A SYSTEM FOR THE RAPID CAPTURE OF VIRTUAL ENVIRONMENTS

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ABSTRACT

Simulation technology is gaining greater fidelity and venturing into new realms such as training for urban combat, counter-terrorism, and emergency responders. For these human simulation applications to mature, detailed databases of urban areas and building interiors are needed. Traditional methods for the generation of 3D environments for simulation require the use of standard NIMA products like DTED, DFAD, and VMAP, however, current detailed data for a desired location is not always available. Furthermore, simulated environments for urban areas require that building interiors be modeled as well. Current methods require building blueprints, surveys, and significant after-the-fact processing to obtain a well-correlated model, easily requiring hundreds of man-hours. This means that it is cost-prohibitive to model more than one or two specific locations for mission rehearsal, and such specific models require a tremendous lead-time. A rapid, cost-efficient method for capturing geospecific locations for simulation and mission-rehearsal is needed.

SAIC has developed the Virtual Environment Capture System (VECS), which allows for rapid generation of building interiors and immediate exterior surroundings. VECS allows the user to capture building geometry and place premodeled furniture elements from the actual environment. A typical office can be captured in detail, with geospecific textures, in less than five minutes. The system uses a laser and optical encoders to facilitate a constructive geometry approach to model the building with a minimum number of data points. The result is an optimized runtime model with a mix of geospecific and geotypical features that requires no post processing, and has both visual elements and the contextual information necessary for Semi-Automated Forces (SAF) computer reasoning over the model. This paper will describe the first year of VECS research, the system hardware and software components, the process and lessons learned from the first modeling contract to utilize VECS, and planned system enhancements.

ABOUT THE AUTHORS

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INTRODUCTION

The Virtual Environment Capture System (VECS) is a combination of hardware and software that allows the rapid, accurate capture of geospecific virtual environments from the real world. This paper will discuss the need that VECS is meant to fill, the VECS design, and how VECS was used in modeling a multi-story office building. Lessons learned and future extensions to the technology will also be discussed.

PROBLEM DEFINITION

As computer hardware gets faster and video systems become more powerful and cost-effective, there is an ever-growing need for geospecific virtual environments that are suitable for run-time systems. If such environments could be created rapidly (in minutes or hours) and cheaply, the technology would drive a plethora of applications, from the traditional military simulation and mission rehearsal to city planning, remodeling, and a variety of entertainment uses. Historically, however, creating such environments is costly, time-consuming, and results in a model that may or may not be accurate.

Requirements

Different end uses will dictate different requirements for the model. In the world of military simulation for example, an environment must be attributed with semantic information so that a Semi-Automated Force (SAF) can reason over it (Pigora, 2001). Road connectivity and room connectivity allow the SAF to navigate. Material properties – muddy ground, pavement, drywall versus cinderblock – allow it to interact with the environment in a more realistic way. Infrared and thermal characteristics allow the simulation of intervisibility for night operations.

While military simulation requires thorough attribution, the requirements for geospecific models might be less than for other applications. When doing mission rehearsal in a building, the placement of the furniture is probably more important than what it looks like – the operative navigating through the hall cares that there is a chair in the way, not necessarily that the upholstery on the chair is red instead of blue. If the end application were real estate however, and the model was being used to give a walkthrough of an expensive property in another city, the agent might want to show off the exquisite detailing around the fireplace. It would be important that the model have that geospecific detailing.

One requirement that most visual systems have in common is that the environment be optimized in terms of geometry and texture footprint. The more optimized the geometry, the more complex a model that can be run on the system with good interactivity.

Thus the ideal modeling system would produce an optimized model in a short amount of time, be cost effective, and be flexible enough to model indoor and outdoor environments with different levels of attribution and geospecific fidelity. These were the goals for the design of VECS.

Current Methodologies

Traditional methods for the generation of 3D environments for simulation require the use of standard National Imagery and Mapping Agency (NIMA) products like Digital Terrain Elevation Data (DTED), Digital Feature Attribute Data (DFAD), and Vector Map (VMAP). This source data contains spatial information that describes the terrain elevation as well as the features present on the terrain, however, current detailed data for a desired location is not always available. Furthermore, simulated environments for urban areas require that building interiors be modeled as well. Walls, stairs, furniture are not available from standard NIMA products.

