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ORIGINAL ARTICLE

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Abstract In this paper, we introduce a European research project, interactive media with personal networked devices (INTERMEDIA) in which we seek to progress beyond the home and device-centric convergence toward truly user-centric convergence of multimedia. Our vision is to make the user the multimedia center: the user as the point at which multimedia services and the means for interacting with them converge. This paper proposes the main research goals in providing users with a personalized interface and content independent of physical networked devices, and space and time. As a case study, we describe an indoors, mobile mixed reality guide system: Chloe@University. With a see-through head-mounted display (HMD) connected to a small wearable computing device, Chloe@University provides users with an efficient way to guide someone in a building. A 3D virtual character in front of the user guides him/her to the required destination.

Keywords Interactive media · Dynamic networks · Personalized and wearable interface · Content management · Mobile mixed reality · Virtual humans · Geolocalization

1 Introduction

Considerable effort has been made to have audio-video systems and applications converge, in particular in home environments with homes as spaces of convergence, and for nomadic users with advanced mobile devices as points of convergence. These trends are important but also have limitations, which we seek to address and overcome: home-centric systems fail to account for increased mobility and the desire to provide continuous service across spatial boundaries outside the home.

In this paper, we address how to move beyond home and device-centric convergence toward truly user-centric convergence of multimedia. Our vision is to make *the user the multimedia center*: the user as the point at which services and the interaction with them (devices and interfaces) converge. A key part of our vision is that users are provided with a personalized interface and with content independent of the particular set of physical devices and their location at anytime. To realize our vision, the approach in the INTERMEDIA system is divided into three main components: dynamic distributed networks, wearable personalized interfaces, and multimedia content adaptation and handling. Each module investigates an ad hoc connection to devices in the environment, a continuous access to multimedia networks, a flexible wearable platform that supports dynamic composition of wearable devices, as well as adaptation of content to devices and user context, respectively.

As one proof of concept, we developed a mobile mixed reality guide system for indoor environments, Chloe@University, as part of the INTERMEDIA ongoing demonstrators. A mobile computing device is hidden inside a jacket and a user selects a destination inside a building through wearable input buttons on a sleeve. A 3D virtual assistant then appears in the see-through HMD, and guides the user to his/her destination. Thus, the user simply follows the virtual guide. Chloe@University also suggests the most suitable virtual character based on user preferences and profiles. Depending on user profiles, different security levels and authorizations for content are previewed. Concerning indoor location tracking, WiFi, RFID, and sensor-based methods are integrated in this system in order to have maximum flexibility.

The remainder of this paper is organized as follows: Sect. 2 describes our envisioned scenario. In Sect. 3, we discuss three main research challenges to achieving the vision. After we explain details of the case study in Sect. 4, Sect. 5 shows preliminary results from the first integrated experiment. In Sect. 6, we conclude the paper with future work.

2 Envisioned scenario

The typical application scenario consists of the office/home use and seamless content delivery with mobile users. This includes the handover mechanisms across various communication networks, edge servers, wearable mobile presentation devices, and adaptable content management depending on various context changes. Following is one of our visionary scenarios.

Chloe prepares herself to go out while listening to her preferred music. She transmits orally her program of the day as well as her itinerary to her electronic agenda, which is somewhere in the house. At the time of leaving, she puts on her INTERMEDIA jacket. At this moment, all the data of each multimedia device are transmitted automatically to her jacket (e.g., the itinerary which she intends to follow this morning and her music selection, see Fig. 1). Chloe gets into her car. The information contained in the jacket is transferred to the electronic device in the car: the car radio and the GPS system for guidance by satellite according to the recorded itinerary.

