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Developing xReality objects for mixed-reality environments

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Abstract. These days technology enables people to collaborate on work, despite being separated by large physical distances. A variety of such systems have been developed to support organisations such as universities or companies. Most of these platforms are focused on conveying information rather than dealing with collaboration around physical activities that are common in product development or university laboratory activities, where, if such work exists, tend to be confined to the use of simulations. In this paper we introduce a system and associated set of techniques that enables teams of physically dispersed workers to collaborate on the construction of products that comprise both physical (hardware) and information (software) based objects in a so-called mixed-reality environment. The work aims to support dispersed development teams such as students, company R&D members or hobbyist (e.g. enabling the creation of virtual *hackerspaces*). As such the work focuses around the use of *Internet-of-Things* technologies to enable people to collectively build new products. In this work-in-progress paper we describe the implementation of *xReality objects* and their communication within an interreality system, extending our previous work towards the creation of a holistic option for enable geographically dispersed teams to collaborate on the construction of mixed hardware and software products.

Keywords. Mixed reality, dual reality, constructionism, virtual laboratory, virtual *hackerspace*, collaborative R&D, blended reality, xReality objects, interreality, human-machine interface (HMI), internet-of-things, tangible user interface (TUI).

Introduction

In previous papers [1] [2] we presented an innovative conceptual model for the creation of a mixed reality learning environment which aimed to enhance distance laboratory activities based on a constructionist perspective [3]. For these learning activities we proposed the use of physical and virtual objects to simulate real interaction with the laboratory equipment and to promote collaboration between students situated in different geographical locations.

In this work-in–progress paper we describe the first phase of implementation of our conceptual model, the *InterReality Portal* and generalise the concept beyond educational applications. Van Kokswijk [4] defined *interreality* as the user perception

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of total integration between the physical and the virtual world, "*a hybrid total experience between reality and virtuality*"; a phenomenon now present in everyday activities such as watching TV, talking by phone with an individual not situated in the same physical space, chatting and sharing information through the Internet using mobile devices or even reading a book -if the reader is very interested on the plot-. As we can see living in two realities is something very common and the human brain manages to switch and blend two (or more!) realities at the same time. However, in these examples, the user is the one who blends both realities and make them work. The user's ability to "switch context between real-local and virtual-distant environments and blend traces of one into the other in a socially unconscious manner (often seemingly simultaneously)" is defined as Blended Reality [5]. Still this mechanism can fail; individuals can get so immersed in the activities they are performing that they can be totally absorbed in one reality at a time, having a lack of presence in the other reality [6]. Lifton et-al. defined this behaviour as the "*vacancy problem*" which limits the capacity of user's presence and engagement to a single reality at a time, as a consequence of user's real immersion to the activity performed at that moment [7].

Dual reality attempts to create an integrated environment able to mirror and complement both, virtual and real worlds, in real time, avoiding the *vacancy problem*, using the combination of a ubiquitously networked sensor/actuator infrastructure and 3D virtual environments [8] performing a real-time data interchange process between the real world and the virtual world. This means that the environment does not stop on a point in between the reality-virtuality continuum [9], such as augmented virtuality (AV) and augmented reality (AR) interfaces which add a data layer to virtuality or reality respectively. Instead it transmits the data from the real world to the virtual world in real-time allowing the existence of the real object and a mirrored virtual representation of the same object, which ideally should be updated one from the other on a bidirectional process.

In [10] [11] we proposed the use of *xReality objects*, which are smart objects coupled to their virtual representation, updated and maintained in real time, to create this dual reality state in order to perform remote collaborative laboratory activities. Smart objects can be defined as "*autonomous physical/digital objects augmented with sensing, processing, and network capabilities*" which can interpret their local situation and status, and can communicate with other smart objects and interact with human users [12]. A key point to differentiate smart objects from *xReality objects* is that the digital representation of the latter emulates the shape, look and status of the physical object in a 3D environment, whereas the digital representation of a smart object is commonly a 2D graphic or table.

The collaborative laboratory activity proposed for our test bed is the creation of a computer science project which combines hardware and software modules to produce Internet-of-Things (IoT) applications emphasising computing fundamentals. Internet-of-Things (IoT) could be defined as "a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network" [13].

