H-Env: An architecture to create intelligent hyper-environments using ubiquitous computing and virtual reality

Nelson D. Filho, Silvia C. Botelho, Jonata T. Carvalho
Renan de Q. Maffei, Rodrigo R. Oliveira, Felipe C. Moraes
Thiago F. Rodrigues, Edevaldo Santos, Rafael A. P. dos Santos
Silvana L. P. Iahnke
Universidade Federal do Rio Grande,
Av. Italia, Km 8, Campus Carreiros, Caixa Postal 474,
96201-900 Rio Grande, RS, Brazil Tel.: +55-53-32336807

Abstract

Ubiquitous computing is considered by many the grand challenge of the moment because of the different kinds of computational problems that it presents. Several works to build intelligent ubiquitous environments, that offer interaction with real world devices to the user in a straightforward way, have been proposed. In this work however we present an architecture, the H-Env, that extend this idea by adding the possibility to create and link many intelligent environments, either virtual or real making it possible to even mix them, offering a system that works not only with the real world entities, but also with virtual entities, thus resulting in a different and interesting form of interactivity. Our architecture seems to be a powerful tool to create pervasive games thanks to his inherent crossmedia aspect. The following paper describes the main idea behind the architecture. It then presents a validation of the already implemented part of the architecture which is the virtual environment module. The tests was performed using different sceneries, including high complexity CAD models.

Keywords:: Pervasive Computing, Virtual Reality, Stereoscopy

Author's Contact:

{dmtnldf,silviacb}@furg.br
{jonatatyska,rqmaffei}@gmail.com
{rodro.ec,felipe.alcm}@gmail.com
{trodrigues02,edevaldosantos}@gmail.com
{rapennas,prof.sille}@gmail.com

1 Introduction

Since Weiser first introduced ubiquitous computing in the early 90's, a lot of research have been developed to solve problems in different areas aiming to fulfill his ideas. By being extremely comprehensive, ubiquitous computing presents challenges in a variety of computing areas. Aspects like, device heterogeneity, input and output, at any moment, new devices on the system, context information management, privacy and security are only a few of the challenges inherent to this paradigm.

Through the concept of ubiquitous computing, several other concepts and research lines where created, some specially interesting to this work, like context-aware computing[Schilit et al. 1994], ambient intelligence (AmI) and Smart Environments (SE), are areas intensively studied today as shown in a recent revision[Nakashima et al. 2010]. The intelligence in this environments is on the fact that its several computing devices, embedded in objects spread on the environment, are capable of perceiving, learning, adapting and reacting to changes, acting always on the users benefit. All this cooperates to make the environment intelligent as a whole.

In a more general form, works cited above, develop user-centered systems, more specifically on humans[Hwang et al. 2009][Lee et al. 2007][Jung et al. 2007]. This type of system implements applications – user-centered – for different purposes like virtual reality, games, video conference, gesture based control, patient monitoring and assistive technology[Nakashima et al. 2010].

Virtual reality is an area which is under development for far longer then ubiquitous computing, presenting its first concrete results in the 60's. Today, virtual reality is already established and its in use in a variety of areas as digital manufacture, training, surgeries, teleoperation, assistive navigation etc.

Once it was proposed, ubiquitous computing was seen as opposed to virtual reality, considering that the user would no longer be inserted in the world of computers, but the computers would be inserted in the world of the humans. Some works, though, use both solutions in a combined way[Lee et al. 2008] [Wang et al. 2007], amplifying theirs benefits and allowing mixed worlds, virtual environments combined with intelligent environments, to be created.

An architecture that can link the real and the virtual worlds with solutions and their interconnections, for each of computational problems involved in the different areas of computing in the simplest and most efficiently possible way is still an unresolved demand, although some related architectures have already been presented [Lee et al. 2008] [Hong et al. 2008]. It is also important that an architecture for this purpose be able to monitor the development technology, that is, provide the opportunity to engage new techniques and technologies to the system over time, considering the accelerated process of computing evolution.