Fig. 1. Visionary scenario

3 INTERMEDIA research challenges

In a modern nomadic lifestyle as shown in the above scenarios, the usage of media is not limited by spaces. New interactive mobile devices like mobile phones, portable music players, personal digital assistants (PDA), and digital multimedia broadcasting (DMB) devices extend the space where people can access multimedia contents. The concept of user-centric convergence will liberate a modern nomadic person from carrying a range of mobile devices by providing personalized access to media regardless of device types. It will extend personal media spaces for a modern nomadic lifestyle by removing spatial constraints in our daily activities. To realize the user-centric convergence, technological advances in a wide range of research domains need to be achieved under the common vision. True multidisciplinary knowledge is then required to realize the innovative device-free, user-centric media environment, which includes mobile networking, a human-centered interface, and multimedia content manipulation. We aim to build three research modules to develop our system.

3.1 Dynamic distributed networking

In this research area, architectural and communication level issues and our current progress are investigated in dynamic networking with heterogeneous devices. Also, separate but highly related issues of security and digital rights management (DRM) for multimedia contents are investigated.

3.1.1 Dynamic networking in the home environment

Today, sophisticated instrumentation and network services allow the on-line use of a large number of heterogeneous devices, through various access interfaces and networks. A vast area of networking research is focusing on the seamless interconnection of heterogeneous network platforms, addressing aspects related to dynamic resource allocation, QoS control, security, and creation of application-layer overlay networks, among others. In this research area, we identify, develop and test a reference wireless ad hoc architecture with support for QoS, multimedia communications and heterogeneous devices in the home environment. The basic idea is related to the fact that we need a highly flexible structure where devices should be able to operate both as terminal and network nodes (multihop ad hoc network) and support dynamic reconfiguration. In this context the resources (bandwidth, energy, storage and computational power) should be accurately managed and controlled, in order to provide adequate support for multimedia content distribution platforms.

3.1.2 Security and DRM

Another sub-component of dynamic distributed networking is to develop architectures and designs for secure, dynamic distributed networking platforms, focusing on home networking issues and security issues. These issues, including DRM management, will be addressed as a whole, so that security is an inherent system property, in order to achieve high availability and security against a wide range of threats. We define a generic, if possible, communication interface targeted to connect the home network. We also address security aspects of the platform on two levels: (1) the communication interface, and (2) secure service provisioning. Since secure service provisioning and DRM management are platform requirements, we develop a framework to provide secure multimedia services over a wide variety of hardware devices, seamlessly in a complete solution. This will enable the use of heterogeneous security primitives, considering the differing capabilities of the hardware components.

3.2 Wearable personalized interface

In this component, we investigate a set of issues to create personal media space, focused on a form of a wearable interface. We also describe technologies of personalized interfaces for different devices. We focus on the issues of personalized interfaces and wearable interfaces for the personal media space.

3.2.1 Personalized interface

The goal of the personalized interface is to provide technical common ground in the area of personalized ubiquitous content interfaces. For example, users in front of the TV in their living room are accustomed to dealing with a remote control to operate and manage DVD players, TVs, or event media centers. However, when leaving the living room, they would like to have the same control over the content: the interface should follow the users. A mobile device could, through WiFi, act as a remote control. Moreover it could serve to geolocalize the user. In another case, when users leave the home for outside or their car, the interface should change even if the content they are dealing with is the same or a transduced version of it. The interaction interface in a car is more buttons, rolling buttons or sliders and the presentation interface and supported interaction functionalities should be adapted again.

3.2.2 Wearable interface

This sub-component is concerned with the integration of wearable and ubiquitous computing technologies as required to support the development of personalized interfaces. For this, we investigate three key activities: (1) the development of a flexible wearable platform that supports ad hoc configuration of different hardware and software components for user interaction with multimedia; (2) research and development of novel interactive technologies and techniques for seamless user interaction across varying sets of devices; (3) investigation and integration of wearable technologies for sensing and modeling of user context. We regard context sensing and context-awareness as another key technology to support personalization of interfaces with models of the user's present situation and environment. Context-awareness has become a research focus, in particular in ubiquitous computing, with an emphasis on predicting user activity based on, for example, location or other physical evidence. Therefore, we also focus on body-worn technologies for user context sensing.

