SCREEN BASED AUGMENTED REALITY FOR ARCHITECTURE

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Abstract. Augmented Reality (AR) technology has the potential to improve visualisation at the early stages of architectural design. The advantages of screen based AR systems over existing head mounted display AR, animation and virtual reality is discussed in terms of (1) improved contextual evaluation (2) social interaction and the integration of analogue media during design review. We describe two complimentary AR systems that explore these advantages: *strollAR*, a mobile set up for use on site; and *video-datAR*, a video database linked to a non-mobile three screen projection system. Outcomes from a prototype implementation are reported.

1. Augmented Reality – Why Bother?

Mobile AR technology has the potential for an improved form of design evaluation in which designs can be simulated within the actual site context. Design visualisation, along with construction supervision and post completion maintenance is one of three uses of AR identified for architecture (Klinker, 1998) . There have been some experimentation with head mounted displays (HMD) linked to GPS tracking that enable a user to see computer models superimposed on actual sites (Donath, 2001, Kuo C., 2004). However more work needs to be undertaken before AR will be useful for design practice, in particular it is proposed here that LCD screens and data projectors rather then HMD, are a more appropriate display technology for architectural design. However given we already have photo realistic animation and virtual reality systems, why bother with either mobile or non-mobile AR?

In the first section of this paper we discuss two advantages over existing visualisation that motivate our interest in developing screen based AR for the early stages of design. We propose there are advantages over animation in terms of providing a ‘reality check’, highlighting actual site conditions rather then the usual abstract context of the 3D preview window, or an idealized backdrop superimposed for client presentations. Secondly, we articulate the capacity of screen based systems to facilitate a more natural mode of discussion and the easy integration of drawing, reports and physical models while viewing the digital simulation. It is these two possibilities – improved contextual evaluation and recognition that design is a social process best undertaken with a range of media - that inform the unique development of screen based AR presented here. Current progress is reported on the development of a mobile screen system intended for on site review, and a second system that adopts a video database approach to allow use in the design studio. In conclusion outcomes from working prototypes are discussed and establish the need for further work on real time lighting and the development of low cost motion tracking.

2. (Because) Context Matters

By way of introduction, AR is placed in relation to the history of design visualization and the predilection in CAAD to represent architecture as a geometric object, devoid of either physical or social context, continuing the trajectory of visulaisation informed by 20th century modernism. From its publication in 1932 until the early 1970's 'The International Style' was the mantra for a period of "impaired vision" in which architecture was "conceived as a thing in itself, as if it were the only building in the world" (Berman, 1988). Commiserate with this ethos, architectural drawings were abstract plans and sections delineating internal function and structure, supplemented with isometric projections to show 3D relationships as if they were describing engine parts. As symbolized by the demolition of Pruet Ego in 1972, architecture as functionalist machine proved a social and cultural failure. The reasons for this are understandably complex and dependent on local circumstances, but one outcome was the relationship between architecture and context became of major concern. New approaches were informed by design visualisation that attempted to place proposals in context: photographic collage; the re-immergence of perspective drawing and sequential sketch techniques; the use of urban figure ground analysis; physical site models and video techniques.

