Towards endoscopic augmented reality for robotically assisted minimally invasive cardiac surgery

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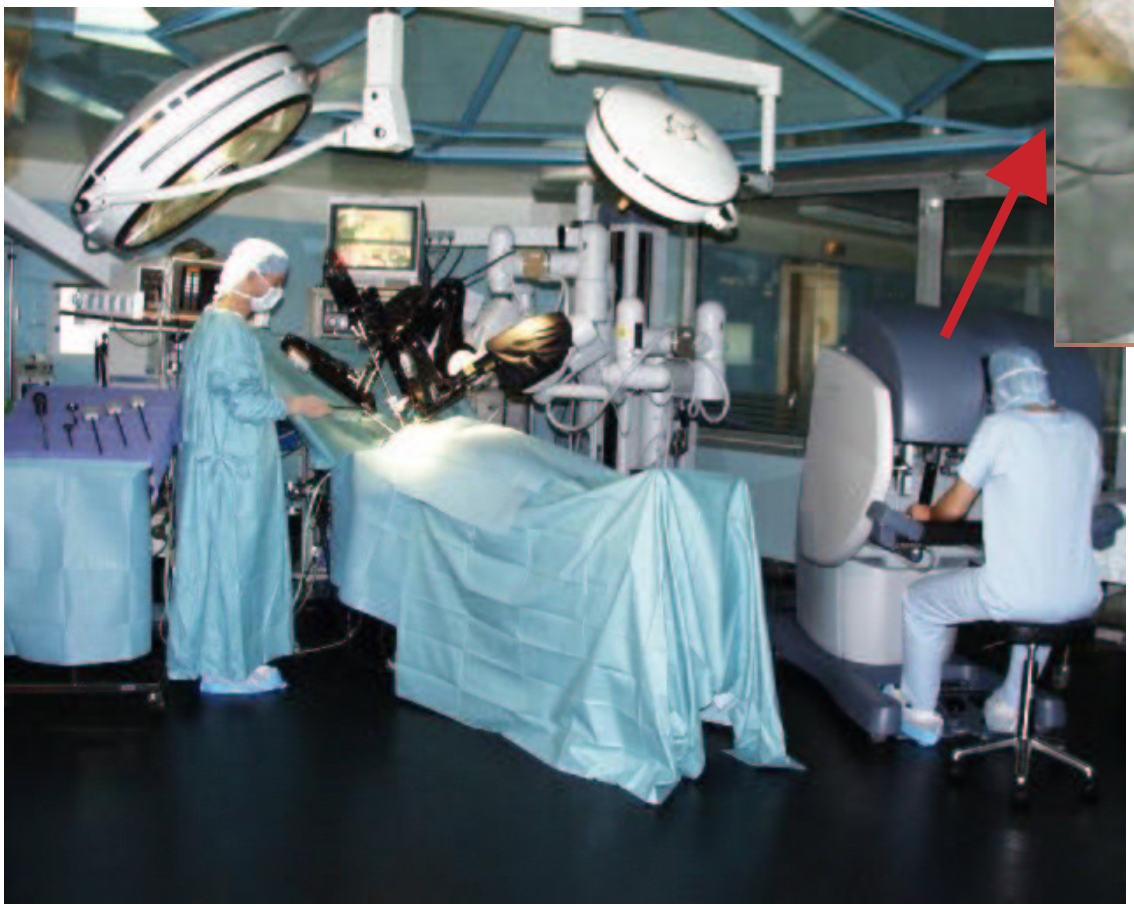
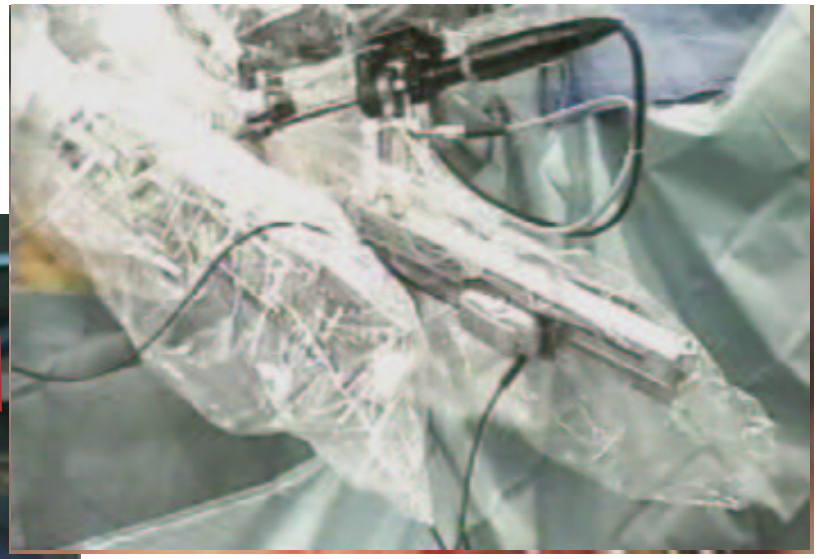
Robotically assisted cardiac surgery