3.3 Multimedia content adaptation and handling

The core issue in the multimedia system for heterogeneous devices is adaptation and sharing content. There are complex issues involved with adapting different media types in a dynamic network environment, which support seamless presentation of media over different devices. This adaptation is supported in the frame of content sharing.

3.3.1 Multimedia content adaptation

This sub-component deals with the means for multimedia content adaptation and tools that provide metadata to be used for adaptation. For adaptation of multimedia content and representation according to user preferences and to the requirements of the distribution networks and presentation devices, we develop tools that allow for the reduction of the impact of network fluctuations on the quality of multimedia presentations as well as the adaptation of multimedia representations for distributed and varying usage environments enabling interactive manipulation. In this context, an investigation of scene description extensions is an important task. As input to the adaptation tools, we also develop semantic annotation tools enabling links between multimedia representation formats on one hand, and content-related or personalized adaptation on the other. Major work items are the development of tools for automatic and autonomous annotation, including content identification as well as the mapping of annotations and scene descriptions into metadata, and the identification and classification of metadata for adaptation of generic media descriptions.

3.3.2 Content sharing in home network

As described in the previous sub-component, the content is adapted according to the capability of the devices and environments. It requires not only simplification of contents, but also to be transformed into appropriate forms. For example, it is desired to convert visual information in auditory information in order to support visually impaired people. The other case of adaptation is semantic filtering. One digital multimedia content has several semantic elements. For example, an acquired digital material has additional information of where to buy/obtain it, how to access it, limit the access rights, etc, along with the content itself. Different devices require different aspects of the information according to the desired activities. Another important aspect is that the shared contents should be interoperable. For example, one photo or movie clip which is annotated by one user should be transmittable or shared to another user. Also, when a user adds or modifies annotations, they should be available to other shared users regardless of its adapted stages. The problem gets more complex for 3D contents, because modifications on 3D content is usually more complex and more interactive. The content sharing platform should support those complex adaptation and sharing processes in an efficient architecture.

4 Case study: Chloe@University

Under the common vision of INTERMEDIA, we developed a guidance application, Chloe@University as a case study. The target is a mixed reality guidance system inside a building. The virtual human walks like a real guide in front of the user. The virtual guide waits for the user or jumps back if it is getting away from the user. We use a more realistic representation by using 3D environments and virtual humans. In this section, we describe details of the whole system structure, hardware and software components, and lessons learned from the first on-site experiment.

4.1 Related work

Mobile augmented reality (AR) systems have been widely employed for mobile navigation assistance as well as recently with interactive virtual character simulations [8]. Such systems typically involve a mobile H/W device such as PDA, ultra-mobile PC (UMPC) or laptop, based on an integrated AR platform allowing for multimodal navigation AR and camera tracking or sensor-based localization while traversing physical buildings or outdoors locations. However, different approaches are followed based primarily on whether indoors or outdoors AR navigation is needed. Accurate tracking and registration is still an open issue and recently it has mostly been addressed by no single method, but mostly through a fusion of tracking and localization methods, based mostly on handheld AR. A truly wearable, HMD-based mobile AR navigation aid for both indoors and outdoors with rich 3D content remains an open issue and a very active field of multidiscipline research [8].

Due to the fact that networked mobile AR users are enabled with wireless radio communication network interfaces (such as WiFi), protocols that provide location estimation based on the received signal strength indication (RSSI) of wireless access points are becoming more and more popular, precise, and sophisticated. The main benefit of RSSI measurement-based systems is that they do not require any additional sensor/actuator infrastructure but use already available communication parameters and downloadable wireless maps for position determination. Their shortcoming for mobile AR is precision; often multiple access points as well as tedious training offline phases for construction of the wireless map are required. Peternier et al. [11] integrated a WiFi-based localization method in a PDA mixed reality system for visualizing virtual characters and 3D content.

