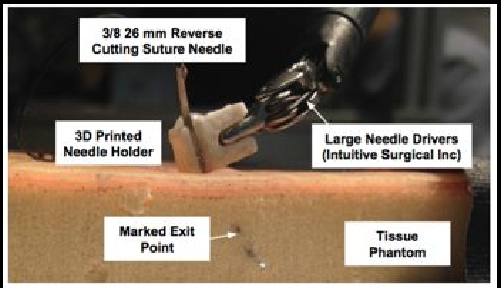
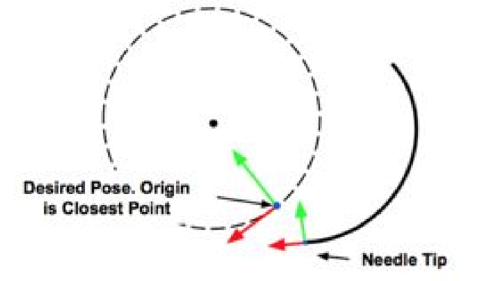
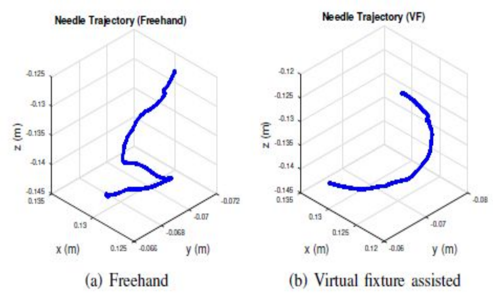
# Virtual Fixture (VF) Assistance for Needle Passing and Knot Tying

***Zihan Chen***, Anand Malpani, Preetham Chalasani, Anton Deguet,
S. Swaroop Vedula, Peter Kazanzides and Russell H. Taylor
zihan.chen@jhu.edu




(a) Freehand (b) Virtual fixture assisted

## Motivation

Suturing is a highly dexterous task in minimally invasive surgery (MIS).

Especially **challenging** for **novice** operators.

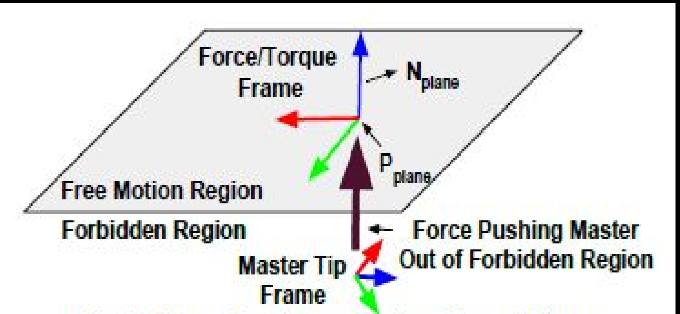
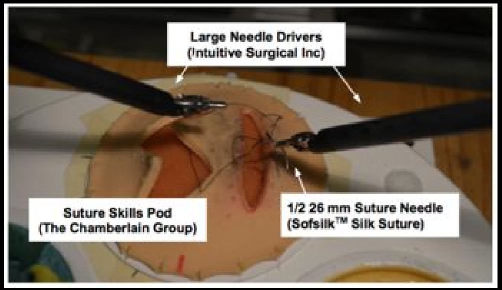
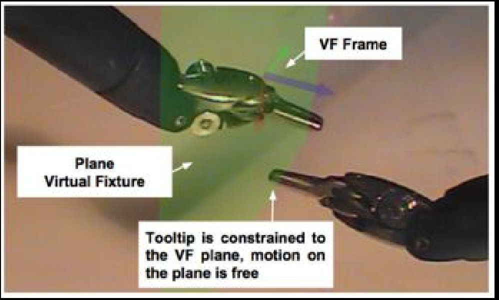
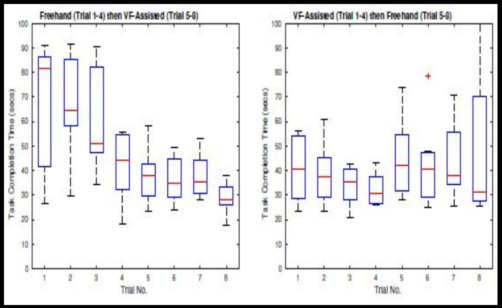



Fig. 2: Plane Forbidden Region Virtual Fixture




User Study: 14 subjects, **better** accuracy, **less** operator workload

JOHNS HOPKINS WHITING SCHOOL of ENGINEERING

LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY

ERC | CISST

IROS 2016 Daejeon, Korea

# Virtual Fixture (VF) Assistance for Needle Passing and Knot Tying

***Zihan Chen***, Anand Malpani, Preetham Chalasani, Anton Deguet, S. Swaroop Vedula, Peter Kazanzides and Russell H. Taylor

**Oct 12, 2016**
**zihan.chen@jhu.edu**

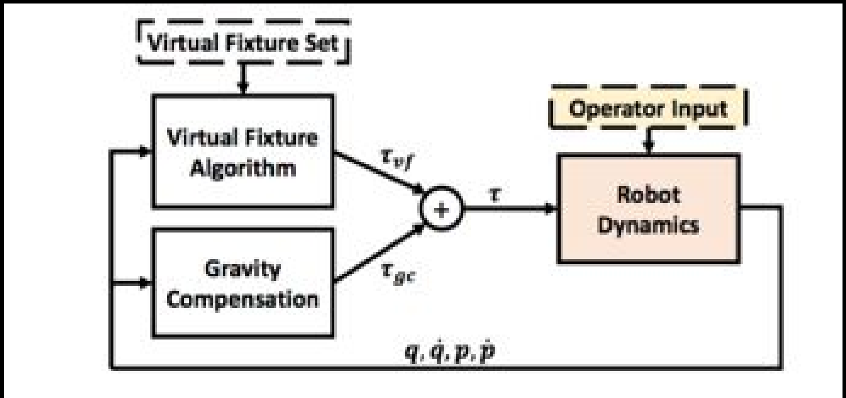
JOHNS HOPKINS WHITING SCHOOL of ENGINEERING
LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY
ERC | CISST

IROS 2016 Daejeon, Korea

# Motivation

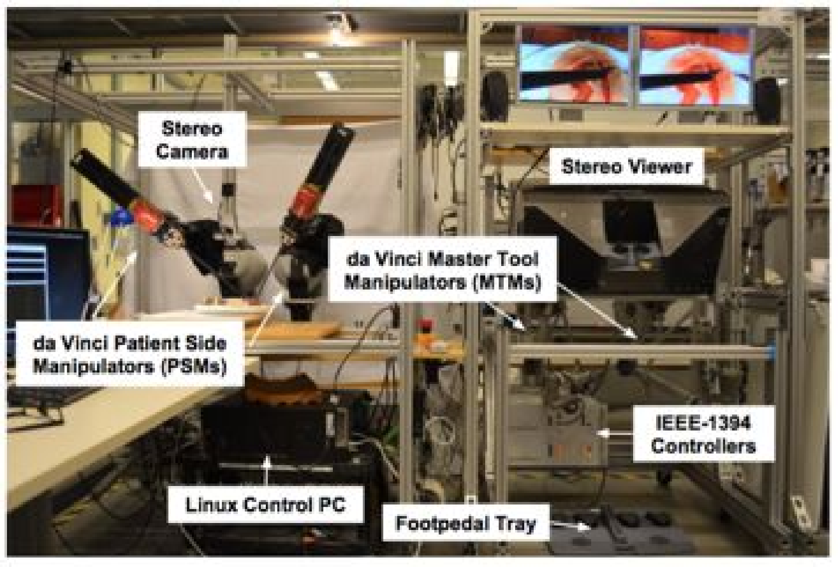
Suturing is a highly dexterous task in minimally invasive surgery (MIS).