Endoscopic view

Precision, dexterity, but...

Incision sites must be carefully chosen/computed

No force feedback (yet)

Reduced field of view

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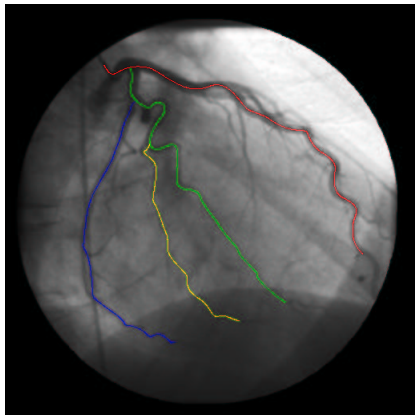
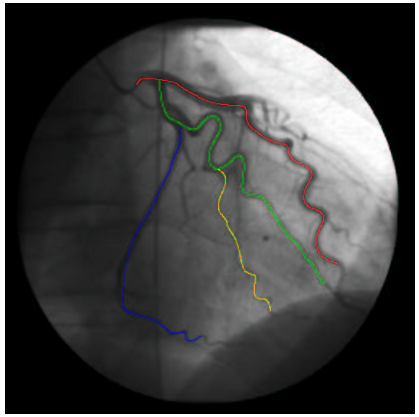
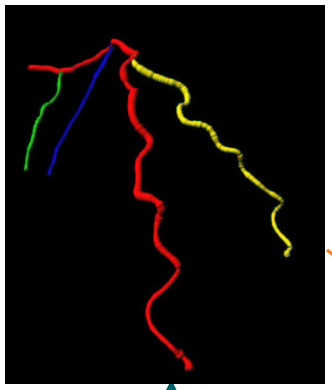
Augmented reality for cardiac surgery

