Dual-user teleoperated system with Virtual Fixtures: Seminar Presentation

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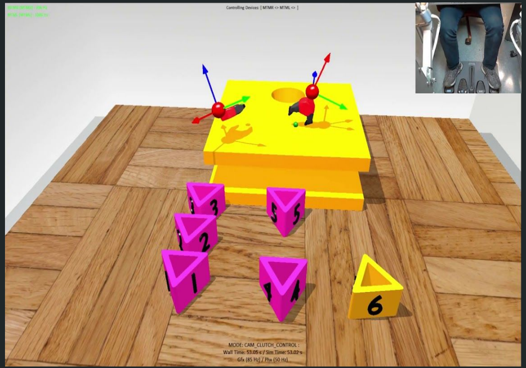
The Project

- ➔ Develop collateral control systems for robotic surgical training in the AMBF simulator
  - Implement dual console control
  - Create training puzzles
  - Code data collection script



The Paper

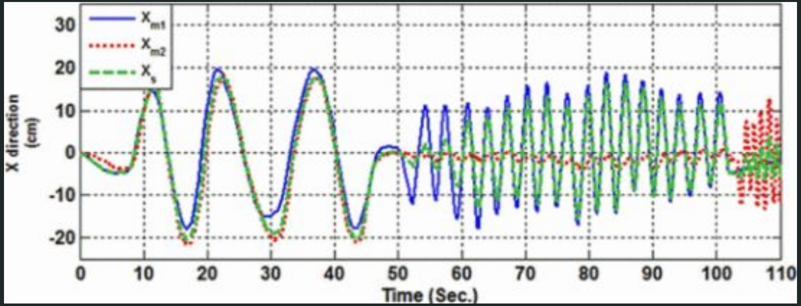
- “A dual-user teleoperated system with Virtual Fixtures for robotic surgical training” by Mahya Shahbazi, S. Farokh Atashzar, Rajni V. Patel
  - Covers the benefits of dual control systems
  - Proposes key metrics to determine user expertise while using control consoles
  - Demonstrates implementation of an adaptive dual control system using virtual fixtures

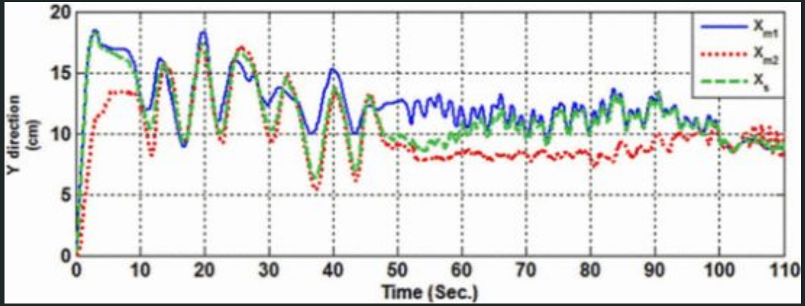
The Problem and Background

- With increasing use of robotic surgical machines, more intuitive and effective training schemes are required
- Current systems rely only on fixed dual control schemes, which are easy to understand but lack flexibility and may slow down the learning process
- Virtual fixtures are abstractions in virtual space to restrict or guide user commands
  - Guidance virtual fixtures
  - Forbidden region region virtual fixtures

Key Result

- ➔ In this paper, researchers were able to successfully create an adaptive dual control scheme using virtual fixtures based to user expertise metrics
- ➔ The paper reveal how such as system is not only possible but works exactly as desired and can be easily adapted in order to cater to different needs or circumstances





Significance of Result

- This result paves the way for more sophisticated dual control schemes, which can be fine tuned to fit many scenarios
- For our project, it represents an alternative method for a dual control scheme as well as defining specific criteria for how to determine trainee expertise
  - Determine effectiveness of a given control scheme
  - Isolate specific types of manipulations and create training schemes to improve them

Methods and Theory

- Generally, behavior should follow: $$x_{sd}(T) = \alpha_{adp}(t)x_{m_1}(t) + \alpha_{adp-T}x_{m_2}(t)$$
- Expertise level of trainee is determined by 4 factors:
  - Total path length (4)
  - Response Orientation (5)
  - Motion Smoothness(6)
  - Virtual fixture Force (7&8)

$$\alpha_\Gamma(T) = 1 - \left|\frac{\Gamma_{m_2}(t) - \Gamma_{m_1}(t)}{\Gamma_{m_2}(t) + \Gamma_{m_1}(t)}\right| \quad (4)$$

$$\alpha_\Theta(t) = 1 - \left|\frac{\Theta_{m_2}(t) - \Theta_{m_1}(t)}{\Theta_{m_2}(t) + \Theta_{m_1}(t)}\right| \quad (5)$$

$$\alpha_\Psi(t) = 1 - \left|\frac{\Psi_{m_2}(t) - \Psi_{m_1}(t)}{\Psi_{m_2}(t) + \Psi_{m_1}(t)}\right| \quad (6)$$

$$\Xi_{m_2}(t) = 1 - \exp\left(-\left(\frac{F_{GVF}(t)^2}{\delta_{GVF}^2}\right)^{m_{GVF}}\right) \quad (7)$$

$$\alpha_\Xi(t) = 1 - \Xi_{m_2}(t) \quad (8)$$

Methods and Theory cont.