In this work we propose an extensible architecture which allows the creation of this type of system, ie, to support the creation and combination of intelligent, real and/or virtual, environments, allowing communications and exchange of context information between heterogeneous entities of different environments. To the set of intelligent environments, real and/of virtual, combined, we have given the name Hyper-environment[1], same term used to denominate the proposed architecture (H-Env). The hyper-environment are not centered on a single user, but many, depending on the logic used to create it. The term user is also not used only to describe a human being, but any participating entity, may it be real or virtual.

The H-Env system has two main modules: real and virtual. The real module works deals with the key features of the ubiquitous computing environments like perception, adaptability, interoperability and others aspects of devices. In the virtual module of the H-Env architecture the system allows the use of various display devices including CAVE'S, conventional CRT monitors and televisions with 3D stereoscopic technology, many control devices and tracking of movements, keyboard, mouse among others.

An architecture that enables the creation of Hyper-Environments presents challenges to be faced in many computing areas . The interconnection and synchronization between the virtual and real environments and entities, the communication between them and the interaction with the Users are only some of these challenges, beyond those inherent to all intelligent systems of ubiquitous computing mentioned previously.

This article is structured in 5 sections. The next section focuses on the major challenges associated with creating contex-aware systems that enable mixed worlds, the main properties and interconnections between the real and virtual worlds, and how this integration can happen, and presents some related work. The Section H-Env: An architecture to create intelligent hyper-environments states the main ideas of the proposed architecture and its use. Section Implementation and Results describes how the already finished part of the

[1]The creation of this new term was made by analogy to Hypertext

architecture is implemented and how the implementation of the remaining part is projected, besides the results of tests performed with our system. Finally, the section Conclusion presents a discussion of the results and the conclusions extracted from them.

2 Virtual Environments and Ubiquitous Computing

Virtual reality and ubiquitous computing are two major areas in computing, being, in a general way, studied separately. Each one presents its own challenges, inherent to the nature of its problems. Offering the possibility of mixing virtual environments and ubiquitous computing, more specifically, real intelligent environments implies, necessarily, into presenting solutions to existing problems in both areas and also to problems that did not exist before, that is, arising from their union.

Differently from virtual reality, which had its first concrete results presented in the 60's with Ivan Sutherland, studies on ubiquitous computing started being developed in the early 90's by Mark Weiser, having its major progresses in the later years.

Through the concepts of ubiquitous computing, context-aware computing has arisen[Schilit et al. 1994]. The context, main key of this system, is defined in several ways by different authors, the most used is given by Dey[Dey 2001] and states that context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between the user and application, including the user and applications themselves something is context because of the way it is used in interpretation, not due to its inherent properties.

Different lines of research exists within ubitquitous computing, some more specific, i.e., communication with heterogeneous devices[Patterson et al. 1990] [Solis et al. 2001], identification of context information [Kunito et al. 2006], context modeling[Indulska and Robinson 2009] [Kock et al. 2009], among others, and some more generic, i.e., middlewares, that aim to offer a mechanism to solve a set of problems inherent from the construction of intelligent environments of ubiquitous computing, the so called context-aware environments.

A recently published work[Gregor Schiele and Becker 2010] presents an extended revision regarding middlewares for ubiquitous computing, identifying the main aspects and classifying them in more general topics. According to the author, there are three factors in projecting a middleware for pervasive computing: organizational model, provided level of abstraction and supported tasks. The organizational model is one of the main aspects upon projection a middleware for pervasive computing and may be classified, according to[Gregor Schiele and Becker 2010], in:

- Smart environment: a huge part of the middlewares of pervasive computing use this organizational model. Can be defined as a limited area, for example a conference room or an apartment, equipped with a variety of sensors and actuators. Works like [Garlan et al. 2002] [Paluska et al. 2008] [Román and Campbell 2000] are considered Smart environment.
- Smart peers: model centered in peers instead of places. The main idea is to extend the pervasive system as a collection of computers that surround a person, independently of their physical location. Works like [Edwards et al. 2002] [Grimm et al. 2004] are considered Smart peers.

A large number of papers that present applications in real environments, it is denoted as ubiquitous service environments [Chang and Lee 2007], or ubiquitous computing environment [Guzman et al. 2008], sometimes just ubiquitous environments [Guzman et al. 2008], among many others, have been developed in recent years.

