Tracking and estimation of surgical tool relative-pose and angle based on the vision system for surgical robot.

MUTHUKRISHNAN, R., KANNAN, S., ZHAO, Y. and PRABHU, R.

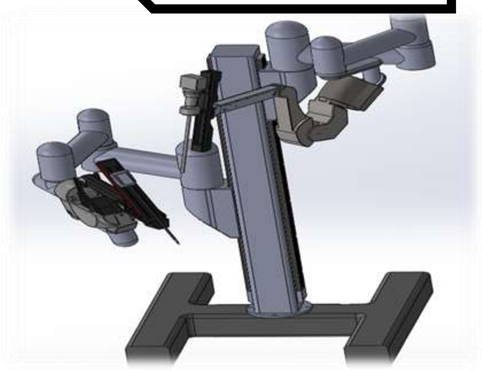
2024

Tracking & estimation of surgical tool relative-pose and angle based on the vision system for surgical robot

Ramkumar Muthukrishnan, Somasundar Kannan, Yafan Zhao, Radhakrishna Prabhu
School of Engineering, Robert Gordon University, Aberdeen, AB10 7GJ, UK
(r.muthukrishnan@rgu.ac.uk; s.kannan1@rgu.ac.uk; y.zhao@rgu.ac.uk; r.prabhu@rgu.ac.uk)

Vision

- This research presents a Virtual Dynamic Tri-crossbar and a Virtual Stable Graph (VDT-VSG) which simplifies the task of tracing the needle angle and location in 2D plane.
- In addition, Virtual Dynamic Line (VDL), helps to quantify the displacement between organ and surgical needle.



Customized Surgical Robot

Mission

- The significant objectives of this research are to achieve,

i. Surgical tool detection
ii. Tool Tracking
iii. Tool observation
iv. Distance, velocity, acceleration and angle estimation with respect to time in seconds

Problem Statement

- There are several issues exist in this Robot-Assisted-Surgery (RAS) realm, especially:

i. Tedious to detect & tract micro range surgical tool
ii. Challenging to work in different illumination condition
iii. Limited field of perspective
iv. Complex eye-hand coordination
v. Mild tremor during surgery
vi. Ambiguous view
vii. Rigorous to perform for prolonged time
viii. Restricted tool manipulation, etc.

Stitching Operation [1]

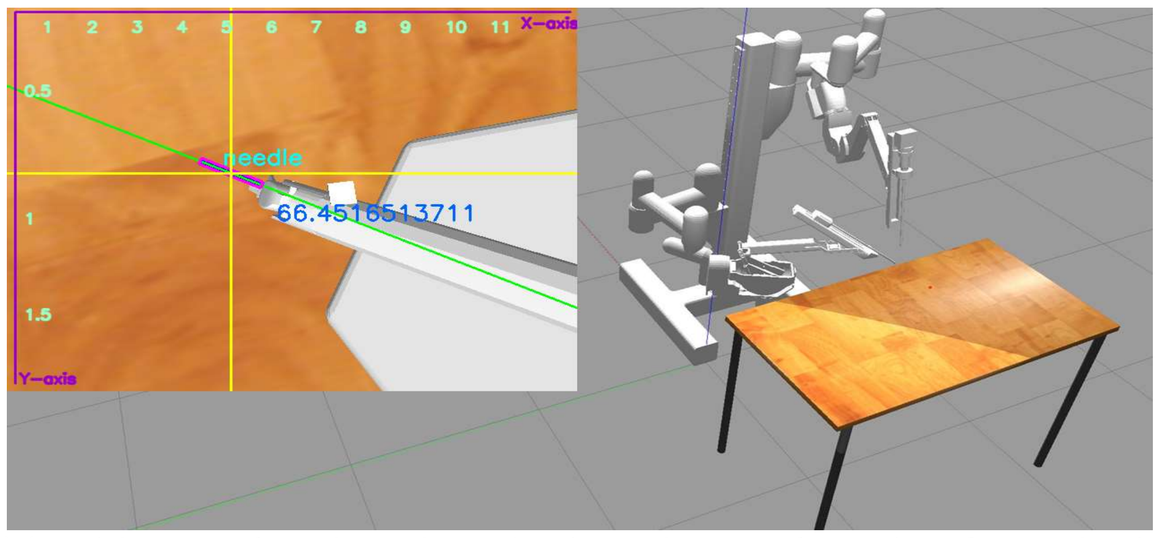
View from Endoscopic Camera [2]

