

Capturing, Modeling, Rendering 3D Objects

Position and Orientation Estimation

Position and Orientation

- Localization
 - Compute the position and orientation of "something" within an environment or relative to an object
 - Something = robot, boat, plane
- Tracking
 - Use a (custom) hardware infrastructure to track an object and compute the position and orientation relative to a chosen origin
- Camera Pose Estimation
 - Compute the position and orientation of a camera within an environment or relative to an object using vision-based methods

Localization and Trackers

- Gyroscopes/Accelerometers



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Localization and Trackers

- Gyroscopes/Accelerometers



Localization and Trackers

- Gyroscopes/Accelerometers
 - Pros: very high accuracy
 - Cons: drift after ~10 minutes
- Potential solution for orientation:
 - Resync periodically with a digital compass
- Potential solution for position:
 - ?

Localization and Trackers

- Magnetic Tracker

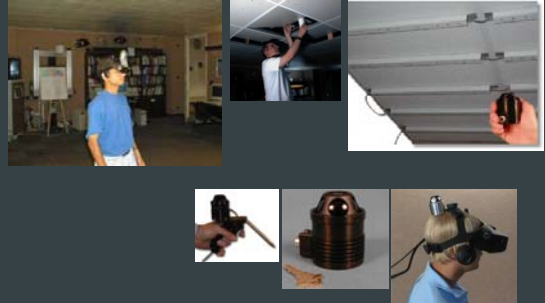


Localization and Trackers

- Magnetic Tracker
 - Pros: simple infrastructure
 - Cons: not very accurate, about 1 meter radius, susceptible to distortions caused by surrounding metal structures

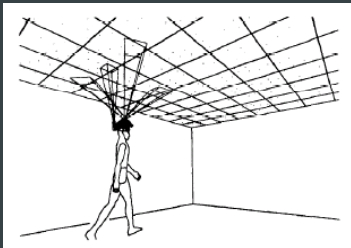
Localization and Trackers

- Optical Tracker (3rd Tech Inc.)



Localization and Trackers

- Optical Tracker (3rd Tech Inc.)



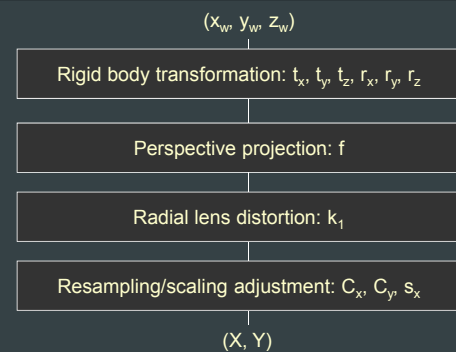
Localization and Trackers

- Optical Tracker (3rd Tech Inc.)
 - Pros: highly accurate
 - Cons: custom/complex infrastructure must be installed, requires line of sight

MIT City Scanning Project

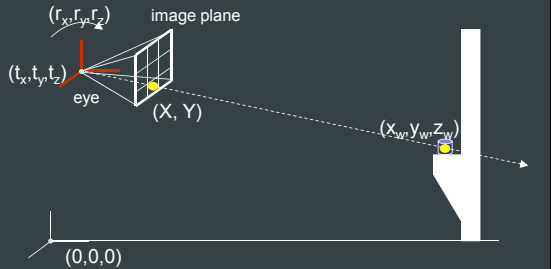
- <http://city.lcs.mit.edu/city.html>

Transformation of a 3D world coordinate to image coordinates



Camera Pose Estimation

- Tsai Calibration
 - External parameter calibration (same thing!)



Camera Pose Estimation

- Tsai Calibration
 - External parameter calibration (same thing!)
- Pose Estimation Algorithm:
 - Calibrate camera
 - Fix internal parameters
 - Move camera
 - Recompute external parameters (e.g. redo calibration)
 - Done

Camera Pose Estimation

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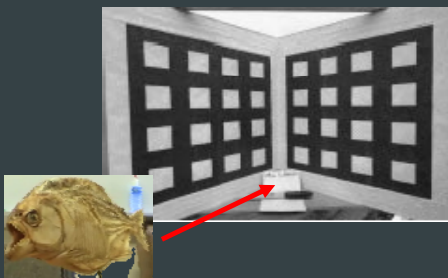
Camera Pose Estimation

- Calibrate with this pattern...