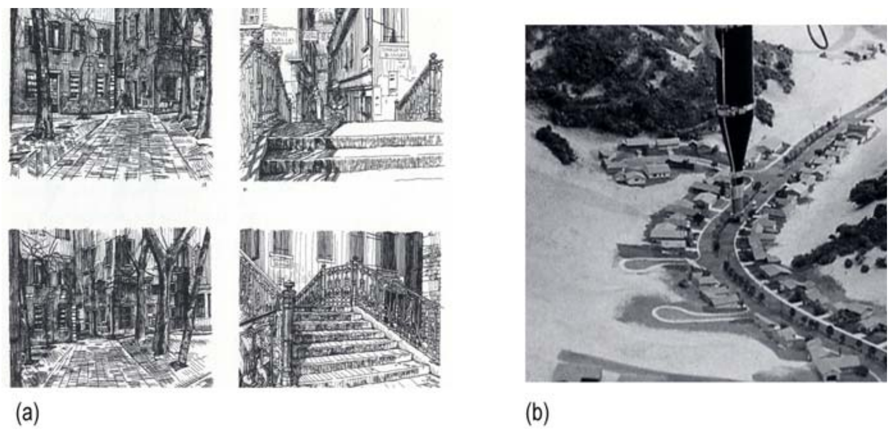

Figure 1: Analogue approaches to visualising built environment design in context: (a) sequential sketching ;(b) video production using miniature camera on a robotic arm and a physical scale model (Bosselmann, 1997).

These analogue techniques were overshadowed in the late 1980's by the widespread take up of 2D CAD software, leading to the sophisticated 3D modelling and animation applications in widespread use today. However, the current ease with which complex geometry and surface qualities can be manipulated in three dimensions has meant 3D visualisation has become, to some extent, a victim of its own success. In the hands of many there would appear to be a predilection for abstract form making undertaken in the contextual vacuum of the 3D preview window. The site context, if present at all, is usually in the form of a blocking model or a superimposed image. It is arguable that in comparison to analogue techniques of the '60's and 70's, the wholesale take up of 3D digital modelling has facilitated a paradigm by which architecture is developed as an isolated object devoid of context. Despite some notable work in academia on the experiential possibilities of animation to contextualise designs (Bermudez, 1995), typical use in practice is as a marketing tool in the form of a linear presentation – the ubiquitous 'fly through'.

The AR research reported here is a continuation of previous studies that are based on an approach to design that gives equal emphasis to the architectural object and the context in which it will be experienced. In previous studio based research we have used videogame software to develop collaborative virtual environments in which site is evoked through texture mapped site models, animated environment maps, lighting and aural soundscapes (Moloney, 2002, More, 2003). The video game technology was used as a low cost form of VR and enabled the fluent testing of a variety of design options and editing in a collaborative virtual environment. However we have found mixed results over the years, with the quality of the contextual framing being dependent on software skills that are above that found in typical design studios - convincing texture mapping, lighting and soundscapes take considerable time to produce the photorealistic outcomes seen in contemporary videogames. In addition, no matter the skill level the virtual environment will always be an interpretation of the actual context.

A shift to AR potentially allows the efficient production of authentic virtual environments but more important then production advantages, AR highlights the dynamic qualities of the built environment, the fact that *context changes over time*. This approach to visualisation, which we term 'temporal context', has two aspects: (1) the evaluation of designs in terms of spatial sequence and multiple viewpoints over time; (2) perceptual change over time due to the rhythms of environmental and occupancy cycles (Moloney, 2006). In the first the viewpoint is in motion, the design evaluated within a continuum of shifting focal points and spatial sequence. Evaluation is in terms of quasi-experience of the site context and the inter-relationships between internal spaces. The second aspect of temporal context involves a static camera and an acceleration of time. Time lapse techniques, used in combination with non-mobile AR have the potential to allow a revisiting of Kevin Lynch's insights on the temporal quality of city form (Lynch, 1972). One of the key issues facing architects and urban designers is the shift from a spatial to a temporal understanding of urbanity, the need for "designers to create appropriate flexible environments permeable to constant and rapid changes" (Echeverri, 2005). We anticipate video based AR, that allows access to a database of time lapse studies may be one valuable tactic to directly incorporate an engagement with this challenge.

3. (Because) Design is A Social Process Involving Mixed Media.

