

## DESIGNWORLD: AN AUGMENTED 3D VIRTUAL WORLD FOR MULTIDISCIPLINARY, COLLABORATIVE DESIGN

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**Abstract.** Large design projects, such as those in the AEC domain, involve collaboration between designers from many different design disciplines in varying locations. Existing tools for developing and documenting designs of buildings and other artifacts tend to focus on supporting a single user from a single discipline. This paper introduces DesignWorld, a prototype system for enabling collaboration between designers from different disciplines who may be in different physical locations. DesignWorld consists of a 3D virtual world augmented with a number of web-based communication and design tools. DesignWorld uses agent technology to maintain different views of a single design in order to support multidisciplinary collaboration and address issues such as multiple representations of objects, versioning, ownership and relationships between objects from different disciplines.

### 1. Introduction

Large design projects, such as those in the AEC domain, require real-time, multi-user collaboration between designers from many different design disciplines in varying locations. Existing tools for developing and

documenting designs of buildings and other artifacts tend to focus on supporting a single user from a single discipline. This paper introduces DesignWorld, a prototype system for enabling collaboration between designers from different disciplines who may be in different physical locations. DesignWorld, as shown in Figure 1, consists of a 3D virtual world for creating and visualizing designs, augmented with a number of web-based tools for communication design.

Previous approaches to collaborative design have used commercial CAD systems for visualization, rather than virtual worlds (Conti et al., 2003), however virtual worlds have the advantage of allowing users to be immersed in the development environment as well as facilitating real-time walkthroughs and collaboration. Previous approaches to multidisciplinary design have used a single shared data model (Krishnamurthy and Law, 1997; Wong and Siriam, 1993). In contrast, DesignWorld, uses agent technology to maintain different views of a single design in order to support multidisciplinary collaboration. This architecture enables DesignWorld to address the issues of multiple representations of objects, versioning, ownership and relationships between objects from different disciplines.

DesignWorld is a conceptual design tool, aimed at the early phases of design in which the scope of a problem is determined by exploring a range of alternative solutions to a brief or set of requirements. Conceptual design is characterised by a high degree of uncertainty and fluid design ideas. To address these issues, DesignWorld provides a sketching tool with which designers can rapidly produce design alternatives, whilst maintaining semantic density and ambiguous representation, and uses a 3D virtual world with a direct-manipulation-style building system that avoids complexity and rigour required for a CAD system.



Figure 1. DesignWorld consists of a 3D virtual environment (left) augmented with web-based communication and design tools (right).

## 2. DesignWorld Architecture

DesignWorld uses a client-server architecture, shown in Figure 2, to provide design and collaboration tools. Designers interact with DesignWorld using a client browser. The client browser, also depicted in Figure 1, has two components, a 3D world window and a web window. The 3D world window is the primary interface through which designers can build representations of design artefacts. We use the Second Life client browser for this purpose. Second Life is an online persistent space, created and evolved by its users with built-in content creation tools.

While Second Life supports collaborative virtual design with built-in design tools, it does not incorporate the multidisciplinary tools required by 'real world' designers such as architects and engineers. In order to provide designers with these additional design and communication tools, DesignWorld incorporates a web window next to the 3D world window to provide additional functionality and an external model to store additional data.

The tools displayed in the web window include interfaces for viewing the non-spatial properties of a design, creating and managing relationships, sketching and audio-visual communication. The viewing and relationship management tools use forms to gather information about requests from designers for new views or relationships. These requests are carried out on behalf of the designer by agents, as discussed later in this paper.

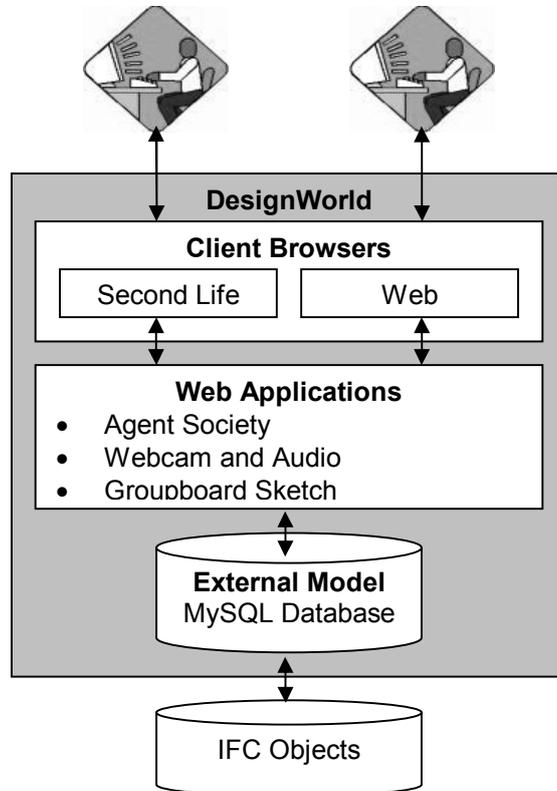


Figure 2. DesignWorld system architecture.

