Visibility in Architecture Extended through Audiovisual Communication Technologies

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Abstract
Audiovisual communication media that are embedded in physical architecture can extend buildings by integrating spaces that are non-adjacent. A large variety of technologies has been developed and subsequently evaluated in this context, such as video conferencing, media spaces and audiovisual technologies embedded in collaborative virtual environments. The resulting extended spatial topologies are designed to increase organisational flexibility, improve team cohesion and to reduce the need for business travel, a concern particularly relevant today. Two effects of this are of interest in the context here. Firstly, when these technologies are always-on as well as widely accessible, and therefore permit spontaneous social interaction, studies have shown how the connected spaces can become an integral part of social life and the existing work processes of a given organisation. Secondly, movement in the connected virtual or remote physical environments can make our bodies appear to be extended through electronic sense organs. In other words, while not being able to physically enter these spaces, we can perceive them with a subset of our perception: in the cases discussed here vision and hearing. Related to both the above, there is good evidence that brain, body and environment cannot be considered separately in our understanding of how we perceive the world, an argument that has been picked up to explain some of the phenomena found in spatial analysis conducted through Space Syntax techniques.

Given the background of technological extensions to our environments and to our bodies, it then becomes necessary to re-evaluate our understanding of movement through architectural environments. This paper begins this process by focussing on one particular issue: visibility in audiovisually extended architectural environments as it is affected by camera technologies. For this purpose, key camera properties are being considered before an overview of 'spatial technological isovists' is presented. This is used to discuss the effects on visibility, access to space and permeability as well as the apparent shape of audiovisually extended architectural configurations.

1. Technology extensions to environment and body

A wide variety of audiovisual communication media have been developed and deployed to overcome the limitations of physical spatial layouts. With the aim to improve organisational flexibility and to allow geographically distributed workplaces, including outsourcing activities and tele-working, organisation are making use of these technologies in the boardroom, ordinary offices and on the desktop. This results in hybrid audiovisually extended spatial environments that consist of a mixture of physical and electronic places of different types and geometries, 'held together' by a variety of technologies.

Some of the most interesting research in this are has emerged from the work in media spaces, placing always-on audiovisual connections within ordinary office environments (Mantei et al. 1991; Dourish and Bly 1992; Adler and Henderson 1994). These were frequently augmented with additional sources of information such as the status of people or resources within the wider office environment. Although relatively small screens were deployed, it appeared that the technology infrastructure spatially and organisationally integrated with the various settings it was deployed in (Dourish et al. 1996).

One particular take on media spaces is the Mixed Reality Architecture (MRA) system (Schnädelbach et al. 2006). MRA establishes a dynamic architectural topology by mediating always-on audiovisual communication through a shared virtual 3D environment. Just like media spaces, it involves the installation of a screen and speakers in conjunction with an echo-cancelled microphone and a camera. This allows configurable virtual office-shares across physical places and serves as an awareness-information and communication tool for everyday social interaction. MRA has been trialled long-term in the UK research environment and its architectural implications have been explored (Schnädelbach, Penn, and Steadman 2007). One of the key differentiating features to conventional media spaces is the aforementioned mediating virtual space, and the spatial complexity that this introduces will be returned to later.

More recently, commercial developments have meant a substantial step up in the available audiovisual fidelity of video-conferencing systems. Taking into account room design, lighting and communication technology has allowed the creation of set-ups that really begin to integrate distributed architectural spaces, not just interactionally, but visually too (Hewlett-Packard Development Company 2007; Cisco Systems Inc. 2008). While the emphasis with these products is on focussed and planned interaction and not always-on communication connections which is of core concern here, the advances in quality are still very relevant for the arguments presented in this paper.

1.1 Embedded technology

From reported experiences in the media space literature and the direct experience with Mixed Reality Architecture, it is clear that the types of environment described here can appear to inhabitants as part of the wider environment. The technologies become organisationally and spatially embedded into their host organisations and associated environments, an issue recently explored across a diverse set of mixed reality experiences (Schnädelbach, Galani, and Flintham 2009 Forthcoming).

Critically in the context of this paper, the extension of the environment is a result of the spatial extensions made possible through audiovisual communication technologies. In this way, the space that can be acted upon or interacted within becomes enlarged beyond local physical space, which for a long time has been the exclusive frame for social interaction. Extensions can then take two (spatial) forms. Most commonly, these are extensions into remote physical spaces, i.e. those spaces that cannot quickly be reached by physical traversal of the architectural configuration under consideration. The example of MRA then highlights the second possibility, as it extends the spatial environment that is perceived and navigated within into virtual space. This virtual space is designed to mediate communication between a number of physical spaces, but also provides a spatial framework for remote social interaction. Architecturally, it also provides a way of making architectural configuration topologically dynamic across the entire 'inhabitable' environment.

