“This Old Digital City”: Virtual Historical Cedar Rapids, Iowa circa 1900

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Abstract. This paper describes the creation of a 3D immersive interactive museum exhibit called “This Old Digital City” (TODC). TODC uses state-of-the-art real-time interactive virtual environment technology to immerse visitors in a 3D reconstruction of turn-of-the-20th-century Cedar Rapids, Iowa. Museum patrons sit in and operate a “time machine” to tour a twenty-five square block region of the city modeled in high-resolution 3D graphics. As visitors tour the city, they are able to access multimedia content associated with buildings and other historically significant sites. We believe that TODC represents one of the first uses of high-end virtual environment technology as an interface to *historical archives*. The paper examines technical modeling and computing challenges, as well as historical and exhibit design challenges.

1. Introduction

Until recently, the high cost of specialized hardware and software made the military and entertainment communities the primary consumers of immersive interactive virtual environment technology. Developments in PC graphics hardware and software have drastically lowered costs and opened the door to application of such technology in non-traditional settings, including historical, cultural, civic, and educational institutions.

This paper presents “This Old Digital City” (TODC), a museum exhibit that uses state-of-the-art real-time interactive virtual environment technology as an interface to historical archives. TODC combines (1) a large real-time 3D visual database representing twenty five blocks of Cedar Rapids, Iowa at the turn-of-the-20th-century, (2) multimedia historical archival “content” associated with many buildings and other significant locations within the city, (3) an immersive environment consisting of three large-rear projected display screens driven by a network of four PCs, (4) a “time machine” interaction device from which visitors control their tour through old Cedar Rapids. Museum visitors interactively control their journey through the restored city; the environment is not pre-rendered nor the paths of travel prescribed. Figure 1 shows an early conceptual rendering of the physical exhibit while Figure 2 depicts the design of the “time machine” interface that was under construction at the time of the writing of this paper.

The TODC project is a major demonstration of the potential for use of interactive virtual environments for historical and other liberal arts applications. The immersive 3D environment

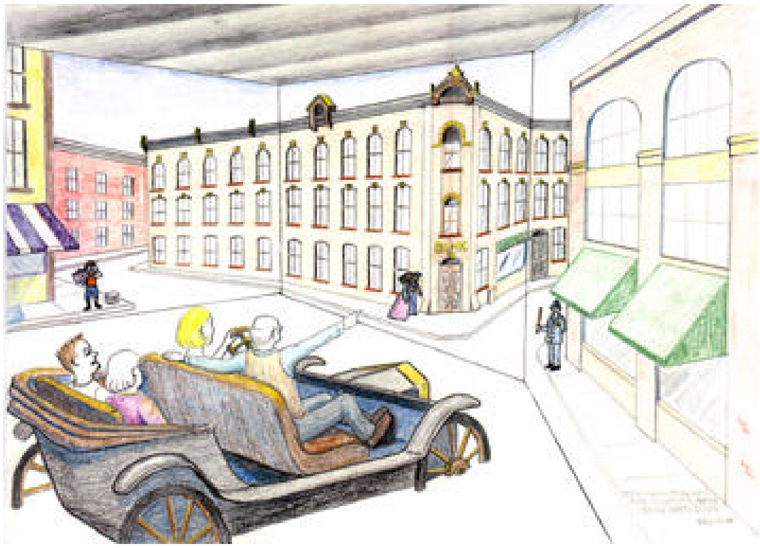

Figure 1. Early artist's rendition of the TODC environment.

provides an engaging and effective interface to museum archives. It is difficult to effectively display large numbers of old photographs and other archival material in exhibit cases, for example. The virtual reality interface to this material addresses not only preservation and space concerns, but enhances the value of the material by providing important spatial context; users get direct 3D visual information about the setting of the archival material.

There is a growing variety of excellent work and exciting projects sharing some of TODC's goals and approaches The April-June 2000 issue of IEEE Multimedia is largely devoted to virtual heritage and gives a good overview of related projects (see, especially, [1,2,3,4,5]).