In [Lu et al. 2007] is presented a framework to deal with multiple environments and multiple contexts in a distributed form. This work introduces the concept of local context management, which aggregate different sensor managers which, in turn, aggregate different sensors. This framework is organized in levels following the OSI model as reference.

In the later years, some works related to both areas where presented. In [Suh et al. 2007] is proposed the new concept of Ubiquitous Virtual Reality (U-VR). The article examines the technical challenges that arise upon implementing systems that use virtual reality techniques together with ubiquitous computing.

The article [Disz et al. 1997] describes an virtual reality environment to simulate physical environments of ubiquitous computing. It is noteworthy that the virtual environment does not communicate with the real environment in this work. In [Nishikawa et al. 2006], which also describes an environment of virtual reality to simulate physical environments on ubiquitous computing, although it is not the main topic of the work, this communication between virtual and real environments exists.

The challenge in creating an architecture for the combination of physical and virtual environments, is the organization of an architecture that addresses all these aspects in efficiently. Depending on the speed of computation evolution, and the emergence of new techniques and technologies, it is important that this architecture be extensible and adaptable to support its maintenance and updating.

3 H-Env: An architecture to create intelligent hyper-environments

A big picture of the architecture is presented at Figure 1 and described in this section. Given the fact that the architecture is a middleware for creation of intelligent environments of ubiquitous computing, may they be real or virtual, we will use the revision presented in [Gregor Schiele and Becker 2010], already cited at the previous section, as base for describing our architecture, classifying it in the categories presented in that paper.

The figure 1 can be seen as follows: (i) entities are presented as rectangles; (ii) the different communication medias are presented as triangles. The colors are the type of media, for instance, visual, sonorous, olfactory etc, and can also be technological medias like wifi, bluetooth, infrared etc. It should be pointed out that medias can be divided in levels of abstraction, which are the information level and the communication level; (iii) circles represent services available, offered by the entities. When an entity offers a service to the others, it starts being part of the middleware, it does not matter which entity offers the service. This services represent transformation of information in three forms, categorized in a format presented in a recent revision[Soylu et al. 2009]: one to one, where one type of media provides an output in another type, fusion of information, where through the several types of input provide one output in another type, or by fission of information, where one input generates several outputs;

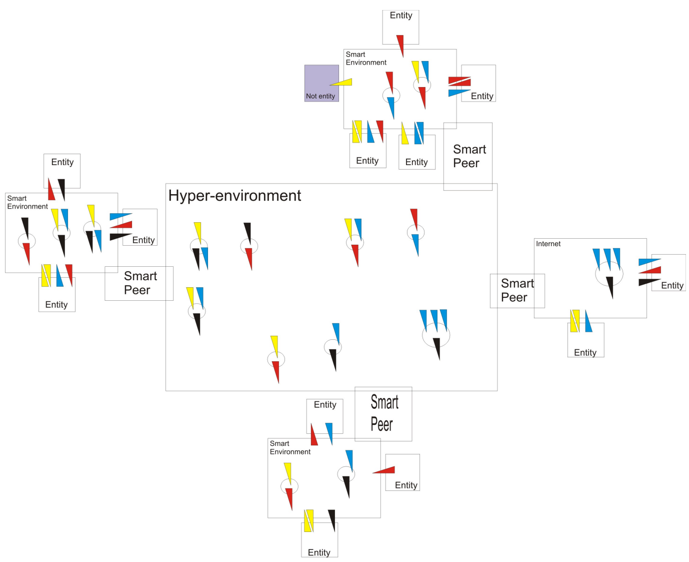

Figure 1: Big Picture of The H-Env Architecture

Entities communicate only by sending an receiving signals of the environment, this concept was built by using nature as a metaphor as cited in section 1. This is done through the medias, being the triangle with two vertices on the entity and one on the environment the sending of a signal from the entity to the environment an the opposite being the receiving of a signal of the environment by the entity. Another important issue is that to exist within the architecture, an entity needs to be perceived by at least one other entity, implying that a device that only captures information, without sending to any other, does not make part of the environment, this is because no other entity can detect it.