"..discussing, arguing, negotiating, forming consensus, trying out ideas and getting reactions, identifying and resolving conflicts, and reaching shared understandings and agreements. It's a person-to-person, social process -not just one of solving technical problems and producing documentation. That's what practical design is mostly about." (Mitchell, 1995)

The second motivation for our interest in screen based AR is the recognition that design is a social process. William Mitchell's keynote in 1995 highlighted that design review and decision making is reliant on conversation and negotiation, usually involving a range of representations – performance data, drawings, physical and computer models. Despite advances in distance based collaboration technology, crucial design decisions are still undertaken in face-to-face review and discussion, "trying out ideas and getting reactions". For this reason we reject visualization based on a HMD. The nuance of eye contact and body language essential to human interaction is lost, and while there have been some attempts to incorporate documents and physical models with the virtual model, the hardware works against the simultaneous use of drawings, reports and physical models. It is this capacity for natural dialogue to evolve in reaction to a range of analogue and digital information, which is the second motivation for this research. Ten years of studio research has confirmed the intuition that the most fertile environment for conceptual design is that which encourages the exploration of design ideas through a range of media. Using techniques we termed 'cross media working' a range of design studios have sought to maximise the possibility of creative insight when ideas are translated between media. The diagram below, resurrected from 1999, articulates the form of complimentary information and interaction possibilities inherent in drawing on a 2D surface, and interacting with physical and digital models.

Figure 2. Cross media Working (Moloney, 1999)

Drawing on a 2D surface engages eye and hand in creative interplay and is still the most 'plastic' of media in terms of the mark-interpret-mark cycle essential to creative design (Herbert, 1993). Engaging with a physical model adds tactile information and conveys a sense of mass but is less plastic in terms of allowing design changes. Complimenting these, a digital model allows exploration through a range of temporal and physical scales, and evaluation within an aural context. Not least, the primary attribute of a digital model is that it is programmable, as evidenced by the current interest in parametric and generative approaches to design. In our experience ideas developed and tested through a range of media – 2D surface, physical, or computer model – and ideally incorporating data on functional performance, allows the most rigorous evaluation at the early stages of design.

4. Where Does AR Fit Into the Design Process?

In summary, screen based AR technology allows the opportunity for improved contextual evaluation, in particular the shift to a temporal understanding of the contemporary city, and as important, the recognition that design is a social process best undertaken with a range of media. Our focus is on enabling simulation at the crucial early stages of design where a range of ideas are being generated and tested. Fig. 3 below locates where we consider AR fits into the design process.

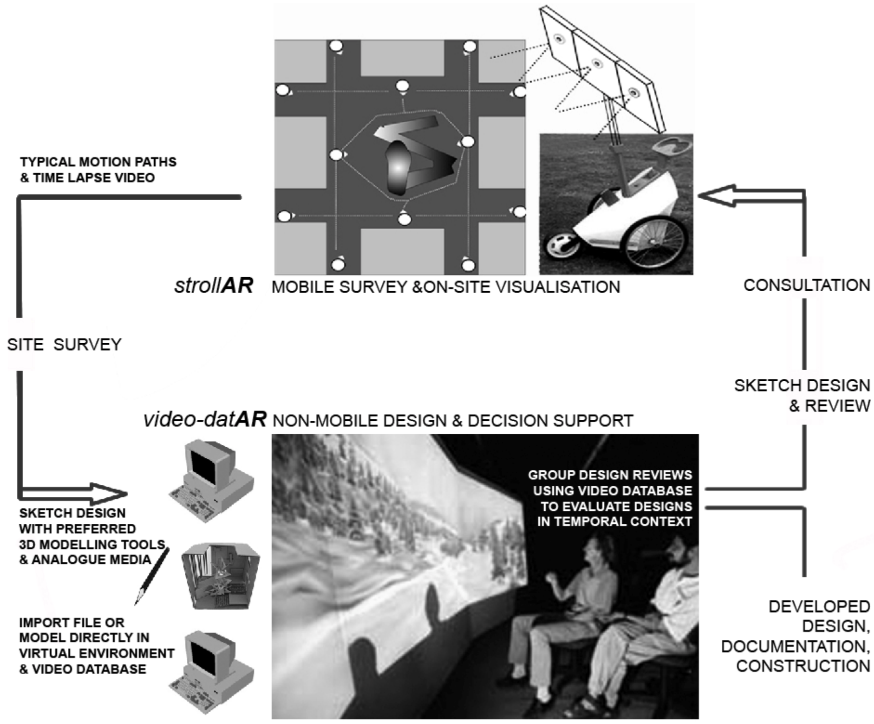

Figure 3. AR in the design process.

