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Computer Vision and Robotics Research at CUED

Department of Engineering
University of Cambridge

Research themes

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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

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- Build 3D model using images from uncalibrated camera

Reconstruction

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- 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

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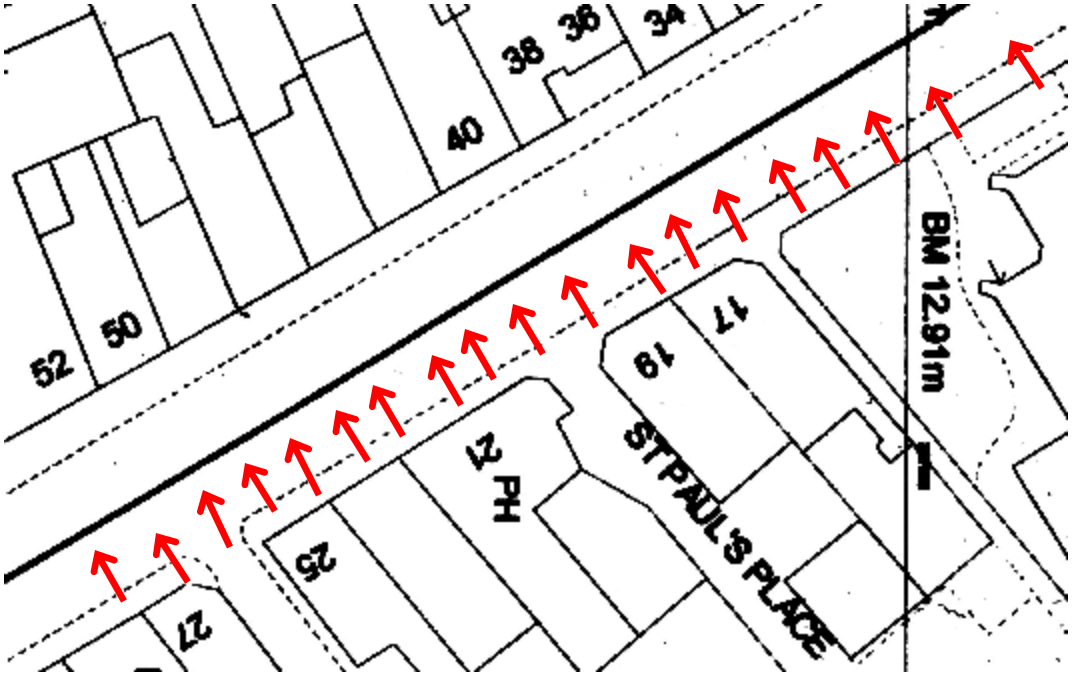
- Determine pose from single image
- Match to database
- Triangulate position



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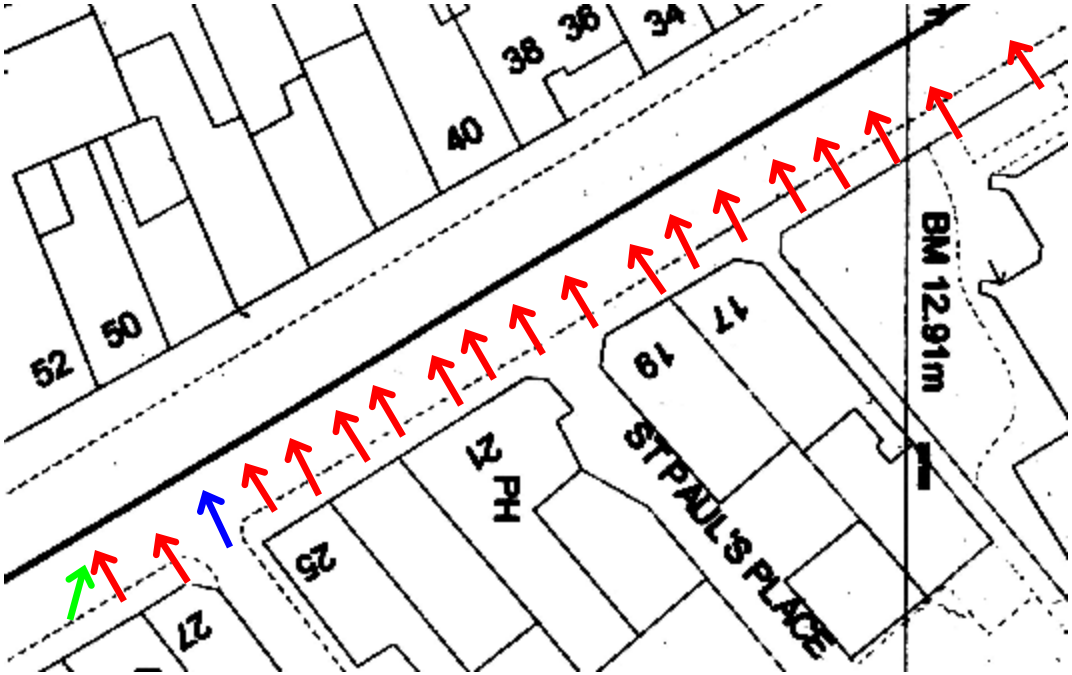

