perspective, nor local expertise – usually it is provisioning of some factual information of performing context-free information processing operations.

Another outcome of the use case analysis is that several functions of the two perspectives actually are quite close. For example, measuring tourist satisfaction is performed by DMOs, but is also performed by tourists during selection of the destination to visit or specific tourist attractions. That supports the original idea of putting both kinds of decision support on one platform, leveraging reuse of some core services.

C. Situation awareness

It can be noticed, both from the analysis of the decision support tasks provided, as well as from decision support literature, that one of the core functions in most decision support systems is the collecting data about the state of the system and its dynamics. These data then may be processed to form convenient and informative visual representations (in “reporting” and data-driven decision support systems), used to build and verify models of different parts of the problem domain (in model-based decision support systems), provided as an input for inference engines of knowledge-based decision support systems to obtain some cues about what can be done. In some sense, decision support is about collecting relevant data about the problem domain, structuring it, and then employing various techniques to make use of these data.

In the domain, where man is the measure of all things, both for tourists who are interested in the behavior of likeminded tourists, and for DMOs whose aim is to change the destination to make it more appealing for visitors, an important source of input data is the data provided by humans. That makes participatory sensing and crowdsensing scenarios highly relevant for the human-computer cloud being developed. Specifically, a human-computer cloud that is aimed on decision support in tourism must (in some sense) support participatory sensing and crowdsensing scenarios.

III. Cloud Computing: mainstream and extensions

According to NIST, National Institute of Standards and Technology, Cloud Computing is *a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction* [41]. The same NIST recommendations document describes three service models that have formed in the area of cloud computing.

- **Infrastructure as a Service (IaaS).** The capability provided to the consumer is processing, storage, network, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software [41].
- **Platform as a Service (PaaS).** The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, and tools supported by the provider (or their third-party alternatives leveraging the same APIs). The consumer does not manage underlying cloud infrastructure but has control over the deployed applications.
- **Software as a Service (SaaS).** The capability provided to the consumer is to use the provider’s applications running on a cloud infrastructure. Again, the consumer does not manage or control the underlying cloud infrastructure, but can control user-specific application configuration settings [41].

As it was noted earlier, typical capabilities provided in the IaaS model are processing, storage, and network. However, the cloud concept is now perceived as something more fundamental and pervasive. Therefore, there are recent developments applying the cloud principles of elastic resource provisioning to a wider spectrum of resources. Relevant developments of this kind can be classified into two groups: 1) cloud sensing and actuation environments and 2) cloud-managed human resource environments.

One of the examples of cloud sensing and actuation environment is [42], where sensing resource is regarded as a service that can be allocated and used in some unified way independently of the application that needs access to the resource. Moreover, based on this work [6] designed a cloud architecture for mobile crowdsensing MCSaaS (Mobile CrowdSensing as a Service). Crowdsensing – is a technology of using a crowd (a large group of loosely connected individuals communicated via Internet) to collect data about physical processes in some area. MCSaaS leverages the fact that modern mobile phones (smartphones) are ubiquitous and usually have many sensors that can be used to collect information. Therefore, MCSaaS defines a unified interface allowing any smartphone user to become a part of a cloud and allow to use his/her smartphone sensors in some way that he/she finds acceptable in exchange for some monetary reward or even voluntary.

ClouT (Cloud+IoT) project [43] falls in the same category and is aimed on providing enhanced solutions for smart cities by using cloud computing in the IoT domain. It proposes multi-layer cloud architecture where lower (infrastructure) layer manages both sensing and computing resources. Both ClouT and MCSaaS approaches are highly relevant to the system being designed, because, as it was noted earlier, smart tourism requires "smartness" of tourist destination, and these projects develop the idea of cloud architecture for smart cities (or a part of it). However, they are focused mostly on sensing resources and consider human resources only due to the fact, that human provides the access to his/her smartphone and can control it to make some operations (i.e. point camera lens to some object and make a picture) requested by the application working on top of the infrastructure layer, or a specific kind of virtual sensor. A human, however, may be not only a supplier of information (like sensor), but a processor of it.

The second group, namely cloud-managed human resource environments, has another perspective aiming on managing member's skills and competencies in a standardized flexible way (e.g. [7], [44]), regarding human as a specific resource that can be allocated from a pool for performing some tasks. For example, in paper [7] the cloud consisting of human-based services (HBS) and software-based services (SBS) is considered. On the infrastructure layer, they define a human-computing unit (HCU), which is a resource capable of providing HBS. Further, a concept of social computing unit (SCU) is introduced, which is a composition of several HCU together providing some HBS (much like a team). Like hardware infrastructure is described in terms of some characteristics (CPU, memory, network bandwidth), HCU in this model is described by the set of skills. The authors do not list the exact skills, leaving it to the application domain.