Algorithm Flowchart

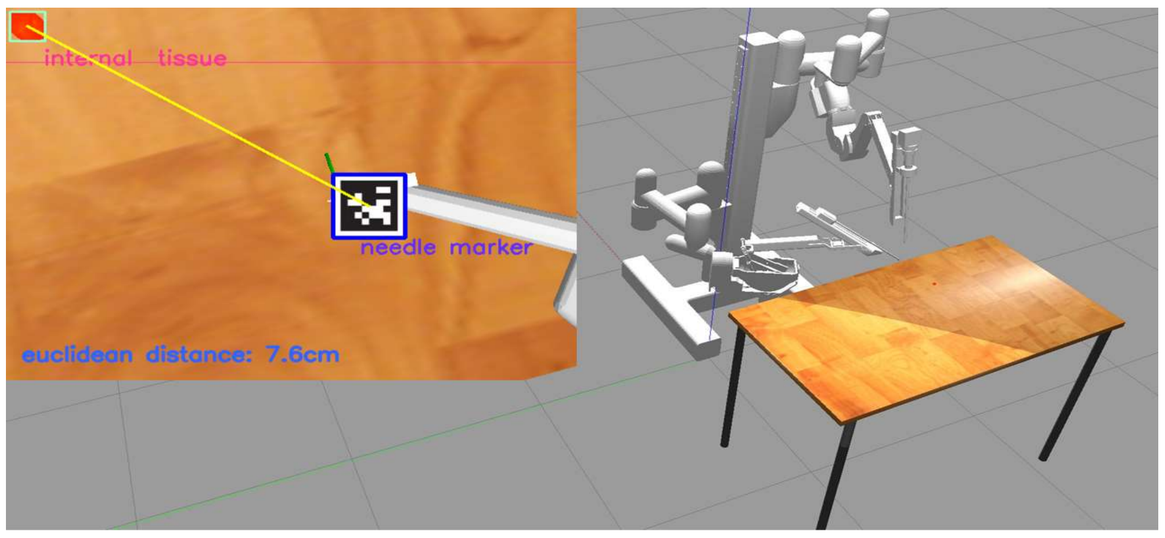
Scene Processing
↓
RGB-HSV conversion
↓
Binary conversion
↓
Obtain tool location coordinates
↓
Develop & overlay VM
↓
Frame conversion
↓
Binary threshold
↓
Get VM location coordinates
↓
Develop VDT-VSG with VDL

Simulation

- Robot Operating System (ROS) was utilized as middleware to process & obtain data from Gazebo simulation platform.

