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Presentations
Computer Vision Research Lab

- Relevant UMass Research — Edward Riseman
- Image Warping for Image Registration — Howard Schultz
- 3D Panoramic Imaging — Howard Schultz
- 3D Terrain and Site Modeling — Edward Riseman
- Aided Search and Target Cueing — Gary Whitten
- Knowledge-Based and Adaptive Image Processing
  Allen Hanson

Considerable overlap of the 5 topics

Interaction between subproblems and solutions

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Computer Vision Personnel

- Allen R. Hanson and Edward M. Riseman
  - Professors, Computer Science Department
  - Co-Directors, Computer Vision Research Lab
- Howard Schultz
  - Research Professor, UMass since 1989
  - JPL, Member of the Technical Staff, 1984-86
  - Bendix Aerospace, Research Engineer, 1982-84
  - ERIM, Research Scientist, 1978-82
- Gary Whitten
  - Research Professor, UMass since 1996
  - University of Maryland, Research Faculty, 1995-96
    - Co-PI with Azierl Rosenfeild, ONR ATR program
  - Martin-Marietta, Senior Scientist, 1990-95
  - Fairchild Western, Senior Engineer, 1985-90

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Relevant UMass Research

- 1993-1996 RADIUS Program DARPA/ORD

  (Research and Development in Image Understanding Systems)
  - 5 Universities and 2 Corporations

- UMass Ascender I
  - Multi-view reconstruction of buildings
  - Focused on accurate 3D acquisition of flat-roof structures
  - Produces textured-mapped CAD models
  - Fly-through visualization

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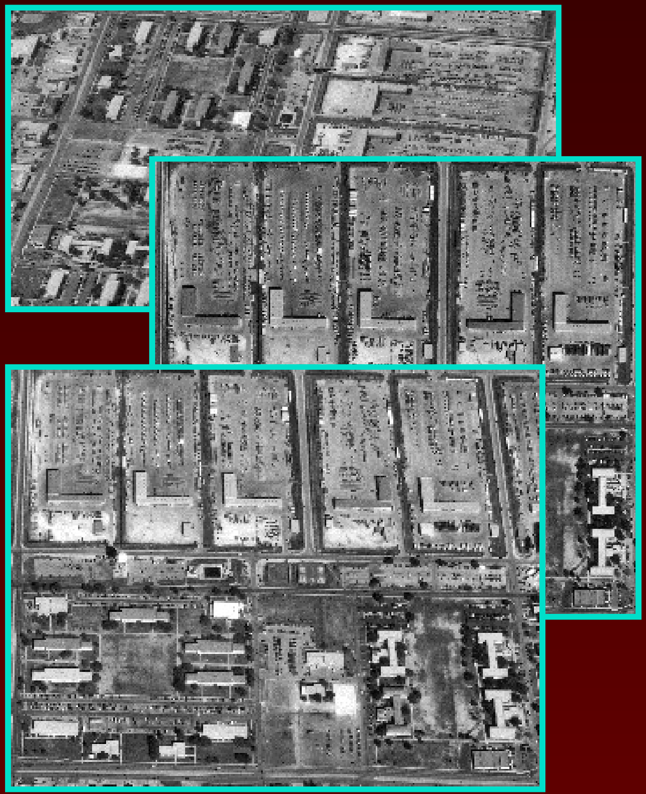
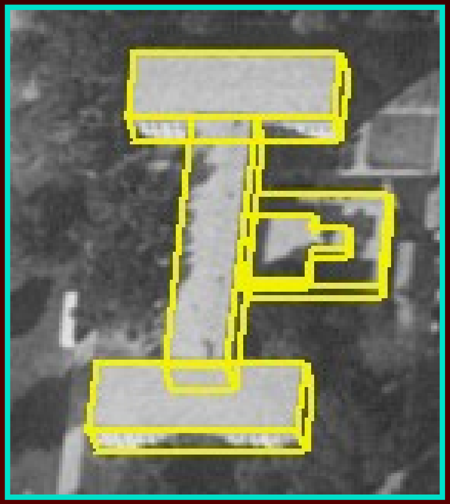
Ascender I

System for Automatic Site Modeling

Multiple Images → Geometric Models



- rooftop detection
  - line extraction
  - corner detection
  - perceptual grouping
- epipolar matching
- multi-image triangulation
  - geometric constraints
  - precise photogrammetry
- extrusion to ground plane
- texture mapping



Relevant UMass Research

- 1996-1999 APGD Program DARPA/NIMA
  (Automatic Population of Geospatial Databases)

- UMass Ascender II
  - Context-sensitive reconstruction of cultural sites
  - Knowledge-based strategies for intelligently invoking algorithms
  - Reconstruction of many types of complex buildings
  - Identification of buildings, roads, parking lots, etc.
  - Reconstruction from SAR and IFSAR images

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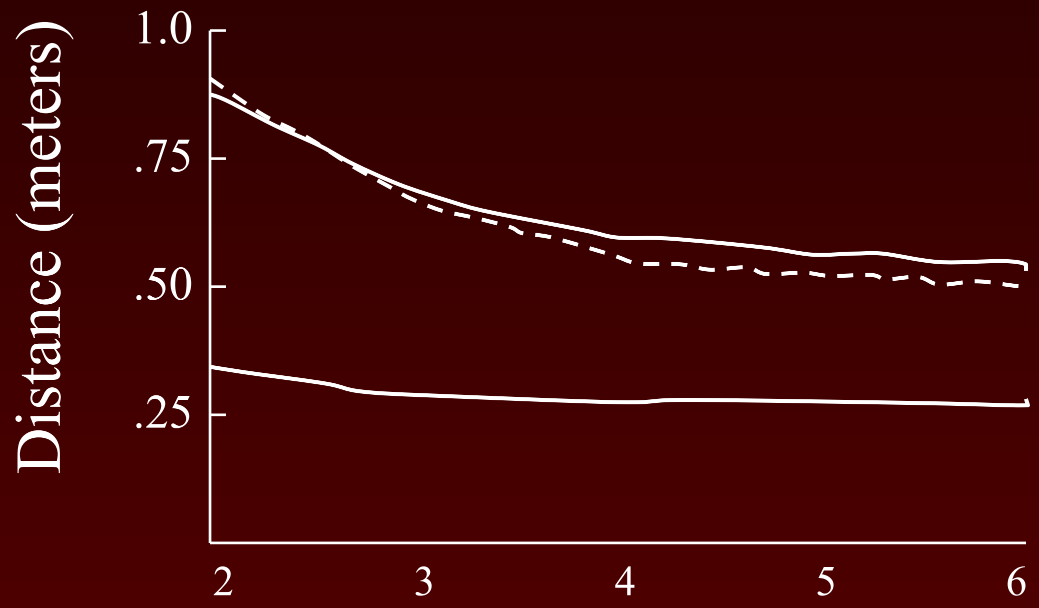
Video Clip 1

Ascender I

3D Accuracy vs. Number of Views



Number of views used vs. 3-D reconstruction accuracy in meters

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3D Reconstruction Accuracy

Image	711	713	525	927
IV Planimetric	0.68	0.73	1.09	0.89
IV Altimetric	0.51	0.55	0.90	0.61

Median planimetric and altimetric errors (in meters) between reconstructed 3-D polygon vertices and ground truth roof vertices.