Especially **challenging** for **novice** operators.




# Approach

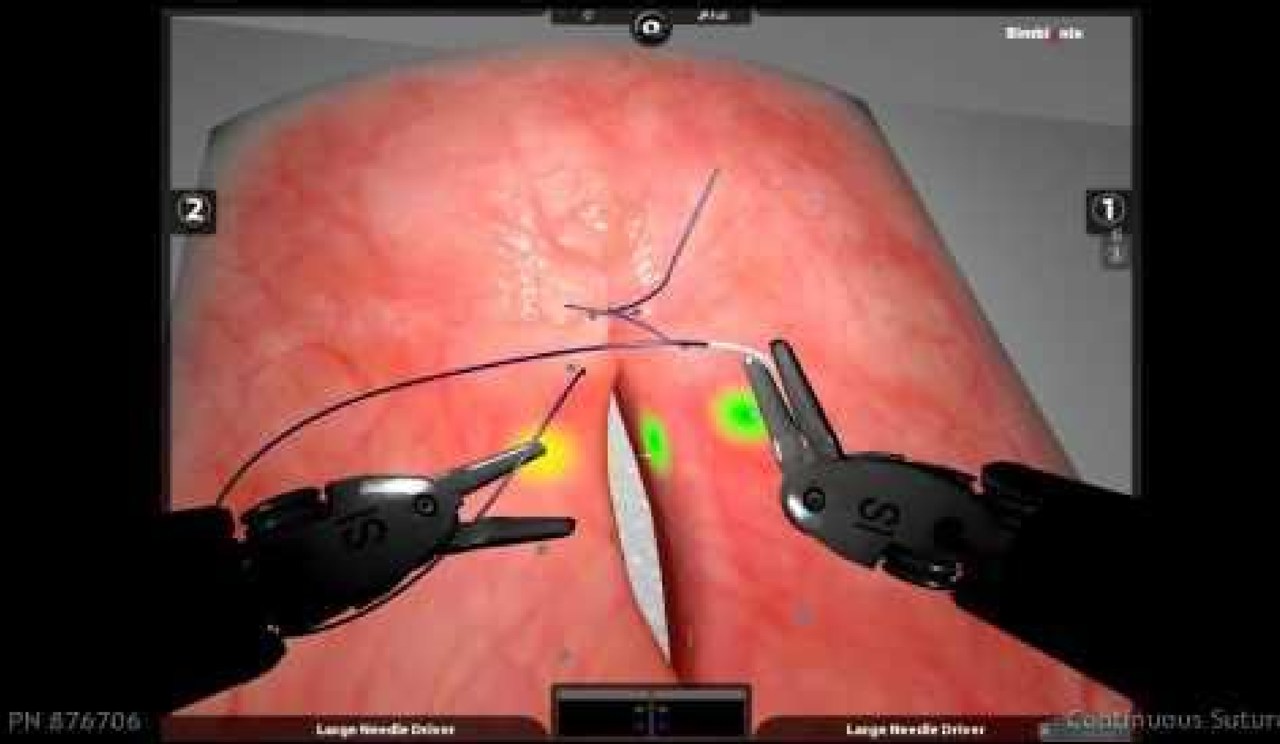
Use VF assistance to improve operation **accuracy** and reducing operator's mental **stress**.



# Contents

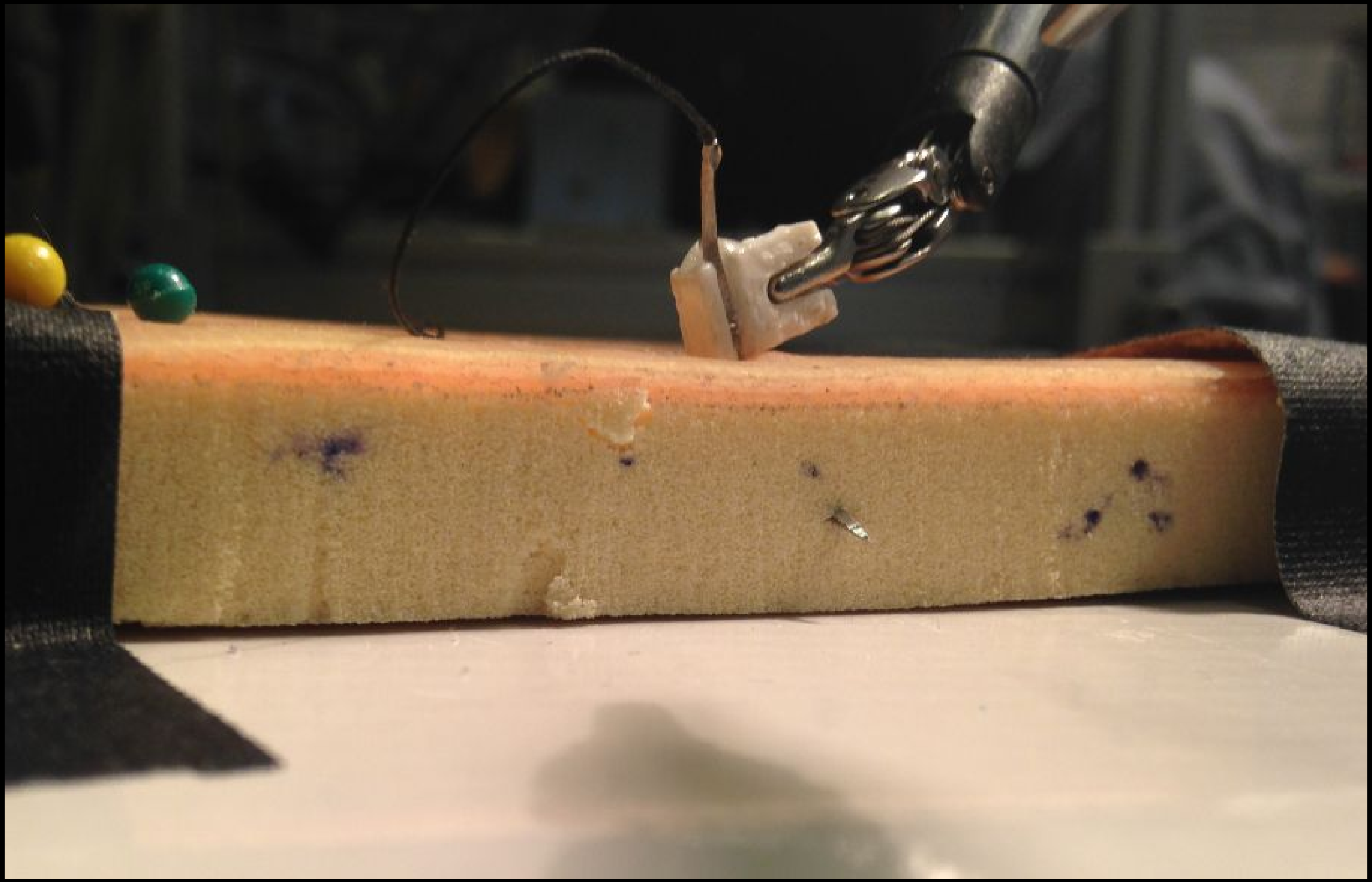
- Suturing Task
- Render Haptic Feedback
- VF1: Needle Passing Task
- VF2: Knot Tying Task
- User Study …