Localisation

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- 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

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- 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

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- Track hand pose in cluttered scenes

Hand tracking

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- 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

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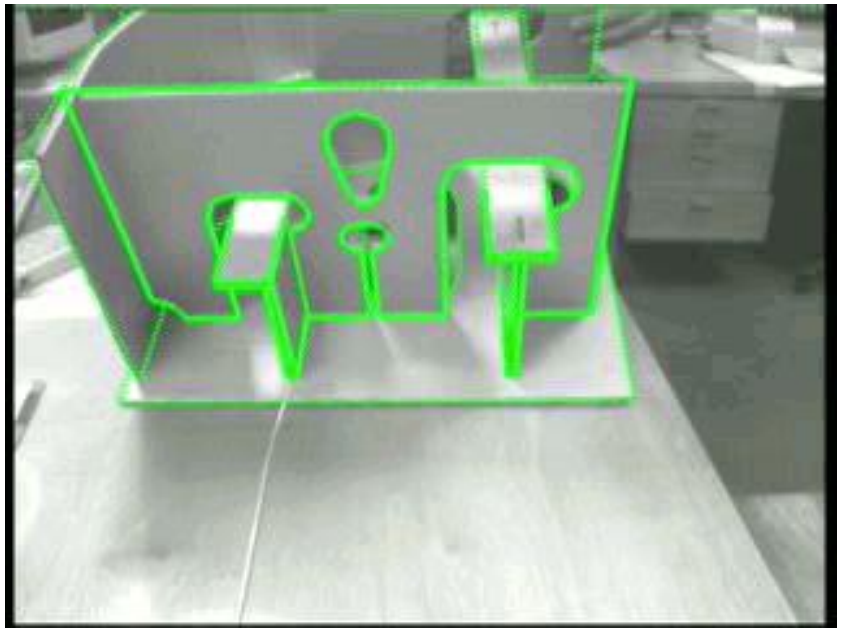
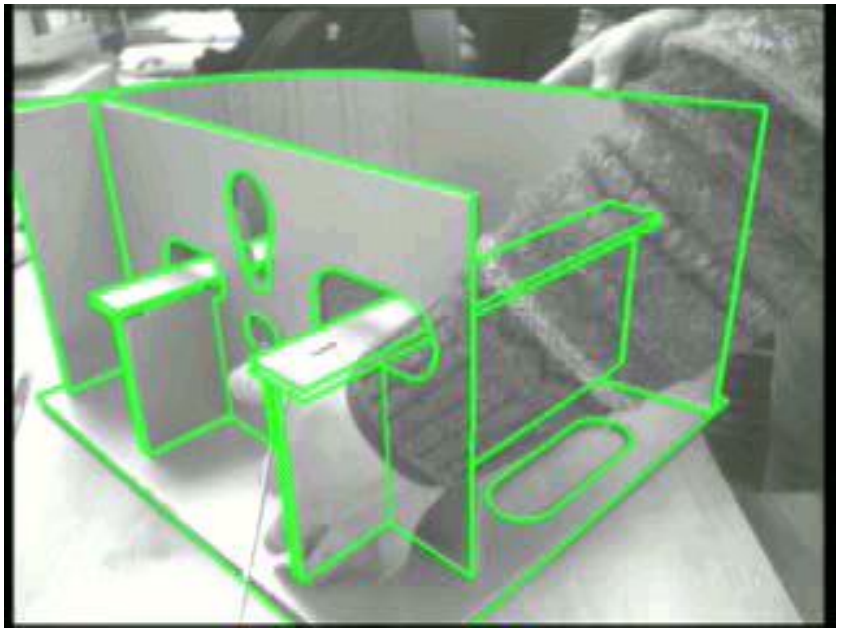
- Track pose of complex structure in real-time (50Hz)
- With robustness to occlusion





Tracking polyhedral models

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- 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

