A ground truth 3D video dataset for Augmented Reality Robotic MIS algorithms

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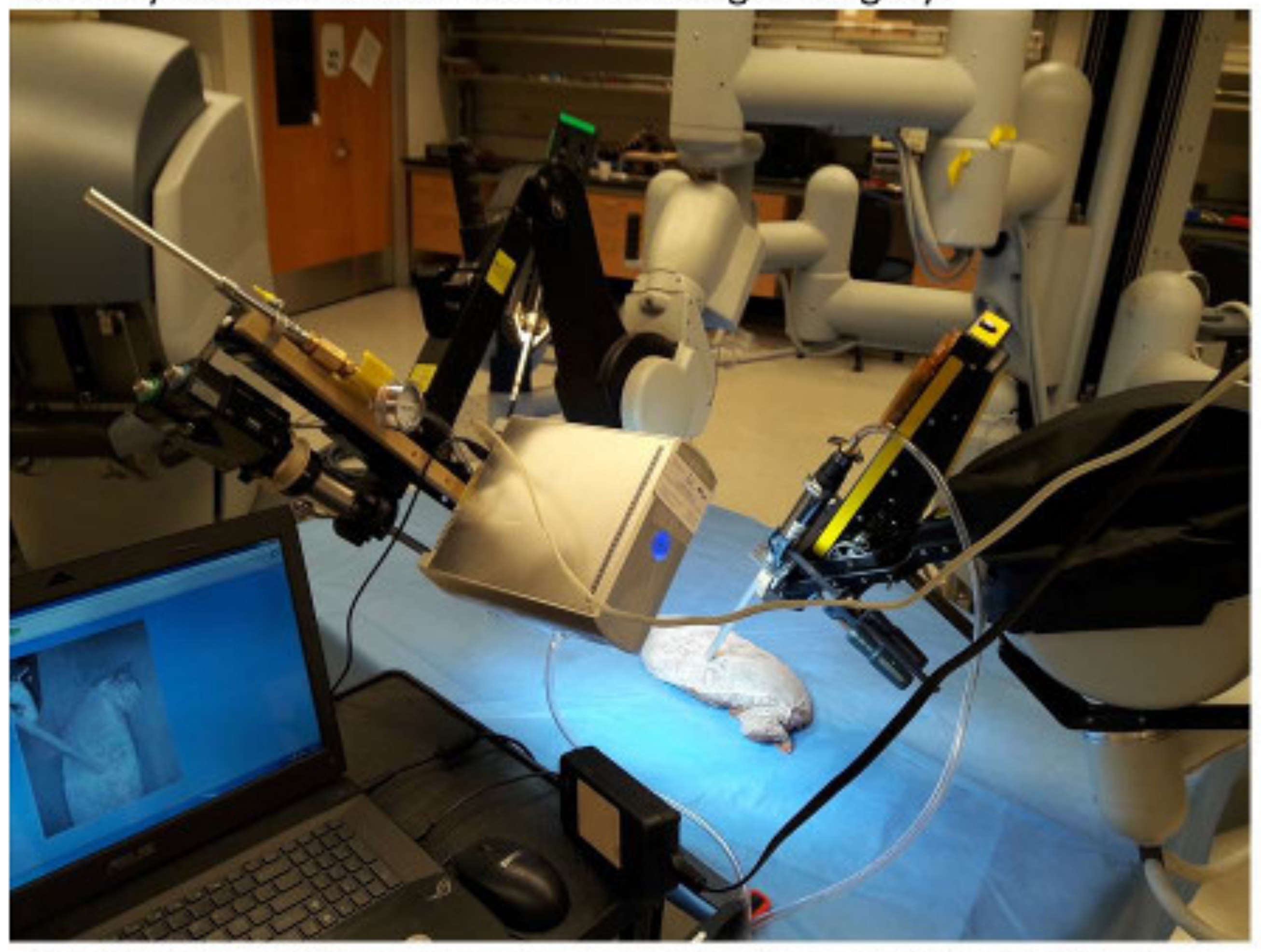
Robotic Minimally Invasive Surgery

Minimally Invasive Surgeries (MIS) allow patients to recover significantly faster than traditional open surgeries, reduce trauma to the body and improve patient post-operative pain. Recent advances in Computer Vision have the potential to improve guidance in MIS. In particular, Augmented Reality (AR) is a promising method to improve image guidance in surgery. This AR model will help to reduce the amount of error during MIS by providing surgeons with a dynamic intra-operative overlay of pre-operative imaging allowing the surgeon to see the location of structures underneath the surface of solid organs. In this work we present a data set to remove barriers to clinically useful real time AR for solid organ surgery.



