

Considerations for the mobile robot implementation of panoramic stereo vision system with a single optical centre

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Overview

- Requirements for robotic applications
- Introduction to panoramic stereo geometry
- Panoramic stereo image analysis
- Orientation correction algorithm
- Incremental position update scheme
- Results
- Conclusions



Distance estimation in robotics

Usage:

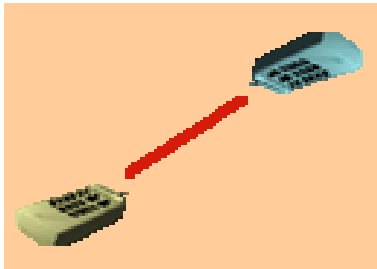
- map-building
- obstacle detection
- navigation and localisation

Requirements:

- region-of-interest can be in any direction
- objects can be far away from the observer

Available sensors

IR



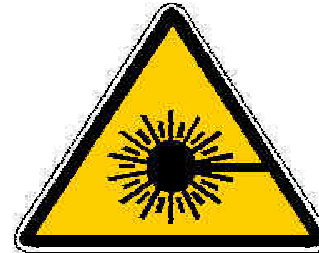
- short range (<1m)
- surface dependent

ultrasonic



- most widely used
- low angular resolution

laser range finder



- accurate
- expensive

stereo vision

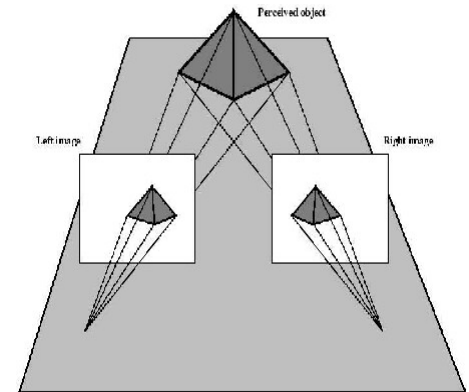


- need more computation
- reasonably accurate

Standard stereo vision

Standard stereo geometry

- two coplanar cameras
- baseline parallel to the image plane
- limited field-of-view



To improve disparity estimation, either

- increase camera resolution (more computation)
- increase baseline separation (limited by robot size)

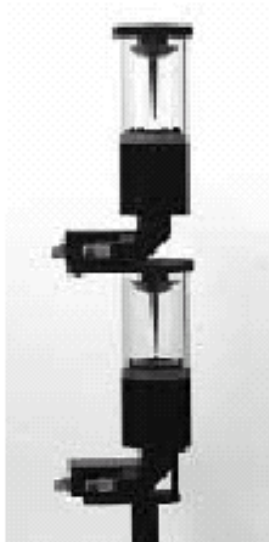
Panoramic stereo geometry

Panoramic stereo geometry

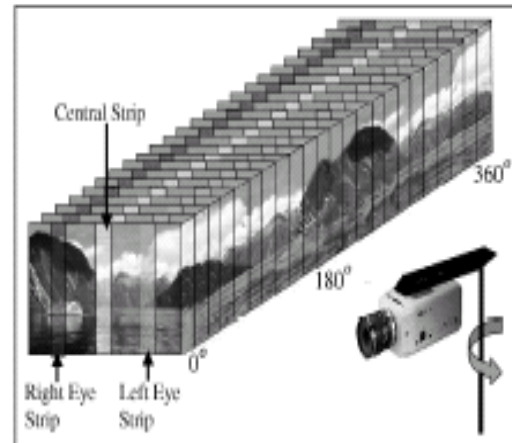
- Individual images can be generated by
 - rotating camera lens
 - multiple cameras
 - top-mounted spherical mirror
- Very large field-of-view