This paper adopts the idea of sensor virtualization and cloud implementation of IoT from [6] and [43], but also extends this idea by directly managing human resources by infrastructure layer (similar to [7]).

There is also numerous relevant research papers on crowdsourcing/crowd computing (including crowdsensing), e.g. [35], [36], [37], [38], [39] where crowd computing platforms are proposed. While using some of the ideas of the existing crowd computing platforms (e.g., typical workflows ensuring quality control, elements of skill management), human-computer cloud is aimed on a standardization of human effort and seamless integration of it into a cloud stack.

IV. Human-computer cloud for decision support in tourism

The proposed cloud architecture touches all the three cloud layers according to NIST: infrastructure, platform, and software. In this section, we first identify potential actors who can interact with the cloud, then describe each of the layers and some of their services.

A. Actors

As it was noted earlier, there are two identified perspectives of decision support, however, the set of actors considered in the analysis and design of the cloud environment is greater. Mostly because of some "auxiliary" actors (that do not directly need decision support) and the fact that some actors share the same perspective. The actors in the system are the following:

Tourists, which are in either phase of performing a trip (see Section II). They are end users of most applications and services of the cloud environment (like trip planning).

DMOs, which have access to those decision support applications that are relevant for managing destination (see Section II), but also can influence the platform layer of the cloud environment, adding new services.

Tour operators/travel agencies, which can access various end user services and applications (acting on behalf of a tourist), but can also provide various services. For example, a tourist can choose whether he/she will use an automated trip planning service, or a trip planning service provided by some travel agency.

Tourist service providers, which provide some auxiliary services, like accommodation, transportation, food etc.

Contributors, which are local citizens or tourists that are available to serve as human resources in a human-computer cloud environment.

Developers, which use the services of the platform layer to create application services for different categories of users.

System Administrators and Infrastructure Providers, which own the required infrastructure.

B. Cloud Layers and Services

All the three models of cloud computing (IaaS, PaaS, SaaS) can be applied to tourism decision support. The proposed conceptual architecture is shown in Fig. 1.

Infrastructure layer: Following papers [6] and [7], infrastructure layer unifies different types of capabilities: traditional computing and storage capabilities, sensing capabilities and human expertise capabilities. Contributors (tourists or local citizens) can join human-computer cloud and define the resources they can provide, time and load restrictions, a type of tasks they may participate. For example, a user may define that he/she is available after 20 p.m. to provide some local information/advices assuming that that activity will not take more than 10 minutes. A contributor may also define the expected compensation for his/her efforts. There are multiple possible schemes of incentivization [46]. Three of them are the most appropriate for this system:

- monetary reward, when a member, providing his/her resources to the cloud is rewarded proportionally to the time of effort and its quality;
- artificial reward measured in some cloud-based "contribution points", allowing, in their turn, to use resources of the cloud in the future. That is very similar to the previous option as these "contribution points" in many senses can be perceived as a kind of currency, locked to the cloud platform;
- voluntary participation. Some papers highlight that tourism is an area where people usually like to contribute (by leaving comments, posting pictures and reports), partially that roots to the traditions of hospitality, partially in actualizing joyful moments of vacations.

It should also be noted, that in this mixed infrastructure tier resources don't have to be locked to tourism. It may be a multi-purpose human-computer cloud, where human resources are described in enough detail to allow usage in main tourism scenarios. Using multi-purpose cloud also has the benefit of resources consolidation, which is crucial in systems including resources as unique and limited as humans. To make this layer universal, the human resource-related components of cloud infrastructure management service leverages an extensible vocabulary of skills (e.g., the key skills that are relevant for tourism domain are [45]: multiple language skills, local knowledge, knowledge of destinations already visited). Human-computer application developers use this vocabulary to specify requirements for human resources, and, on the other hand, contributors use this vocabulary to filter the stream of incoming requests.

Infrastructure management service also collects information about effectiveness of each contributor (separately for each skill a contributor is allocated by) and uses it in further allocation requests. Specifically, virtualized resources of each contributor are described with the historically determined effectiveness, thus it allows to allocate, for example, a "local expertise in Paris" contributor with performance "expert" to ask him/her a question.

