



Universitat de Barcelona, Departament de Personalitat, Avaluació i Tractaments Psicològics

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As part of the European Research Council (ERC) Advanced Grant, 2009-2014. Project TRAVERSE, we wish to purchase an immersive CAVE¹-like system according to the following specifications.

1. Contractor Background, Services and Contributions

1.1 Complete System

We require a CAVE environment supplied by a contractor capable of offering customers a complete turnkey service, including all peripheral systems such as *tracking, viewing, and auralisation* devices.

The CAVE system would consist of, but not necessarily be limited to, the following components and services, some specific requirements of which are set out in detail in the remainder of this document:

- Projection system
 - High resolution 3 projection walls and floor (the walls should be at least 2.20m height)
 - One, or more, full HD active stereo projector per wall (or passive stereo with circular polarization or Infitec technology)
 - Our aim is for a pixel size equal or less than 1,75mm
 - 10 x 3D glasses, according to type of projection offered, stereo or passive
- Audio system
 - Full spatialised auralisation system
 - Speakers system.
 - Headphones.
 - Audio processor and software.
- Tracking system
 - Fully- tracked VR immersion (360° look-around capability) for 1 prime user and several observers
 - Devices for head-tracking
 - Devices for hand-tracking
- Graphics system
 - PC cluster. Master PC and separate PC(s) per CAVE wall
- Software

¹ We use the term 'Cave' to refer to the generic type of system first constructed at the University of Illinois at Chicago, and referenced in Cruz-Neira, C., et al., The Cave: audio visual experience automatic virtual environment. Communications of the ACM, 1992. 35(6): p. 64-72.



Software for system management (switch on/off, basic configuration of devices, etc.).
Touch screen control system for this purpose

- Other
 - All required cabling, converters, electronic devices, software, etc. to guarantee system integration and operation
 - Room setup consultancy (building works; electrical installation; light and air conditions; etc.)
 - Documentation and training for technical staff, both in-depth for a CAVE day-to-day manager, and for principal users;
 - Operation, maintenance, and possible upgrades with spare projectors and computers.

The contractor must provide all equipment and installation as the prime contractor except and unless specifically requested by the University of Barcelona and/or noted in this document. At completion of the installation, the equipment should be ready for operation.

The contractor will supply and install the fundamental software that is required to successfully drive the CAVE system. The software to drive the CAVE will be specified as part of the response to this call. It is desirable that the software is appropriately industry standard, and argumentation regarding the extent to which this is the case shall be given in the response.

The issue of high resolution at reasonable cost will be very important in the consideration for deciding on the outcome of this call, in conjunction with the other critical factors.

1.2 Track Record

The contractor with a successful bid must have successfully built and installed CAVE systems before with other customers. Any company bidding for this tender must have proven technology, and must be able to demonstrate existing installations. The company must have a track record in immersive visualisation systems. By 'immersive' we mean a visualisation system such that users are immersed in a surrounding 3D stereo projected view of the virtual world, and are able to interact with objects by virtually (visually) touching them, and where their view is updated in real-time according to their head position and orientation.

1.3 Third Party Support

The company must give Information about any third party suppliers essential in providing materials or components for the system.

2. Physical Properties and Spatial Arrangement

2.1 Projection Walls

The CAVE environment must consist of at least 4 walls forming a *cuboid*, front, left, right, floor, together with associated projection systems. The minimum height of this *cuboid* must be of 2200mm. The viewing volume must have projection on the three walls and the floor, and the joins between the walls must not interfere with the projected image.

The CAVE must have a self-supporting structure that does not contain materials that would hamper the performance of the tracking to be used. Each wall will consist of a single, one-piece, projection screen. The screens must be of semi-rigid or rigid material to reduce interference by air movement within the viewing volume, and to eliminate problems of thermal sag. It is intended that haptic devices (not included in the current contract) will be used within the environment; therefore the construction must be such that movement of air by objects within the viewing area are unlikely to



displace the display surfaces. The joins between the walls must not interfere with the projected image; in particular there must be less than one pixel of dark space between any of the adjacent surfaces.