Existing panoramic stereo systems



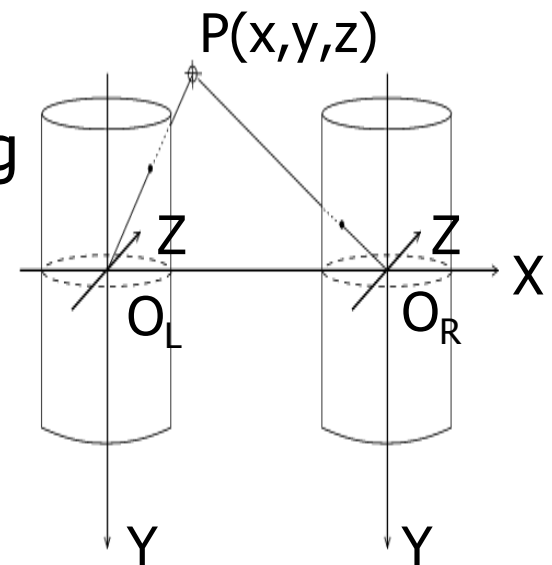
Specially designed
stacked mirrors
(Gluckman, 1998)



double slit rotating
panoramic camera
(Peleg, 2001)

Proposed system

- Goal: estimate the object distance
- Sensor: cylindrical panoramic single optical center camera
- Pros: minimal change to existing hardware
- Cons: uncommon panoramic stereo camera configuration





Proposed system

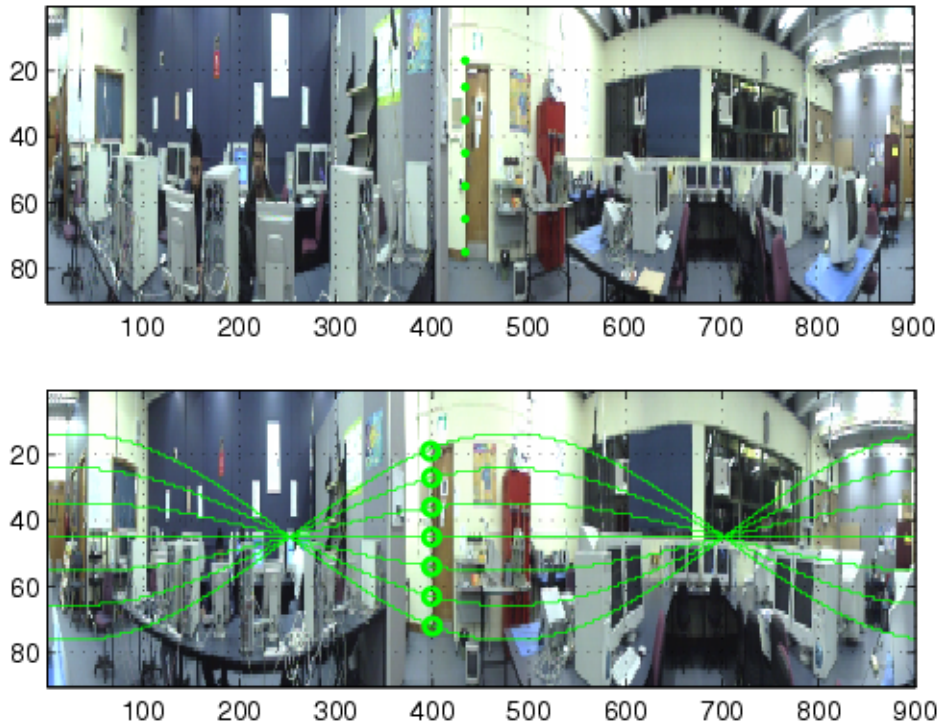
Input:

- Panoramic image sequence taken at known robot position and orientation

Procedure:

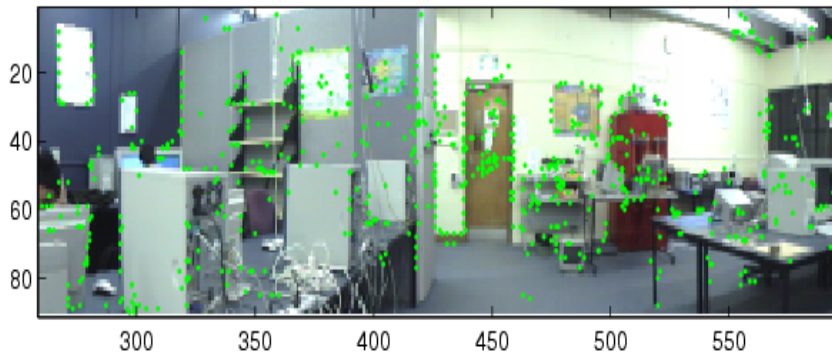
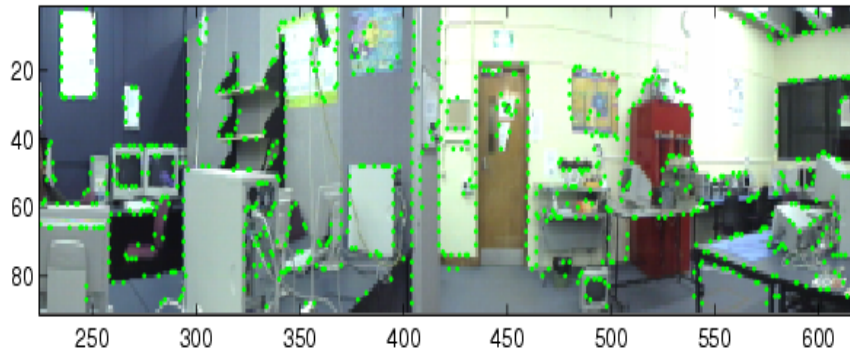
1. Stop the robot when moved to a new position
2. Take a new panoramic image
3. Form a stereo image pair with the first image in each sequence
4. Stereo image analysis
5. Merge the results

Epipolar line



- Curved epipolar lines
- Converge to singularity points at the epipoles

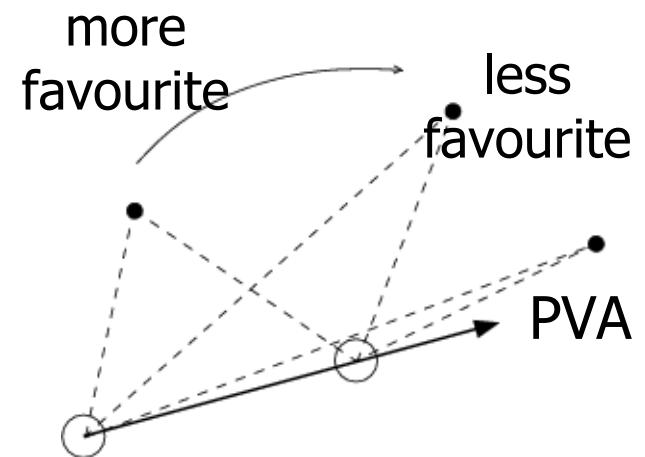
Stereo image analysis



- Processed on grayscale image
- Corresponding points are found by modifying the Shirai Algorithm
- Calculates disparity
- Object position is given by triangulation

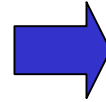
Principal viewing axis

- Principal viewing axis (PVA) is the extension line between the camera centres
- Azimuth difference decreases when getting closer to PVA.
- Reduced accuracy in disparity estimation