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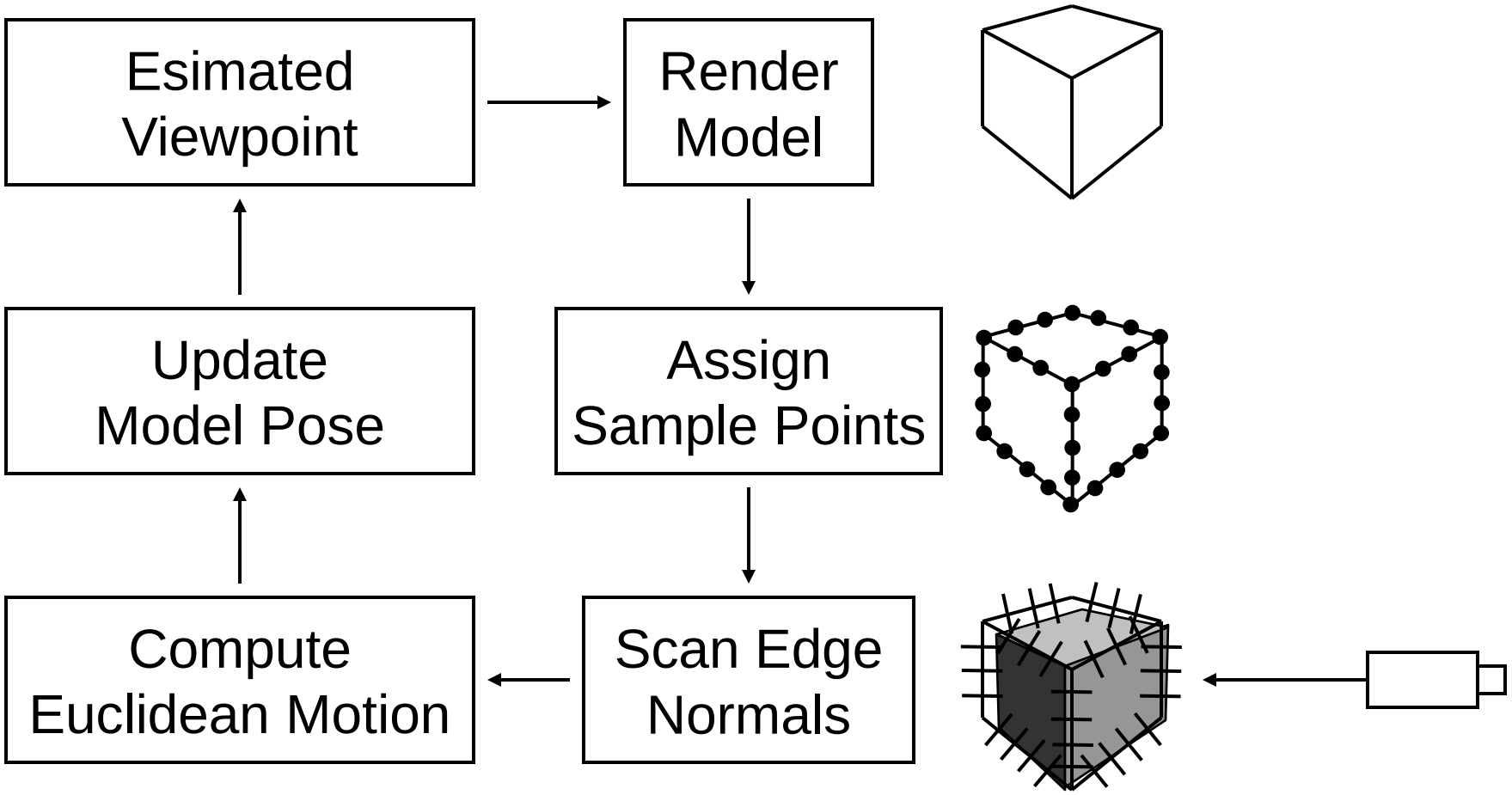

Articulated structures

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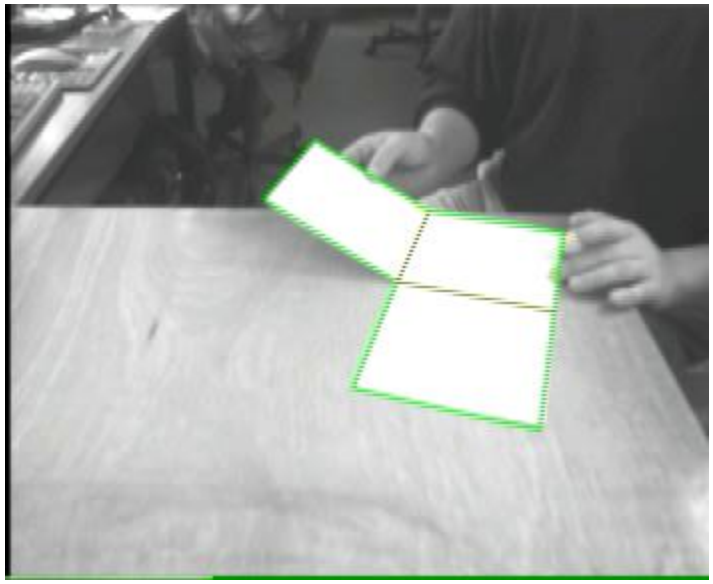
- Extend tracking to articulated structures
  - Revolute and prismatic joints impose constraints
  - Exploit mathematics of Lie groups to satisfy constraints



