PARAMETRIC HOUSING IN REMOTE AUSTRALIAN INDIGENOUS COMMUNITIES

Timothy Sullivan, MDesS (Technology) Candidate 2013, tim.architecture@gmail.com
Harvard Graduate School of Design, 48 Quincy St, Cambridge MA., USA

ABSTRACT
Parametric Housing in Remote Australian Indigenous Communities is an investigation into utilizing existing and emerging technologies to allow for the design and construction of more suitable, cheaper and sustainable living environments. By examining the supply of Indigenous housing by the Australian Government, many layers and scales of complexity are apparent. These complexities, sometimes extreme, help to test out the hypothesis that intuitive interfaces, parametric design, digital fabrication, and BIM (Building Information Modeling) are robust and flexible enough systems to deal with such multivalent issues and dichotomous stakeholders whilst still facilitating housing that better suits the lives and aspirations of its users. The consequential improvement in the housing design, construction and maintainability will improve the living conditions of many, as well as create a more economical development standard.

KEY WORDS
Parametric Design, Indigenous Housing, BIM, Digital Fabrication, Mass Customization, CIM.

AUTHOR

INTRODUCTION
Firstly, this paper will discuss Indigenous housing supply in Australia and highlight some of the issues, some unique to this type of housing. It will then discuss how the complexity of these problems is beyond the ability of the traditional linear design system. Then, it will propose an integrated design system that is open and dynamic and allows for greater complexity. This allows the designer to manage the design issues at the appropriate breadth and scale.

As an introduction, BIM, parametric design, digital fabrication, mass customization, are all emerging technologies that are changing the way architects design; and the built environment is constructed. Each technology contributes in its own way, but the real potential of these technologies is unlocked when they are integrated with a digital consultation interface into a design system that can engage the complexity of the contemporary practice. Such a system allows for a paradigm shift in how buildings are designed, constructed and managed.

INDIGENOUS HOUSING
Australian Indigenous people exhibit some of the worst development indicators of any socio-economic group in any industrialized country (Cooke et al., 2007). According to the United Nations, the quality of life of Australian Aboriginal people is the second worst of the planet. (Cooke et al., 2007) Their culture and social systems have been shattered by colonization. Social problems like domestic violence, substance abuse and severe malaise are endemic in many communities (Wild & Anderson, 2007). Despite years of intervention by the non-Indigenous community and government, the cycle of poverty, depression and violence continues to impact
many Aboriginal families (Wild & Anderson, 2007).

Contributing to this cycle is the deplorable state of the quantity and quality of Indigenous housing (Wild & Anderson, 2007). It is widely accepted that there is a clear link between the health and social problems of Indigenous communities and the inadequate and inappropriate housing options available. (Wild & Anderson 2007) Whilst the Australian Government recognizes this and commits resources to the issue, the problem continues to deteriorate. (Brough, 2007)

Many potential interventions into the process have been identified. Below are a selection that a more integrated design system would be able to engage with:

**Build more houses** - The backlog in housing contributes to overcrowding, (Wild & Anderson 2007) which means houses that were designed for a family of 4 can end up sheltering 25 people. (Pholeros et al., 1993) Overcrowding exacerbates social dysfunction and contributes directly to the incidence of domestic violence, child abuse and the accelerated dilapidation of housing. (Ballie, 2007. Wild & Anderson, 2007).

**Make houses cheaper** - Housing can be exponentially expensive due to remoteness, with materials, labor and expertise usually imported from the closest city. A very basic family home is considered cheap at US$450,000. (Donald & Canty-Waldron 2010).

**Culturally appropriate design** - When housing is supplied, it is not only expensive it remains on many levels grossly inappropriate, (Neutze, 1999) so many of the social and health issues reappear. The bureaucracy that supplies the housing cannot hope to deal with all the intricacies of each individual client’s needs, particularly cultural idiosyncrasies, community values, extreme remoteness, and harsh climatic conditions. (Fien et al. 2008) The bureaucratic method tends towards attempting to solve the complex issues by generating ‘one size’ solutions. This means that for most projects, it seems the government inevitably becomes the client rather than the residents (FaHCSIA, 2009). This may suit the bureaucracy’s short-term aims, but it creates housing outputs so undifferentiated and unresponsive they can fail to satisfy many of the communities’ and the original project’s requirements and can even become dangerous and harmful to the health and safety of its occupants.