Coronarographic sequences

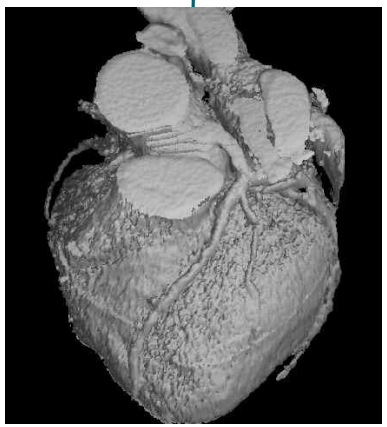




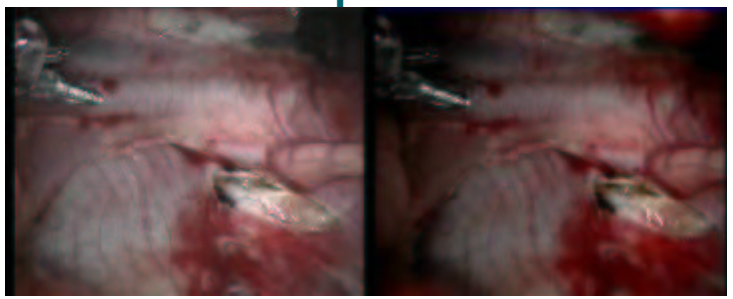
3D+t model



CT scan/MRI

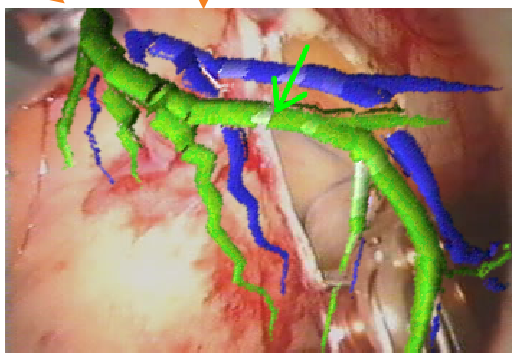


Endoscopic stereo



Robot coordinates

Real-time registration



Augmented reality

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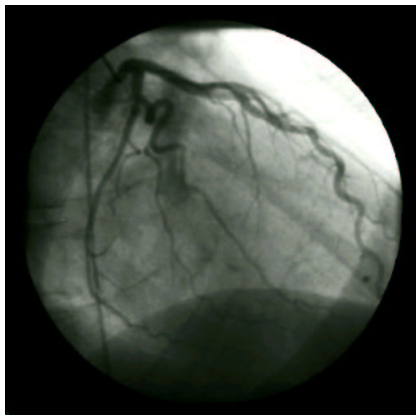
3D+t coronary tree model