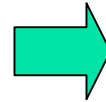
Two specific problems

The robot orientation may not be sufficiently accurate in practice



Orientation correction algorithm

Reduced disparity estimation accuracy along PVA



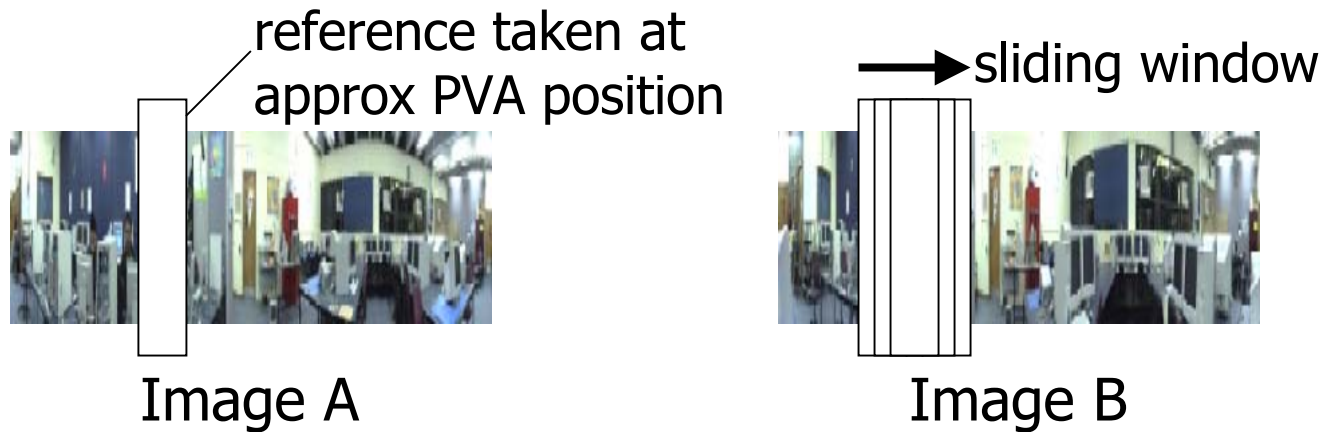
Incremental object position update scheme

Tested with real robot



Orientation correction

- image regions near PVA should be similar



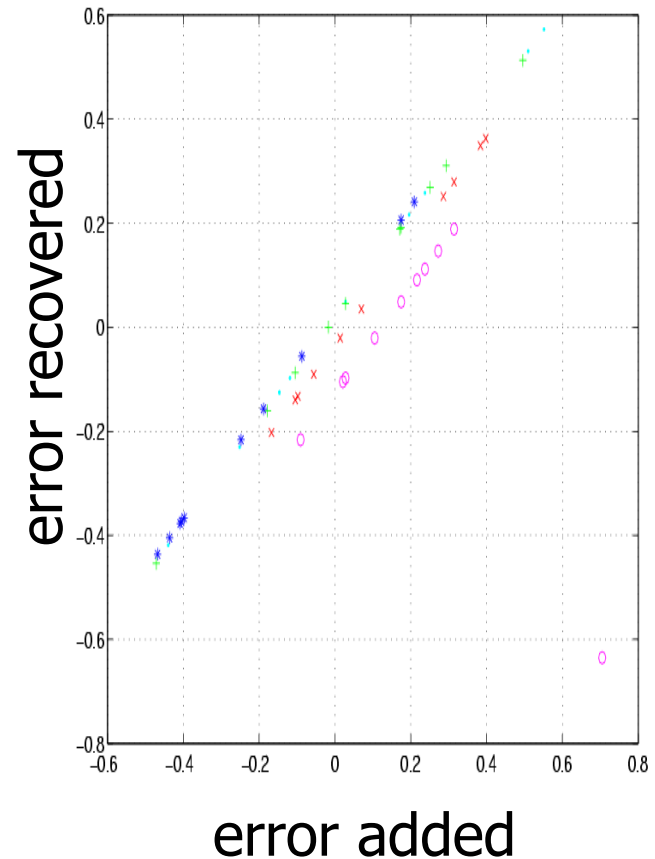
Calculate dissimilarity (DS) value



$\operatorname{argmin}(DS) = \text{actual PVA position}$

Orientation correction results

- Including 5 image sets
- Normally distributed random orientation error was added
- Good recovery of added orientation error



Incremental disparity update

- Uncertainty in disparity is high when close to PVA
- Replace obstacle position estimate if
 - the latest observation is further away from PVA
 - Mathematically, it is equivalent to minimising the projection length of the feature vector to PVA
 - i.e. replace the existing reading if

