Harmonizing interoperability - Emergent serious gaming in playful stochastic CAD environments

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Abstract. Computer-Aided Design (CAD) applications often promote memorable experiences for the wrong reasons. Coupled with complex functionality and poor user experience the learning curve is often steep and overwhelming. Invoking design creativity remains limited to conveying established geometry. Gameplay conversely excels in memorable and formative experiences and could spur intuition and natural creativity. If games are profoundly imbued for purposeful play, thriving on tacit and explicit user knowledge, a CAD system carefully stylized with ludic mechanisms could potentially be highly productive. An emergent serious game (SG) and CAD system may then hold promise. Preliminary feedbacks suggest a game-CAD environment incorporating interoperable mechanisms of CAD and SG systems to exchange creation improves user interactions resulting in better evolution of the workflow. The emerging scenarios presented reports a transformative approach to understanding of relationships in CAD use, learning and play mechanisms that enhance creativity and innovation.

1 Introduction

Product design is a complex set of activities beset not only by the limiting enablers but also by the unwitting impact of mediocre designs. Small errors in the early design phases may not be apparent until it becomes too late. Consequently, co-design ideation spaces, where product ideation is first developed and designs made become central to the development cycle, innovation and creativity [1, 2]. Ideation is the "ability one has to conceive, or recognize through the act of insight, useful ideas" [3]. However, current CAD systems (enabler) are governed by rigid rules and predetermined "canonical" procedures that limit user/designer creativity.

Gaming, though, has extended beyond its natural boundary of entertainment and is now associated with the process of problem solving and even questioning of scientific viewpoints through active game-play. The rules of game interaction or game mechanics include the concepts of usability and playability which are focused in a less stringent environment which provides a more intuitive user experience (UX). The transition from masses to user centered design paradigms sees engineering creativity being compromised. One reason is that the problem-solution space is challenging, a complex balance between representation, generation, and search of a design space in pursuit of original design solutions.

This paper presents the notion of playful CAD environments as a transformation technology to address current drawbacks such as complex menus, limited interactive assistance during the design task, informal conceptual design tool and the fixation on design routines that stifle users' creativity and intuitive notions.

2 The CAD-Game Conundrum

Research has showed that CAD users spend more time in learning the CAD system than actually using it [4]. The most important challenges facing novices are: the ease of learning, memorization and error-free use. The hypothesis is that such skills can be acquired much faster by experiencing product design in a gaming world. User experience and "interactional intention" are fundamental in design process; however, they are not easy to formalize in standard CAD systems. Games though provide enhanced cues and/or error notification instantaneously. This contrasts with CAD where users themselves judge errors.

A game is an abstract control system [5] where state-change during play and progress are controlled by rules [6]. In comparison, CAD (e.g. SolidWorks, Catia, ProE) operates via variations of sets of parametric functions. This approach creates a gap between the user and the CAD system where user experience, learning threshold, system functionality, performance and productivity are directly influenced and constrained (Fig. 1a). Design tasks instead become one of finding alternative event structures. Not surprisingly engineers' perception and UX have been compromised by the system's functionality and step-by-step evolution (for example the function structures of Pahl & Beitz) [7].) In "Digital Natives, Digital Immigrants" [8], Marc Prensky cites a case where mechanical engineers learned CAD software by playing an FPS-like game called "The Monkey Wrench Conspiracy." Then, perhaps enriching CAD environments by applying gaming techniques and mechanisms may improve the efficacy of design and productivity while enhancing user experience (memorable and formative). Digital gaming systems are complex and comprise interactive technologies, media, and simulation technologies [9], often with a story/plot. Games could provide a context for creativity coupled with challenges ranging from decision-making and problem solving strategies through to action reflexes [10].

A game architecture can be approached using the tetrad of Schell [11]: aesthetics, mechanics, technology and storytelling. However, as Church [12] cites, "The design is the game; without it you would have a CD full of data but no experience." Games and their design approach are different compared to traditional design and productivity domains such as CAD. Games actively encourage a variety of experiences while CAD strives for consistency at all times. Design is often viewed as a transformation from function to form, while the process of synthesis is the creation of a form that meets functional requirements. To create a synthetic CAD-game eco-system both game design and design synthesis methods must be extrapolated to allow metacognition to be triggered and enhanced through enriched visualization of the design/process flow.

