CONSTRUCTION AIDs: Augmented Information Delivery

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ABSTRACT: *This paper investigates the potential delivery of design information to construction sites through smartphones and tablet computing devices. There continues to be an increase in the complexity of Building Information Models (BIMs), which are capable of representing a variety of building aspects. This can encompass physical models, construction models as well as thermal and energy models. Despite the wide spread adoption of computing by architectural, engineering and construction (AEC) industries over the last thirty years, and notable attempts to deliver information digitally (Fu et al. 2006), this sophisticated data continues to be abstracted to paper drawings for information transfer. In this paper we review test cases in data delivery that appropriate the 'good enough' methodology found in contemporary computing culture. Augmented Reality (AR) tools are used as a vehicle to deliver information, which provides insights into the resistances and opportunities that AR and mobile computing might present within design and construction. In this project we adopt the 'good enough doctrine' that resonates with contemporary digital media. Using AR techniques (GPS, LLC tags, markers etc.) we rethink the delivery of information direct to location through smartphones and handheld tablets. Our project chooses not to replicate sophisticated BIM functionality such as collision detection, 4D time management or programmatic interrelations that has been explored elsewhere, for example in Plume and Mitchell's A Multi-Disciplinary Design Studio using a Shared IFC Building Model (2005). Rather, following suppositions from the 'good enough' phenomenon, it potentially supports the provision of 'good enough' information to a critical mass of participants. It interrogates notions of information densification and localised delivery, which are shifting the contemporary landscape of consumer computing. Finally it presents observational evidence that points to opportunities and resistance that AR may offer within design and construction.*

KEYWORDS: *Augmented Reality, Smartphones, Mobile computing, Communication, Construction, Design, BIM.*

1. INTRODUCTION

The increasing complexity of computing hardware and software within the AEC industry can be viewed as diverging from current trends in consumer computing. The computing power of devices such as the Apple iPad or Google Android powered gadget is modest when compared to a CAD workstation. iPads and iPhones deploy single applications that have limited functionality, which leaves both the device and application very easy to use. A device can hold hundreds of such applications, each tailored to a particular function and easily accessed through the iTunes store or Android Marketplace. Applications typically cost $2-40 rather than the $2000-4000 of popular CAD software. The increased sophistication of AEC software also opposes what WIRED magazine recently called the 'good enough revolution' (Capps 2009); where cheap and accessible services and devices are proving better at mobilising people than their complex counterparts. For example, until they were recently made redundant by smartphones, point and shoot digital video cameras like CISCO's 'flip' were outselling feature rich professional or semi-professional video cameras. We extend this critique to software such as SketchUp and Google Earth, which are perhaps emblematic of this phenomenon in design and construction. Although SketchUp and the 'flip' come under criticism for lacking sophistication they are 'good enough' for most purposes and mobilise a critical mass of participation and content. Notably this critical mass is having effects on consumer computing; innovative new applications made through 'mashing' simple services together continues to gather momentum in the contemporary digital landscape. Such innovation can be found in design (McMeel 2010), although it is hindered where software, services and applications continue to be overtly complicated. We speculate that the high level of specialised operational knowledge that CAD software like Revit requires inhibits mobilisation of a critical mass of participation within construction and thus potentially hinders innovation and problem-solving.

Our theme of consolidation is inspired by the writings of Deleuze and Guattari (2004, pp.361-364). By drawing on examples where a biological organism's metamorphosis is triggered by a critical mass of organic material they theorize densification is essential in generating newness. Into this mix we introduce the work of architectural theorist Richard Coyne and the philosopher Andy Clark. Clark has advanced the radical proposition that thought is spatial (Clark 2001), and Coyne hypothesises that virtualized environments can hinder cognitive activity. This critical grounding provides a point of departure for our discourse on AR within design and construction environments.

Elsewhere the authors are exploring the phenomenon of information densification in construction (McMeel and Amor 2011). Evidence suggests the noise and furor that accompanies on-site communication can be couched in terms of Deleuze and Guattari's themes of densification and newness, inasmuch as they serve to catalyse problem solving and reveal new opportunities. In *Difference and Repetition* Deleuze (Deleuze 2004, p.144) expounds the benefits of cross-communication between heterogeneous systems, suggesting, "something passes between the borders, events explode, phenomena flash, like thunder and lightening." We speculate that low cost and easy to use smartphones contribute to the cross-communication of highly specialised discipline-based systems of construction, thus have the potential to spark "spatio-temporal dynamicism" and enhance problem solving and collaboration in the design and construction environment.

