DIGITAL ECOLOGIES: A SHIFTING PARADIGM FOR CONSTRUCTION

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ABSTRACT: *Many industries are currently being transformed, through phenomenon driven by what is being described as 'cloud computing' or the emergence of new 'digital ecologies.' Here we explore this concept's potential within the construction industry through the creation of a Revit 'Add-on' created with its proprietary API and an iPad application, which facilitates a direct and immediate exchange of information between people gathering data at the point of work (POW) on site and the central Revit BIM. The paper reflects on some known obstacles to this approach, particularly the latency and inaccuracies that exist between the model and the actual building as well as complexities in transferring the model from a desktop computer to low powered, usable and site friendly devices. We focus on a test case in defect management and expose emergent possibilities for improvement through techniques that are driving 'digital ecology;' we appropriate the Revit API, deposit data on a cloud service and develop a 'single serving' iPad application. We have hypothesised elsewhere, that construction operates through negotiating tensions, frictions and potentials created within its inherent complexity of people, materials and disciplines. In this paper we go further and suggest that construction exhibits the behaviour of an ecology. There is a chequered history of the construction industry gaining advantage from appropriating organisational methods from other disciplines. However, having suggested construction exhibits the behaviour of an ecology, our test case points to opportunities where adopting the 'digital ecology,' making easy to use mobile applications and leveraging localised delivery of site data could potentially improve existing construction and facility management processes.*

KEYWORDS: Revit, API, Digital Ecology, Locative Media, iPad, Application

1. INTRODUCTION

We are becoming evermore attuned to the notion of digital ecologies or *the Internet of things*. Where a multitude of objects are interconnected and communicating, much like a biological ecology. This communication is, or appears close to, real-time and in popular computing it is changing the dynamics of many industries and driving new innovations; the most interesting and influential of which are unexpected. The popular photo-hosting site Flickr was an unexpected success originally only a part of *Game Neverending* a massive multiplayer online game (MMOG). The mobile application *Waze,* which appropriates crowd-sourced information about location and traffic then redeploys it through map and location aware services to report real-time traffic conditions, is finding popular usage specifically to subvert police traps and speed cameras. We can observe—with some regularity—through innovations such as Dropbox, Foursquare and Yelp, when ecologies of data sources and services are made available, new and unexpected innovations emerge that reshape industries and activities.

The New York Metropolitan Transport Authority (MTA) has capitalised on this phenomenon (Press 2010) by making their real-time transportation data available to developers. Within hours mobile phone applications and websites emerged appropriating that data and combining it with other information and services, such as Google Maps, to provide a wide range of utility and functionality. Traditionally such a company might use customer surveys to elicit functionality for new services, then take the most popular ones and undertake an extensive software development process to realise them. However, making the data available has resulted in considerably more niche software and applications tailored to specific needs and much more easy to use. A café developed a live notice board that told people exactly how far away their bus was from the bus stop directly outside. Increasing the convenience and likelihood of individuals using this café, as well as increasing usage of the MTA services. 'Hacking' and 'mashups' are increasingly important in contemporary innovation, the authors have previously interrogated this notion within design and construction (McMeel et al. 2011a; McMeel 2010). In this paper we advance the discussion asking if benefits from open and available data and services might be possible within construction? We begin to unpick this question by asking how might we implement a 'digital ecology' to test this supposition? Then ask where might it be implemented?

In terms of how, the introduction of new technology has a long and tumultuous history in construction, with high failure rates (Peansupap et al. 2005, 193). This failure is not unique to construction, Kling has conducted many studies on a variety of organisations uncovering motivations and results of technological introduction (Kling 1980;

Kling 1996; Kling et al. 1984). He identifies a recurring problem where change is required in one area of an organisation to benefit another area; the operation being disrupted by change does not gain advantage or benefits from it. Another issue reveal by Peansupap et al is technology's failure to meet expectations. This is also not unique to construction, the digital designer and innovator Jeffery Veen has identified this as a cause of poor uptake of technology in other industries (Veen 2004). Both Kling and Veen point to a lack of consideration for nuances within existing processes; an affected process should be easier, or at the very least, not more difficult. Within this context the authors made a number of presentations—of mobile technologies—to architects, stimulating discussion. This has pointed to frustration with the *snagging* process, which we will discuss in greater detail in section 2. The question of 'how' is thus driven by a problem sedimented within the context of design and construction, not by available or novel technology. According to Kling and Veen attending closely to this defined group and the targeted 'snagging' process should provide the necessary guidance when faced with the question 'how?'