1.2 Technology around the body

The study of the long-term deployment of Mixed Reality Architecture (MRA) has then provided an example of how technology designed to be embedded into the environment can act as extensions to people's bodies in that environment, at least for certain groups of people. Without going into too much detail, inhabitants in MRA had different levels of access and, resulting from this, familiarity with the interaction in MRA. The group with most access, did most of the virtual navigation, even if the decision making process was frequently shared between multiple people (Schnädelbach et al. 2006). In what follows, the way the body became augmented in virtual and in physical space will be discussed in turn:

Firstly, the sense of movement through virtual space was provided by the joystick interface, where physical movement was quite literally translated into virtual movement (e.g. tilting the joystick forward moved the virtual office representation forward). This was coupled with the changing imagery on the large and rather immersive projection screens used in the offices. One might argue that in this way, although originally designed to represent a spatial entity, the virtual representations of physical office spaces became an extension to the body of the person navigating with it. By way of moving this representation, the person gained access to different parts of the virtual environment, extending the senses of vision and hearing of the person into that space. It was also clear how the position and orientation of these representations gained social meaning. The MRA technology as a whole extended the scope of inhabitants' speech to be heard and the scope of their representation to be seen by others in the form of their video image. Equally, others in the MRA referred to office representations by the name of the person of its main inhabitant, and this points to the possibility that office representations had become extensions to inhabitants' embodiments in the eye of other inhabitants, too.

Secondly, inhabitants' bodies have also been extended into remote physical space although in a more limited way. Vision and hearing were supported, while movement was not, i.e. while it was clearly possible to look into remote spaces and listen to conversations taking place within them, people could not change their remote perspective in any way.

While extensions to body and embodiment were may be by-products (while very interesting ones) of the experience with MRA, there are of course technologies that address technological extensions to our bodies in a more direct way. In the project Cyborg, Kevin Warwick has experimented with implanted RFID chips to control aspects of the environment and a robotic arm; and to communicate with his wife also implanted with such a chip via 'radiotelepathy' (Warwick et al. 2004). In the Wearcam set of projects, Mann has explored wearing body mounted cameras in public spaces to capture and augment information perceived in the outside world, displaying images back to the person wearing the equipment, using a wearable display (Mann 1997). While the above two examples are technology extensions directly to our bodies, it is also worth looking at the area of Tele-presence. Here, the concern is to give people a view into and representation within a remote space, usually through a remote-controlled piece of technology equipped with cameras, microphones and speakers (Paulos and Canny 1997; Meccano 2009). This then not only allows audiovisual access to those remote spaces, but also provides a bodily representation of the person for others to interact with. Considering the speed in which technological extensions to our environment and to our bodies are being developed, it can be argued that there might be a point where we never perceive a technologically unmediated environment through a technologically unaugmented body.

2. Experiencing the world

The above is clearly important as there is good evidence that body and environment need to be considered together in our understanding of how we perceive the world. This understanding can be traced back to a number of sources, making their way into design, human computer interaction and Architecture, as will be briefly summarised in what follows.

Gibson's concept of affordances suggests that possibilities for action are latent in our environment and that these are dependent on the actor involved (Gibson 1979). This points to a three-way relationship between environment, actor and activity. As an example, one might consider a window that affords a view outside to an adult but not to an infant, who cannot reach. Critically, in this original concept, affordances do not necessarily have to be apparent to the actors. Norman has introduced this concept to design, focussing on a slightly different angle, when he concentrated mainly on those affordances that are or can be made to be visible to a person interacting with the environment, in a drive to support intuitive interaction (Norman 1999). This concept has then been applied to Human Computer Interaction through the work of Gaver (Gaver 1991); while Dourish has deepened the analysis of embodied interaction with computer systems by outlining a set of key principles to be considered for design (Dourish 2001).