The traditional methods of generating geospecific 3D models of buildings rely heavily on manual modeling using 3D modeling tools, guided by building layout drawings or CAD data. Most of the time these models lack furniture and other navigational aids and may not reflect post construction modifications to the current building. Other systems exist which can capture the actual building state, however they are not very practical for real time applications. Laser scanning systems, for example, provide the user with a very high detail representation of the room environment. However, as the laser scans from one viewpoint, occlusion by furniture and other objects in the room requires multiple passes to be integrated together,

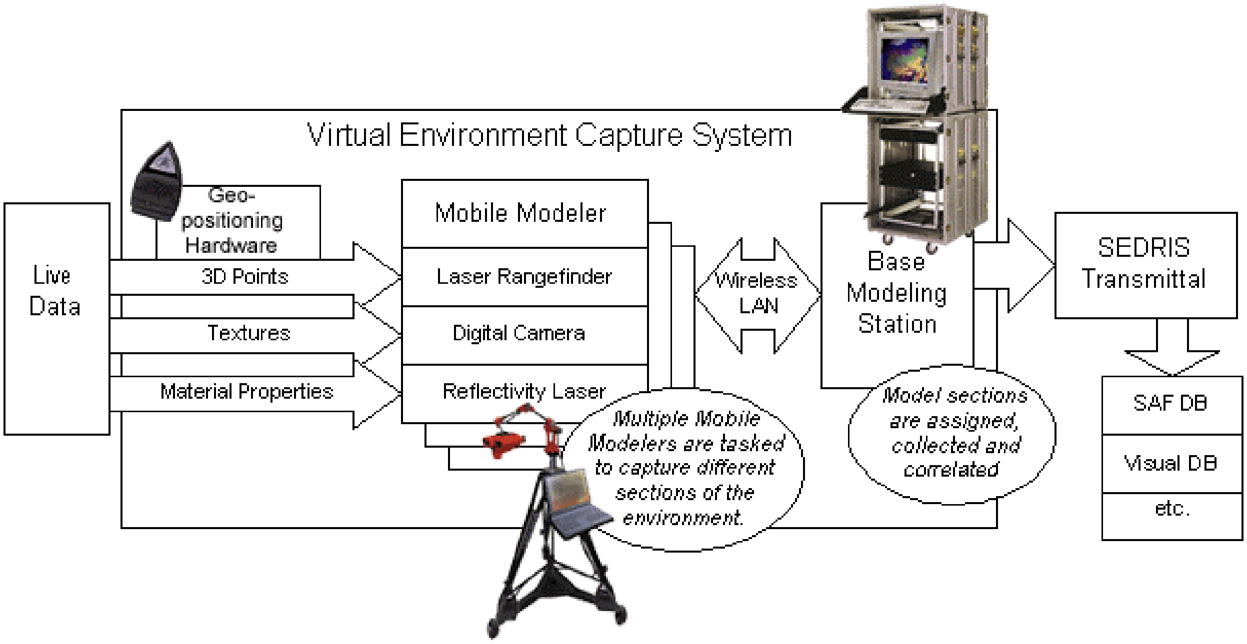

Figure 1. The VECS Conceptual Diagram

usually resulting in a model that still has “shadow areas” that the laser scan did not see. The geometry created by these systems is a point cloud, often post processed into a “bag of polygons.” It is very dense data, good for preserving detail but unsuitable for real-time applications. It has no contextual information or separation between the room geometry and the polygons belonging to the objects inside the room. Costly post processing is required to create separate, lightweight models for each object and to add any necessary attribution. Laser scanning systems are also very expensive. Theodolite techniques and model scanning techniques can capture real world data, but are not practical for building interiors. Theodolites, used by surveyors, are aimed at an outdoor 2D market and do not capture geospecific textures. Model scanners can be used to scan furniture and other small objects, but are not suitable for capturing room and building geometry.

