The Collective Experience of Empathic Data Systems

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Deliverable 4.1

CXIM 2.0 Environment

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Executive Summary

The main objective of WP4 is to create a common synthetic reality platform where CEEDs application will be deployed. This objective comprises the further enhance the eXperience Induction Machine (XIM) architecture (CXIM 2.0), which includes the development of a portable infrastructure, and the development of novel visualization technologies and algorithms suited for large data sets.

This document describes the design and implementation of the CXIM 2.0 environment and details the changes of hardware and software made to the previous XIM. On section 2 is described the general architecture and the hardware, then on section 3,4 and 5 it's described each of the systems that CXIM 2.0 provides and the devices and software applications that controls them.

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1 Introduction

1.1 Existing XIM architecture and infrastructure

The eXperience Induction Machine (XIM) is an immersive room located at SPECS Laboratory in the Universitat Pompeu Fabra in Barcelona, Spain. It's equipped with a wide range of sensors and effectors (Figure 1). XIM was designed as a general purpose infrastructure to investigate human-artifact interaction and to support the research of specific questions that include how a spatial enclosure can affect and interact with its visitors, how humans can act, exist and behave in both physical and virtual spaces, the construction of socially capable believable synthetic characters and the development of a framework for interactive narratives. XIM was based on a system call "Ada - the intelligent space" that was build for the Swiss national exhibition Expo.02, a fair that has been visited by over 560.000 people over a period of 6 months (Eng K. et al 2003). A modified version of the system was instaleld at SPECS laboratory to develop experiments in neuroscience.

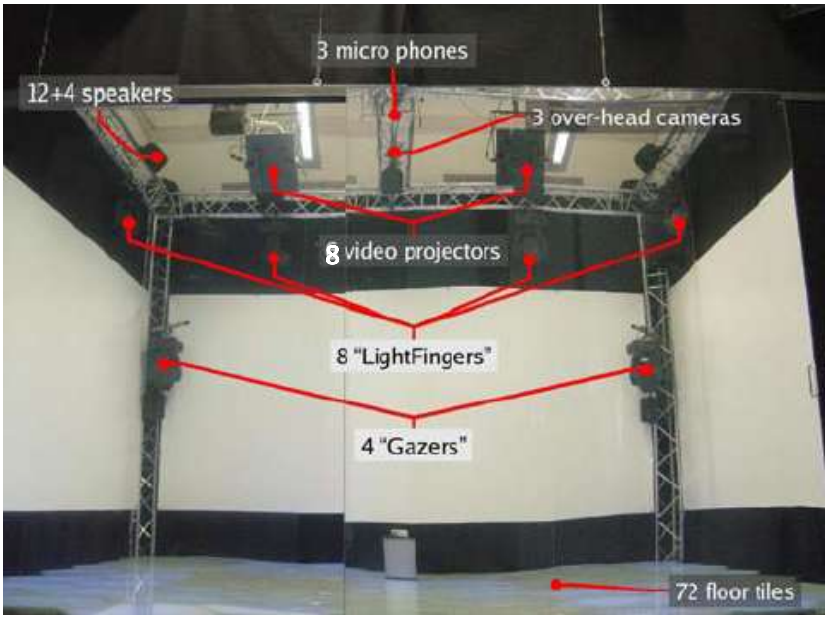

Fig. 1 - ***Picture of the XIM room at UPF facilities.***

The XIM architecture is running on a cluster of computers, each controlling various aspects of the XIM. The projection system employs 8 projectors, driven by 4 computers. The overall control system is implemented using the large-scale neuronal system simulator "IQR[1]". It

[1] http://iqr.sourceforge.net

interfaces with a range of devices including a floor controller, sonification, LightFingers, Gazers, loudspeakers and microphones.

1.2 Upgrading XIM to CXIM 2.0

During February 22-26, 2011 BME visited the XIM facilities at UPF in Barcelona to review in detail the current hardware (HW) and software (SW) infrastructure of the existing eXperience Induction Machine (XIM). Throughout the week the team had detailed discussions on current and future requirements, control infrastructures, legacy devices, rendering architecture and visualization methodologies, including the use of avatars and high fidelity virtual humans.