Visual servoing system

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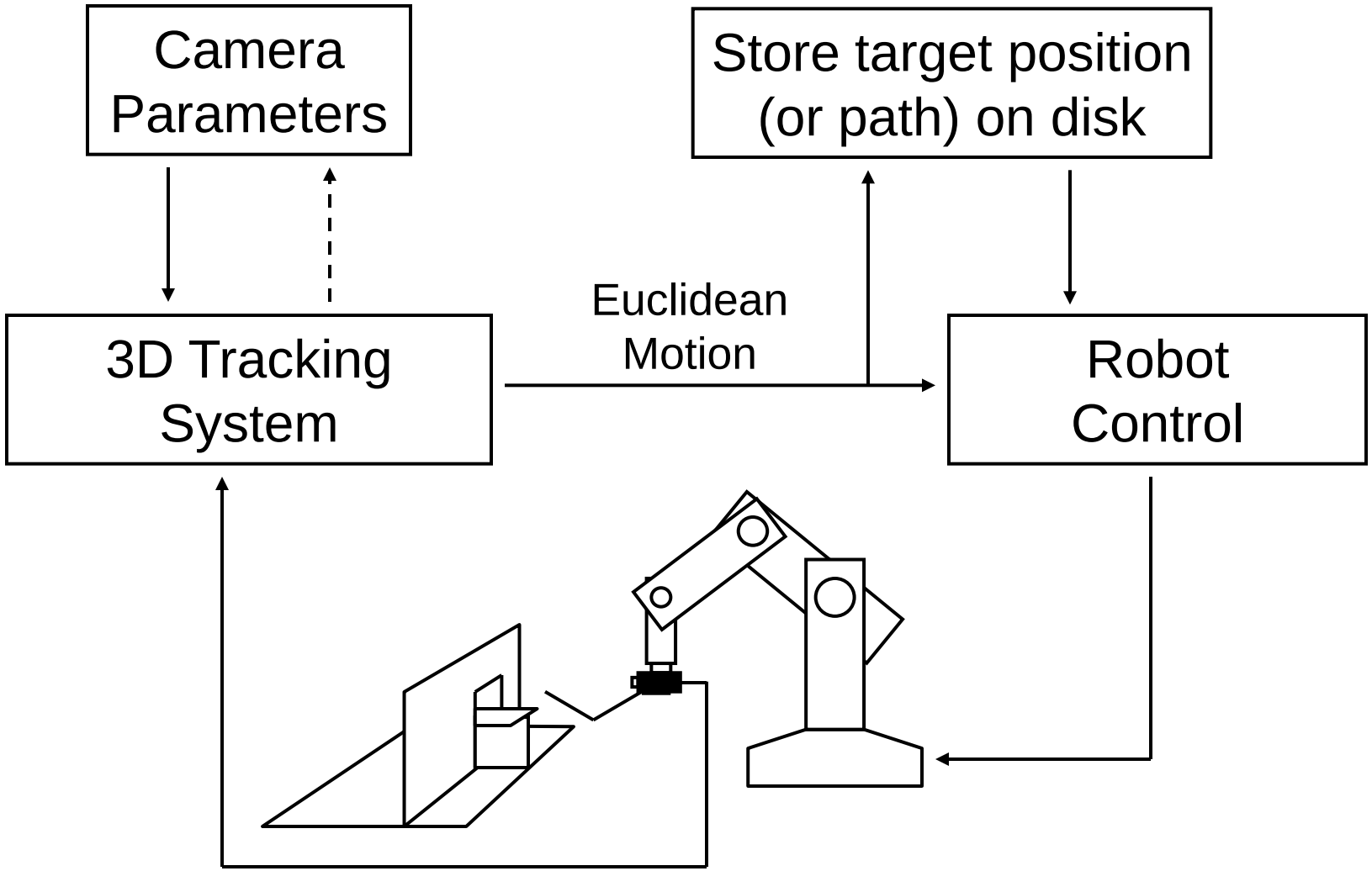

Closed-loop robot control

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Following a trajectory

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Key Challenges

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- 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