Supporting Collective Intelligence for Design in Virtual Worlds: A Case Study of Lego Universe

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Abstract. This paper analyses virtual worlds with reference to the technological facets that can support of collective intelligence in design. These include graphical simulation tools, communication, design and modelling tools, artificial intelligence, network structure, persistent object-oriented infrastructure, economy, governance and user presence and interaction [1]. Recent studies [2] and applications [3, 4] have shown that the combination of design, modelling and

1. Using virtual worlds to achieve collective intelligence in design

Virtual worlds are complex, multi-faceted technologies. Facets of virtual worlds include graphical simulation tools, communication, design and modelling tools, artificial intelligence, network structure, persistent object-oriented infrastructure, economy, governance and user presence and interaction [1]. Recent studies [2] and applications [3, 4] have shown that the combination of design, modelling and
communication tools, and artificial intelligence in virtual worlds makes them suitable platforms for supporting collaborative design, including human-human collaboration and human-computer co-creativity. Virtual worlds are also coming to be recognised as a platform for collective intelligence [5], a form of group intelligence that emerges from collaboration and competition among large numbers of individuals. Because of the close relationship between design, communication and virtual world technologies, there appears a strong possibility of using virtual worlds to harness collective intelligence for supporting upcoming "design challenges on a much larger scale as we become an increasingly global and technological society" [6], beyond the current support for small-scale collaborative design teams.

Collaborative design is relatively well studied and is characterised by small-scale, carefully structured design teams, usually comprising design professionals with a good understanding of the design task at hand. All team members are generally motivated and have the skills required to structure the shared solution space and to complete the design task. In contrast, collective design [6] is characterised by a very large number of participants ranging from professional designers to design novices, who may need to be motivated to participate, whose contributions may not be directly utilised for design purposes, and who may need to learn some or all of the skills required to complete the task. Thus, the facets of virtual worlds required to support collective design differ from those required to support collaborative design. Specifically, in addition to design, communication and artificial intelligence tools, various interpretive, mapping and educational tools together with appropriate motivational and reward systems may be required to inform, teach and motivate virtual world users to contribute and direct their inputs to desired design purposes. Many of these world facets are well understood by computer game developers, as level systems, quests or plot and achievement/reward systems. This suggests the possibility of drawing on computer gaming technologies as a basis for harnessing collective intelligence in design.

Existing virtual worlds that permit open-ended design – such as Second Life and There – are not specifically game worlds as they do not have extensive level, quest and reward systems in the same way as game worlds like World of Warcraft or Ultima Online. As such, while Second Life and There demonstrate emergent design, they do not have the game-specific facets that focus users towards solving specific problems required for harnessing collective intelligence. However, a new massively multiplayer virtual world, Lego Universe¹, combines open-ended design tools with levels, quests and achievement systems. This world is an interesting study from the design perspective.

¹ www.legouniverse.com
This paper analyses virtual worlds with reference to the technological facets that can contribute to the support of collective intelligence in design. We then discuss how these facets support the design, communication, motivational and educational requirements of collective intelligence applications. We argue that there is a mapping between game elements – such as level systems, quests or plot and achievement/reward systems – and the requirements to achieve collective intelligence in design. The paper concludes with a case study of the Lego Universe multiplayer online game. We evaluate, with reference to our newly defined technology spaces, the potential of this or similar tools to move design beyond the individual and small-scale professional design teams to harness large-scale collective intelligence through mass participation. We also consider the types of design tasks that might best be addressed in this manner.

2. Facets of multiuser virtual worlds

Multiuser virtual worlds are computer-based, networked, simulated environments. Various virtual worlds exist that simulate realistic or entirely fictional environments. Users inhabit and interact with virtual worlds using avatars. Depending on the virtual world, users can use their avatars to interact with each other or with the environment that may be made up of the terrain, landscape and ambient elements, artefacts such as building elements and furniture, and computer-controlled avatars.