The DesignWorld external model is a MySQL database. The database schema is compatible with Industry Foundation Classes (IFCs) (IAI, 2000) so a model can be uploaded from IFC compatible applications such as ArchiCad for use in collaborative sessions. The external model contains project information for a group of objects, and for each object there is discipline, versioning and relationship information. The key data tables in the external model are the object, relationship, project, citizen and discipline tables as shown in Figure 3. The citizen table holds information about the virtual world identity of designers. The object table holds information about 3D objects built in Second Life. Each citizen and each object is part of a project. In addition, each object has a citizen owner. Citizens have a discipline so the discipline of each object can be determined via its owner.

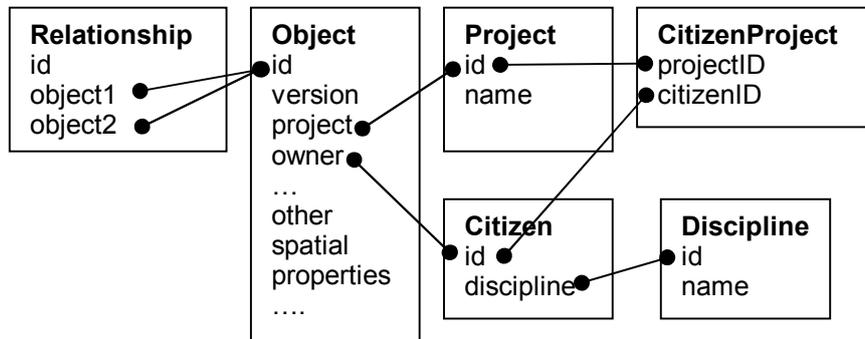


Figure 3. Overview of the DesignWorld external model schema.

### 3. 3D Virtual Worlds

A virtual world is a distributed, persistent, virtual space. People can interact with other people, objects or computer controlled agents using an avatar controlled by the mouse and keyboard. DesignWorld uses the Second Life ([www.secondlife.com](http://www.secondlife.com)) virtual environment as the platform for design and collaboration. Second Life allows collaborative manipulation and visualization of shared objects, both synchronously and asynchronously. Designers can select from a range of primitive objects with which to build, which can then be further modified using a number of built-in tools to achieve more complex objects.

DesignWorld is an improved version of the CRC Collaborative Designer (CCD) prototype (Rosenman et al., 2005). CCD was implemented using the Active Worlds ([www.activeworlds.com](http://www.activeworlds.com)) virtual world platform. The new version as implemented in Second Life provides facilities for modeling objects in the world and additional programming capability for associating agent models and an external data model with objects in the world.

### 4. Agents

Agents are systems which can sense their environment using sensors, reason about their sensory input and affect their environment using effectors. DesignWorld agents perform tasks such as view creation and version management on behalf of designers. Designers wishing to perform a design action communicate their request to an agent, using one of the web-based design tools. After sensing a request, the agent uses a reflexive reasoning process to carry out the action for the user (Maher and Gero, 2002). Their effectors allow them to modify both the 3D environment and the web-pages to carry out these actions. DesignWorld agents can create different views of a design, manage relationships and import designs from other IFC compatible systems.

#### 4.1. MULTIPLE-VIEWS

The models created by members of different design disciplines are influenced by the different functional concerns of those disciplines. For example, an architect may be concerned with the design of functional spaces within a building while a structural engineer may be concerned with the position of load bearing walls. A single model approach to multidisciplinary design is insufficient for representing these different functional concerns (Rosenman and Gero, 1996). The agents in DesignWorld keep track of the objects created by each discipline in order to maintain information relevant to the different functional concerns of designers from different disciplines. A selection of viewing tools enables designers to view the components relevant to them.

##### 4.1.1. *The Discipline Viewer*

The discipline viewer uses object ownership and discipline information stored in the external model to construct different views of a design with respect to the discipline of its designers. Designers can view the parts of a model that are relevant to their discipline by clicking on the appropriate view button in the web-browser to send a request to the discipline viewer agent. The agent retrieves a list of relevant objects from the external model then modifies the transparency of objects in the 3D world so only the relevant objects are visible. Two views of a tower model, an architect's view and an engineer's view are shown in Figure 4.

##### 4.1.2. *The Object Property Viewer*

The object-property viewer uses discipline and relationship information stored in the external model to display non-geometric properties of objects that are not visible in the 3D virtual world. Designers view non-geometric properties by clicking on the desired object in Second Life then clicking the view button in the web page to send a request to the object-property viewer agent. The agent retrieves the properties from the external model and displays them in the web browser. The non-geometric properties that can be viewed are specific to the discipline to which the object belongs. These properties are attached to the object by agents in DesignWorld. At present, non-geometric properties are not imported from the IFC model but could be in the future.