Relevant UMass Research

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- 1989-1995 ONR Basic Research

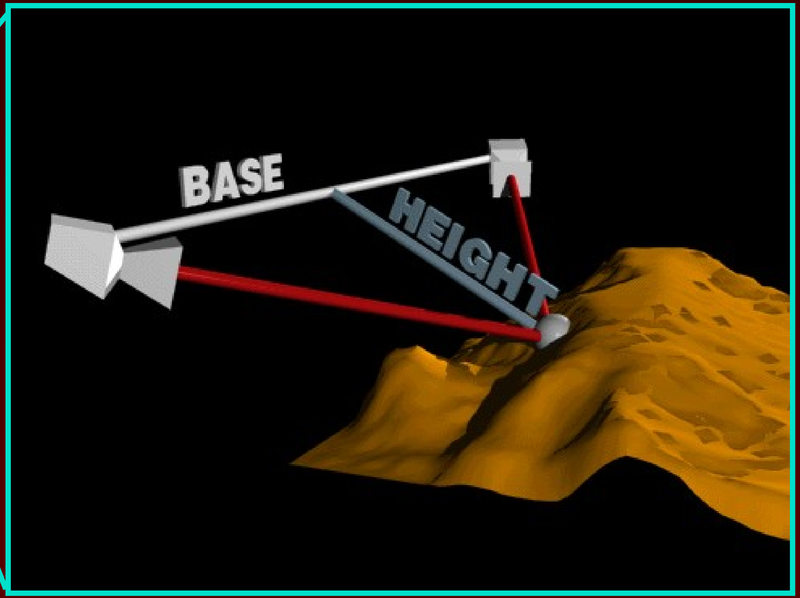
  (Recovering the Small Scale Structure of the Ocean Surface)

- Terrest (Terrain Reconstruction System)
  - Produces a digital elevation map from pairs of aerial images
  - Adapted from oceanographic to land-based applications
  - Utilized in DARPA-Army Unmanned Ground Vehicle (UGV) program
    - Path planning
    - Visibility analysis
    - Battlefield awareness and visualization

Terrest

Terrain Reconstruction System

- Goals
  - Rapid and accurate generation of elevation maps
  - Multiple Images/Sensors
  - Oblique Images
  - Widely Separated Images
  - Large base-to-height ratios
  - Subpixel precision
  - Capable of using a-priori information (DTED, etc)
  - Capable of running on distributed systems



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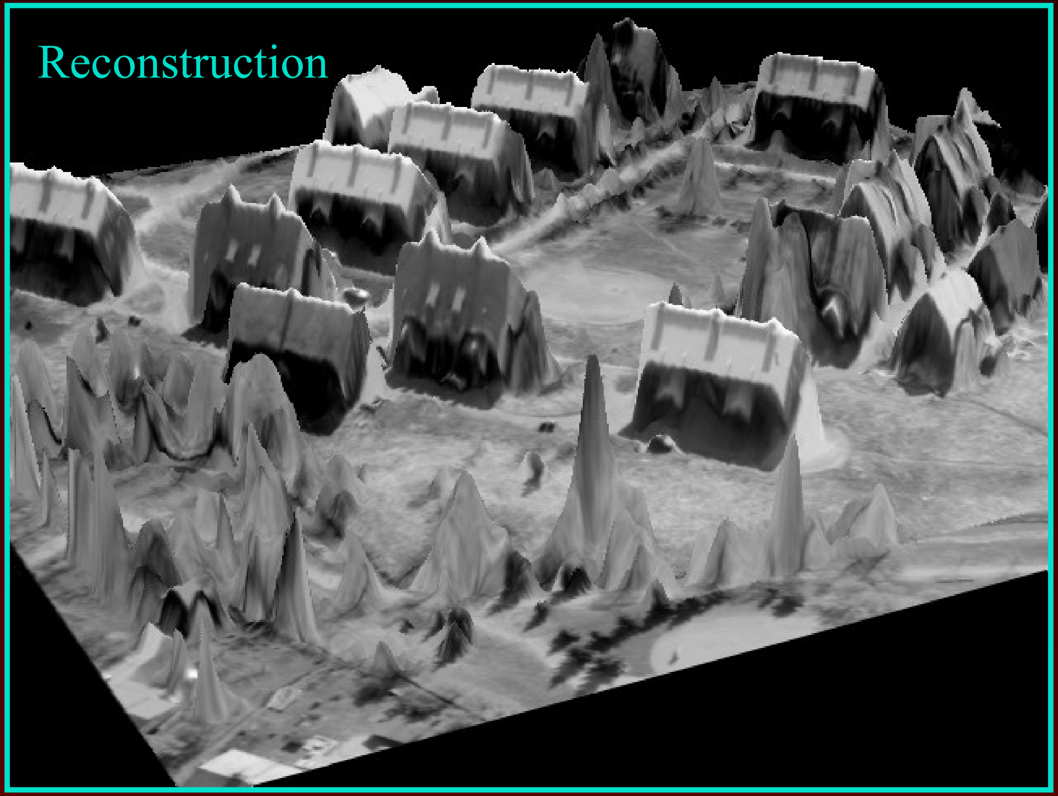
ISPRS ‘Flat Scene’



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Video Clip 2

Terrest

Relevant UMass Research

- Fusion of Information from the above programs
  - 2D lines, corners, polygons from images
  - 3D lines, corners, surfaces from DEMs
  - Grouping to construct buildings
  - Applying constraints during stereo analysis to improve DEM generation