**Design healthy, safe homes** - Inappropriate materials, bad workmanship, unsafe design and climatically unsuitable design contribute heavily to many of the health issues and dilapidation of housing in remote communities. (FaHCSIA, 2007)

**Maintainability** - Another issue is the environment is often exceedingly harsh and faulty installations are common (Pholeros et al. 1993). This not only degrades the life of the building, it is especially hard on the fixtures, brand new commercial grade toilets, taps and ovens, can become inoperable within months instead of years. Repairing so many faults means the bureaucracy becomes overwhelmed, creating maintenance interminable waiting times that can extend onward of years. The remoteness exacerbates this with unaccountable contractors and parts suppliers being located far from the problem. Poorly maintained housing is not only dangerous to its inhabitants it causes further dilapidation.

**Manage the assets better** - Currently, projects seem to be implemented piecemeal, with little
post completion analysis. (Ballie, 2007) This means that mistakes as well as successes are not identified and fed back into future initiatives. Introducing tracking of accountability and responsibility for good and bad outcomes means the process is constructive and self-improving.

**COMPLEXITY**
This is a complex problem. To start to tackle such a multifarious problem the design system must be able to tackle the design of a house at multiple scales. The traditional linear design system isn’t able to engage with the issues in this way. This paper proposes that to engage with a problem as complex as this, a new type of design system is required.

By re-designing the design process, the designer can engage with all of these issues and come up with some potential techniques and solutions that can address the problems that adversely affect the lives of clients. The case study is especially salient because Indigenous housing procurement is a process where architecture has historically played no role, due to perceived extravagance and cost, lack of engagement by the profession, and the absence of capability to tackle the problem at requisite scale and multiplicity.

**TECHNOLOGIES**

**Digital Interface** - Firstly, The paper will look at one of the main design issues: consultation. This paper proposes that the BIM model can be extended through an intuitive digital interface to collect more accurate design data and mobilize it directly into the BIM.

Basically, consultation in any form, is an interoperability issue. Stakeholders communicate with designers in different semantic languages. The parties rarely understand each other. A lot of valuable information is either lost in translation, or misunderstood. This is particularly salient when dealing with many Indigenous stakeholders. Designers are unlikely to speak the Indigenous spoken language or anything remotely like it, and their potentially disparate cultural backgrounds mean they can share few semantic understandings and ontologies.

Despite this challenge, consultation has been identified as an essential element in designing appropriate housing for Indigenous communities (Wild & Anderson, 2007). This is particularly important in communities where some of these idiosyncratic traditional cultural differences can greatly affect how communities use and relate to the built environment. Traditional kinship and avoidance systems can make western style socio-spatial organization the cause of community discord and domestic violence. Unfortunately, even under the best of circumstances, it is hard for Indigenous clients to get their voices heard and convey appropriate design instructions. (Lee, 2005) A general lack of respect and understanding by the government, along with a troubled history of governmental and community relations make this process especially difficult.

This proposed end-user interface is connected via data outputs to the BIM. It would be simple to use, be culturally appropriate, allow for flexibility yet be already constrained to the limitations of the project. These limitations can be set by environmental and climatic conditions, group cultural norms, and stakeholder requirements. An example would the minimum and maximum floor areas or the pre-determined orientation of buildings. The interface, running through a computer, or tablet could be adapted to each language group, even haptic devices like a physical models that transmit adjustments to the interface, or sensors recording movement could be utilized to create more appropriate and effective consultation.
The interface also holds a secondary, but important role in the process. It demonstrates to the user that their input and opinion is valued, and that their culture is considered and important in the process. This increases the likelihood that the house will be appreciated and respected. This goes a long way to not only repair a history of willful disinterest, but it also helps create a sense of ownership and pride of the home and a recognition of its connection and importance within the community.

Although there is a lot of focus on the interoperability issues within computer systems, which are difficult enough, the biggest interoperability issues are between human systems basically the person to person, culture to culture translation. Creating an interface that can efficiently translate design data and bridge this cultural gap is an important and essential step to improve the process.

**Parametric Design** - Parametric Design becomes the structure that allows the interface to deliver a controlled output. So, whilst consultation is important, the suppliers of the housing, usually the Federal Government, have their own set of requirements. Among these are perceived value for money, non-extravagance, cost effectiveness and design that is linked to results. Importantly though, there are a lot of design decisions that the Government as a funder, does or should not specify, nor even have an interest in. It is within these spaces that the parametric system really shines.