StrollAR is a mobile screen based system that is initially used to survey the site, collecting a database of motion paths and time lapse studies. We do not consider mobile AR suitable for the act of designing, but the same system used for the site survey can also be used later as a community design consultation tool. StrollAR is complemented by a second system that is intended for use by designers in a studio situation. Video-datAR allows designs to be developed and reviewed in relation to the survey video and time lapse studies. Designers can work either directly in the virtual environment software that has been developed using the Deep Creator SDK, or design with their preferred software and import models for review. This can be undertaken on a desk top machine , allowing sketches and physical models to be used to facilitate the mode of cross media working we have found to be productive. For larger group reviews there are advantages in using a three screen projection facility that allows design permutations to be edited and reviewed in a mode of semi-immersion. The scale and wide field of view of the projection maximizes engagement, yet allows a valuable 'distancing', and the simultaneous evaluation of models and drawing, The capacity to shift focus from immersive screen to reports, sketch books, orthogonal drawing and physical models encourages the 'reflection in action' acknowledged as most conducive to creative design (). Once design options have been agreed and developed, we then foresee the mobile strollAR can then be re-utilized to communicate and discuss the outcomes with a wider range of stakeholders on the actual site.

5. Prototype Implementation

A prototype of strollAR has been implemented using an adapted child buggy on which are mounted a video camera tripod, workstation laptop and a LCD screen. An application was developed using AR toolkit , with video from two cameras composited in real time to produce a wide field of view. Typically mobile AR for external use requires the use of expensive sub-metre GPS technology to accurately locate the design model in relation to the camera perspective. As discussed, strollAR is initially used to survey the site, and for these purposes a standard Bluetooth GPS with 3 - 4 metre accuracy was adequate as the intent is to generate motion paths that can be adjusted back in the design studio. Time lapse video was captured with standard electronic devices attached to digital still cameras to complete the survey task. For use of the same system for on site design review, we have trialed a unique tacking system that uses two digital compass to track camera pan and the motion of the buggy, with an odometer recording the distance traveled. The tracking system worked in principle but the digital compass used had interface issues affecting the rate at which compass updates were returned. In order to test the relative accuracy of the digital compass and GPS a software simulation was developed to determine the performance requirements for further development. The software simulation indicated that sub-metre accuracy in X/Y is possible with the low cost digital compass / odometer approach However, accuracy is dependent on calibrating the position to known locations or ‘way points’ .This would affect flexibility in use, but given that for the proposed use as a design consultation tool camera paths and way points can be determined in advance, this limitation would be acceptable. During the survey stage position data is saved along with a time code, but after testing data transfer rates with USB2 and firewire cameras, a decision was made to use digital video camcorders. This increases the video quality dramatically and allows tape storage that is then accessed for the second system. Video-datAR was implemented using the Deep Explorer SDK, which we have previously used for videogame like virtual environments. Deep Explorer was chosen as it is in our experience the most complete and sophisticated real time design environment, and one which allows compatibility with an extremely wide range of 3D modeling and animation applications. Users can choose to develop ideas in their favorite application or design directly in the virtual environment, which is linked to the video database. Designs can then be tested in context with the video camera paths and time lapse studies. The 8:3 aspect ratio of the video negates the ‘tunnel vision’ issue of perspective viewing and allows the wide screen format of a two or three screen projection facility to be used effectively. An interface has been developed for group review involving non digital experts that allows design options and video contexts to be easily interchanged, and subject to position, scale and rotation translations.