In terms of where, snagging is perhaps a suitable place for intervention. Throughout construction there is a substantial difference between the project documentation—be that printed schematics or digital building information models (BIM)—and the site condition. This difference reduces as the project continues although some might argue the documentation never actually catches up with the site until the preparation of the 'as built' documentation. That notwithstanding, during snagging this difference is at an absolute minimum and there is a reasonable similarity between the documentation, model and the physical building. At the very least this minimises disparity, latency or inconsistency that has been identified as limiting practice-led research on actual construction documents and materials (Plume et al. 2005).

2. CONSTRUCTION

Snagging processes can be frustrating, but are a key stage in construction. They occurs just prior to building hand over and is the process where any minor defects in the construction, such as a cracked ceiling tile or damaged paint or plaster, are identified and remedied so a completed building can be handed over to the client. Predominantly a paper-based process where defects are identified by the architect or project manger on-site; they are usually reformatted and logged off-site before being passed to the contractor for remedial action. As groups of snags are rectified they will be inspected by the architect or manager and logged as complete.

On commercial projects defect lists can extend to hundreds of individual items distributed throughout an entire building. A particular point-in-case is current processes being executed in the aftermath of the Christchurch earthquake. The defect logging processes is considerable, our informal discussions with architects suggest for every hour spent on-site recording building defects, they spend at least another hour rewriting and reformatting the documentation for the numerous stakeholders, such as engineers and insurance companies. In both these examples, to some extent, what is considered suboptimal is the rewriting and reformatting of a singular source of information, as well as problems and delays that arise from documenting and finding the exact location of defects.

It is within this context that we conceived of an application for managing defects with superior location awareness and cloud or online-based storage to facilitate a more efficient repurposing of data. Informed by the Metropolitan Transport Authority example discussed in the introduction we focused on a strategy that would present data in an open and available format and location, as well as the development of an application for recording snags. The application should facilitate note taking and reading/writing data to an online source. The note should have location information to help with locating the snag precisely within a building. From our discussions with several architectural firms we arrived at a general briefing document that included a 3D interface on a tablet device where snags could be recorded at exact locations. This application should also assist with the repurposing and rewriting of repetitive information, making the processes more efficient. This focused the development on three areas:

1. Strategy for moving a BIM model to an iPad.
2. Online storage, visualisation and manipulation in a resource constrained device.
3. Making information on the iPad available for appropriation by a nascent 'digital ecology' of systems.

Cheshire Architects made available to us the Revit model of their Q Theatre building in Auckland city centre. The model provided us with an archetype of realistic detail, quality and information, as it exists within a real construction project. This is also a fairly typical size of commercial construction project, a three story existing building converted to provide three main performance spaces; the main auditorium can hold a maximum audience of 450 people. The construction cost was approximately NZ$21 million (12.8 million euro), however most importantly this was not a demonstration exemplar for the purpose of research, it was an actual industry created BIM.

3. CONVERSION CONTROL

The desire to have a 3D interface with some interaction capability to locate snags in 3D space directed us to investigate games engines. Some recent work using Unity3D (Boeykens 2011) revealed the interactive possibilities as well as some strategies for moving from a BIM model to a mobile device. It also has an integrated workflow for publishing to iOS devices like the iPhone and iPad, which made it an attractive option.

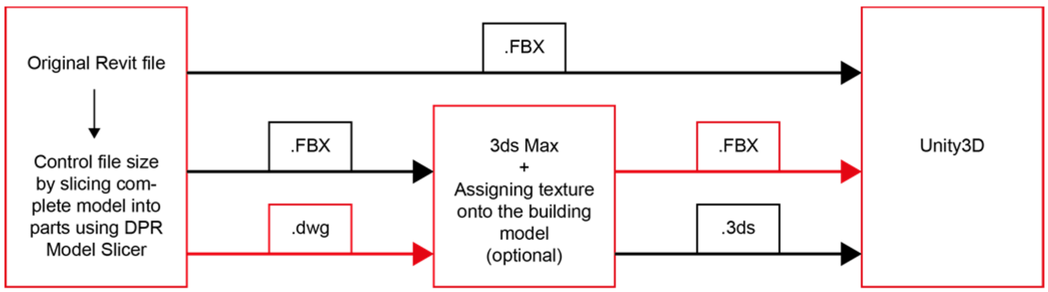

Figure 1. Conversion pathways explored by Jae Shin

Advancing Boeykens' work we explored the conversion potential. What was revealed through conversion was the propencity of certain pathways illustrated in Figure 1 to drop location information. Retaining this information is of critical importance within our context, the highlighted pathway of Revit to 3DS Max via dwg format and from 3DS Max to Unity3D via fbx format—although suboptimal for the translation of textures—was highly reliable for transfering object location and coordinate information between the BIM environment of Revit and the Unity3D environment.