From a collaborative design perspective, the compelling features of virtual worlds are the online social experience and the capacity for users to design and model without being physically co-located. This may include designing terrain, buildings, rooms, furniture, avatars, clothing or other artefacts. The support for collaborative creativity offered by multiuser virtual worlds forms a foundation for their support of design activities. However, other facets of virtual worlds that can be considered to broaden their application include their graphics technology, network structure, persistence, theme, communication tools, design tools, artificial intelligence, economy, user representation and governance. These facets differentiate multiuser virtual worlds from computer-aided design (CAD) tools such as Maya, 3D Studio Max, AutoCAD and Revit which place the most focus on the graphics technology and design tools facets and little or no focus on facets such as communication, artificial intelligence, economy and governance.

Table 1 presents thirteen facets of multiuser virtual worlds relevant to collective intelligence and design, and compares virtual worlds and CAD software through these facets. We draw on literature from both the virtual world community [1] and the design community [2] to construct this list. It is apparent from Table 1 that CAD tools alone are insufficient for the emergence of collective intelligence as most of them do not yet support a massively multiuser shared
representation for design. There are also no explicit internalized representations of design tasks or rewards/motivation for achieving those tasks in traditional CAD software. These are areas that can be addressed using gaming technologies.

Previous work [2] has focused on defining technology spaces for three facets of virtual worlds (Facet 1: design tools for modeling new artifacts; Facet 2: support for communication; and Facet 3: the ability to incorporate artificial models of cognitive design processes) and determining how these three facets make virtual worlds useful as platforms for human-human collaboration and human-computer co-creativity in design. This section considers the remaining ten facets (Facets 4-13) and how they can be harnessed to go beyond small-scale collaborative design towards large-scale collective design. In particular, we discuss how virtual worlds can fulfil the representational, communication and motivational requirements for collective intelligence in design identified by Maher and al. [6]. We also introduce and discuss a fourth requirement: participant education.

<table>
<thead>
<tr>
<th>FACET</th>
<th>CAD PACKAGES</th>
<th>MULTIUSER VIRTUAL WORLDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Design tools</td>
<td>Aimed at design detailing by expert designers for different specialties. Usually complex and highly expressive in geometrical modeling.</td>
<td>Not all virtual worlds incorporate design tools. Those that do aim to support at non-professional designers. Tools are often simplified to suit this context.</td>
</tr>
<tr>
<td>2 Communication tools</td>
<td>Synchronous and asynchronous, often without the representation of the participants.</td>
<td>Synchronous and asynchronous, includes text chat, voice, graphical communication cues and group management tools.</td>
</tr>
<tr>
<td>3 Artificial intelligence</td>
<td>Some support for scripted behaviours</td>
<td>Support for computer-controlled non-player characters (NPCs) and scripted object behaviours</td>
</tr>
<tr>
<td>4 Graphic technology</td>
<td>2D and 3D graphics with different visualisation modes (e.g. wireframe, solids, etc.)</td>
<td>Can be text-based, 2D graphics, 2.5D (isometric), 3D</td>
</tr>
<tr>
<td>5 Network structure</td>
<td>Single, local user or internet-based synchronous (e.g. ArchiCAD Teamwork) or asynchronous (e.g.</td>
<td>Online, massively multiuser.</td>
</tr>
</tbody>
</table>
SUPPORTING COLLECTIVE INTELLIGENCE FOR DESIGN IN …

| 6 | Persistence | World shuts down when users close application. World state can be saved and exchanged between different CAD packages (interoperability). | World persists online even when users logoff. Databases archive personal items, but no archival facilities for world state. |
| 7 | Tutorial tools | User manuals, built-in tutorials, workshops. | Game-play scaffolding, e.g., tutorial areas, character levels. |
| 8 | User representation | User controls a camera/viewpoint. | Avatars represent users/players. User may also control a camera. |
| 9 | Theme | Usually professionally oriented for industries such as architecture, industrial design, structural/mechanical engineering, etc. | From realistic to imaginative: simulation, education, sports, adventure, science-fiction, fantasy, world-building, role-playing, etc. |
| 10 | Task definition | Provided by customers or managers, externally to the application. | In the form of quests, missions or achievements given by NPCs or otherwise defined by the game interface. |
| 11 | Reward system | Remuneration or awards external to the application. | In-world money, items, experience points, levels. |
| 12 | Economy | All design resources embedded in the application are available to users. Designs can be sold in the real-world. | Resources for design can cost game-world or real-world money. Designs themselves can be sold in-world or out in real-world. |
| 13 | Governance | Terms of use agreement and other business contacts. | World designers impose global laws (e.g. terms of use agreement). Emergent localised governance by users. |