The material of the screens must be compatible with a full spatialised auralisation system, *which does not have to rely on headphones* in order to be usable.

A description of the material components, treatments, and construction of the CAVE floor must be given, and experience on the likely continuity of image between floor and the remaining walls discussed based on prior experience.

2.2 Footprint

The total system including projection devices must fit in a reasonable manner into the space shown in Appendix A. The space occupied on the ground is likely to be approximately 3m by 3m. The height must be appropriate to this size of CAVE and nevertheless fitting with the space available within the room. The dimensions of the available room are ~11 x 12 x 5 metres (see appendix A).

A plan for how the system could be located into this space must be provided as part of the bid. Such a plan must detail building work that would be required within the space available in order for this to be usable as the location for the CAVE system. Contractors must supply drawings showing how the equipment will fit into the available space. The contractor should provide details of any special environmental, physical, structural or access requirements associated with their installation, its construction, operation and maintenance.

It must be possible for several people (at least 4) to occupy the interior of the CAVE viewing volume at one time, and a further number of people to have an uninterrupted view into the viewing volume from outside the viewing volume.

2.3 Health and Safety Issues

Information regarding the health and safety aspects of the environment must be provided. This includes, for example, electrical issues, and the potential risk associated with collapse or falling of structures such as walls, mirrors, and projectors.

3. Projection and Viewing

3.1 Projectors

The projectors must have the following minimum technical specifications:-

- 3-Chip DLP technology.
- Stereoscopic technology: active stereo is the preferred technology but passive stereo with circular polarization or Infitec technology is also accepted.
- Minimum resolution: Full HD (1080p)
- Preferred light output: ≥ 3000 ANSI lumens per wall
- Minimum contrast ratio: 2000:1
- All projectors must be of the same type, and incorporate technology to guarantee the system homogeneity:
 - Advanced geometry adjustment methods to guarantee the best matching across the system screens keeping image quality.
 - Light output control methods to guarantee brightness homogeneity across the system screens.
 - Colour space control methods to guarantee colour homogeneity across the system screens.



- Other: liquid cooling, anti-dust seal system, etc are desirable features.

3.2 Pixel Accuracy

Our goal is for the projection pixel size, taking into account screen size and projectors resolution, to be equal or less than 1.75mm.

The system should be able to have at least one-pixel accuracy at the seams where two abutting screens join. The active sides of the cube must be accurately joined by a butt edge, along which the display may be aligned to an accuracy of one pixel. This should eliminate the black line that may appear on the join of each wall.

3.3 Wash-out

The approach to the minimisation of 'wash-out' must be clearly stated and provide a good solution. Wash-out occurs where the light from adjoining walls interferes with the light distribution on neighbouring walls thus changing the overall illumination of the projected images compared to that required.

3.4 Reference Alignment

The CAVE environment should be supplied with an independent reference alignment system that enables the display to be aligned and calibrated against an accurate reference.

3.5 Stereo Eyewear and Emitters

The system must initially be supplied with sufficient emitters and glasses for at least 10 people to view (but not necessarily be tracked) simultaneously in the whole projector volume.

4. Audio

4.1 Audio system

A full spatialised auralisation system must be provided. By 'auralisation' we mean to model the acoustic performance of built spaces using radiosity and ray tracing, or other computational methods using a global acoustic solution. This therefore places a more stringent performance requirement on the CAVE than just 'spatialised audio'. Interactive auralisation and sound rendering will be integrated with visualisation to provide a unique facility for spatial immersion. The computer audio system will *also be capable* of driving binaural sound on tracked headphones and a multichannel loudspeaker system. It will be used to model acoustical environments based on the physics of sound propagation and reflection.

4.2 Audio Partner

The contractor must liaise with the preferred audio partner, if any, for a full 3D spatial audio system to be incorporated into the system.

5. Tracking

The principal viewer must be tracked for location within the viewing volume. The performance of the tracking devices must be described, and some of the basic requirements are:

- Precision and accuracy: $<5\text{mm}$, $\leq 1^\circ$
- Latency: $\leq 10\text{ms}$



- Jitter free tracking

The extent to which the contractor has experience of working with said tracking devices must be specified, for example, previous successful installations, and/or collaborations with the suppliers of such tracking devices.