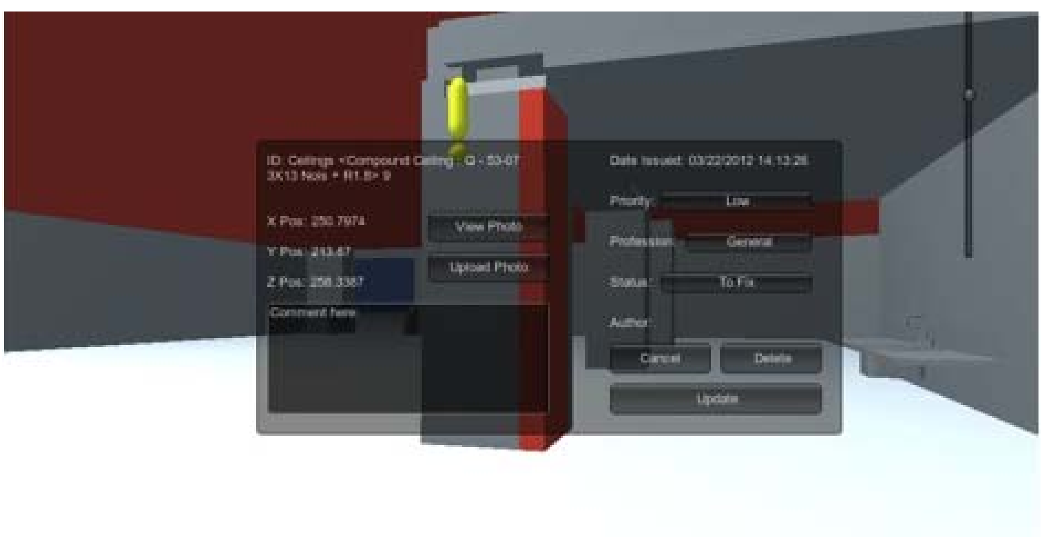

Figure 2. iPad application screenshot showing highlighted snags and the interface for adding information.

The size of the model was another known issue, where the processing power available and required for BIM on desktop computers is not availabe on mobile devices; causing slow performance and rendering any innovation inneffectual. With Unity3D there is a standard game methodology of incremental loading, whereby as a viewer's proximity to an object increases, the object will load into the environment; as the viewer moves further away from an object it is purged from the system. This ensures a smaller number of polygons are being handled than if the entire model was loaded. We experiemented with the useful DPR model slicer (http://modelslicer.dpr.com/), a Revit add-on for slicing a model into specific sized segments. These were then exported through the identified workflow in Figure 1, thus retaining their relative position to each other within Unity3D. Although this worked very well, through experimentation we found with a second generation iPad it was possible to load entire floors of the Q theatre building and still retain smooth movement (Figure 2)

The main limitation we discovered through this processes was an unsatisfactory translation of the material quality of the building, which can be seen in Figure 2. Although Boeykens claims Unity3D has better material possibilites than alternatives like the *Unreal Editor*, it remained problematic to get both textures and acurate location information translated from Revit into Unity3D.

4. ONLINE STORAGE

The availablty of information for other applications within our nascent digital ecology is important. Web server access is no longer complex or costly, the interested amateur can obtain it through free sources on the internet, for the professional Amazon's highly reliable web services are availble. Even Autodesk has its own proprietry cloud offering for Autodesk users in the form of Autodesk 360 (https://360.autodesk.com/Landing/Index). The very popular Dropbox (https://www.dropbox.com/home) has its own proprietry API and enables powerful sharing possibilities between users and application. With these services the potential to create a distributed network and filing system for projects using public and reliable services is not unrealistic. Thus the possibility—as seen in the MTA example in our introduction—to create a framework for open and available data to stimulate developer innovation is a highly realistic proposition.

