Modeling and Visualization

1. Research Team

Project Leader:	Prof. Ulrich Neumann, *IMSC and Computer Science*
Other Faculty:	Prof. Suya You, *IMSC and Computer Science* Prof. Suresh Lodha, *UC Santa Cruz* Prof. William Ribarsky, *Georgia Institute of Technology* Prof. Promod Varshney, *Syracuse University* Prof. Avideh Zakhor, *UC Berkeley*
Graduate Students:	Jinhui Hu, Bolan Jiang, Kelvin Chung, Kyung Kook Park, Ismail Oner Sebe, Hongmin Tu,
Industrial Partner(s):	Northrup Grumman, Olympus, Hewlett-Packard

2. Statement of Project Goals

This project addresses several research topics related to virtual reality, augment reality, geometry modeling, motion tracking, and visualization. The primary objective of this research effort is to devise new and innovative approaches and technologies that would improve the capabilities of information extraction, fusion, interpretation, and visualization from multiple sensor sources and dataset, suitable for various time-critical applications.

Scene modeling: While current sensing and modeling technologies offer many methods are suitable for modeling a single or a small number of objects, the creation of detailed wide-area models still remain costly and difficult to produce. This problem is the main impetus for our work. Our long-term goals are the scientific knowledge needed for creating detailed 3D models of large urban areas that include the internal and external features of buildings, surface streets, subsurface infrastructure, and vegetation, as well as moving people and vehicles, and data from multiple sensors. This research will benefit many applications including urban planning, geo-information systems, virtual reality, and military operations.

Motion tracking: This research front is for the development of innovated multi-sensor fusion technology that primarily uses for outdoor motion tracking. The aim is to produce technology that is general-purpose, operates in unprepared-environments, and is feasible with current or near term technology. Particularly, we develop techniques towards the system requirements we consider essential to the hybrid tracking system. The effort of this research is complementary to current trends in NRL's BARS system. Other areas of potential use include virtual reality, HCI, and robot navigation.

Data fusion and visualization: This research front focuses on the problem of dynamic visualization of multiple image/video/data streams from different sources and platforms. The problem we emphasize is providing some way for people to digest and understand all this information easily with some sense of the spatial, temporal, and truthful nature of the information. The efforts of this research will benefit many application in commercial, law enforcement, security surveillance, environment monitoring, traffic measurement, and military applications (Figure1).

We develop an integrated prototype system by combing those researches to illustrate the utility and benefits of our technologies.

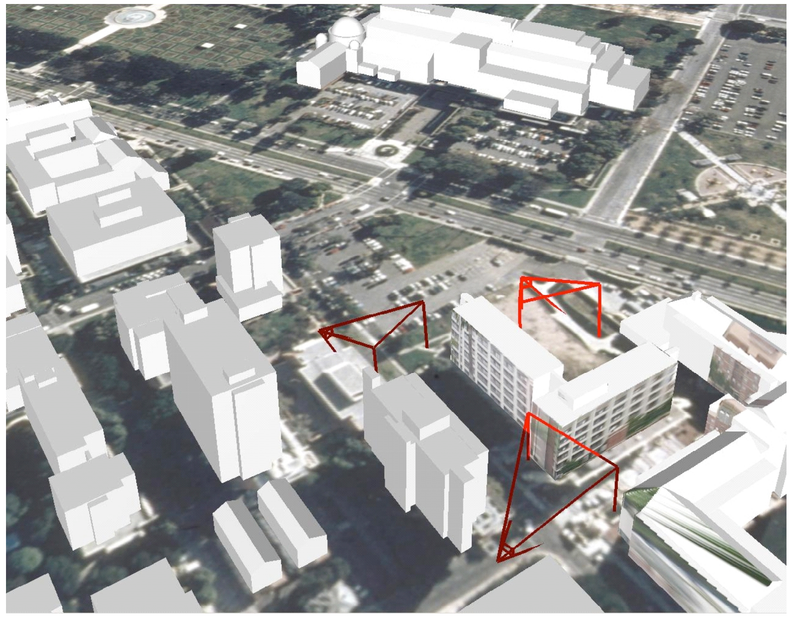

Figure 1 - An AVE visualization shows static building models of the USC campus and a static aerial texture on the ground. The red frustums show the positions of three video sensors projecting real-time video onto the surrounding building model sides. The user has complete viewpoint control for flying over or into the scene while live video is visualized.