This document describes the work it has been done during the first year of the project in WP4 and the upgrade made to the XIM environment in terms of hardware and software to adequate it to the necessities of the CEEDS project, based on these premises:

- Reliability of the servers
- Processing capacity
- Audiovisual systems
- Sensors systems (floor, tracking)
- Security and networking
- Space used by servers and noise generated

2 Networking and servers

The update of the hardware and networks systems was one of the important parts of the work for the CXIM 2.0 environment. In the first stage the server machines were upgraded to better handle the network connectivity and to improve the processing capacity needed for running the CEEDs applications. To reduce the number of physical machines and to provide a scalable solution for future needs a virtualization server was acquired. Additionally a new KVM system was purchased to provide multiple work stations for development and to better support the administration of the machines from a remote console.

At the end of the current reporting period the new server and display machines are installed and running in the CXIM space. All services from the old machines were transferred to new physical and virtual servers.

2.1 Network configuration

One important improvement with respect to the previous XIM is the configuration of a dedicated network. Previously the network needed to go through a series of switches and firewalls controlled by the UPF IT services, which rendered connection between applications running in XIM and the exterior world difficult. The new network setup is used for the communication of the cluster with the outside (through internet). With the current configuration the communication ports for all applications running in CXIM 2.0 can be configured directly from a console. In practice this allows to administrate connections between applications running in CXIM 2.0 and the portable CXIM or other external devices like phones, tablets, etc.

The CXIM 2.0 network was configured as two networks: The internal LAN and the DMZ[2] (De Militarized Zone) as is shown in Figure 2. In the DMZ zone are the servers that offer services for the external network, such as database engines, web services or communications services (YARP). Consequently the firewall only allows connections to specific ports of these machines. The remaining servers that are used for storing all process for running an application, grouped in the audiovisual system, sensors and computing are connected to the internal LAN. Each of these systems controls specific hardware or runs specific applications. Each of the servers and the upgrade made to the system will be explained in details in the subsequent sections.

[2] http://en.wikipedia.org/wiki/DMZ_(computing)

