Tracking and Visualization with Models and Images

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Goal: 4D Visualization of Battlefield Environment

- Combine all manner of images, models, video, and data in a *coherent visualization* that supports
  - Varied media types and layers of abstraction
    - images, video, text, paths, hyper-links, communications, …
  - Varied certainty of content
    - position, time, recognition, source, …
  - Varied temporal acquisition/display
    - archival, current, projected

Focus: Models, Images, Tracking

- Projecting multiple images onto base models to create common visualization
- Calibrating scene features (points and lines) to create or refine models
- Sensor fusion for outdoor tracking

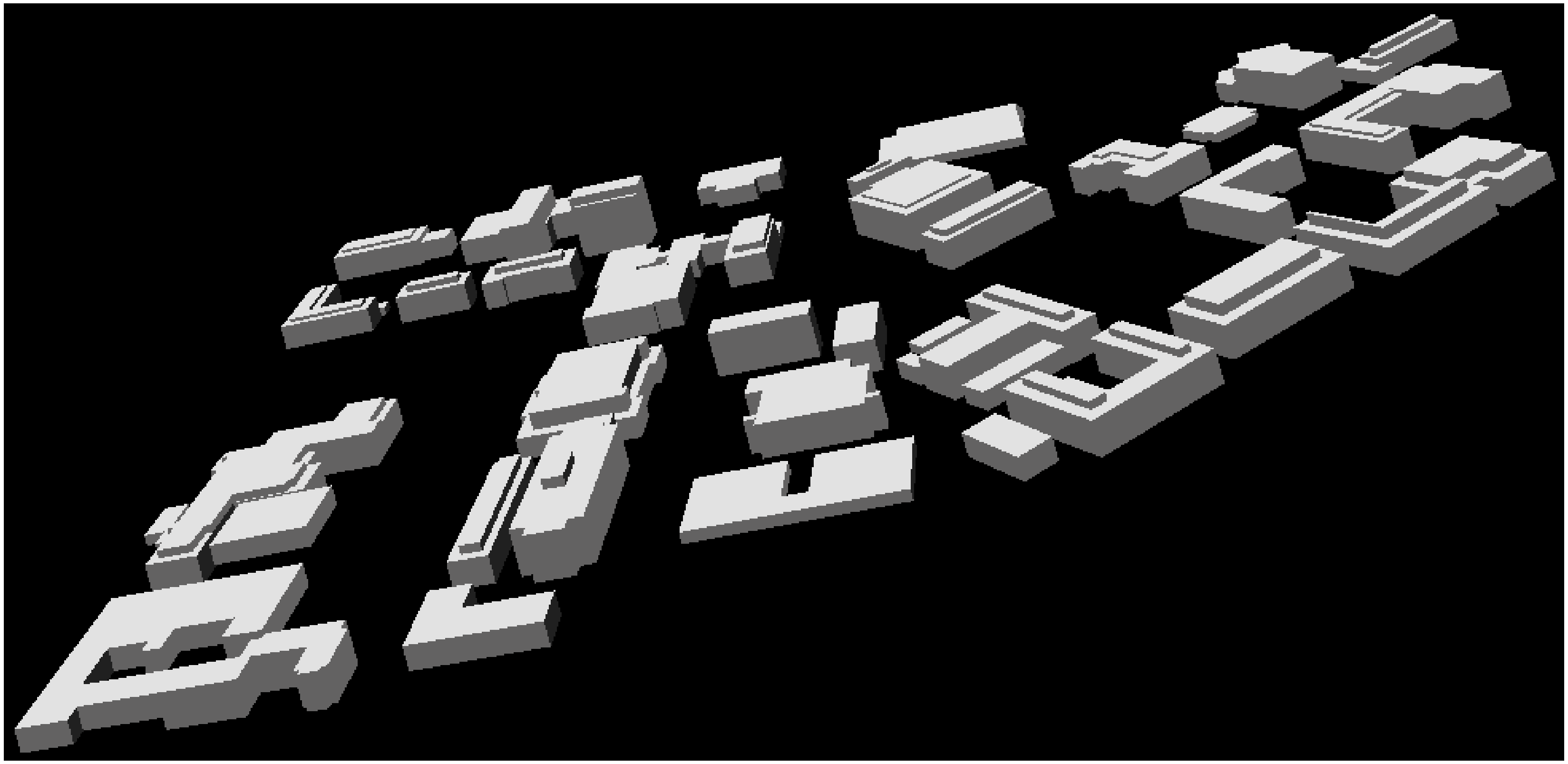
Integrate 2D Images as Textures on 3D Models