2. DESIGN AND CONSTRUCTION SPACES

In this section we expand on Deleuze and Guattari's conception of space in terms of the striated and the smooth as a framework for conceiving of design and construction. There is evidence to suggest design and construction are not separate procedures (McMeel 2009), although design operations may be see as declining during construction they do not cease. We hypothesize that design and construction operate in two predominantly disparate spaces, the striated and the smooth. Deleuze and Guattari use a variety of models such as 'maritime' or 'technological' to articulate the levels on which these spaces operate. We will focus on their 'nomadic' model of striated and smooth space as a useful metaphor to conceive of design and construction.

2.1 A typography of space

In Deleuze and Guatarri's models of space the 'striated' is recurrently identified through repetition. This could be repetition through rhythm (musical model) or through horizontal or vertical lines (mathematical model). Their description resonates with what we will call 'design space;' the CAD and BIM (building information models) environments we are increasingly finding design operating within. These measured and exacting environments operate on notions of precision; they cannot as yet operate with fuzzy or approximate data. BIM software both requires and promotes the affordances of striated space (Fig. 1), a space that demands measurement, demarcation and precision.

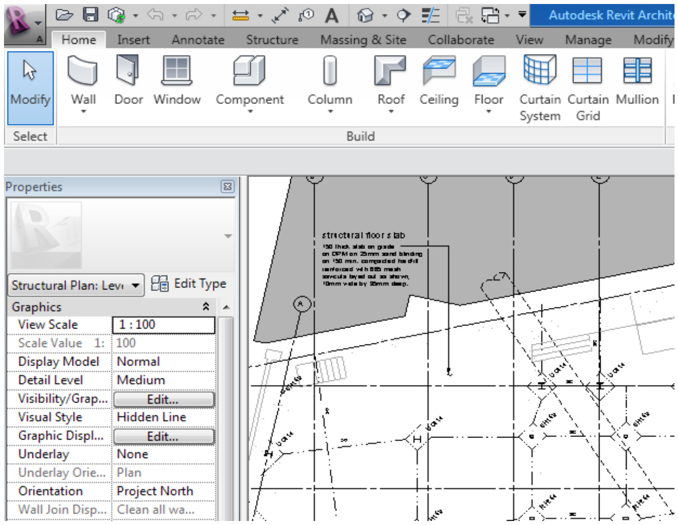


Fig. 1: The ‘striated’ space of the Autodesk design software Revit.

The measurement and demarcation that defines striated space is not identifiable in smooth space. When referring to smooth space Deleuze and Guattari use the word haptic; it is tangible and corporeal though lacks precise delineations. This resonates with the noise of the construction site, take for example the location shown below (Fig. 2) which awaits a staircase installation. Although staircase markings can be identified, closer inspection reveals evidence of change, revision, and movement. In this particular instance a beam affecting the staircase was only accurately located after work began; this impacted on the available head height and affected the ‘going; and ‘rise’ of the staircase. As the consequences of these changes became apparent the marking and prospective staircase changed to ensure continued conformance to regulations.

Fig. 2: A 'smooth' space on a construction site awaiting a staircase.

Deleuze and Guattari lay claim to the notion that these two spatial conditions are never mutually exclusive, they always exist simultaneously in a state of constant flux and tension. Although Fig. 1 and Fig. 2 present observational evidence the metaphor resonates with contemporary construction, it nevertheless challenges much of the contemporary work on negotiating relationships within design and construction. Some initiatives suggest a more comprehensive mode of documentation (Roy et al. 2005) that not only conveys physical assemblies and relationships but also contains some instruction from the designer on the ‘craft’ of making. Others are attempting to ‘lock-in’ design through more rigorous processes that will reduce subsequent design changes during construction (Kagioglou et al. 2000). We theorize that Deleuze and Guattari’s spatial metaphor is perhaps a useful lens for viewing design and construction. A designer, for example, is never totally removed from construction, they imagine the final building, a component, staircase or intricate assembly of a detail. The builder uses the idealized and abstracted drawings of the designer; a measured and precise representation of place that requires a cognitive leap to negotiate the relationship between the striated abstracted drawing with the physical limits of the actual staircase location. This framework of co-existence is useful within the context of design and construction because arguably very few agents and technologies operate between the two spaces. Cushman (2003) reports that knowledge exchange across disciplines can improve subsequent construction processes, however it is noted that often these knowledge exchanges happen at the end of a construction process.