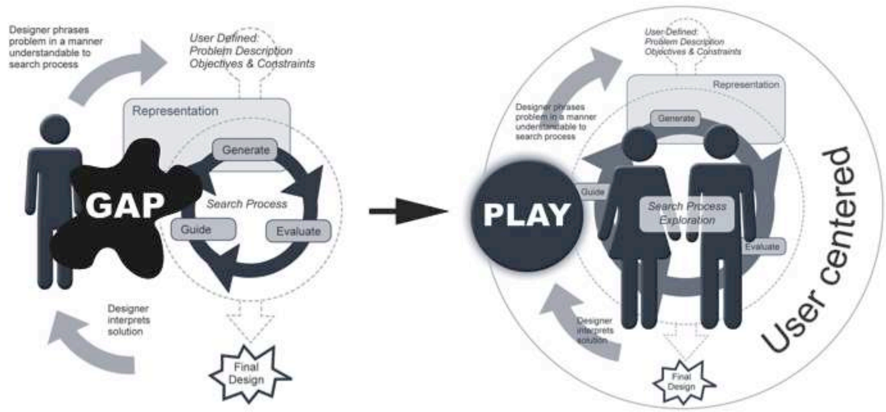

Fig. 1. (a) Identification of gaps in user experience in CAD systems [18]. (b) User centered playground with stochastic CAD eco-system.

3 User centered playground with stochastic CAD eco-system

A design solution space is always infinite and includes past, present, and future design states. If this space is describable to a computational game-based eco-system, then the challenge is to effectively find, search, and explore the solutions that best meet the demands of the design problem. A game-like environment has the potential to directly and positively reinforce the user experience and its creativity, as well as enhance new insights in understanding and learning. This design solution space enables the challenging task to target the problem definition in direct assimilation with the possible solutions that are emulated and represented by the CAD-Game System (CGS) (Fig. 1b).

Furthermore, the CAD-Game System could introduce some randomness in finding neighboring solutions preventing to become trapped in a local neighborhood. The CGS nudges (Fig. 2) the CAD-players to keep on creatively tracking and backtracking to iterate and re-iterate in the design solution process to provide more than one final design outcome. The general consensus is that bringing product design as CAD play and SG mechanisms/concepts together is fundamental to the future development of next generation intuitive design environments.

4 CAD-Game for enhanced creativity and motivational design

A game is an effective and engaging environment that is accessible anywhere, at any time, on demand, at your leisure and to your liking. Game playing offers learners motivation for acquiring new skills and/or to enhance the current skill-sets to improve individual capabilities [4, 13]. Games can be a cost-effective solution (savings) to support just-in-time ideation and/or creative design with periodic or continuous feedback. The ubiquity of games thus provides rich resource for improvement and adaptation in contextualized environments to communicate design. Since communication is a critical component of any design process, it fundaments the premise of using a game-infrastructure for CAD in support of users.

Some games are very difficult to play, not least to master. The demands for the user(s) are based on a serendipitous combination of skills (i.e. awareness, hand-eye coordination, tacit knowledge, creative cognition, etc.). The various levels of complexity and challenges are dominant features of game environments and are interoperable with CAD Game Eco-systems.

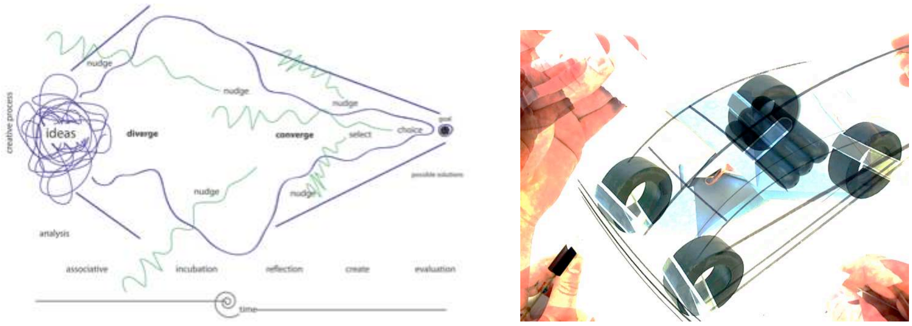

Fig. 2. (a) Scenario for Game-based CAD [16]. (b) Possible collaborative interactive solutions.