Our data recording equipment attached to a da Vinci MIS robot

An Augmented Reality Pipeline for MIS

- AR image guidance uses several steps to track unseen structures in a solid organ.
- Accuracy at each step is determined by the input data quality.
- Output of one step is input to the next
- **High quality AR is impossible without high quality depth map data**

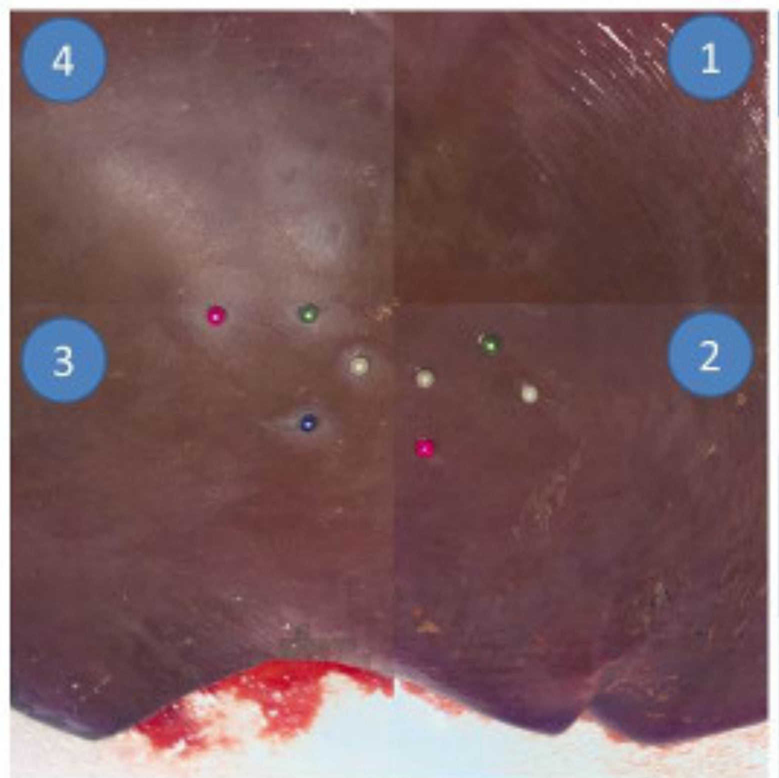
Gathering Surgical Data

Currently, no high quality depth map data exists from the first pipe stage. Without this data, the step from reconstruction to tracking is impossible. We therefore created novel equipment and methods to build depth maps

Equipment	Function
Hydraulic da Vinci Tool	Accurately controllable da Vinci tool for palpating a liver. Allows AR pipeline results to be verified against a known movement
Laser Depth Scanner	Replaces laparoscope with accurate depth map sensor. Highly accurate color depth maps allow a higher quality AR pipeline then is possible with normal cameras
Pressure Gauge	Measures force feedback from the controllable da Vinci tool. Force measurements can be used to verify the physics estimation in the last step of the AR pipeline

Tissue Preparation for AR Algorithms

The laser Depth Scanner is accurate but not designed for biological tissue. Several schemes of tissue preparation were tested with AR algorithms