Wheeler's embedded-embodied approach to cognitive science in general and artificial intelligence (AI) in particular in turn suggests that we smoothly cope with a dynamic world through an extended system of brain, body and environment (Wheeler 2005). As Dreyfuss before him, who had already criticised classical approaches to AI for attempting to build intelligent machines that depended on representations of their environment (Dreyfus 1992), he draws on Heidegger's philosophy to argue that knowledge about the world becomes much more knowing how to act rather than gathering, storing and acting upon abstract facts. Therefore, the world becomes relevant to us in terms of how we might be able to act upon it, a very similar view to Gibson's affordances. This is what Wheeler terms 'online' intelligence, a 'suite of fluid and flexible real-time adaptive responses to incoming sensory stimuli' (Wheeler 2005), quite separate from our capacity to abstractly reason about the world, for example when planning ahead. This then must be fundamentally intertwined with our bodies and our environment: our bodily features clearly affect our perception of the world. For example, the position of our eyes gives us a very specific type of vision.

Equally, cognition cannot be separated from the environment as our sense of the world depends on frequent and continuous sampling of our surroundings. As Space Syntax as a theory is fundamentally concerned with the link between the environment and our behaviour, the embodied-embedded approach has obvious attraction to the field as is evident in recent publications (Penn 2003; Fatah and Hanna 2007).

3. Visibility in a technologically extended world

Arguably, if the environment that can be acted upon and within becomes extended through technology, and the range of our sense organs becomes extended into digital and remote physical places, the way we traverse such hybrid spatial configurations might well change in comparison to un-augmented physical environments. This can then affect who we encounter and who we avoid as '…spatial configuration tends naturally to define certain patterns of co-presence and therefore co-awareness amongst the individuals living in and passing through an area.' (Hillier 1996).

Having opened this larger argument, and with the aim to begin to explore this further, the remainder of the paper will focus right back down on one particular area: visibility in audiovisually extended spatial environments. This is because visibility is very interesting in this context for at least two reasons: Firstly, cameras and displays (together with microphones and speakers) are the building blocks that allow architecture to be digitally extended, as they extend what is visible from different physical locations. Secondly, the analysis of visibility in architectural configurations is an important tool for the understanding of the relationship between those configurations and human behaviour (Benedikt 1979; Turner and Penn 1999).

To begin the discussion, one might want to consider the effect of a physical spatial extension to a building (not involving media technologies) on the properties of its spatial configuration. To illustrate this, a visibility graph analysis each has been performed on the Tate Gallery (London) layout (included with the Depthmap distribution) and on the original layout extended through a mirrored copy of itself, respectively. Figure 1 shows visual integration in the original Tate gallery, with highly integrated spaces located in the main central corridors.

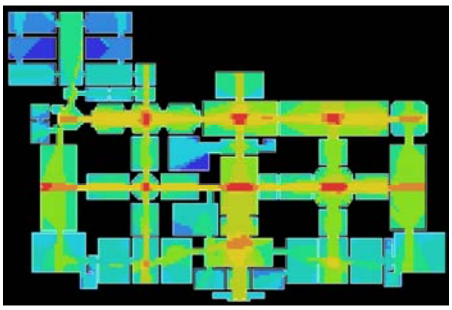

Figure 1
Single Tate Gallery and mirrored copy: Visual Integration [HH] (Depthmap 8)

The spatial configuration has then been changed to include a mirrored version of the gallery, attached at one of the more segregated spaces in the bottom right of the original layout. Running a second visibility graph analysis (using the same parameters) then clearly demonstrates how spatial integration is modified with visually highly integrated spaces shifting to the former periphery of the original single gallery configuration.

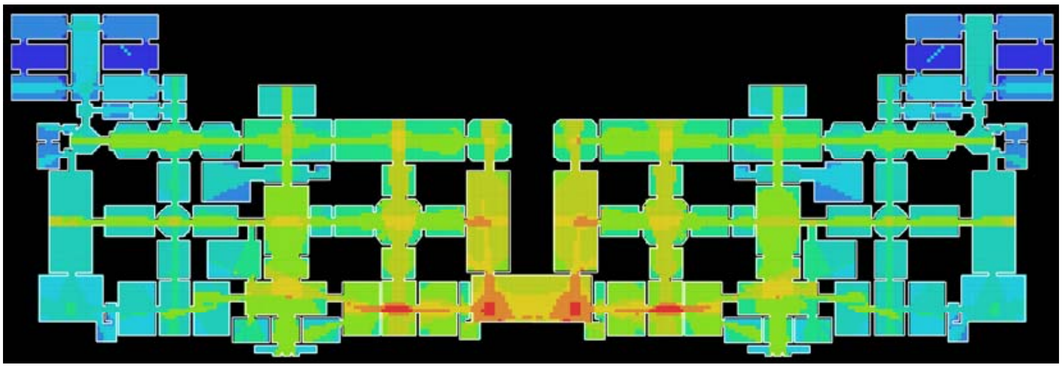

Figure 2
Mirrored linked Tate Gallery: Visual Integration [HH] (Depthmap 8)