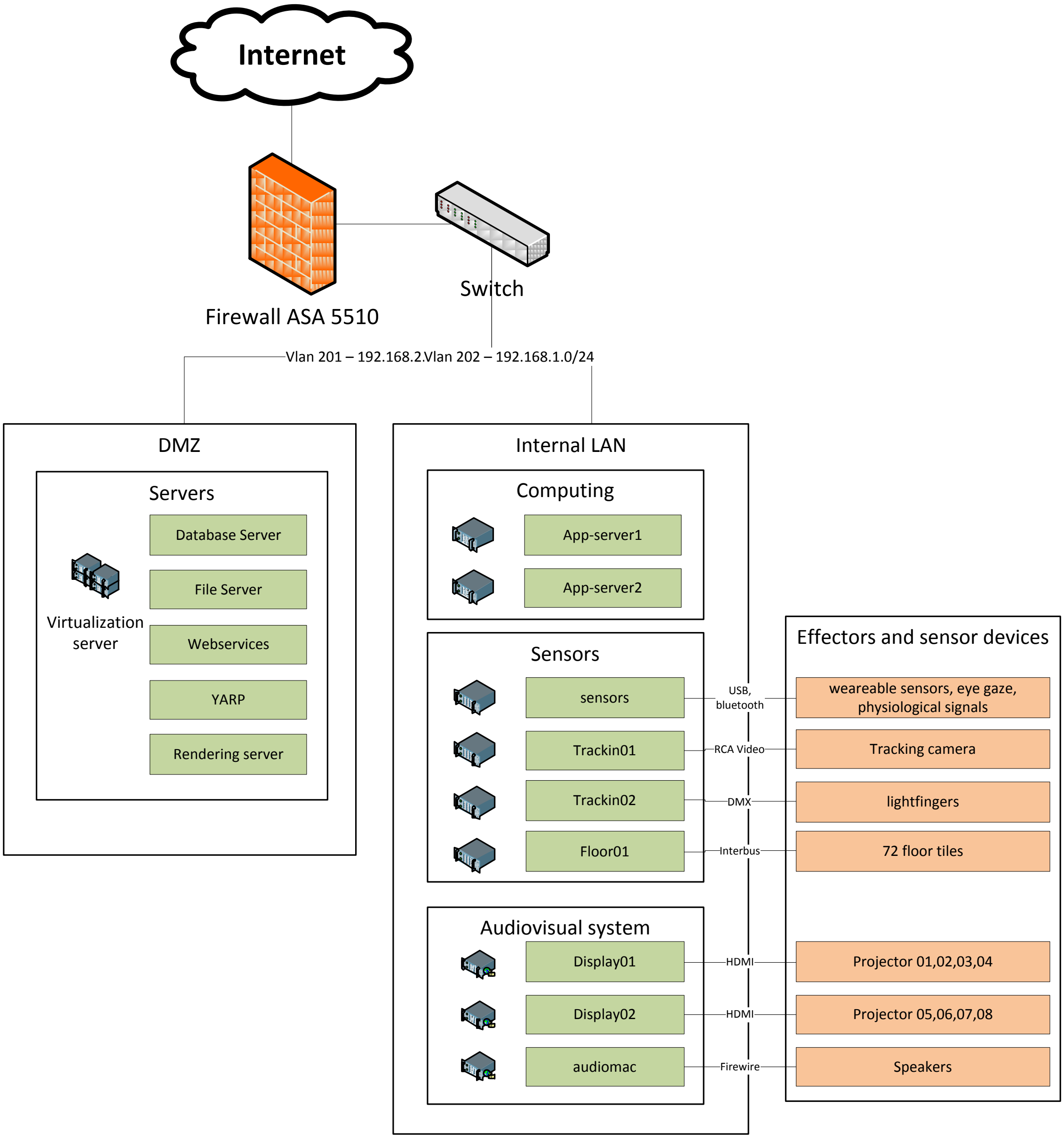

Fig. 2 - *Network diagram of CXIM 2.0*

2.1.1 Firewall

The firewall was upgraded from a server machine to a hardware firewall. This upgrade reduces the latency of the communication between the CXIM 2.0 machines and machines outside the CXIM environment, improves performance and security. It also facilitates the administration of firewall rules.

The acquired equipment is a CISCO ASA 5510 unit that is rackable, and allows secure remote access through VPN and has a web interface for administration.

Fig. 3 - ***Picture of the firewall CISCO ASA 5510***

2.1.2 Switch

A switch is needed to route the network connections of the machines in the environment. For security reasons a switch with capabilities to configure two different sub-networks was required. One for a De Militarized Zone (DMZ) and a second network with all machines that are intended only to be visible by the machines in this subnet, like the displays, processing and sound systems.

The acquired equipment is a HP 2910al-24G unit that is configured with the two networks. This equipment provides a good throughput (interfaces of 100 and 1Gb), can be mounted in a rack, and is "ultra-dense", meaning it uses less space in the rack. Additionally the unit can be easily extended to work with additional switches if there is a need to connect more machines to the environment.

Fig. 4 - ***Picture of the Switch HP 2910al-24G***

2.2 Servers

The following sections explain the hardware chosen for the servers. The applications installed on these servers will be described in sections 3,4 and 5 which elaborates on the specifics of the CXIM 2.0 system.

2.2.1 Computing

To provide the needed computing power the existing machines were upgraded to dedicated professional servers that have high computing capacities and can be dedicated to run the components of CEEDs applications such as the narrative engine, composition engine and CEEDS Sentient Agent (CSA). Additionally a dedicated server to handle the input sensors of CXIM 2.0 such as the wearable sensor t-shirt, sensing gloves, wii, kinect, etc was added to the system.

The system was upgraded with three HP proliant DL160 G6, Xeon E5506 at 2.13 GHz servers. These servers are high performance, low cost, ultra-dense rack server designed for memory intensive High Performance Computing (HPC) environments, web serving and memory intensive applications.

Fig. 5 - ***Picture of the sever HP proliant DL160 used for storing computation services and control sensors***

2.2.2 Virtualization server

For optimization of space and scalability a virtualization server was added to the CXIM 2.0 environment. This server allows creating virtual machines to run dedicated services specific to CEEDs applications, independent of the operating systems that is used. Such applications will include database engines, inter-communication servers (YARP) and other components of the CEEDs architecture.

For the hardware a HP ProLiant DL360 G7 server with high capacity of computing and storage was selected. The virtualization software used is VMware ESXi that runs directly on top of the physical server. The server is partitioned into multiple virtual machines that can run simultaneously, sharing the physical resources of the underlying server. This software delivers industry-leading performance and scalability.

Fig. 6 - ***Picture of the server HP ProLiant DL360 acquired for the virtualization services***

Fig. 7 - ***Schematic view of the VMware ESXi software that allows creating virtual machines over a unique server.***

2.2.3 Display

For the display systems the requirements of the applications and the visualization engine (Unity3D) were evaluated. An additional requirement was the final configuration of the projectors (8 projectors). The decision was taken to upgrade the system with two displays machines with high end graphics cards with 4 display outputs each. With this configuration the visualization systems can handle the output to 8 projectors and can be extended in the future to handle more projectors (e.g. to handle projections in the floor or the ceiling).