2.2 Tools of the trade

The tools of design and construction are specialized and have evolved to serve particular needs. Hammers, spirit levels and saws have evolved to serve the needs of the tradesmen; pens, pencils and paper have been tweaked and tuned to serve the specific needs of design professionals. Even the pointed and precise pencil of an architect is quantitatively different from the chunky and robust pencil of a carpenter. Increasingly CAD and BIM are becoming ubiquitous, employed by architects, engineers and consultants who ultimately translate and manipulate designs within these software environments. The computation and simulation that occurs in design space is ultimately stripped away and converted to abstracted drawings (Fig. 3) that have changed little in the last two hundred years. Even with the proliferation of computing technology in the last fifty years and the widespread adoption of computers by the AEC industry in the last thirty years, the ontology of communication between disciplines and across the design and construction space has changed little in the same period.

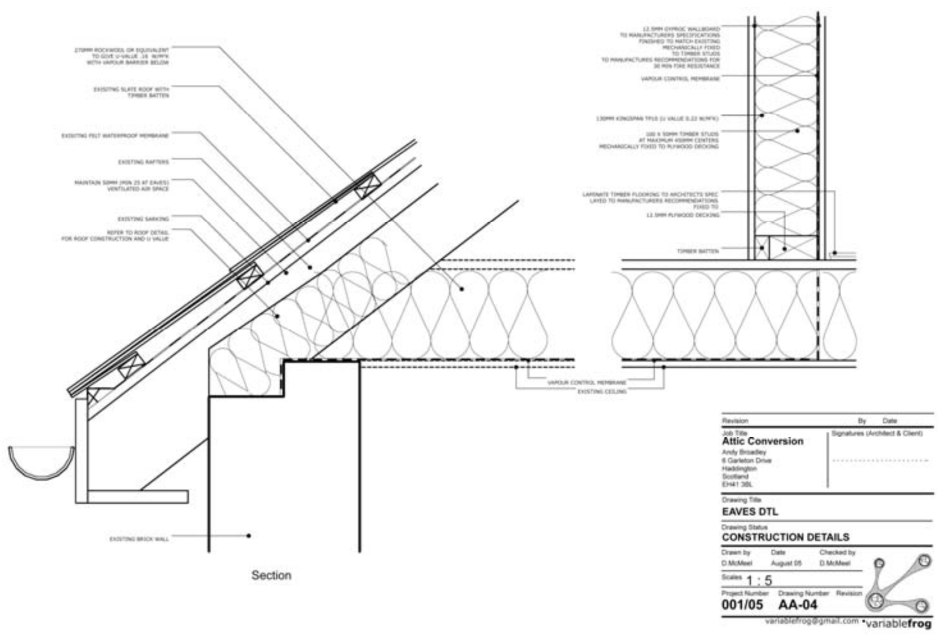


Fig. 3: A drawing for communicating a design intent.

Arguably, with the increased fragmentation of the construction process, the site meeting has added relevance. As tradesmen and sub-contractors are employed for a small fragment of time for a small fragment of work, the site meeting is perhaps the only occasion where designers, contractors and sub-contractors are in the same place at the same time. Although they may be unwieldy, long and occasionally fractious they serve as an important mechanism creating a feedback process between the two spaces. As construction evolves so to the design evolves, and like any substantial moving mass—be it physical or informational—repositioning releases energy, potentially causing breakages and creating tensions. In any building project these shifts and changes are ameliorated by design revisions, adjustments and alterations within the construction programme.