# Suturing Task




IROS 2016 Daejeon, Korea

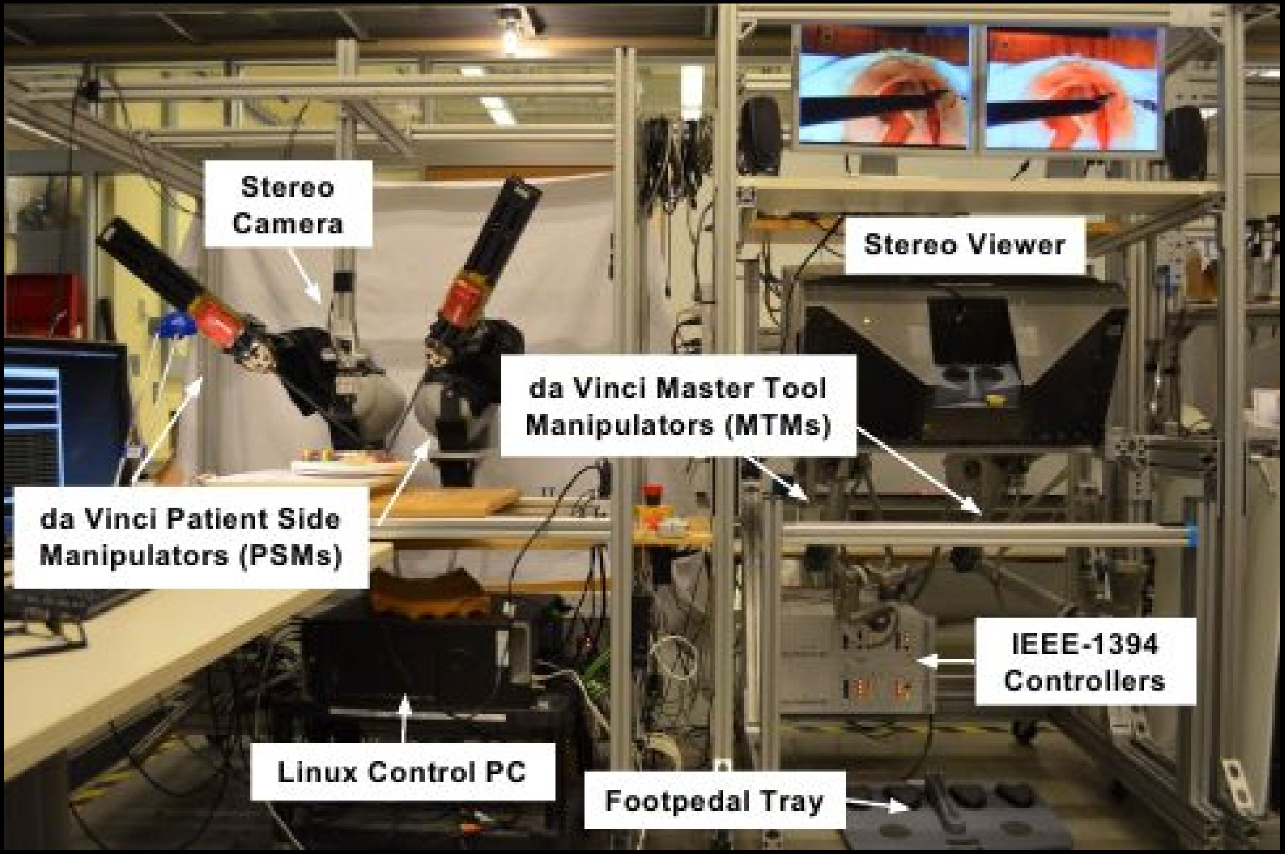
# Why Do We Need VF?



Johns Hopkins Whiting School of Engineering | Laboratory for Computational Sensing + Robotics, The Johns Hopkins University | ERC | CISST

IROS 2016 Daejeon, Korea

# System: Hardware



# System: Block Diagram

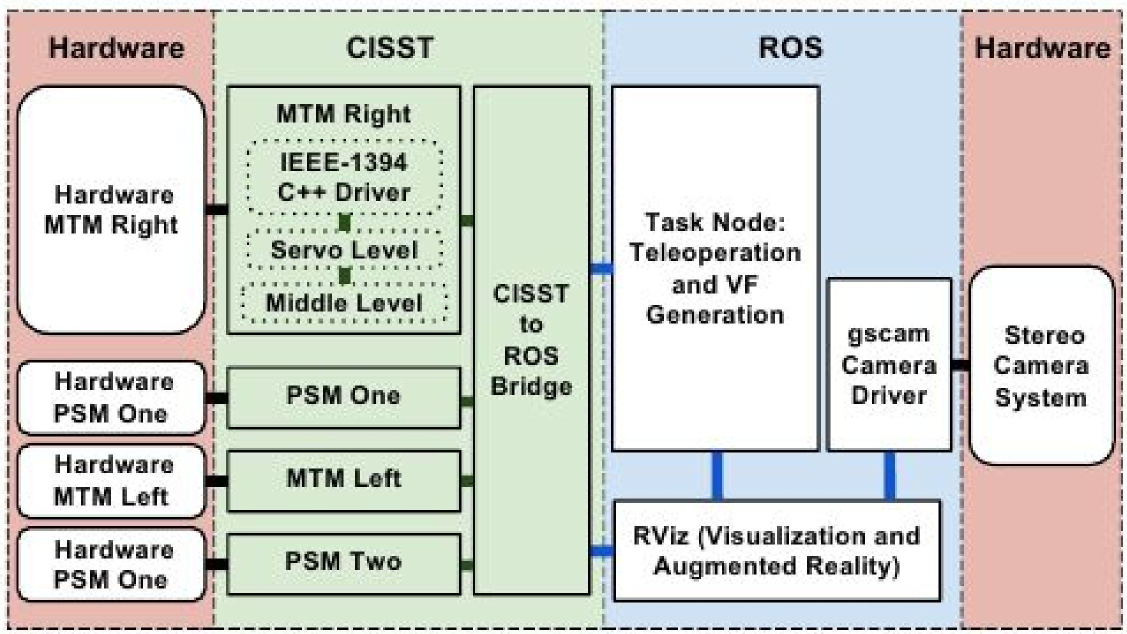
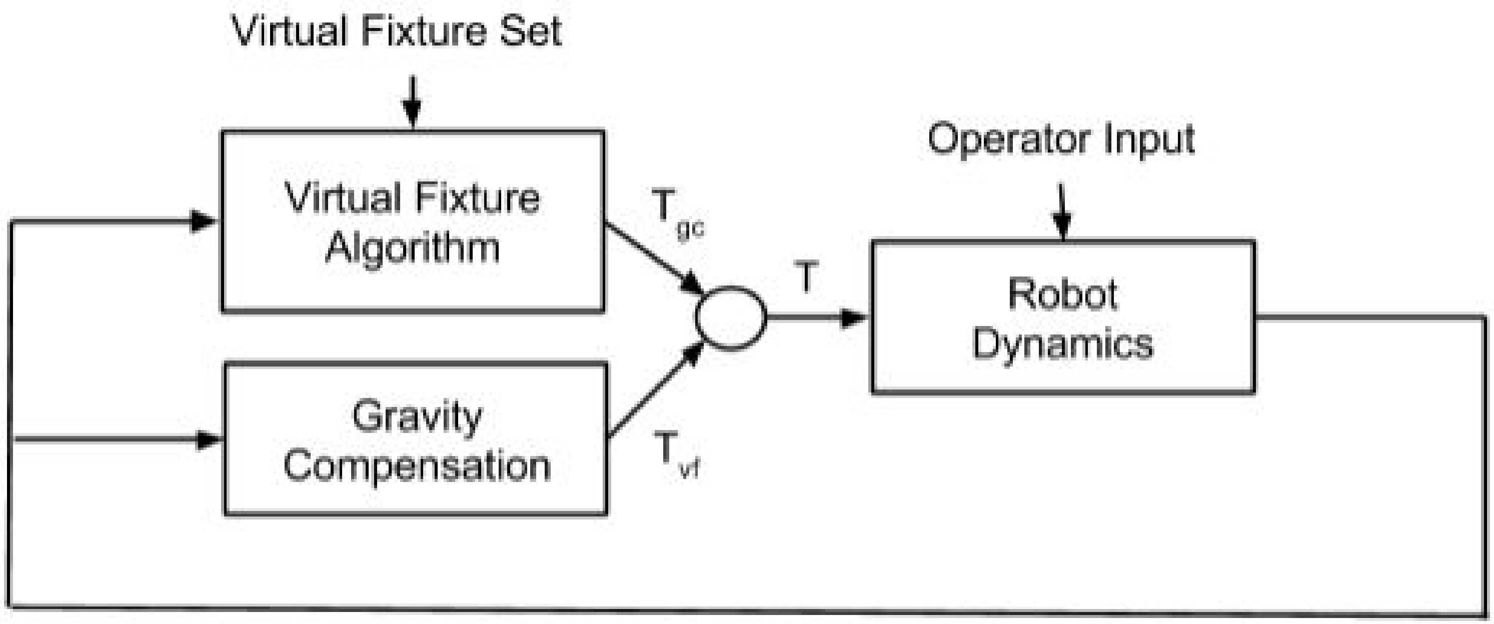