The display system is upgraded to work with the chosen solution of 8 projectors for the projection system (described in section 5.2). In order to meet the requirements of space optimization by reducing the number of display machines graphics cards with multiple outputs were evaluated. The chosen graphics card is an AMD FirePro V7900 Professional with AMD Eyefinity technology that supports four simultaneous and independent monitors from a single graphics card.

The solution implemented for the display system comprises two display machines with one V7900 card each. Hence, with the two machines 8 projectors can be controlled. Though it would be possible to have multiple cards in a single machine, the decision was taken against this solution because at this moment one of the rendering engines used by the CEEDS applications (Unity3D) cannot take advantage of the hardware acceleration of multiple cards in a single machine.

Fig. 8 - ***Picture of the graphic card AMD Firepro V7900 and the four display outputs***

2.2.4 Remote console administration (KVM)

To provide work stations for developers, and to facilitate the administration of the CXIM 2.0 machines the keyboard-video-mouse (KVM) switch was upgraded. The chosen solution is an Altusen KH2508A KVM switch that allows CXIM 2.0 users to access and control multiple computers from two PS/2 or USB KVM consoles. Operators working at up to two consoles can independently and simultaneously take control of up to 8 computers (matrix KVM). Using two identical units up to 16 computers can be controlled.

Fig. 9 - ***Picture of the KVM system Altusen KH2508A used for work stations and administration.***

2.2.5 Tracking, Floor and sound

The machines than control the interface to the tracking system, the pressure sensitive floor and the sonification system were maintained from the previous XIM design. The rational for this decision is that these machines have specific hardware interfaces to sensors and effectors with corresponding operating systems versions.

Although at present each of these systems are up to date to meet the CEEDS requirements, alternatives for future upgrades were evaluated, specifically taking into account the requirements for building a portable version of CXIM. For the pressure sensitive floor alternatives are described in section 3.1.

2.3 Hardware accommodation

The machines described in the previous sections are mounted in a single rack next to the CXIM 2.0 installation. The rack organizes the machines in terms of physical space and organizes all electricity and networks connections of the cluster. Additionally the rack is optimized for the thermal regulation of the servers. Figure 9 shows the configurations of the servers in the rack. Compression of all machines into a single rack was an important improvement with respect to the previous XIM, where the servers were mounted in two racks, occupying more space and generating more heat and noise in the room.

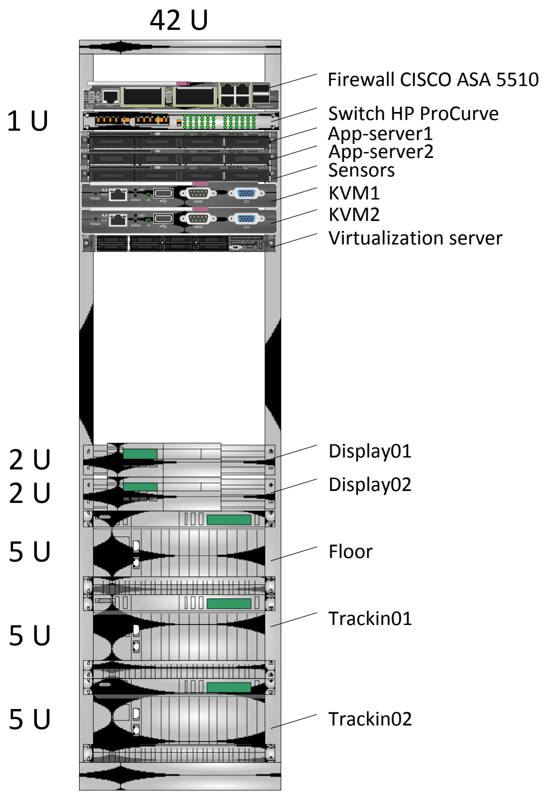

Fig. 10 - ***Final configuration of XIM 2.0 rack after upgrade***

3 Physical sensors

3.1 Pressure sensitive Floor

CXIM 2.0 maintains the luminescent and pressure sensitive floor of the previous version of XIM that consists of 72 individual tiles (Delbrück et al, 2007). Three force sensing resistors in each tile are used to measure the load and send these values to the control computer via InterBus interface. The colour of each floor tile can be set to any RGB value.

