Ontology-based Mobile Smart Museums Service

Approach for small & medium museums

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***Abstract*—The proposed service suggest the visitor a museum which is currently better to attend, based on visitor preferences and current situation in the region. For this purpose, smart environments of region museums have to be organized. The smart environment is a decentralized infrastructure which allows different devices to share required information between them. Every user of the smart museum service has a mobile device connected to the smart environment. This mobile device communicates with other devices of the smart environment to suggest the best museum for attending at the moment, and prepares an excursion plan for this museum. Prepared excursion plan based on the visitor's preferences, the current amount of visitors in each museum room and other context information (closed exhibits, reconstructions, seasonal exhibitions and other) acquired from Internet and intranet services. Proposed service increases popularity of small and medium museums in the world, reduces traffic jams in museum rooms, and allow museum visitor to plan his/her time more efficiency way.**

Keywords-knowledge management; ontologies; Internet services; user profiles; smart environment; decentralized architecture; indoor positioning.

I. INTRODUCTION

The paper extends the approach to context-oriented knowledge management for supporting visitors through their mobile device in museum smart environment (presented in AFIN 2011 conference [1]) to assist visitors in an area with several museums.

Recently, the tourist business has become more and more popular. People travel around the world and visit museums and other places of interests. They have a restricted amount of time and usually would like to see many museums. Proposed service increases popularity of small and medium museums in the world. However, overwhelming majority of these museums has limited space for visitors causing accumulation of visitors and increasing waiting time for them.

In this regard an approach is needed, which allows assisting visitors (using their mobile devices), in planning their museum attending time and excursion plans depending on the context information about the current situation in the museum (amount of visitors around exhibits, closed exhibits, reconstructions and other) and visitor's preferences.

Usually, smart and medium museums have a limited amount of money and often purchasing a set of expensive audio guides is not possible for them.

The main benefit of the presented approach is assisting visitors in the museum smart environment using personal mobile devices. Such mobile devices should have Wi-Fi connection and possibility to show appropriate information to visitors.

Main problems of the approach are:

- To organize information sharing possibilities between different devices in museum;
- To determine indoor position of the visitor;
- Tto develop context driven ontology-based approach for assisting visitors in museum.

The smart environment is an aggregation of devices, which can interact with each other and use pertinent services regardless of their physical location. Such technology has a decentralized architecture and allows seamless integration with other systems, services, and program modules.

Decentralized smart environment in the proposed approach allows mobile device of every visitor acquire information from other visitor's mobile devices and services (e.g., museum services or external services) and based on this context information make own decision about the best excursion plan for this visitor taking into account visitor's preferences.

Research efforts in the area of the smart environment have become very popular recently. Such topics of research as smart home, smart car, etc. are widely discussed on research conferences (e.g., Smart Homes [2], RuSMART [3]). In such systems all elements have to interact and coordinate their behavior without any user intervention.

Modern tendencies of information & communication technologies require development of stable and reliable infrastructures to extract and keep different kinds of information and knowledge from various members of the smart environment. The smart environment assumes more than one device that uses common resources and services. One of the most appropriate approaches to implement such infrastructure is applying knowledge management systems.

There is a large amount of research works in the area of indoor positioning, e.g., Google Indoor Maps [4], Qubulus indoor positioning [5], Walkbase indoor positioning platform [6], Ericsson Labs [7], Intel Place Lab [8]. Broadcom introduces new GPS chip (BCM4752), offering a platform for development of indoor positioning applications [9].

Our experiments show that it is possible to determine visitor's position in the museum using Wi-Fi with accuracy of 2-3 meters. For this purpose, a set of Wi-Fi hot spots should be placed in a certain way.

Museums of a certain area can be considered as a smart environment where each exhibit, group of exhibits, or museum is represented by a service or a set of services. Each device can interact with these services and with other devices. The visitor's mobile devices interacts with each other and with different services in museum smart environment and provides the visitor with an acceptable plan of museum attendance, excursions inside museums based on the museum context (amount of visitors at exhibits, closed exhibits, reconstructions and other) and visitor's preferences.

Visitor's mobile device can also provide textual, graphical, video and audio information about the exhibition for the visitor in his/her language.