The rest of the paper describes the TODC project in detail. Section 2 provides the project's background and history. Section 3 describes the physical components of the exhibit. Sections 4 and 5 detail the most technically substantial components of the project: development of the 3D visual database and associated visualization and interaction software. Section 6 discusses interesting issues in the design of the interactive experience; in particular, it examines the tension between providing visitors freedom to explore, which enhances immersion, and the desire of exhibit designers to guide visitors to particular experiences and content (scripting experiences can quickly destroy immersion). Section 7 describes the impact of the TODC project on the regional school system, including current and future involvement of elementary and secondary students in content development for the project. Finally, Section 8 describes plans for enhancing the exhibit over the next two years.

2. Background

The TODC project was born in a casual grocery store encounter between History Center curator, Marise McDermott, and Digital Artefacts president and University of Iowa graduate student, Joan Severson. Ms. Severson had been working in the Computer Science Department's virtual environments laboratory (Hank lab: http://www.cs.uiowa.edu/~hank) and thought this was an ideal opportunity to apply the technology in a new way.

The University of Iowa is a leader in real-time virtual environments, particularly real-time driving simulation. It hosts The National Advanced Driving Simulator (NADS), the world's most sophististicated driving simulator (http://www.nads-sc.uiowa.edu), and its predecessor, The Iowa Driving Simulator. Over the past eight years, Cremer and Kearney have worked on techniques for behavior and scenario control for driving simulation and other real-time interactive virtual environments. The Hank lab contains a small driving and bicycling environment used for basic research in driving simulation methods and software, and for experiments on child bicycle safety in conjunction with psychology researchers. Physically, it consists of three 2.44 meter by 3.05 meter

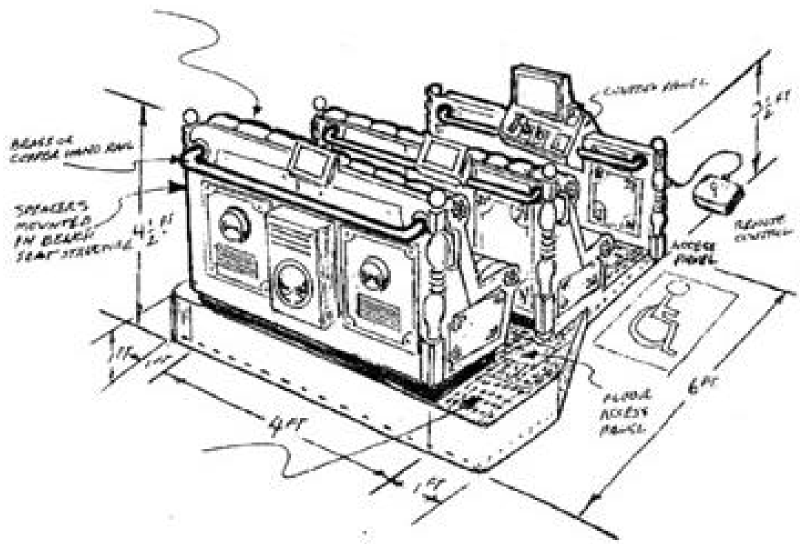

Figure 2. Design sketch for the “time machine” interface.

rear-projected screens, arranged at right angles to provide drivers/riders a field of view greater than 200 degrees (see Figure 3).

In summer 1999, The History Center, The University of Iowa, and Digital Artefacts, LLC, agreed to collaborate to develop the TODC exhibit. TODC is an ambitious project for a relatively small museum in a city of 100,000 people. Technologically, for instance, the real-time computer graphics required by the exhibit is at the very limit of what can be done on (several) reasonable cost PCs. The first phase of the project took one year (8/99 to 8/00) and cost approximately $300,000. The large screens, projectors, the “time machine”, and additional non-computer hardware accounted for approximately one half of the cost. Computer hardware costs were approximately $15,000. Modeling, software development, and other personnel expenses constituted the bulk of the remaining costs. Substantial additional developments are planned over the next two years.

