Remote Telesurgery

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Telesurgery

- Telesurgery means performing surgery via robotic tools, as opposed to traditional laproscopy or even more traditional open surgery.
- This allows surgeons to perform “minimally invasive” operations with more control than ordinary laproscopy.

Da Vinci Robot

- The da Vinci Robot, build by Intuitive Surgical, has become the most commonly used instrument for telesurgery.
- It has two parts: the control console and the patient side.

Image from http://www.davincisurgery.com, ©2009 Inuitive Surgical, Inc.

Remote Telesurgery

- Remote telesurgery is the same as normal telesurgery, except that the surgeon and the patient are separated by significant distances.

Remote Telesurgery

- In 2001, Dr. Jacques Marescaux was able to perform a gall bladder surgery while he was in New York and the patient was in France.

Image from J. Marescaux, et al., "Transatlantic robot-assisted telesurgery," Nature, vol. 413, pp. 379-380, 2001.

Remote Telesurgery

- Dr. Mehran Anvari has since performed many remote telesurgical cases in Canada.

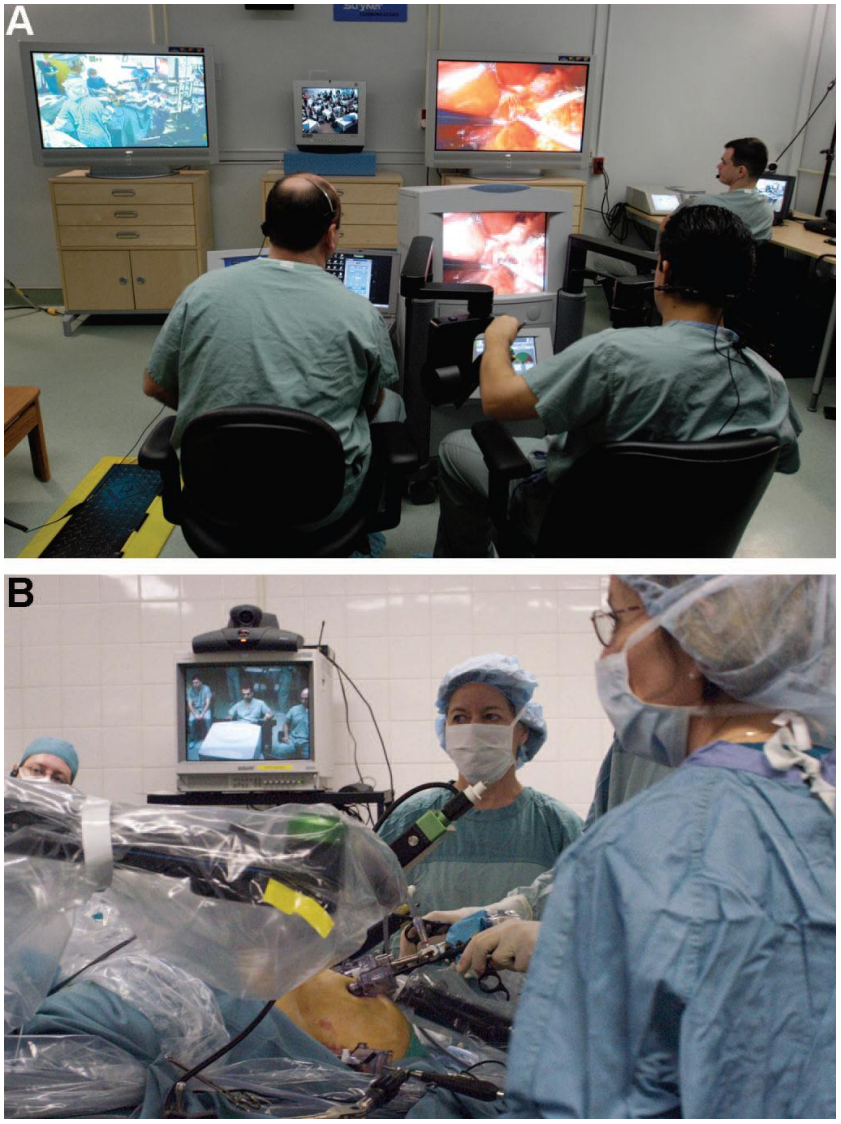


Image from M. Anvari, et al., "Establishment of the world's first telerobotic remote surgical service: for provision of advanced laparoscopic surgery in a rural community," Annals of surgery, vol. 241, p. 460, 2005.

