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Videogame Technology Re-Purposed: Towards Interdisciplinary Design Environments for Engineering and Architecture

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Abstract

The author and associated researchers have in previous projects adapted videogame technology for design in the context of architectural design education. This paper reflects on this body of research: the original motivations and aspirations; what threads may be productively revisited; how contemporary shifts to parametric design and building information modelling may be incorporated; and considers how some aspects of game play, in particular competition, may seed Interdisciplinary Design environments for Engineering and Architecture (IDeEA).

Keywords: architecture and design engineering education, simulation environments, videogame technology, serious games.

1. Introduction

Architectural design researchers have been appropriating videogame engines for some years as a low cost form of virtual reality in order to create simulations of design proposals. While it is difficult to pinpoint the start of the experiments, the first high profile use is reported at Cambridge University, where the Quake engine was utilised for architectural visualisation in the late 1990’s. The use of Quake and subsequent engines such as Half Life and Unreal occurred throughout many institutions in the following decade. The adaption of videogame technology for design continues with next generation technology such as Cryengine and Unity [1]. Our interest was with the use of multiplayer game engines to support what are known as Collaborative Virtual Environments (CVE), in which the
technology facilitated virtual design studios. This approach allows a form of design collaboration known as “designing within the design” [2] where communication between collaborators and critics occurs within the emerging architectural form and simulated environment. Our use of video game engines for these purposes tailed off around 2006 for various reasons, including commercial design software adopting features such as real-time visualization, thus negating some of the advantages of videogame technology. Recently we have been re-examining the potential of videogame technology in the light of contemporary shifts to interdisciplinary collaboration and the uptake of parametric design within both architecture and engineering.

The paper is structured around three sections. In the first the original rationale of using a multiplayer game engine is summarized and discussed in relation to the contemporary uptake of parametric design and building information modelling. The review does not identify particular software attributes, but attempts to identify the relative strengths from a designer’s perspective and with a focus on the early stages of design. A second section addresses an alternative approach informed by serious games and aligned with what has been termed ‘communitition’, where game mechanics are used to foster collaborative design innovation. A concluding section outlines an approach to interdisciplinary design education for architecture and engineering that builds on previous research and the shift to parametric design, while exploiting aspects of game play to foster engagement of students.

2. Videogame technology, collaborative virtual environments, BIM, and parametric design

We have reported elsewhere key points of advantage in the use of a CVE, in comparison to typical software used in architectural design education [3]. In summary these are:

- **Design iterations.** Fluency of editing in real time, and the subsequent scope to make changes up to the last minute encouraged experimentation similar to the mark - interpret - mark cycle of sketching by hand.
- **Sound as notation.** Sound was an effective way to communicate intent in terms of spatial characteristics or materiality, and to convey a sense of occupation and functional use.
- **Context over object.** The ability to explore projects in real time reinforced the importance of context, and challenged object based thinking where architecture is conceived as geometry devoid of occupation.
- **Participatory critique.** Reviewers can actively explore the design, rather than the passive observation of pre-rendered animations.

There were also some significant problems encountered, which included:

- **Model size constraints.**
- **Specialist technical skills required to create convincing real-time models and contexts.**
- **Poor file interoperability between typical design software and videogame authoring environments.**
- **When the novelty of working in ‘game space’ wore off, we found students were less engaged.**

2.1. Review in relation to contemporary advances in design software

Ten years ago we argued an application based on a multiplayer game engine can be positioned between the high end visualization capabilities of VR, and the high dimensional accuracy of 3D CAD. While a game engine CVE can be seen as ‘budget’ VR, it is arguable that full immersion and highly detailed representations is a hindrance to collaboration and design thinking, particularly at the early formative design stages. Therefore we proposed that the most suitable use of game engine-based virtual environment is during the early design stages, where a relatively low level of detail and a shared experience are conducive to creative thinking. As we are considering revisiting collaborative virtual environments for interdisciplinary design, the above rationale for positioning a game engine based CVE can be revisited in the light of contemporary advances in design software and practice. In this regard, the most significant shifts are the uptake of Building Information Modelling (BIM) and the development of parametric and generative design software. Both of these technical developments are aligned with shifts in design practice and strategy: BIM enhances collaboration between architecture and engineering disciplines; while thinking explicitly in terms of design parameters, shifts activity from discrete design modelling to that of developing multiple design iterations from a generic model. While the focus of the review will be in relation to architectural design, some reference will be made to parallel developments in design engineering technology.
2.2. Building information modelling...enhanced by a game engine

