Validation of Vision-Based Range Estimation Algorithms Using Helicopter Flight Data

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Objective

Demonstrate effectiveness of an optic flow method for passive range estimation using a Kalman-filter implementation with helicopter flight data

Overview

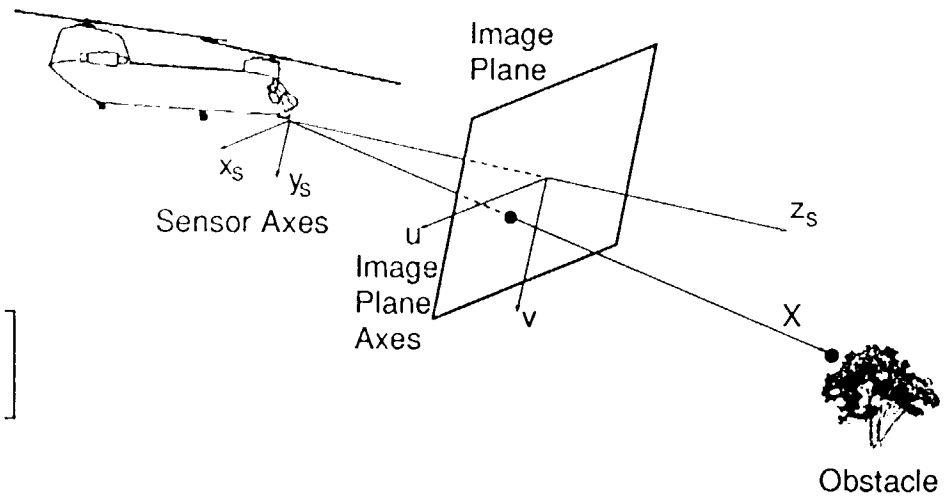
- Ranging Algorithm
- Flight Experiment
- Analysis Methodology
- Results
- Concluding Remarks

Range Estimation Algorithm

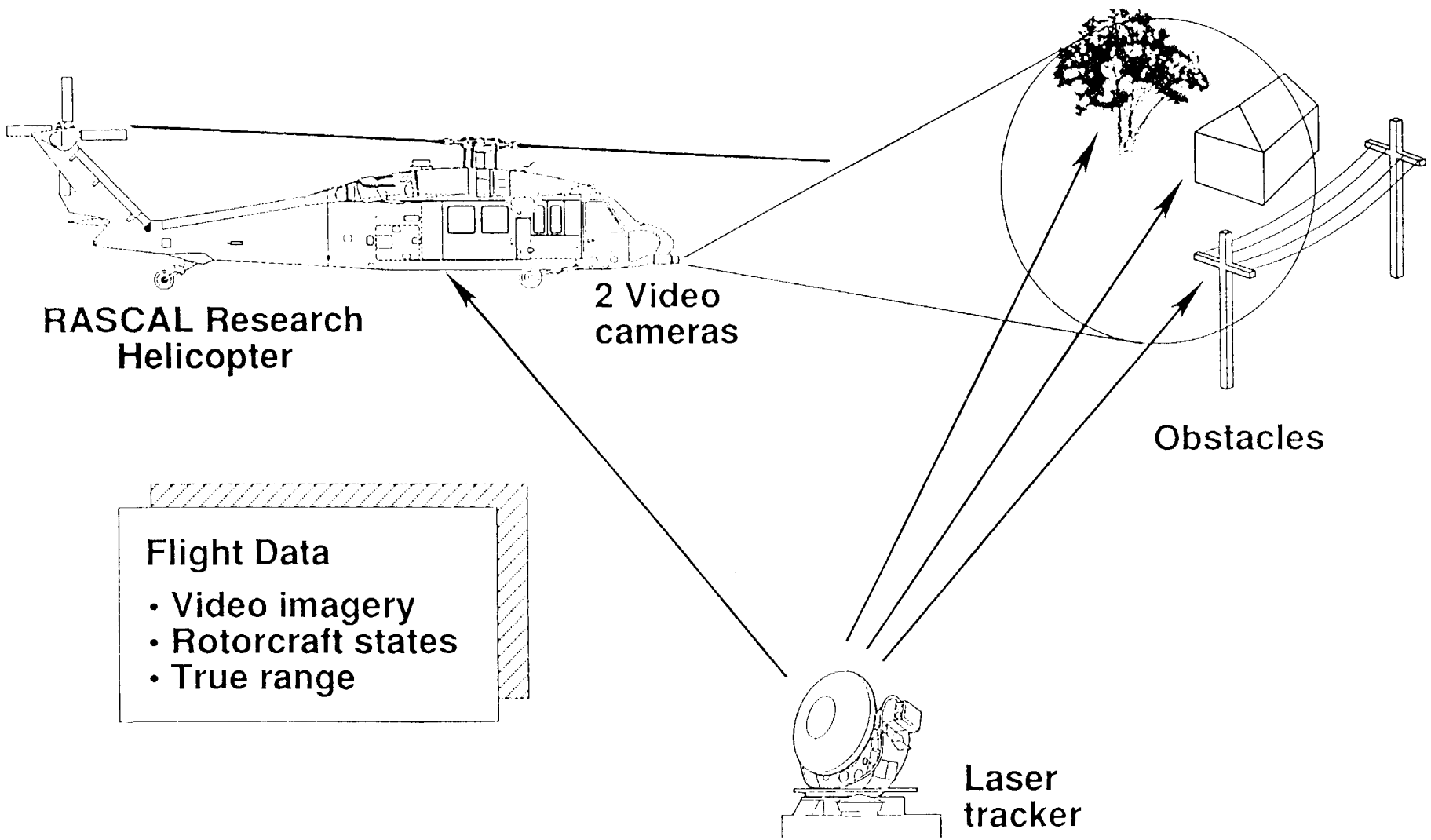
- Monocular range-from-motion
- Camera motion state assumed known
- Feature-based approach for optic flow
- Correlation method for feature matching
- Kalman-filter implementation for range estimation