The case for Remote Telesurgery

- Allows inexperience surgeons to ask for help from more experienced surgeons
- Reduces patient travel time
- Multiplies the effectiveness of the most expert surgeons

Remote Manipulation

- The ideas here can be applied to any of a number of remote manipulation tasks.
- Any task where the operator is separated from the actual task has the same sort of problems

Other Examples

Nuclear Tests

Bomb Disposal

Space Exploration

Images from Wikipedia

Remote Manipulation

- The difference with remote telesurgery is that
  - No part of the robot is autonomous (unlike the Mars Rovers)
  - The separation distance is very significant (unlike bomb disposal robots or nuclear testing robots)
  - Surgeons do not want to adjust to delays in communication, for safety reasons

Video Games

- Multiplayer video games also deal with similar issues.
- The difference is that each player interacts with a local model, which is updated by network messages
- In contrast, the surgeon cannot operate on a local model, because soft tissue cannot be accurately and safely modeled

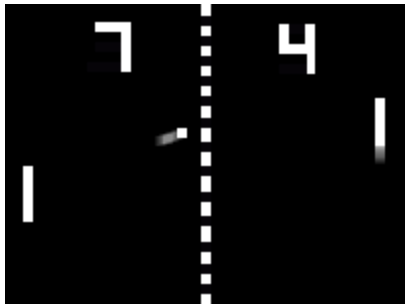


Image from Wikipedia

Closing the Loop

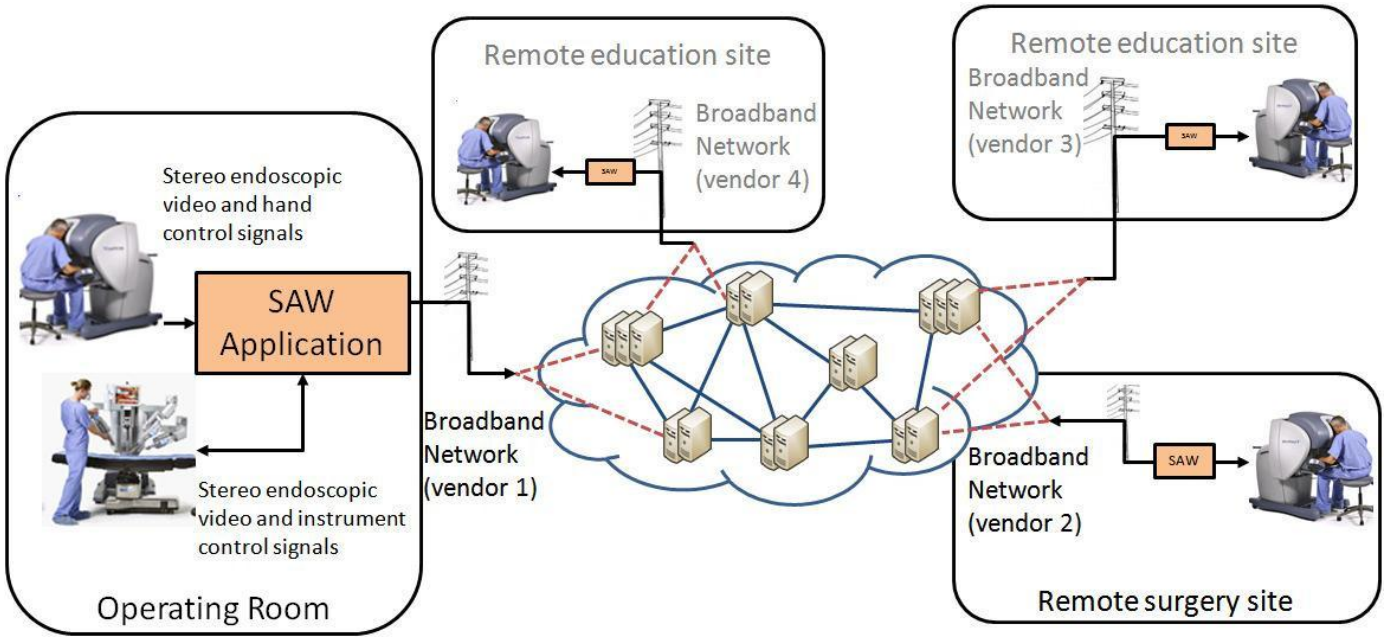
- Ideally, we would like the entire loop (ie, the time between when the surgeon moves his hand and when he sees the result) to be under 130 milliseconds.
- This would make the surgery seem “real-time” to the surgeon.