#### 4.2. RELATIONSHIPS

DesignWorld allows designers to create and view relationships between different objects. Relationships express the connections or commonalities between objects in a design. At present the types of relationships supported by DesignWorld include 'corresponds to', 'bounds', 'decomposes to', 'supports', 'adjacent to' and 'is a' relationships. A relationship is created by

selecting a set of relating objects, a relationship type, a set of related objects and a number of notification types. Notification types are the means by which designers will be notified if another designer moves an object that is part of one of their relationships. Currently the only notification type is a dialog box which pops up in the Second Life window. In the future email notification may also be possible. Once these options have been selected, a message is sent to the relationship manager agent to create the relationship by storing it in the external model.



Figure 4. Multidisciplinary views of a tower design. An architect's view (top) and an engineer's view (bottom).

#### 4.5. IMPORTING IFC MODELS

The DesignWorld external model is compatible with Industry Foundation Classes (IFCs) (IAI, 2000) providing the potential for models to be uploaded from IFC compatible applications such as ArchiCad for use in collaborative sessions. At present this functionality is limited by the Second Life object representation to simple IFC models containing primitive shapes, but a new Second Life object representation is being developed which is expected to make the upload of more complex designs possible. Designers upload their models by using the web-browser to send a request to the builder agent to build the objects in a specified .ifc file. This file is then uploaded to an EDM database and converted into SQL format and loaded into the external model. The builder agent then reads data about individual objects from the external model and constructs the objects in the 3D world. Figure 5 shows a simple house model imported from a .ifc file.

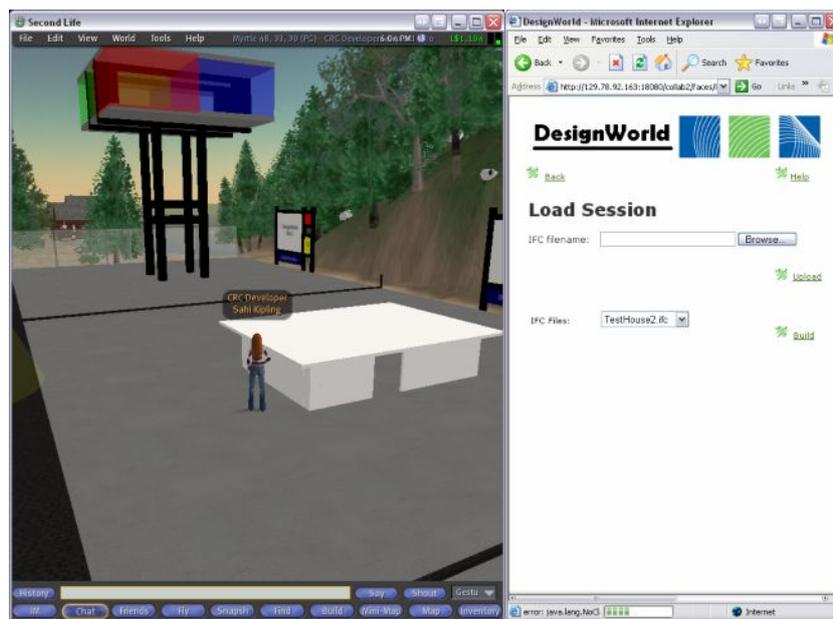


Figure 5. A simple house model uploaded from a .ifc file.

### 5. Communication Tools

Typically, avatars communicate in 3D virtual worlds using chat. This becomes inadequate in designs situations where there is a need to convey complex ideas while manipulating objects in the design. DesignWorld offers video and audio transmission facilities to support communication during

design. These additional communication tools are provided within the web browser and are integral to DesignWorld.

## 6. Sketching

While designers can collaborate on the 3D model of the design in the virtual world, many design ideas cannot be expressed in a 3D model. DesignWorld provides a sketching tool that allows designers to share their design ideas before committing them to a change in the 3D model. This part of the environment uses the Groupboard ([www.groupboard.com](http://www.groupboard.com)) sketching tool. This tool enables designers to draw on a blank page, or over a snapshot of the site or current 3D model.

## 7. Conclusion

DesignWorld is a prototype system for enabling multidisciplinary, distributed collaboration. DesignWorld consists of a 3D virtual world augmented with a number of web-based communication and design tools. Unlike previous approaches, DesignWorld, uses agent technology to maintain different views of a single multidisciplinary project. It addresses the issues of multiple representations of objects, versioning, ownership and relationships between objects from different disciplines. We have evaluated the interface of DesignWorld by setting up design tasks for pairs of professional architects to work on in a time controlled experiment. We also studied two designers playing the role of an architect and an engineer while designing according to a specification over the period of one week. In all of our trials we have received feedback on improving the interface. The move from ActiveWorlds to Second Life improved the designers' ability to create new objects and build models in the 3D virtual world. The combined 3D world and sketching tool in one environment allowed the designers to move between developing ideas and building models. In the future we will be studying the designers' perceptions of the effectiveness of the agents supporting multiple discipline views.

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