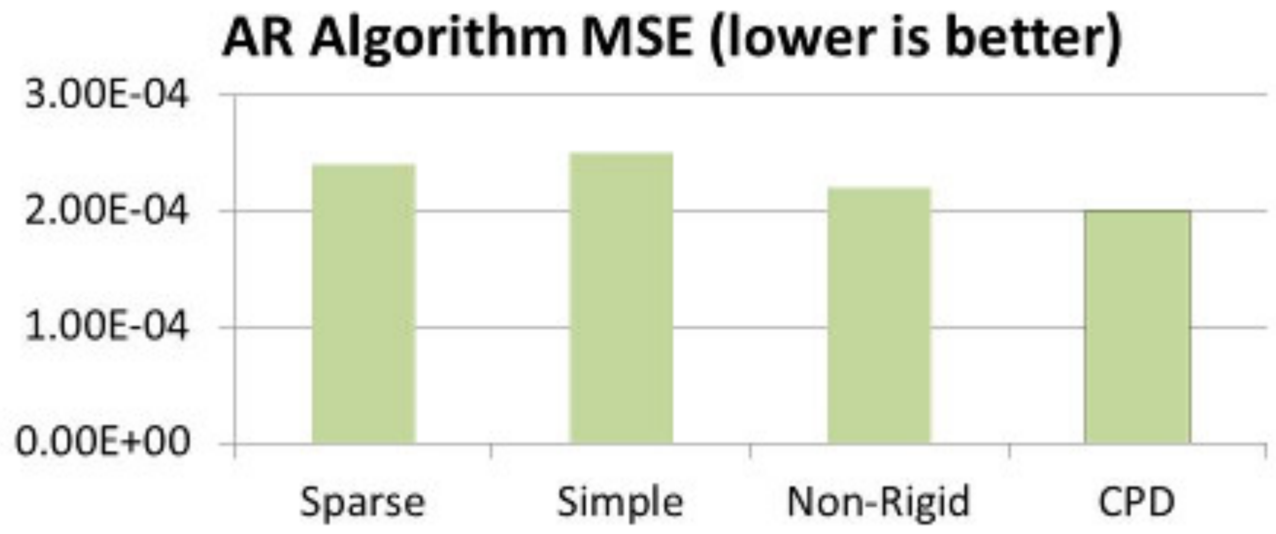
Tissue Preparation
[1] Saline Solution
[2] Saline Solution + Fiducial Markers
[3] Talcum Powder + Fiducial Markers
[4] Talcum Powder

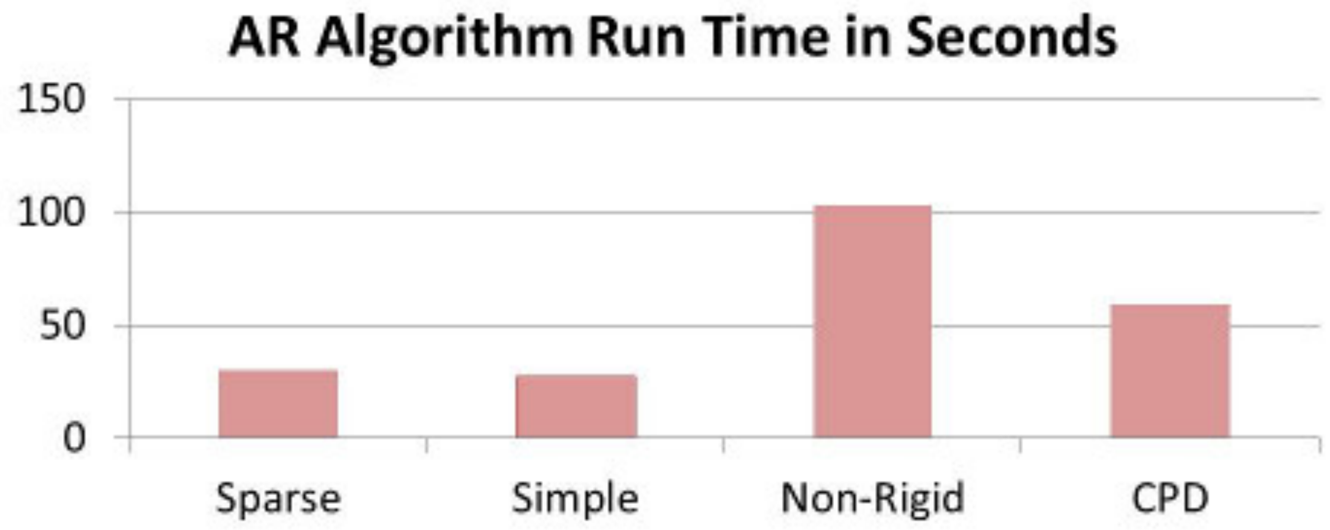
Tissue Preparation Schemes (Listed Clockwise from Top Right)

AR Results Using our Data

To demonstrate a use for our dataset we tested it with four algorithms that can be used in the transform field measuring AR step. These perform non rigid or rigid 3 Dimensional registration.