In the research scenario proposed by us, the user creates mashups between virtual and real objects to produce a computer-science tangible deliverables, developing problem-solving skills by the correlation between concepts and real tasks (Problem-based Learning) [14]. Our original work focused on education where we found that most of the laboratory activities for distance learners were focused on simulations using software interfaces (virtual laboratories or eLabs) having minimum or no interaction with real equipment and, in most of the cases, performed using idealized data [15]. In addition, a great deal of research on virtual laboratory activities is focused on a single student, whereas real laboratory activities are usually performed as a group, considering collaboration between individuals on the resolution of a problem.

In a comparable way, product development in companies and even hobbyist's "*do it yourself*" (DIY) projects are based on collaborative work and problem-solving strategies, therefore the use of an interreality system such as the one proposed could help to support quick prototyping for companies or hobbyists on different geographical locations. A special scenario could be the use of our proposed interreality environment in *hackerspaces* or *makerspaces*. There is no standard definition for a *hackerspace*; several sources define them as "*local spaces where hackers can meet, share knowledge and work on projects*" [16]; "*community-operated physical places, where people can meet and work on their projects*" [17] or "*a physical location with tools and diverse experts who can help collaborate on projects in a wide range of scales, but it connotes a philosophy of doing things with no particular preference to empirical or theoretical methods*" [18]. However there is a common idea on these definitions: a *hackerspace* has a physical location for collaborative co-creative work. The use of an interreality system on *hackerspaces* could enhance participation of distance users on the creative process by using virtual collaboration through *xReality objects*. These ideas could also be used on other scenarios where collaborative co-creative work is needed for geographically dispersed users, such as product research and development, telework, etc.

In the following section of this work-in-progress paper we start by describing the conceptual model and architecture of our interreality system before moving on to discuss implementation and future work. The first phase of our research involves the use of a single *dual reality* state, the following phases will include the incorporation of a two or more users and the management of multiple *dual reality* states, mirroring two or more *xReality objects* on a single virtual environment in synchronous time.

1. Conceptual model

Figure 1 shows the conceptual model proposed for the use of two or more interreality systems to create coordinated multiple dual reality states. In this diagram an interreality system is formed by 3 components: a) the *physical world*, where the user and the *xReality object* are situated; b) the *virtual world*, where the real-world data will be reflected using the virtual object; and c) the *interreality portal*, a human-computer interface (HCI) which captures the data obtained in real-time by the *xReality object*, processes this data so it can be mirrored by its virtual object and thereby links both worlds.

The Context-awareness (CA) agent periodically requests information from the *xReality object* to identify any change on the object and gather data from the sensors. The Mixed Reality (MR) agent obtains the information collected by the CA agent and translates this as an updated state/action in the virtual object. When this process is replicated on a second interreality system, the Dual Reality agent (DR) manages the multiple dual reality states to synchronise the virtual object(s) and show a unified virtual representation following these predefined rules [2]:

a) A change in any Virtual object of a given InterReality Portal results in identical changes to all subscribing InterReality portals.
b) A change in an *xReality object* of a given InterReality Portal results in changes in the representation of the real device on all subscribing InterReality portals.

In any of these cases the *xReality object* executes a discovery service which allows the interreality system to get updates and reflect them on the virtual environment.