- Resulting function for adaptive control value:

$$\alpha_{adp-T}(t) = \alpha_{\aleph}(t).\ \alpha_{\Gamma}(t).\ \alpha_{\Theta}(t).\ \alpha_{\Psi}(T).\alpha_{\Xi}(t) \tag{10}$$

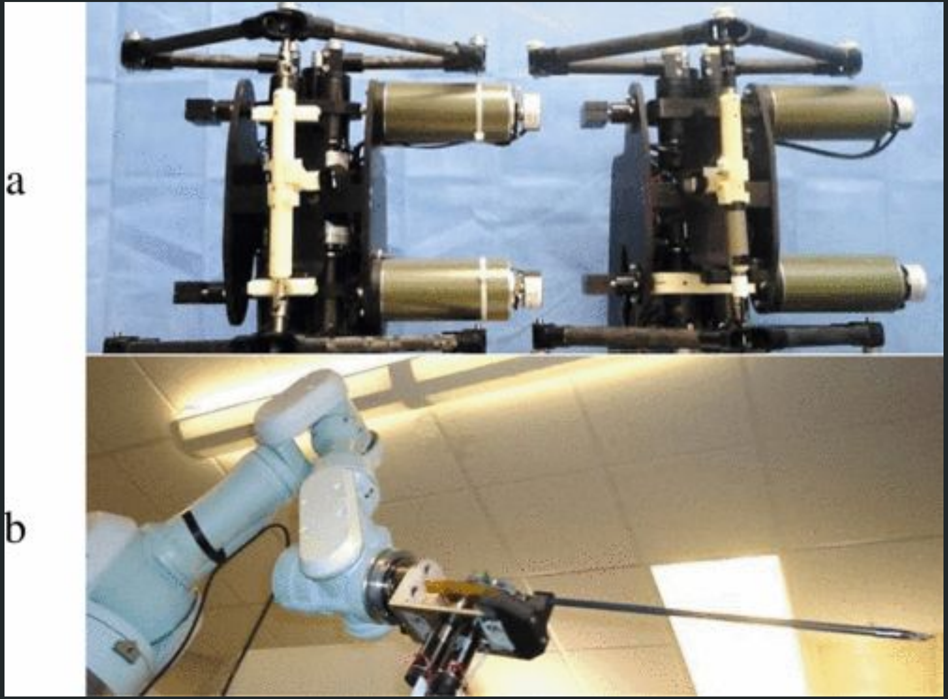
- Guidance virtual fixture set-up:
  - Fgvf = 0 if:

$$(x_{m_{2,x}} - x_{m_{1,x}})^2 + (x_{m_{2,y}} - x_{m_{1,y}})^2 + (x_{m_{2,z}} - x_{m_{1,z}})^2 \leq R_{VF} \tag{11}$$

  - Radius of Virtual fixture influence:

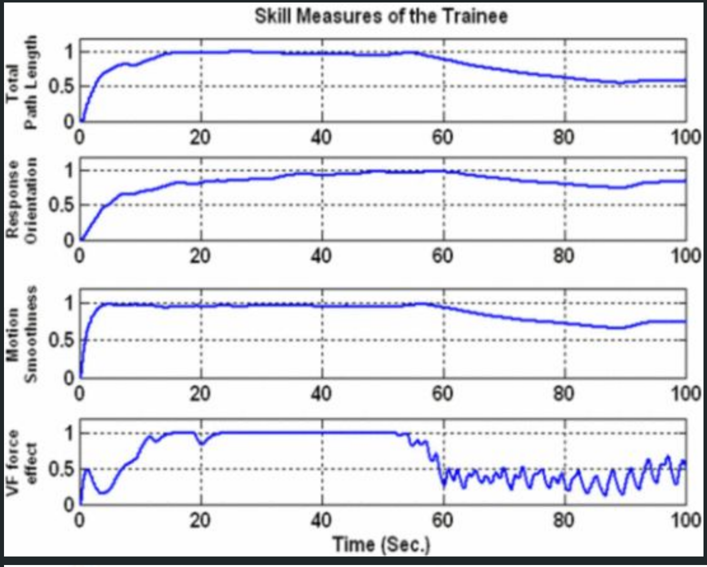
$$R_{VF} = R_0 - G_0 ln(1 - \alpha_{adp-T} + \epsilon) \tag{12}$$