Following the organizational model presented by [Gregor Schiele and Becker 2010], our architecture is considered hybrid, mixing smart environment with smart peers. On H-Env smart environments are related to locus, this is, a specific environment, i.e., an office, a hospital etc. In our case, this locus can even be virtual, not considered in the referred revision. On the hyper-environment level, the organizational model used is of smart peers, where each environment is a peer.

To be part of the hyper-environment, an entity has to necessarily be in a smart environment. In this case, allowing entities present in any part of the globe, even not being related to a specific locus, can be made by considering the Internet as a smart environment, allowing entities and its services to exist on the hyper-environment through the Internet.

About the levels of abstraction presented in [Gregor Schiele and Becker 2010], the architecture is again hybrid. The H-Env utilizes an Configurable automation on smart environments, where some specific configurations about the services supplied within the environment need to be configured manually and the most basic level of abstraction, needed by all smart environments, is supplied automatically. On the hyper-environment however, as the possibly available solutions supplied by the merging of all different smart environments is too wide, the utilized approach is simplified exposure, where the middleware only offers the information provided by the lowest level of abstraction.

On the tasks supported, presented in [Gregor Schiele and Becker 2010], H-Env was projected to work with the building blocks approach, in this case its possible to attach new tasks to the working system. Initially the architecture was developed to support two of the three tasks presented at the revision: Spontaneous Interaction and Context Management. Each of this tasks will be described in the following items:

- Spontaneous Interaction: The architecture H-Env guarantees, transparently, that heterogeneous devices communicate and interact with each other in an automated way. This layer of the architecture guarantees interoperability, aspect which is considered fundamental in the bibliography for ubiquitous systems[Soylu et al. 2009]. It is in this layer that, the communication protocols for service discovery, entity discovery and information routing through devices, will be implemanted.

- Context Management: This task is responsible for defining how the context is modeled and distributed along the system, acquisition and fusion of sensors informations, and provision and access to information relation entities. It is in this level that the services and the methods of accessing this services are implemented in the H-Env architecture. The organization of context in our architecture is made in a distributed form, using as base the model presented at[Lu et al. 2007]. In each smart environment exists an entity responsible for managing the context of that environment, in this local scope this management is made in a centralized form. In the hyper-environment, however, the information of context is organized in a distributed way, being spread across the local context managers. The group of context managers of the different environments is responsible for the context management of the hyper-environment, aggregating pertinent information when the environments are connected, and being irrelevant when they environments are isolated.

The smart environments are connected to the hyper-environment through a specific entity, which on the figure 1, are labeled Smart Peer. This entity is also responsible for the local context management. This type of organization is possible as shown in[Gregor Schiele and Becker 2010], the smart environments usually have a stationary computing structure, allowing centralizing certain types of services. This optimizes the architectures functioning and avoids the need for special treatment of several types of problems related to fully distributed architectures, this is, no type of centralization.

4 Implementation and Results

The system is not fully developed yet, the current system support visualization of virtual entities (a virtual reality engine) and cooperation between them. The system is strongly based on SOA and we are building our system on top of web services, a solution that seams to have became a standard of the industry. Our solution uses DPWS for finding and comunicating with devices so any device that does not support it has to be adapted, we strongly based our topology on[Park et al. 2009].

With the available system, the tests where made through a TV that supports active stereoscopy (figure 2) using also a tracking device for navigation, in order to view CAD models in the shipping industry in different scenarios. In addition, the visualization was carried out on computers geographically distributed with users communicating via chat.