The following scenario can be considered. A tourist arrives to St. Petersburg. He/she is going to attend the Hermitage, the Museum of Karl May Gymnasium History, Dostoevsky museum. The tourist adds his/her interests to the user profile within the intelligent museum visitor's support system. The intelligent museum guide suggests the visitor to see the St. Isaac Cathedral and Kunstkamera too. It proposes the visitor to attend at first day the Hermitage, because it is Wednesday (usually on Wednesdays the Hermitage is less crowded). When the visitor's mobile device connects to the museum smart environment, acquires current situation in preferable for the visitor museums and proposes to attend the Dostoevsky museum and Kunstkamera. When the visitor approaches the exhibit he/she gets audio, textual and video information about it from appropriate services through the Internet or intranet.

The rest of the paper is structured as follows. Section II presents an overview of mobile museum guides systems and indoor positioning systems. Section III introduces developed approach to knowledge management in museums smart environment. Information model of museum visitor's profile is given in Section IV. The case study can be found in Section V. Main results are summarized in Section VI.

II. RELATED WORK

There are several research works and projects related to assisting visitor in museum and providing information about museum exhibition. The following ones are worth to be mentioned.

Google Art Project [10] is a tool from Google that lets user visit world's most important museums of art, via a virtual tour. The Art Project is available for more than a thousand works of art.

The overall objective of the SMARTMUSEUM project [11] is to develop a platform for innovative services enhancing on-site personalized access to digital cultural heritage through adaptive and privacy preserving user profiling.

The main research activity of HIPS project [12] is development of an approach for navigating artistic physical spaces (i.e., museums, art exhibitions). The system is meant to provide the visitor with personalized information about the relevant artworks nearby. The information is mainly audio in order to let the user enjoy the artworks rather than interacting with the tool.

Bohnert et al. [13] describe a system for providing a visitor with a challenge of selecting the interesting exhibits to view within the available time. It includes the recommendation and personalization process, i.e., the prediction of the visitor's interests and locations in a museum on the basis of observed behavior.

Kuflik et al. [14] describe an approach for supporting users in their ongoing museum experience, by modeling the visitors, "remembering" their history and recommending a plan for future visits. This approach identifies some of the technical challenges for such personalization, in terms of the user modeling, ontologies, infrastructure and generation of personalized content.

Project CRUMPET [15] has realized a personalized, location-aware tourism service, implemented as a multi-agent system with a concept of service mediation and interaction facilitation. It has had two main objectives: to implement and trial tourism-related value-added services for nomadic users across mobile and fixed networks, and to evaluate agent technology in terms of user-acceptability, performance and best-practice as a suitable approach for fast creation of robust, scalable, seamlessly accessible nomadic services.

Existing systems don't take into account information about the current situation in the museum, and they are oriented to assist user only in one museum whereas the proposed approach allows monitoring the current situation in several museums and its using for visitor assistance. Also, the approach presented in the paper allows using visitor's mobile device for assisting the user. It is not needed to provide special equipment for museums.

Therefore, the indoor positioning problem needs to be considered.

F. Bohnert et al. [16] mentioned that there are two major schemes of indoor positioning: signal propagation and location fingerprinting. They have proposed several algorithms (based on both schemes) for indoor positioning and compared it. Each algorithm has advantages and drawbacks described in the paper in detail.

In [17] T. Kuflik et al. present Wi-Fi-based indoor positioning technique with position accuracy of one to three meters. The technique was tested on the Nokia 770 Internet tablet.

Place Lab [8] project's aim is to determine user location indoor and outdoor. Technically, the system is based on radio beacons, which periodically sent radio signals by Wireless LAN access points, fixed Bluetooth stations, and GSM towers. Accuracy of the presented approach is 13-30 meters.

EZ Localization algorithm is presented in [18]. It is a configuration-free indoor localization scheme that uses existing Wi-Fi infrastructure to localize mobile devices. The accuracy of EZ approach is about 2 meters.

The Horus [19] is a WLAN Location Determination system characterized by high accuracy: through a probabilistic location determination technique and low computational requirements: through the use of clustering techniques.

RADAR [20] is a radio-frequency based system for locating and tracking users inside buildings. RADAR is based on empirical signal strength measurements as well as a simple yet effective signal propagation model. Accuracy of the RADAR is a few meters.