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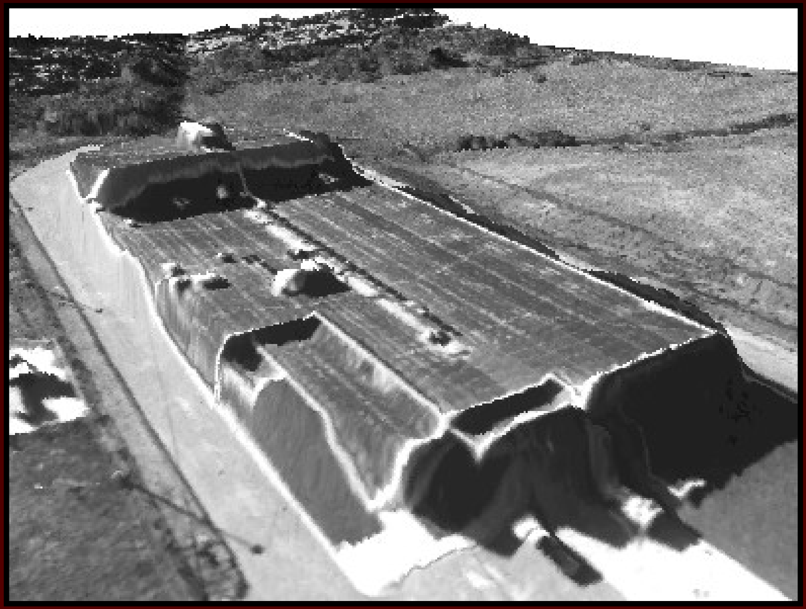
Results: Denver, Co.

Texture-Mapped Rendered Elevation



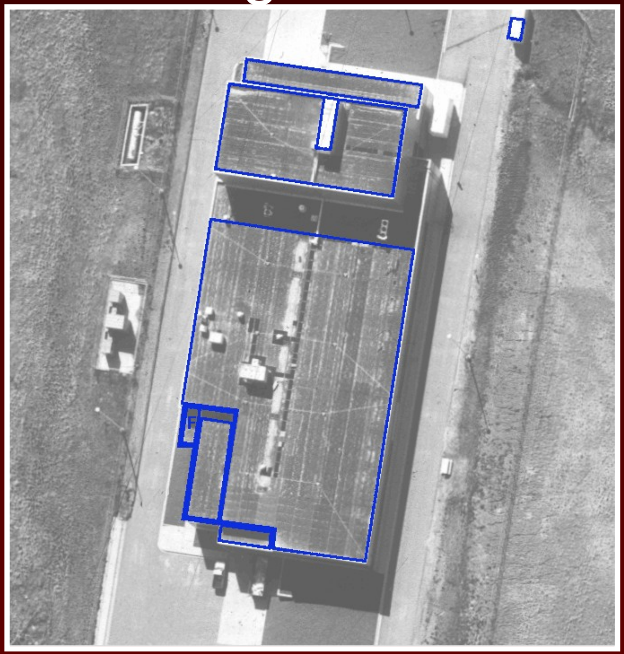
DEM + Optical 1

Results from Ascender and Terrest

2D building rooftops

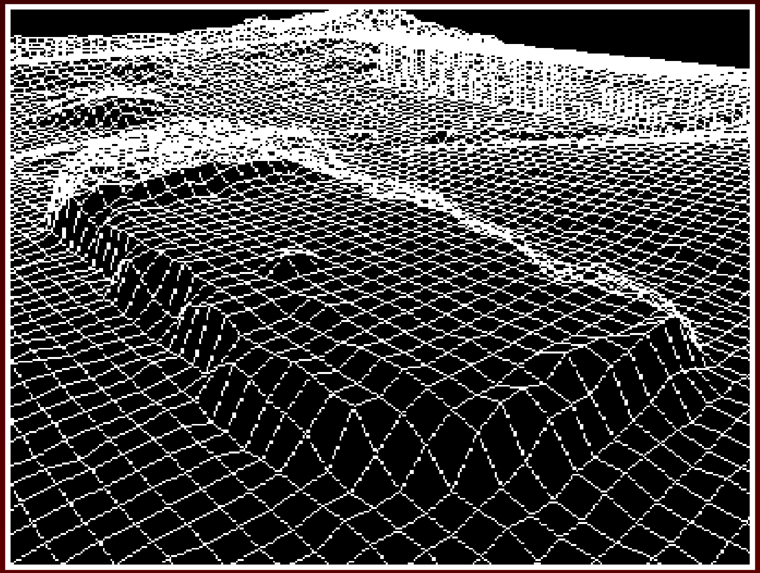
DEM

Building Extraction



+

Wireframe DEM



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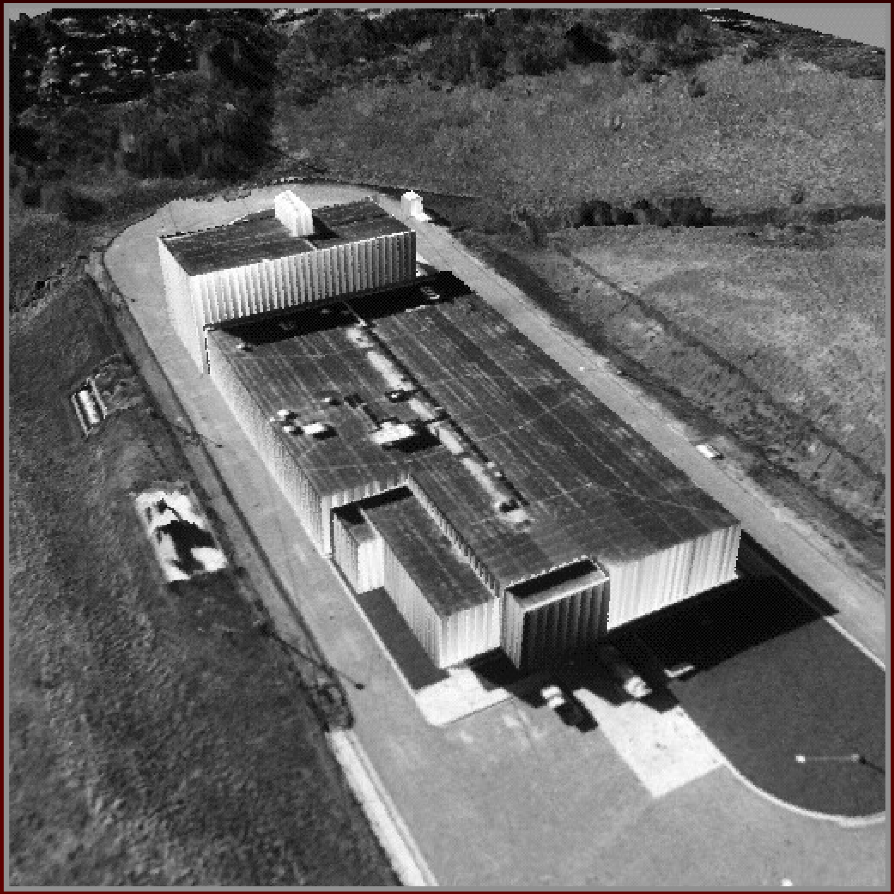
DEM + Optical 1