Algorithm	Best Feature	Worst Feature
Sparse ICP	Error Resilience	Inaccurate
Simple ICP	Fast	Inaccurate
Non-rigid ICP	Error Resilience	Slow
Non-rigid CPD	Accurate	Slow



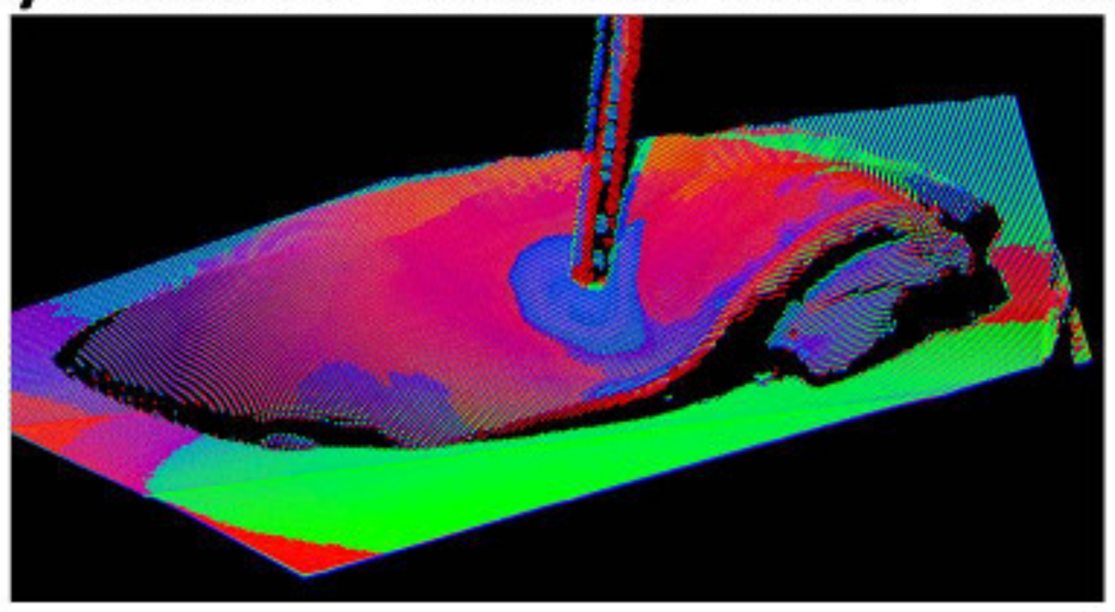


Call to Action

We have proven that this data set is useful, we invite researchers to:

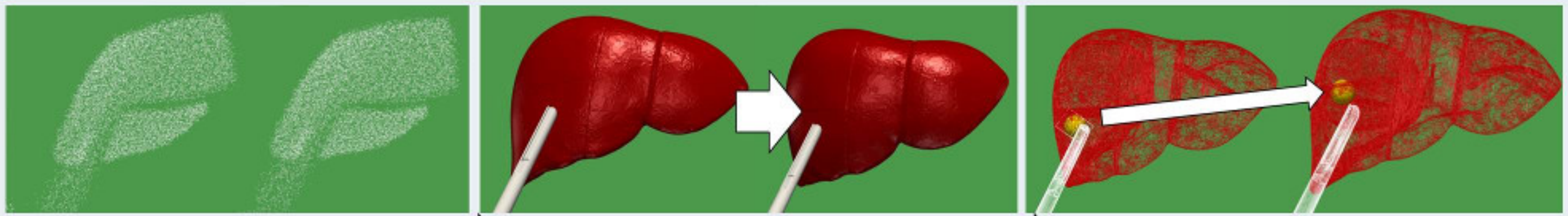
- Apply the same method to generate data sets on other surgeries
- Use our data set to test and develop registration algorithms

Stay tuned for enhanced follow on work



High quality transform field AR step using our data

Augmented Reality Concept: A Tumor in Yellow is Overlaid on Surgeons Video Feed



Compute depth map from camera → **Measure surface transform field** → **Perform AR Physics simulation on MRI**

Major steps to convert conventional video to augmented reality video overlay on surgeons display

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