Overlay Network Approach

- Most previous remote telesurgeries have used private networks. This is expensive and not scalable.
- The only one that didn’t use a private network experienced latencies over 700 ms.

Overlay Network Approach

- By using an overlay network approach, we
  - Greatly reduce both jitter and latency
  - Increase reliability and availability
  - Allow multicast, for educational purposes

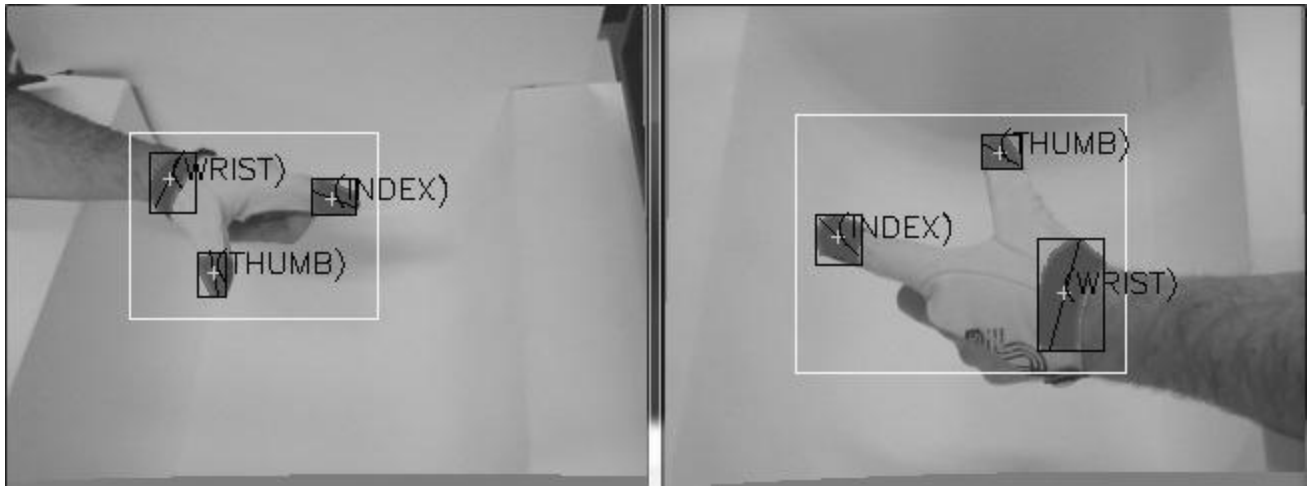


Suurballe's Algorithm

- For added reliability, we would like to send the video stream twice, on two disjoint paths.
- Suurballe's algorithm runs in $O(E + V \ln V)$ and gives two disjoint paths such that the sum of their latencies is minimized.
- We would prefer an algorithm that returned two disjoint paths such that the latency of the worse one was minimized.