Camera Pose Estimation

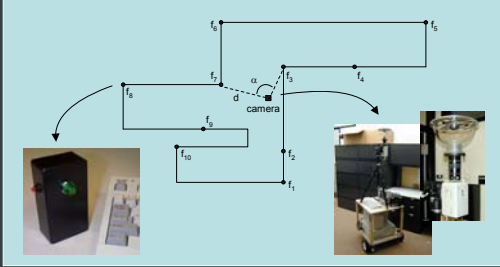
- Then fix internal parameters and do pose estimation...



Landmark-based Camera Pose Estimation

- Summary
 - Place landmarks throughout the environment (or around the object)
 - Obtain the projections of landmarks onto captured images
 - Works with a calibrated traditional camera
 - Works with a calibrated omnidirectional camera
 - Compute pose from the landmark projections

Landmark-based Camera Pose Estimation

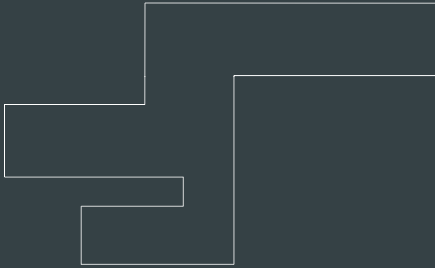


Landmark-based Camera Pose Estimation

- Major challenges
 - Landmark placement and correspondence
 - Where should we place the landmarks and how do we know which one we are seeing?
 - Pose estimation from landmarks
 - How do we compute position and orientation from the landmarks?
 - Landmark-Pose Optimization
 - Can we optimize/improve estimates for both landmark positions and camera pose?

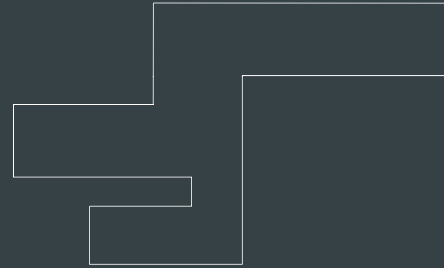
Landmark Placement and Correspondence

- Background: Art Gallery Problem
 - Definition



Landmark Placement and Correspondence

- Background: Art Gallery Problem
 - Convex decomposition



Landmark Placement and Correspondence

- Background: Art Gallery Problem
 - Creating a sufficient solution satisfying the constraints of
 - Maximum distance to a landmark: D
 - Minimum number of visible landmark: V
 - Minimum angle to a pair of landmarks: A

Landmark Placement and Correspondence

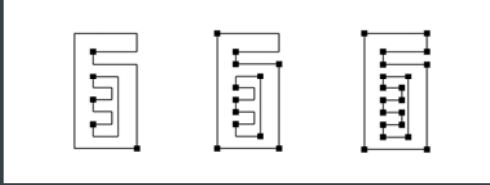
- Background: Art Gallery Problem
 - Creating a sufficient solution satisfying the constraints of
 - Maximum distance to a landmark: D
 - Minimum number of visible landmark: V
 - Minimum angle to a pair of landmarks: A

Redundancy value for landmark i is

$$r_i = w_v(v_{\min} - V) + w_d(D - d_{\min})/D + w_a(a_{\min} - A)/(180 - A)$$

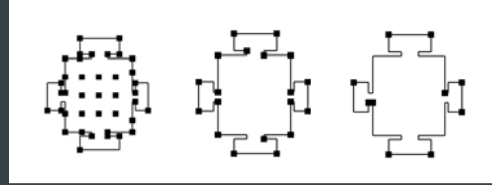
(iteratively remove from previous slide...)

Landmark Placement and Correspondence



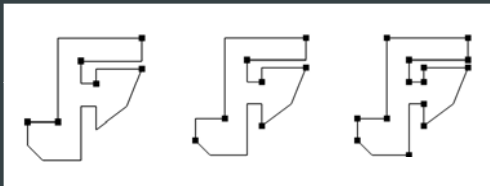
- + → V

Landmark Placement and Correspondence



- + → D

Landmark Placement and Correspondence



- + → A

Landmark Placement and Correspondence

- Creating a sufficient solution satisfying the constraints of
 - Maximum distance to a landmark: D
 - Minimum number of visible landmark: V
 - Minimum angle to a pair of landmarks: A
- Can also add accuracy requirements...
 - Distribute landmarks so as to
 - Guarantee a desired pose accuracy, or
 - Compute the pose accuracy of a given placement

Landmark Placement and Correspondence

- Uncertainty given distances

(1 or 2 distance case, d and $e...$)