Combined Results

DEM Alone



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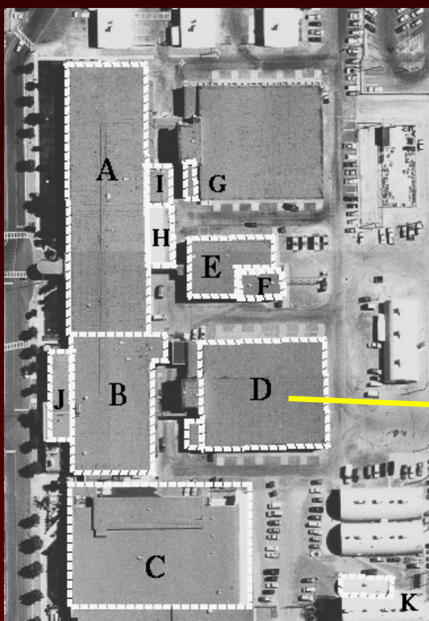
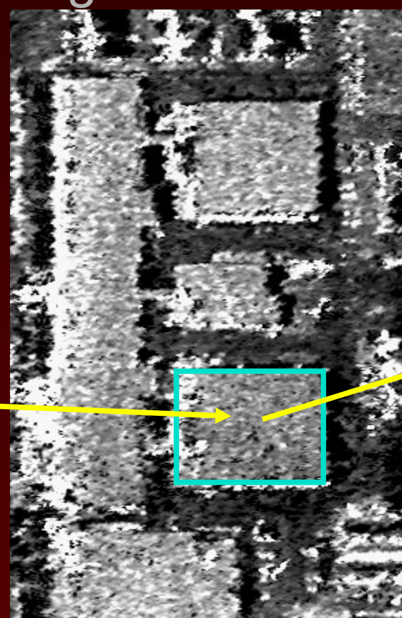
Kirtland AFB

Optical w/ 2D polygons from Ascender



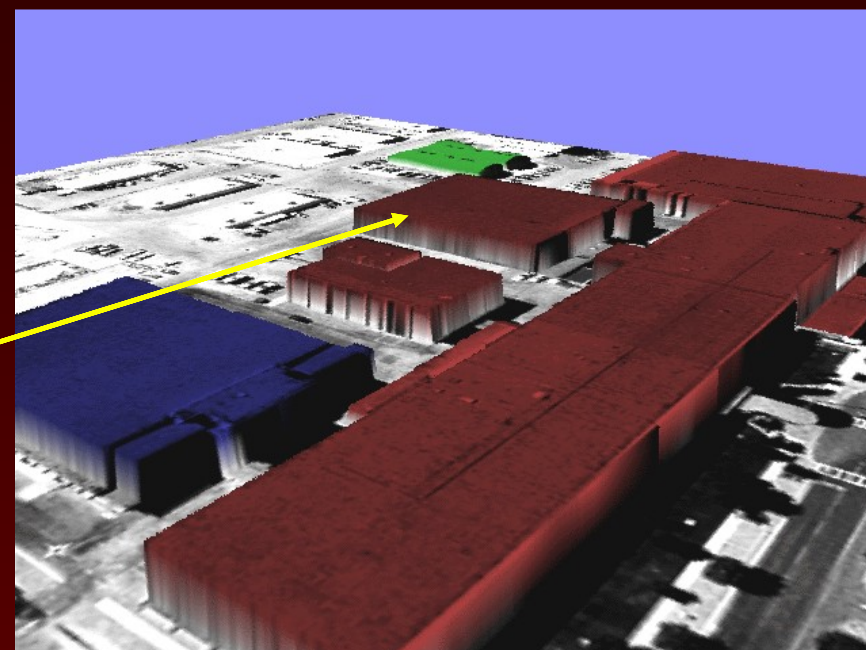
Project to IFSAR

Registered IFSAR



Median Elevation

Reconstruction



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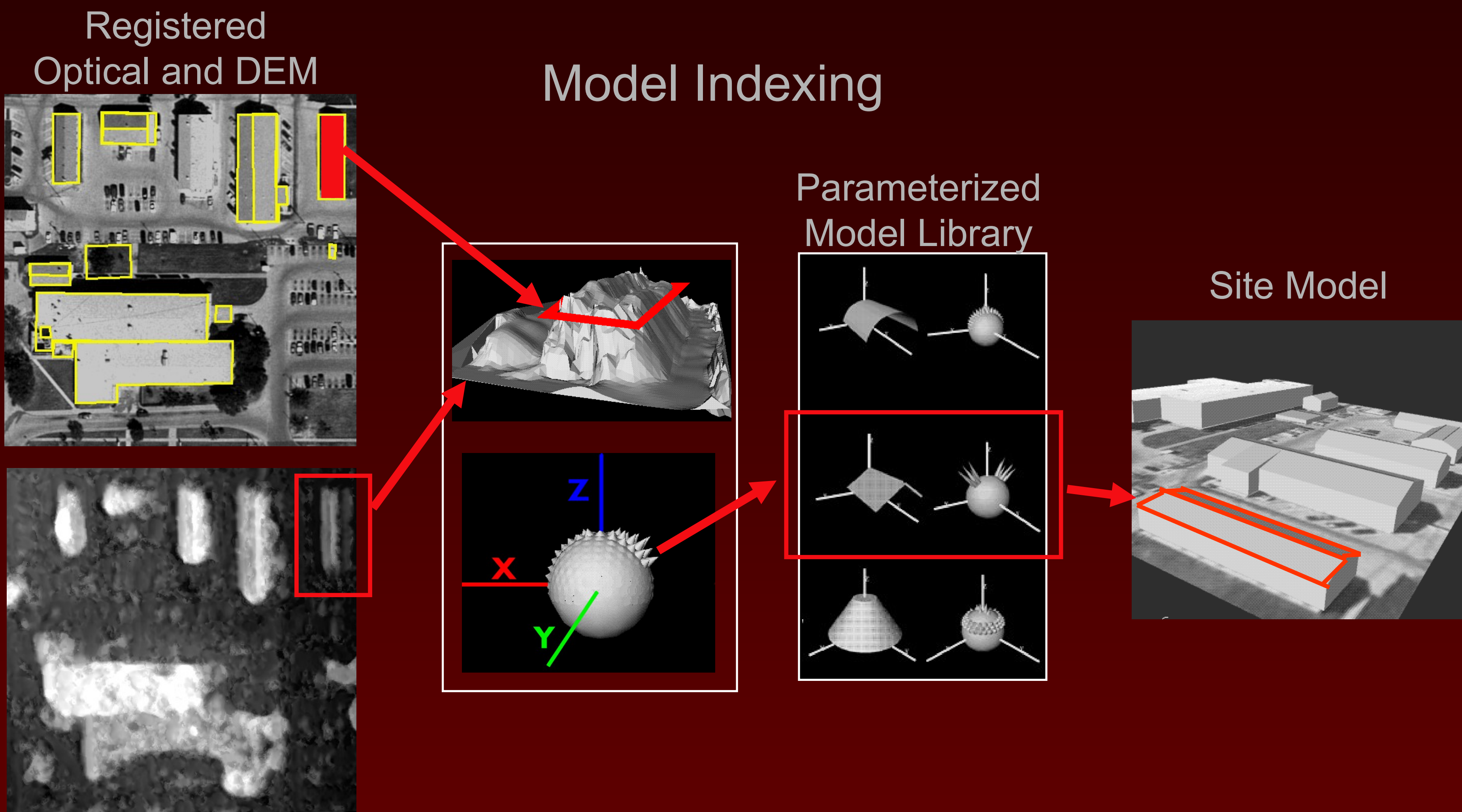
Approach: 2D Polygons + DEM