2.1. Facets 4-6: Graphics technology, network structure and persistence

The earliest virtual worlds were text-based, multiuser dungeons (MUDs) and object-oriented MUDs (MOOs). MOOs such as LambdaMOO [7] are distinguished from MUDs by the ability for users to program the MOO server, expanding and changing how it behaves for all users. More recently,
improvements in computer graphics and networking capabilities have made large-scale, persistent, multiuser 3D virtual worlds possible. Current examples include Active Worlds2, Second Life3, There4, Moove Online5, Kaneva6, World of Warcraft7, EVE Online8 and Ultima Online9.

Individual gaming and social virtual worlds do not provide the breadth of representation types that professional CAD tools provide (e.g.: wire-frames, solids, 2D/3D views, etc.), but this has both advantages and disadvantages for collective intelligence. Simplified representational tools are one means to support the novice designer, who does not have the knowledge required to manipulate complex design representations. The massively multiuser nature of virtual worlds is critical for bringing together large numbers of people to form a collective. Likewise, the persistent nature of virtual worlds permits seamless continuation of activities despite of geographical and time differences.

2.2. Facet 7: Tutorial tools

The technology spaces defined by Merrick et al. [2] for Facets 4-6 have two dimensions: complexity and integration with the virtual world. Tutorial tools can be classified in similar dimensions. Many older games were sold with a paper game manual containing descriptions of all elements of game-play, external to the game. Players read the manual and then played the game. Nowadays, most games come with integrated tutorials so that players can learn the rules of the game as they play. Techniques may be as simple as disabling more advanced tools until the player has mastered simple game-play, game regions of progressively increasing difficulty, or complex character levelling systems.

The integrated techniques described above are useful for collective intelligence in design as they permit the participant to begin work immediately, and provide a way to scaffold their experience so that they progressively learn new skills and can complete more complex design tasks. To better facilitate collective design, new tutorials tools that are beyond the purpose of learning the game environments and direct game-playing techniques will also be required, to assist participants in learning design and collaboration skills at their suitable levels.

2.3. Facet 8: User representation

In contrast to CAD tools where the user controls a camera or viewpoint only, most online 3D virtual worlds have highly expressive mechanisms for players to represent self. Players are represented by customisable avatars that can evolve.

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2 www.activeworlds.com 6 www.kaneva.com
3 www.secondlife.com 7 www.worldofwarcraft.com
4 www.there.com 8 www.eve-online.com
5 www.moove.com 9 www.uoherald.com
during game-play. This permits players to take on a role while in collective activities such as playing the game or participating in design collaboration and is also a source of reward and motivation. This establishes a sense of presence in virtual worlds and is especially critical for user identity in a team environment, attracting and sustaining a sufficiently large user-base for collective intelligence to emerge.

2.4. Facet 9 : Theme

Virtual world themes can range from realistic (e.g. : Second Life) to imaginative (e.g. : World of Warcraft). Themes include simulation, education, sports, adventure, science-fiction, fantasy, world-building, role-playing and so on. The theme of the virtual world (and the plot if it is a game world) are also important for attracting participants. In addition, the theme can determine the age group and interests/expertise of participants.