In [21], an indoor localization application leveraging the sensing capabilities of the current state of the art smart phones is presented. Application is implemented for the using on smart phones and it integrates offline and online phases of fingerprinting. Accuracy of presented approach is up to 1.5 meters.

There are many systems and services which solve the problem of indoor positioning. Some considered papers propose algorithms and some propose the complete services or applications which can be used for determining indoor position.

III. ONTOLOGICAL APPROACH OF SMART MUSEUMS SERVICE

The approach presented in the paper relies on the ontological knowledge representation. The conceptual model of the proposed ontological approach is based on the earlier developed ideas of knowledge logistics [22]. In this work, the ontology is used to describe knowledge and information in the smart environment. It allows providing interoperability between different devices in smart environment.

The architecture of the approach is presented in Figure 1. Mobile devices interact with each other through the smart environment. Every visitor installs smart environment client to the mobile device. This client shares needed information with other mobile devices in the smart environment. So, each mobile device can acquire only shared information from other mobile devices. When the visitor registers in the service, his/her mobile device creates the visitor's profile (which is stored in a cloud and contains long-term context information of the visitor). This profile allows specifying and complements visitor requirements in the smart environment and personifying the information and knowledge flow from the service to the visitor. Utilizing of clouds for keeping user profiles allows visitors to change their mobile devices without loosing any settings for using the system. As clouds keep only user profiles, which consist of small amount of data, it is not needed to think about performance of this access.

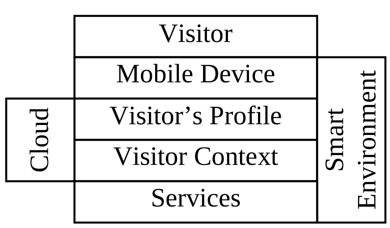

Figure 1. Architecture of the proposed approach

Each time when the visitor appears in the smart environment, the mobile device shares information from the visitor's profile with other devices.

Visitor context accumulates and stores current information about the visitor in the smart environment (current visitor context). It includes:

- Visitor location;
- Museum reaching times for the visitor;
- Current weather (in case of rain it is better to attend indoor museums);
- Visitor role (e.g., tourist, school teacher);
- Information about closed at the moment museums or exhibits;

For getting external information for different system modules, the services are used. Four types of services are proposed:

- Positioning service (calculates current indoor and outdoor positions of the visitor based on raw data provided by visitor mobile device);
- Information service (provides visitor mobile device with needed information about exhibits, e.g., Wikipedia, Google Art Project, other information services, museum internal information services);
- Current situation service (provides information about the current situation in the region, e.g., weather, GIS information, traffic information);
- Museum / exhibition (provides information related to the museum and exhibits, e.g., holidays, closed exhibits).

The proposed ontological approach to Smart Museums Service is presented in Figure 2.

Each visitor has a mobile device, which communicates with mobile devices of other visitors (shares own information to them and gets needed information), uses different services for getting and processing information, accesses and manages the visitor's profile, and processes information and knowledge stored in visitor context.

Visitor's profile and context have stored in the cloud, which allows visitors to access them from any internet enabled devices (when the visitor changes his/her mobile device it is needed only to install the appropriate software to use the new device). Also, clouds allow transferring complex calculations from mobile devices to the clouds.

The visitor context is formed based on the interaction process between the visitor's mobile device and different services through the smart environment. The context is the description of the visitor's task in terms of the ontology taking into consideration the current situation in the museum. Visitor's task in the proposed approach is a list of museums the visitor would like to attend.

Ontology in the smart environment is used for the interoperability support of different mobile devices and services. It describes the main terms used for the museum smart environment description and relationships between them. Mobile devices and services use the ontology for the information and knowledge exchange.

The following scenario for using the proposed service is considered.