As has been highlighted in previous work (Schnädelbach, Penn, and Steadman 2007), audio-visually extended architecture can be described in a similar way to an extent, in the way that integration is affected. However, this was limited, as it allowed only for a broad overview of the effect. It quickly becomes clear that there are a number of camera related issues that need to be considered in more detail and these will be set out in what follows.

3.1 Cameras and camera placement

The properties of the cameras used in the spatial extension of architecture and the details of their placement are key issues to consider. It is generally assumed here that to embed audiovisual technologies into buildings and their organisations, large display screen sizes are important and that screens can indeed be the size of an entire wall as illustrated in Figure 3.

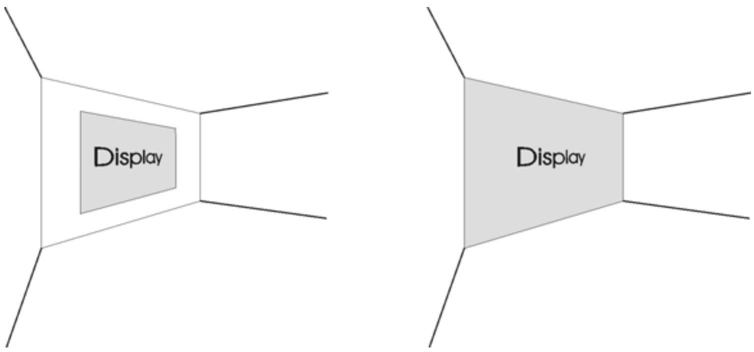

Figure 3
Large embedded screen (left) and Wall as screen (right)

To enable interaction with the screen (looking at it and being seen at the same time), cameras are then placed as close as possible to the centre of the screen, facing orthogonally away from it and at the interacting inhabitant(s). Most commonly, cameras are placed in the plane of the screen surface at the top of the screen, so not to obstruct the view of the images displayed. There are also technical approaches that would allow placement of cameras behind the screen, which then enable true eye contact and avoids people trying to interact without being in camera shot (Ishii, Kobayashi, and Grudin 1992; G+B Pronova 2008; Uy 2006). However, these are either not widely available or are somewhat impractical (e.g. they require a large space behind the display screen or a complicated set-up). They will therefore not be considered in this analysis for now.

3.1.1 Camera properties

There are then a set of camera properties that are important. Firstly there are a set of core properties. The maximum capture resolution determines the detail that can be seen in a connected space. The field of view of the lens determines the area that can be covered, and this can be fixed or dynamic through a manual or motorised zoom. In addition, the aperture of the lens impacts on the area of observed space that is actually in focus. Secondly, the potential dynamics of the camera set-up need to be considered. Most commonly, cameras are in fixed locations and are set up with a particular orientation to a room and its occupants. Therefore, people who are looking at a camera feed remotely will not be in control of any aspect of that camera in most cases, while there have been developments in that direction in media spaces (Gaver, Smets, and Overbeeke 1995) and virtual reality CAVEs (Cruz-Neira, Sandin, and DeFanti 1993).

3.1.2 Sharing displays

Another important aspect of display screens and cameras concerns their shareability amongst multiple people physically close by. Ordinarily, everyone located around a display screen making a digital connection between two spaces, will have the same access to it. In contrast to a physical doorway between two spaces, the view point into the other space remains the same however for everyone present around the interface. Even if the perspective of a single person can be accounted for as highlighted in the examples above, displaying multiple perspectives at the same time is currently technically cumbersome. If cameras are indeed placed with individuals as the work by Mann highlights (Mann 1997), shareability of perspective is entirely lost.

3.1.3 Physical – virtual camera

An additional level of complexity is introduced when a mediating spatial environment is introduced as is the case with Mixed Reality Architecture (MRA) approach. The view into the 3D virtual environment in MRA is generated based on the view from a virtual camera that has been set up with a series of certain properties, equivalent to those of physical cameras. Understanding the view into another physical space then at least involves understanding the view of one virtual camera and that of one physical one. This complexity is further increased through the fact that virtual cameras are more easily made to be dynamic, i.e. their properties can change during use.