For CEEDs the software that receives the pressure detection from the floor and sends the information to connected clients was updated to send the messages through the YARP[3] server (the communication platform choosed for all CEEDS applications). This means that the information produced by the floor can be used by any client of the CXIM2.0 architecture.

BME evaluated different options to upgrade the floor to a different system. To match the visual feedback capabilities of the current interactive floor different configurations and options both for the portable version (if deemed necessary) and to retrofit the existing hexagonal grid were evaluated. Several colour RGB tiling solutions are available..An example is the iColor Tile MX line from Philips Color Kinetix[4] or simpler edge-based illumination models such as the iColor Cove EC[5]. To control these tiles the CXIM system will be able to use DMX or if new HW is designed, we will most likely opt to use independent serial controller via an USB link.

Floor projection would offer a viable alternative of the tiles system when used in the portable XIM or the CXIM 2.0. Depending on the number of projectors used for the main surround video feature, an additional 2-4 projectors might be available to produce visual scenery or to reproduce the tile-based interaction in simulated mode.

At present the floor will be maintainted for the CXIM 2.0 environment, but this is subject to change depending on the evaluation of BME for the portable version.

Fig. 11 - ***An application using the pressure sensitive floor in the XIM***

[3] http://eris.liralab.it/yarp/

[4] http://www.colorkinetics.com/ls/rgb/tilemx/

[5] http://www.colorkinetics.com/oem/lamps/cove_ec/

3.2 Tracking

A multi-modal tracking (MMT) system is integral part of XIM (Mathews et al, 2007). The MMT uses information from the pressure sensitive floor and an overhead infrared camera. The software integrates both sources of information and delivers input to the world-model maintained by the system, which includes, among others, exact positions of users in XIM.

The software consists of an application based on OpenCV[6] named "AnTS" developed at the UPF. This software takes the camera image as input and analyzes the image to identify the visitors in the room. On top of AnTS the software framework "Traza" integrates the information from the pressure sensitive floor to maintain a list of the visitors' position in the space and their ID.

In the previous version of XIM the Traza software was sending the information to connected clients through UPD ports. For CXIM 2.0 the software was modified to use YARP to transmit messages to connected clients, hence making the information available to any application within the architecture.

Fig. 12 - ***Left: Interface of the AnTS software and the camera image used to track visitors in CXIM 2.0. Right: Interface of the Traza software.***

3.3 Sensor devices

The environment will incorporate interfaces for devices that are developed by WP2 (see D2.1). Physiological and brain signals, gestures, eye gaze, and speech will be acquired through wearable and/or portable sensing frameworks and serve as input to the CEEDs applications.. A dedicated sensor server will provide the corresponding hardware and software interfaces. Currently CXIM 2.0 has been tested to interface to devices like BCI, kinect[7] and wii remotes[8] to control applications.

[6] http://opencv.willowgarage.com

[7] http://en.wikipedia.org/wiki/Kinect

[8] http://en.wikipedia.org/wiki/Wii_remote

4 Computing and control systems

4.1 YARP server

The YARP[9] server is the software component of the architecture that enables the communication between processes of CEEDS applications. YARP (Yet Another Robot Platform) is an open source software platform developed for interconnecting sensors, processors and actuators in robots. YARP meet very well with the communication requirements of the CEEDS project, and an extensive description of YARP and the comparison with other communication software can be found in the delivery D5.1.

In the CXIM 2.0 architecture a YARP server needs to be available for all process to interchange messages, and will be used with devices external to the local CXIM 2.0 network. The central server is installed in a virtual machine and can be configured to receive and send messages to machines outside the CXIM 2.0 network by configuring the Firewall of the system.

4.2 File server

The CEEDs applications might need to interchange files between each other; hence the CXIM 2.0 environment will provide a file exchange server (NFS; network file system) to enable this feature.

4.3 Database engine

One of the clear necessities of CEEDs applications is the ability to handle large volumes of data and be able to explore them. The CXIM 2.0 is designed to implement this feature in a scalable fashion by allowing the creation of dedicated virtual machines and installing the database engine that is choose for each applications (e.g. MySQL, PostgresSQL, or any other). Additionally, the system allows increase the storage space by adding more disk to the virtualization server.