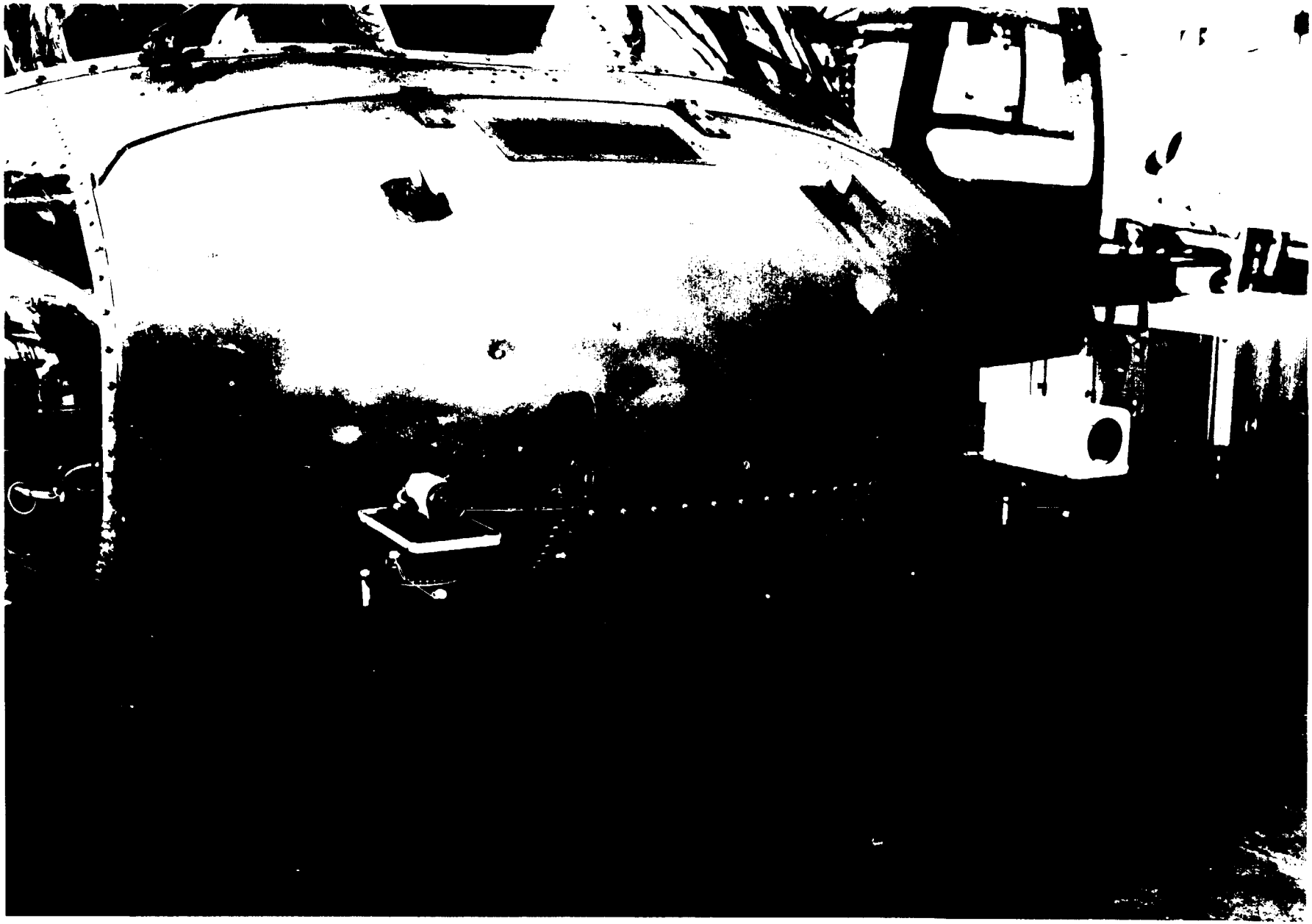
$$\dot{X} = -V_S - \omega_S \times X$$
$$Z = HX$$

$$X = \{x_s, y_s, z_s\}^T$$
$$Z = \{u, v\}^T$$
$$H = f \begin{bmatrix} 1/z_s & 0 & -x_s/z_s^2 \\ 0 & 1/z_s & -y_s/z_s^2 \end{bmatrix}$$

