ShadowLight: A Flexible Architecture for Immersive Rapid Prototyping and Design

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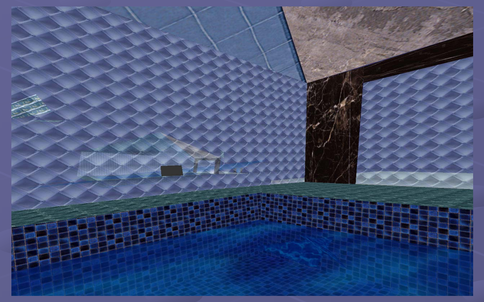
ABSTRACT

ShadowLight™ is a virtual reality application that provides a spatially immersive environment for rapid prototyping and design. Rather than restricting users to the fixed toolkit of artistic or construction-centric manipulators of traditional systems, it provides a novel degree of flexibility by supporting a plugin architecture that allows the designer to utilize high-level components as the design media.

Through this architecture, developers can create new functionality that integrates seamlessly with other elements in the ShadowLight framework. Each plugin provides its own interaction and simulation logic, allowing plugins that support static brush strokes to coexist with animated objects and complex physical simulations.

Once a plugin is created, it may be used as an element on the designer's palette to be freely utilized as the media for creation. A given design created in ShadowLight may consist of interactively drawn static brush strokes and polygonal elements side-by-side with interactively placed intelligent agents and physical simulations. ShadowLight provides a consistent and intuitive interface to this functionality, seamlessly integrating the differing media into a single design environment.



Schematic sketch of a pool house at full scale

MOTIVATION

- Conventional media do not provide an intuitive environment for the expression and refinement of spatially oriented design
- Traditional computer modeling software systems present a three-dimensional medium, but partially negate the effectiveness of that medium by constraining the user with a two-dimensional interface both during creation and in experiencing the resulting world
- Physical models provide that three-dimensional interface, but often impede the iterative refinement process by making modifications more difficult
- Design evaluation at full-scale is usually impossible due to technical and cost constraints
- Virtual prototyping applications seek to address these issues and provide a more natural environment for design by exploiting immersive virtual reality. However, current virtual prototyping applications are mostly relegated to highly specialized industry-specific tools with limited interactive manipulation capabilities
- Existing VR modeling systems are very specialized and only support certain design tasks
  - Art-centric: focus on sculpting or painting
  - Polygon-centric: very limited freeform abilities
  - Object-centric: can only select from a predefined set of shapes
- Current plugin architectures for VR systems do not facilitate mixed-media creations, they are still subject to the limitations of their host application, so that a plugin in a sculpting app cannot easily provide polygonal creation
- VR operating systems operate on a "region of space" basis instead of an individual object basis

Freeform sketching using a ribbon tool

THE SHADOWLIGHT EXPERIENCE

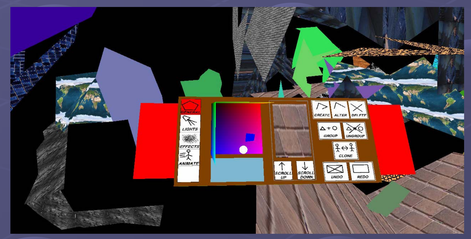
- ShadowLight provides a loosely defined environment capable of sustaining interactive schematic design using a variety of virtual media types
- Design in ShadowLight is based around the notion of a "world", defined as an infinitely bounded space that serves as the medium in which the designer composes
- To interact with this world, a six-degree of freedom "wand" is used which provides three buttons and a joystick. The wand is tracked over a certain physical space in front of a stereo-projected surface, such as a CAVE™ or ImmersaDesk™. The user may navigate about the world by pointing the wand in the desired direction of travel and pushing forward on the joystick. No global collision detection is performed, so the user is free to travel to any location in the world through any path, to freely explore the space from locations not possible in real life
- Rather than providing a built-in set of manipulators keyed to a particular set of design tasks, ShadowLight uses a flexible plugin model. The types of worlds that can be created are determined by the set of plugins available
- Plugins are self-contained applications, with their own interaction, processing, and simulation logic. Hence static sketches and annotations can coexist with dynamic and reactive elements like fluid simulations.
- Plugins can be combined and used in many ways. For example, an architect might use a fluid simulation to provide a realistic atrium waterfall, while an instructor might use it to teach wave properties. An artist might use a ribbon tool to sketch freeform designs, while a researcher might use it to annotate a simulation. ShadowLight encourages this plurality of purpose through its plugin architecture