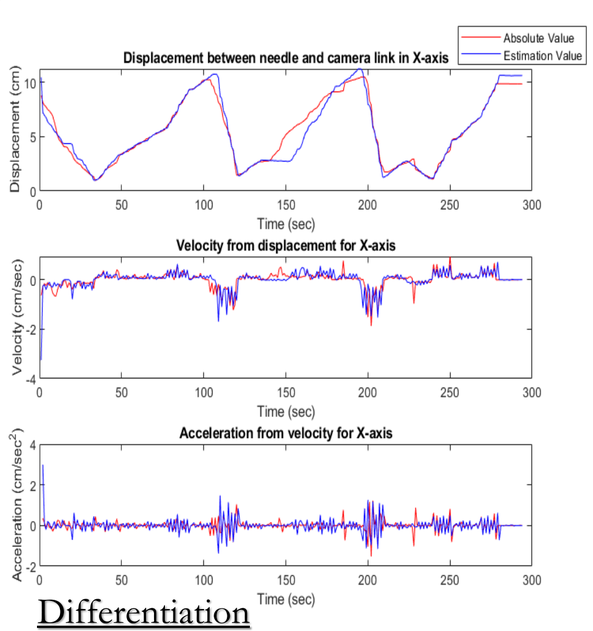


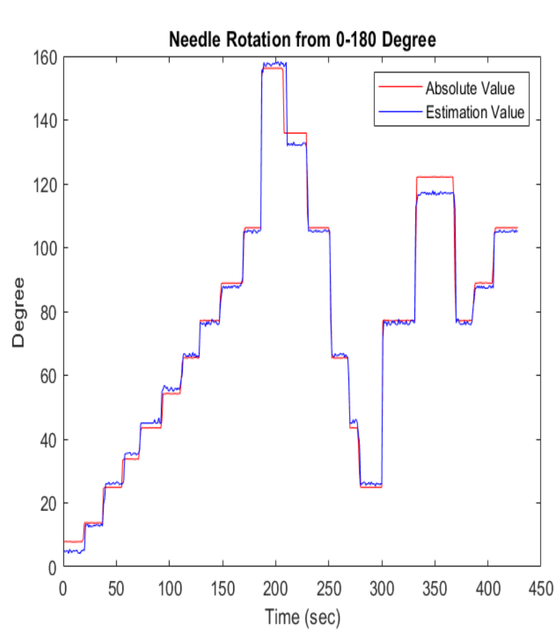
Tracking and estimating the location and angle of surgical needle

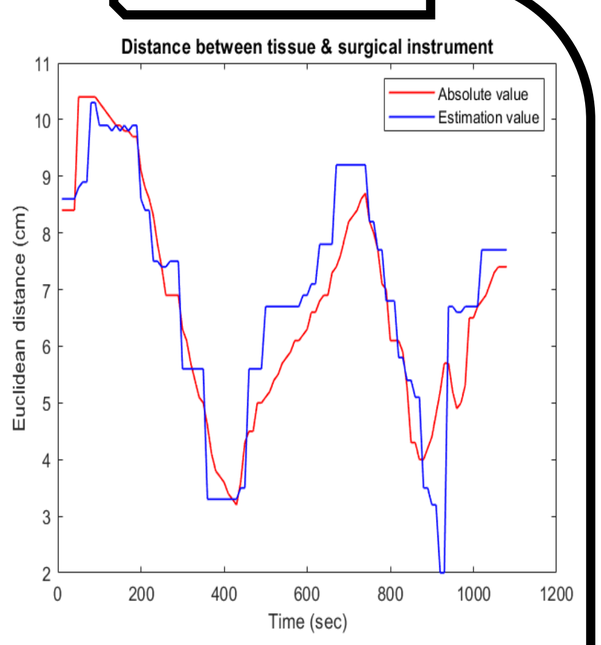


Detecting and estimating the relative displacement between organ and surgical needle

Results







Differentiation

s''(t) = v'(t) = a (t);
v = ds/dt;
a = dv/dt;
a = d^2s/dt^2

S= Displacement,
v=Velocity,
a=Acceleration,
t=Time

R_{SP} = cos−1 ∗ (DP) = Radian
R_{SP} = $roll_{SP}$ ∗ ((180)/ π) = Degree
$e_{disp(SP)} = \sqrt{X^2+Y^2}$,

Applications

- Tracking in cell and development biology
- Autonomous/semi-autonomous surgical robots
- Sensing in surgical operations using vision.

References

1. https://www.google.co.in/url?sa=i&url=https%3A%2F%2Frobots.ieee.org%2Frobots%2Fdavinci%2F&psig=AOvVaw0zu4W-rGXZtlEZCOva1yT3&ust=1670105968654000&source=images&cd=vfe&ved=0CBAQjhxqFwoTCIjbs8792_sCFQAAAAAdAAAAABAJ
2. https://www.google.co.in/url?sa=i&url=http%3A%2F%2Fmindrayendoscopy.com%2F&psig=AOvVaw2qzyMR_fvE7cxD_9VRkEHY&ust=1670106620088000&source=images&cd=vfe&ved=0CBAQjhxqFwoTCIjruJD-2_sCFQAAAAAdAAAAABAJ