Overcoming Technical Barriers in Forward-Deployed Telesurgical Robotics

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Background

- Multi-Domain Operations will require a wider disbursement of troops and medical teams limiting the availability of specialized surgeons at point of need[1].
- CONUS-based fixed MTFs can be key force multipliers for remote support by projecting capability forward with telemetry, telehealth and robotic surgical capabilities[2].
- Telesurgical technologies will be hindered by the deleterious effects of high latency and low bandwidth from operational communications conditions

Objective

- Develop a novel prototype telesurgical robotic platform, the Taurus-M, capable of being deployed with forward operating surgical teams.
- Investigate and develop surgical perception techniques to accurately locate and track soft tissue as well as tools to build autonomous surgical subroutines and digital simulations of the surgical scene.
- Conduct a proof-of-concept surgical study on live porcine models by successfully performing a temporary vascular shunt insertion with the Taurus-M robot semi-autonomously assisting a local surgeon.

Approach

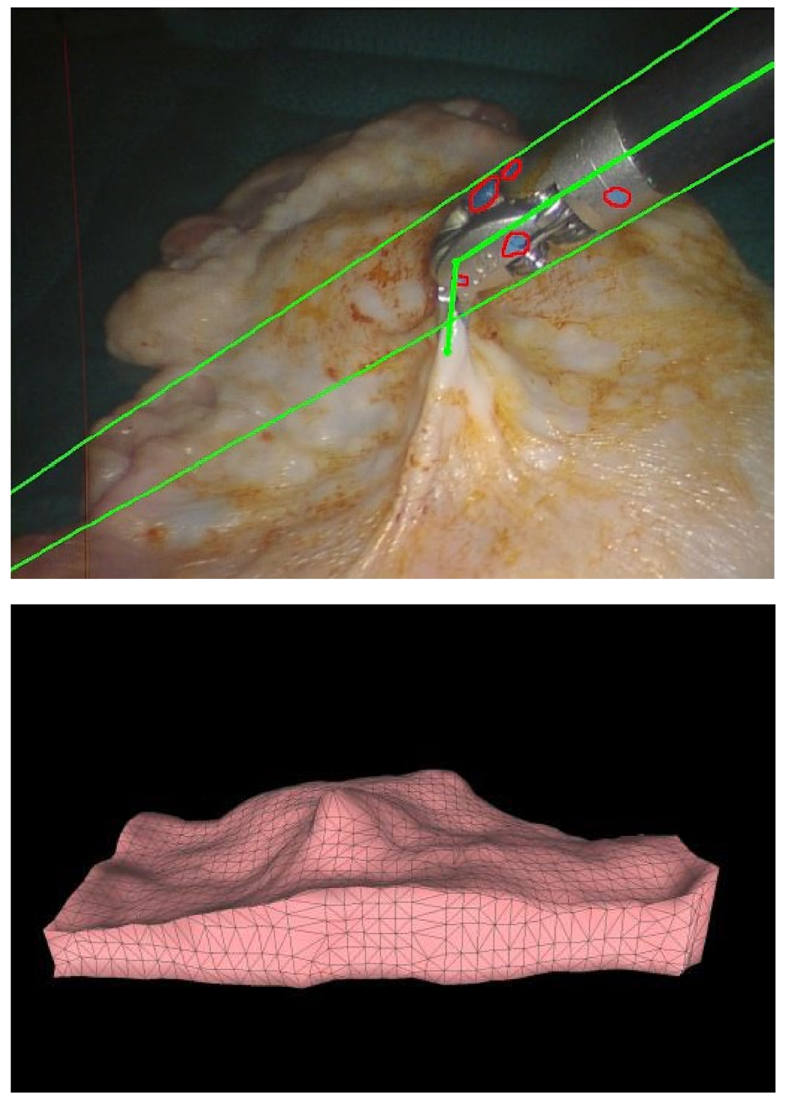
1. **Low SWAP-C Surgical Platform** - Adapt previously developed Taurus robot designed for explosive ordinance disposal to support state-of-the-art da Vinci Xi surgical tools to enable teleoperated surgeries.
2. **Surgical Perception** - Develop perception algorithms to generate an accurate simulation representation of the surgical site. Develop a Virtual Reality (VR) Operator Control Unit (OCU) in which the surgeon can teleoperate the Taurus-M inside the simulated representation of the surgical site. Pass only the changes in the scene and robot state across the network reducing the bandwidth to kilobytes.
3. **Intent-Based Control** - Develop semi-autonomous surgical subroutines so smaller motion tasks of the robot can be broken down into "surgemes". Develop a control scheme where the remote teleoperator provides high-level surgical decisions and the robot carries out low level motion planning by interpreting intent, negating effects of high latency.