9 http://eris.liralab.it/yarp/

5 Audiovisual system

5.1 Graphical rendering engine

Based on the range of CEEDS applications and future applications with visualization needs that are going to be deployed in CXIM 2.0, several rendering engine were evaluated using the following criteria:

- Increase productivity regarding creation of virtual worlds, animations, characters animation and behaviour
- Ability to reuse component of already implemented solutions and state of the art functionalities (e.g. shaders, collision algorithms, 3D models, virtual worlds, etc).
- Create and individually control multiple virtual cameras which are needed for the rendering of virtual environment in CXIM 2.0.
- Produce rendered images in the GPU memory using render-to-texture features and map those textures on any 3D object or simple image plains
- Apply shaders for edge blending, and to compensate projection anomalies and surface unevenness.

The list of candidates evaluated was:

- Virtual Human Interface (VHI)[10]
- Torque Game Engine[11]
- Unity 3D[12]
- Unreal[13]
- Crytek[14]

As the Unity3D engine allows high level scripting in both the standard C# and the JavaScript programming languages plus custom component integration, this engine was proposed by UPF after the evaluation. Additionally, Unity3D provides an Integrated Development Environment (IDE) and a collection of high level editor and components. The rendering quality of Unity3D is at the level of state of the art standards. Some other add-on features such as physics, inverse kinematics, browser plug-in, and internet based asset delivery are also important factors that have been considered. Last but not least Unity3D has a growing community of developers.

UPF has licensed the professional version of the engine, but partners can develop their applications using the free version. During the second year it will be also evaluated the use of the BME VHI capabilities specifically regarding the use of virtual avatars and evaluate how can be integrated with Unity3D.

[10] The software is developed by BME based on the Nebula game engine

[11] http://www.garagegames.com/

[12] http://unity3d.com/

[13] http://www.udk.com/

[14] http://www.crytek.com/

UPF has developed a component for Unity3D that enables the engine to send and receive commands via YARP. This allows a CEEDS application developed in Unity to receive information and send control command to any of the devices in the environment, e.g. the floor, tracking system, etc.

5.2 Video projectors

To select the new set of projectors of CXIM 2.0 a range of consumer level devices were evaluated applying the following criteria:

- Short throw to allow users to get as close to the screen as possible without causing shadows (possibility to reduce the current configuration from 8 to 4 projectors)
- 3D ready to support optional 3D content with active glasses without the need for special projection surfaces
- Brightness and contrast at 3000-3500 ANSI lumen consumer level will most likely be enough for the given lighting conditions. High contrast is more important than brightness level
- Vertical keystone correction of preferably 30-40 degrees

BME made a first selection of products available on the market based on these criteria and evaluate the following projectors:

- **Optoma EW-610ST** 3100 ANSI / 3000:1 contrast / V-Keystone 40 degs.
- **BenQ MX812ST** 3500 ANSI / 4500:1 contrast / V-Keystone 30 degs.
- **Acer S5200 3000** ANSI / 2500:1 contrast / V-Keystone 40 degs.
- **Epson Powerlite** 177W 4000 ANSI / 500:1 contrast / V-Keystone 30 degs.

Non-short throw projectors were considered, as they will offer more choice, but were rejected as they would need to be mounted at large distance hence occasionally causing shadowing effects or would require the use of a mirror system to lengthen the path (a complicated and expensive option). Furthermore high resolution models and 3D ready features are not as common (typically they are not available above 1280x800 resolutions, only in professional, expensive models) and these type of projector use an image ratio of 4:3 which is not suitable for the space. With these criteria BME proposed the following projectors for CXIM 2.0:

- Epson Powerlite Pro G5450WUNL 4000 ANSI / 1000:1 contrast / 1920x1200 / 16:10 / HV-Keystone 30 degs.
- Dell 1610 HD 3500 ANSI / 2500:1 contrast / V-Keystone 40 degs.
- NEC NP32500W with lens NP01FL 4000 ANSI / 500:1 contrast / V-Keystone 30 degs.
- NEC PA500U with lens NP01FL 5000 ANSI / 2000:1 contrast / V-Keystone 30 degs.
- SONY VPLFE40 with lens VPLL-1008 4000 ANSI / 700:1 contrast / VKeyston 30 degs.
- Hitachi CP-SX635 with lens FL-601 4000 ANSI / 700:1 contrast / VKeystone 30 degs.
- Mitshubishi WD8200U with lens OLXD-2000FR 6000 ANSI / 2000:1 contrast / V-Keystone 30 degs.
- Sanyo PLC-XM100 with lens LNS-W21 5000 ANSI / 1000:1 contrast / VKeystone 30 degs.

- Sanyo PLC-ZM5000 with lens LNS-W21 5000 ANSI / 2000:1 contrast / VKeystone 30 degs.