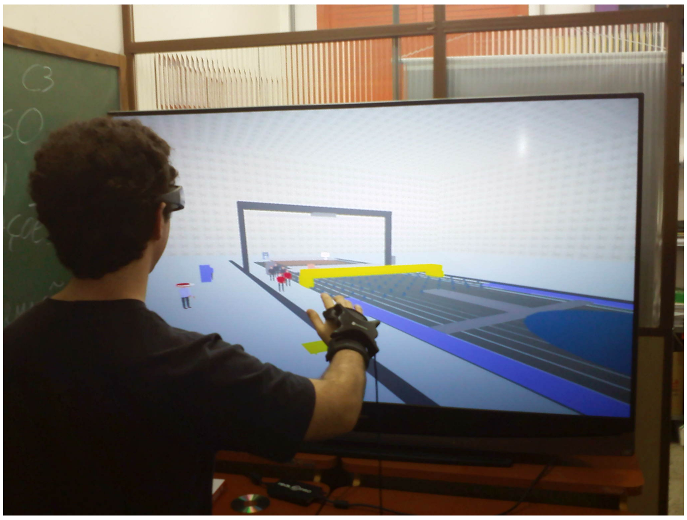

Figure 2: Active stereoscopy on a 3D TV

Entities are every object, seen (or interacting in some way) in the virtual environment or in the real environment. In this application we have a scenery with a CAD model, some other entities and their representation[2].

5 Conclusion

The Virtual reality technology is already widely studied, however, is has been limited by hardware. With advances in technology and the popularization of devices that were previously restricted to a niche market, solutions that were previously shown to be inviable serving as a new direction of the market.

Ubiquitous computing on the other hand is relatively new, and though several works deal with this issue, there is real perspective that shows how this is going to be in the future.

This paper shows how to build a context-aware system that is both real world and virtual world friendly. Our system supports interaction with multiple entities that may be anywhere in H-Env. We will finish the current implementation and publish real testing on our ubiquitous system, later this year.

[2]As real world data acquirement is not integrated, this is purely virtual

References

CHANG, J.-W., AND LEE, H. 2007. Context-aware architecture for intelligent application services in ubiquitous computing. In *ICSC*, 275–281.

DEY, A. K. 2001. Understanding and using context. *Personal and Ubiquitous Computing 5*, 4–7.

DISZ, T., PAPKA, M., AND STEVENS, R. 1997. Ubiworld an environment integrating virtual reality, supercomputing and design. In *Sixth Heterogeneous Computing Workshop*.

EDWARDS, K. W., NEWMAN, M. W., SEDIVY, J. Z., SMITH, T. F., BALFANZ, D., AND SMETTERS, D. K. 2002. Using speakeasy for ad hoc peer-to-peer collaboration. In *2002 ACM Conference on Computer Supported CooperativeWork*.

GARLAN, D., SIEWIOREK, D., SMAILAGIC, A., AND STEENKISTE, P. 2002. Towards distractionfree pervasive computing. In *IEEE Pervasive Computing*.

GREGOR SCHIELE, M. H., AND BECKER, C. 2010. *Pervasive Computing Middleware*. Springer Science+Business Media, LLC.

GRIMM, R., DAVIS, J., LEMAR, E., MACBETH, A., SWANSON, S., ANDERSON, T., BERSHAD, B., BORRIELLO, G., GRIBBLE, S., AND WETHERALL, D. 2004. System support for pervasive applications. In *ACM Transactions on Computer Systems*.

GUZMAN, G., PINEDA, A., TORRES, M., MENCHACA-MENDEZ, R., AND MORENO, M. 2008. Geographic-aware architecture for the interoperability of ubiquitous components. *Networked Computing and Advanced Information Management, International Conference on 1*, 416–421.

HONG, D., HOLLERER, T., HALLER, M., TAKEMURA, H., CHEOK, A. D., KIM, G. J., BILLINGHURST, M., WOO, W., HORNECKER, E., JACOB, R. J. K., HUMMELS, C., ULLMER, B., SCHMIDT, A., VAN DEN HOVEN, E., AND MAZALEK, A. 2008. Advances in tangible interaction and ubiquitous virtual reality. *IEEE Pervasive Computing 7*, 2, 90–96.

HWANG, R.-H., TSAI, S.-Y., AND WANG, C.-Y. 2009. Ubiphone: Human-centered ubiquitous phone system. *IEEE Pervasive Computing 8*, 2, 40–47.

INDULSKA, J., AND ROBINSON, R. 2009. Modelling weisers sal scenario with cml. In *2009 IEEE International Conference on Pervasive Computing and Communications*.