Video Clip 3
Data fusion

Relevant UMass Research

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- 1998-2001 NSF Environmental Monitoring project
  - Global forest management using aerial and satellite images
  - Terrain classification using real-time interactive decision tree classification
  - Video sequence registration and analysis
  - Automatic aerial photogrammetry

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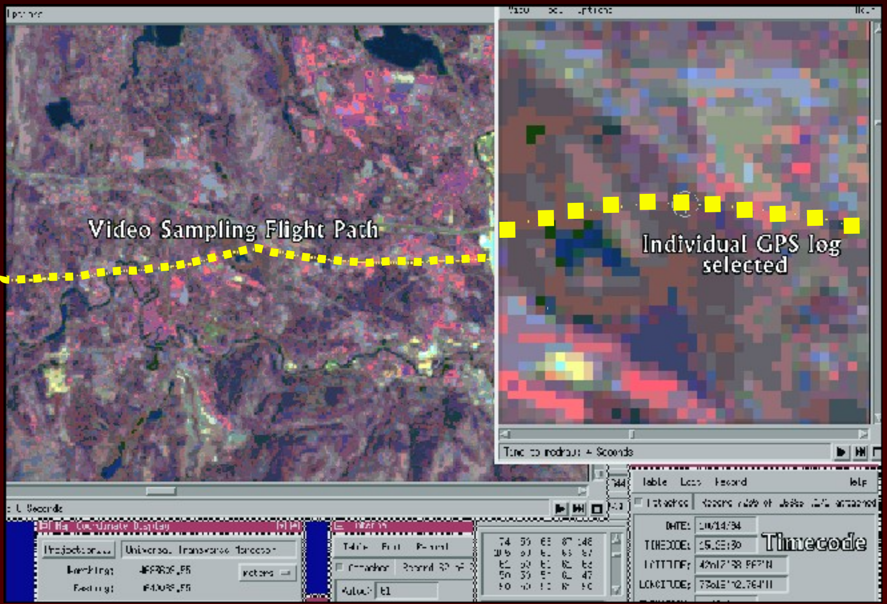
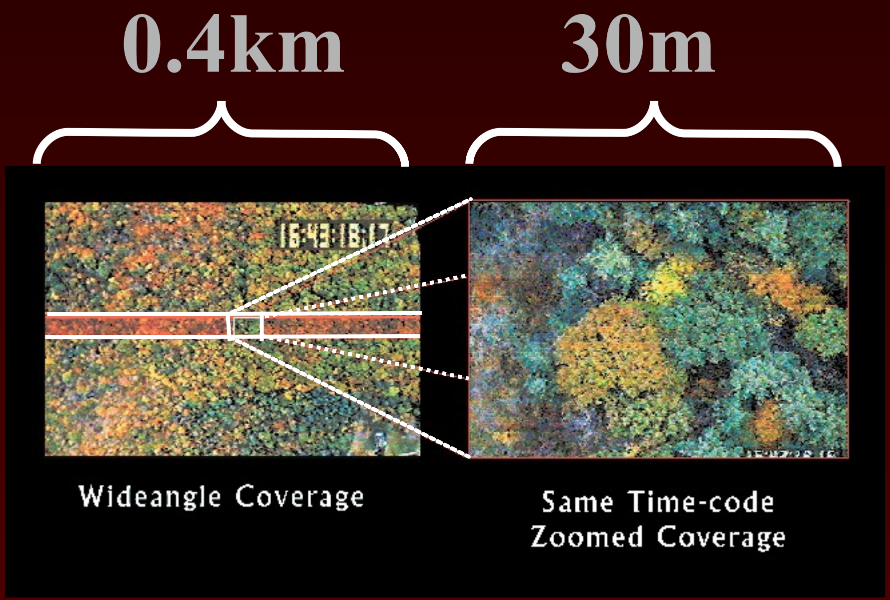
Vegetation classification and image registration



Hypercluster image with GPS-logged points shown in yellow.