Koestler's [14, 16] view of creativity considers the externalization during the early stage of the design process, wherein the ideational concepts stemming from the mind's eye (inner visions), metacognitive aspects, imagination, mental divisions and distractions are transformed and represented. Design intents are fused together to create content through this in the creative act. The creative act initiates with a complete and boundary-less attitude towards inner and outer space. As with state changes in game play a current design state and context has no bearing until a cognitive nudge (Fig. 2) forms a solid representation. From this point on the challenge is to complete the design task at hand by bringing possible conclusions with iterative solutions. To paraphrase Dalcher [15] we concur that design is neither orderly nor linear; it implies a continuous and active search to resolve trade-offs and satisfying constraints.

Initial CGS research [16, 17] in Fig. 2 and 3 show how the creative human capability (imagination and inspiration) and capacity to playfully collaborate in design processing coincide with the intuitive natural human ability to interact, communicate and challenge conventional thinking.

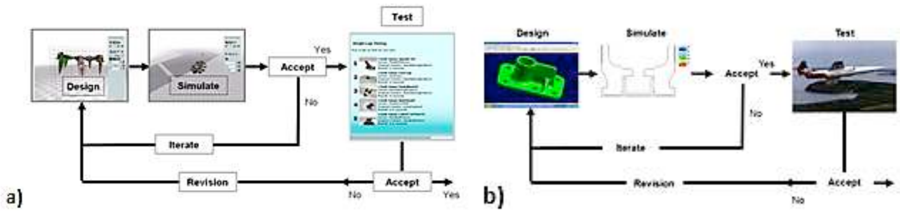

Fig. 3. Comparative game-CAD design and simulation scenarios [17]. (a) CAD-game. (b) Conventional CAD.

When a CAD system is designed to accept input with the user defining the rules in comparison with the game system, is it possible for the game UX to be transferred to fit a CAD system? If so, could gaming make the user design process in CAD more interactive and meaningful? Many studies providing a useful list of game-relevant issues and cognitive models that aid the understanding of the outcome of the experience [18, 19] yet none has been able to evaluate which game mechanics or set of game mechanics cause engagement with a system. There is lack of statistical models to evaluate whether engaging and enjoyable interactions have taken place and under which specific game mechanics.

5 Implemented Playful CAD Environments

To establish a trace about the usefulness of a CAD-game environment and UX, a study with industrial stakeholders were asked to optimize the design of an existing bracket to meet an engineering product design specification. As part of this activity participants used a parametric CAD design system [20].

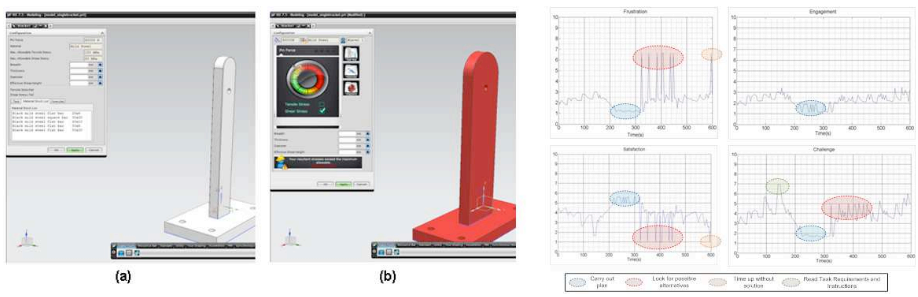

Fig. 4. UI of Bracket Design Experiment. (a) Conventional UI/CADT. (b) Game-like UI/CADG. (c) Affect response of design task in CAD-game environment [20].

Each session comprises two different user interface (UI) settings (Fig. 4a and b) with no time restriction for task completion. Analyzing the psycho-physiological signals and action data, an interaction model was established identifying which of the proposed game mechanics contributed the most to enhance the user experience and to relay gain and winnings to the user's efforts (rewards & achievements). The affective response (Fig. 4c) indicated a clear preference of CGS over conventional CAD.