- Use sensor models and 3D models of the scene to integrate image data from different sources
- Produce visualizations from arbitrary viewpoints
- Textures can be
  - *static* precomputed mapping of images to models
  - *dynamic* projections onto models – slide projectors

Textured Models

- E.g.,VRML (Virtual Reality Markup Language) provides a standard 3D model representation
  - developed for web applications
- Objects (e.g. buildings and roads) and terrain represented by a list of polygons
- Textures for each polygon are described by a corresponding polygon in an image
  - model to image mapping is *pre-computed* by projecting the model on to the image by a known sensor model

Generate 3D Building Models



Projected view of models from stereo or any modeling method

- models courtesy Prof. Ram Nevatia

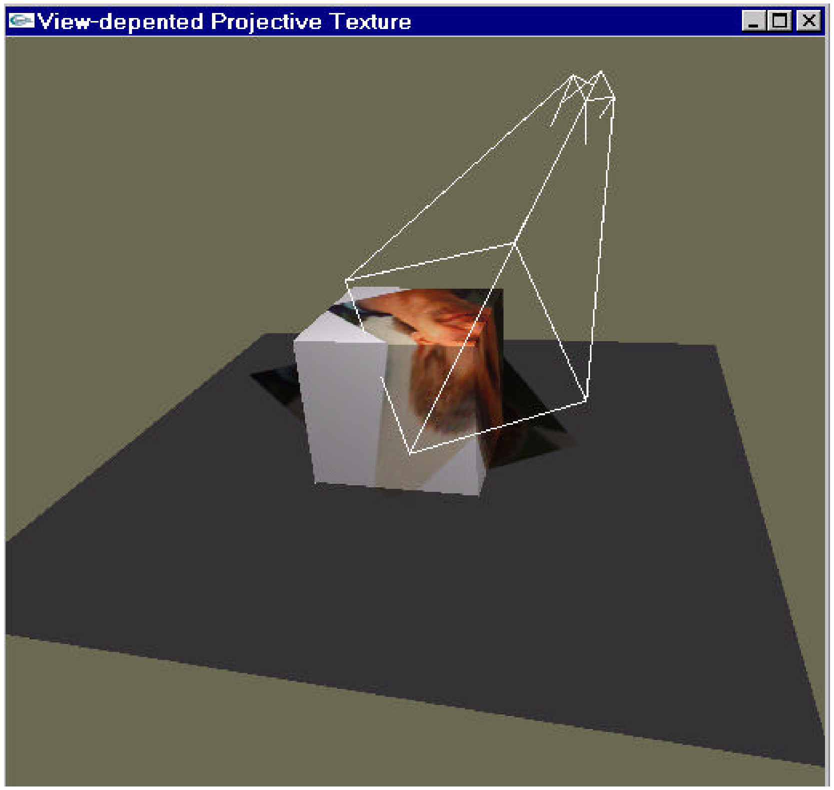
Models Projected on Aerial Image as Texture

- Models and texture relationship is static
- No new images can be added without preprocessing
- No moving camera images (video)
- No scene updates

VRML player video

Visualization as Texture Projections

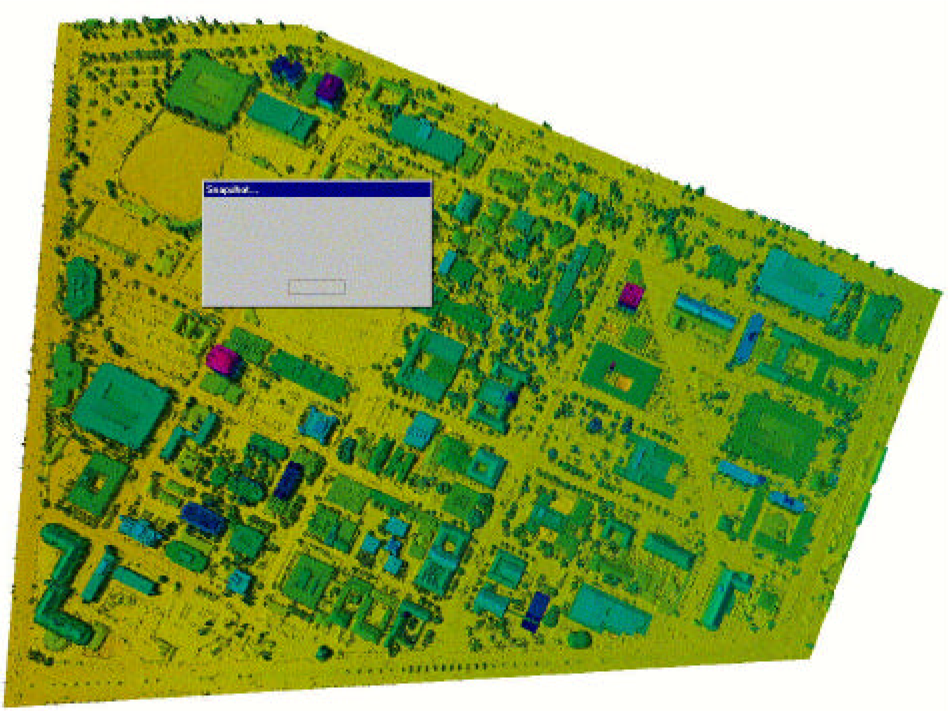
- *Dynamic* images or video are projected onto scene model
- Camera motion “paints” images on model to reflect most recent information
- Simultaneously visualize *many* images projected on the same model