The concept of a 3D model where material, performance and cost information are associated with geometric components has been around at least since the 1970’s. Over the last 10 years software development and uptake in industry has accelerated, not least due to BIM being mandated by the US and UK governments for public funded buildings. While in theory 3D BIM modelling can occur at the very early stages of design, the reality is that BIM is used primarily in the detailed design and construction phases. This enables project management and coordination between architects and engineers, including the capacity for environmental performance simulation. In effect, BIM is networked 3D CAD and it would appear the comparisons with a game engine CVE and 3D CAD still stand. The fluid semi-immersive environment of a CVE enabled iterative design and evaluation in a quasi-realistic context, while typically BIM has been relatively pedestrian and orientated to detailed design and production after the major design decisions have been made. There has been experimentation with exporting BIM models to game engines [4] and a recent new product (Fuzor) provides a bi-directional link between the industry leading software Revit and a videogame like real time visualization environment [5]. This includes many of the features we developed in our earlier research and potentially is an off-the shelf option for architectural / engineering collaborative design studios (at present the educational pricing is prohibitive). Fuzor includes structural, mechanical and electrical design, real time lighting visualization, clash detection, rain simulation and enables design components to be annotated for collaboration purposes.

This recent link from a leading BIM technology to a commercial virtual environment is a positive step to enabling some of the advantages we had identified in our earlier research with re-purposed videogame environments. What is increasingly clear is that the shared 3D modelling and simulation enabled by BIM will require architecture and engineering consultants to work much more closely together. At present most collaboration and simulation feedback on design performance occurs at the detailed design stage. However as there is much to be gained by performance simulation when a range of conceptual design options are being considered, we can anticipate closer collaboration at the early design stages. This in turn suggests much closer collaboration will be required between engineering and architecture in academia. Typically this does not occur in any significant way for various reasons, not the least the pragmatics of class sizes and physical separation. One way to address some of these issues is through virtual design studios undertaken online and this is where real time environments (such as Fuzor), potentially provide an engaging technology in which architectural design, design engineering and performance simulation can be undertaken concurrently.

2.3. Parametric design technology at multiple scales

While the underpinning concepts of parametric design have also being long established, the last ten years has seen an acceleration in software development and uptake in academia and industry. What is commonly referred to as parametric design is more correctly described as associative geometry. Each component or assembly in a parametric model is linked such that when changes are made to one component of the model, any required changes to other associated geometric elements are automatically propagated. This enables a highly interactive design process where multiple design options can be extracted from the one generic model. In architecture the majority of design software has always had the capacity to create parametric library parts, and the two leading 3D BIM modellers (Revit and ArchiCAD) have inbuilt associative geometry capacity. Much of the hype around ‘parametric design’ in architecture is due to the huge uptake in a spline geometry 3D modeller that incorporates a graphic programming interface (Rhino/Grasshopper) [6]. This enables highly complex arrangements of curvilinear associative geometry to be quickly generated and updated. Besides the now waning interest in curvilinear geometry, the key to the popularity is the graphic programming environment. Programming in architectural design has had a 40 year history in architectural research, but the skills required proved a barrier for most designers, who typically do not have an aptitude for scripting [7]. Graphic programming interfaces such as Grasshopper allow designers to work in a more direct mode, adjusting parameters through sliders and getting immediate visual feedback. The geometry can also be mapped to data sets, thus allowing variables such as sun angles or wind data to be used to influence form generation. While architectural designers have always considered multiple performance aspects, the capacity to interact directly with environmental and other parameters is potentially one of the more significant shifts in design activity. Researchers are exploring ways to link environmental and other functional data with parametric design at the early
stages of design [8], and in some case experimenting with generative algorithms to produce optimal design configurations [9].