3. Physical Components of the Exhibit

The primary physical components of the exhibit include display screens, projectors, computers, and the “time machine” interface.

The exhibit contains three display screens, each approximately 1.83 meters wide and 2.44 meters tall. One is in front of the “time machine”, while the left and right screens are at 120 degree angles to the center screen. Enclosures behind the screens contain LCD projectors and mirrors allowing rear-projection display in a compact package.

The “time machine” seats four or more people. (See Figure 4 for the exhibit designer’s sketch. At the time of writing, the time machine was complete but had not yet been delivered to the museum. See http://www.historycenter.org for images of the final exhibit components.) The exhibit interface is designed to be wheelchair accessible. Passengers drive the “time machine” via a joystick-like control device. A separate manipulator may be used to change the view up and down when the vehicle is stationary in the environment. A set of buttons is available for activating available multimedia content within the environment, and for selecting customized less-interactive “tours” for those whose do not choose free exploration.

The virtual environment is implemented on a stand-alone network of four 1GHz Pentium III PCs. The high fidelity of the TODC visual database is at the limit of what can be rendered effectively using PC graphics technology. In fact, the exhibit requires one dedicated high-end graphics PC for each screen. The prototype system running in August 2000 used graphics cards based on 64MB NVIDIA GeForce2 chipsets. The museum installation, which will officially open

Figure 3. The Hank bicycling simulation environment.

10/27/00, will use cards based on GeForce2 Ultra chipsets. We render three screens at 768 by 1024 pixels, antialiased, at 30 frames per second. The fourth PC is used to process user interaction, audio, and to synchronize, via custom software, the three graphics computers.

4. Construction of the 3D Historical Model

The construction of the 3D model was both the most technically difficult as well as most interesting component of the TODC project. The goal was to model the streets, sidewalks, buildings, and other artefacts within a twenty-five block region of downtown Cedar Rapids. Urban renewal programs in the mid-twentieth century destroyed most circa 1900 buildings (replacing them, usually, with architecturally much less interesting ones). Of the more than 100 buildings modeled so far in the TODC project, only six remain standing.

Construction of the 3D model, then, had to rely largely on historical data. The key materials were (1) photographs, postcards, and newspaper images, (2) insurance maps, (3) city records, (4) blueprints, and (5) reference books about building materials, paints, etc. of the period. In addition, present-day GIS data was used to create the basic terrain for the visual database (but had to be modified to reflect some known differences).

The History Center, the City of Cedar Rapids, and several individuals and organizations, amassed a collection of thousands of black-and-white and sepia-toned photographs from the period. Sanborn insurance maps, which contain detailed building information (key dimensions, business names, and so forth), were used to georeference the images.

Building geometry was constructed from information in the images and Sanborn maps. The primary modeling tool used was Multigen Creator. High-quality texture maps were created to enhance the visual detail. Since TODC visitors examine buildings at fairly close range (much closer than in flight simulators, for instance) it is very important that textures be as high resolution as possible to maintain visual fidelity. This was a significant factor in our need for the most advanced graphics cards; we require substantial texture memory, which has not previously been available on PC graphics cards. Even with 64MB of dedicated graphics memory, we need to use, for some of our textures, the texture compression features of the newest graphics cards. Screen snapshots from the partially completed TODC environment are shown in Figures 4 and 5. Figure 6 shows a historical image used as raw material for the building in Figure 5.