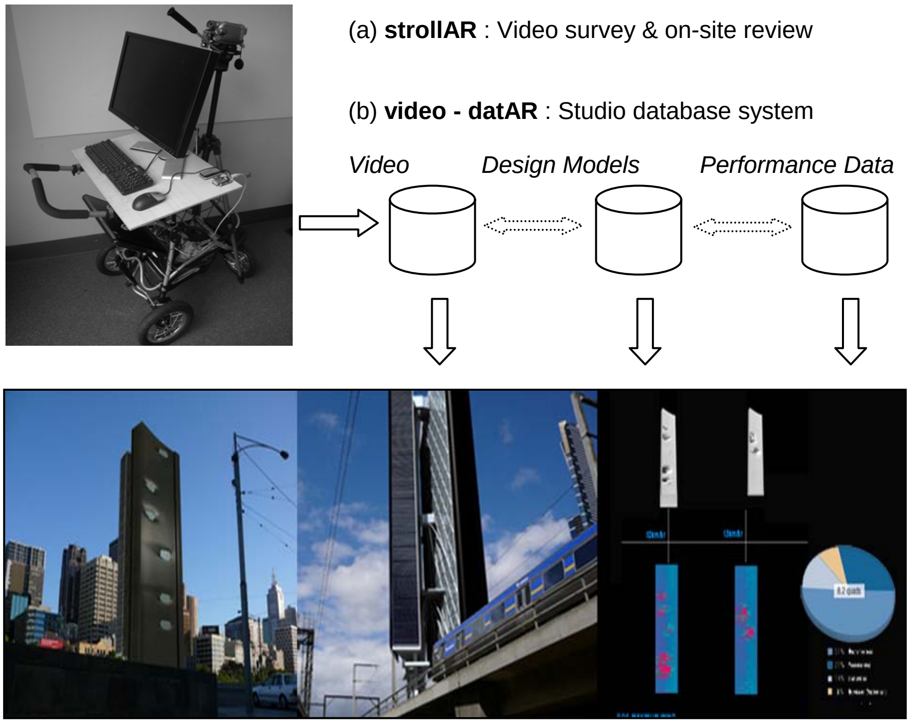

Figure 4. Pilot study prototype systems: (a) mobile StrollAR and (b) non-mobile Video-datAR.

6. Discussion and Further Work

The above implementation shows promise, but has revealed more technical work is required. The issue of a cost effective and robust tracking system needs to be addressed if the use of AR for on site evaluation is to be used in practice. To this end the digital compass approach undertaken here will be further developed. Another technical issue that must be addressed is the synchronization of lighting between the site video and the design model. When developing preliminary ideas, designers do not want to invest too much time on lighting, yet the incongruous appearance of an incorrectly lit model against the photo-real video context is a distraction. In further work we intend image sampling of the video frames to determine lighting data and use this to automate the real time illumination of the design model.

Once the technical issues have been resolved full user trials need to be undertaken to explore further the value of working in photo realistic context at the early stages of design. We are aware that there are some researchers who propose a degree of abstraction is essential to creativity, or that architectural design ideas are best explored using drawing notation such as plan and section (Allen, 2000). To a degree this has informed the use of screen based AR as it allows sketches and intuitive manipulation of physical models to be undertaken in conjunction with the video-datAR playing in the background. Moreover, we will experiment with video filters that allow users to determine the degree of photorealism they find most conducive to decision making at the early design stage. In addition there is the possibility of incorporating generative approaches to design within the Deep Creator virtual environment, as all geometry modifiers can be updated in real time.

The use of AR here has privileged the visualisation of design ideas in context, as a deliberate counter to the Cartesian vacuum of typical 3D modeling software. This of course does not negate the need for functional performance simulation to be undertaken. To this end we will develop the initial work on integrating environmental analysis to enable concurrent evaluation of qualitative and quantitative performance. The underlying principle to this research with AR is flexibility – the realization that design is undertaken across a range of media, scales and degrees of realism and abstraction. The novel aspect being developed is the foregrounding of time in relation to context. As acknowledged this is not a new idea, but one that was arguably interrupted by the ubiquitous use of abstract 2D and 3D software design tools. To design in relation to a range of temporal scales is a challenge for contemporary architecture, but given the accelerated rate of change and personal mobility of the 21st century, it is an issue that will be increasingly important.

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