JUNG, J.-Y., HONG, Y.-S., KIM, T.-W., AND PARK, J. 2007. Human-centered event description for ubiquitous service computing. In *MUE '07: Proceedings of the 2007 International Conference on Multimedia and Ubiquitous Engineering*, IEEE Computer Society, Washington, DC, USA, 1153–1157.

KOCK, G., RIBARIĆ, M., AND SERBEDZIJA, N. 2009. Modelling user-centric pervasive adaptive systems the reflect ontology. In *Intelligent Systems for Knowledge Management*.

KUNITO, G., SAKAMOTO, K., YAMADA, N., TAKAHASHI, T., AND TANAKA, S. 2006. Architecture for providing services in the ubiquitous computing environment. In *ICDCSW '06: Proceedings of the 26th IEEE International ConferenceWorkshops on Distributed Computing Systems*, IEEE Computer Society, Washington, DC, USA, 60.

LEE, H., PARK, J., PARK, P., JUNG, M., AND SHIN, D. 2007. Dynamic conflict detection and resolution in a human-centered ubiquitous environment. In *UAHCI'07: Proceedings of the 4th international conference on Universal access in human-computer interaction*, Springer-Verlag, Berlin, Heidelberg, 132–140.

LEE, Y., OH, S., SHIN, C., AND WOO, W. 2008. Recent trends in ubiquitous virtual reality. *International Symposium on Ubiquitous Virtual Reality 0*, 33–36.

LU, K., NUSSBAUM, D., AND SACK, J.-R. 2007. Globecon: a scalable framework for context aware computing. In *EuroSSC'07: Proceedings of the 2nd European conference on Smart sensing and context*, Springer-Verlag, Berlin, Heidelberg, 190–206.

NAKASHIMA, H., AGHAJAN, H., AND AUGUSTO, J. C. 2010. *Ambient Intelligence and Smart Environments: A State of the Art*. Springer Science+Business Media, LLC.

NISHIKAWA, H., YAMAMOTO, S., TAMAI, M., NISHIGAKI, K., KITANI, T., SHIBATA, N., YASUMOTO, K., AND ITO, M. 2006. Ubireal: Realistic smartspace simulator for systematic testing. In *UbiComp 2006: Ubiquitous Computing*.

PALUSKA, J., PHAM, H., SAIF, U., CHAU, G., AND WARD, S. 2008. Structured decomposition of adaptive applications. In *6th Annual IEEE International Conference on Pervasive Computing and Communications*.

PARK, H., PAIK, E.-H., AND KIM, N. 2009. Architecture of collaboration platform for ubiquitous home devices. *Mobile Ubiquitous Computing, Systems, Services and Technologies, International Conference on 0*, 301–304.

PATTERSON, J. F., HILL, R. D., ROHALL, S. L., AND MEEKS, S. W. 1990. Rendezvous: an architecture for synchronous multi-user applications. In *1990 ACM conference on Computer-supported cooperative work*.

ROMÁN, M., AND CAMPBELL, R. H. 2000. Gaia: Enabling active spaces. In *Proceedings of the 9th ACM SIGOPS EuropeanWorkshop*.

SCHILIT, B. N., ADAMS, N., AND WANT, R. 1994. Context-aware computing applications. In *IN PROCEEDINGS OF THE WORKSHOP ON MOBILE COMPUTING SYSTEMS AND APPLICATIONS*, IEEE Computer Society, 85–90.

SOLIS, I., OBRACZKA, K., AND MARCOS, J. 2001. Flip: a flexible protocol for efficient communication between heterogeneous devices. In *Sixth IEEE Symposium on Computers and Communications*.

SOYLU, A., CAUSMAECKER, P. D., AND DESMET, P. 2009. Context and adaptivity in pervasive computing environments: Links with software engineering and ontological engineering. *Journal of Software 4*, 9, 992–1013.

SUH, Y., KIM, K., HAN, J., AND WOO, W. 2007. Virtual reality in ubiquitous computing environment. In *International Symposium on Ubiquitous VR*.

WANG, K., CHEN, I., ABDULLA, W., SALCIC, Z., AND WUNSCHE, B. 2007. 3d virtual interface for ubiquitous intelligent environments.