Texture creation could not be achieved simply by scanning photographs; the photographs were black-and-white or sepia-toned, but we wanted a colorful restoration! Based on photographs and scanned images, we built a library of “digital artefacts”: windows, frames, doors, awnings, and other building components. To historically faithfully “colorize” these components and the

Figure 4. A screenshot of a partially completed train station in the TODC visual database.

buildings themselves, we consulted historical architectural reference materials and worked closely with an architectural historian. Many of the elements, materials, and paint combinations of the buildings are no longer used or seen in Cedar Rapids. For example, slate roofing and pressed tin cornices are no longer used and were not clearly visible in the photographs. In order to create the texture maps and geometry to illustrate these elements, the architectural historians provided illustrations and books on turn-of-the-century Midwest architecture.

Building the TODC environment required a basic understanding of multiple disciplines: art, real-time computer graphics, architectural history, historical map cartography and museum archives. It is almost impossible to find one person with a solid understanding of all of the elements. Communication between the historians, computer scientists, and artists was one of the most challenging factors in developing the historical environment. The role of the modeler and texture artists was to break up black-and-white images into basic geometric shapes and textures that would make up the buildings, artefacts and terrain of the environment. Difficult decisions had to be made when deciding which elements of a complex object, such as an ornate Victorian building, could be represented in the model. Polygon, texture, and person-time constraints necessitated exclusion or simplification of some features or elements. Artists and historians worked together to make decisions that would be both historically representative and technologically feasible.

Like any other illustration, aesthetics and style consistency were considerations when developing the texture maps for the environment. One illustrator created most of the textures. Other texturers were guided by the lead illustrator to ensure a consistent look and feel in the environment. This is an important consideration when working with more than one illustrator. Imagine having a portrait done by two artists. One uses rich and intense colors with broad strokes, while the other's style is soft and subtle. The inconsistency would distract from the actual content of the painting.

Figure 5. Screenshot from partially completed TODC virtual environment

5. Visualization, Interaction, and Multimedia Software

Custom visualization and interaction software for the project was developed using C++ and the OpenGVS (http://www.opengvs.com) real-time graphics toolkit. Some visibility preprocessing was done on the 3D model to reduce the scene depth complexity (an important quantity related to the total number of rendered pixels and the "fill rate" limitations of graphics cards). The software also controls a digital and analog data acquisition board in the master PC that receives from and sends data to the "time machine" interaction devices.

Multimedia video and audio content is stored in MPEG-2 format. When touring the city, visitors encounter "sprites", simple animated human models, that point out (e.g. by saying "Hello there, friend. Would you like to take a look at my shop?") the availability of multimedia content associated with a site. If the visitors choose to activate the media via a button on the time machine interface, the system software presents the appropriate video on the center screen (overlaying a portion of the suspended 3D visual).

The multimedia content consists primarily of video produced from high-resolution scans of black-and-white and sepia-toned images, with panning, zooming, and other common effects, along with professionally produced accompany music and narration. In addition, the environment contains short narrative audio sequences that are triggered automatically when visitors traverse certain locations in the city. Finally, ambient or background audio with sounds of horses, trains, people, etc. is present throughout most of the environment.

6. Visitor Scenarios

Providing user-directed and user-paced navigation and exploration of virtual environments (as is done in video games) can be immersive, engaging and entertaining. However, allowing the user free reign in navigating a virtual environment becomes problematic when pedagogical goals and time constraints within the environment are considered.

A virtual environment exhibit in a museum generally requires limits on user time to ensure reasonable traffic flow and allow many visitors to experience the exhibit. On the other hand, in an educational setting we want ensure that the user experiences and interacts with all of the planned curricular content. If the purpose of our virtual environment is to present an educational narrative, directed or orderly navigation along virtual learning paths in the environment may become a necessary constraint on users.

The initial TODC installation software is designed around a goal of five- to ten-minute user experiences in which visitors have free control but are "enticed" to access particular content. One means for time control in TODC is use of a token slot on the time machine. Depositing a token activates the exhibit for a specified period. When the next "driver" reactivates the machine, he or she may choose to continue from the current location or start from one of several standard starting points.