We created a free web server account at Free Web Hosting (http://www.000webhost.com/) and established a simple POST and GET protocol using the php language for exchanging information between the web server and the iPad application. Initially this accessed data from a comma separated variable (CSV) file to prove proof of concept. The iPad application was handling information quite efficiently, firstly an XYZ location coordinate and the name of the object as defined by Revit was passed to Unity3D, then the annotation, author information, time etc. Essentially just standard information that is recorded as part of existing snagging processes. Using the Revit object identifier to coordinate the location information between Revit and Unity3D our framework was freed from the need to continually transfer 3D model data. Thus once the model was encoded on the iPad, using standard web protocols, providing there was reliable WiFi or 3G connectivity, we could send and receive data with considerable speed and reliability.

Returning to our earlier analysis we are careful to consider where change is being implemented. Being a standard format the CSV file can be opened in Microsoft Excel, where we would begin formatting the information. Continuing research is developing a MySQL database to replace the CSV file as the underlying data resource for the application. Supporting this digital ecology with a database provides the potential for users to manage snags centrally and export them as standard formats (.xls, .doc, .rtf) where they can be passed onto contractors, thus not imposing change on other processes or people. Moreover there are many sophisticated issue tracking systems developed for IT support (http://bestpractical.com/rt/) that could potentially be tailored to meet very sophisticated managerial needs within this context. For now we continue to focus on the management of snags, particularly to investigage if we could facilitate a two way data exchange between the mobile model and the BIM. Existing mobile BIM offering, such as Graphisofts BIMx, have a unidirectional flow. From the BIM software onto a mobile device. If we are to buy into the digital ecology we want to have a multidirectional exchange, the possibility of data flowing and being exchanged within the ecology on multiple levels. Revit comes bundled with a powerful API, and in the next section we will discuss our investigation into creating a Revit add-on to pull the infromation—created on the iPad and stored on our web server—back into Revit.

5. API

As the name suggests, building information models (BIMs) are no longer just geometrical representations they are information rich descriptions of many aspects of a building, from geometry to engineering schematics and object specifications. Following the earthquake in Christchurch there is an increased onus being placed on documenting construction process particularly where this involves deviations from specification. We speculate the proposed digital ecology concept provides a framework—if desirable—to draw from a manifold of processes, procedures and decisions, which could be encoded in the BIM description.

The key functionalities we require of the API here are reading a CSV file, drawing the location information from set fields in the file and creating markers related to each defect at its respective location within the BIM model. There are some tutorials for working with the API provided by Autodesk (http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=2484975), as well as a comprehensive developers guide and software development kit (SDK). Add-ons can be written in both the Visual Basic (VB) and C# programming languages.

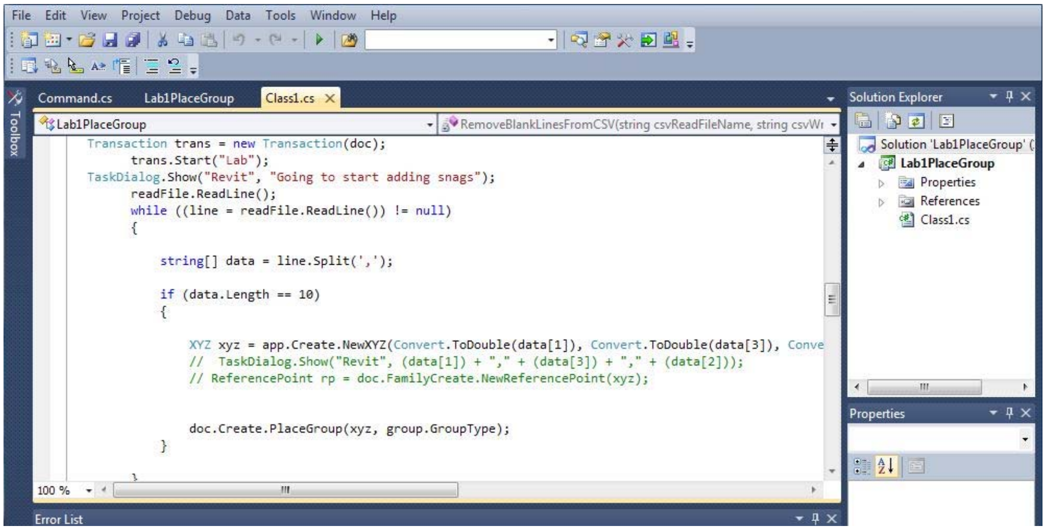

Figure 3. Visual C# Studio environment with some of our API add-on code.