Based on BME reports UPF evaluated the equipments for the visualization system, and contacted local resellers to run tests in the CXIM 2.0 space at UPF as the spatial configuration was different to BME facilities and can change the final configuration. The following projectors models were evaluated for CXIM 2.0 with respect to image quality and the possibility to reduce the display configuration from 8 to 4 projectors:

- Epson EB-G5750WU
- EPSON G-5600NL
- NEC PA500U
- NEC PA550W

Fig. 13 - ***Images of the projection test in the XIM room. The left image shows the equipment mounted and the right image shows the test made to measure the maximum distance without shadows using one projector per screen.***

After performing the evaluation, the conclusion was that a configuration of 8 projections was necessary to maintain the distance from which the user is throwing a shadow on the projection screen to the specified maximum distance. Note that avoiding shadows is crucial for increasing the immersion of the user in the CXIM 2.0 environment. For the image quality aspect we found that the model G5750WU from Epson offered the best compromise in terms of quality and price.

Fig. 14 - ***Picture of the projector Epson PowerLite Pro G5450WUNL***

5.3 Projection screens

To further enhance visual quality the projection screens were upgraded. The solution chosen is a continuous screen that covers the four lateral walls without gaps in the corners (compared to the previous XIM). This increases the immersion of the users in the projected environment.

5.4 "LightFingers"

"LightFinger" refers to the 8 movable theatre lights that are controlled via USB using the DMX protocol. The system was already present in XIM and will be available for CXIM 2.0. For CXIM 2.0 the server software was updated to allow control of the devices via YARP. The server software is installed on a dedicated tracking machine and will be maintained from the original XIM architecture.

5.5 Sound

At present the sonification system of XIM will be maintained as is for CXIM 2.0. The system comprises a PC running the Apple operating system, a FireWire controlled multi-channel sound card (PreSonus FirePod), 4 amplifiers, and 8 speakers in the space. This system will be further developed in task 4.4 (Sonification technologies) to generate real-time compositions based on the visualized content. The original hardware an Apple machine was maintained from the original architecture.

6 References

[1] Eng K., Klein D., Baebler A., Bernadet U., Blanchard M., Costa M., Delbruck T., Douglas R. J., Hepp K., Manzolli J., Mintz M., Roth F., Rutishauser U., Wassermann K., Whatley A. M., Wittmann A., Wyss R., Verschure P. (2003) Design for a brain revisited: The neuromorphic design and functionality of the interactive space Ada. Reviews in the Neurosciences. 14: 145-180.

[2] Delbrück, T., Whatley, A. M., Douglas, R., Eng, K., Hepp, K., & Verschure, P. F. M. J. (2007). A tactile luminous floor for an interactive autonomous space. Robot. Auton. Syst., 55(6), 433-443.

[3] Mathews, Z., Bermudez i Badia, S., & Verschure, P. F. M. J. (2007). A Novel Brain-Based Approach for Multi-Modal Multi-Target Tracking in a Mixed Reality Space. Proceedings of 4th INTUITION International Conference and Workshop on Virtual Reality 2007 (2007).

[4] Takacs, B. (2005). Special Education and Rehabilitation: Teaching and Healing with Interactive Graphics. IEEE Comput. Graph. Appl., 25(5), 40-48.

[5] Takacs, B. (2008). How and Why Affordable Virtual Reality Shapes the Future of Education. IJVR, 7(1), 53-66.

7 Annex

7.1 Comparison of projector models

	 **Epson** **PowerLite Pro G5450WUNL**	 **NEC** **PA500U**
Basics		
Brightness (Lumens)	4000 ANSI	5000 ANSI
Contrast (Full On/Off)	1000:1	2000:1
Speakers	7.0W Mono	10.0W Mono
Audible Noise	35.0 dB	38.0 dB
Weight & Dimensions		
Weight	6.8 kg	8.0 kg
Size (cm) (HxWxD)	15 x 47 x 31	14 x 50 x 36
Compatibility		
HDTV Formats	720p, 1080i, 1080p/60, 576i, 576p	720p, 1080i, 1080p/60, 576i, 576p
EDTV/480p	✔	✔
SDTV/480i	✔	✔
Component Video	✔	✔
Standard Video	✔	✔
Digital Input	HDMI	HDMI
Personal Computers	✔	✔
Optical Features		
Zoom Lens	Powered	**
Lens Focus	Powered	Manual