Before the very recent introduction of UMPCs or SmartPhones with CPUs of significant computational capacity for AR [8], PDAs were the only truly mobile alternative for AR researchers. However, a number of computational issues such as lack of dedicated 3D capability and floating point computational unit made their work difficult. Wagner and Schmalstieg [13] have employed PDAs as handheld display devices for AR applications, whereas [7] and [10] allowed for a custom made connection with a special micro-optical HMD.

4.2 Ubiquitous wearable MR interface

The wearable MR platform consists of three distinct parts: a jacket with an embedded user interface (UI), a Liteye-

Fig. 2. User interacting with the i-jacket

500 monocular see-through head-mounted display (HMD) and an ultra-mobile PC (UMPC, Sony Vaio UX70) as shown in Fig. 2. The decision of using MR instead of augmented-reality (AR) has been motivated by the relatively poor results yet achieved in the field of mobile indoor tracking. Indeed, techniques like pedestrian dead reckoning (PDR) [2] or Bayesian localization framework using WiFi signals [6] does not give satisfying enough results to ensure the registration process needed for convincing AR.

MR interfaces can be sometimes confusing, as the virtual content is not integrated into the reality. To overcome this issue, we added an MTx inertial tracker to the HMD such that our system can obtain the orientation of the user's head in real-time. Thus, the map always remains "world-aligned", which means what is in front of the user on the superimposed map is in also in front of him/her in reality.

4.2.1 User interface

The buttons available on the jacket are represented next to the map on the HMD along with a description of their respective functionalities as you can see on Fig. 3. This way, the buttons may have different functionalities according to the context. Plus (+) and minus (−) buttons for instance, are used to select your destination, but while on the move, those same buttons are used to zoom in and out of the 3D map. Alternatively, the user can use voice commands to interact with the UMPC.

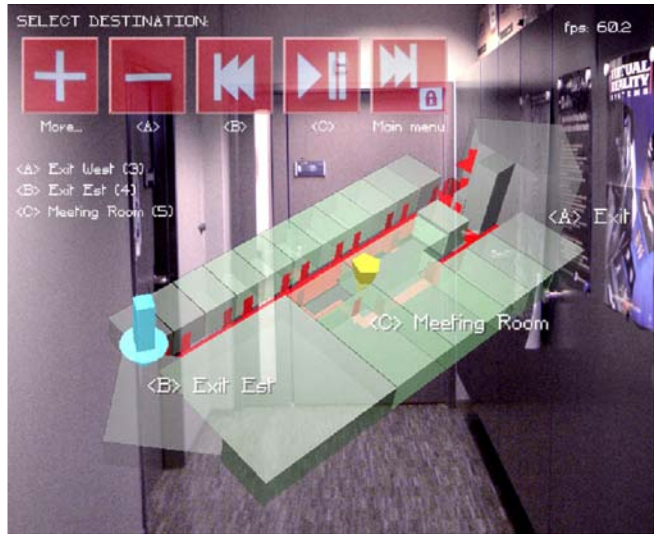

Fig. 3. MR view of the graphic UI during selection of destination

4.3 Fusion of tracking methodologies

The purpose of localization is to provide some kind of location information of the user. To do this, we have been using three different techniques that we enable/disable or combine according to the context and location of the user in order to improve localization in areas where one of them would lack accuracy. Each tracking methodology provides a variable "trustness" value that is used to determine their relative importance in the localization process.