Methods

1) Taurus-M Surgical Robot

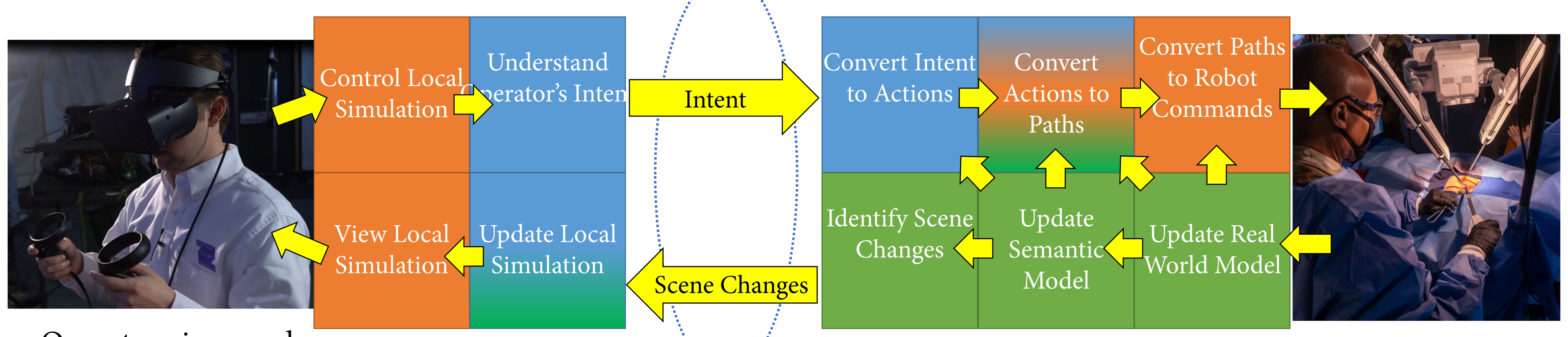
Taurus-M robot is capable of assisting in specialized surgeries. It is teleoperated by a VR headset and shown here performing a microvascular anastomosis

2) Perception Algorithms for Surgical Scene Simulation



Perception algorithms are used to create an accurate digital simulation of the surgical scene. Only changes in the scene and state are needed to be passed over the network, thus reducing bandwidth

3) Intent-Based Control Reduces Network Performance Requirements



Operator views and manipulates a local simulation of the remote robot and world to complete tasks.

High-Level semantic commands ("Intent") enable operation over Low-capacity networks.

Actual robot responds to commands and provides sensed information.

Results

- We successfully developed the Taurus-M surgical robot, weighing ~20lbs, capable of providing highly-dexterous surgical assistance through teleoperation.
- We developed perception algorithms capable of detecting, segmenting and tracking both soft tissue and surgical tools in the surgical field of view. Our perception algorithms have also successfully located and segmented vascular tissue in preparation of a semi-autonomous vascular shunt placement procedure.
- We successfully demonstrated the intent-based semi-autonomous surgical framework by remotely performing the FLS pegboard challenge in a simulation environment and having a dVRK interpret commands and complete the challenge on a real pegboard.
- A final demonstration of a proof-of-concept temporary vascular shunt placement procedure on live porcine models will be conducted in March 2023. The Taurus-M will be teleoperated and semi-autonomously assist a local surgeon during the procedure.

View inside the surgeon's operator control unit

Conclusion

- This project will establish a semi-autonomous robotic framework that will enable safe and effective telesurgery in forward care environments, providing a force multiplier for forward surgical care by extending the reach of remote specialist surgeons during Multi-Domain Operations.

References

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[2] U.S. Army Medical Center of Excellence. (2021). Army Futures Command Concept for Medical 2028.

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