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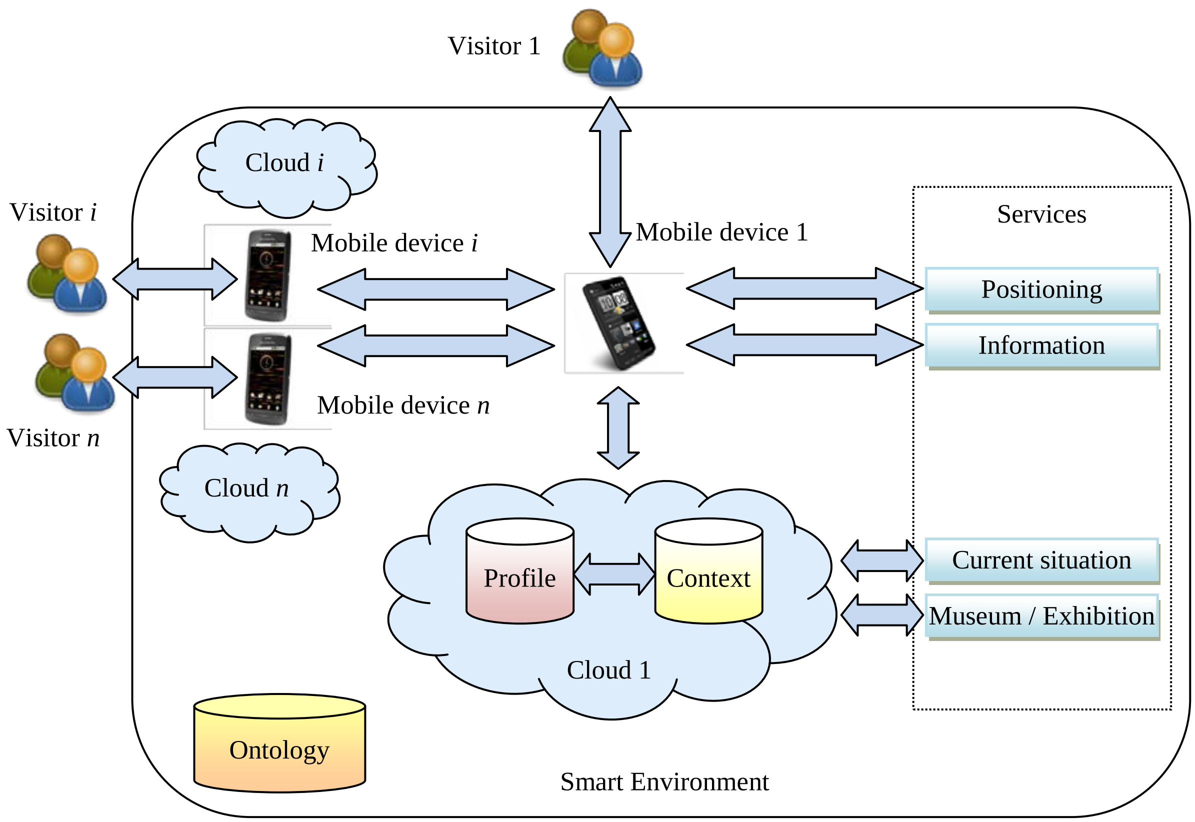

Figure 2. Ontological Approach of Smart Museums Service

A visitor arrives to a region. His/her mobile device finds the museums the visitor is going to attend in this region (stored in the visitor's profile). The mobile device generates the context, which describes the current situation of this region. It connects to different services to extract information about interesting museums (working time, closed museums, closed exhibitions, statistical occupancy of interesting museums for the next few days) and propose to the visitor preliminary interested museums attending plan.

When the visitor is going to attend the museum (next day), the mobile device updates the context by current situation in the region, e.g.: weather (in case of rain it is better to postpone attending outdoor museums), traffic situation on the roads, current museum occupancy, and expected museum occupancy (based on communicating with mobile devices of other visitors). Based on this information, the corrected museum attending plan can be proposed to the visitor.

When the visitor enters the museum an acceptable path for visiting museum rooms is built based on the museum room occupancies at the moment. Using location service and Wi-Fi infrastructure the mobile device calculates the visitor's location and shares it with other devices. Information about exhibits is acquired from the information service and displayed on the visitor's mobile device.

IV. VISITOR'S PROFILE

Most of user profile models include such information as: first name, last name, gender, date of birth, languages, and contact information and user position. This information is also important for intelligent museum visitor's support. Based on this information the service can update the excursion plan for the visitor. The visitor can hide his/her personal information from other visitors for privacy purposes. It is stored in the "Personal Information" module (Figure 3).