Increasingly, mobile phones are becoming implicated in the amelioration of change during construction (McMeel 2007), and previous work by McMeel suggests text messaging and mobile phone calling has a considerable affect on the relationship between design and construction space (McMeel 2009). Smartphones and tablet computing now offer increased potential for delivery, communication and representation of design and construction information through handheld devices. Within digital media, mobilising a critical mass of participation is key in effecting change (Polovina et al. 2004, McGonigal 2011). CAD and BIM continue to be available only to small numbers and communication continues to be via paper-based documentation, while mobile phones are available to a wide range of people within construction and provide access to a raft of potentially compelling technologies such as QR codes, GPS and Augmented Reality.

3. TEST CASES IN AUGMENTED REALITY

Over the course of a twelve-week project, a group of design students at the University of Auckland were challenged to explore AR within the context of both the design and occupancy of place. While this program is contained within the architecture course, the class is specifically concerned with exploring new and emerging media for the design and use of space. Our intention was simply for students to explore AR using their individual creative processes or spatial/technological requirements for driving their ideas. The organisers had at their disposal two Google Android powered Samsung Galaxy Tabs and one iPhone 4. These were available to the students enrolled on the course and could be 'check-out.' All of these devices are capable of running several free AR applications; although it transpired that a high number of students had access to iPhones or iPads and a strong sense of collegiality meant there was a lot of resource sharing by individuals fortunate enough to own one.

The design students enrolled in this course do not take mandatory coding lessons, although having used software such as Second Life and Rhino they are not unfamiliar with computer languages and coding. It is recognised that overcoming technical problems would form a portion of the course, however the intention was to maintain a critical focus on the design intent through this problem solving. Preliminary research into available AR applications found junaio (www.junaio.com) to be the most suitable in this case. Junaio provides good documentation and results could be achieved with a small amount of coding knowledge in the form of basic XML and free online storage space. Two basic types of AR are available within junaio, objects such as 3D models, and images and videos can be attached to locations or they can be attached to images. Junaio is working towards image recognition rather than using geometric markers that other AR toolkits are employing, this was also an attractive capability within the context of a design course. We explored alternatives such as Layar however it required knowledge of MySQL databases and requires the download and installation of proprietary software for locating and converting files for inclusion within the Layar framework. Junaio provides tutorial examples, files of basic code snippets and simple models that enabled a novice to 'copy and paste' code to obtain a basic working system. The junaio Google group forum also provided direction to free online web services (http://www.000webhost.com/) that work with the junaio API. Together these resources, along with some step-by-step tutorials and workshops under the guidance of the organisers, facilitated students without any particularly high level of programming knowledge to get an AR point of interest (POI) working and viewable on a junaio channel quickly.

Essentially there are three components within the junaio AR ecosystem, a smartphone running the junaio AR application, a content server and finally the junaio application management (JAM) server hosted by junaio. The JAM server takes requests from the junaio application running on a smartphone, obtains the relevant data from the content server and pushes it out to the junaio application. The content server is not hosted by junaio it is a standard php server that must adhere to certain communication protocols; students used the free web services mentioned previously, which proved to be reasonably reliable. Junaio has parsing and checking protocols in place but essentially the JAM server takes the data from the content server and pushes it out to the junaio application. Understanding this workflow was key and students were talked through it very slowly and then step-by-step they were introduced to setting up each of the three individual components of the ecosystem. They were also introduced to some 'best practice' document management for working with remote files. However, best practice workflow is not always the quickest and several individuals developed quicker working methods that ultimately resulted in loss of work.

The intent of the project was to focus on use-case scenarios for the communication and interaction with design documentation. In the following sections we will discuss and analyse several projects that emerged from the AR workshop.

3.1 Cross-faculty communication

In *Difference and Repetition* Deleuze discusses how different systems evolve unique "in-itself" ways of operating. This has been explored ontologically by Lee (Lee and McMeel 2007) within the context of design and construction. Deleuze goes on to explain the potential for dynamic newness, emergence and opportunities that become manifest during cross-faculty communication (Deleuze 2004, p.144); however the problems of this type of communication are also exposed to scrutiny:

“The transcendental operation of the faculties is a properly paradoxical operation, opposed to their exercise under the rule of a common sense. In consequence the harmony between the faculties can only appear in the form of a *discordant harmony*, since each communicates to the other only the violence which confronts it with its own difference and its divergence from the others.” (Deleuze 2004, p.183)