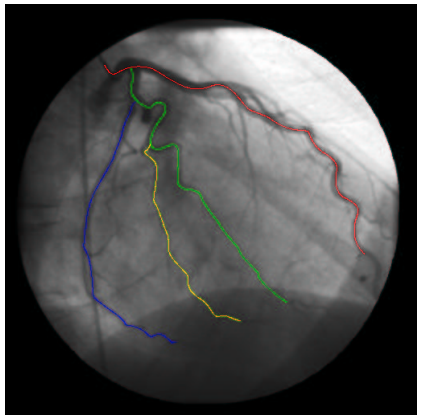
n sequences,

different incidences

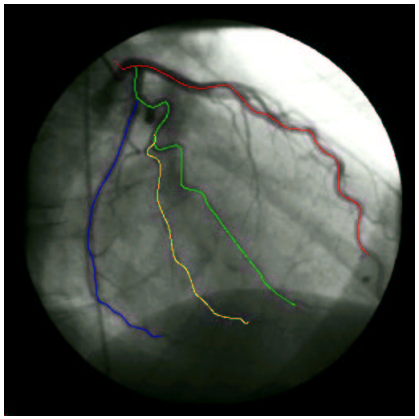
Image sequence



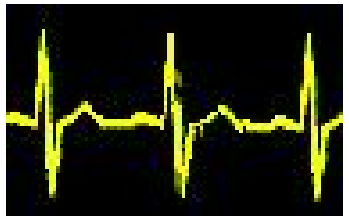
Semi-interactive drawing



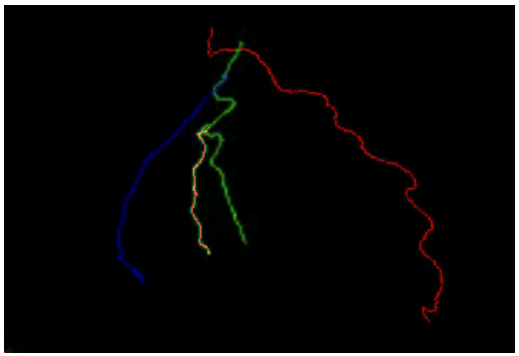
2D tracking



ECG

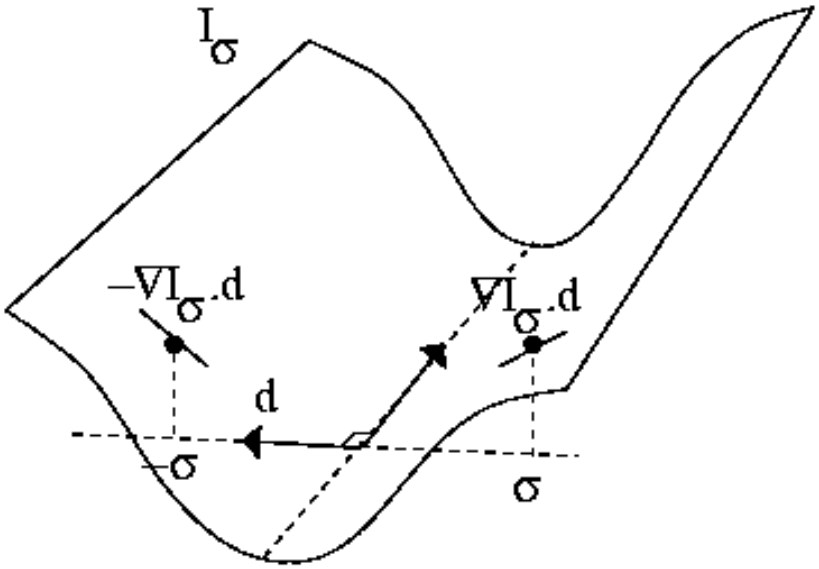


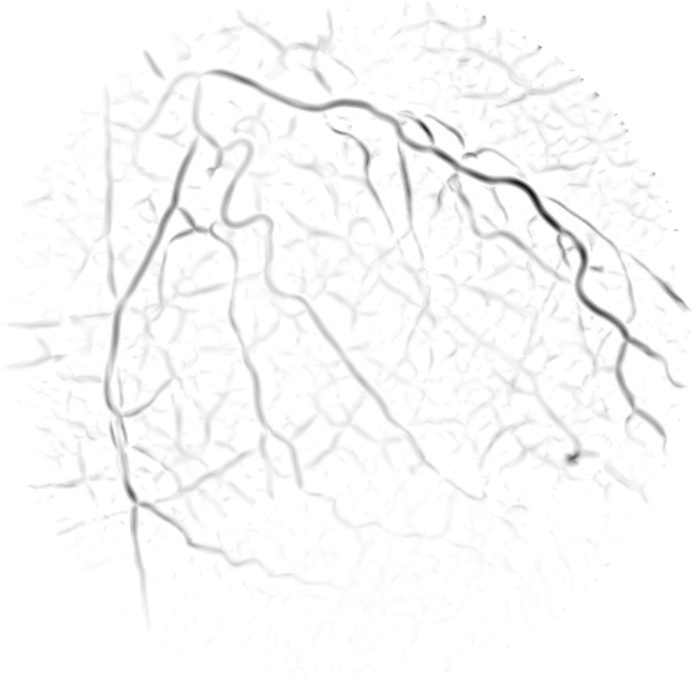
Stereoscopy on synchronous images



2D artery segmentation

- Various sizes, multiple moving objects
- Model-based multi-scale analysis





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Segmenting and tracking 2D coronaries

- Semi-interactive drawing on one frame, based on dynamic programming (intelligent scissors)
- 3-Step tracking from image n to n+1:
  - prediction from n-1 to n motion
  - affine snake based on multi-scale energy
    (global deformation)
  - B-spline snake (local deformations)