Design engineering, product and industrial design have also engaged with parametric design, both with Rhino / Grasshopper and with design software such as SolidWorks. The advent of additive manufacturing and the proliferation of 3D printing have amplified the potential impact of parametric design, particularly in relation to small scale products. ‘Middleware’ companies such as Digital Forming [10] are already realizing mass customization via web based design interfaces linked to 3D printing on demand. At present such mass customisation design and manufacture interfaces are limited to a certain scale, but it would be expected larger scale 3D printing technology will develop. The paradigm of web based products based on parametric design and distributed manufacture can be scaled up and combine a range of manufacturing process, but this is likely to require a number of components that can be easily assembled by end users. As exemplified by Ikea, it is worth noting that the uptake of self-assembly products is as much to do with simple jointing systems and assembly, as the design of the end product [11].

Mass customization via parametric design is, to a degree, also available at the building scale, although this is typically more constrained in terms of variability. Prefabrication and web based design interfaces, extend the tradition of the adaptable design catalogue typically used by volume house builders. See for example, the Flatpakhouse Company, where an 8’ wide wall module with 16 cladding / window options can be ordered in unlimited single floor design configurations and up to 4 levels high [12]. The company uses the internet for layout, but typically clients interact with a designer who advise through the process. This modular approach still requires fabrication in a factory and the use of the company’s assembly team to construct the house. An alternate approach based on the availability of portable steel forming machines, shifts the process from modular prefabrication to onsite factory. See for example Scottsdale Construction Systems who provide design software (including structural engineering and truss design), roll forming software, and a range of steel roll forming machines, all of which can be configured as a mobile factory and shipped to site in a container [13]. The accuracy of manufacture and interlocking jointing enables quick assembly by a semi-skilled labour force, has led to many applications in developing countries.

3. From game technology to game play

The above overview of the uptake of BIM and parametric design captures some significant changes since our early research in using videogame environments for design education. In terms of visualization and simulation, the trend is towards the two-way interchange between commercial software and real time ‘videogame like’ environments, which simplify the procedure for producing realistic models and contexts. This directly addresses one of the stumbling blocks with our previous research, where the workflow was complex and typically required significant new skill acquisition. While this is encouraging, some of the aspects that our research located are overlooked: such as spatialized sound to convey material qualities and functional occupation; and the problem of engagement, once the novelty of using game-like design software wears off. While technical requirements are likely to be addressed, student engagement in an interdisciplinary learning environment is perhaps the most challenging. One tactic for addressing engagement between students and academics from separate disciplines may lie in the origins of the technology – gameplay.

The use of game mechanics for education and learning known as serious games, has emerged over several years and has proved effective in many contexts [14], but has had minimal uptake in architecture: Coyne has explored a theoretical basis for how the characteristics of computer games align with design activity in terms of repetition and variation [15]; while Woodbury et al have used game metaphors to encourage form exploration for architecture [16]. There has been more experimentation with serious games in engineering [17], while Kosmadoudi et al have undertaken an extensive review of games that enhance learning CAD [18]. However in this preliminary review, there is minimal activity that that has explored the interdisciplinary context of engineering and architecture. There is also minimal evidence of architecture or engineering researchers who foreground competition, one of the fundamental characteristics of a game. The emphasis, as with most other serious game case studies in education, has been on providing game-like environments that emphasize collaboration that generally avoids explicit competition.

Outside education and in relation to a parallel field of research on collective intelligence, the capacity for competition to enhance innovation in design has recently emerged. This alternate to the consensus model of collective intelligence as applied to collaborative design, is that of explicit competition within a shared environment. As an example, the lighting company Osram leveraged the collective intelligence of online communities to develop and refine a range of designs. Social network analysis of the Osram competition reveal there is a correlation between
highly competitive behaviour (with a degree of collaboration) and innovative design. Hutter et al capture this mode of competitive, but communal design activity through the term ‘communtition’. The insight from this study reveals that “while competition reduces collaboration, it also spurs community members’ interest in innovation activities” [19]. The Osram study reveals that been able to track other design development and communicate while competing, was an essential factor in successful innovation. Reflecting on the Osram results, we have undertaken a pilot study of communitation in the context of architectural design in which six designers were presented with a ‘kit of parts’ and employed both quantitative and qualitative scoring criteria, in an open competitive environment. This has been reported elsewhere [20]. In summary an analysis has resulted in the following key observations on the pilot study.