THE VECS SYSTEM

The overall concept of the VECS system is to have several “Mobile Modelers,” wearable computer platforms that incorporate a variety of data gathering sensors, including a rangefinding laser, camera, and possibly thermal or infrared imaging equipment. The Mobile Modeler is used to position and scale premade models, build simple geometry interactively, and capture geospecific textures and attributions. The users divide the environment to be captured into sections, with each Mobile Modeler communicating back to a Base Station, which gathers and correlates the sections as they are captured. The Base Station and Mobile Modelers will communicate via a wireless LAN, and position data will be tracked with Time Modulated

Figure 2. The Mobile Modeler Prototype.

Ultra Wide Band (TM-UWB) technology (see Figure 1).

Following is a brief description of the VECS system. For a more detailed discussion including hardware, software, and model structure, please see (Graniela, 2002).

A Mobile Modeler prototype was built and used in the creation of a model of STRICOM's Central Florida Technology Development Center (CFTDC). The current Mobile Modeler configuration consists of a wheeled tripod with the data gathering sensors mounted on top. The sensors include a 5-degree of freedom arm with a laser rangefinder for gathering 3D points, and a camera for capturing geospecific texture information. A notebook computer running the Mobile Modeler interface is mounted on the tripod,. The Mobile Modeler software is operated by voice commands, allowing hands-free operation for manipulating the data gathering sensors (see Figure 2). The Mobile Modeler software operates in a local coordinate space, and uses a leapfrog technique to keep the coordinate space as it moves. Model placements are sampled from the first position, the tripod is moved, and the same model placements are sampled again in the same order, providing a transform between the two tripod locations. A single office can be used as a simple example of Mobile Modeler operation. The user would first select a library of premodeled items, in this case a collection of geotypical office furniture (see Figure 3). The Mobile Modeler would be placed in the center of the room. First, the walls, ceiling, and floor would be captured. Walls are assumed to be vertical and floors and ceilings to be horizontal, so two points to define the orientation of the wall plane and one for each of the floor and ceiling are sufficient to capture the basic room geometry. These geometry elements clip against each other. A door can be cut into a wall with two points that define the upper corners. Geotypical furniture models which best match the furniture in the room are then selected and placed with a minimum of data points. Most models are placed with one to four data points, where the first point defines the position of the first front corner of the model, the second point defines the position of the second front corner providing