4.3.1 WiFi localization

This localization system presents a major advantage: it runs on any WiFi-enabled device and makes use of preexisting WiFi access points. For the Chloe@University project, we need a localization system which provides a room-sized precision and high accuracy. Our system works in two phases: the off-line phase which consists in collecting signal strength data in order to build a signal map, and the real-time phase, corresponding to the localization phase and based on the previously acquired signal map. During the offline phase, the user creates a navigation graph: each room (or part of corridor) is represented as a vertex of the graph, then the user has to link neighbor vertices between them and records signal data (access point identifiers and signal strengths) for each vertex. After this quick training phase (some seconds per vertex to capture signal data), the localization system is ready to use: the application takes four WiFi samples every second, applies a median filter on this new data to reduce the noise, and locates the user (by a simple distance calculation) according to the signal map acquired during the off-line phase. The system uses a navigation graph to ensure that the new position is realistic (close to the previous one).

4.3.2 Zigbee localization

A major advantage in using sensor networks [1] for localization is that sensor networks may already be available in the environment to acquire context information, thus there is no need for additional hardware. Secondly, the sensor networks often employ localization for their own purposes (for instance to relate the context information to the actual position). We consider a range-based [12] localization system which estimates the location of the sensors based on the estimate distance from (previously deployed) anchor nodes whose actual position is known. We estimate the distances based on the RSSI parameter (receive signal strength indicator). The mobile sensor (in fact the mobile user) receiving the beacons emitted from the anchors estimates the RSSI and performs the localization algorithm. The localization algorithm first approximates the distance between the mobile sensors and the anchors based on the one-slope propagation model [9].

4.3.3 RFID localization

We also used a prototype radio frequency identification (RFID) positioning system. It may work as an alternative to the other positioning engines or in collaboration with them in order to provide improved coverage and accuracy especially in confined spaces where the signal strength of the WiFi access points (APs) or sensors network is diminishing. The position is realized using a computing device equipped with a single RFID reader and multiple active tags placed in fixed locations, which act as beacons to obtain the position of the computing device. We use active tags which can provide us with an amplified signal that increases the reading distance of the tag compared to the reading radius of passive tags. When the reader is within the transmission radius of a tag, the tag will send a packet with information such as its unique ID, RSSI, age of the tag in seconds, the site code and the tag type. In order to make our positioning system even more accurate, we are using a triangulation algorithm to estimate the position of the device instead of simply using the location of the tag with the strongest signal the reader receives.

4.4 Wearable 3D virtual guide

Augmented reality-based virtual guides require robust, cumbersome and complex platforms to be adopted, mainly because of the fine accuracy required to blend virtuality with reality. We decided to use a less constraining mixed reality approach: by using the different localization techniques, we can determine a fairly approximate position of the user. This information is used to determine an area of interest (AOI) surrounding the user with a variable size depending on the accuracy of the localization (less accuracy means larger areas to compensate the lack of precision, thus assuring that the user's real position will always be within the AOI). We use the embedded 3D capabilities of the Chloe@University framework to render a 3D virtual reconstruction of the surrounding environment (rooms, walls, corridors, etc.), by using the orientation sensor to align this view with the reality thus showing a 3D world-aligned fly-by representation on the user head-mounted display. This approach allows us to give the user relevant information according to his/her position, even on zones only partially covered by our localization systems. The orientation sensor also simplifies the linking between the 3D virtual reconstruction of the surroundings and reality.

4.4.1 Ultra-mobile rendering

Real-time computer graphics are a computationally expensive task that difficulty fits on mobile devices with very limited resources. For the Chloe@University project we used ultra-mobile devices featuring basic 3D hardware acceleration as the wearable framework main core. We choose the MVisio 3D Graphics Engine [10] as the rendering software, which takes advantage of the graphics card acceleration available through OpenGL or OpenGL ES, depending on the platform it is running on. MVisio allows to easily load, manipulate and display 3D content like models, skinned characters, textures and videos on heterogeneous devices, including PCs, CAVEs and different mobile or ultra-mobile devices. The graphics engine itself also takes care of the optimizations required to perform at a decent frame rate with low resources by internally readapting different codepaths for speed, using levels of detail or by automatically releasing resources to the system when no longer required.