Museum visitors can have different roles (e.g., individual visitor, family, group of schoolchildren and other). Intelligent museum visitor support system can take into account this information for building the plan of the excursion. Some parts of the visitor's profile can be hidden from other visitors (for example, if the visitor would like to attend museum anonymously). For this purpose the visitor has to choose which information can be accessible to other devices. It is needed to provide the system with information about visitor's hardware and software capabilities, because based on this information the system suggests the visitor which types of exhibit descriptions (audio, video, textual) he/she can use. This information is stored in the "System Information" module (Figure 3).

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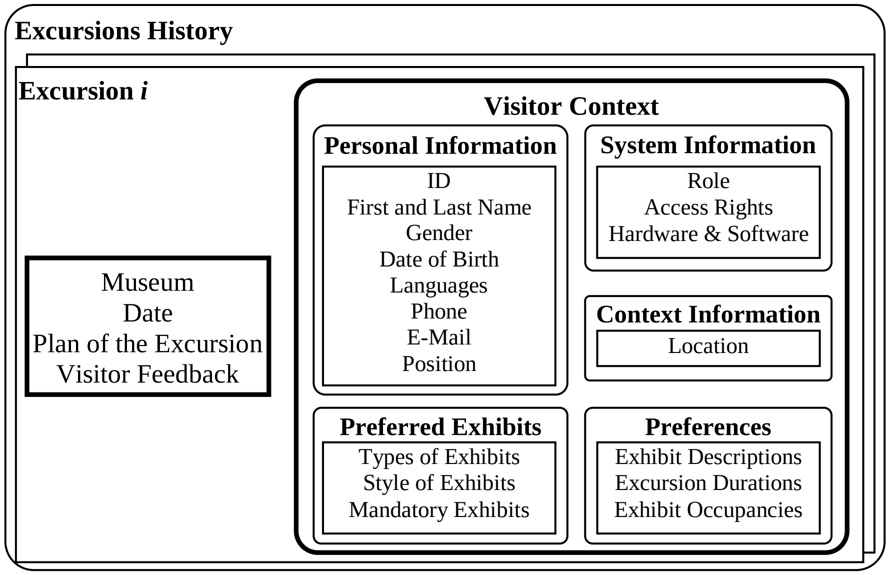

Figure 3. Model of museum visitor's profile in intelligent museum visitor's support system

Since the proposed service is context-oriented, it is necessary to determine the location of the visitor in time. For this purpose the module "Context Information" is proposed. For building an acceptable plan of the excursion the service needs information about exhibits preferred by the visitor: types of exhibits (paintings, ancient items and other), styles of exhibits (modern, impressionism and other), and mandatory exhibits the visitor has to see (e.g., Benois Madonna, the Hermitage). Also, the visitor's profile has to keep the long-term context information about preferable types of exhibit description (audio, video or/and textual), excursion duration (how much time the visitor can spend at this museum), exhibit occupancies (in case of high occupancy of an exhibit the visitor might prefer to skip this exhibit or to try to see it later).

To keep the history of interaction between the visitor's device and the museum smart environment for its further analysis, all excursions of this visitor, including the museum name, date, plan of the excursion, visitor's feedback about the excursion, and the visitor's context at the moment of excursion are stored in the visitor's profile. Based on this information, the visitor's preferences and preferred exhibits can be semi-automatically identified using ontology-based clustering mechanisms described in [23].

V. Case Study

The intelligent museum visitor's support system has been implemented based on the proposed approach. Maemo 5 OS – based devices (Nokia N900) and Python language are used for implementation.

An open source software platform (Smart-M3) [26] that aims to provide a Semantic Web information sharing infrastructure between software entities and devices is used for system implementation. In this platform the ontology is represented via RDF triples. Communication between software entities is developed via Smart Space Access Protocol (SSAP) [26].

Different entities of the system are interacting with each other through the smart environment using the ontology. Each device has a part of this ontology and after connecting to smart environment it shares a part of the own ontology with the smart environment.

The system has been partly implemented in the Museum of Karl May Gymnasium History [27] located in St. Petersburg Institute for Informatics and Automation Russian Academy of Science building.