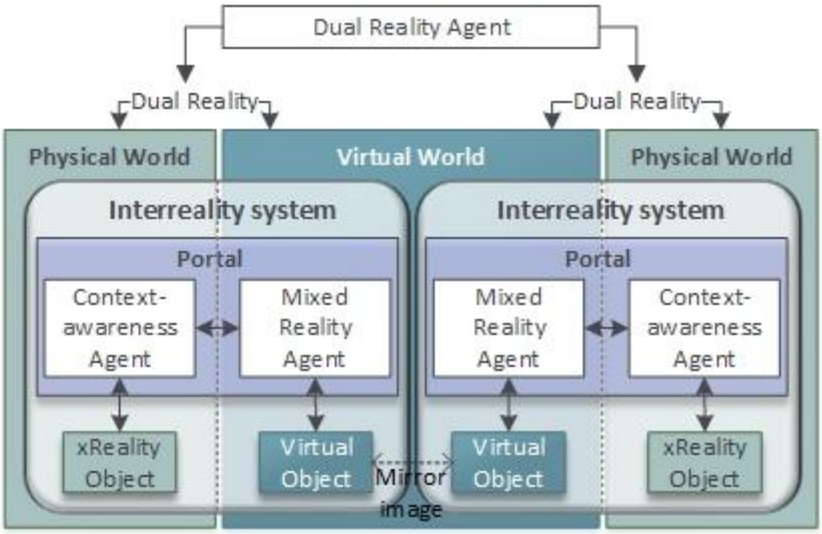

Figure 1. Conceptual model

1.1. xReality object

Figure 2 represents the conceptual construction of an *xReality object* and a virtual object. Following the ideas of smart objects on the Internet-of-Things (IoT), an *xReality object* has a unique ID, a list of available services (e.g. to get data or receive data) and in some cases rules (e.g. a certain object cannot work without fulfilling some preconditions). In a similar way each virtual object has a unique ID, one or more behaviours attached (e.g. the virtual object must behave as a solid object according to physical variables, such as weight, gravity, etc.) and rules similarly to the *xReality object*. The ID is the key to have the *xReality object* identified by the CA agent. Once identified the MR agent can access their predefined properties (rules, services and behaviours), to be used on the visualization layer, and update their status.

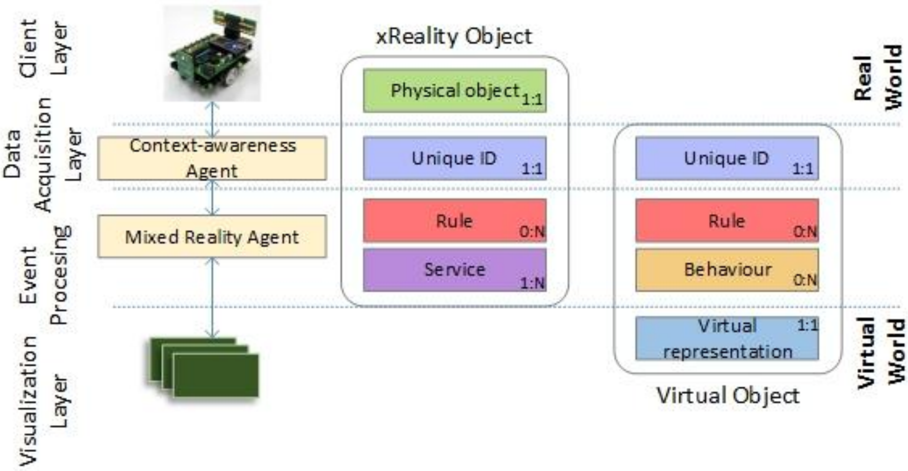

Figure 2. *xReality Object* Conceptual Model [10]

2. Implementation

Our implementation follows the main idea behind the tangible user interfaces (TUI) paradigm described by Fishkin [19], "*a user uses their hands to manipulate some physical object(s) via physical gestures; a computer system detects this, alters its state, and gives feedback accordingly*". In our case, while the user manipulates the xReality object, the InterReality Portal detects the changes on the structure/services available and updates the state of the virtual object giving feedback to all the subscribing interreality portals. Figure 3 exemplifies the proposed architecture that communicates the xReality object with the InterReality portal. As previously stated on section 1.2, an *xReality object* is usually implemented as a physical object with a unique id and predefined rules and behaviours (fig. 2). In our implementation the *xReality object* is formed by a group of interchangeable pluggable components, to create a mashup with a main component which identifies and integrates the others. This main component is the one that runs a discovery service to capture changes on the *xReality object* composition and to keep updated the virtual representation. These changes include modifications on the components connected to the main board and updates on the state of each component.

Guinard et al. [20] describe two types of mashups on the Web of Things (WoT): 1) physical-virtual mashups (or cyber-physical systems) and 2) physical-physical mashups. The first category refers to a combination of physical devices and different services available through and end-user interface, similar to Chin's virtual appliances approach [21]. The second category refers to a physical user interface that uses real-world services without requiring an end-user interface, such as a computer or HTTP browser. The mashup created by our implementation could be considered physical-physical when connecting the xReality physical components, and physical-virtual when this components are coupled to their virtual representation.

The implementation of multiple dual reality states using the rules defined on section 1 is as follows:

a) In case of a change of a virtual object of a given InterReality Portal, the MR agent will update and link the virtual objects maintaining the multiple dual reality status.
b) In case of a change in the components of an xReality object of a given InterReality Portal, the CA agent detects which components are still available and the current status; if the object structure differs on the number or type of components available and the current structure is not replicated on the other xReality object, the InterReality Portal through the MR agent will block the use of the new component(s) on both xReality objects until both users decide if they want to keep the new structure or if they want to return to a previous state. Otherwise the MR agent will update and link the virtual objects maintaining the multiple dual reality status.