4.4.2 Path-planning

To efficiently guide a user, the system requires to determine the path from the source to the destination. Furthermore, if the user deviates from his/her original way, this path has to be updated accordingly. Path-planning was developed based on the graph theory. The 3D map data contains a graph which consists of the set of vertices and links. A vertex corresponds to an end point or every crossing point of several ways, and a link to a way like the corridor and stairs. To extract this information on a 3D building plan, a tool was developed within the authoring application 3D Studio MAX to edit the map. As other inputs, the path-planning module receives a user's current location from the localization module, a destination point selected by him/her with the wearable input device (textile buttons on the jacket sleeve), each of which is mapped on a vertex of the graph. The module then calculates the path from the source to the destination using a dedicated version of the A^* algorithm [5].

4.4.3 Content protection

Regarding content protection, the generated routing data file that contains the necessary information data is used by the Chloe@University application in order to guide the user towards its path. The file is stored in the user's device and should be protected against non-legitimate users. In order to achieve that, we utilized specific cryptographic primitives, thus providing protection of the routing data file and confidentiality. Basically, we used a symmetric encryption/decryption algorithm, which encrypts the generated file into the device's filesystem and decrypts it when it is required. The algorithm that we used is the AES (or Rijndael), which is a block algorithm of fixed block size 128 bits, having encryption/decryption keys of variable key length, (in our implementation, we used 128 bit keys), and also working in ECB mode [4]. The whole procedure regarding encryption and decryption of the routing file is transparent to the end user.

5 Results

We integrated all software components that were discussed in previous sections into our mobile mixed reality guide system. Figure 4 illustrates the current overall architecture of Chloe@University. In the current implementation, 3D content is maintained in a computing device and used for path-planning and displaying output by the MVisio platform. Three different localizations and a keyword recognition module from the user-selected destination give inputs to the path-planning module. For the realization of mixed reality system, the system uses an orientation tracking module for displaying the virtual scene, adjusted according to the real viewpoint of a user.

5.1 Lessons learned

The concept of a virtual character which provides a user with the most suitable multimedia services according to his/her preferences wherever he/she goes at any time fits well into the vision of INTERMEDIA (user-centric media convergence), and the part our research is challenged by as follows:

- Security and DRM for the protection of multimedia service contents (e.g., encrypted 3D building plan).
- Personalized interface in order to provide users with the most preferred services (e.g., personalized virtual guide)
- Wearable interface for giving users user-friendly and comfortable interaction with hardware devices (e.g., see-through display and wearable input devices)

5.1.1 Localization accuracy

In order to assess the accuracy of our WiFi localization system, we organized two experiments on two different sites. The first experiment took place in our lab, which consists of a few corridors and many rooms, while the second took place in an "open space" type building. 50 measurements were made on each site. The distances between each measured position and the actual position were noted and classified into three categories: "good" for a distance of less than 5 m, "average" for a distance between 5 and 10 m, and "bad" for longer distances. As shown on Table 1, greater accuracy is achieved in a modulated space. This is due to the variations of the signal strength caused by the walls and doors. These results are quite satisfying for our goal, which was to accurately detect the area of interest (such as a room) of a user. It can also be noted that the results of the second experiment were affected by