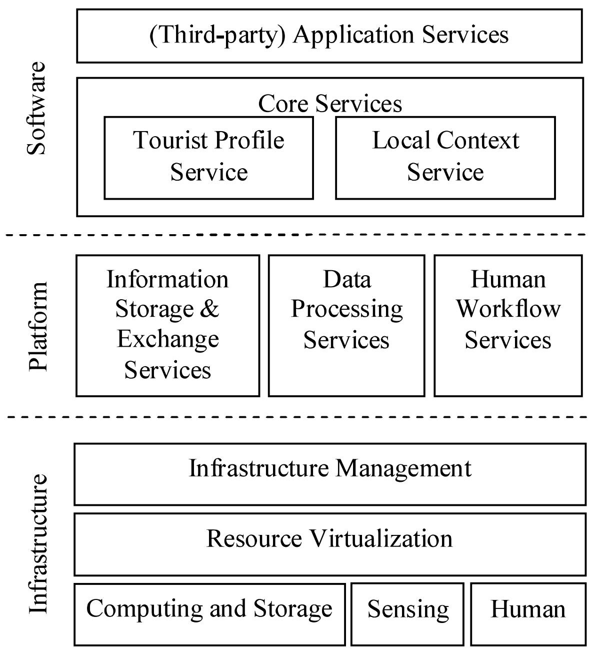

Fig. 1. Conceptual architecture

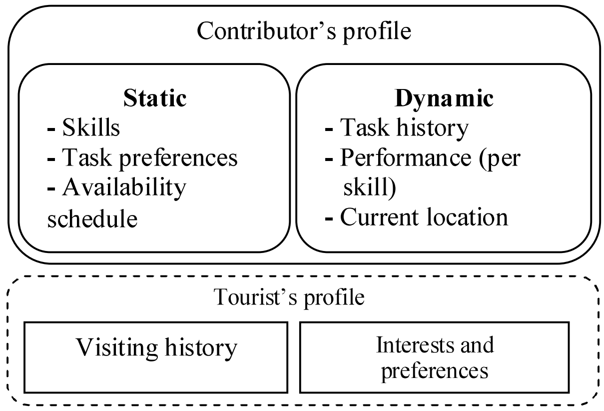

Fig. 2. Human resource profile

There is an optional link between description of a contributor's resources and tourist profile in case tourist also plays a role of a contributor (see Fig. 2). This allows, for example, to allocate for some task only those humans who visited certain location less than a year ago (provided they explicitly agreed to be contributors in the cloud and installed the client software).

Platform layer: This layer consists of a set of multi-purpose services that can be leveraged for building tourism applications (among others) that use human expertise. The services of this layer include three main groups:

- scalable information storage and exchange services;
- data processing services;
- services providing convenient abstractions for arranging workflows, including human efforts.

The first group include database services and various services, implementing different architectural approaches to information exchange (message passing, blackboards etc.).

Data processing services receive, process, and aggregate data from the sensors of smart destination allowing applications to use this data in a convenient and flexible way.

Services of the last group serve to make resource allocation transparent for developers of applications based on human input. For example, imagine an itinerary planning application that involves correction of the itinerary by people familiar with the area of planned trip. If this application is developed from scratch the developers would need to promote it to collect a rather big number of participants. However, if built on the base of human-computer cloud infrastructure, a developer can rely on allocation of human resources from the cloud. Moreover, platform layer may provide, for example, an Iterative-Improvement (see, e.g. [47]) human computation pattern that is implemented as an allocation of several human members (meeting some requirements), and redirecting a task to them in sequence. An application developer could then just use this service, sending to it an initial itinerary received from the user