3.2 Visibility in AV extended environments

Having set up these key properties, what remains now is a much more detailed look at some examples of environments that have been extended through audiovisual communication media. This will focus exclusively on the aspect of visibility as relevant for architectural configurations in contrast to but also in the context of previous work on the affordances of media spaces (Gaver 1992).

3.2.1 The extended space

The following illustrates two spaces (A and B) connected via a media connection. As suggested earlier, one entire wall in each acts as the display surface, in an attempt to as closely as possible simulate an actual connection via a physical opening. Both of these display surfaces have a camera, pointing away from the screen and into the room, associated with it. In this example case, each camera directly feeds the screen in the respective other space, establishing a two-way link. On the left, spaces A and B are physically joined via a room-width and ceiling-height opening for comparison. To illustrate the spatial properties of this configuration, a single isovist is drawn from viewpoint A1, reaching out into both parts of the joined space.

The centre and right hand side of the graphic then illustrates the environment extended through the video link described above. Screens are represented with orange lines in place of the physical join between A and B. Cameras are indicated through their field of view and a connecting line in black for the video transmission. Isovists across the space are drawn as before, and these are now linked through the media connection. In this context, it is important to understand them as one isovist, although they appear separate in the illustrations.

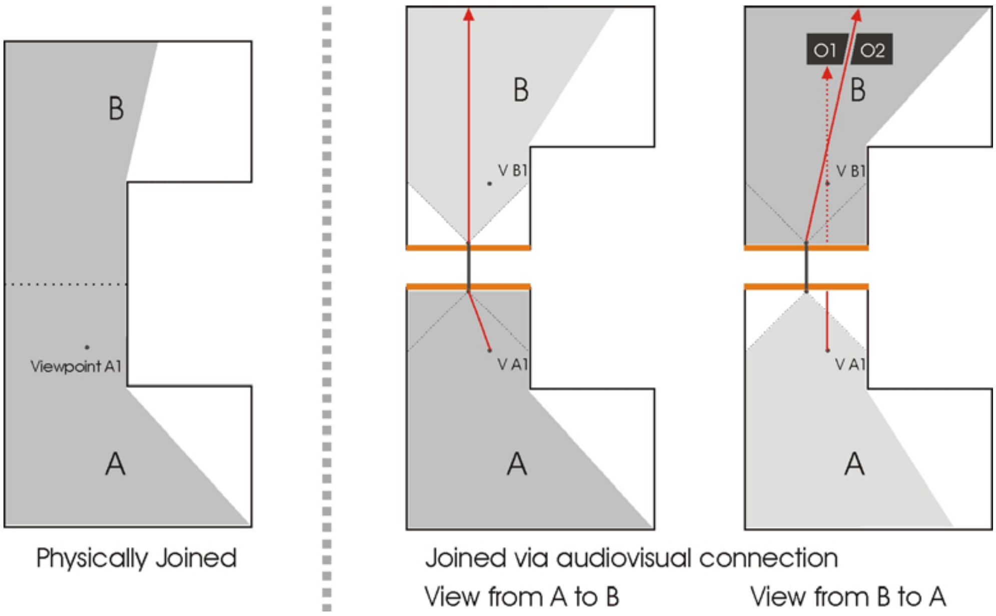

Figure 4
Space connected via audiovisual link

In the centre of Figure 4, the view from viewpoint A1 into B shows no change of the part of the isovist located in A compared to the physically joined version, while the part of the isovist located in B is now shaped by camera placement, orientation and field of view. Looking back from viewpoint B1 into A has the same effect, with an isovist shaped by the physical environment in both spaces (local and remote) as well as by the camera technology. It is clear that the effect is quite dramatic, removing from view two triangular areas directly around the screen area but also providing a view slightly deeper into the remote space around the corner.

To illustrate a second effect of the embedded camera technology, lines of sight have been added to the illustrations in red. The view from A1 into B is necessarily via the display screen. Looking at the centre of the screen and therefore the camera, results in a view of the centre of the camera feed captured from B (centre of Figure 4 'View from A to B'). Focusing on an off-centre location results in a view which is proportionally off-set in the associated camera feed (Figure 4 right 'View from B to A). In the example here, a view straight at the screen is illustrated and this results in an 'angled' view in B. This allows a view through the gap between objects O1 and O2, which would normally be blocked (illustrated through red dotted line, clearly shifting the perspective into the other a room in a very unintuitive way.