2.5. Facets 10-11 : Task definition and reward

Task definition falls under the "content" sub-dimension of representation defined by Maher and al. [6] for collective intelligence in design. It includes the design problem and its constraints. Existing collective intelligence applications take various approaches to task definition. Some applications reveal the task explicitly [8], while in others the player must discover the task [9]. The reward for using these applications is intrinsic to the player, such as a sense of achievement, glory of winning, etc., and is not specifically defined by the collective intelligence application.

In contrast, many multiuser online games have a structured chain of task definition and reward, supported by computer controlled non-player characters (NPCs)(Facet 3). Players interact with NPCs and are given "quests" or "missions". On completion of the quest, players return to the NPC to receive a reward. This may be in-game money, experience points, levels, equipment, clothing or other artefacts associated with the theme of the game or the player’s avatar.

Task definition, whether implicit or explicit, is a critical component of a collective intelligence application. Essentially these are the tasks towards which the collective effort will be driven. For solving real world design problems, task must be sufficiently well defined and unambiguous if a meaningful solution is to emerge. The use of NPCs and quest/reward chains offers a possible approach to this.
2.6. Facet 12: Economy

Virtual worlds can have closed economies (e.g., World of Warcraft) or they can permit the exchange of in-world money for real-world money (e.g., Second Life). In-world money can be used as rewards and as a basis for the trade of virtual items such as land, clothing, furniture or resources.

In CAD software, all design resources embedded in the application are available to users in an unlimited fashion. In contrast, in game worlds resources must frequently be discovered, fought for or purchased. While this may seem a barrier to progress, when carefully managed it can act as a motivator. The scarcity or abundance of a resource impacts on the ease or difficulty of the task [10]. Completion of tasks requiring resources can become a reward for the effort of gaining the resources.

2.7. Facet 13: Governance

World designers impose global laws on virtual worlds in the form of terms of use agreements and end user licenses. However, structures may also be in place to permit localised self-government to emerge among players. In Second Life for example, land owners can impose building regulations over small regions. In World of Warcraft guild officers can regulate the conduct of guild members. Inclusion of mechanisms for emergent self-organisation and self-government is important for structuring communication among members of a large collective.

2.8. Summary

The discussion above shows that virtual worlds have the potential to fulfil the design representation, communication, motivation and educational requirements of collective intelligence applications. Table 2 summarises the manner in which this is achieved by mapping each facet to one or more of these requirements. The next section looks at a specific example of a virtual game world, Lego Universe, that permits and requires players to use open-ended design tools to play the game. We discuss the lessons we can learn from this game for developing future collective intelligence applications for design.
Table 2. Facets of multiuser virtual worlds and their main relevance to collective intelligence and design

<table>
<thead>
<tr>
<th>FACET</th>
<th>CONTRIBUTION TO COLLECTIVE INTELLIGENCE AND DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Design tools</td>
<td>Design representation; Communication</td>
</tr>
<tr>
<td>2 Communication tools</td>
<td>Communication</td>
</tr>
<tr>
<td>3 Artificial intelligence</td>
<td>Design representation; Communication; Motivation</td>
</tr>
<tr>
<td>4 Graphics technology</td>
<td>Design representation; Communication</td>
</tr>
<tr>
<td>5 Network structure</td>
<td>Communication</td>
</tr>
<tr>
<td>6 Persistence</td>
<td>Design representation; Communication</td>
</tr>
<tr>
<td>7 Tutorial tools</td>
<td>Education</td>
</tr>
<tr>
<td>8 User representation</td>
<td>Communication; Motivation</td>
</tr>
<tr>
<td>9 Theme</td>
<td>Design representation; Motivation</td>
</tr>
<tr>
<td>10 Task definition</td>
<td>Design representation; Motivation</td>
</tr>
<tr>
<td>11 Reward system</td>
<td>Motivation</td>
</tr>
<tr>
<td>12 Economy</td>
<td>Motivation</td>
</tr>
<tr>
<td>13 Governance</td>
<td>Communication</td>
</tr>
</tbody>
</table>

2.9. Case Study: Lego universe

The following sections discuss Lego Universe [11, 12] with reference to the thirteen facets of virtual worlds introduced above. The purpose of the case study is twofold. First we use it to validate our thirteen facets by demonstrating their presence in an existing virtual world. Secondly, we use the study to emphasise how these facets can support collective intelligence in design.