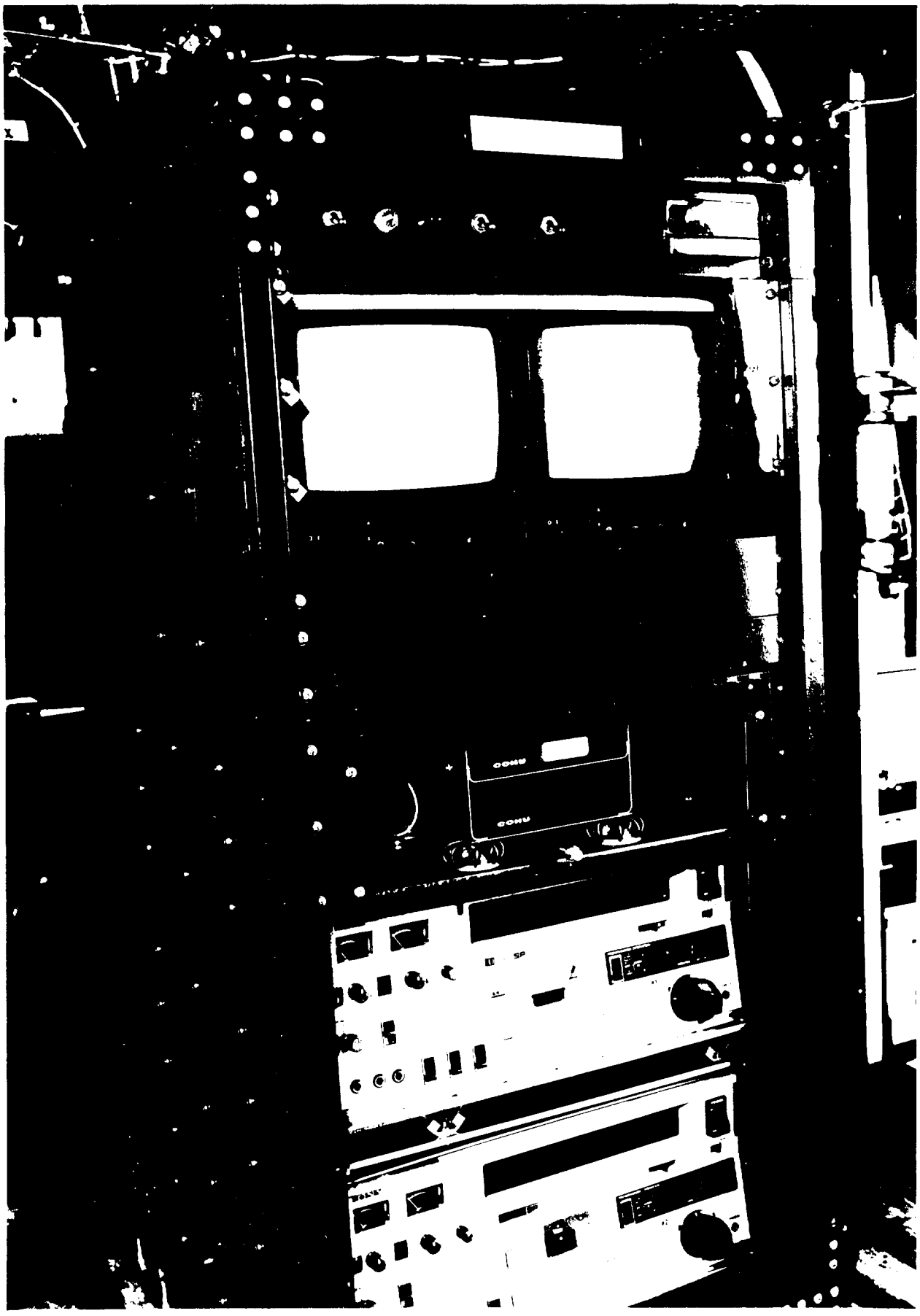


FLIGHT EXPERIMENT DESCRIPTION





Camera Installation



On-Board Operator Station

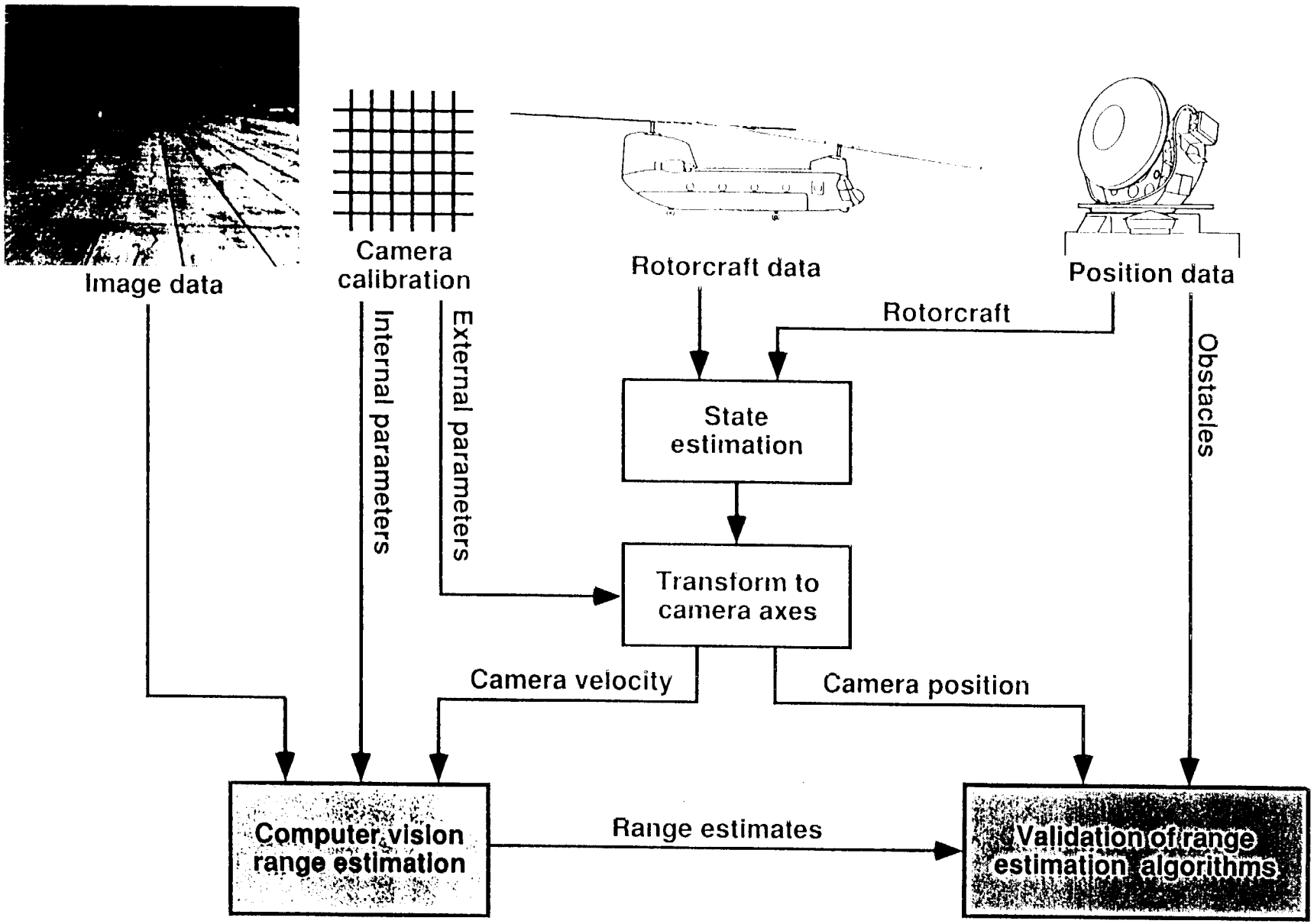
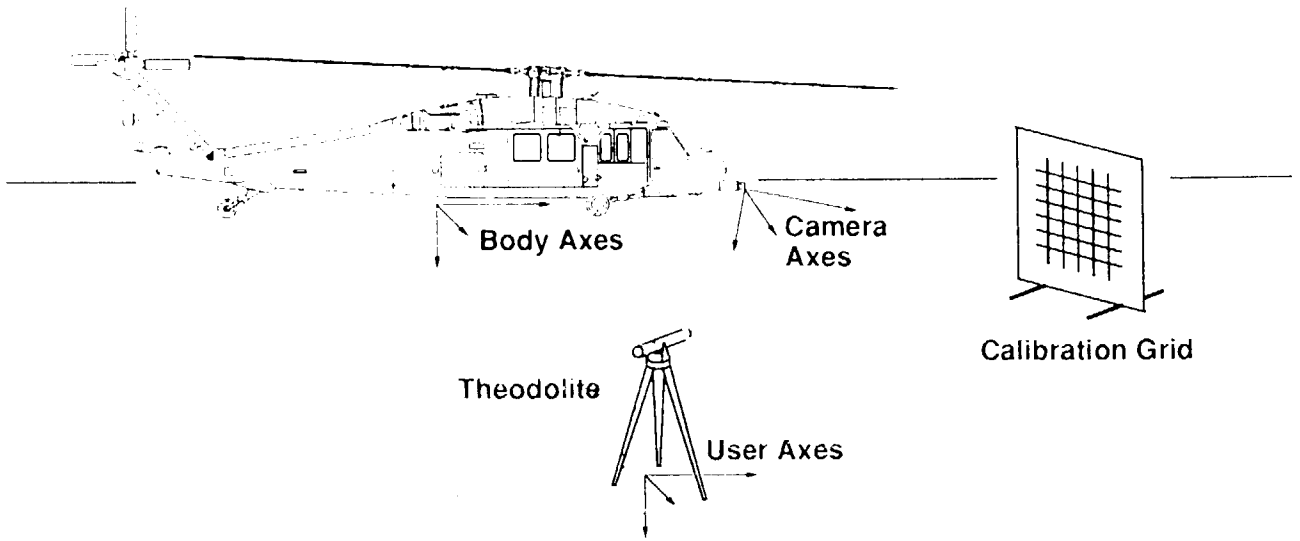


Image data
Camera calibration
Rotorcraft data
Position data
Rotorcraft
Obstacles
Internal parameters
External parameters
State estimation
Transform to camera axes
Camera velocity
Camera position
Computer vision range estimation
Range estimates
Validation of range estimation algorithms