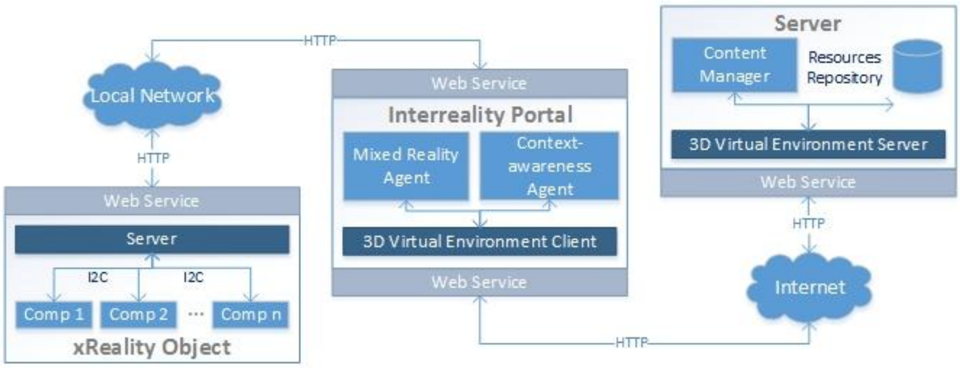

Figure 3. Proposed architecture

Communication between the *xReality object* and the 3D virtual environment (3D VE) client was implemented using a RESTful API. The Web of Things (WoT) proposes the use of web standards to integrate real-world things into the existing Web by changing real objects into RESTful resources that can be used directly over HTTP [20]. To do so, we decompose each component's into services that can be identified using URIs and use HTTP's main operations (GET, POST, PUT, DELETE) to interact with the object. Once the CA agent implemented on the 3D VE collects or sends this data, the MR agent matches an action to be performed on the visual representation.

2.1. xReality object

As previously mentioned, our implementation of an *xReality object* is formed by two different types of components: the main module, which detects other components and works as a hub to connect them to the interreality system; and a group of interchangeable pluggable components which comprises different sensors and actuators to allow the creation of diverse physical mashups.

The description of the *xReality object* implementation was defined as follows:

a) *Main component*: The main component was implemented using a small low-cost computer, the Raspberry Pi[2] (RPi), which uses a linux-based operating system. The Raspberry Pi (RPi) is an open-source single board computer created for educational purposes; however, due to its cost, size and low power requirements has been used as a key component in embedded systems and implementations by hobbyist and creative hackers worldwide. We use a RPi as the main component on the xReality object, to identify other pluggable components and to send/receive information from the InterReality portal through a RESTful API. This latter was implemented using Bottle[3], a python-based Web Server Gateway Interface (WSGI) micro web-framework distributed as a single file module and has no dependencies other than the Python Standard Library which makes simple and lightweight. Python[4] is an open-source general-purpose programming language which promotes simplicity and code readability.

b) *Pluggable components*: The components of the *xReality object* were implemented using a toolkit of diverse pluggable network-aware hardware boards which can be interconnected to create a variety of Internet-of-Things (IoT) projects such as mobile robots, mp3 players, heart monitors, etc. The Fortito's Buzz-Board Educational Toolkit[5] allows the creation of quick prototypes by using combinations of modules plugged together. The discovery and communication of the boards with the main component (e.g. the RPi) was implemented using a python library for the Inter-Integrated Circuit bus (I^2C). I^2C is a multi-master serial single-ended computer bus created by Philips in 1982 for attaching low-speed peripherals [22] and allows the RPi to control a network of device chips using two general purpose I/O pins and a python library.