Position at image n-1

affine prediction

affine snake result

B-snake result

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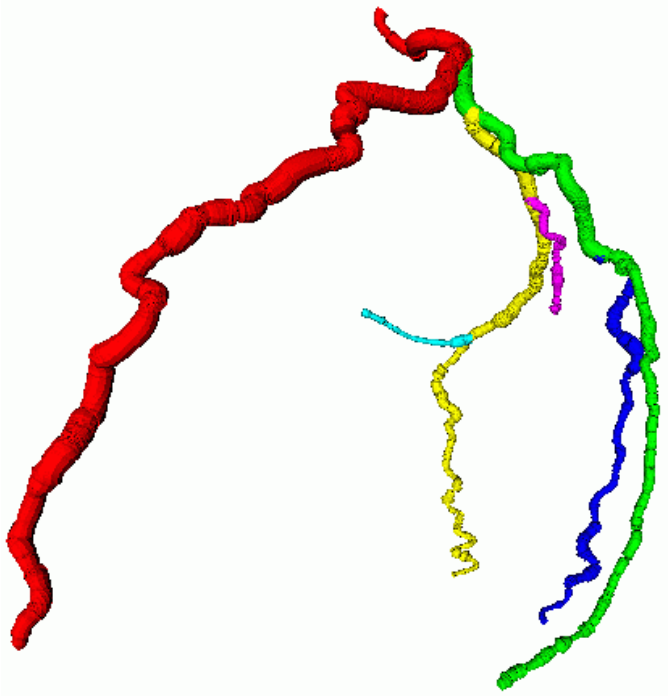
3D+t coronary tree reconstruction

- Non-simultaneous stereoscopy
- Matching by dynamic programming, with "weak" epipolar constraint
- Bundle adjustment to compensate global translation

3D+t reconstruction 3D reconstruction



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Full 3D+t heart model

- Register 3D coronaries with 3D heart surface from CT-scan or MRI
- Compute heart motion from 3D+t coronaries
- Apply this motion to 3D heart surface to "animate" it
- Work in progress...

Endoscopic stereoscopy

- Calibration
  - off-line (using calibration grid)
  - during operation: self-calibration
- Tracking
  - stereo tracking of feature points
  - motion+structure from motion
- Correlation-based stereo
  - parallel implementation

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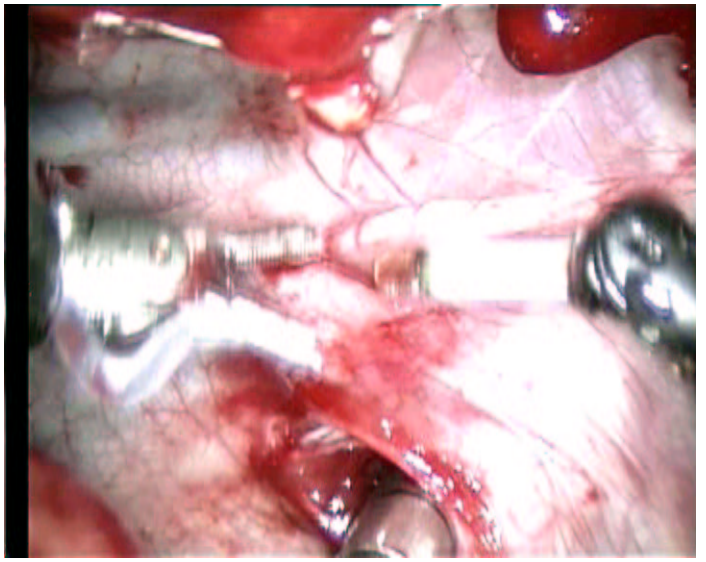
Foreground/background classification

- Necessary to separate organ surface from instruments full background
- Using z (from disparity) and color
- Enables "diminished reality"
- 3D mosaic, using tracked points



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Augmented reality

- Registration between stereoscopy and 3D(+t) heart model
- Video-rate overlay, using robot articular coordinates for endoscope motion, and ECG for heart motion
- Update position parameters whenever a registration result is signaled
- Software integration & real-time issues

Conclusions

- One particular application generated many sub-problems:
  - 3D+t heart modeling
  - Stereoscopy & registration from endoscopic views
  - Integration, real-time issues
- Application-driven but generic algorithms