Calibration

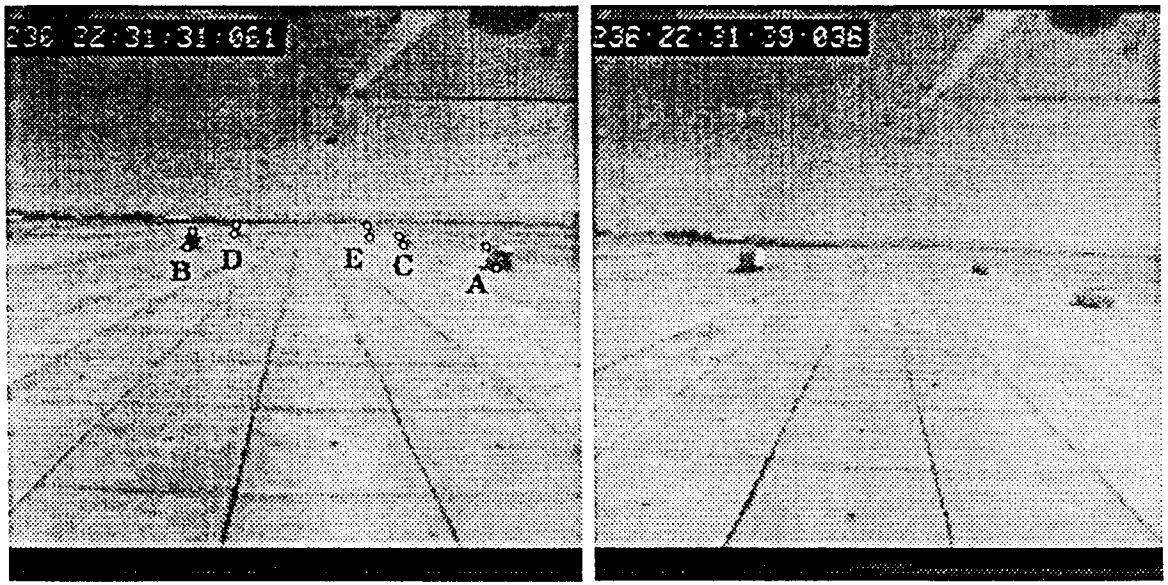


- Calibration parameters define the transformation of object points onto the image plane
- Calibration parameters
  - -- Position/orientation (6 unknowns)
  - -- Imaging model (4 unknowns)

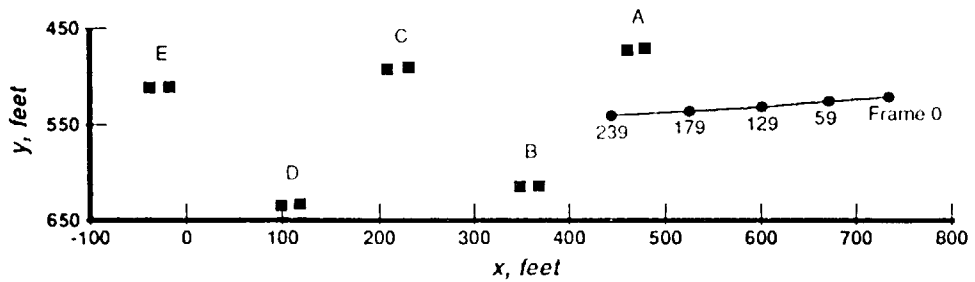
Analysis Methodology

- Validate algorithm with different flight sequences
- Points of Comparison
  - -- Range accuracy
  - -- Convergence time
  - -- Range at convergence