Lens Shift	Horiz + Vert	Horiz + Vert
Digital Keystone	Horiz + Vert	Horiz + Vert
Lens Options	✔	✔
Variable Iris	**	✔
Light Source		
Type	275W E-TORL	**
Life	2000 hours	3000 hours
Quantity	1	1
Display Attributes		
Native Resolution	1920x1200	1920x1200
Maximum Resolution	1920x1200	1920x1200
Aspect Ratio	16:10 (WUXGA)	16:10 (WUXGA)
Display Type	3 LCD	0.8" 3 LCD
Electronics		
H-Sync Range	15.0 - 92.0kHz	15.0 - 108.0kHz
V-Sync Range	50 - 85Hz	48 - 120Hz
Pixel Clock	162 MHz max	**
Maximum Power	413W	477W
Voltage	100V - 240V	100V - 240V
FCC Class	**	B
Special	Picture-in-Picture RS232 Port USB Port 2:3 Pulldown 2:2 Pulldown Closed Captioning Wired Networking DICOM Crestron RoomView™	Picture-in-Picture RS232 Port USB Port Closed Captioning Blackboard Mode Wired Networking DICOM Crestron RoomView™
Comments	Five lens options — interchangeable bayonet lens options, including short-throw, long-throw and rear-projection; plus horizontal/vertical lens shift for flexible setup configurations	Stacking capability. Wirelesss LAN module available.

Tab. 1 - *Comparision table of the projector models NEC PA500U and Epson Powerlite G5450WU*

7.2 Projection distances

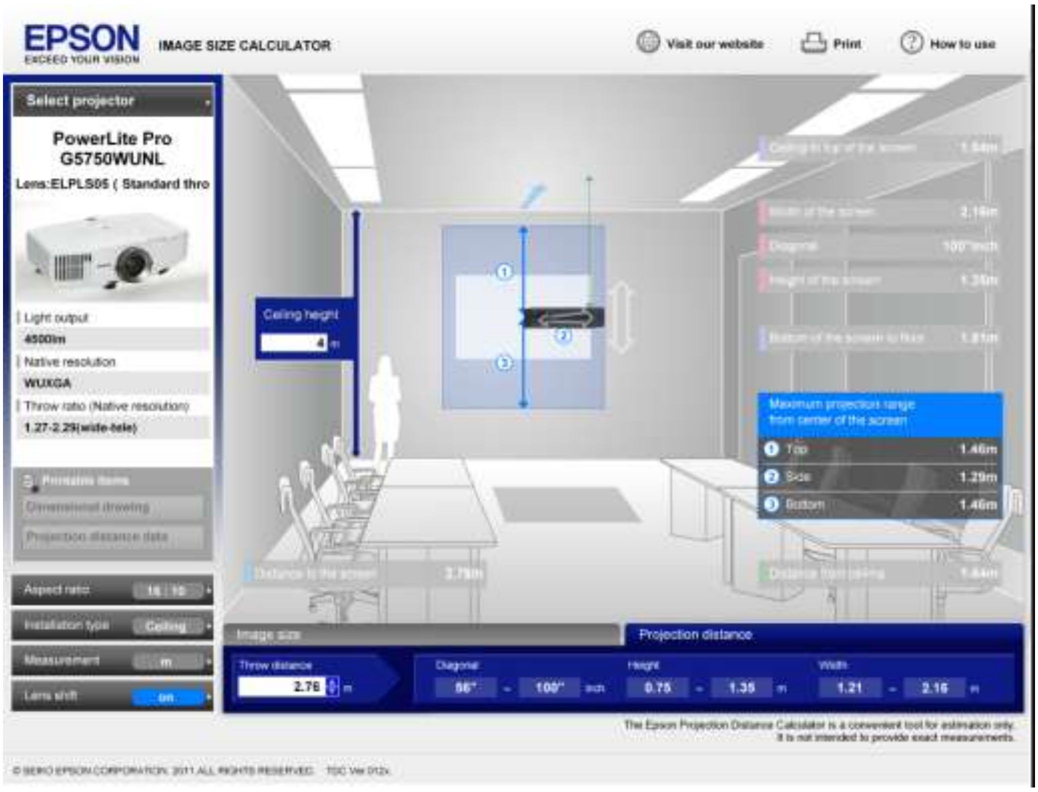

Fig. 15 - ***View of the image size calculator from Epson [15] used to validate the projection distances in CXIM room and later validated with the model in the room.***

[15] http://www.epson.com/alf_upload/landing/distance-calculator/