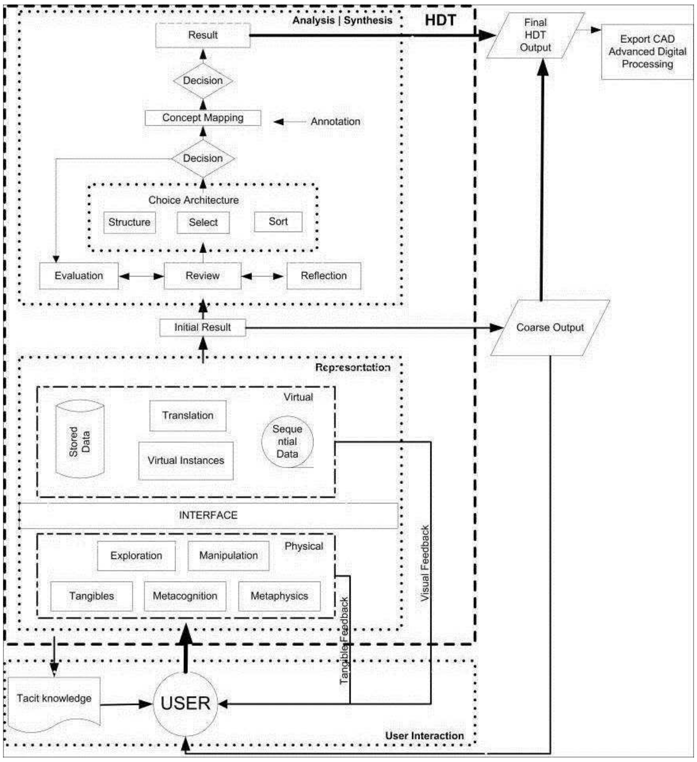

Fig. 5. Flow diagram of user-centered hybrid CAD environment embedded with fuzzy and logic mode [16].

The approach towards a boundary free Playful CAD environment to author and build hybrid design tools is to create blended virtual environments (Fig. 5). Designers are tethered to virtual digital realities where tools are developed and designed by system engineers and software programmers. It is apparent that loss of control, manual dexterity and intuitive interactions surface as a result of this mismatch [21]. Virtual reality environments are also eluding, and to paraphrase Lanier [22], users are reduced to conforming to the system rather than demanding the system be adaptive.

Meta-cognitive aspects, creativity and intuitive user interactions are measurable. By observing the creation of mental models of objects (representation) and design creation (generation), an analysis of how well an iterative outcome (solutions) meets the design goals and constraints (evaluation) can be understood [23]. Feedback on improvements to the design for the next iterative sequences (performance feedback & status) provides further subjective and objective groundings (Fig.6).

Emergent progressions towards such environments have already been conducted to investigate how game mechanics are implemented in CAD UI and how a new model with psychological relationships (engagement) mapped to the user interactivity with a system (user actions), can provide an insight in the metrics of specified game mechanisms progress in a system [20].

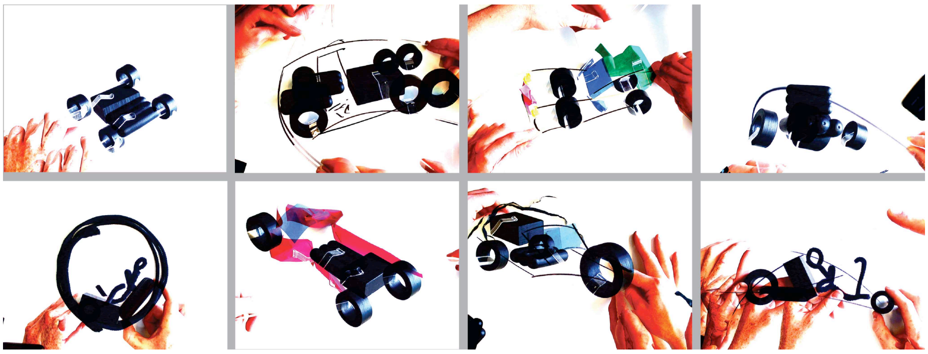

Fig. 6. Representation and generative content [16, 21].

A preliminary study [20] conducted involved users divided in two groups - A & B - designing both in the game-like environment of BAMZOOKi and the commercial CAD package of Solid Edge V20 (Fig. 7a). Group A designed a given task from a CAD perspective, focusing in the exact dimensions of the task. Group B designed a given task from a game perspective, focusing in the successful simulation of the task. The psycho-physiological measurements (EEG and GSR) of both groups were recorded, through physiological monitoring and feedback device. The results showed there was a positive response of the users whose design interface was embedded with a game element. Especially the stress levels (GSR) and the creativity levels, which can be seen with an increase of theta waves (EEG), differed from the users who designed a task without the game element and who didn't show any significant changes in their emotional responses (Fig. 7b).

