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A PC-based Virtual Reality System for facility layout design

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A PC based proto-type VR layout system has been developed using the latest 3D real-time VR rendering graphics library, RenderWare™. This proto-type will enable a designer to layout a design in 2D drawings and visualize it in 3D perspective at the same time. This feature allows an engineer to present a new facility layout to the end-users so that potential usability problems can be identified and corrected through a visual 'walk-through'. In a study concerning facility layout, Kew (1996) reported that involving users in the early stage of a design could avoid costly mistakes. The visual 'walk-through' would facilitate this early stage participation. Another feature of the program is the ability to combine multi-layer designs in one set of computer-generated 3D models. Without this, engineers are left to debug a multi-layer design in their minds. In this paper, the design and implementation of the proto-type program are discussed with case illustrations.

INTRODUCTION

Historically, facility layout engineers used two dimensional (2D) paper drawings to communicate their ideas. Most of them were presented in plane view and elevation views. These drawings were very difficult to maintain and create. With the use of Computer-Aided Design (CAD), 2D drawings can be produced effectively in either paper or electronic formats. However, visualizing a 2D drawing is not an easy task since the drawing is not in perspective and lacks "reality" (Templemen, 1996). Furthermore, a multi-storey facility layout would require multiple 2D drawings and the engineers would have to visualize and debug the designs in their minds.

Although 3D Computer-Aided Design (CAD) programs are available for architecture and facility design (e.g., 3D-Studio™, Auto-CAD™), they do not provide continuous 3D graphics rendering. A virtual reality (VR) simulation program (e.g., World-Tool-Kit™, Cosmo Player™), on the other hand, provides continuous rendering of graphics but not the editing and drawing features offered by the 3D CAD programs. At present, both CAD and VR visualization programs exist separately, but there are very few applications that will combine the two. In order to fill the gap, the 3D CAD and the VR technologies can be integrated to provide a user-friendly environment in which designers can edit their designs and also visually 'walk-through' them in real-time without switching from one program to another. This paper describes the implementation of a prototype VR facility layout program. The aim is to demonstrate the benefits of integrating VR and CAD technologies.

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SYSTEM DESCRIPTION AND BASIC OPERATION

Overall system design

The objectives of the prototype VR facility layout program are to: (i) provide a user-friendly environment for engineers to create and modify the layout of a single-storey plant; (ii) support the layout of a multi-storey plant; and (iii) provide real-time virtual 'walk through' of the layout in 3D perspective. In order to fulfill these objectives, the prototype program supports basic convenional CAD functions and provides (i) pre-drawn facility modules; (ii) multi-layer designs; and (iii) real-time VR simulation. This protoype program was developed using Visual Basic on Windows95 platform with the latest 3D real-time rendering graphics library, RenderWare™ (Renderware, 1998).

Basic CAD functions and pre-drawn objects

Unlike creating an artistic painting or a sculpture with a CAD program, the focus of facility layout is not to create new objects but to place existing objects (e.g., milling machines, workstations, assembly lines) within a pre-determined space. Consequently, the prototype program would mainly support editing functions (e.g. move object; copy object). Instead of providing drawing functions (e.g. create object), a library of pre-drawn objects is provided. Since CAD drawings of common manufacturing machinaries are readily available, an import facility is provided to up-load additional objects from CAD drawings.

Similar to the conventional CAD environment, the program operates in four views (plan, side, front, and perspective), each occupying a separate window (Figure 1). This four-view feature is similar to the traditional CAD tools in the market (e.g. 3D studio™, AutoCAD™). The parallel projection method is used to create the 2D projections in the plan, side, and front views. Users can move objects along 2D axes when working in these windows. The perspective view is the VR simulation. Users can steer their view-points and perform real-time visual walk through of their layout design.

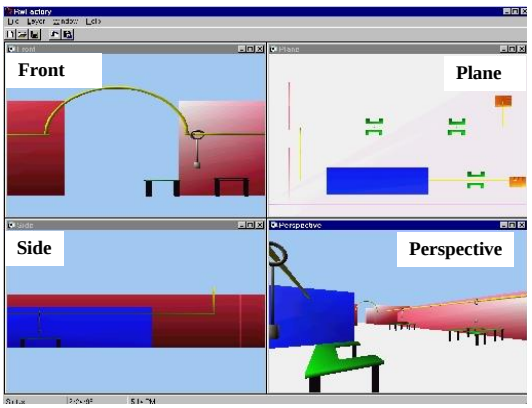

Figure 1. The four views provided by the prototype VR layout program.

Stereo visualization

The perspective view can also be displayed in the stereo mode. In this mode, images for the left and right eyes are displayed alternately in interlace format. Thirty frames of left images and thirty frames of right images are displayed within one second. In order to view the left and the right images in stereo, users are required to wear an io-glass™ head-set, which is a commercially available PC-based VR head-set. With this feature, a client can view and visually walk through the layout design in stereo. Figure 2 illustrates the perspective view in the full screen. The stereo mode is not shown in the figure.