3. Project Role in Support of IMSC Strategic Plan

The main goal and mission of IMSC is to create Immersipresence, or a state of highly efficient interactions between humans and machines. This project explores how to create a highly comprehensible presentation of multiple channels of visual information. The techniques we develop may be extendible to GIS, security, and educational applications. Any time there are multiple views of a spatial setting, this approach has application. In the communication vision scenario, multiple views of each participant are treated as a case of multiple views of a single virtual space in order to perceptually-fuse the participants into one spatial setting.

4. Discussion of Methodology Used

We address a complete modeling system that can model complex object structures with irregular shapes and surfaces. Our approach is based on the use of laser scanning sensors to quickly acquire to 3D models of scenes. To verify and refine the acquired raw model, we propose to use a primitive-based approach to segment the object boundaries, do the model refinement, and assemble a complete scene model. We explore a set of appropriate model primitives and fitting strategies to handle a range of complex buildings with irregular shapes.

Our tracking efforts focused on a hybrid tracking framework that integrates model-based vision tracking and other sensor modules (such as INS and GPS). In this framework, the central unit will be the gyro sensor that continually reports real-time data streams in raw data form. These sensed raw data streams will be fed into a fusion filter combined with constrains provided by the model and tracked natural features for attitude computation and pose update. The model constrains provide the necessary pose reference in the 3D world, and the natural features constraint the solution to converge to a stable and accurate pose estimate.

To cope with the aforementioned limitations of static models and visualizations of environments, we introduce the concept of an Augmented Virtual Environment (AVE). AVE is a comprehensive framework of data fusion, analysis, and visualization that incorporates and presents all the sensors, data, objects, and scenes within a common virtual world to produce a concise and coherent representation for time-space interpretation of real world scenery. In an AVE system, geometry model of environment is augmented with images to create an augmented virtual environment that provides a visualization of both the geometry and dynamic imagery in a common 3D context. The AVE fusion not only adds the image information to the visualization, but adds it in the 3D context of the model, allowing dynamic images, events, and movements captured in video to be visualized in the same 3D context from arbitrary viewpoints (Figure 1).

5. Short Description of Achievements in Previous Years

We employed laser scanning sensor to quickly collect 3D geometric samples of an environment. We acquired LiDAR model of entire USC campus and surrounding Coliseum area, and processed it with our developed modeling software.

We combined a differential GPS receiver with a commercial orientation sensor to produce a self-contained portable tracking system coupled to a video camera. The tracking data can be encoded and stored with the camera video stream in real time on the hard-drive of a laptop computer. The complete system is housed in a backpack for mobility.

We constructed an AVE prototype for testing and demonstrating our algorithm research efforts in a laboratory setting. We developed several core technical issues essential to an AVE system include real-time video/image acquisition, camera pose tracking, and dynamic texture projection.

5a. Detail of Accomplishments During the Past Year

Recent technical effort continues the algorithm and technique research for scene modeling, pose tracking, and AVE visualization. Much of our work in this period involved the scheduled tasks presented in last report, which produced following threads:

Scene modeling: We have developed techniques and a semi-automatic system to model, refine, and extract complex urban infrastructure structures from LiDAR. The previous system however is a fragmented set of processes that are manually invoked in sequence to perform LiDAR data re-sampling, hole-filling, tessellation, feature extraction, and model-fitting. In this period, we re-designed the whole system structure and integrated these fragmented processes into a single complete application with a consistent interface and interactive user input. We demonstrated the new system's ability to model a variety of complex buildings rapidly and accurately from the LiDAR data of USC campus and the data provided by US Army NightVision laboratory. We added the modeling system a new capability to use other multiple sensing sources, such as imagery, to increase the automation of the feature extraction and model refinement of LiDAR sensing data. We also started to work on a ground based laser scanner to acquire facade models of buildings.

Dynamic object modeling: We addressed the algorithm developments for automatic analysis imagery and other sensor data for tracking and modeling of dynamic events and objects (of primary interest are people or vehicles) through the scene. In this research, we developed approaches for dynamic object tracking, shape modeling, and their visualization in 3D world. We demonstrated the benefits of using this type of dynamic object representation and 3D visualization that can greatly improve and enhance people's capability of rapid and accurate exploitation of dynamic events derived from large environment.