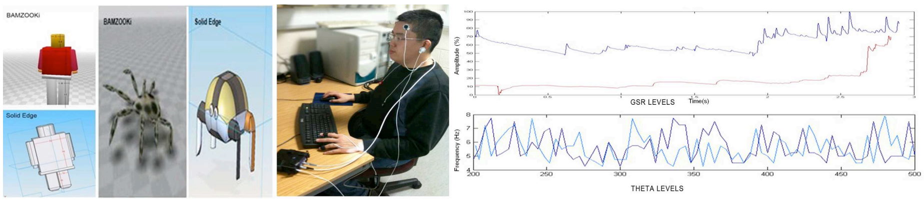

Fig. 7. (a) Design parameters: CAD-game vs. conventional CAD. (b) Behavioral and neurophysiological response in CAD-game and conventional CAD [20].

Design apart, assembly activity represents over 60% of the manufacturing costs therefore a system whereby engineers can build mental models for assembly planning in VE could be beneficial for the conceptualization/ideation stage and the products' competitive route to market. In this respect it is important to meet the requirements of design for manufacturing and assembly (DFMA) [24], Fig. 8.

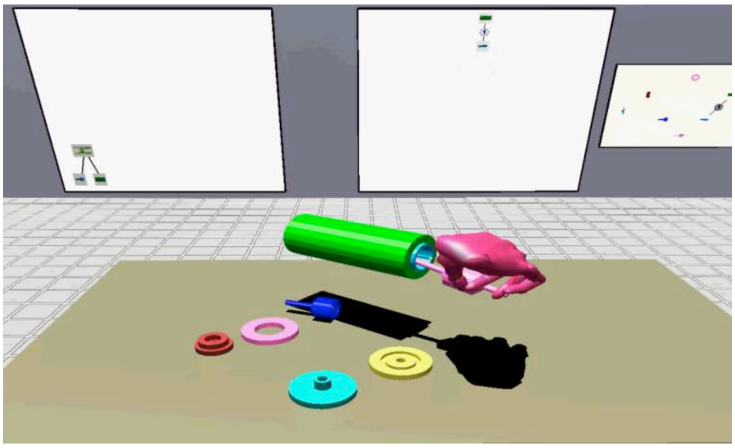

Fig. 8. Assemblability testing and generation of assembly plans in virtual environments [24].

The integration of sensory feedback, such as haptics and audio, has already shown to enhance user performance [25]. However, there is limited reported research that includes SG in virtual assembly environment [26]. The generation of assembly sequence is a task that requires building mental models to develop strategies necessary to obtain not only feasible assembly sequence but also the most feasible sequence or optimum assembly sequence. The potential of including SG in assembly design and planning would provide important assistance to the operator in making decisions on which part should be assembled first in order to build the product. Operation sequencing via assembly trials for which the operator get notified about his performance with reference to the optimum assembly plan could enhance his skills by building mental models of assembly operations.

6 Conclusions

For CGS, as with the design and development of SG, it is important to integrate the game aspects into the CAD Eco-system, i.e. supporting the co-creative product development process; this will contribute to a stimulated and improved user-experience. Employing game mechanisms as pointed out above in conjunction with a multi-disciplinary and cross-domain approach can create an enriched stochastic design space. Contextual knowledge and content developed using a CGS would document and present to users an immediate insight to understanding the design process in a superfluous and engaging way. This means users acquire a full understanding, have real-time access to data, get instant-rewards and rich iterative content for future ideation and work.

Initial implementation and testing the usefulness of experimental CGS environments have been conducted. The measures of meta-cognitive aspects, creativity and intuitive user interaction indicate the benefits of CGS in terms of gaining user experience.

The results of research in CGS have also revealed many emergent issues and challenges. These manifest in many different forms and areas across the domains of SG and CAD. The rapid technological change impacts on users and influences perceptions of uptake. Sustainable adaptation of SG and CAD development requires further insights of the dynamic and synthetic mechanisms to avoid functional redundancies. Awareness and adoption of CGSs within industrial environments continues to be limited, and actions need to be taken to reveal the benefits of a CGS oriented approach not only in industry but also in education.

Interoperability is fundamental to CGS deployment. The transition from process base to knowledge embedment in engineered products mean industries now require formats to unobtrusively capture and externalize knowledge for reuse [27, 28]. However, a means of evaluating design quality, engineers' confidence levels and solution integrity is not trivial.

The research presented herein show promise and evidence that SG in CAD supports this direction.

Acknowledgments

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