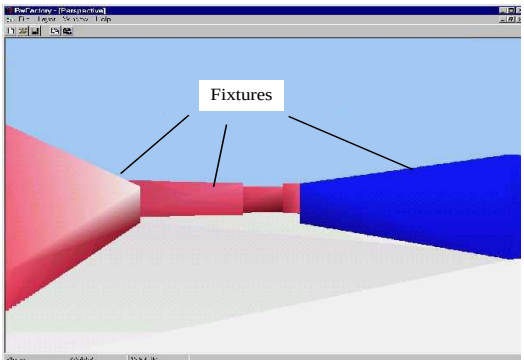

Figure 2. The perspective view in full screen (images shown are fixtures: walls and booths).

Fixture template

Most facility layout exercises involve the rearrangement of workstations or assembly line modules around certain fixtures within a plant. In an effort to increase the user-friendliness of the VR layout program, a template feature is provided. Users can create a fixture template of a plant by loading objects like walls, booths, pillars, and rooms. This template can be a starting point of any new layout design. Figure 2 illustrates a perspective view of a fixture template and Figure 3 illustrates an example layout on top of the illustrated fixture template.

Multi-layer design

This prototype program supports mutli-storey layout design. Users can create and select up to 50 layers of design. Once a layer is selected, it is displayed in the plan, side, and front views for users to modify. The whole multi-layered design can be viewed in the perspective view (Figure 4). In order to assist the alignment of objects between layers, laser anchors (vertical lines going through adjacent layers) can be created. Also, objects of different layers can be collapsed onto one layer to aid alignment. This feature can be very useful in aligning layers of ceciling pipes.

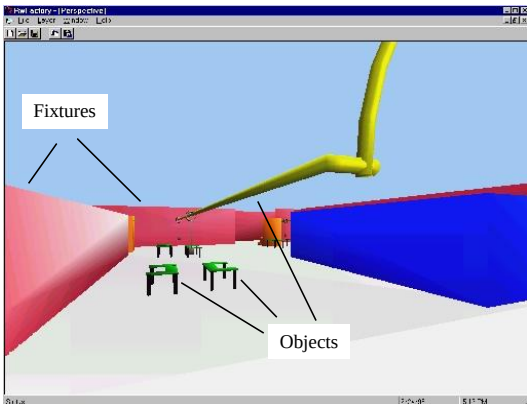

Figure 3. A perspective view of an example layout using the fixture template illustrated in Figure 2.

IMPLEMENTATION

Programming

The prototype program was written in Visual Basic version 5.0 with the graphics library provided by RenderWare™. Visual Basic version 5.0 is an event driven window programming language. It stays idle, when no event is triggered. This is particularly useful for running concurrent tasks. In this case, the four views presented in different windows were defined as four concurrent tasks.

RenderWare™ is a PC-based Virtual Reality (VR) graphics-rendering library. Its codes have been optimized to support Intel-MMX™ instruction sets, and also the 3D hardware accelerators Direct3D™ so as to increase the run time performance of the program. Renderware operates around the concept of a digital space called the 'virtual world'. Once created (using the API functions 'RwOpen' and 'RwCreateScene'), 3D objects can be uploaded into this 'world'. In order to view the objects within this 'world', 'virtual camera(s)' are installed (using the API function 'RwCreateCamera'), and the view of the camera(s) are displayed in a window (e.g., the plane view). A camera view can be created using parallel projection method (e.g., the plan, side, and front views) or perspective projection method (e.g., the perspective view). The effects of visual 'walk through' are facilitated by coupling the pointing position of the 'virtual camera' to the position of a PC mouse.

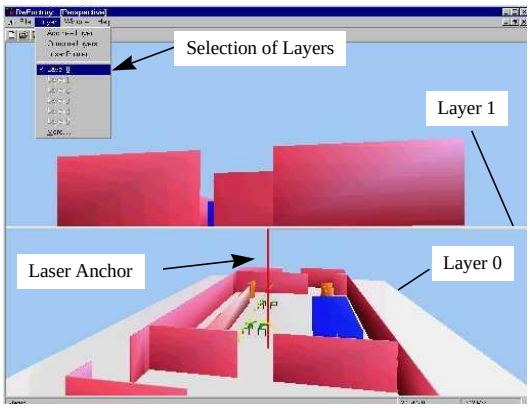

Figure 4. The perspective view of a mutli-layer design (the use of laser anchor is also illustrated).

File Format and Conversion

The RenderWare™ library provides a file conversion facility to translate 3D studio models (*.3ds) and AutoCAD models (*.dxf) into RenderWare™ models (*.rwx) which can then be uploaded into the 'virtual world'.

CONCLUSIONS AND FUTURE WORK

A prototype PC based Virtual Reality (VR) layout program has been written to demonstrate the benefits of integrating CAD and VR technologies. Examples of useful features include: continuous visual 'walk through' in perspective view during the whole design process; ability to handle a mutli-storey facility of up to fifty floors; and a library of pre-drawn 3D objects. With this prototype system, engineers can let the end-users visually inspect a plant layout before it is implemented. This could, potentially, save time and money if mistakes are identified and corrected during the design phase. With the completion of the prototype system, factory visits have been scheduled to collect feedback from the industry concerning the field applications of this prototype.

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