3.2.2 Viewing position

There is another effect of the audiovisual link between A and B. Very much unlike the situation when A and B are connected physically, the isovist in B does not change with different viewer locations in A (compare VA1 to VA2 in the figure below), while the viewable area in A does indeed change as one would expect.

Again, this feels counter-intuitive. In the comparatively much more controlled environment of virtual reality Caves (Cruz-Neira, Sandin, and DeFanti 1993), head tracking is frequently used to provide at least one observer with the correct perspective into a virtual environment. At present, this is too unwieldy for more general applications, but it remains a technological option in the long run.

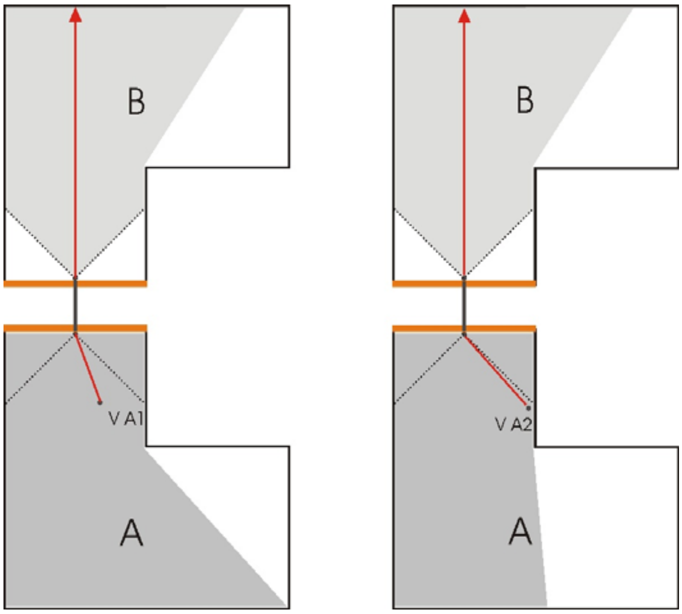

Figure 5
Different viewing positions in A

3.2.3 Camera properties

However, the isovist in B does change with a dynamic change of camera properties and these include field of view, orientation and location, in particular its relationship to other surfaces.

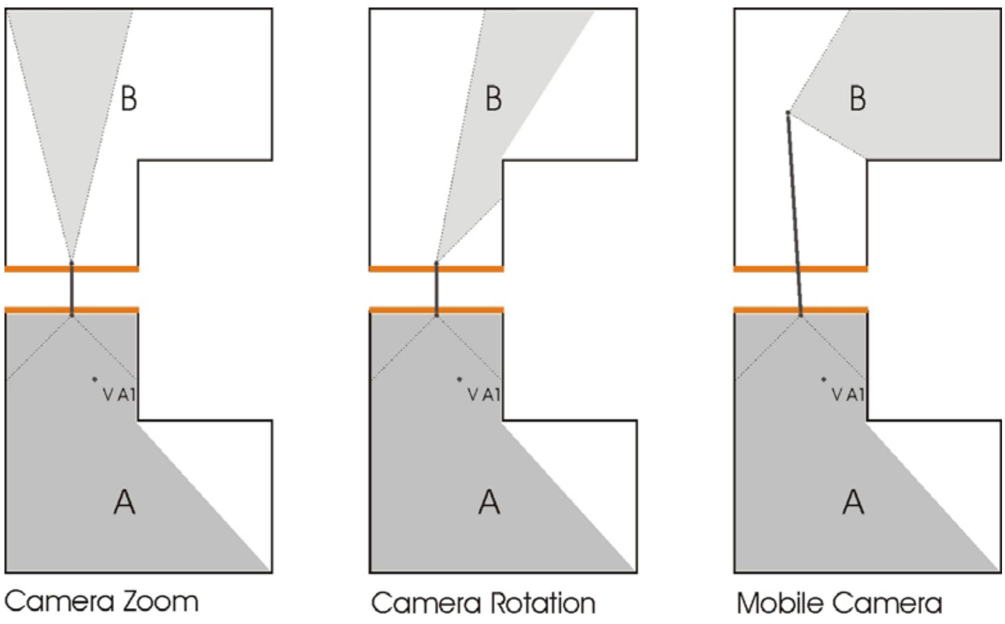

Figure 6
Varying the camera properties

The left hand side of Figure 6 shows an isovist across the media connection that has a very narrow field of view in B due to the camera being zoomed in, while the centre shows a camera being rotated slightly towards the right. The most extreme change is shown on the right of the figure above, where the camera is mobile and enabled to roam around in B. All three adaptive cameras placed in B are here assumed to be controllable in some way by a person located in A.