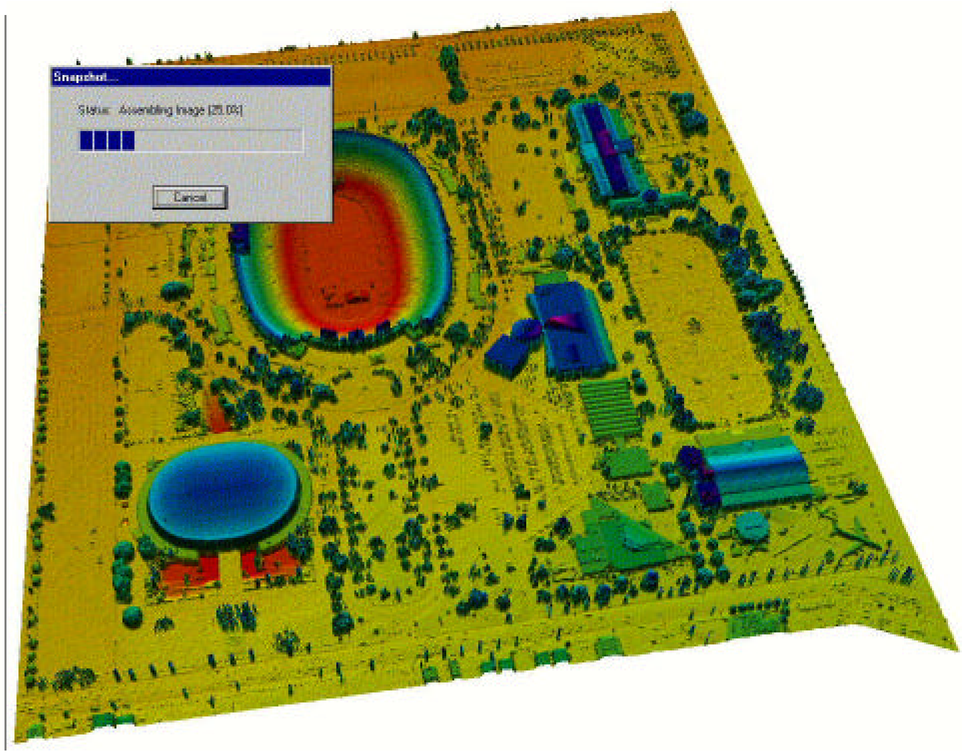


Projection onto LiDAR

USC LiDAR data courtesy Airborne1 Inc.

- 3D point-cloud accurate to sub-meter in ground position and cm in height





Texture Projection Goals

- Near-term: Textured-LiDAR renderer
  - Point-cloud, tessellation, texture projection
  - Speed with 100K-1M points
  - Video textures (multiple streams)
- Long-term: Automatic data classification
  - Building extraction
  - Vegetation extraction

Tracking & Autocalibration

- People with sensors (or unmanned sensors) moving in environment provide textures and data for visualizations…
  - *Where are they? Where are they looking?*
- Tracking provides position and orientation
  - Tracking is possible with landmarks in view
  - Autocalibration allows tracking in regions beyond/near landmarks – also can improve/refine models
  - Sensor fusion (GPS, vision, gyroscopes) adds more tracking information for wider areas