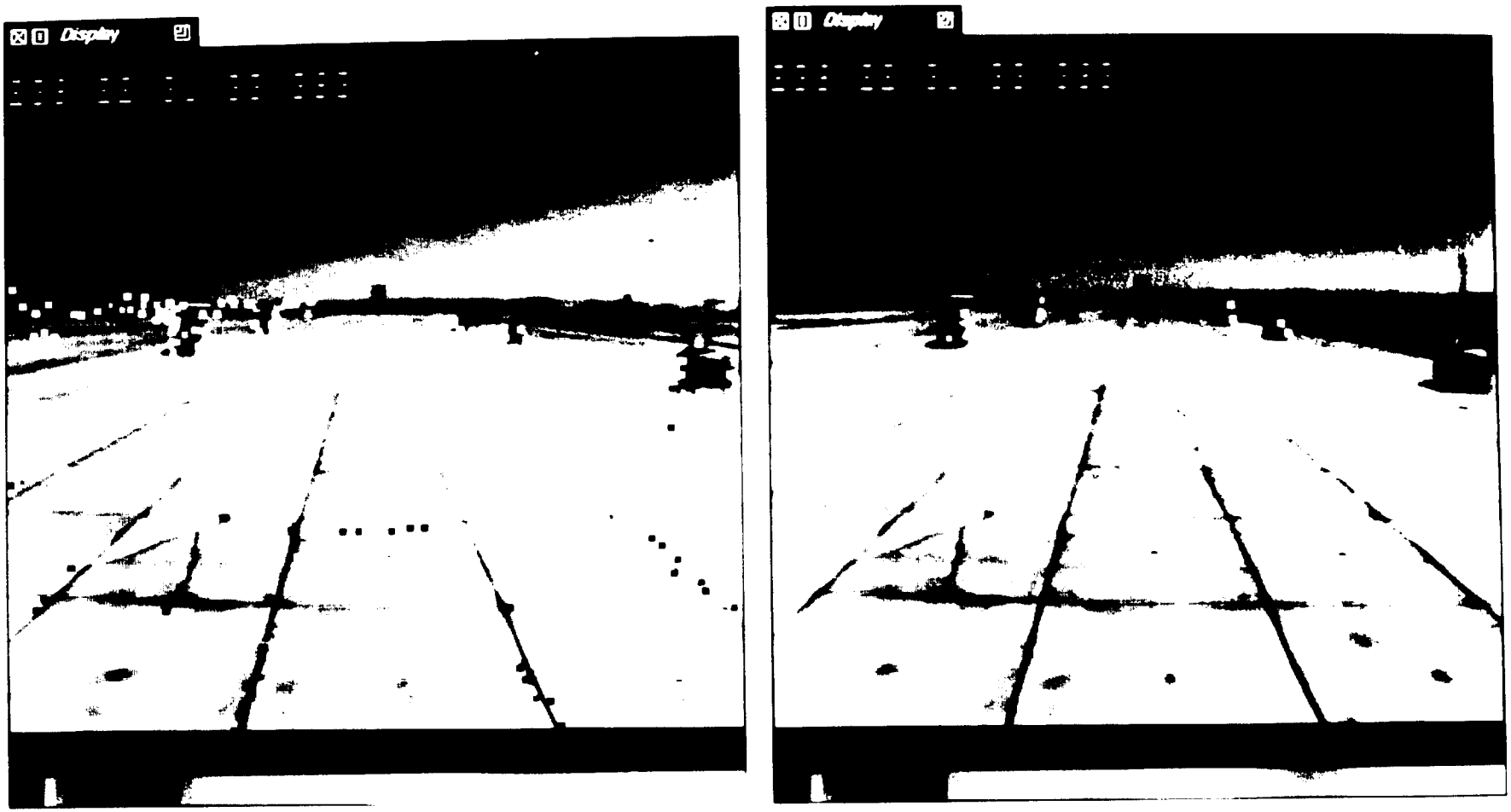
Line Sequence



Frame 0 Frame 239

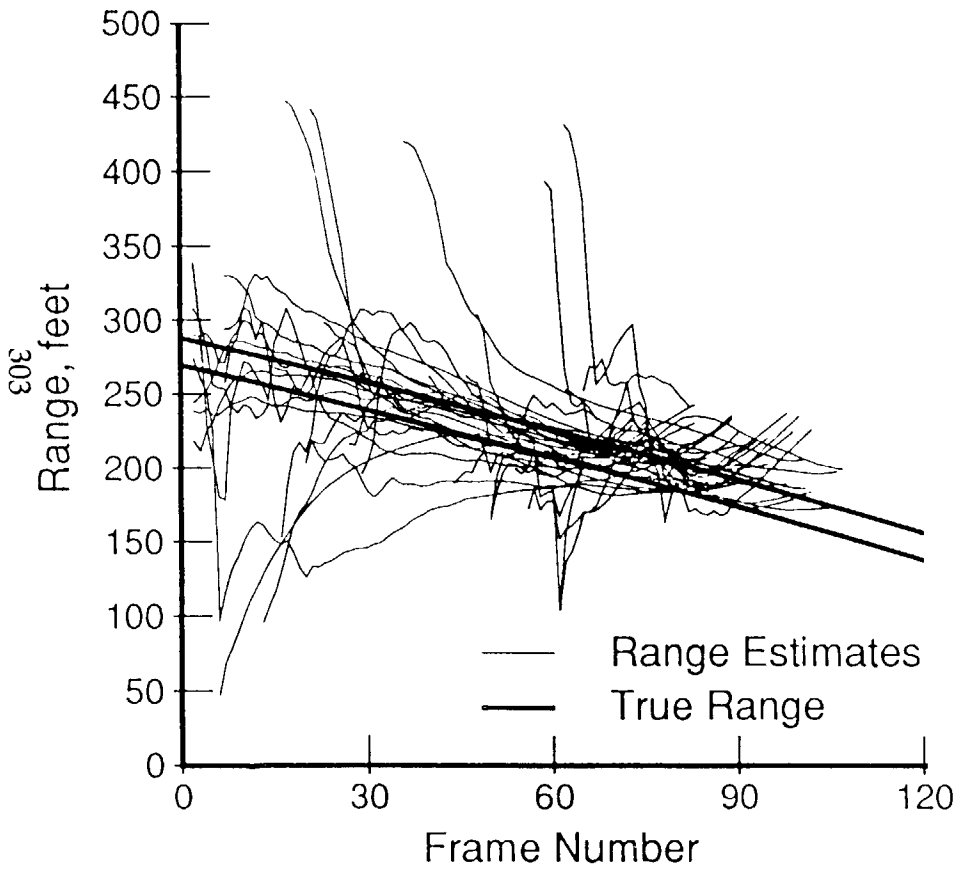


Camera Path and Measured Truck Locations

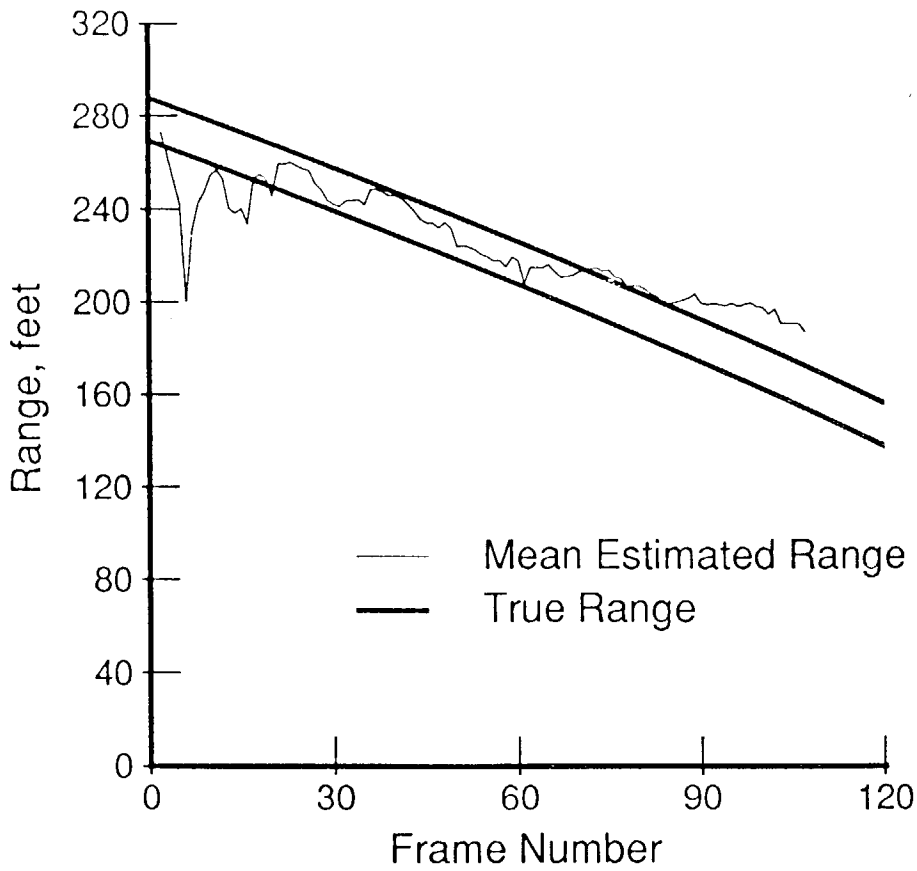


Helicopter Sequence Images with Features

Range Estimates for Truck A

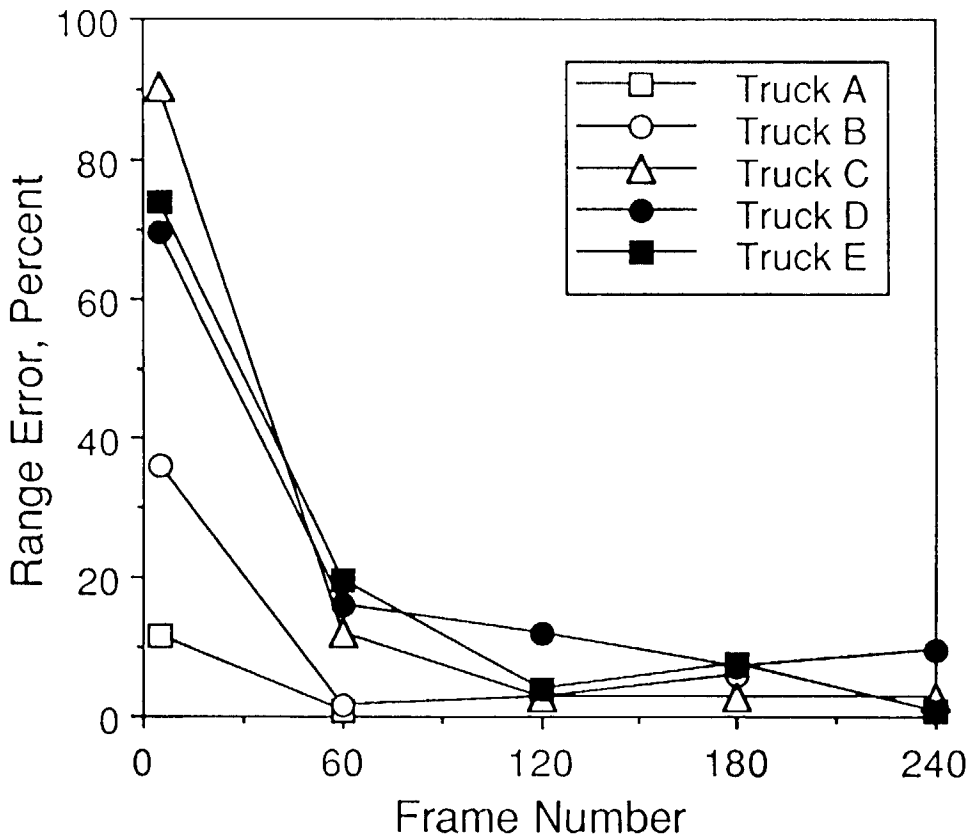


Individual Range Estimates