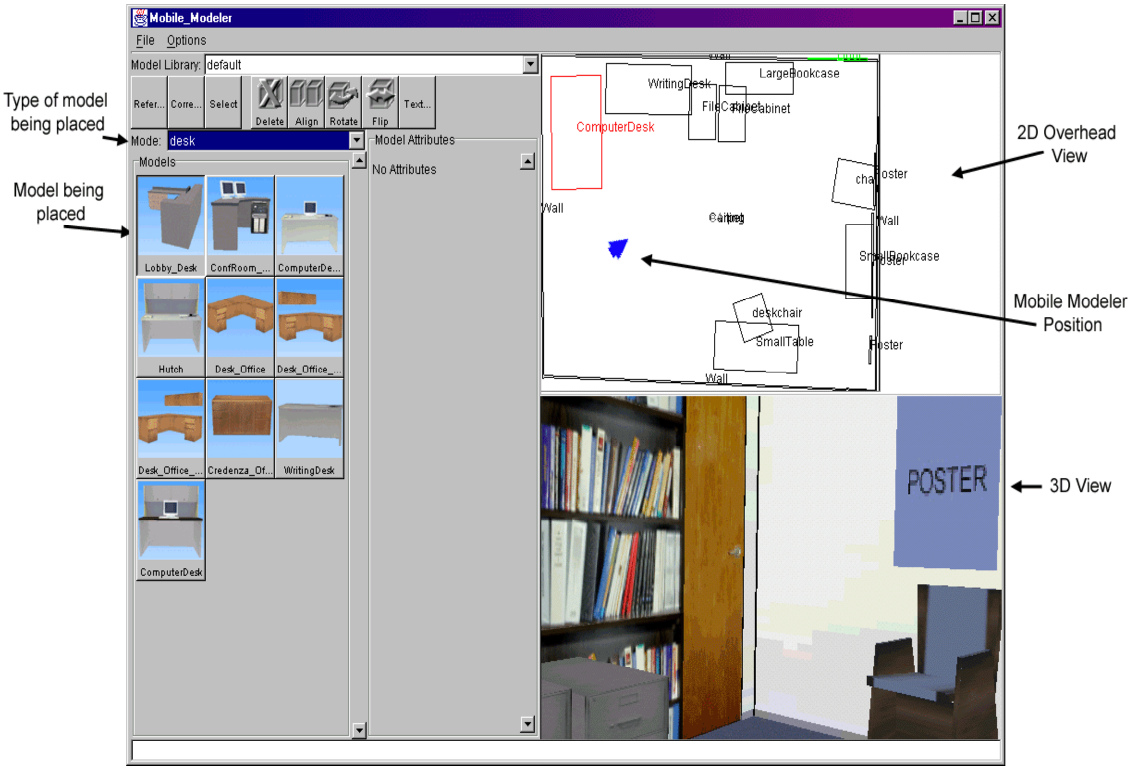

Figure 3. The Mobile Modeler software interface.

heading orientation and overall scale, the third point defines the height scale, and the fourth, depth scale (see Figure 4). After the model is placed with the first point, the subsequent points are captured only if orientation and scale modifications are desired, and the user can go on to the next model at any time. There are basic editing commands for model placement, such as rotate by 90 degrees, align with another model, and delete. The model may also be selected and repositioned by capturing another set of placement points. The final model can be saved in VECS proprietary format or exported to one of several standard formats.

Because the geometry placement is done with modal operations, contextual information is automatically built into the model. Walls, doors, windows, and furniture are identified as such. Placing a door also defines a semantic aperture for room connectivity. The user may also input extra attribute information as needed.

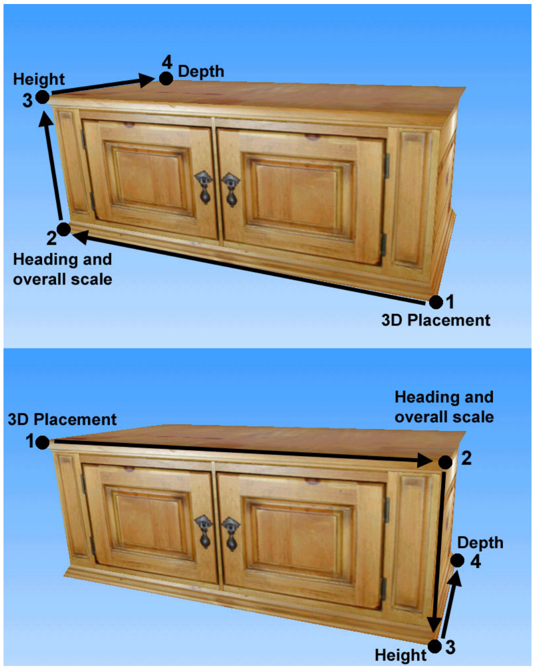

Figure 4. Two sets of possible placement points

One of the most powerful features of VECS is the ability to capture geospecific textures interactively. Geometry for a picture or poster is placed by selecting placement points for three corners, then the user points VECS at the center of the picture to capture the texture. The texture is automatically cropped, orthorectified, and applied to the picture geometry. This method can also be used to make crude models when there is no close match found in the model library. A cube is placed and sized for the model needed, and one or more textures captured and applied to the cube.

A PRACTICAL EXAMPLE: CFTDC MODEL

To be successful, a modeling system must be useable for a real-world modeling problem. The VECS prototype, consisting of a single Mobile Modeler unit with an indoor laser for rangefinding is obviously not yet suitable for capturing all aspects of a virtual environment. To illustrate the methodology that will utilize VECS in a practical situation, the effort to model STRICOM's Central Florida Technology Development Center (CFTDC) will be used as a sample task.