Working tightly with the interface, the data is extracted into the parameters that define and shape a complicated BIM model. The BIM model is a mix of predesigned components and design frameworks that are built up by the parametric data that is translated through spreadsheets and databases. With a few hours human work (and a fair chunk of scripted automation), a unique building, designed to consider all its stakeholders, as well as its context and environment, is modeled and ready for fabrication.

**BIM** - The BIM model is the gatekeeper of the information that is translated from consultation through to construction and maintenance. The BIM model becomes in a way its own intuitive interface, this time not for the user, but for the government. It is able to talk in the language of the bureaucracy, it can output massive amounts of data that can be used to account for everything that could conceivably be required. For example, costing at all stages of the project, identifying potential economies of scale, sharing of information across associated government departments, etc.

The BIM model also serves a very important role in facilities management, as inadequate maintenance one of the biggest contributors to negative health outcomes. (RAIA, 2008) BIM allows for maintenance to be managed systematically. It makes possible proactive risk management rather than management on failure. Additionally design and manufacturing faults/issues can be dealt with at scale, rather than individually.

Another benefit of BIM is that the model becomes an asset in itself. There is the aspiration to greater self determination in many communities, and BIM becomes essential in successfully handing over the infrastructure from the Federal to Indigenous governments, allowing them understand and manage the current status of their new assets.

Related to these two last benefits is the opportunity to scale the BIM model up another level, to that of a CIM Community Information Model. This allows the community’s building assets to be considered together or individually. This is important, particularly for govt. departments that need to disaggregate their assets and information into more manageable chunks.
**Digital Fabrication** - Supplying prefabricated housing to remote areas, usually invokes prefabricated sheds delivered on the back of a truck. The communities get delivered housing that is all the same, made from cheap industrial materials unsuitable for habitation (Memmott, 1988). No jobs are created and no one knows how to fix anything (Wild & Anderson, 2007).

Whilst this type of construction is undesirable, some prefabrication techniques still hold potential, particularly when the building is broken down into components, for example complete wall assemblies. Healthhabitat has had great success with its prefabricated wet areas (Pholeros, 2011). Prefabrication allows a balance between cost savings, expertise, simplification, maintainability, and local skill building. So, instead of producing a house out of thousands of small pieces, the project is broken down into manageable chunks. The construction system borrows techniques from the aircraft, shipbuilding and car industries where the parts become independent components that are assembled into the whole.

By looking at the construction of a building, from a manufacturing standpoint some of the big barriers to implementing good design in remote communities fall away. This breaking down of the complexity of construction into components has many benefits. It simplifies design, construction, project management, installation, and maintenance. Importantly, by coupling Computer Numerical Control (CNC) fabrication with parametric design, mass customization is enabled without additional cost or complexity.

Another benefit is the recyclability of building designs. Instead of designing buildings from scratch with a few recycled construction details, assemblies can be adjusted rather than recreated to suit the new conditions. This creates impressive efficiencies within the documentation stages of a project, that not only save time but as the model is constantly reviewed, tend towards documentation that is of better quality (and has less errors).

Also, when the building is broken into smaller assemblies, the job of on-site construction is simplified. Joining the assemblies to the frame becomes the main concern of the builder.

Traditionally, joining is what builders do but by using assemblies the scale is changed. So, instead of joining tens of thousands of components to assemble one building, the onsite builder now only has to concern them self with a few. The joining of a wall to a frame may be more complex than one piece of timber to another, but overall the benefits of reducing the overall site complexity is clear.

Another huge benefit of component-based systems is the ‘patchwork’ benefit illustrated in the book “refabricating Architecture” (Kieran & Timberlake 2004). Many assemblies can be assembled simultaneously, as the consequential ordering required of traditional construction is no longer a barrier. This simplifies and exponentially speeds up construction, particularly on site, where construction could now take weeks instead of months/years.

The component system also transforms maintenance. Indigenous housing projects are often extremely remote from urban centers. If something breaks down, a contractor often needs to travel extreme distances by private charter to assess the repair before they can decide what parts and tools they require. With a component system, whole assemblies can be shipped, to be swapped out with the faulty component. The faulty component can be returned for warranty claim or refurbished for the next repair. Depending on the repair, the labor could be done by previously trained community members who helped installing the assembly during initial construction. Additionally, as the environment can be very harsh many components and assemblies may quickly and unexpectedly become unfit for purpose. Alternatives may need to replace failing components. These could be swapped out on a large scale proactively, before.
POTENTIAL IMPLEMENTATION
As an example of how this system could be implemented in a community this paper suggests the following hypothetical case.
The interface is customized according to the particularities of a community chosen for a housing program. The interface customization would be informed in consultation with community members, community leaders, Govt. departments, and perhaps anthropologists, and construction consultants. The interface is also customized around the types of data required by the parametric model i.e. room widths, materials, fenestration etc.