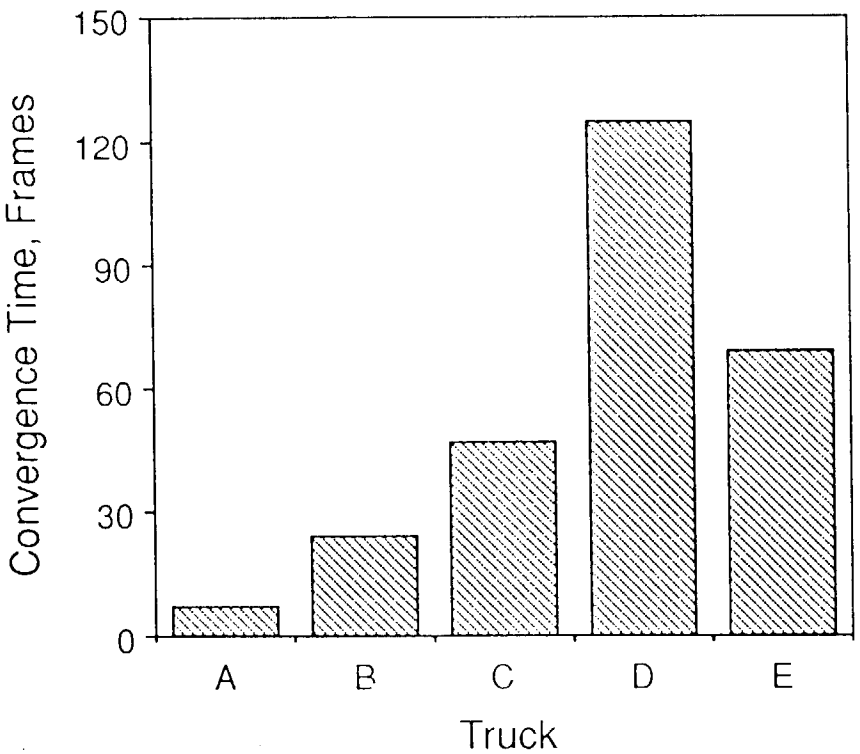


Mean Range Estimate

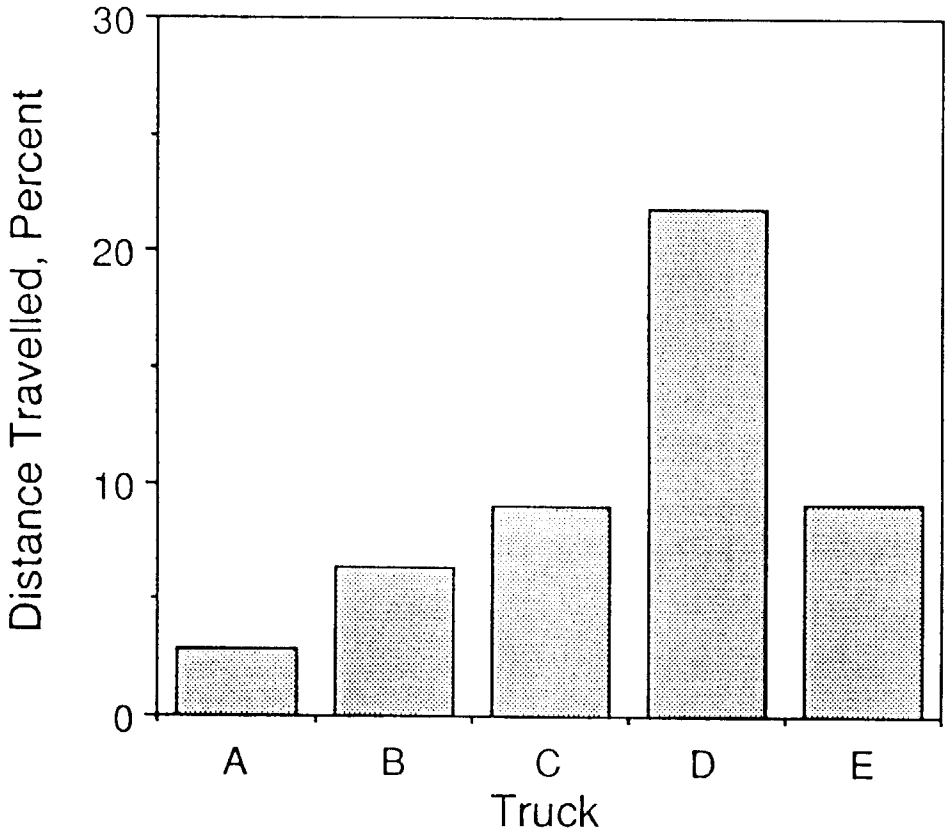
Range Accuracy



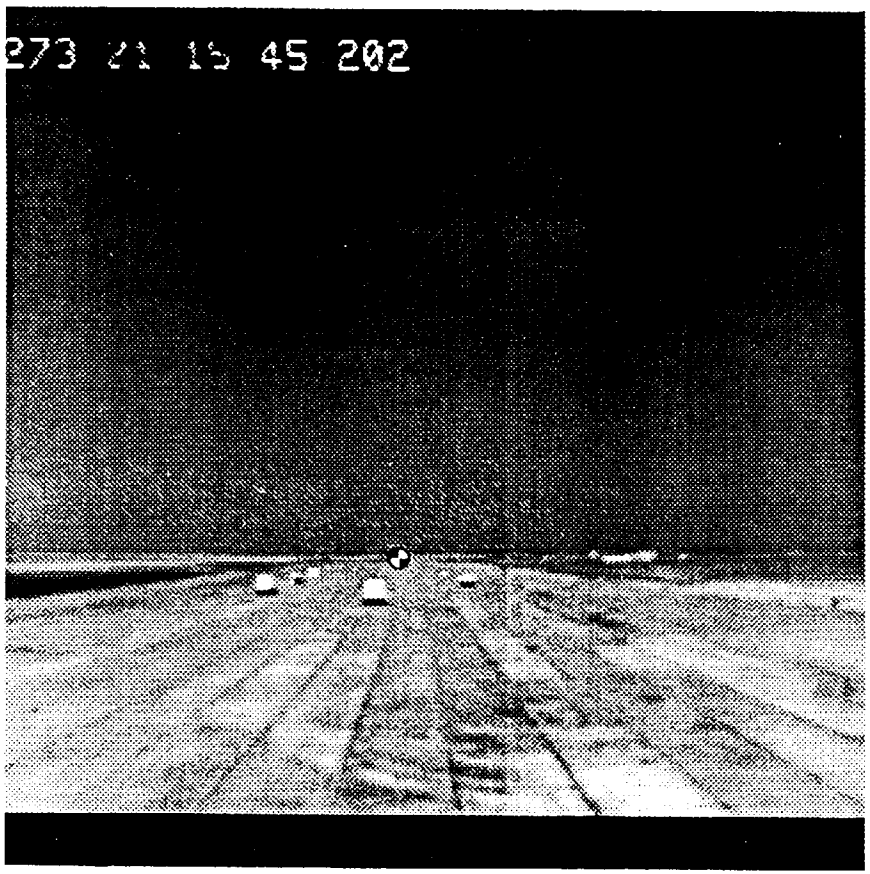
Time for Convergence



Distance Travelled for Convergence



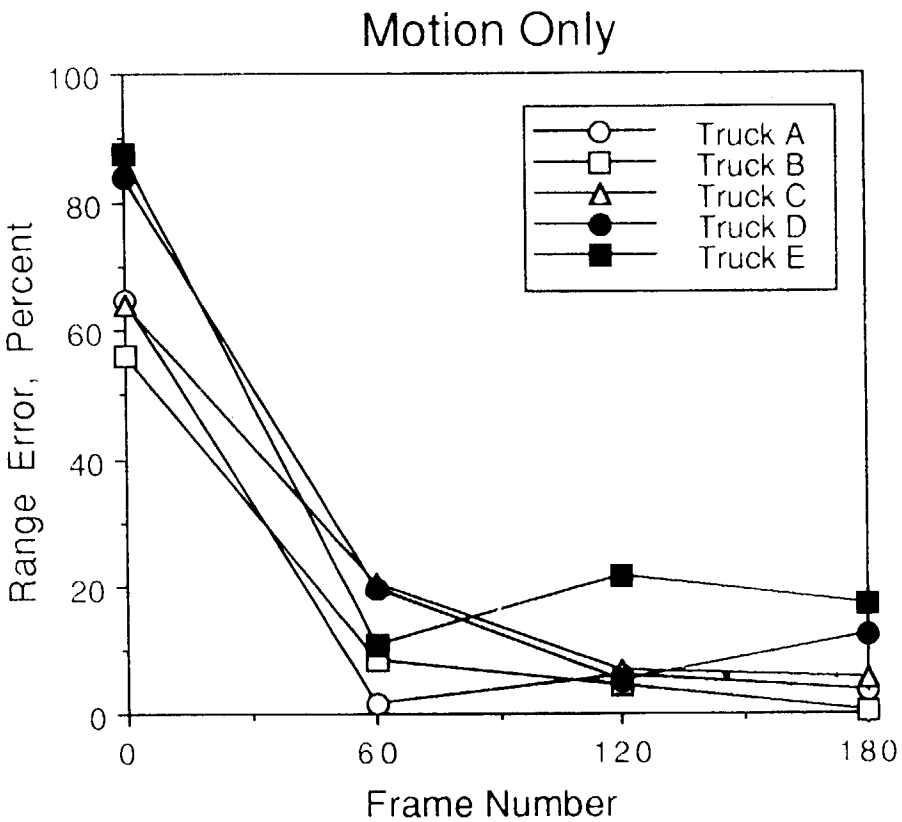
Stereo Line Sequence

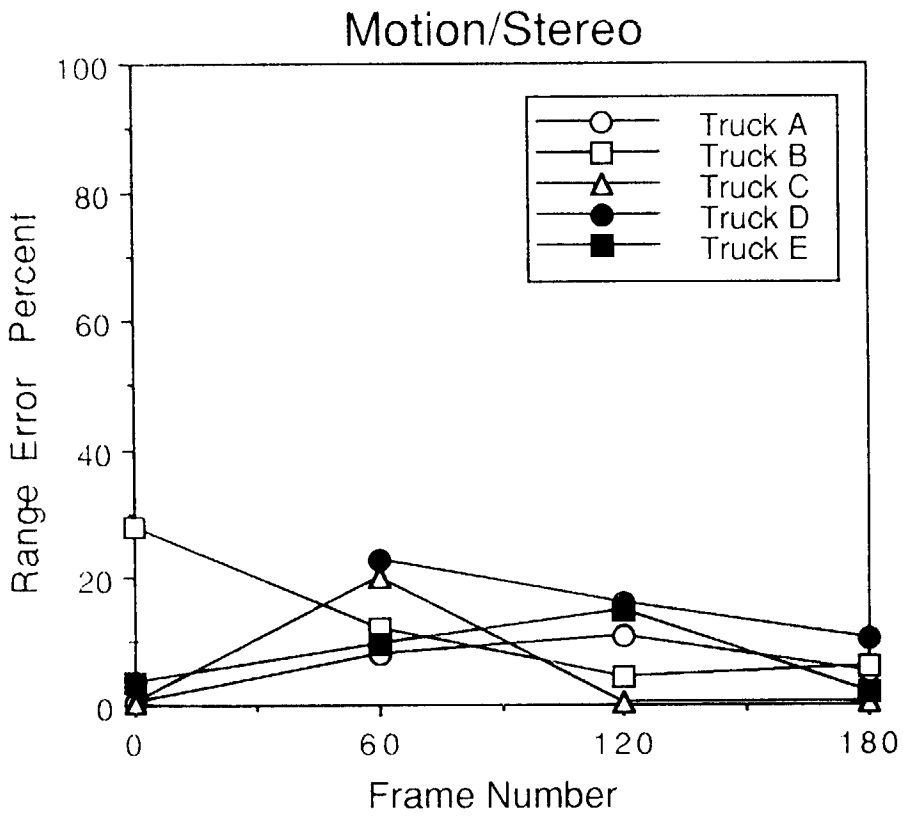


Frame 0