Fig. 7: Block diagram showing hardware/software connection, software components implemented in both *cisst* and ROS environments

# Help User by Providing Haptic Feedback

# Master Controller




**q** joint position **dq** joint velocity **x** cartesian position **dx** cartesian velocity
**T** joint torque applied to robot **$T_{vf}$** joint torque from virtual fixture controller
**$T_{gc}$** joint torque from gravity compensation

# Impedance Virtual Fixture

**Master Virtual Fixture Controller**

**Given**

$F = [R, \vec{p}]$: current pose    $\dot{p}$: current velocity

$F_c = [R_c, \vec{p}_c]$: position compliance frame with respect to master

$\vec{k}^{(+)}, \vec{k}^{(-)}$: stiffness gain    $\vec{b}^{(+)}, \vec{b}^{(-)}$: damping gain    $\vec{g}^{(+)}, \vec{g}^{(-)}$: force bias terms

if (Enabled) begin

  $\vec{q} = F_c^{-1}\vec{p} = R_c^{-1}(\vec{p} - \vec{p_c})$    // position error

  $\vec{v} = R_c^{-1}\dot{p}$    // velocity on compliance frame

  for $i \in \{x, y, z\}$ do

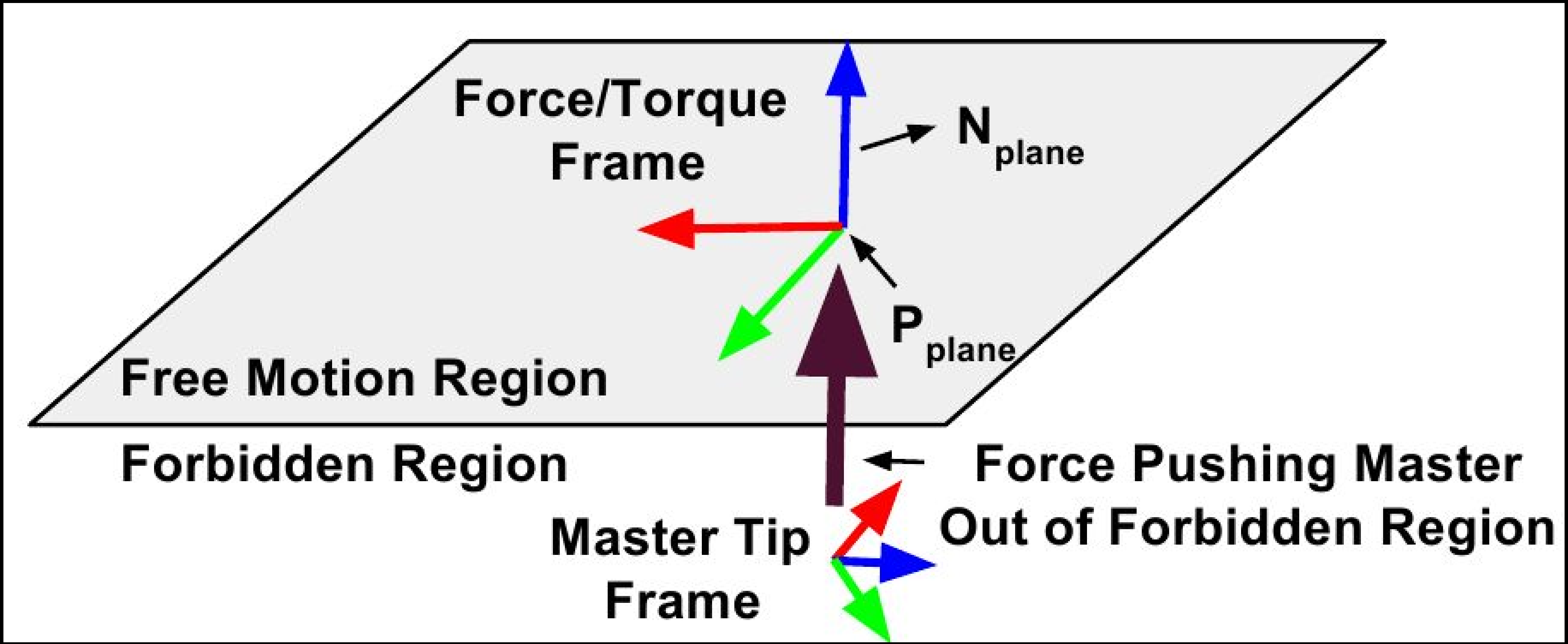
    { if ($\vec{q}_i \leq 0$) then $\vec{g}_i = \vec{g}_i^{(-)} + \vec{k}_i^{(-)}\vec{q}_i + \vec{b}_i^{(-)}\vec{v}_i$    else $\vec{g}_i = \vec{g}_i^{(+)} + \vec{k}_i^{(+)}\vec{q}_i + \vec{b}_i^{(+)}\vec{v}_i$ }