In this respect the construction site offers both communicative opportunity and challenges for AR. There are a number of factors that restrict cross-disciplinary communication within design and construction. The availably and identification of information at the point of activity (POA) on site is cited as key to improved problem-solving (Peansupap and Walker 2005), yet drawings are primarily generalised and fragmented abstractions. General arrangement (GA) drawings lack assembly detail, assembly detail (AA) drawings lack aesthetic considerations and aesthetic renderings lack—although they might imply—either of the aforementioned. Furthermore, scale and temporality play a part; GA drawings are typically A1 (841 x 594mm) or A0 (1189 x 841mm) and often dominate the early construction programme. AA drawings are A3 (420 x 297mm) or A4 (297 x 210mm) and have more relevance in the later stages of construction; renderings—arguably the most relevant for conveying design intent—don’t generally play a part in construction documentation. Compounding these factors, various stakeholders such as architects, engineers and interior designers all have different documentation. Each specialist has a unique perspective and documentation of their contribution to the design and construction process.

The following test case explores how AR can potentially cut through various modalities of documentation and provide multifaceted exposure to information specific to a particular site location.

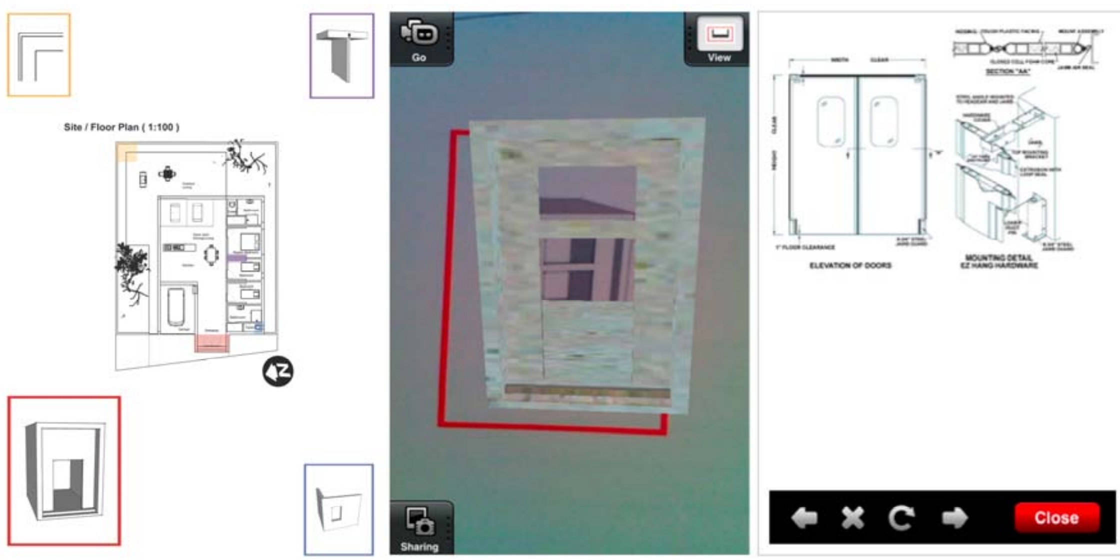


Fig. 4: Test case in using AR to cross a variety of communicative modalities – general arrangement drawing (left), AR model (centre) and assembly drawing (right). Project by Tommy Shin.

This project by Tommy Shin seeks to enhance design communication to a multi-disciplinary group using AR. When review panels within a School of Architecture critique design the discussion can quickly shift from conceptual or aesthetic considerations to an interrogation of the details of construction. Each stakeholder in the critique could demand a different type of information. This test case rethinks the traditional GA drawing (Fig. 4 – left image), using AR it becomes a tool providing immediate links to a variety of modes and layers of information. Typically, a GA drawing would have text references to redirect a viewer to particular component or assembly drawings. This example has substituted these text references for small 3D renderings—aesthetic references—to the pertinent details. Here Tommy provides aesthetic information and also draws on the image recognition capability of junaio to add another mode of communication. When these images are viewed through a particular junaio GLUE channel on a mobile phone, a 3D detailed model is ‘glued’ onto the image (Fig. 4 – centre image). Now as a viewer moves round the image they will move round the AR model glued onto it; thus enabling visualisation of the detail from any perspective. This does not preclude the image containing a traditional text reference that would enable someone to find the relevant component or assembly drawing. However junaio provides a ‘link’ facility for a recognised image; Tommy uses this to immediately ‘link’ to a detailed drawing that can be loaded onto the mobile phone (Fig. 4 – right image). This notion was advanced further by Tim deBeer who wanted to convey dynamic information. He draws on the animation capability within junaio to convey assembly information. CAD files were imported into the Blender modelling program for conversion into the required file type (md2) for junaio. Animation within this software was surprisingly technical and problematic for the designers. Though Tim’s working prototype (Fig. 5) still manages to demonstrate a proof-of-concept showing assembly animations triggered by a recognised image.