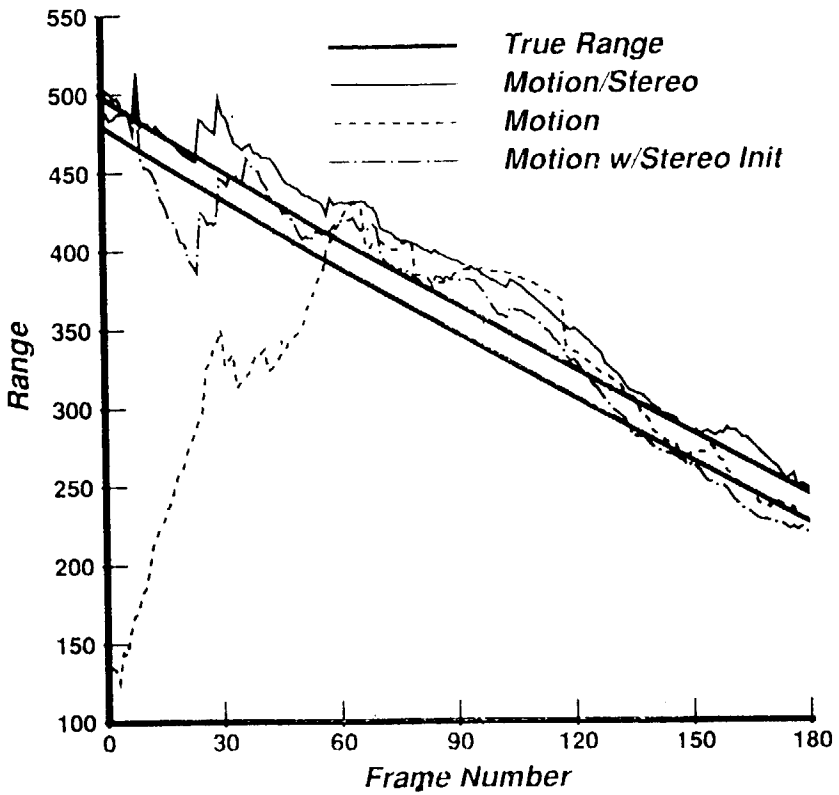
Frame 179

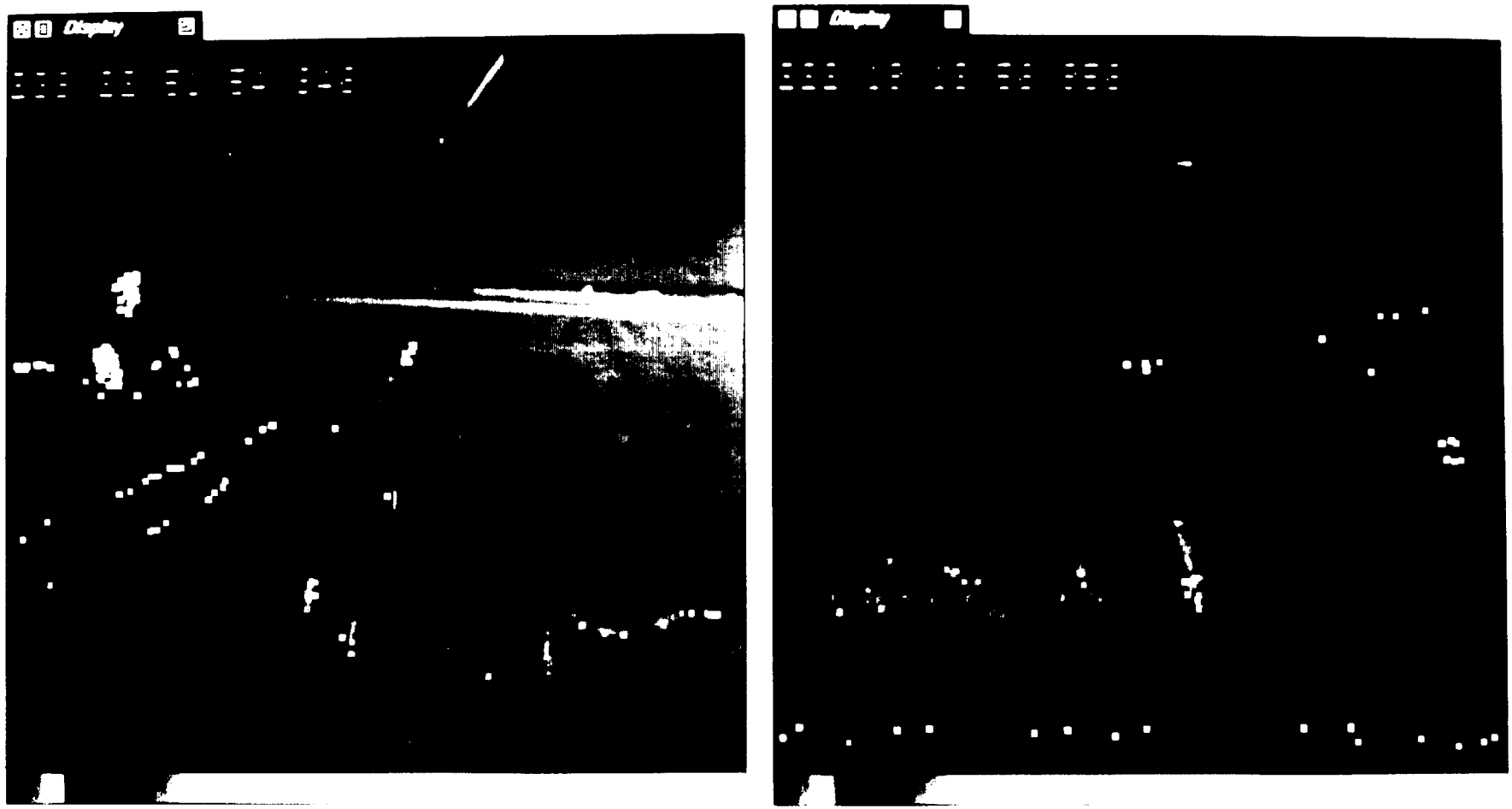
Range Accuracy





Comparison of Ranging Methods for Truck A





Feature mapping on open-field images.

Concluding Remarks

- Successful validation of vision-based ranging algorithms using helicopter data
  - General sensor motion
  - Realistic sensor vibration
- Algorithm demonstrates robust performance with range accuracy of about 10% for objects whose range is up to 10 times the distance travelled
- Research issues
  - Combination of motion and multisensor ranging methods
  - Frame rate selection
  - Calibration
  - Generalized motion
- Future Work
  - Further processing of multicamera sequences
  - Infrared image sequences