The visitor downloads software for getting intelligent museum visitors support. Installation of this software takes few minutes depending on operating system of mobile device (at the moment only Maemo 5 OS is supported). When the visitor runs the system for the first time the profile has to be completed. This procedure takes not more than 10 minutes.The visitor can fill the profile or can use a default profile. In case of default profile the system can not propose preferred exhibitions to the visitor.

Response time of the Internet services depends on the Internet connection speed in the museum, number of people connected to the network, and workload of the services. Average response time should not exceed one second.

A museum attending plan is presented in Figure 4. It consists of five museums: the Hermitage, Kunstkamera, the Museum of Karl May Gymnasium History, St. Isaac Cathedral, Dostoevsky museum.

Three top screenshots (Figure 5) present the visitor's profile. According to the model of museum visitor's profile in intelligent museum visitor's support system it consists of personal information, system information and visitor preferences (preferred exhibits and other preferences). The fourth screenshot shows an exhibit description acquired from an external Internet service (e.g., Wikipedia).

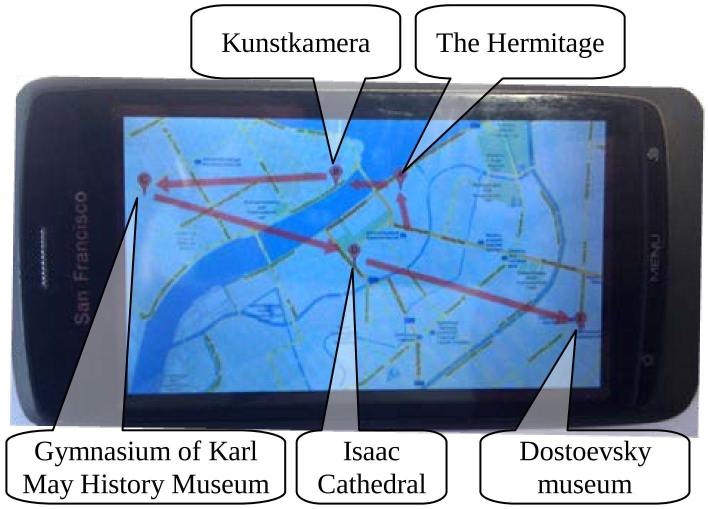

Figure 4. A smaple of museum attending plan in a visitor mobile device in the center of St. Petersburg.

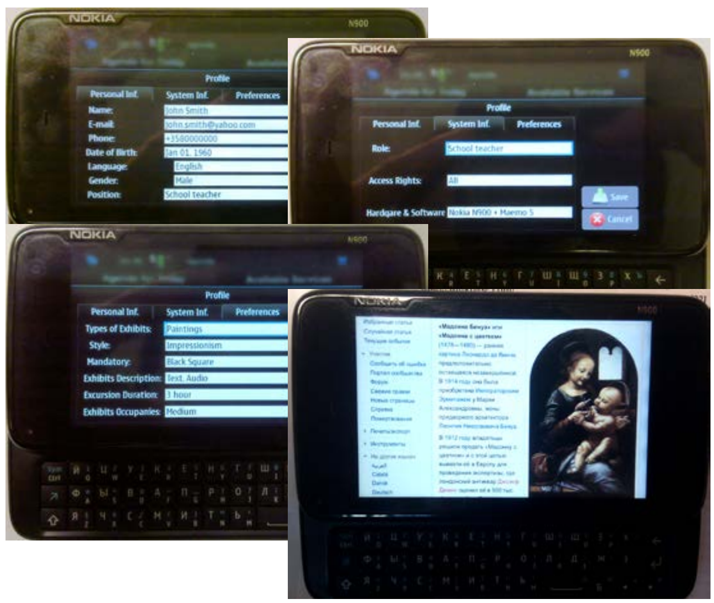

Figure 5. A sample of visitor's profile and exhibition description on the visitor mobile device.

VI. Conclusion

The paper presents an innovative ontology-based approach to mobile smart museums service for supporting visitors in museum smart environment in a region using their mobile devices. This approach allows devices of different visitors to interact with each other for the purpose of generating personal museums attending plan and guiding visitor in the area of museum. User profiles allow keeping important information about the visitor and using it in the smart environment.

Since there is no the centralized server in the proposed system, the performance is affected by the number of visitors indirectly. If there are many visitors using the system, the bottleneck of the system performance will be network capacity and Internet services.

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