3.2.4 Embedded in virtual environments

For those architectural topologies that have been extended across shared virtual environments (e.g. Mixed Reality Architecture), the analysis of visibility across different spatial units, becomes more complex again. The graphic below illustrates the connection between the same two rooms A and B discussed previously, across a shared virtual 3D environment. This environment is displayed on a room-height and width display, similar to the direct audiovisual connections discussed above.

As A and B are embedded in a shared virtual environment, their positions relative to each other are flexible and can be controlled by their inhabitants. Here, B is shown at an angle towards A, but still in view of A's virtual camera (VC-A - This refers to the camera generating the view into the virtual environment from and for space A).

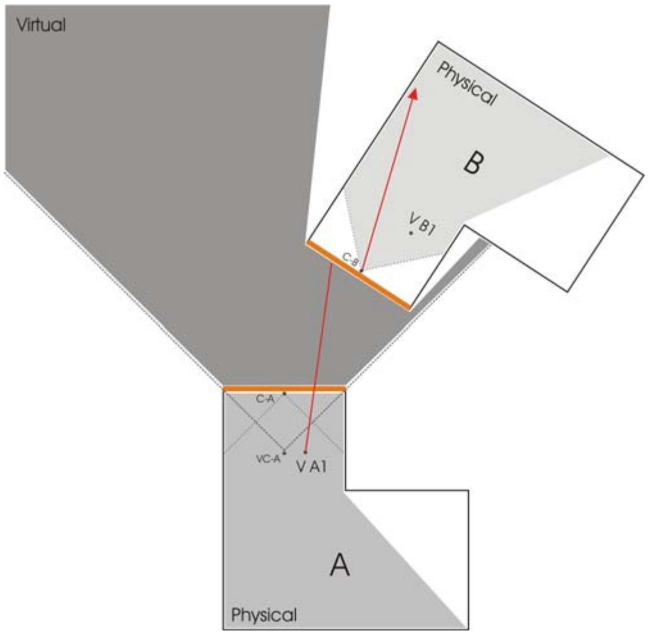

Figure 7

Isovist across local, virtual and remote space

To consider visibility across, the starting point is the examination of the view from VA1 back into B. For VA1, the virtual environment appears visible full screen. Within that virtual environment, a representation of B is visible that has live video from B attached to one of its surfaces. Via this live texture, the parts of B that the camera can see become visible in A.

Visibility between A and B therefore depends on a whole host of factors: the viewing position (VA1) in front of the display of the 3D virtual environment, the position and field of view of the virtual camera of space A, the virtual position and orientation of B in relation to A across the shared virtual space and finally the position and field of view of the physical camera located in B. This complexity is then reflected in the complexity of the Isovist that can be drawn between the two spaces, consisting of multiple parts: a local physical part which is generated in the usual way, a virtual part extending into the 3D shared environment (represented in darker grey in Figure 7), which is determined by the properties of the virtual camera associated with the representation of A and finally a remote physical part, determined by the properties of physical camera in B.

Very importantly, these relationships are not fixed. They can adapt in at least two different ways. The location and field of view of the virtual and physical cameras can change, as already highlighted previously. May be more interestingly, the geometrical relationship between A and B can change within the 3D world, which is driven by the social interaction taking place in the extended physical-virtual architectural topology (Schnädelbach, Penn, and Steadman 2007).

4. Summary and discussion

Overall, this paper has discussed the properties of hybrid architectural spatial topologies, consisting of locally accessible physical spaces, remote spaces connected through media connections and mediating virtual spaces. This has been done mainly through a focus on the specifics of camera technologies that are being used for this purpose and their effect on visibility across the configuration. Clearly, this leaves out our other senses entirely, but the focus was on visibility as it is seen as such an important concern in our understanding of the relationship between environment and encounter patterns. The following concludes this paper by discussing four key issues that have been highlighted through the arguments presented here.

