# Improving Surgical Robotics Training with Haptic Virtual Fixtures: An Experimental Study

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## Context

**Virtual Simulated** surgical scenes are a versatile and powerful tool in the formation of robotic surgeons

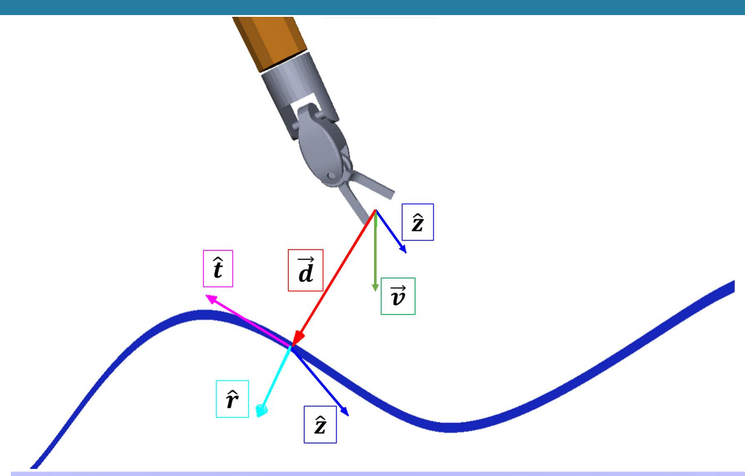
**Haptic Virtual Fixtures** could compensate for the lack of tactile feedback, achieving:

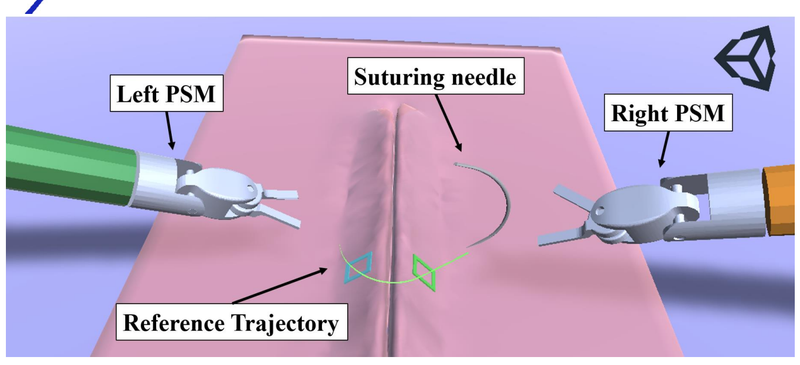
- Less intra-operative injuries [1] → Patient
- Reduced cognitive load [2] → Surgeon

## Goals

- Build a **realistic surgical simulator**
- Implement a **virtual fixture framework** [3]
- Conduct an experimental study and **assess their role and effectiveness** on the training of novice users

## Materials and Methods




| Feedback Force | Feedback Torque |
|---|---|
| $\boldsymbol{F}_{elastic} = \boldsymbol{d}$ | $\boldsymbol{T}_{elastic} = acos(\boldsymbol{z} \cdot \boldsymbol{t}) \cdot \boldsymbol{z} \times \boldsymbol{t}$ |
| $\boldsymbol{F}_{viscous} = \begin{cases} \boldsymbol{d}, & if\ \boldsymbol{v} \cdot \boldsymbol{d} < 0 \\ rotate(\boldsymbol{v}, \theta, \boldsymbol{r}), & otherwise \end{cases}$ | $\boldsymbol{T}_{viscous} = \frac{d}{dt}\left[acos(\boldsymbol{z} \cdot \boldsymbol{t})\right] \cdot \boldsymbol{z} \times \boldsymbol{t}$ |

### Framework

- Manipulators of a *daVinci®* surgical robot
- Unity virtual suturing task
- ROS interface

ROS

The robotic surgical tools (PSMs) in the virtual surgical scene recapitulate the motion of the real ones, allowing the practitioner to **safely** and **repeatedly** perform a surgical suturing task