Early development work (Figure 3) shows the basic functionality, reading a CSV file and adding markers in the Revit environment at points contained within the CSV file (https://vimeo.com/36167862). By using a CSV file we could test suppositions regarding information interchange by accessing the data with traditional spreadsheet software such as Microsoft Excel or OpenOffice. With our current work the CSV file will give way to a MySQL database as the information repository, which will in turn generate the necessary file types for additional applications within the digital ecology. The scale, rotation and position of the snags were proportional however they did not match the master BIM model. We were able to execute manual translations on the BIM file so the snags matched the building. This was of course not optimal, an automatic translation and one-off configuration procedure would be desirable in this type of context. Nevertheless the final process of automatically creating markers in Revit at the same location as snags were recorded in the iPad application (Figure 4) can be seen online at https://vimeo.com/40420799.

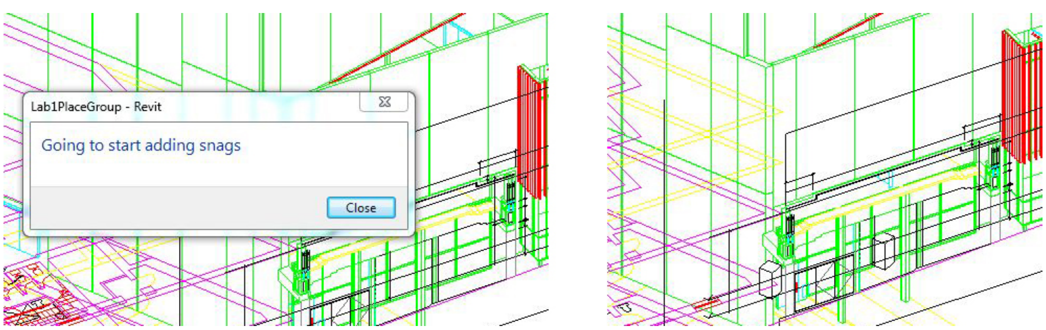

Figure 4. The Revit model before adding snag markers (left) and after (right).

It is reasonable to ask how might such an ecology grow? Subsequent to this project we have had discussions with pipe manufacturers that are looking for ways to provide total lifecycle management of their assets; from recording data of pipe manufacture, testing, installation to ongoing maintenance until replacement. Managing defects and maintenance within facility management is not unlike snagging, only more difficult as buildings are fully operational, furnished and occupied. These examples suffer from data input at a variety of times, locations and mediums, which results in fragmented data repositories that complicates timely and meaningful access. Already in popular culture we are seeing the notion of the digital ecology reduce this type of problem; predicaments caused by temporal and spatial disparity within data. Might it reveal a means to identify successful and unsuccessful combinations of consultants, contractors and sub-contractors? Would having access to lifecycle information on a building reduce the unknown factors for contractors or sub-contactors making tenders? Sophisticated project management software creates dynamic Gantt charts where elements are contingent on each other, how far are we away from an iPhone variant that tracks them and informs key stakeholders of milestones that are approaching or milestones that have shifted because of decisions being made elsewhere? We have discussed elsewhere the importance of physical meeting within the dynamics of construction processes (McMeel et al. 2011b), any suggestion it can be automated or purged from construction is overly simplistic. Thus this research is not to replace humans with some Marxist dystopian, rather it is to investigate where and how digital technology might be leveraged to augment natural and already effective behaviours.

6. SUMMARY

Given the closeness of the model to the site condition at the snagging stage of construction, it is perhaps more useful to have a location and spatial interface at this stage than any other. The Unity3D game engine provides powerful loading methodologies that render the problems associated with large files on mobile devices almost completely void. Although the translation of texturing and materials requires further investigation, by establishing a relationship between the location information within Unity3D and the Revit BIM model we were able to exchange modestly sized data packets containing coordinate information rather than large proprietary 3D object files leaving the data more accessible for other applications.

Perhaps most importantly it points to the potential of open information and standard protocols for communication; the same trends that can be observed in consumer computing. This one test case does not provide immediate solutions for innovating with mobile technology but it demonstrates how quickly it can be conceived, developed and tested within a digital ecology using services already available to the consumer. It is a demonstration of the possibilities of current innovations for design and construction and an exhortation to consider software and services as part of the complex ecology of construction and enable freedom for them to be meaningfully appropriated by developers and innovators beyond their immediate corporate ‘family.’

7. ACKNOWLEDGMENTS

The authors would like to thank Remy Lim who created the iPad application and Tommy Shin who worked on import/export pathways for the Revit model; Cheshire Architects for the use of their Q Theatre BIM model. We would also like to thank Rowan Walker who did some early development work on the potential of mobile snagging applications for construction processes.

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