4.1 Visibility

It has been shown how visibility in audiovisually extended architecture depends on the shapes of the various virtual and physical spaces that it consists of as well as on the properties of an arrangement of a diverse set of cameras, creating what might be called 'spatial-technological isovists'. Additionally, two other important differences to physical architecture have been highlighted: through the deployment of camera technologies, the overall configuration can become dynamic (e.g. changes in existing connections or connections to entirely different places) and only parts of the configuration can be physically traversed with one's own body (e.g. excluding tele-embodiment (Paulos and Canny 1997)). If these technologies then do indeed become embodied, i.e. cameras and the views they generate are associated with individuals (Mann 1997), there is a further issue: the architectural configuration becomes more undemocratic as 'what you see is not what I see' anymore.

4.2 Embedded – embodied access to space

To what extent can we then 'smoothly cope', to borrow Wheeler's term, within such a hybrid audiovisually extended body-environment artefact? As access to it is driven and supported through technology, it is clearly very different from access provided through our unmediated sense organs. This will require some learning, and the problems this can cause can easily be observed when watching a novice Skype user trying to remain in camera view. However, when audiovisual communication technologies become embedded into the building fabric and are available longer-term, and associated conventions of use have become established, people are indeed able to cope with stimuli and activities that span the hybrid topology very comfortably, as the experience with Mixed Reality Architecture has shown. Arguably, if this was not the case, these types of environments would be totally unsuitable for everyday use.

4.3 Permeability

As already mentioned, although visibility across the interface between local and remote as well as physical and virtual spaces has been discussed here in detail, it is clear that true permeability at the screen does not exist at present. What is possible though is the interaction across the screen surface. One might compare this to interaction at the threshold of a space, a door to a house or open window into the front garden, for example. Just like other architectural interfaces, these technological thresholds therefore attain special significance, their properties and location in the architectural configuration become important.

Paths through audiovisually extended architecture then consist of multiple parts. There are segments of paths that are entirely located in physical space, influenced by physical visibility. Individuals might then encounter an interface or threshold to a digital or remote physical space. Visibility analysis has already been used to most optimally place display screens (Scupelli, Kiesler, and Fussell 2007) and this paper has started to discuss visibility across the interface. At the interface, people can then to some extent enter a connected environment. In audiovisually connected spaces, they will achieve access through their senses of vision and audition and paths continue as far as the camera reaches. In virtually extended spaces (e.g. MRA type environments) physical movement can go over into virtual movement and the extent to which this can be staged has been explored previously (Koleva et al. 2000). Finally, with the inclusion of remote tele-embodiment (Paulos and Canny 1997; Meccano 2009), paths can continue in remote physical spaces. This discussion can be related to the much wider concern of interaction trajectories, further details of which can be found here (Fitzpatrick 2003; Benford et al. 2009 Forthcoming).

4.4 The shape of extended space in AV extended environments

As access to different parts of the spatial configuration varies so widely, our perception of it varies too. The shape of this audiovisually extended Architecture that we build up as an artefact to reason about must therefore also be very complex? This is a question for further research, although one might attempt a first sketch.

Local physical space, the space that we occupy with our bodies, is shaped fundamentally through our sense organs and Penn has argued that this is framed by 3 dimensional Euclidean space (Penn 2003). Penn also argues that non-local spaces appear topological to us, i.e. the exact angular and distance relationships between spaces cannot generally be recalled and this appears to be backed up by Lynch's original analysis of sketch maps (Lynch 1960). However there is some contention around this latter point, as Montello has pointed out that there is evidence that metric plays a role here too (Montello 2007).

In the architectural spaces considered here, one can additionally identify 'technologically local and remote spaces'. Technologically local spaces are those spaces that are currently connected and are in view. They are mainly shaped by the transmission and display technologies in use. In many cases this will mean that they appear rendered in 2 dimensions on a flat display surface, while this clearly depends on the actual technology used (3D display technologies are becoming more widespread). Technologically remote spaces are those that are part of an architectural configuration, one or more spaces of which have been connected through audiovisual technology.

These might arguably be perceived in a topological fashion, as there is some initial evidence that this might in fact be the case (Koleva et al. 2001). This is an interesting research area in need of further exploration.

4.5 Outlook

To further this discussion, an extension of the existing spatial analysis tools would be required. To make those useful in the context here, they would have to include spatial links that are non-physical, and the description of those links would need to include information about what types of interaction are possible across them (visual, audio or possibly even traversal). In addition, new spatial types would have to be added, i.e. those that can be viewed but cannot be entered, as most technologically connected spaces fall into this category. This might then need the building of a more fine-grained relationship between visibility and permeability in architectural configurations, to be able to analyse to what extent spaces that can be seen (through a window, atrium or technological extension) but not entered, impact on movement patterns.

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