  $\vec{f} = R_c\vec{g}$    // virtual fixture force

end

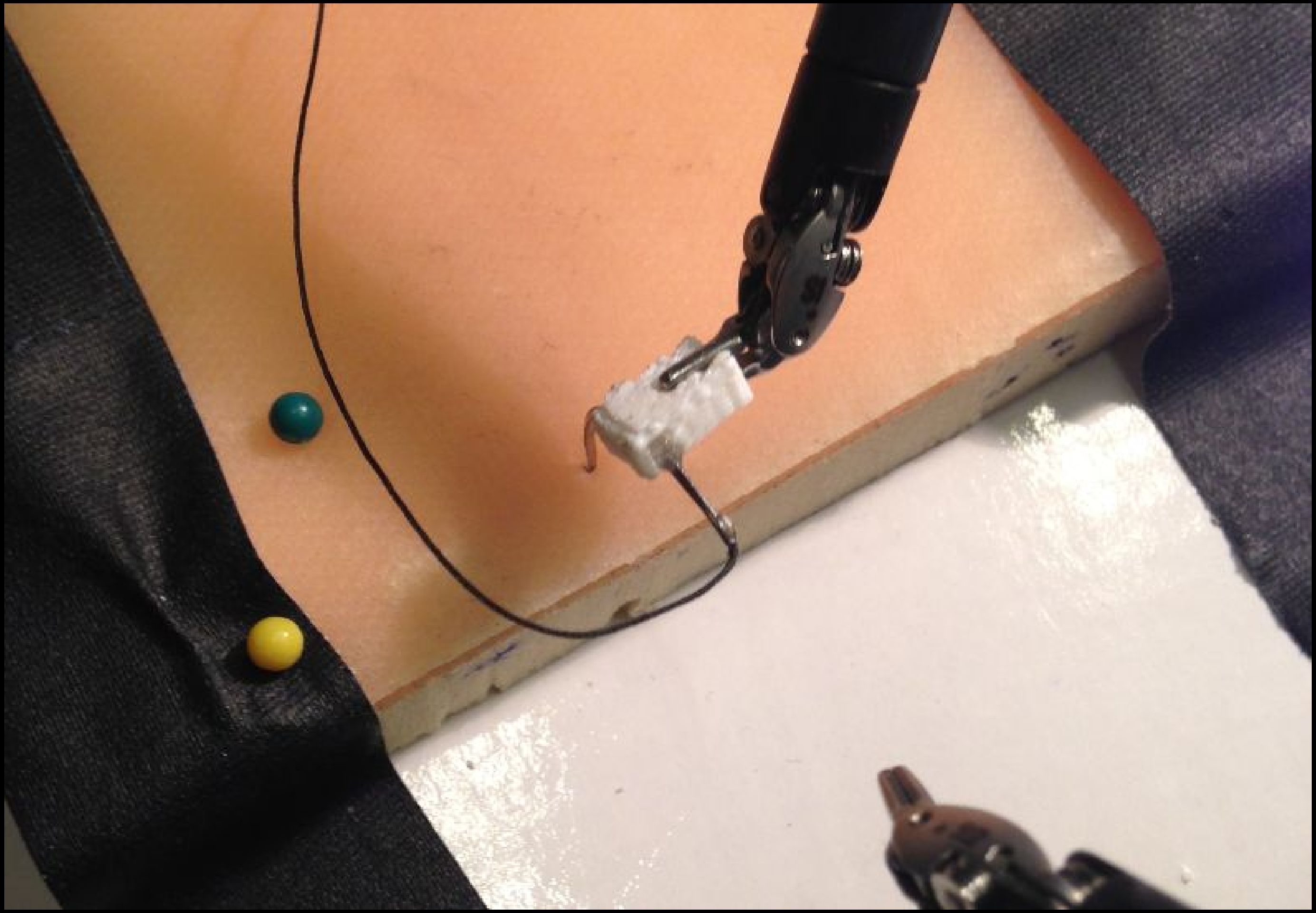
Fig. 5. Master Virtual Fixture Controller

