Ontology-Based Human-Computer Cloud for Decision Support: Architecture and Applications in Tourism

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ABSTRACT

A variety of information processing and decision support tasks (especially in the context of smart city or smart tourist destination) rely both on the automated and human-based procedures. The article proposes a multi-layer cloud environment that, first, unifies various kinds of resources used by these information processing and decision-support scenarios (hardware, software, and human), and second, implements an ontology-based automatic service composition procedures that can be used to build ad hoc decision-support services for problems unknown in advance. The service composition is based on uniform description of all parts of the environment with a help of ontologies. The article describes the architecture and models of the novel human-computer cloud environment. It also describes several scenarios of decision support in tourism leveraging the proposed human-computer cloud concept.

KEYWORDS
Crowd Computing, Crowdsourcing, Human in the Loop, Human-Machine Systems, Smart City, Smart Tourism

INTRODUCTION

Current developments of information technologies and artificial intelligence allow to automate variety of information processing tasks that are required for decision support. However, some problems are still hard to deal with solely by computer environments. That stems partially from the nature of these problems (e.g., dealing with common sense, uncertainty, incomplete definitions, audio- or visual- information processing) or from the lack of specialized sensing and actuation infrastructure in locations that, however, can be reached by humans. That is why humans still play an important role in many information processing workflows.

Moreover, the development of information and communication technologies (and, especially, Internet) has led to the emergence of a new kind of hybrid human-machine systems, where distributed group (crowd) of people becomes involved in the process of information provisioning and processing. Examples of these new kind of systems include microtask markets (with the most prominent Amazon
Mechanical Turk), various citizen science projects (Franzoni & Sauermann, 2014; Shamir, Diamond & Wallin, 2016), community sense and response systems (e.g., Faulkner et al., 2014), general collaborative mapping (e.g., OpenStreetMap, Google Map Maker, WikiMapia), crisis mapping (e.g., Ushahidi; Meier, 2017) and many others.

Common problem with the systems that require human attention and human input is that each of these systems usually needs a large number of contributors to function and collecting this number of contributors may require significant effort and time. Therefore, the motivation of this paper is to develop a unified resource management environment, that could serve as a basis on which any human-based application could be deployed much like the way cloud computing is used nowadays to decouple computing resource management issues from application software. That would significantly streamline the development of human-based applications and services that are important and inevitable in some application areas.

One of these areas is e-Tourism (and decision support in e-Tourism), where human input and human involvement is essential due to the subjective nature the domain. Therefore, to motivate the development of the human-computer cloud, decision support in tourism is discussed and projected on the generic architecture of the cloud environment.

One of distinctive features of the proposed concept is ontological representation of cloud resources, which simplifies the problem of human resource description and discovery. Ontological representations and mechanisms are also used ‘on top’ of the unified resource management to implement an ad hoc decision support environment, where ontology-driven human-computer service composition allows to perform decision support tasks that don’t have specialized services.

The paper is organized as follows. Background section clarifies the topic and the goal of the paper by providing more details on how human-powered systems and modern cloud systems are interrelated and demonstrating why e-Tourism is a very promising domain for human-computer cloud being proposed. Related work section overviews current developments in the areas of human-computer cloud environments, ontological modeling for cloud environments and decision support in tourism. The Architecture section contains the description of the proposed architecture, including principal actors, service layers and interactions needed to implement some typical cloud environment operations. Finally, the Applications in Tourism section discusses two typical scenarios showing how the proposed architecture can be leveraged to implement typical information processing and decision support problems in tourism domain. The results achieved are summarized in the Conclusion.

**BACKGROUND**

Cloud computing technology has become a de facto standard in elastic hardware and software resources provisioning, as it has established a convenient way to abstract computational resources needed by an application and to dynamically adjust the needed amount of resource. National Institute of Standards and Technology (NIST) recommendations document (Mell & Grance, 2011) 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;
- **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;
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