2.2. InterReality Portal

Finally, the implementation of the InterReality Portal was done using two main components:

a) An *immersive environment*: To create the immersive environment we use Immersive Display Group's ImmersaStation[6], a semi-spherical sectioned screen with a desk attached to simulate a natural position for performing learning activities, allowing a free-range of head movement without the need of any intrusive body instrumentation (e.g. special glasses).

b) A *3D virtual environment*: To visualise virtual representations of the *xReality objects* we developed a 3D GUI on Unity3D[7], a cross-platform game engine used to create interactive 3D content which supports C# and JavaScript

[2] Raspberry Pi Foundation – http://www.raspberrypi.org
[3] Bottle: Python Web Framework - http://bottlepy.org/docs/dev/
[4] Python - http://www.python.org/
[5] Fortito Ltd – http://www.fortito.mx/en
[6] Immersive Display Group - http://www.immersivedisplay.co.uk/immersastation.php
[7] Unity3D Game Engine - http://www.unity3d.com/

> routines. The aim of this virtual reality GUI is to create a synthetic experience for the user due to the user's sensory stimulation generated by the system [23]. It is based on client-server architecture, where a client is used on each immersive station to and the server manages and updates the multiple dual reality states (fig. 3).

Figure 4 illustrates all the parts on our implementation of a single Interreality system. The portal is formed by the immersive environment and the 3D GUI pictured on the upper part of the image. The 3D GUI shows the virtual representation of an *xReality object*: the main module and two pluggable secondary components with their metadata (ID and name). On the left corner, the image displays the implementation of the *xReality object*, using a RPi (main module) and two objects: Fortito's *BuzzBerry*, which acts as a hub to connect different boards to RPi's primary I^2C channel, and *BuzzLed7*, a board with four 7-segment displays (secondary component). The hub (*BuzzBerry*) is just a bridge between the RPi and other objects; it cannot interpret data and it does not have any service/function available, therefore according to smart object's definition presented at the introduction of this paper it does not qualify as a smart object and does not present any metadata on the 3D GUI. Through the 3D client interface the user can send an update to the *xReality object* and get a request for the current status of the Buzz-Led7 and the RPi. To do so, the 3D GUI uses the RPi IP (Internet Protocol) address in the local network and the RESTful API implemented to retrieve information as a JSON object. Then it parses the information retrieved and shows it on the client interface. Currently software components can be depicted as a list of available services for each BuzzBoard on the contextual menu, but the combination of the different components will allow also the mixture of their services to create a mixed reality mashup using software (services) and hardware (components).

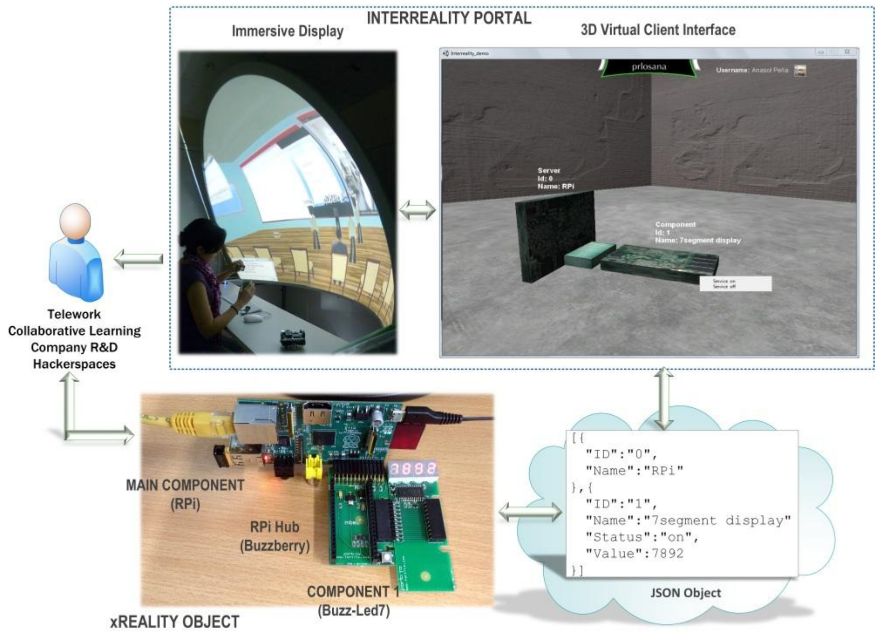

Figure 4. Interreality system

The first process on a session in the Interreality portal is the identification of all the actors/objects involved on the process of Blended Reality creation. To identify all the changes on the xReality object, a routine on the main component (RPi) periodically scans the I^2C bus looking for changes on the pluggable components.

For user identification and validation we use OpenId[8], an open standard created to consolidate user's digital identities on the Internet. By using this standard we eliminate the creation of the authentication layer sending this to third-party validation web services, furthermore enabling the possibility for our system to interact with other social sites. Once the user is authenticated by a third-party service, it is possible to match the user id, in this case an email address, to the user's profile on the system.