At the same time as the interface is being customized, a general parametric BIM model is being adapted that considers more fixed concerns such as climatic, cyclonic, structural, and general cultural requirements, it also considers more particular potential design limitations that appear during consultation for the interface.

The community now has a generalized interface that can be individualized with a users personal information, and a BIM Model that meets the general housing requirements of the community.

An individual (or family) user is selected, personal details are loaded and the user is given access to the interface. At first a guided introduction built into the software familiarizes the user with how the interface works. Then the user is directed to a process that helps them choose a suitable site for construction. Considerations such as location of avoidance kin, spiritual places, humbug (noisy places), and community services allow the user to make an informed decision. Design consequences that may effect the user are clearly shown. Once the site is chosen a diagram using traditional iconography, blends with a 3d architectural representation of their house. The user can adjust the diagram so the plan better suits their needs, for example they may want traditional larger bedrooms for all the genders to sleep together, or they may want western nuclear style bedrooms. They may want the bedrooms separated from the living areas, so visitors are better separated. Any changes they make to the diagram by pulling and dragging the diagram affect the 3d building model in real-time. The geometric logic of the 3dModel in the interface, matches the logic of the parametric model, so the data extracted from the interface maps directly into the Parametric model. When the user is complete, any problems encountered are feed back into the system improving it for the next user.

The results are then sent to the parametric BIM model, that then updates the general model into a user’s personal 3d model with the data it requires. The data may be mix of information such as coordinates, measurements, spatial and programmatic hierarchies or even RGB values. A technician fine tunes the now individual model and once complete, fabrication data is delivered digitally to the fabricator for manufacturing. Construction elements are delivered, mostly prefabricated, and assembled onsite with the help of local community members. Any errors or issues in fabrication or construction are also fed back into the model and the process.

The BIM model is kept and becomes an important tool for maintaining the investment, and assessing its effectiveness and improving the design of future housing.

CONCLUSIONS
In conclusion, the combination and integration of the discussed technologies particularly the digital interface and mass customization allow the designer to engage effectively in the issues that were outlined above:
Build more houses - Prefabrication allows for faster construction, particularly at scale, the digital interface allows for a condensed, improved consultation phase.

Make houses cheaper - Prefabrication can be a cheaper alternative to standard construction in remote locations, the digital interface makes the consultation process much cheaper than the traditional techniques. Mass customization allows for design variation without additional cost when compared to traditional design.

Culturally appropriate design - Digital interface linked to catalog of parametric design options allows for truly differentiated housing outcomes that have built-in controls to encourage culturally appropriate design.

Design healthy, safe homes - By constraining the BIM model, healthy housing benchmarks are preserved. Proven safe design elements are preserved and replicated. Quality control is transparent and responsibilities documented. Prefabrication allows for quality inspection before construction is complete.

Maintainability - The BIM model facilitates risk planning and helps manage design and fit-out issues so that the maintenance is systematic, cost effective and efficient.

Manage the assets better - The information model is not only essential in managing individual buildings, to identify failures and successes, it can be expanded to manage the community assets and infrastructure at different scales.

A non-linear design system that utilizes this suite of new technologies, allows for new possibilities to emerge and the design process can encompass the scale and complexity of the many issues. By focusing alone on the consequential economic benefits of reduced social dysfunction, reduced health costs, and housing that doesn’t prematurely fall into disrepair, this proposal is clearly economically viable. Risk is also minimized as the design system is scalable. A pilot implementation could be attempted and effectiveness gauged before expanding the project, from a single test dwelling to the massive country-wide scale of the current SIHIP program.

Using these technologies independently could certainly alleviate some of the problems, but when used together, they can achieve much more. The combination facilitates an open, fluid system that creates better, safer housing for the user and more transparent, cost effective, and predictable outcomes for the government.

ACKNOWLEDGMENTS
Parts of this paper were prepared for an MDesS independent study module in Spring 2012 with Andrew Witt, Director of Research at Gehry Technologies.

REFERENCES