# Example Plane VF

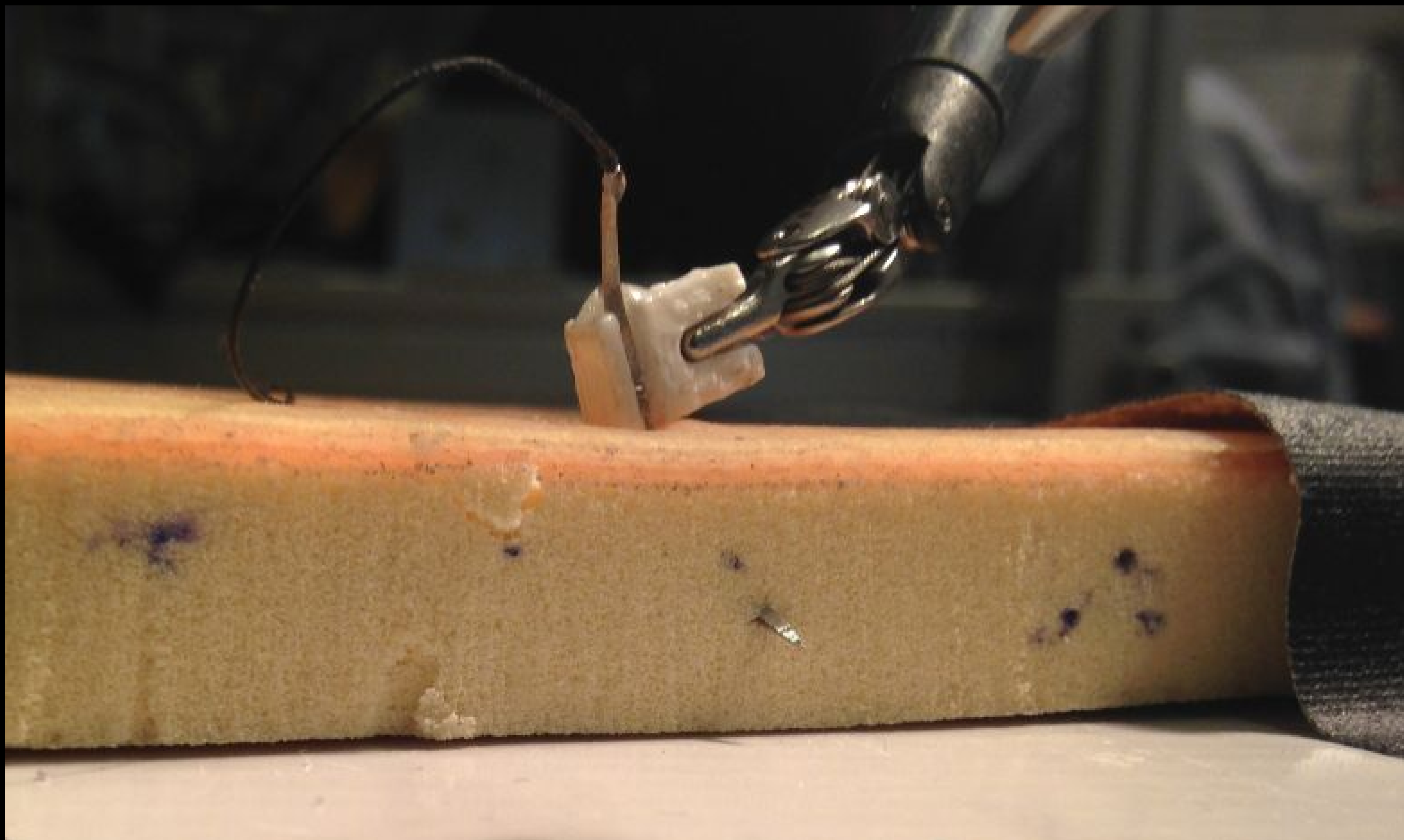


# Virtual Fixture for Needle Passing Task

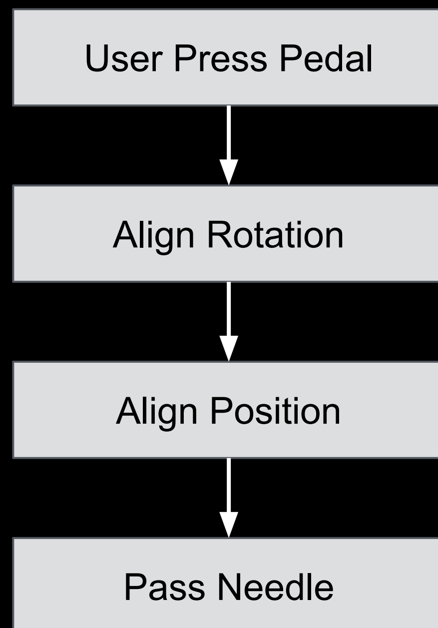
# Needle Passing: Position



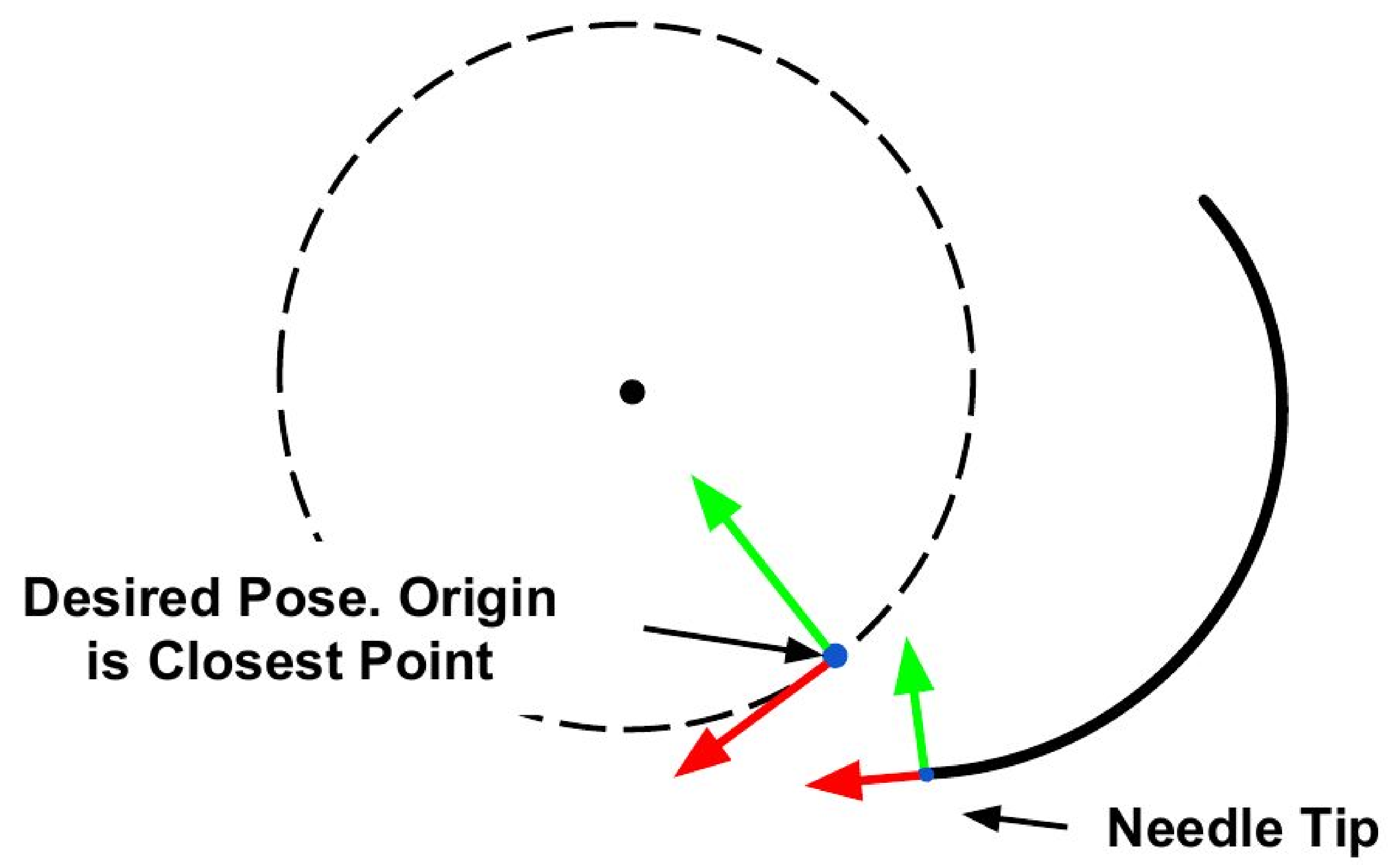
# Needle Passing: Bite



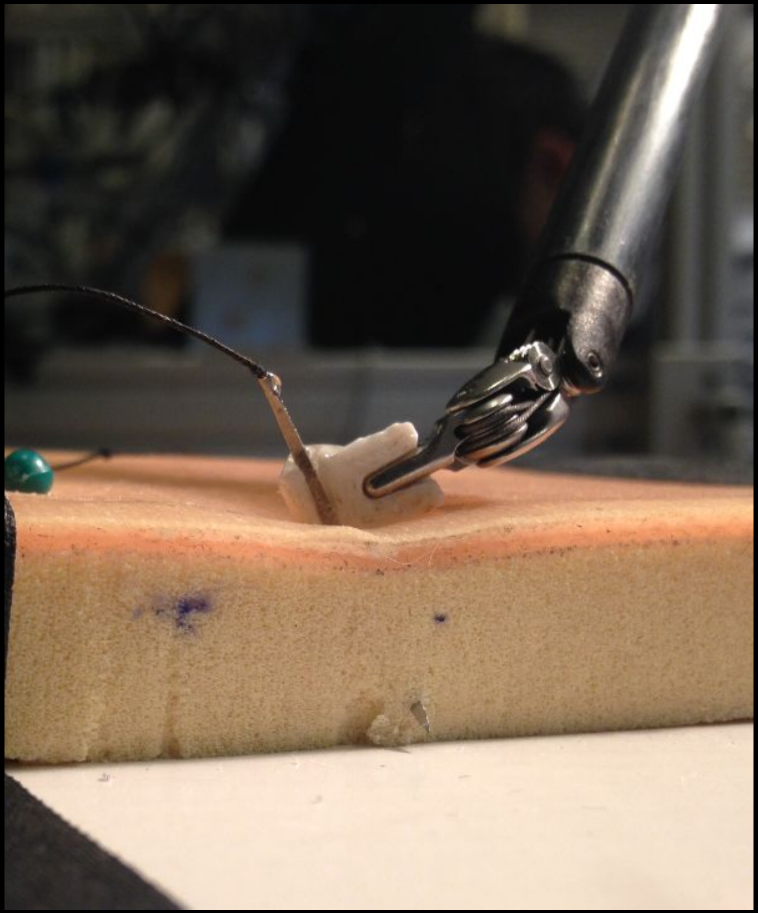
# Needle Passing



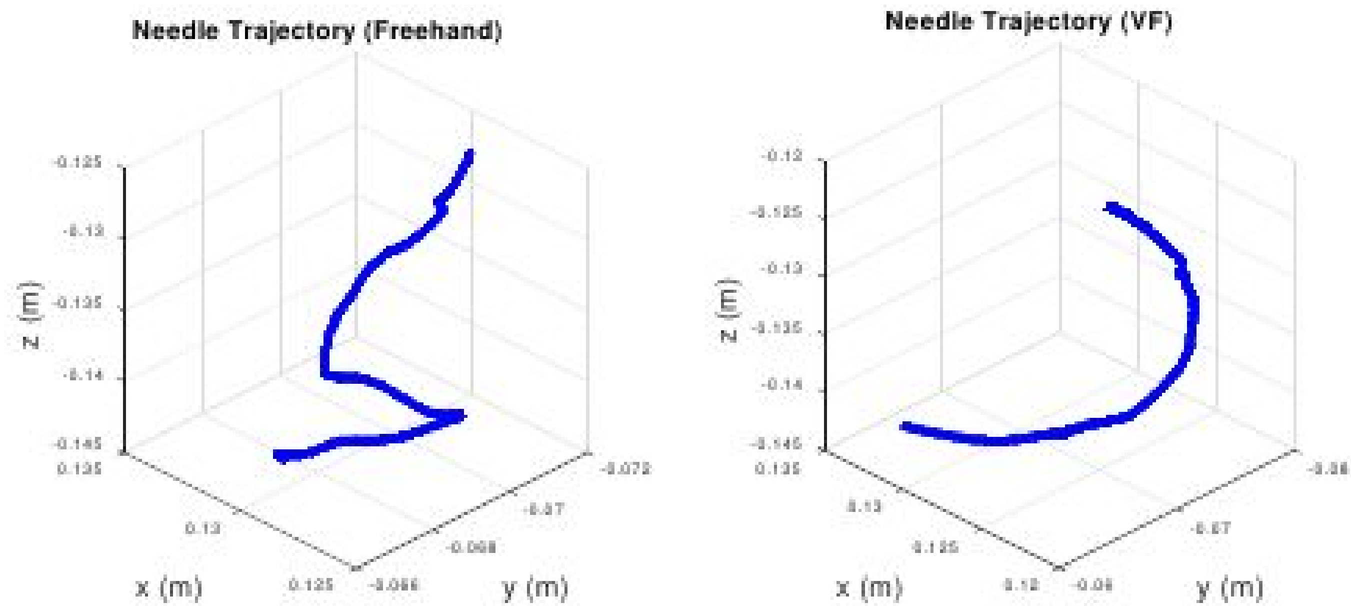