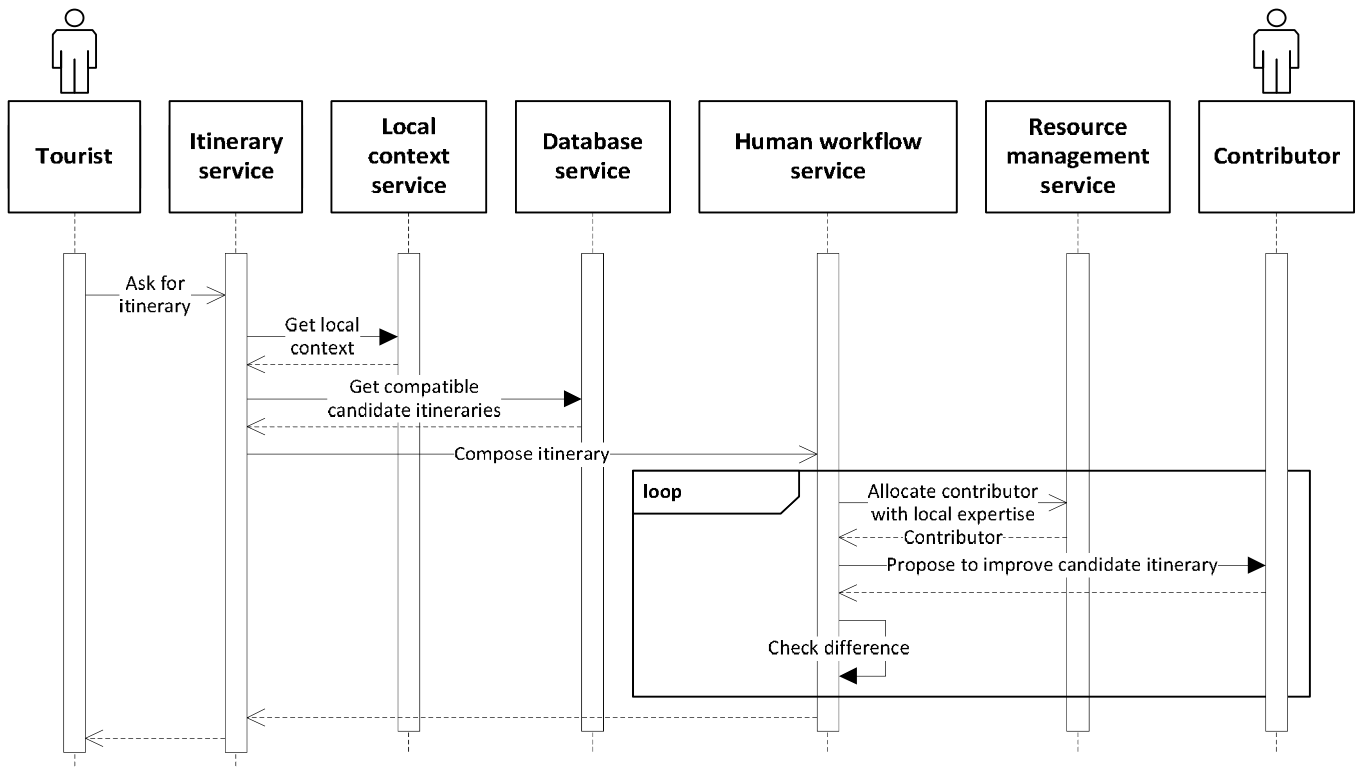

Fig. 3. Sequence diagram of itinerary creation scenario

and general requirements to members who can take part in itinerary planning.

Software layer: This layer includes services that are useful for particular tasks in decision support. These services can be divided into two groups: core services, that implement some general operations, and specific services, exposed to end users. Core services actually could be a part of PaaS, but the delineation between these two is application domain orientation. Platform is kept application domain independent, exposing only general mechanisms, whereas SaaS layer is actually domain specific.

Core services include profile management service representing a centralized storage of user's history and preferences, and a local context service. A user may define what information of his/her profile can be accessed by other services in different queries (personalized or anonymized). Local context service provides various information about current situation in the selected area.

Application services can be divided by primary user: tourist services and DMO services. Tourist services include attraction information and recommendation services, itinerary planning, local transport information etc., while DMO services include opinion monitoring, usage statistics services and other needed by DMO to reach good awareness of the situation in tourist destination.

V. Application Scenarios

This section briefly outlines two application scenarios, how they are to be implemented using the proposed conceptual architecture. One scenario for tourist's perspective and one for DMO's.

A. *Create a trip itinerary*

Creating an itinerary is a typical task performed in tourist's perspective (see Section II), i.e. either by tourist or by travel agency. Usually it is performed either in the trip planning phase, or in the trip execution phase (when environment changes and original plan, if any, turns out to be invalid). As this is an end user functionality, it is to be implemented in a SaaS layer, moreover, there might be several concurrent implementations of itinerary planning services, provided by various vendors, with different characteristics (price, time etc.). This paper focuses on the demonstration of an itinerary planning service that makes full use of human part of human-computer cloud environment. Input for this service includes:

- tourist destination, where local itinerary is to be built;
- time constraints, specified as absolute timestamps of the time frame that should contain the itinerary. Absolute time stamps may be useful to consider inclusion in the itinerary of some unique events that might occur in the specified destination;
- tourist preferences (shared portions of the information contained in tourist information profile and additional requirements) including places a tourist would like to see, those he/she already seen, general interests etc.

