Computer Vision and Robotics Research at CUED

Department of Engineering
University of Cambridge
Research themes

Application of well-founded mathematics to tough problems:

• **Reconstruction** (construction 3D models from uncalibrated images)

• **Localisation** (determining pose from no/weak prior information)

• **Visual tracking** (following pose of complex structures)
  – Applications in
    • Gesture-based interfaces
    • Augmented Reality
    • Visually guided robotics
Reconstruction

- Build 3D model using images from uncalibrated camera

Haniwa Sequence under Circular Motion
Reconstruction

• Exploit geometric properties of circular motion to
  – Recover axis of revolution
  – Determine camera characteristics (including focal length)
  – Compute orientation of each image

• Use silhouettes to carve 3D model

• Refine 3D model by registering and carving silhouettes of novel views
Localisation

- Determine pose from single image
- Match to database
- Triangulate position
Localisation

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Localisation

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Localisation

- Uses constraints offered by architectural scenes
  - sets of edges converging on two orthogonal vanishing points

- Transforms novel view into canonical frame

- Matches stored view using feature correspondence
  - well-localised features (peaks in autocorrelation function)

- Camera localised by triangulating features
Visual tracking

• Pose determination from video stream

• Using CAD models of target structure
  – Polyhedral Models
  – Curved Structures

• Applications
  – Gesture-based user interfaces
  – Augmented reality
  – Visual servoing
Hand tracking

• Track hand pose in cluttered scenes
Hand tracking

• Articulated CSG hand model
  – Truncated quadric primitives
  – 27 raw degrees of freedom (6 pose, 21 internal)

• Learn reduced dimensionality configuration space
  – exploit constraints derived from task

• Build hierarchical tree of templates derived from model
  – Use statistical pruning and Bayesian framework to determine pose
Tracking polyhedral models

- Track pose of complex structure in real-time (50Hz)
- With robustness to occlusion
Tracking polyhedral models

- Use CAD model Rendered in predicted pose
  - Pose represented by Lie group
  - Velocities correspond to Lie algebra

- Match rendered edges with image edges at sample points
  - Model non-Gaussian statistics of edge measurements

- Can also recover camera parameters
  - focal length etc.
Visual tracking system

- Estimated Viewpoint
  - Update Model Pose
  - Compute Euclidean Motion
- Render Model
  - Assign Sample Points
  - Scan Edge Normals
- Estimated Viewpoint
- Render Model
Articulated structures

- Extend tracking to articulated structures
  - Revolute and prismatic joints impose constraints
  - Exploit mathematics of Lie groups to satisfy constraints
Visual servoing system

- Camera Parameters
- 3D Tracking System
- Store target position (or path) on disk
- Euclidean Motion
- Robot Control

Diagram showing the flow of information between the components of the visual servoing system.
Closed-loop robot control
Following a trajectory
Key Challenges

• Robustness
  – Improved statistical models and dynamical filters
  – Detection and recovery from failure
  – Automatic initialisation

• Integration
  – Sensor fusion (edge, texture, inertial tracking)
  – Processing many cameras (using distributed processing)
  – Closing the AR loop using gesture interfaces

• Reconstruction
  – Rapid building of 3D models from unconstrained data
  – Maintenance of CAD models to reflect changes