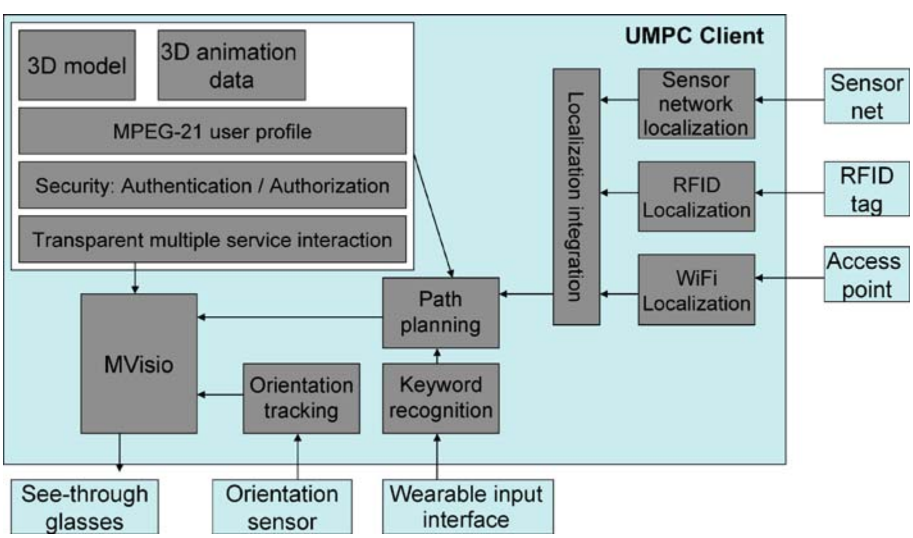

Fig. 4. Overall architecture

Table 1. Results of the accuracy for our two experiments

Accuracy	1. Modulated environment	2. Open-space environment
Good	78%	61%
Average	18%	27%
Bad	4%	12%

the movement of dozens of people walking around in the open-space and thus permanently altering the RSSI used in the localization algorithm.

We also performed the experiments for the Zigbee localization in a typical office environment, which is harsh for wireless communication due to multipath reflections from walls and the possibility of interference from other electronic devices. For the experiments we used a Sensor Network of 7 MicaZ [3] which use the Chipcom CC2420 radio sub-system. The experiments consist of a set of measures between anchors and the mobile sensor. Each measure collects 300 RSSIs, where every RSSI is averaged over a set of 100 samples. Each sample is obtained exchanging a beacon packet between two sensors every $1/32$ s, using the highest transmission power of the MicaZ. During our experiments we observed the typical features of radio channels: asymmetrical links (the connectivity from Node A to Node B might be different than that from Node B to Node A), non-isotropic connectivity (the connectivity is not necessarily the same in all the directions from the source), and non-monotonic distance decay (nodes that are far away from the source may have better connectivity than nodes that are closer). We note that non-monotonic distance decay is the main cause of localization error.

5.1.2 Platform robustness

The framework main application was responsible for integrating the different functionalities, from the data acquisition of the different modules, to their processing and visualization. We pushed the limited hardware available on the Sony UX70 to its limits, stressing the CPU, GPU and USB powered connectors intensively, thus quickly draining the battery from full to empty after about 1 h of non-stop use of the platform.

Data acquisition was performed by the three localization modules, the orientation sensor and the jacket interface, all connected to a battery powered USB-hub. These modules were not very resource demanding, requiring only a regular update of the values returned. On the other side, they required special care concerning the power supply, partially dispensed by the Sony UX70 itself and a secondary battery pack.

3D rendering was performed in real-time on the Sony UX70, featuring an Intel GMA950 graphics card supporting OpenGL 1.4 and thus performing a good amount of operation on the GPU. Images were displayed via the VGA output to the Liteye-500 HMD at a resolution of 800×600, 24 bit. Building models were made by basic primitives like cubes and planes, with no textures, requiring only few triangles (between 1000 and 3000, depending on the building). The virtual guide model is very detailed, using a detailed texture and about 10 000 triangles, animated through a skeleton with a skinned mesh. An average scene total geometry count is between 12 000 and 15 000 triangles, including the site models, the virtual human, the graphical user interface and a dynamic light source. We measured an average framerate near 20 frames per second, ranging from 8–10 fps when the camera was pushed fairly far back to enlarge the area of interest in zones with low localization coverage, to 40–60 fps when only small portions of the surrounding had to be visualized.