5.2 Illumination Tracking

It would be useful if the system includes software for interfacing to the position of the principal observer. This software should modulate the light intensity over the projected surfaces to correct for the gain of the screen material used and remove contrast hotspots when seen by the tracked observer. That is, if a uniform light level should be seen over the entire surface, then the software must make this appear to uniform regardless of the scatter of light at the screen. This relates to 3.3 above.

5.3 Location Tracking

The principal viewer must be tracked for location within the viewing volume. It must be possible to use any commercially available tracking system. Recommendations are sought from suppliers as to which system should be used, but suppliers must be aware that other research equipment brought into the viewing volume may require different tracking systems from that recommended and the equipment must not prohibit or present additional difficulties to such use.

6. Graphics System

The graphics system must be a workstations cluster, made by one master workstation and separate workstation(s) per CAVE wall. It must provide high performance based on state-of-the-art technologies.

7. Software

7.1 Management software

The contractor must provide a configurable control system to make the system operation process (switch on/off devices, configuration, etc.) simple and intuitive. This software used for system management must work via the local area network, so that management can be done by any PC connected to the network. Moreover, a touch screen interface for system management should be installed on the CAVE room.

7.2 Simulation software

The contractor will supply and install the fundamental software that is required to successfully drive the CAVE system. This software must have a proven track record in the field, and it is desirable to be appropriately industry standard (a short discussion, with regard to the extent to which this is the case, shall be given in the response). The software to drive the CAVE will be specified as part of the response to this call and it should be considered as an option in terms of the quote. Some of the minimum requirements are:

- Intuitive graphic interface.
- Easy and effective management of most VR devices (visualization, tracking, interaction, etc.), via standard protocols (preferably VRPN).
- Easy and effective contents integration (at least from the most standard software, i.e. Maya, 3DS, etc.) and optimization (animations, lighting, textures, shaders, portals, LODs, etc.).



- Advanced programming features: visual programming, scripting (based on standard language), SDK for easy plug-ins addition.
- Compatibility with DirectX and OpenGL. Easy portability of developed contents to be shown on different systems.
- Other features as AI, physics simulation, collaborative simulations, etc. would also be appreciated.

8. Other

8.1 Integration devices

All required cabling, converters, electronic devices, software, etc. to guarantee system integration and operation must be provided.

8.2 Training

The contractor must detail its training services that are for the training of technical staff to deal with the day to day operation and calibration of the system. The cost thereof must be clearly specified. The contractor will provide training in the set up and maintenance of the equipment as part of this supply. This will cover the calibration of the equipment and maintenance of the system to a system user level.

8.3 Maintenance

The contractor will provide maintenance and support for all hardware and software for a minimum period of three years. The contractor will further undertake to be able to supply components and replacements for maintenance for a period of not less than five years from the date of order.

The contractor must detail its servicing and maintenance conditions and the cost thereof. The minimum required conditions are:

- Minimum of 1 preventative visits per year.
- Minimum service availability between the hours of 9h00 and 18h00 (local time), Monday to Friday, excluding local statutory holidays.
- Maximum response time for telephone technical support: 4 hours.
- Maximum on-site response time: 48 hours.
- Travel and lodging cost should be included for 1st level service calls.

The contractor must give details of their capacity to provide user support, calibration, maintenance, repair and on site service for the installation, including projection systems, audio and tracking devices. The disposal of local services (both contractor and devices manufacturers) will be valued.

8.4 Third Party Support

The company must give information about any third party suppliers essential in providing materials or components for the system.

9. Delivery

9.1 Delivery Date

The system must be successfully installed and invoiced so that payment is possible before the date specified in “see clause particular statement”.