Autocalibration

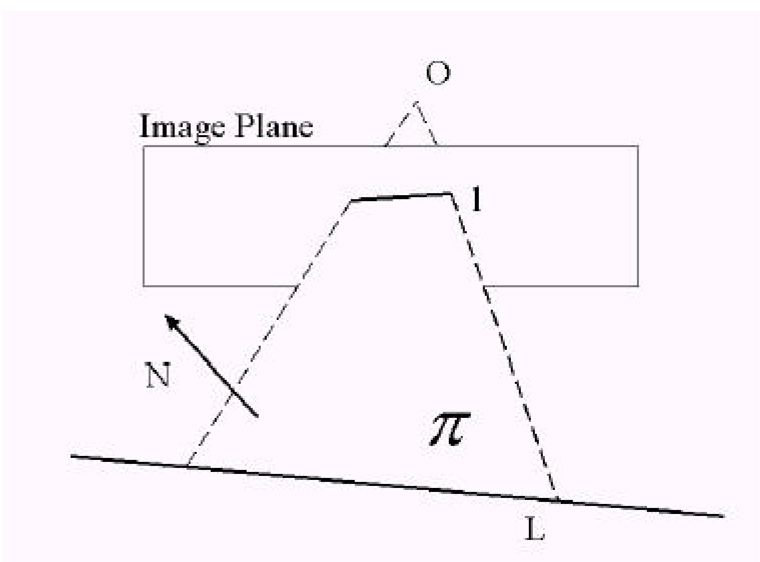
- Point AC developed in past 2-3 years
- Line tracking and autocalibration is new [ISAR2001]
  - Pose from 3D calibrated lines or points
  - Autocalibration of 3D lines

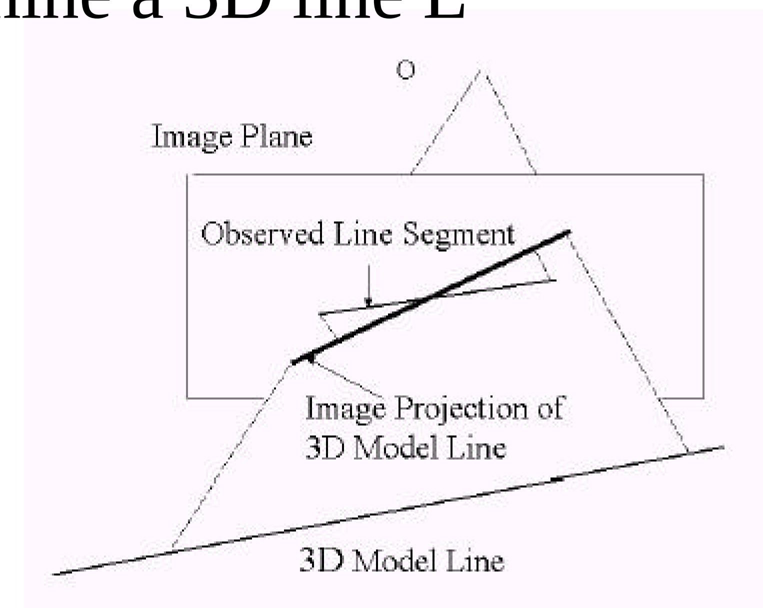
OUTDOOR

INDOOR

Line Representation

- 2D line: Ax+By+C=0
- 3D line: intersection of two planes in space
  - Unique representation (minimal) has four parameters $N_1, N_2 \in (x, y, 1)$ for a given ($R_1 T_1$, $R_2 T_2$) to uniquely determine a 3D line L