Fig. 5: Animation of different elements of a building viewed through the junaio mobile phone application. Project by Tim deBeer.

Returning to our theoretical grounding and Clark’s suppositions regarding scaffolds, we might conceive of drawings as cognitive scaffolding for construction. Each type of drawing and discipline provides unique insights to different facets of a project; although for most of construction there is temporal, spatial or ontological distance between them. This project advances the drawing as technological scaffolding for cognition, it uses AR to augment the drawing and potentially reduce the distance between the different design and construction spaces within the building process; increasing the opportunity for cross-disciplinary communication.

4. COGNITIVE SCAFFOLDING

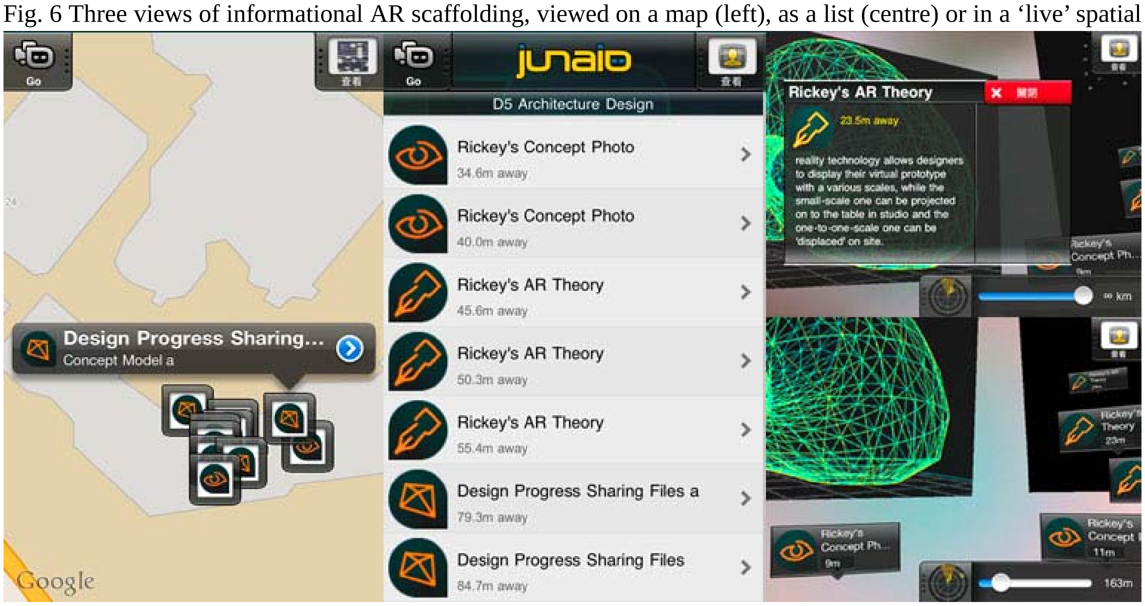
In this section we will look at how AR might be used for the construction and exploration of a design process in spatial terms. According to Clark, human beings are adept at using technology for personal enhancement (Clark 2003). In fact he claims the extent to which human beings use technology to construct these cognitive scaffolds far surpasses any other species (Clark 2001, p.19). Invoking Hutchins (1995), Clark puts forward a particularly compelling example of a cricket (Clark 2001, pp.8-15). The mating ritual comprises of the male calling, the female recognising the male call, calculating from where it comes and then ambulating in the direction of the male. The dominant theories in cognitive science would suggest we have just described three distinct cognitive activities. Clark contests this notion and explains the cricket’s ears are on its forelegs and open to the world at two points, a single sound reaches the ear through slightly different routes and slightly out of phase. This phase difference favours the male call, consequently it would appear that the male mating call is one of the few sounds that can be heard clearly through the female’s aural scaffolding. Having ears located in the forelegs results in ambulation and rotation directly affecting the clarity and directionality of the sound and thus the prospective mate. Clark theorises what appears to be a complex three-stage linear cognitive process is in fact shaped into a single cognitive operation, with the help of the cricket’s evolved biological ‘scaffolding.’ Clark goes on to single out human beings use of technology and design to enhance or increase the efficiency of thought as far surpassing any other species. Thus we contend that design; architecture and now augmented reality are implicated in supporting or hindering cognition.