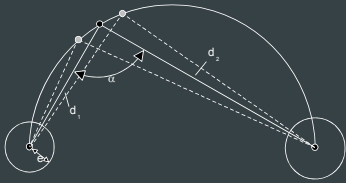
Landmark Placement and Correspondence

- Uncertainty given distances



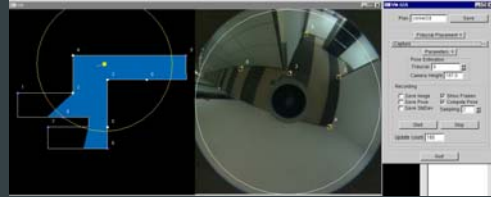
Landmark Placement and Correspondence

- Uncertainty given distances and angle



Landmark Placement and Correspondence

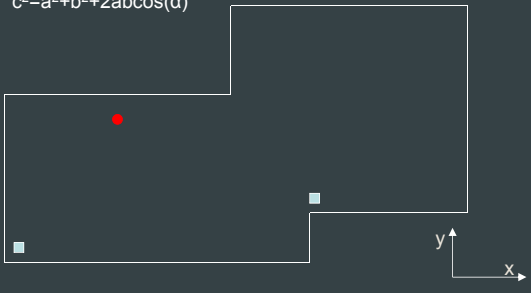
- Correspondence and Visibility



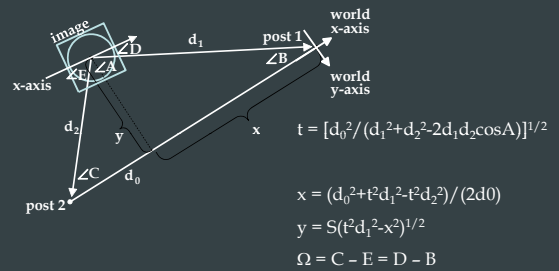
Pose Estimation from Landmarks

- Let's do a simple 2D example...

$$c^2 = a^2 + b^2 + 2ab \cos(\alpha)$$

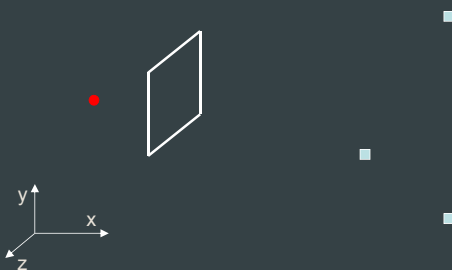


Pose Estimation from Landmarks

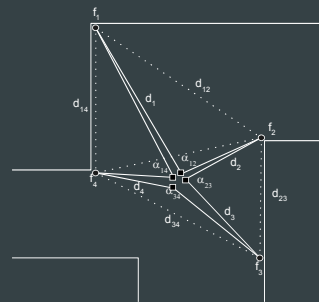


Pose Estimation from Landmarks

- Let's do a simple 3D example...



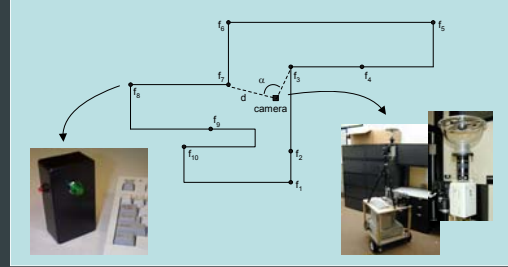
Pose Estimation from Landmarks



Optimization

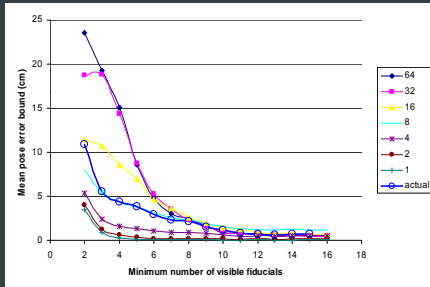
- Use a procedure related to “bundle adjustment”
 - A nonlinear optimization method [Triggs00]
- Summary:
 - Improve pose estimates
 - Improve landmark estimates
 - Loop back until converges
 - ...

Optimization



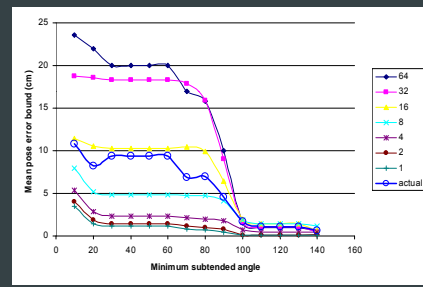
Optimization

- Increasing minimum visible landmarks



Optimization

- Increasing minimum subtended angle by landmarks



Optimization

- Increasing maximum distance to landmarks