EKF for Pose and AC

Simulation with 100 inch volume and 50 lines

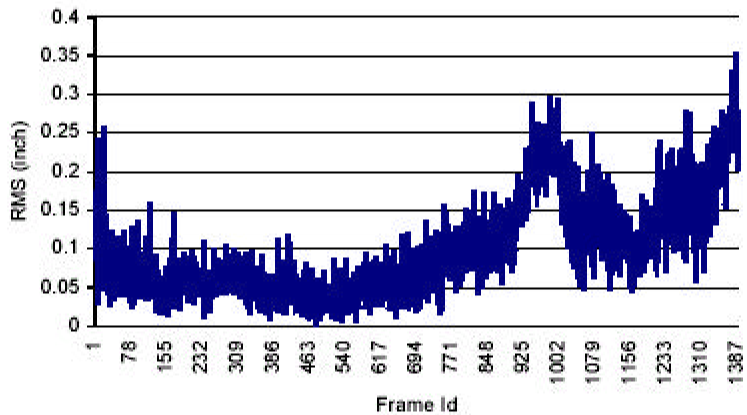


Fig. 3 (a) camera position error

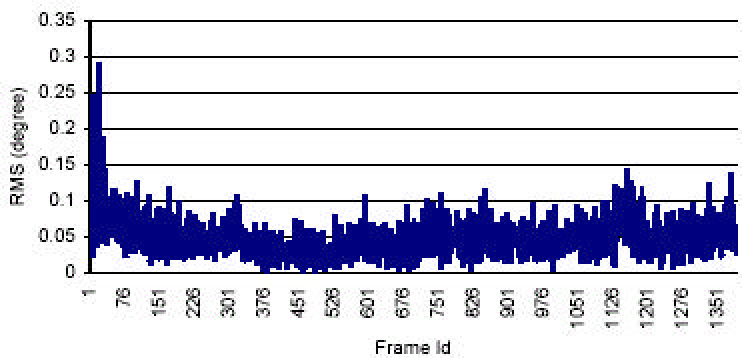


Fig. 3 (b) camera orientation error

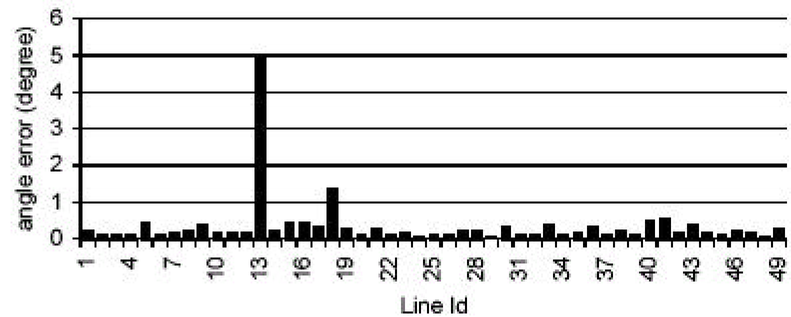


Fig. 4 (a) angles between auto-calibrated lines and the corresponding true lines

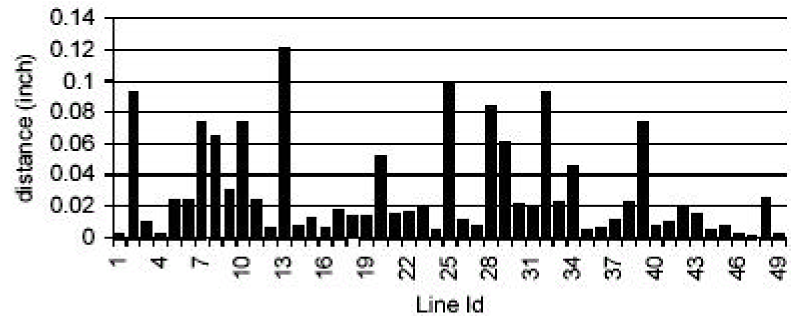


Fig. 4 (b) distances between auto-calibrated lines and the corresponding true lines

Fig. 4 Errors for auto-calibrated lines

Sensor Fusion for Outdoor Tracking

- Track 6DOF pose over wide area outdoors
  - Varying sensor data availability and data rates
    - vision, GPS, gyroscope, compass, accelerometer
  - Varying certainty of measurements
    - spatial and temporal noise and precision
  - Fusion models and algorithms
    - underdetermined system needs constraints
    - real-time execution on wearable/portable systems

Mobile Tracking/Sensor Testbed

- RTK differential GPS
  - Ashtech Z-Sensor base/mobil
- 3D gyros/compass
  - IS300 and Systron Donner Gyrochip array
  - Panoramic and forward-down or side-down cameras
- Scene model (e.g., LiDAR) provides landmarks for pose and autocalibration as well as base-model for visualization of acquired images/video

Future Plans

- Outdoor multi-sensor tracking and image/video acquisition for visualization
- Texture projection onto LiDAR models
- Autocalibration of building features and model segmentation/refinement
- Distributed visualization (GT, UCB)

Related Publications

- J. W. Lee, S. You, and U. Neumann. “Large Motion Estimation for Omnidirectional Vision,” *IEEE Workshop on Omnidirectional Vision*, with CVPR, June 2000
- J.W. Lee, U. Neumann. "Motion Estimation with Incomplete Information Using Omni-Directional Vision," *IEEE International Conference on Image Processing (ICIP'00)*, Vancouver Canada, September 2000
- S. You, U. Neumann. "Fusion of Vision and Gyro Tracking for Robust Augmented Reality Registration," *IEEE VR2001*, pp.71-78, Yokahama Japan, March 2001
- B. Jiang, U. Neumann, “Extendible Tracking by Line Auto-Calibration,” submitted to ISAR 2001