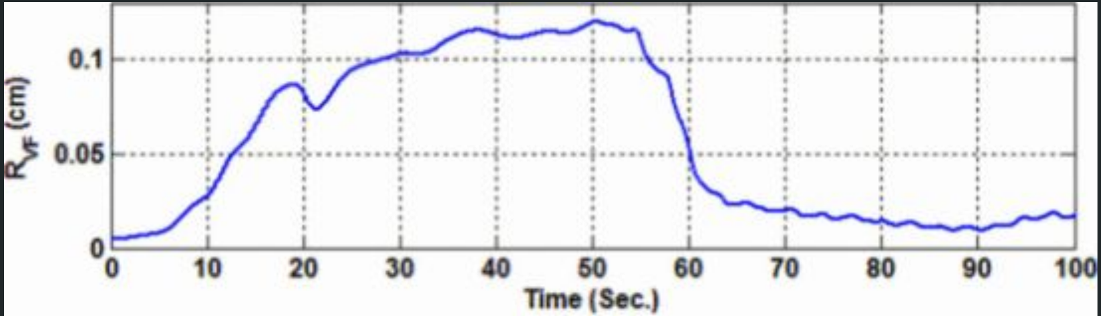
The Experiment

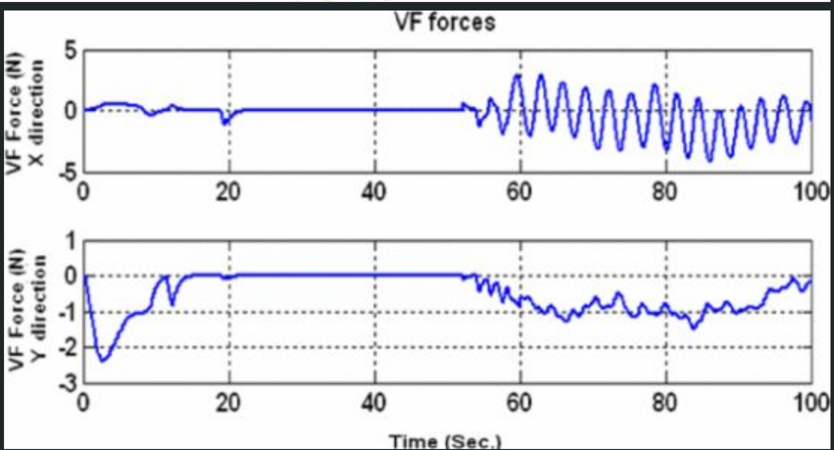


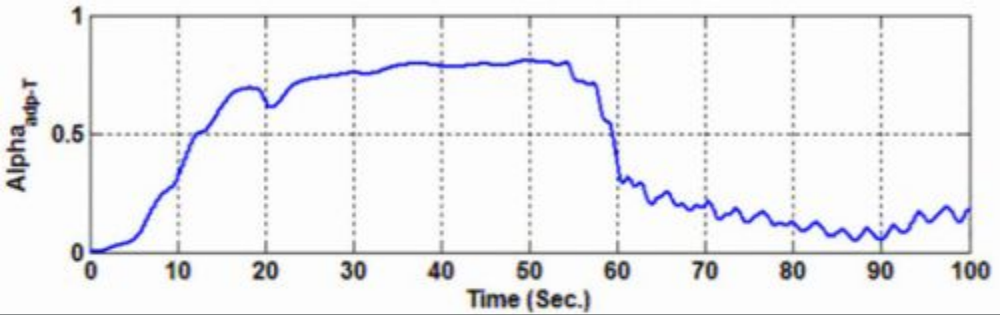
- ➔ Maximum trainee control set to .9 and VF spring stiffness set to 30N/m
- ➔ Trainees were first asked to follow the motion of the expert as closely as they could from (t = 0 ➔ t = 50)
- ➔ At t > 50, trainees were asked to hold controls at a single location as firmly as possible while expert continue to move his controls

The Experiment cont.









Criticisms

- Virtual fixture radius adaptation
  - Increasing proficiency demonstration results in increased freedom
  - Since this is training the opposite should be true
- Not tested in a specific task scenario
  - This experiment was conducted generically to prove the system works but was not actually tested in real task (virtual or otherwise)
- Assumes force feedback is inherent to dual control scheme
  - A topic of debate and one we have explored in our own project, and understand its purpose but don’t agree with its necessity

Next Steps

- ➔ Testing effectiveness of this adaptive dual control scheme in surgical training
- ➔ Implementing different styles of virtual fixtures for training in order to practice specific tasks or manipulations

Conclusion

- There are many ways to implement dual control schemes for surgical training
- A singular most effective scheme has yet to be determined, but most likely different set ups will be used in different situations
- There is still a lot of work that needs to be done in terms of the development of these new robotic surgical training procedures

Reference

M. Shahbazi, S. F. Atashzar and R. V. Patel, "A dual-user teleoperated system with Virtual Fixtures for robotic surgical training," *2013 IEEE International Conference on Robotics and Automation*, Karlsruhe, 2013, pp. 3639-3644.