Dual camera video strip

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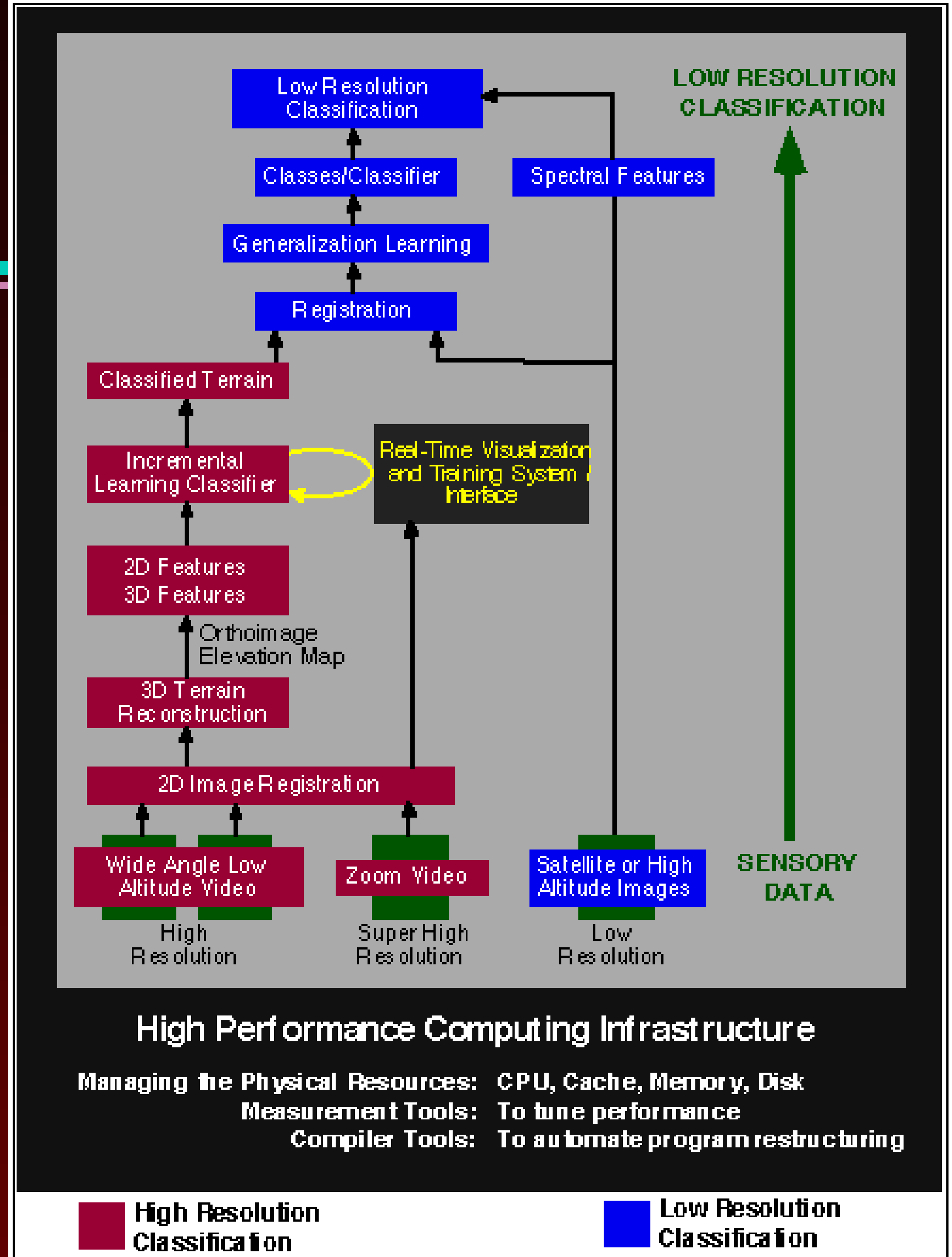
Aerial Image Interpretation and classification for environmental monitoring



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Video Clip 4
Interactive Teacher-Learner Classifier

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Relevant UMass Research

- 1998-? DARPA SAFER Mobile Robot Project

  Interdisciplinary -

  vision, robotics, AI, software engineering

  - Cooperative mobile robots in search and rescue
  - Multiple mobile robots and sensor configurations
  - 3D obstacle detection and avoidance
  - Object (human) recognition
  - 3D reconstruction from Panoramic images

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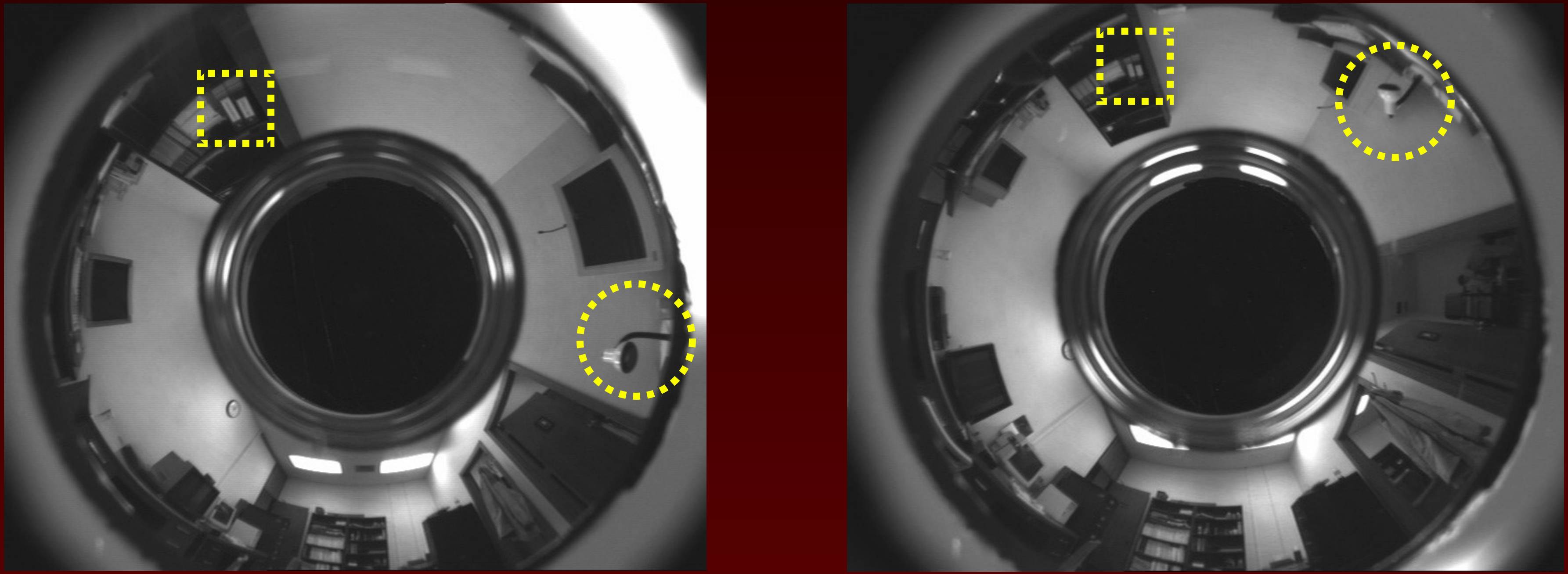
Robotic Panoramic Sensor for 3D reconstruction

- Current UMass projects with similar panoramic sensor



- Change in azimuth and scale of an object determines its location in space

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Image Warping for Image Registration

- Precise image registration depends on
  - Sensor projection model
  - Internal model parameters (focal length, distortion, ...)
  - Sensor physics (IR, EO, Radar, ...)
  - External parameters
  - Scene geometry

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Context Sensitive Image Warping

Scene Geometry

- Objects at infinity
- Distant objects not at infinity
  “billboard objects”
- Close objects

Warping Function

- No depth information required
- Depends no distance to target
- Some level of 3D reconstruction required

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Image Registration

- To register objects at infinity
  - No 3D information
  - Requires calibration parameters measured at assembly
    - Sensor models
    - Focal length
    - Lens distortion
    - Relative orientation between sensors