- The kit of parts fulfils its role of both a limiting resource and a motor for innovative use and reuse.
- An intuitive interface in combination with challenging tasks is an activity that is engaging.
- Access to other ‘competitors’ designs stimulates further design iteration.
- Seeing micro problem solving as a series of design puzzles enables a productive design flow.

4. Towards interdisciplinary design environments that embed game mechanics

While the above pilot study shows some promise in relation to a significant problem identified in our earlier research (that of maintaining student engagement), it does not address one of the key issues that has emerged over the last decade - the need for an interdisciplinary approach to sustainable design. As identified above, in terms of design practice there is a shift towards performance simulation (BIM) and parametric design process across both architecture and design engineering. These mark significant changes in (a) the requirement for interdisciplinary collaboration, including the crucial early stages of design and (b) design process. Designs are being tuned from multiple design parameters with an emphasis on environmental, functional and material performance. While this has always been the case to varying degrees, the explicit manipulation of design parameters to generate multiple design solutions removes the lingering modernistic notion of the individual creative ‘genius’. Rather than creating ‘something from nothing’ the emphasis is on the capacity to edit and tune the best design from parametric models that embed performance feedback. The solitary designer is a dinosaur in a 21st century landscape where the design challenges are inherently complex and interconnected. Conceiving design in terms of dynamic variables that cross disciplinary boundaries provides an alternate paradigm. This requires a significant shift in design education and the development of new process, technology and skills aligned with both parametric design and information modelling. To this end, Figure 1 locates an alternate approach to the use of game engines to support collaborative design education at the early stages of design. This builds on the previous research outlined above and the shift to parametric design, while exploiting aspects of gameplay - in particular competition.

The simulation environment is conceived as self-contained with parametric design geometry linked to simulation components, which can give feedback on quantitative parameters (e.g. environmental performance, structural integrity, cost). These would be updated through real time ‘scoring’, so the impact of design decisions can immediately be evaluated against other design iterations. Complementing this would be qualitative criteria (e.g. elegance, originality, marketability) that would be scored by reviewers and /or potential users. Each design would be
stored in a repository and available to be viewed and used as the genesis for iterating alternate, better performing solutions. Design could occur in single player mode where the student would role-play the various disciplines or involve interdisciplinary teams of students. As well as competition, other gameplay mechanics could be incorporated such as leaderboards and ‘levelling up’ to more difficult design scenarios. This ‘design play’ environment is intended for the early sketch stages as a primer to seed collaboration, which can be extended to more developed design scenarios including the use of BIM, virtual and physical prototyping (Figure 2).

Figure 2: Interdisciplinary Design environments for Engineering and Architecture (IDeEA)

In summary, it is proposed that advances in both technology and practice require paradigm shifts in education for architecture and design engineering disciplines. As one way to begin, video game engines provide both an underlying technology and a mode of engagement that may be productively explored to support interdisciplinary education, particularly where students and staff are not co-located. As indicated in Figure 2 the 4D sketch design game environment is part of a range of Interdisciplinary Design environments for Engineering and Architecture (IDeEA) that span sketch design, developed design undertaken in sync with virtual prototyping, through to physical prototyping. This transition from sketch design games to detailed design and prototyping is intended to scaffold skills and help to build working relationships between engineering and architecture students. Throughout IDeEA, the emerging designs are reviewed against a full range of quantitative and qualitative parameters, enabling complex and sometimes competing design aspirations to be communicated and evaluated.

In order to progress IDeEA this preliminary overview needs to be extended to a full literature and project review, relevant technology in which to undertake further pilot studies needs to be identified, and larger scale case studies planned, implemented and evaluated for a range of design scenarios.

References