This implementation can be regarded as a type of tangible user interface (TUI). According to Ishii et al. a TUI is a user interface that ''augment the real physical world by coupling digital information to everyday physical objects and environments'' [24]. Brave et al. proposed 4 types of TUIs [25] based on: a) a graphical user interface (GUI), b) a GUI using Computer Supported Cooperative Work (CSCW) in real-time, c) a TUI, and d) a TUI using Computer Supported Cooperative Work (CSCW) in real-time. For our implementation we use both a GUI (a 3D virtual space) and a TUI (in the form of xReality objects). The first stage of our implementation is focused only on one environment but the following stages involve the use of CSCW in real-time.

Another point to consider is user's perceptual coupling of these tangible and intangible representations. As stated by Sears et al. to enhance perceptual coupling is essential to work on real-time on "the coincidence of inputs and output spaces (spatial continuity of tangible and intangible representations)" [26]. Currently intangible representation on our implementation focuses on visual simulation, through immersive hardware and software, and tangible representation is embodied on haptic simulation using *xReality objects*; however this does not limits the use of other type of stimuli such as aural or vocal on our future work.

Summary and future work

In this paper we briefly explained our previous work and the rationale behind our research which is to enable groups of geographically dispersed workers to collaborate on the construction of an Internet-of-Things system. Such groups might be drawn from sets on online learners (students), members of a company R&D team or hobbyists who are using this system to create a virtual *hackerspace*. In terms of the science we described the architectural model and implementation of the first stage of our mixed-reality learning environment using web standards and physical objects embodied on the mashup of Fortito's Buzzboards and the RPi. In particular we introduced the concepts and architectural design of an *xReality object* and showed how it is linked to a virtual representation within the Interreality Portal using a 3D engine. This work is part of a much larger project which aims to build and test such a system operating between continents so, in that respect, this paper describes components of that longer term aspiration, setting up the basis for our upcoming research. For the next phases we will

[8] OpenId Foundation - http://openid.net/

explore the design and implementation of mixed reality laboratory activities managing a single dual reality state and we will extend our research to the management of multiple dual reality states adding a collaborative layer to the laboratory activity between two or more learners in different geographical locations. Our main contribution from this paper is the proposed *xReality object* architecture and implementation of our collaborative learning interreality environment.

This work can be interpreted from a number of different points of view. At the lowest level it can be regarded as a micro intelligent environment in which *xReality objects* (i.e. product component) can be coupled using a discovery service to create small stand-alone appliances. From another point of view there is the possibility to scale it up to an intermediate level through the interaction with virtual components enabling systems of interconnects appliances to be formed (so-called virtual appliances). The Final point of view is the construction of macro intelligent environment (i.e. interconnected and potentially geographical dispersed appliance) creating the intriguing possibility of implement a large scale network of Interreality portals connected on different locations.

Much work still needs to be done before answering the various research questions set out in this paper, such as the technical issues relating to the management and creation of blended reality; evaluating the perceptual coupling of tangible to intangible representations and the diverse aspects concerning the use of *xReality objects* in collaborative co-creative activities. In this respect we look forward to presenting further outcomes of this research, as our work progresses, in subsequent workshops and conferences.

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References

[1] A. Peña-Ríos, V. Callaghan, M. Gardner and M. J. Alhaddad, "Towards the Next Generation of Learning Environments: An InterReality Learning Portal and Model," in *8th International Conference on Intelligent Environments 2012 (IE'12)*, Guanajuato, Mexico, 2012.

[2] A. Peña-Ríos, V. Callaghan, M. Gardner and M. J. Alhaddad, "InterReality Portal: A mixed reality co-creative intelligent learning environment," in *1st Workshop on Future Intelligent Educational Environments (WOFIEE'12)*, Guanajuato, Mexico, 2012.

[3] S. Papert and I. Harel, Constructionism, Ablex Publishing Corporation, 1991.

[4] J. van Kokswijk, Hum@n: Telecoms and Internet as Interface to Interreality : a Search for Adaptive Technology and Defining Users, Bergboek, 2003.

[5] S. A. Applin and M. Fischer, "A Cultural Perspective on Mixed , Dual and Blended Reality," in *IUI - Workshop on Location Awareness for Mixed and Dual Reality (LAMDa'11)*, Palo Alto California, USA, 2011.