EVOLUTION

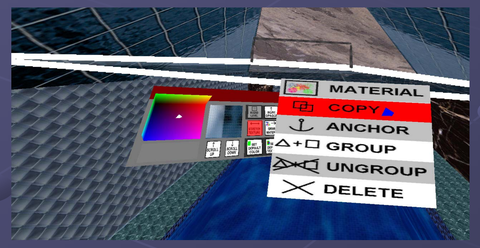
- ShadowLight has been in continuous use for almost three years
- It has been used by architectural design students, middle school students, and the United States Army
- Over its three years of use, three successive versions have been developed to incorporate suggestions and address unique user needs
- The breadth of its user community has caused a lot of challenges due to each group's unique needs
- The plugin architecture was developed as a way to allow a single application to mediate between these diverse requirements, by becoming a different environment to each user group
- The first version of ShadowLight only allowed worlds composed of independent static polygons. The second version added enhanced materials support and improved the manipulation capabilities. The third version, with its plugin architecture, was designed to allow arbitrary objects to be added to worlds

INTERFACE

- The user interface in ShadowLight has been constantly refined based on informal user studies
- The first version of ShadowLight was based on a desktop modeling interface. It had an ever-present floating palette mimicking the menu and buttonbar of a desktop package. It was also mode-based like most desktop modelers, forcing the user to switch between selection/manipulation and creation tasks. While this model works fine for desktop software, it proved very cumbersome in VR
- After a year of continual use of ShadowLight 1, the results of informal user observations were applied to design a new interface. The second interface was designed from the ground-up for VR, and used new context-aware popup menus to access common commands. The mode-based interface was replaced by context-aware wand actions, and the floating control palette was replaced with a floating materials palette that could be summoned and dismissed on demand
- User studies showed that the interface of ShadowLight 2 was quite intuitive for our user demographics, and we had few major suggestions for changes. Hence, the interface to ShadowLight 3 was based on ShadowLight 2. However, the menus and palettes are now dynamic and can be modified by plugins to add/remove/modify elements as necessary

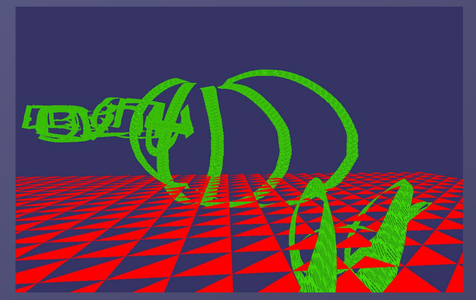


ShadowLight 1's mode-based palette



ShadowLight 2's popup menus and materials palette

ShadowLight 3's central popup menu



Ribbon tool used to annotate a fluid simulation

MIXED MEDIA

- Traditional VR libraries are designed to write single applications that stand alone. ShadowLight allows independently-written applications to be combined and used together in a single world
- VR operating systems treat the output of applications as standalone regions in space. ShadowLight is based on independent objects, allowing the output of multiple plugins to be combined into a single space, such as using a ribbon tool to annotate a fluid simulation
- VR operating systems act as an interface layer to string together legacy applications. ShadowLight treats plugins as full-fledged core components. Plugins can be written to be aware of each other and call functions within each other and ShadowLight provides object-level services such as polygon management and manipulation

UI architecture professor Joy Malnar critiquing a student's design. Photo by Bill Sherman

CONCLUSION

- ShadowLight has been actively used by University of Illinois architectural design students, local middle school students, and the United States Army
- Over its three years of continual use, ShadowLight has evolved considerably to better fit the needs of its users
- The plugin model of the latest version was designed specifically to allow the application to mediate among these widely varied needs
- To an architect, ShadowLight is a virtual prototyping tool, while to a middle school student, it is an educational platform, and to a military researcher it is a rapid evaluation environment. In short, ShadowLight becomes a different tool to different people, based on the available plugins that are created for their needs, providing an atmosphere in which an idea may be intuitively created, explored, evaluated, and refined, using whatever combination of instruments, interaction, and media makes the most sense

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