Visitors who choose to tour freely are, as mentioned earlier, enticed to visit locations with associated multimedia content by sprites located in the vicinity of historically significant places. The visitors can ignore the sprites or choose to "visit" the locations and access the associated multimedia, which usually includes image-based video from the interior of the relevant building and accompanying narration.

We are also exploring several less-free constrained guided tour scenarios. Our experience in driving and bicycling simulation environments shows that some people are not especially comfortable with the full freedom afforded by virtual environments; some people simply wish to be shown around. Thus, we are creating guided tour scenarios that partially script the movement through the environment. Visitors will visit a predetermined sequence of locations, with the computer software controlling the gross motion path while the visitor retains some control over fine variations (this is somewhat analogous to rides at some amusement parks in which a vehicle is loosely coupled to a guiding rail).

Determining how to effectively use this environment for historical educational purposes will be an exciting challenge. Museum visitors will be surveyed regarding their experience with the TODC exhibit and the results assessed to help refine the interface and content. A prototype version of the exhibit ran for ten days at the Iowa State Fair in August 2000. The prototype employed a single 50-inch plasma display screen and a simple joystick interface. Approximately 1000 people, mostly children, tried the prototype (many more watched but did not interact with the system) and some were surveyed about their experience. At the time of writing, the data had not been analysed. We informally observed, however, that it is likely that we will need to provide multimedia content that is tailored to different audiences. The content included at the State Fair exhibit consisted of videos 1.5 to 2.5 minutes in length. Senior citizens and other adults seemed to like this level of content quite a lot, but many of the children preferred to terminate the multimedia early and continue exploration of the environment. Some of this can be attributed to the noisy distracting environment at the Fair, but we believe that the exhibit will be most effective if we develop alternative versions of content appropriate for different visitor groups. We also expect to employ some goal-directed techniques such as information "treasure hunts" to encourage children to access and attend to multimedia content.

Ultimately, we hope to explore and develop effective approaches to interactive narrative scenarios that integrate methods employed in traditional mediums such as story telling, theatre, and cinema to guide users through a series of immersive virtual experiences or educational narrative events. Plausible events and activities within the environment would need to be developed to transparently motivate or direct the user to navigate and interact with the environment to experience the embedded educational content.

7. Educational Impact

We are very excited about the potential educational impact of TODC and similar uses of virtual environment technology. One reason is that the project represents a tight coupling of cutting edge technology and liberal arts content. This has several benefits: the use of such technology excites and engages students; it exposes students to new uses of technology; and it familiarizes them (through, e.g., an associated "how it was created" in-museum kiosk and a WWW site) with the technology behind real-time computer graphics and visualization.

Several students from local elementary and secondary schools participated in the first phase of TODC development. They used city records and museum archives to research content associated with several significant buildings. We are now working with regional schools to

Figure 6. One of the historical images we used to as raw material for TODC modeling. This building is the one in Figure 5.

include TODC as a significant curriculum component. We are working to develop school-appropriate versions of the TODC software, and to provide software tools that will enable students to develop models and content for use both within the classroom as well as for submission and inclusion into TODC and similar museum exhibits.

8. Status and Future Plan

As described above, a TODC prototype was completed and used extensively at the Iowa State Fair in August 2000. The official museum exhibit opening is 10/27/00. The initial environment feels like a frozen snapshot of a “dead” city; it does not contain significant active characters. Beyond educational curriculum development, plans for the next two years focus on two aspects: (1) bringing the city to life by adding semi-autonomous period-appropriate virtual human characters (agents) as well as vehicles, animals, etc. to the environment, and (2) enabling “time travel” by extending the coverage of the project to other time periods, including the mid-20th century and the present. Inclusion of non-scripted culturally appropriate characters is a difficult problem still largely the domain of research organizations. But, based partly on our experience with scenario control and authoring for real-time driving simulation, we are confident that we can enhance the vibrancy of the TODC environment with modest use of directable virtual characters. The addition of more time periods will provide, among other things, vivid visual history of the course of development of the city.

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