# Needle Passing Bite VF



# Does it WORK?



# Does it WORK?

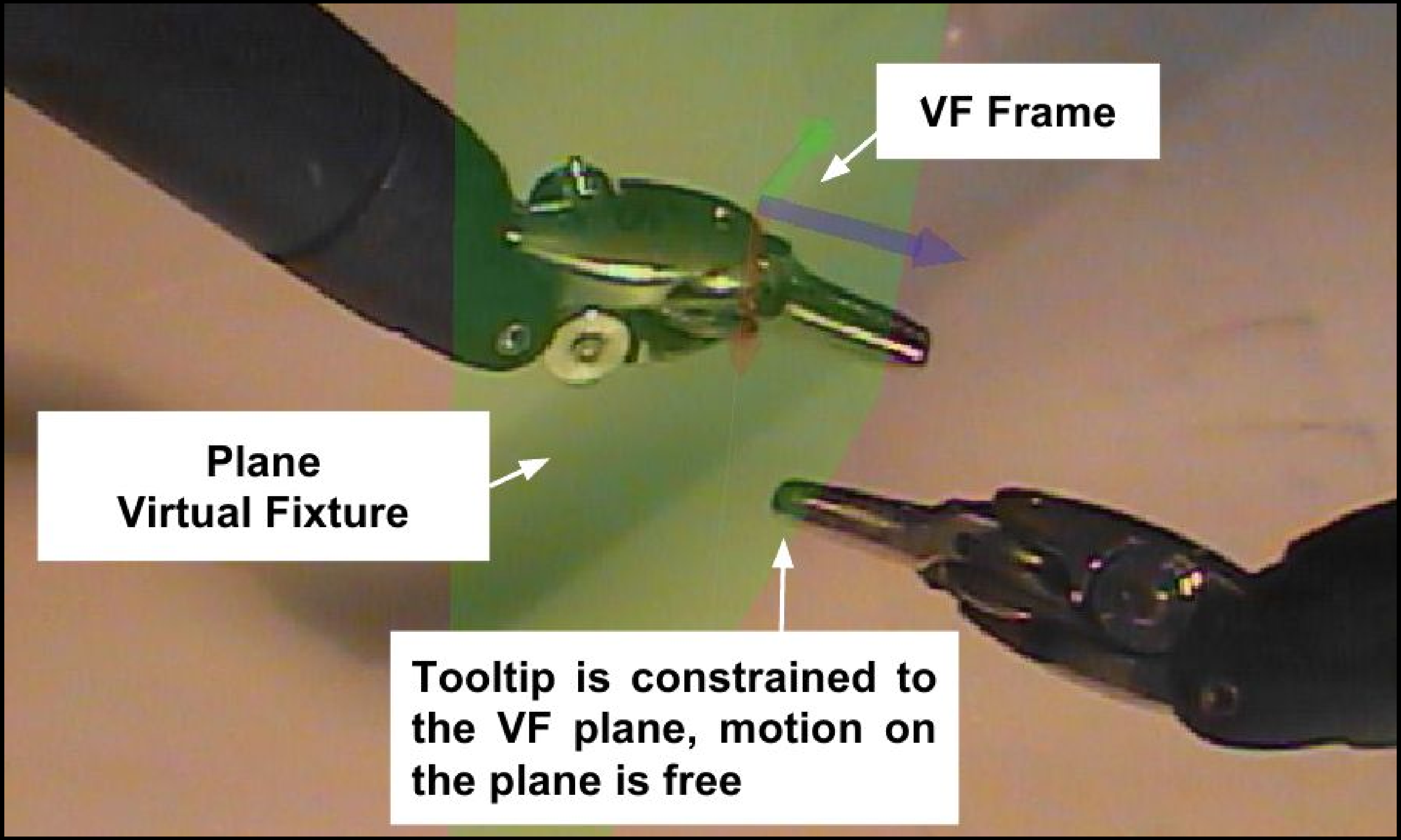



(a) Freehand (b) Virtual fixture assisted

Fig. 9: Comparison of needle passing trajectories: left is needle trajectory in freehand motion, right is trajectory from the same user with virtual fixture assistance.