6 Conclusions and future work

In this paper, we introduced a network of excellence research projects, interactive media with personal networked devices (INTERMEDIA). Our vision is to propose a technology beyond the home network and device heterogeneity enabling continuous multimedia services wherever a user goes. To reach this vision, we challenged ourselves with three main research components: dynamic distributed networking, wearable personalized interface, and multimedia content adaptation and handling. As a case study of the project, we developed the mobile mixed reality guidance system, Chloe@University under the INTERMEDIA vision. Although currently we integrated the part of our main research modules, we plan to integrate dynamic networking support and seamless session continuation from indoor to outdoor environments as well. The final INTERMEDIA framework will be implemented as a form of INTERMEDIA jacket, which enables a user to be a true multimedia center.

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References

1. Baronti, P., Pillai P., Chook, V., Chessa, S., Gotta, A., Fun Hu, Y.: Wireless sensor networks: a survey on the state of the art and the 802.15.4 and ZigBee standards. Comput. Commun. **30**, 1655–1695 (2007)
2. Beauregard, S.: A helmet-mounted pedestrian dead reckoning system. In: Proceedings of the 3rd International Forum on Applied Wearable Computing (IFAWC 2006), pp. 15–16. VDE-Verlag, Bremen (2006)
3. Crossbow Technology Inc.: http://www.xbow.com. Accessed 2007
4. Daemen, J., Rijmen, V.: AES Proposal: Rijndael. http://csrc.nist.gov/archive/aes/index.html. Accessed 2007
5. Hart, P.E., Nilsson, N.J., Raphael, B.: A formal basis for the heuristic determination of minimum cost paths. IEEE Trans. Syst. Sci. Cybern. **4**(2), 100–107 (1968)
6. Ladd, A.M., Bekris, K.E., Rudys, A.P., Wallach, D.S., Kavraki, L.E.: On the feasibility of using wireless ethernet for indoor localization. IEEE Trans. Robotics Automat. **20**(3), 555–559 (2004)
7. Makri, A., Arsenijevic, D., Weidenhausen, J., Eschler, P., Stricker, D., Machui, O., Fernandes, C., Maria, S., Voss, G., Ioannidis, N.: ULTRA: an augmented reality system for handheld platforms, targeting industrial maintenance applications. In: Proceedings of the 11th International Conference on Virtual Systems and Multimedia (Ghent, Belgium), pp. 681–684. Archaeolingua, Ghent (2005)
8. Papagiannakis, G., Singh, G., Magnenat-Thalmann, N.: A survey of mobile and wireless technologies for augmented reality systems. J. Comput. Animat. Virtual Worlds **19**(1), 3–22 (2008)
9. Patwari, N., Hero, A.O., Perkins, M., Correal, N., Odea, R.: Relative location estimation in wireless sensor networks. IEEE Trans. Signal Process. **51**, 2137–2148 (2003)
10. Peternier, A., Thalmann, D., Vexo, F.: Mental Vision: a Computer Graphics Teaching Platform (Edutainment 2006, Hangzhou, China, April 2006). Lect. Notes Comput. Sci., vol. 3942, pp. 223–232. Springer, Berlin Heidelberg New York (2006)
11. Peternier, A. Vexo, F. Thalmann, D.: Wearable mixed reality system in less than 1 pound. In: Eurographics Symposium on Virtual Environments 06, pp. 35–44. Eurographics Association, Lisbon (2006)
12. Savvides, A., Han, C.C., Strivastava, M.B.: Dynamic fine-grained localization in AdHoc networks of sensors. In: Proceedings of the 7th International Conference on Mobile Computing and Networking (MobiCom 2001), Rome, Italy, July 2001, pp. 166–179. ACM, New York, NY (2001)
13. Wagner, D., Schmalstieg, D.: ARToolKitPlus for pose tracking on mobile devices. In: Computer Vision Winter Workshop 2007, Austria 6–8 February, pp. 139–146. Czech Society for Cybernetics and Informatics, St. Lambrecht (2007)









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