Image Registration

- Factors for Registering objects not at infinity
  - Calibration parameters, plus
  - Distance to target
    - radar
    - sonar
    - parallax
- Factors for Registering close objects
  - Calibration parameters plus
  - Full or partial 3D reconstruction
    - model matching
    - stereo

Calibration

- UMass calibration lab designed for
  - video and small format cameras
  - Geometric accuracy to ~ 0.001°
  - Radiometric accuracy to 1:1,000

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Panoramic Image Stabilization

- From a sequence of overlapping digital
  - Create a mosaic (composite) image
  - Individual images are seamlessly patched
  - New images overwrite old images
- For most applications the mosaic grows indefinitely
- For panoramic applications the mosaic image wraps around

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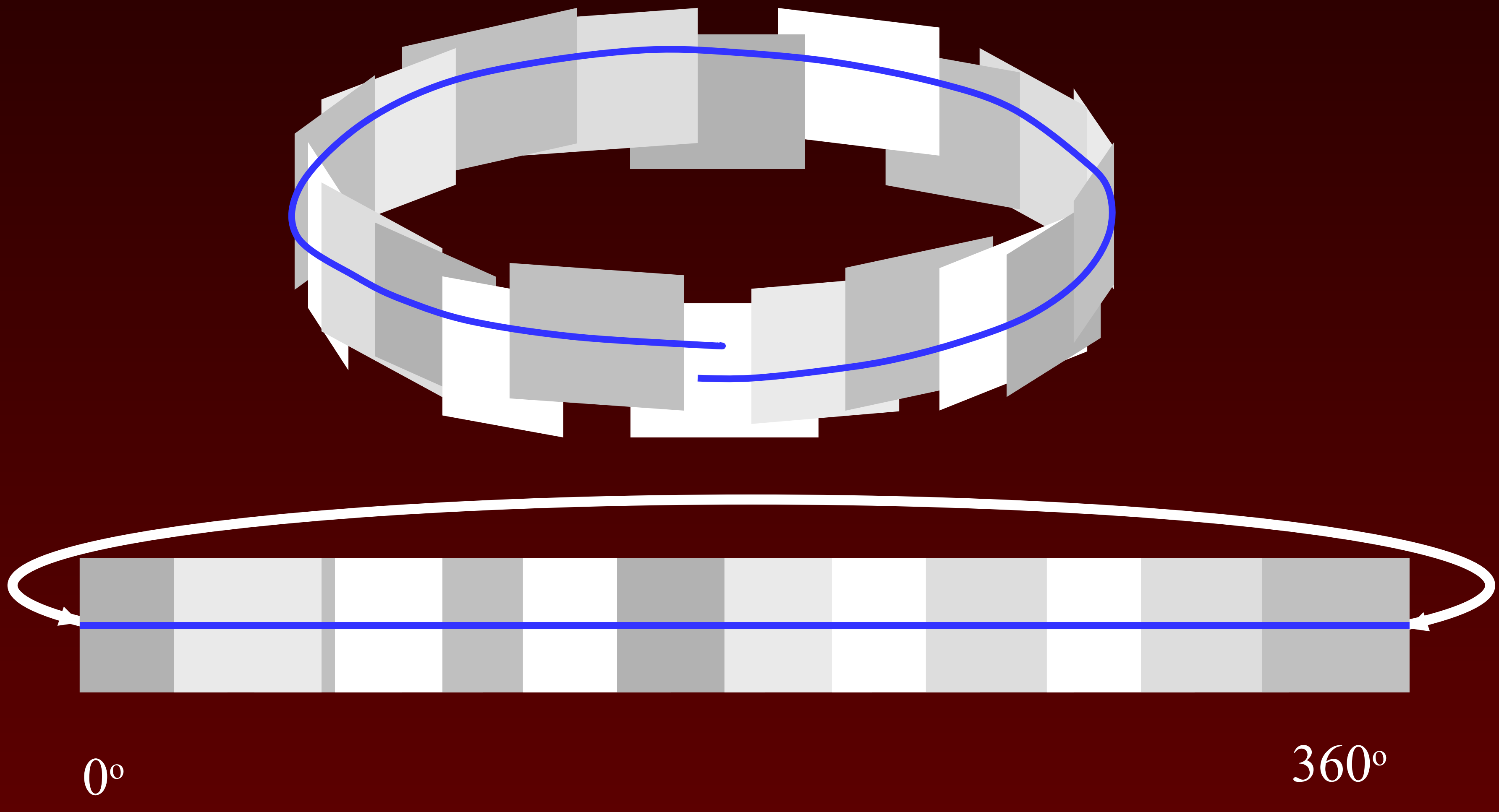
Approach

- Motivated by DARPA VSAM program (Video Surveillance and Monitoring)
  - Processing video sequences for
    - motion detection
    - stabilization
    - object tracking
    - activity recognition
  - Relevant factors for submarine domain
    - unmodeled sensor motion
    - small temporal interval
    - small image displacement

Mosaic
from an image sequence

Panoramic Mosaic from an image sequence



3D Panoramic Imaging

- With the current configuration
  - Operator sees only one frame at a time
  - Maximum scan rate is 6 seconds
- A stabilized panoramic view enables
  - The operator to see the entire field-of-view
  - Separates scene acquisition and viewing procedures
  - Much faster, more reliable observations
    - A full panoramic view will take ~2 seconds to generate
  - Computation of the distance to an object from multiple panoramic views