Lego Universe is situated in a persistent online, multiuser, 3D virtual world. As discussed previously for Facets 4-6, a multiuser technology providing a shared representation is a basic requirement for the emergence of online collective intelligence. Lego Universe provides such a platform.

The theme of the game (Facet 9) is based on the story of four explorers who have found a powerful source of energy, called the Imagination Nexus. This Nexus could create anything, but one of the explorers was chaotic, and spawned evil creatures. The Nexus exploded, creating a host of small worlds and an evil Maelstrom that generates creatures of chaos to attack these worlds. Players must use their imagination and creativity to defeat the Maelstrom [12].
The emphasis on imagination (also an avatar attribute) and creativity forms the basis for a game that incorporates and requires designing. Players must "collect" or "earn" imagination points to permit them to build. Likewise, players must build to complete predefined "missions" or "achievements". Designing is thus an integral and unavoidable part of advancing in the game.

Players are represented in-world (Facet 8) by an avatar with the appearance of an LEGO figurine (called a minifigure) [11]. Players can customise their minifigure at the start of play, as shown in Figure 1, and also collect new components to continue customising their minifigure during game-play. Minifigures have a backpack for storing items such as clothing, weapons and bricks for building. They also have a passport for recording details of the player’s profile, their current missions and their achievements.

Players start their life in Lego Universe on a starship damaged by the Maelstrom. The starship is essentially a tutorial area (Facet 7) [12], with pop-ups offering tips on how to move and play. One such example is shown in Figure 2. Crates are littered about, containing players’ first building bricks and in-world currency. Players receive their first "mission" from a NPC called Bob who teaches them how to build objects in the game. The tutorial spaceship teaches and also introduces the achievement aspect of game-play. Achievements are similar to, but more generic than, missions. Players receive a Universe Score for completing achievements, which also act as currency. Some of the more significant achievements also cause packages to appear in a player’s mail box, containing blocks or other inventory items.
The tutorial area is an important educational tool for familiarising new players with the virtual world and with how to build basic LEGO designs. Early missions require players to learn to design early in the game. From the perspective of building a collective intelligence application, this is important for focusing participants’ efforts quickly on desired tasks. We envisage that similar tutorial areas and NPCs could also be created to develop participants’ design and collaboration skills in a collective intelligence application.

![Image](image.jpg)

*Fig. 2. The Lego Universe tutorial area. Players learn the basics of game play here, including how to build simple LEGO designs. Image from [11].*

There are four main types of design and modelling (Facet 1) in Lego Universe: quick-build, modular-build, free-build and property-build. Players can build once they have earned their thinking hat and have sufficient imagination points. Building uses up imagination points.

- **Quick-Build**: While traversing the *Lego Universe*, players may find piles of Lego. If they shift-click the pile an object will be built that can be used in a mission. Sometimes certain extra bricks may have to be collected before a quick-build can be performed.

- **Modular-Build**: Players can also collect models throughout the game. These permit players to build more complex structures using a basic plan. Players must collect the basic parts and then drag these onto the model outline as shown in Figure 3. Modular-builds are required to achieve certain game-play objectives. For example, for players to leave the tutorial starship or travel between worlds in the *Lego Universe* they must build a rocket.

- **Free-Build**: Free builds are required to solve puzzles and progress in the game. Players may come across a pile of LEGO bricks and need to build the bricks into a form that permits them to solve a nearby puzzle such as...
bypassing an obstacle. Examples include building bridges to cross a chasm or building stepping stones to climb a cliff.

- **Property-Build**: As players progress in *Lego Universe* they have the opportunity to acquire their own property. They can then enter the Free-Build mode on their property and use bricks or models they have collected to create any design they wish. One example is shown in Figure 4. Approximately 80,000 different bricks are available to be collected. This permits players to design complex structures, once they have collected appropriate bricks and/or models. Designs can be programmed with behaviours to make them animated or interactive.