**Suturing**: Complex wrist articulation + Bimanual coordination

## Experimental Study

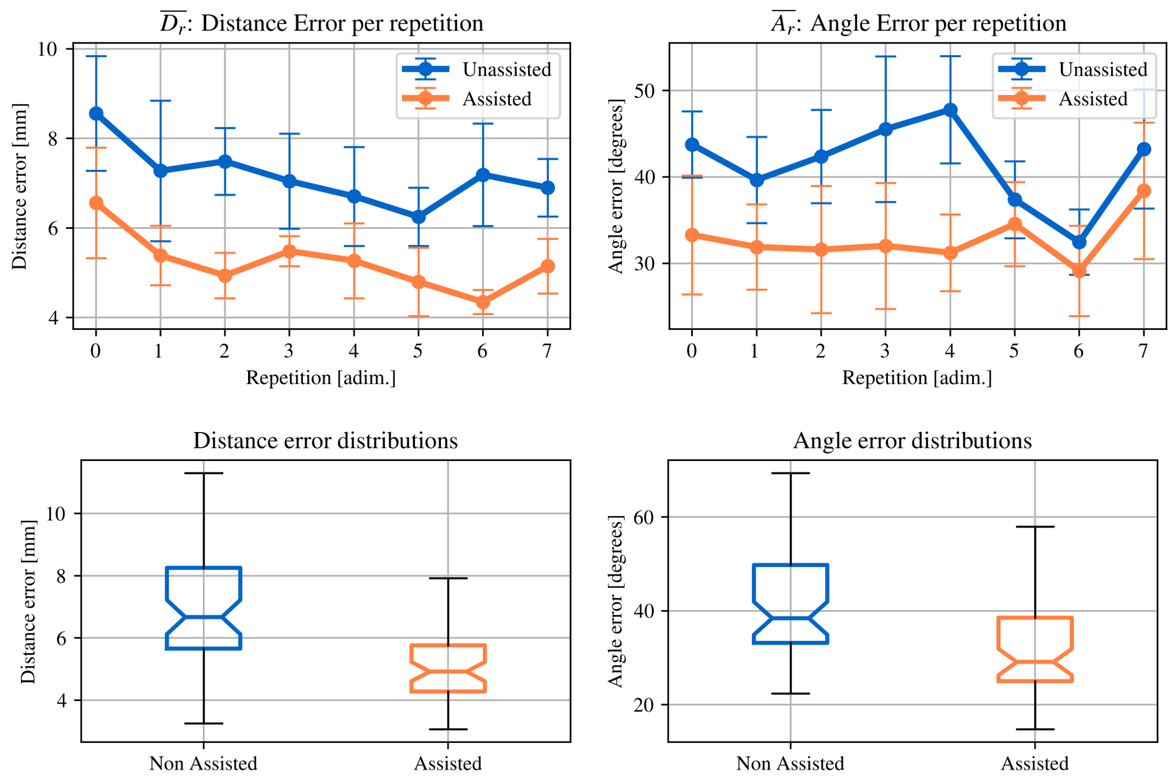
**Control** group of 4 subjects: Performs the suturing **without** haptic assistance (8 repetitions)
**Assisted** group of 4 subjects: Performs the suturing **with** haptic assistance (8 repetitions)

**Evaluation metrics:**

- $\overline{D_r}$: Distance RMSE from the needle's tip to the closest point in the reference trajectory, at repetition $r$
- $\overline{A_r}$: Angular RMSE between the z-axis of the needle reference frame and the trajectory tangent vector, considered at the closest point, at repetition $r$

Metrics are evaluated since the moment the needle tip enters the tissue until the needle feather exits it, with a logging frequency of 30Hz.

## Results




## Conclusions

- Employing virtual fixtures in a simulated surgical environment represents a promising approach for **improving surgical outcomes** and **reducing intra-operative errors** or injuries
- Trainees who were assisted by haptic virtual fixtures achieved a **better performance** both on average and over time
- Haptic assistance is **beneficial in a surgical training context**

## References

[1] H Xin, J S Zelek, and H Carnahan. *Laparoscopic surgery, perceptual limitations and force: A review*, 2006.

[2] Ankur Kapoor and Russel H. Taylor. *A Constrained Optimization Approach to Virtual Fixtures for Multi-Handed Tasks*. IEEE Xplore, 2008.

[3] Stuart A. Bowyer, Brian L. Davies, and Ferdinando Rodriguez Y Baena. *Active constraints/virtual fixtures: A survey*. IEEE Transactions on Robotics, 2014.

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