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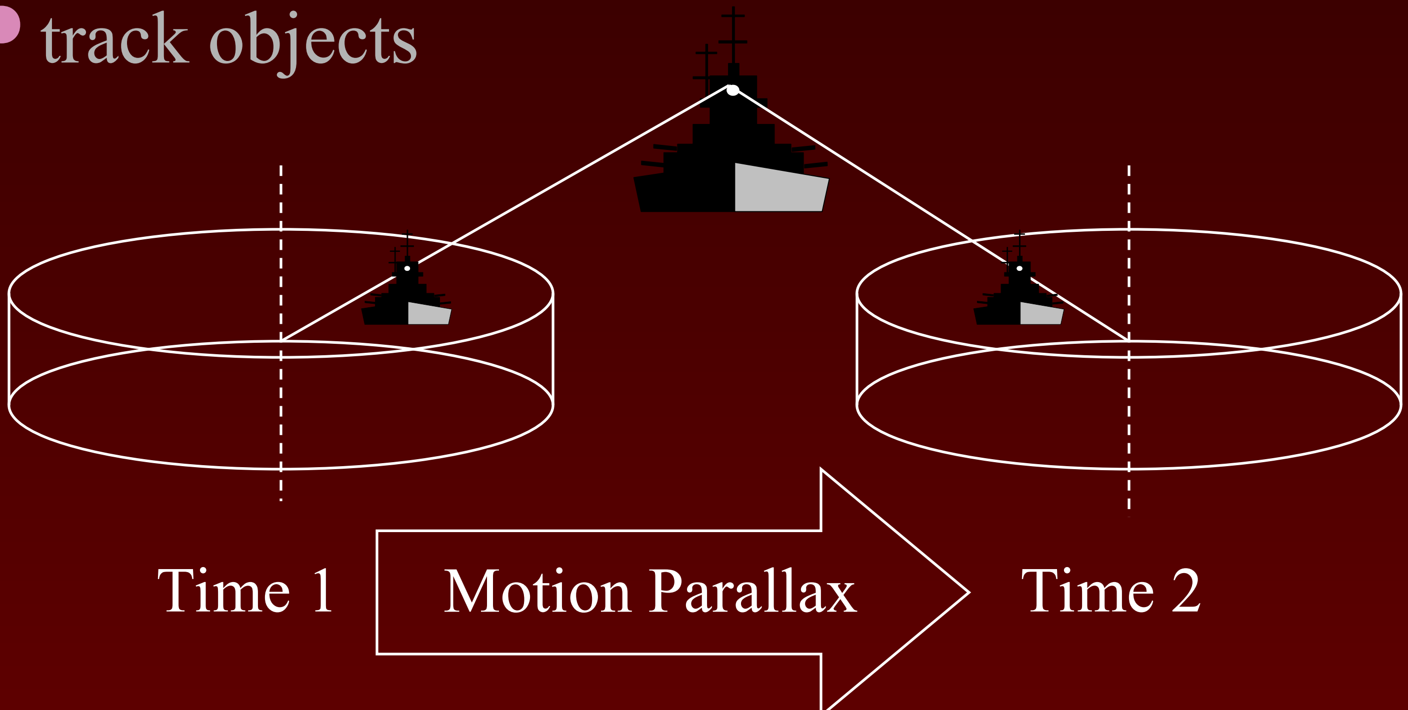
3D Panoramic Imaging

- From two stabilized panoramic views
  - determine the location of targets
  - track objects



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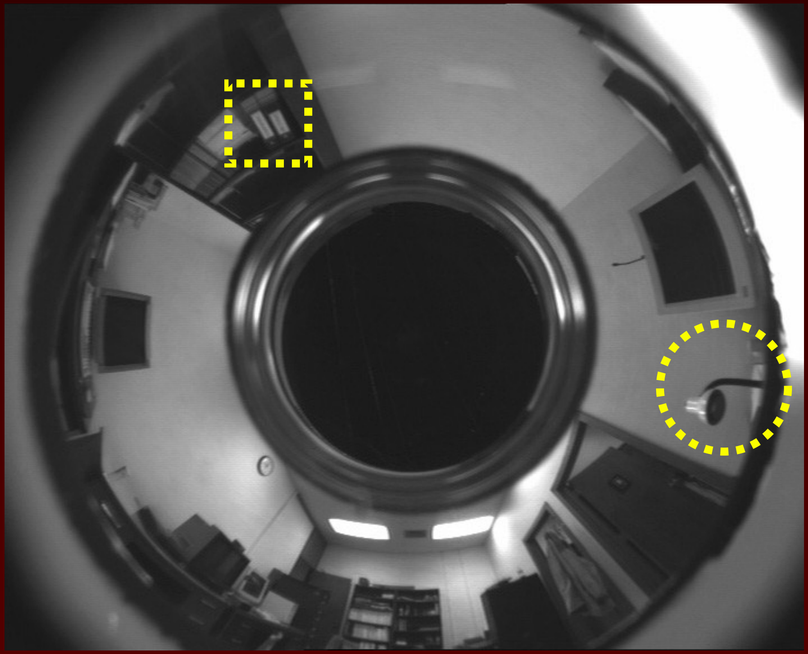

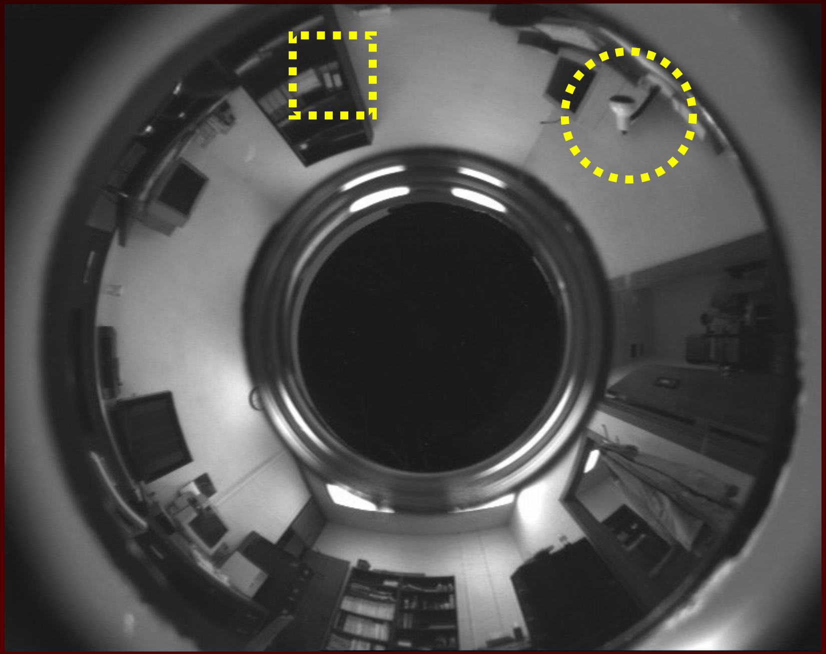

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3D Terrain and Site Modeling
Naval Scenarios

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- DOD Joint Program Office (JPO)
  - UGV - Unmanned Ground Vehicle Program
  - UAV - Unmanned Air Vehicle Program

- UAV Images could be used by UGVs for
  - 3D terrain modeling
  - mission rehearsal
  - path planning
  - ATD and ATR

3D Terrain and Site Modeling Naval Scenarios

- Naval UAV images for
  - 3D site modeling of coastal regions
  - Register periscope images with 3D terrain models
  - Visualization fly-through
  - Training and mission planing
  - ATD and ATR

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3D Terrain and Site Modeling Naval Scenarios

- Motion Sequences from Periscope Images
  - 3D reconstruction from ocean level views
  - Frontal view of coast allows accurate range estimates
    - cannot view building roofs
    - obscure terrain (e.g., behind buildings)
  - Panoramic views enables reconstruction of the complete surrounding naval environment

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