Scope

The CFTDC occupies part of a two-story building. There are offices on both floors, and a highbay area that extends up through the second floor. First, requirements were derived through interfacing with the customer. To define the scope, a series of questions were asked. What will the model be used for? What delivery format is desired? Which sections of the building should be modeled as geospecific, with exact models of the furniture present, and which could be geotypical, with generic office furniture models placed? Which sections should not be modeled at all? How much of the environment outside of the building should be modeled?

After asking these questions, it was determined that the model would be used for both simulation and for visual walkthroughs. It must be compatible with the ModSAF and OTBSAF family of SAF simulations, which meant that it must be structured in accordance with the contextual information needed by the SAF. The visual components of the model must be compatible with immersive 3D visual displays. Based on these requirements, the delivery formats specified were OpenFlight for the visual components, with a correlated Compact Terrain Database (CTDB) format for the simulators.

The two planned uses for the database also dictated what should be geospecific and what should be geotypical. Obviously, geotypical requires less custom model building, and is more cost-effective. This was sufficient for the SAF applications. Since the model was to be used in mixing live and virtual simulations, it was important that it be well correlated spatially, but a virtual desk did not necessarily have to be the same color and design as the real one – it merely had to be in the same place (see Figure 5). To use the model for conducting virtual walkthroughs of the building, however, geospecific furniture and signage should be used. Accordingly, the more public areas such as the lobby, main conference room, and demo facilities were designated as geospecific.

Execution

The first task was to make an initial survey and compile a list of geospecific models that would have to be built and added to the VECS library. These included distinctive pieces for the geospecific areas such as the lobby desk and the conference room table, as well as some common office furniture used throughout the building. Typical office items such as break room appliances, copiers, and interior doors were already in the VECS model library.

Figure 5. Real world location (top) and virtual environment (bottom) utilizing geospecific textures captured and applied by the Mobile Modeler and a mix of geospecific and geotypical models.

Since this was the first major project undertaken with the VECS system, it was decided to model some areas using both traditional methodologies and VECS, in order to compare the results. Other sections were done by exclusively traditional means or exclusively VECS, depending on which was most applicable.

VECS was used to capture several single-room areas, including complex environments such as the lobby and the main conference room, which contained a large conference table, numerous chairs of different types, side desks, pictures, a projector and computer, and a multimedia equipment control console. The conference room was modeled in approximately twelve minutes, using one Mobile Modeler and a library of premodeled furniture. Textures for pictures on the wall, the clock, and the projection system were captured interactively (see Figure 6).

Figure 6. The CFTDC Conference Room model

Two of the offices were used as comparison cases. The bounding geometry (walls, ceiling, and floor) were modeled from building blueprints, then modeled again with VECS and also physically measured with a tape measure. The bounding geometry for one office was also modeled several times with VECS to test repeatability. Results were found to be within specified tolerances for the building model.

One area that proved to be problematic was the leapfrogging technique used to maintain the local coordinate system as the tripod was moved. The 5-DOF arm, when articulated in different ways to reach the same point, gave slightly varying results. Thus, when points were sampled, the tripod moved, and the points resampled, they were shifted slightly. The resulting error made moving the tripod more than once or twice impractical. The sections of the model captured with VECS were done in discrete chunks, and assembled afterwards.

CONCLUSION

Advances in graphics technology will continue to drive the demand for detailed, geospecific virtual environments for use in simulation, entertainment, and a host of other disciplines. In order to create these environments accurately and inexpensively, a technology must be developed that can easily capture data from the real world. VECS allows the rapid capture of building geometry and interior details.

The prototype Mobile Modeler has proven itself in practical application. The next step is to incorporate outdoor range finding laser technology such as the theodolyte survey equipment used for the CFTDC exterior, and development of a Base Modeling station that could correlate data from several Mobile Modelers working in parallel. More accurate geopositioning for the data sensor platform, such as TM-UWB technology, will make the bulky articulated arm redundant and allow more efficient repositioning for the Mobile Modeler units.

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