$$\hat{V}_{Xm} \cdot \hat{V}_n < \hat{V}_{Xm} \cdot \hat{V}_{prev_obsv}$$

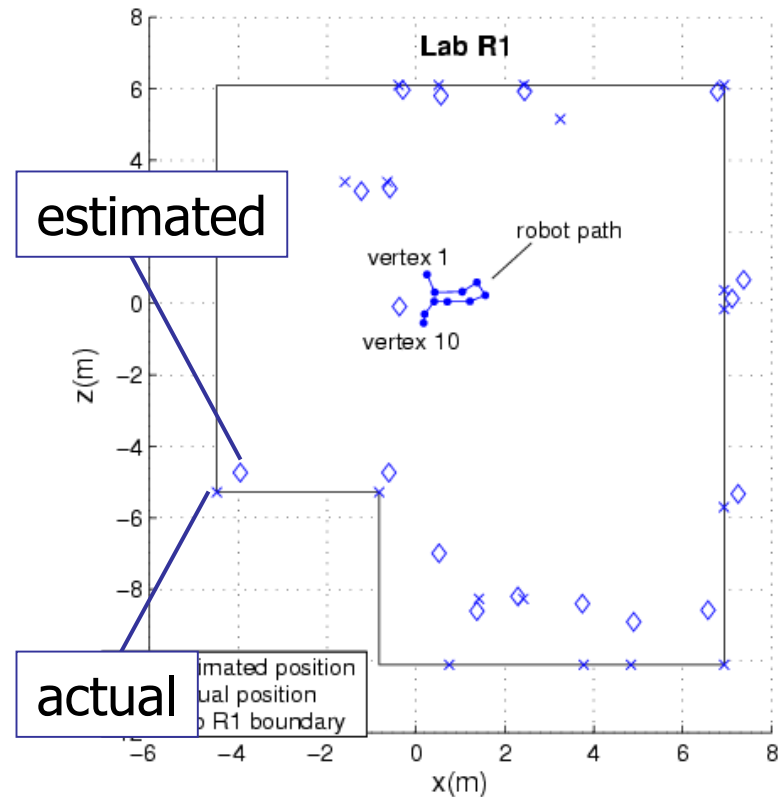
unit vector
from 1st image
to the feature

unit vector
for the nth
baseline

unit vector for the
baseline associated
with previous
observation

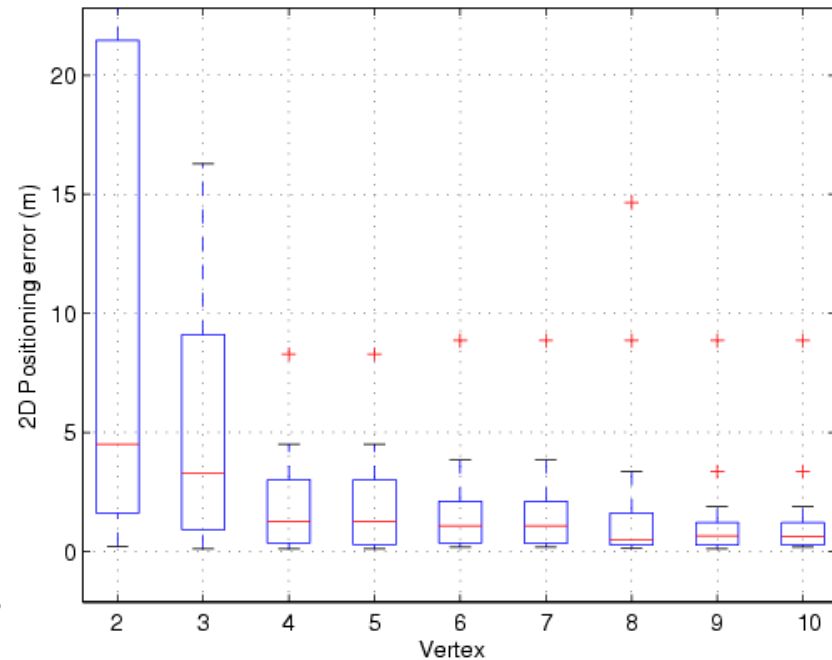
Results

- Implemented on a B21r robot
- The robot followed a path with 10 stops.
- Most obstacles are far away from the robot.
- Results in small pixel discrepancy.



Results

- The physical position of 18 features was measured
- Show gradually improved results
- Outliers due to mismatching of corresponding points





Conclusions

- Developed a panoramic imaging system with a single optical centre for robotic applications.
- The required stereo image analysis for this camera configuration has been studied.
- An orientation correction algorithm and an incremental updating scheme has been developed for the system.
- The robot implementation gives acceptable results.



Question time