Returning to the domain of architecture, we should perhaps acknowledge that historically buildings and public spaces served to do more than provide a utility of place. From hieroglyphics found on Egyptian Pyramids to elaborate friezes adorning Roman public buildings we find architecture serving to record and recollect memory and collective experience. Perhaps Peter Zumthor serves as a contemporary example of the architect as creator of environmental scaffolding. In *Thinking Architecture* Zumthor (2006) explores the notion of architecture evoking memory. The sound of gravel underfoot can trigger a remembrance from an earlier experience; the feel or look of a door or handle can elicit a childhood memory of the need to pull or slam the door. Couching Zumthor's reflections within Clark's suppositions we propose that this is architecture as cognitive scaffolding. Zumthor approaches architecture with subtlety, he has added steam, sound, and light to his architectonic toolbox and creates architecture that has the sensuous and the experiential at their core. Zumthor is reported to have said of his Bath House at Vals:

"The meander, as we call it, is a designed negative space between the blocks, a space that connects everything as it flows throughout the entire building, creating a peacefully pulsating rhythm. Moving around this space means making discoveries. You are walking as if in the woods. Everyone there is looking for a path of their own." (O'Grady 2009)

These are designed as places of discovery, relaxation and stimulation. Rather than an individual configuring space for their own relaxation or writing process, here the architect designs to enhance a particular emotional and cognitive state. Complicating this for architects and designers is the current proliferation of augmentations to our intended reality. Freely available mobile phone applications like junaio, Layar, Aurasma and Wikitude to name but a few allow digital scaffolds and topologies to be overlaid on reality, we speculate this effects personal perceptions of architecture and place, consequently there is an impact on creative processes be they writing or design.

Fig. 6 Three views of informational AR scaffolding, viewed on a map (left), as a list (centre) or in a 'live' spatial



view (right), which responds to panning, tilting and movements of the phone. Project by Rickey Gong Wang.

This test case uses AR as a metaphorical 'transporter' by using junaio's LLA markers. These markers contain latitude, longitude and altitude (LLA) information. Once recognised, the smartphone discards any current locative information in-lieu of the data contained in the marker. This functionality is intended for use indoors, where it is typically difficult to get an accurate location lock. However, Rickey appropriates this utility to literally transport the viewer to his design space. The designer is still making decisions regarding the content of his design space, we can see (Fig. 6 – centre image) notes on theory, design progress, concepts etc. Rather than representing an idea as an abstract concept, now a person or group of people can be transported into the design narrative (Fig. 6 – right image); design decisions can be viewed within the noise and furor of the creative process. Noise and furor, we have theorised elsewhere (McMeel et al. 2011) contributes to problem solving during construction.

5. CONCLUSIONS

Design and construction processes are comprised of temporally, spatially and conceptually distinct constituents. The first test case in this paper provides us with a glimpse of AR increasing the potential for accessing different types of documentation and representation of design. A drawing can now serve as a portal to disparate information that is location specific, increasing ease of access to different stakeholders drawings, documents or models of a building project. In our second test case a designer 'transports' us within the noise and furor of his design process. Informational noise that—we hypothesise—provides raw material to serve as a catalyst for Deleuze and Guatarri's consolidation of new creations and solutions. Although our test cases are admittedly modest in scope they emerged from a contemporary pedagogical design environment occupied by designers fluent with mobile phones and locative media. They present observational evidence of compelling starting points for reconsidering 'aids' for design and construction processes.

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