Motion tracking: We developed a real-time hybrid tracking system that integrates gyroscopes and line-based vision tracking. Gyroscope measurements are used to predict pose orientation and image line feature correspondences. Gyroscope drift is corrected by vision tracking. System robustness is achieved by using a heuristic control system to evaluate measurement quality and select measurements accordingly. Experiments show that the system achieves robust, accurate, and real-time performance for outdoor environment.

AVE visualization: We built an AVE system for the rapid creation of accurate wide-area virtual reality visualization from multiple sensors. We re-designed and improved the video projection algorithm. We implemented a fast one-pass approach utilizing graphics hardware to achieve real time rendering. Current high-performance GPUs, such as NVidia's GeoForce-3 or above, support supports 24-bit shadow maps in hardware, allowing users to access and program these hardware resources for their own operations. With this new AVE version, we achieved real time rendering (26 Hz) of 1280x1024 visualizations with four concurrent texture streams projected onto our campus model.

We integrated the techniques described above and constructed a room-size 3D visualization environment. The system is used for demonstrations of the AVE concept and as a testbed for algorithm developments. The display consists of an 8x10 foot screen, back-projected by a sequential-frame stereo video-projector. Demonstrations of the AVE system have been presented frequently to visitors.

6. Other Relevant Work Being Conducted and How this Project is Different

The techniques we developed are novel and unique in many aspects. Most existing modeling systems facilitate geometric modeling through the manipulation of either standard geometric primitives, libraries of pre-modeled objects, or manual digitizing of key points. Creating models of a large environment in this fashion takes enormous effort, skill, and time. Our modeling approach can rapidly model complex scene with irregular shapes and surfaces, suitable for producing large-scale urban models at modest cost. Camera pose tracking is common in the augmented reality community. There are ONR and Columbia University projects pursuing hybrid GPS/inertial sensor tracking and image annotation. However, neither pursues the pose stabilization with vision. Furthermore, we first propose the concept of AVE visualizations of fusion multiple video with the 3D context of models, which offers the capability to capture, represent, and visualize dynamic spatio-temporal events and changes within a real environment.

7. Plan for the Next Year

We are continually exploring each of relative issues. The success of the AVE prototype enables us to quickly move forward to our ultimate goal. Some ongoing and future work are: full automatic 3D model segmentation; new methodologies such as tensor voting for 3D modeling and fitting; hierarchical model representation and semantics; and some open issues related to AVE projection such as old projection persistence, and multiple video bandwidth requirements. In addition, we are planning to explore several potential areas to apply our AVE technology in commercial, law enforcement, security surveillance, and defense applications.

8. Expected Milestones and Deliverables

The developed technologies and system can be delivered in several forms including source code or libraries. The deliverable elements are summarized below:

- Backpack system for video and camera pose acquisition
- Software for hybrid vision, GPS, and inertial sensors tracking
- Software for automatic model mesh production from LiDAR data
- Software for complex building extraction and refinement
- AVE visualization system for dynamic image/video/model fusion

9. Member Company Benefits

The developed technologies can benefit many applications. Large-scale scene modeling is required for the fields of engineering, mission planning, urban planning, training simulations, entertainment, GIS systems, and military applications. Our work on LiDAR modeling is highly interesting to military agencies such as the US Army NightVision laboratory, and is in use at the U.S. Army Topographics Engineering Center.

Tracking is a critical component in many applications, where require accurate estimating position and orientation of a camera moving freely in a wide area outdoor environment. The hybrid tracking technology we developed is complementary to current trends in NRL's BARS system. NRL has our software and is currently integrating it into their AR research platform.

Dynamic visualization and AVE projection has wide potential for various time-critical applications in commercial, law enforcement, environment monitoring, and security surveillance. Demonstrations to several defense contractors (Raytheon, Lockheed Martin, and Northrup Grumman) have produced a great deal of application ideas and interest. We developed an on-site demonstration unit for Northrup Grumman (Carson CA), further discussions are underway towards incorporating AVE into products. A new project has also started with HP for using AVE methods in visualizing data, and with the Institute of Creative Technologies (ICT) for future command-post training.

10. References

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