K-Wire Tracking in 3D Camera Views

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Background

• K-wire insertion currently requires many X-rays

• Misplacement could damage important structures in the body

• Current tracking solutions are ineffective for K-wire
  – Traditional computer vision solutions fail
  – Trackers cannot be placed on it

• Propose to use convolutional neural network trained on RGB images

Solution

Deep learning based K-wire tracking algorithm using RGB images
- Eliminates the need for multiple X-ray images
- Can be easily integrated into augmented reality solutions to orthopedics surgery

Technical Approach

• Create data
  – Create a modular data set by capturing foreground and background separately

• Design network
  – Design and train a CNN based neural net to segment K-wire in RGBD images
  – HED for tool tracking[^8] , U-Net[^9]...

• Pose estimation from segmented stereo image pairs

Deliverables

Minimum

• Phantom to create training data
• Modular data set
  – Foreground videos with K-wire against drape
  – Segmentations of the K-wire position
• Calibrated stereo cameras
• CNN trained on K-wire video with plain background to segment it

Expected

• Realistic data set of surgical workspace by composing foreground and background videos of surgical workspace with instruments (i.e. scalpel)
• Algorithm to extract K-wire orientation from segmentation in 2D
• CNN trained with realistic data that can segment the K-wire

Maximum

• Algorithm to extract K-wire position and orientation in 3D in free space
• Algorithm to estimate position of K-wire tip with occlusion
Data Set Creation – Capturing Images

Foreground images

Varying Lighting

Varying Colour

Increasing Complexity

Background images
Data Set Creation – Composing Images
Data Set Creation – Challenges

- No colour blending
- Too perfect colour blending

- Histogram matching in each LAB channels
- Outward Gaussian blurring on the mask to smooth edges
Technical Approach – Holistically-Nested Edge Detection
U-Net

Fully convolutional network: retains semantic context, better for memory usage

U-Net

- Fully connected layers replaced by convolutional layers
- Usual contracting network supplemented by upsampling layers: increase the resolution of the output.
- High resolution features from contracting path combined with upsampled output: retains image context
- Originally used with ~30 images! (with extensive augmentation)
U-Net: Training with Level 1 Images

- 5 Layers
- Cross entropy loss with weight balancing
- Adam optimizer

a) Original images   b) Ground truth  c) Predictions
Possible solutions:
- Experiment with hyper-parameters etc
- Train using higher level images directly
- Better post-processing
U-Net: Challenges

Possible solutions:
- Experiment with hyper-parameters etc
- **Train using higher level images directly**
- Better post-processing

Disjoint masks (train for longer)
Low quality masks

a) Original image  b) Prediction  c) After post-processing
U-Net- Retrain with Level 2 Images

Original  Ground truth  Epoch 1  Epoch 25  Epoch 115  Epoch 200
U-Net: Retrain with Level 2 images

Results

Much better results on Level 1 images!

- Refine network
- Post-processing

a) Original image  b) Prediction
U-Net: Further

• Refine network to increase accuracy
  – Iterative!
  – Better post-processing methods

• Validation with new data

• Orientation estimation in 3D
## Dependencies

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<thead>
<tr>
<th>Dependency</th>
<th>Status</th>
<th>Plan</th>
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<tbody>
<tr>
<td>Access to servers for training CNN</td>
<td>In progress</td>
<td>In discussion with Alex Johnson</td>
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<tr>
<td>Get Keras installed in server</td>
<td>In progress</td>
<td>Contacted Anton</td>
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<td>Access to camera and surgical instruments</td>
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<td>Access to segmentation library</td>
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<td>Create a phantom</td>
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<td>Observe K-wire use in clinic</td>
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<td>Obtained access to MARCC cluster, run on desktop with GPU</td>
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<td>Usage limit on thin6 server</td>
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<td>Task Name</td>
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<tr>
<td>Minimum Deliverables</td>
<td>Create phantom</td>
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<td>Make data set of modular video components</td>
<td>K-wire on plain background</td>
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<td>Segment k-wire positions</td>
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<td>Extract 3D pose of Kwire from data</td>
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<td>Take videos of surgical workspace</td>
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<td>Validate segmentation results</td>
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<td>Expected Deliverable</td>
<td>Augment data set</td>
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<td>Compose segmented K-wire videos with surgical workspace</td>
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<td>Refine CNN</td>
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<td>Validate 3D pose estimation from stereo pairs</td>
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<td>Maximum Deliverables</td>
<td>Extract 3D pose of Kwire from data</td>
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<td>Create algorithm to estimate K-wire tip position</td>
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<td>Evaluate K-wire tip position estimation in phantom</td>
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Reading List


5. Lee et. al, Simultaneous Segmentation, Reconstruction and Tracking of Surgical Tools in Computer Assisted Orthopedics Surgery