![Fig. 3. Modular build. Players put on their thinking hat to enter build mode. They drag the basic parts they have collected onto the model outline. Images from [11].](image1)

![Fig. 4. Property-build examples. Players can build anything they want, as long as they have collected the bricks. In game "friends" can collaborate build together on a given property. Images from http://static.gamesradar.com.](image2)

Of the various build types, free-build and property-build are the most interesting from the perspective of collective intelligence as both permit open-ended (free) use of building materials. Free-building to solve puzzles can be thought of as a request to the collective for solutions to a particular design problem. The design problem is framed by players’ surroundings and by the
materials they have available. Additional information may also be provided within the text of a specific mission.

The Lego Universe user interface provides a number of tools for communication (Facet 2) with other players. A chat window permits players to chat with other players nearby (see Figure 5) and a friends list permits players to view when known players are online. Friends can be assigned different levels from casual acquaintances to "best friends". In addition to text chat, emotes such as dancing or cheering are also possible. The "friends-list" is an important part of collaborative design in Lego Universe as players who are friends can property-build together and can trade the bricks used to build.

![Lego Universe interface](http://static.gamesradar.com)

**Fig. 5.** A screen-shot from Lego Universe showing the 3D view of the local environment, the 2D view of the wider environment at the top right, the communication (chat) window at the bottom left and avatar attributes at the top left. Image from http://static.gamesradar.com.

Lego Universe does not have tools for managing larger groups of users (such as guild management tools in World of Warcraft). This is possibly because Lego Universe is aimed at a younger audience.

Lego Universe incorporates three kinds of artificial intelligence (Facet 3): enemies, partner characters and support characters. Support characters provide missions and reward chains (Facets 10-11), buy and sell goods (Facet 12) and contribute to the look and feel of the virtual world. Partner characters include pets, which are a form of reward/motivation. Enemies attempt to prevent players from completing missions.
The game is governed by a terms of service agreement (Facet 13). Limited communication tools, as well as a young target audience, limit the amount of in-game emergent self-governance by players. Limited communication tools can, however, be an advantage for collective intelligence applications. Studies have shown that too much communication about off-task issues can inhibit progress towards goals. In addition, previous such games [9] have shown that even if communication tools are not provided, participants will find ways to communicate if necessary.

3. Conclusion

This paper has analysed virtual worlds with reference to thirteen technological facets to explore the potential of virtual worlds for fulfilling the representational, communication, motivational and educational requirements for achieving collective intelligence in design. We conclude that virtual worlds do have potential to provide sufficient technologies to satisfy these requirements, although it remains to be seen if existing worlds combine these tools appropriately for collective intelligence to emerge.

To create real-world collective design tools, some of the main areas for research and development are highlighted below:

- **Design, modelling and artificial intelligence**: Understanding the needs and appropriateness for supporting both expert and novice designers. Creating environments that enabling different forms of collective design intelligence. These can range from collective design outcome as a synthesised artifact and solution, to collective design knowledge building without resulting in a tangible design artifact and solution but providing cultural and perceptive values to design and design communities. Artificial intelligence can be considered to better utilise in supporting these goals.

- **Theme and task definition**: Development of game themes that are both motivating and relevant to a wide range of real-world design tasks. The game theme will influence the manner in which design tasks are presented in quest/reward chains, and how motivating they are to participants. This requires tasks sometimes to be defined implicitly for the mass participants with an alternative theme that will interest them, but at the same time with embedded design values. A successful example of such is espgame.org, which brings vast participants online to play (to the players) a game but (to the game’s creators) a new way to design captions for digital images on the Internet, through mass participation.
• **Communication**: Understanding the tradeoffs between providing explicit communication tools, which could be misused, and limiting communication or assuming that participants will find other ways to communicate.

• **Economy**: Understanding the balance between unlimited building resources and requiring players to compete for building resources, in order to provide incentive for mass participation.

References