ReachIn

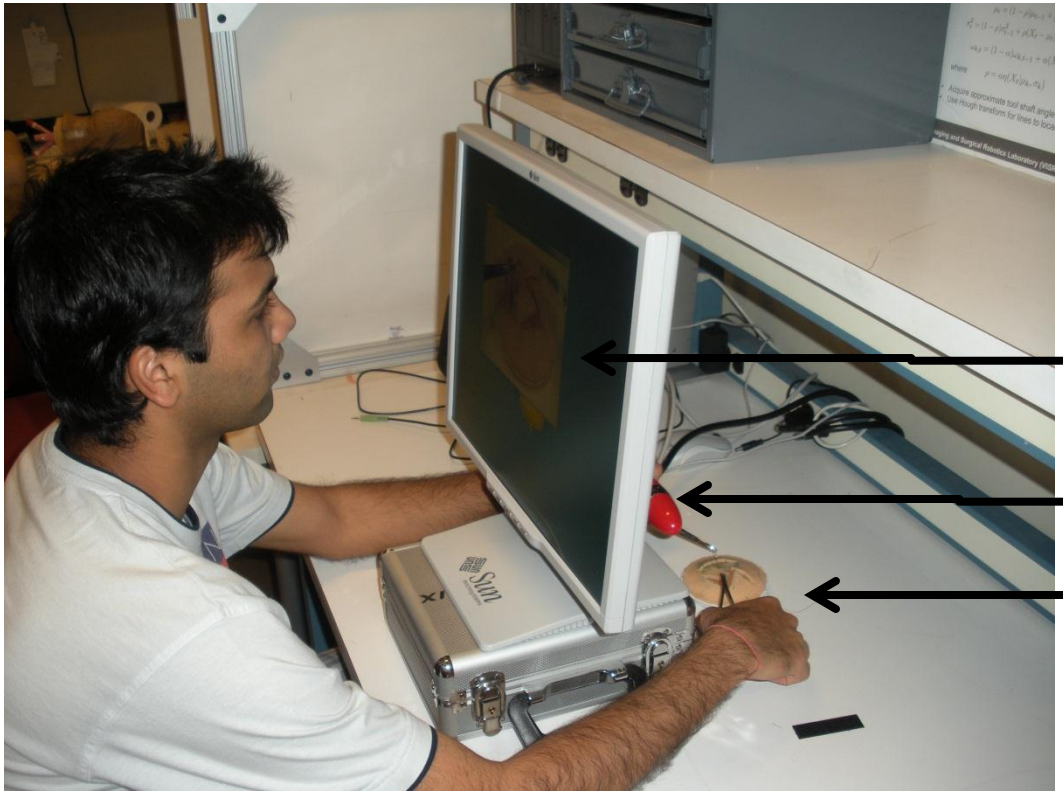
- A gestural interface for controlling the da Vinci robot (created by Kelleher Guerin).
- Sends video from the da Vinci, using our codec, to another machine for remote telesurgery.



Latency Demo

- Here the user is separated from a task by a camera and video stream.
- We can vary the latency in the video stream.
- There is some inherant delay, due to the camera and display. Even at a nominal 0 ms of delay, there is ~60 ms of delay.

Demo setup



Thanks to Anand Malpani for being our model.

Latency Demo

- We have found that it is possible to adjust to most constant latencies, given time.
- Even though we can adjust, it is very tiring.
- We have found that it is very difficult to adjust to varying latencies.

Video Demo

- Sending video from Hackerman to NEB
- We losslessly compress the video with gzip and send it via UDP over the LTN network
- We could compress it further, but this adds more delay

Demo Setup

Washington, DC

Sending video signal from Hackerman Hall to the DSN lab in NEB, via the LTN network.