9.2 Project Plan

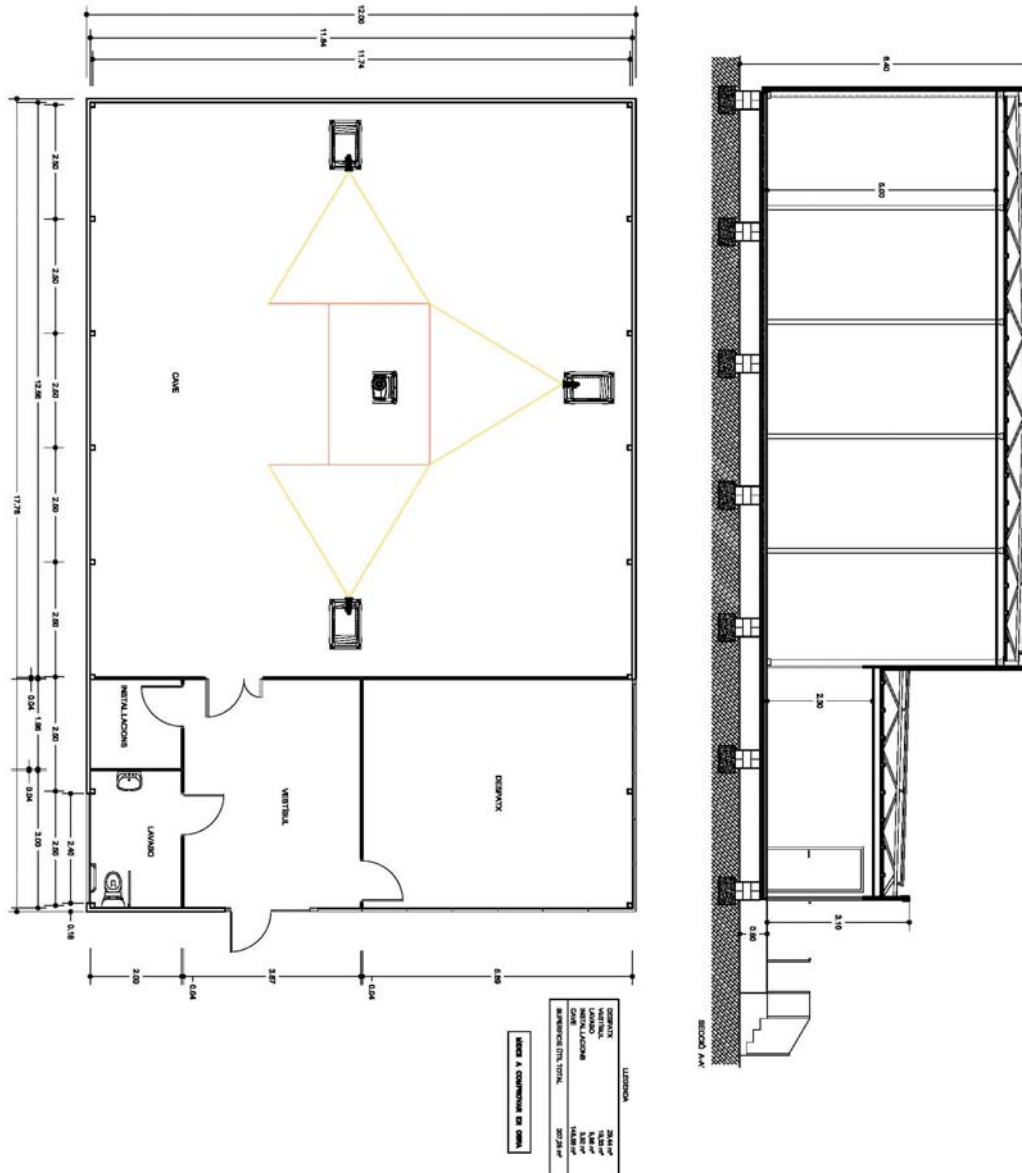
Contractors must provide an outline project plan as to how progress would be made towards installation covering the period from the day from which the contract is agreed, until the day from which the University of Barcelona can provide a CAVE service.

Barcelona, 20th October of 2010

Mel Slater

Principal Investigator

10. Appendix A



$h = 5$ metres (height of cave area)