[6] J. Lifton, M. Laibowitz, D. Harry, N.-w. Gong, M. Manas and J. A. Paradiso, "Metaphor and Manifestation— Cross-Reality with Ubiquitous Sensor/ Actuator Networks," *IEEE Pervasive Computing,* vol. 8, no. 3, pp. 24-33, 2009.

[7] J. Lifton and J. Paradiso, "Dual Reality: Merging the Real and Virtual," *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering,* vol. 33, no. 1, pp. 12-28, 2010.

[8] J. A. Paradiso and J. A. Landay, "Cross- Reality Environments," *IEEE Pervasive Computing,* vol. 8, no. 3, pp. 14-15, 2009.

[9] P. Milgram and F. Kishino, "A taxonomy of virtual reality displays," *IEICE TRANSACTIONS on Information and Systems,* Vols. E77-D, no. 12, pp. 1321-1329, 1994.

[10] A. Peña-Rios, V. Callaghan, M. Gardner and M. Alhaddad, "Remote mixed reality collaborative laboratory activities: Learning activities within the InterReality Portal," in *The Intelligent Campus International Symposium (IC'12)*, Macau, 2012.

[11] A. Peña-Rios, V. Callaghan, M. Gardner and M. J. Alhaddad, "End-user programming & deconstrutionalism for collaborative mixed reality laboratory co-creative activities," in *2nd European Immersive Education Summit (EiED'12)*, Paris, 2012.

[12] G. Kortuem, F. Kawsar, D. Fitton and V. Sundramoorthy, "Smart objects as building blocks for the Internet of things," *IEEE Internet Computing,* vol. 14, no. 1, pp. 44-51, 2010.

[13] H. Sundmaeker, P. Guillemin, P. Friess and S. Woelfflé, Vision and Challenges for Realising the Internet of Things, Cluster of European Research Projects on the Internet of Things (CERP-IoT) - European Commission, 2010.

[14] K. -. K. Ngeow and S. Yoon, "Learning to learn: preparing teachers and students for problem-based learning. ERIC Digest.," 2001. [Online]. Available: http://www.ericdigests.org/2002-2/problem.htm. [Accessed 03 2012].

[15] Z. Nedic, J. Machotka and A. Nafalski, "Remote laboratories versus virtual and real laboratories," in *Frontiers in Education*, 2003.

[16] E. Blankwater, *Hacking the field. An ethongraphic and historical study of the Dutch hacker field,* Universiteit van Amsterdam, 2011.

[17] "Hackerspaces," [Online]. Available: http://hackerspaces.org/wiki/. [Accessed 15 04 2013].

[18] M. Altman, Interviewee, *Founding a Hackerspace: An Interactive Qualifying Project Report.* [Interview]. 2010.

[19] K. P. Fishkin, "A taxonomy for and analysis of tangible interfaces. Personal and Ubiquitous Computing," vol. 8, no. 5, pp. 347-358, 2004.

[20] D. Guinard and V. Trifa, "Towards the web of things: Web mashups for embedded devices.," in *GuinardIn Workshop on Mashups, Enterprise Mashups and Lightweight Composition on the Web (MEM 2009), in proceedings of WWW (International World Wide Web Conferences),* Madrid, 2009.

[21] J. Chin, V. Callaghan and G. Clarke, "Soft-appliances : A vision for user created networked appliances in digital homes," *Journal of Ambient Intelligence and Smart Environments,* vol. 1, no. 1, pp. 69-75, 2009.

[22] NXP Semiconductors, "NXP," [Online]. Available: http://www.nxp.com/documents/user_manual/UM10204.pdf. [Accessed 25 02 2013].

[23] G. J. Kim, Designing virtual reality systems: the structured approach., Springer, 2005.

[24] H. Ishii and B. Ulmer, "Tangible bits: towards seamless interfaces between people, bits, and atoms," in *Conference on Human Factors in Computing Systems (CHI'97)*, Atlanta, 1997.

[25] S. Brave, H. Ishii and A. Dahley, "Tangible Interfaces for Remote Collaboration and Communication," in *In Proceedings of the ACM conference on Computer Supported Cooperative Work (CSCW'98)*, 1998.

[26] A. Sears and J. A. Jacko, The human-computer interaction handbook: fundamentals, evolving technologies and emerging applications, CRC Press, 2007.