The itinerary service is built using database service and human workflow services provided by the cloud platform. The database service is used to store accepted (and probably high quality) itineraries made for different users in the past, and the human workflow service is used to define an Iterative-Improvement scheme for itineraries being composed. Besides, the itinerary planning service uses some of the core application services, e.g. local context service (providing current and predicted information about weather, traffic situation etc.).

Itinerary service first enriches the incoming request with local context, supplied by local context service, then looks up in the database past accepted itineraries for users with similar preferences and in similar contexts, and finally via human workflow service allocates several contributors (both among past tourists and local citizens) to review and possibly improve candidate itineraries (Fig. 3).

B. *Post-tour survey*

This simplified scenario corresponds to *Measuring travel motivators* activity performed by DMOs (see Section II). The idea is that DMOs may want to ask some questions to tourists recently visited destination or some particular attractions (and therefore, this activity is also related to the last phase of a tourist's trip). To do this, an opinion monitoring in the application layer can be used. Opinion monitoring service also uses human workflow service provided by the cloud platform, but workflow here is quite simplistic – just collect the required number feedbacks from contributors without any processing (Fig. 4). The selection of contributors is performed by resource management service, based on survey query and extensive information about contributors (which includes areas of expertise and, most important for this scenario, travel history).

VI. CONCLUSION AND FUTURE WORK

This paper presents a conceptual architecture of an intelligent decision support system for tourism based on a novel human-computer cloud paradigm. Specifically, it analyzes the variety of tasks and operations typical for information and decision support in tourism, and proposes a conceptual architecture of a tree-tiered human-computer cloud, addressing these tasks and operations.

Future plans are connected with the concretization and implementation of the architecture. Two primary directions are the following: 1) multilevel standardization of human-computer cloud APIs – resource management, platform level and service level, and building a decision support architecture on the basis of these APIs; 2) particular models to define the contract between a human contributor and a cloud infrastructure as well as algorithms to follow this contract allowing high throughput.

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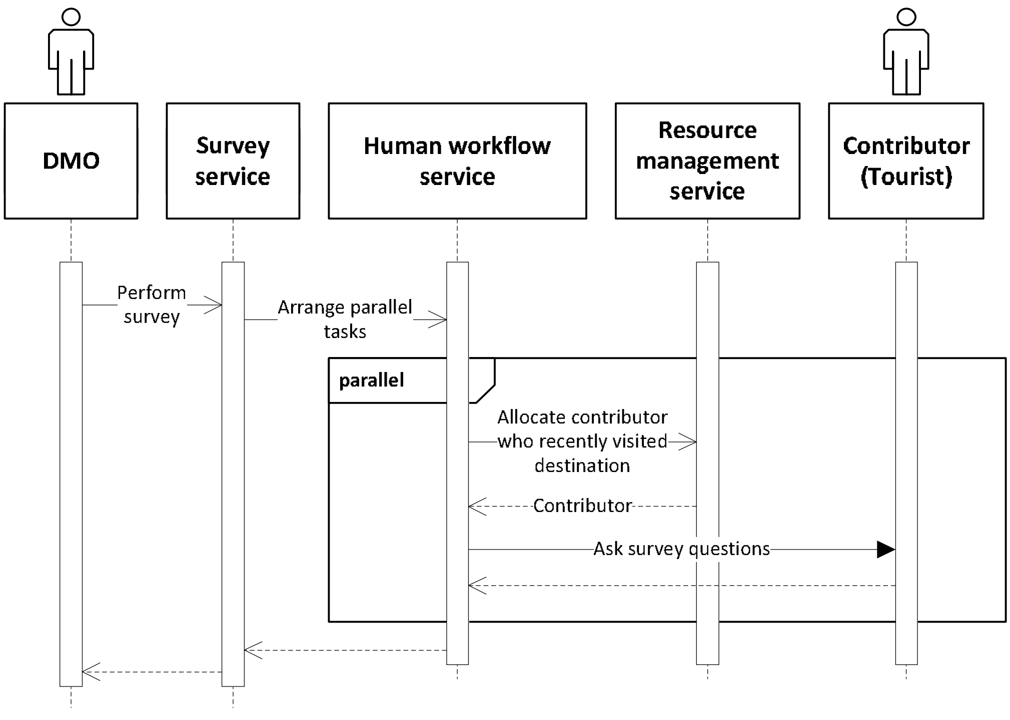

Fig. 4. Sequence diagram of post-tour survey scenario

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