# Virtual Fixture
# for
# Knot Tying Task

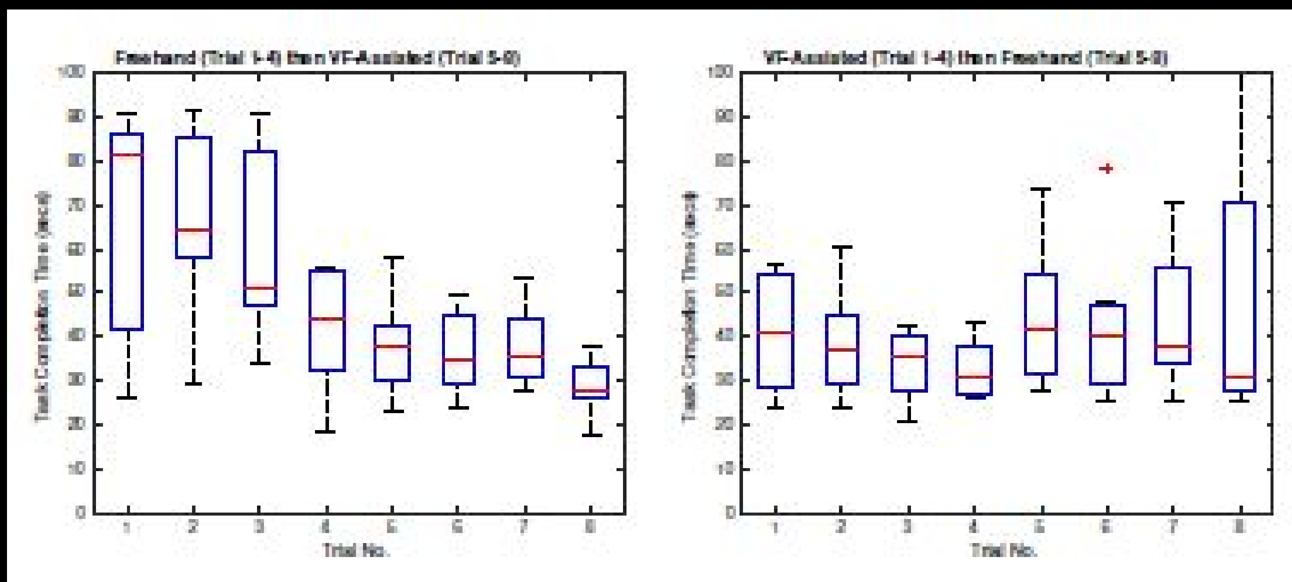
# Knot Tying VF



# Experiments & Results

**Adverse Events:**

Average number of slips drops from 1.5 in freehand mode to 0.34 with VF. ($F_{1,84} = 28.87$, $p < 0.01$)



# Results: Operator Workload

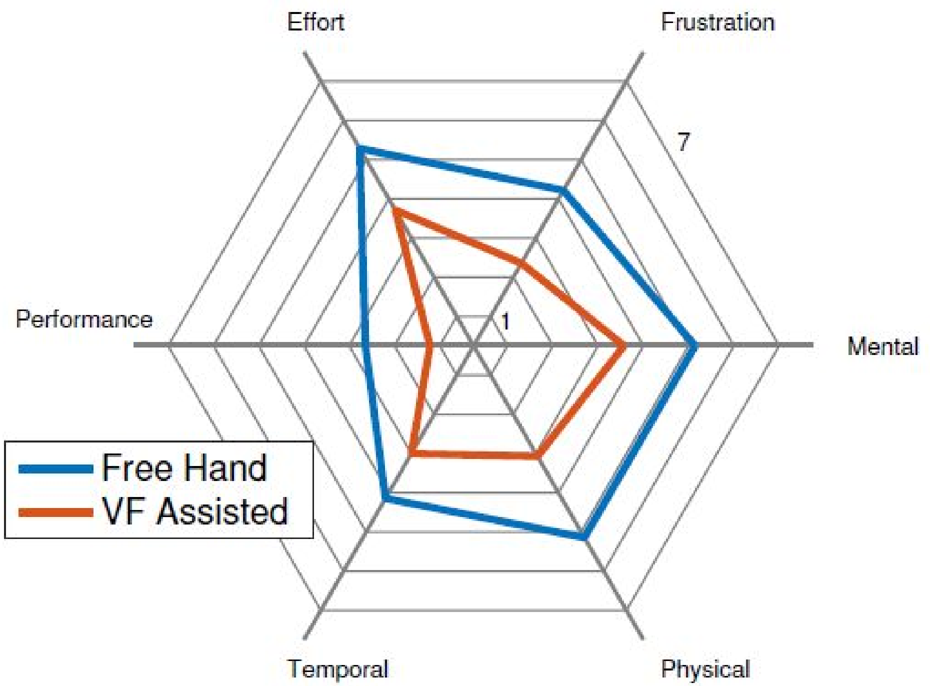
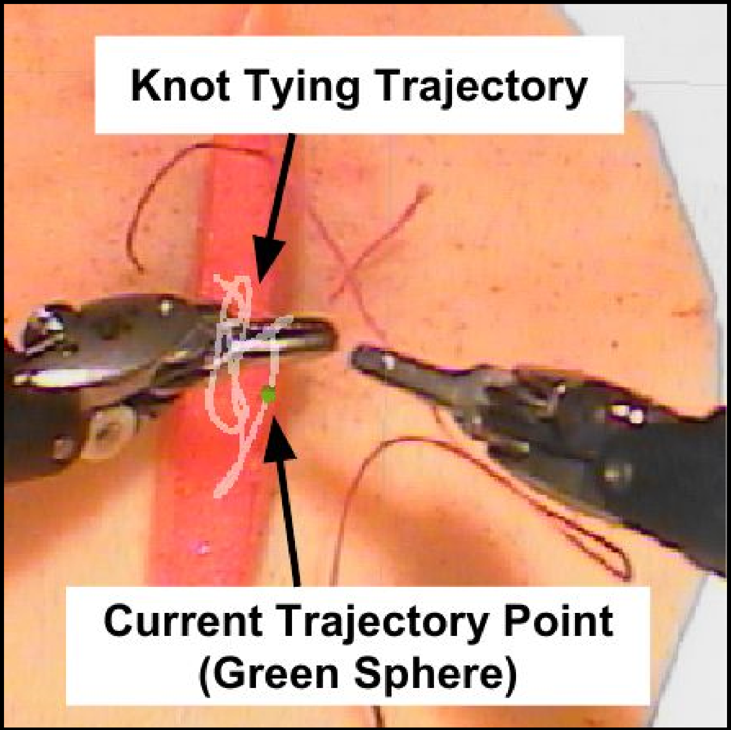



Fig. 14: Knot Tying Task, NASA TLX survey radar plot of average categorical workload as self-reported by the users. Workloads increase from the center.

# Future Work




- New virtual fixtures
- Evaluate effect on learning

# Thank You !

zihan.chen@jhu.edu