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Haptic Feedback in Robot Assisted Minimal Invasive Surgery

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Technical Aspects of Multimodal Systems

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Outline

Haptic Feedback

Minimal Invasive Surgery

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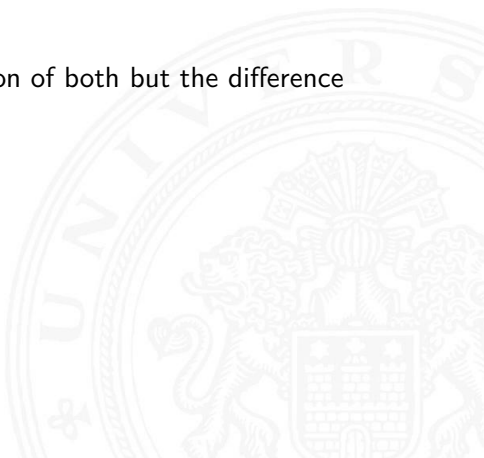


What is Haptic Feedback?

Haptic feedback is generally divided into two different classes:

1. Tactile Feedback
2. Kinesthetic (Force) Feedback

Haptic feedback is the combination of both but the difference between the two is quite complex





1. Tactile Feedback

- ▶ The things we feel on our skin.
- ▶ The tissue, has a number of different sensors embedded in the skin and right underneath it.
- ▶ These sensors allow our brain to feel things such as vibration, pressure, touch, texture etc.

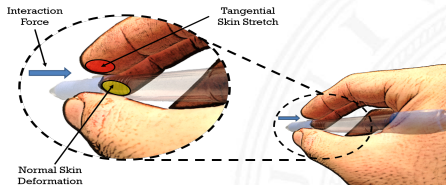


Fig. 1.

2. Kinesthetic (Force) Feedback

- ▶ The things we feel from sensors in our muscles, joints, tendons. Weight, stretch, joint angles of your arm, hand, wrist, fingers, etc.
- ▶ PlayStation's force feedback.

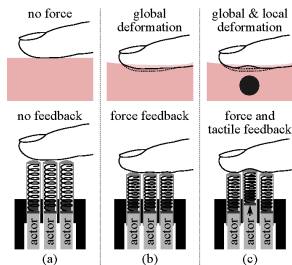


Fig.2



Minimal Invasive Surgery (MIS)

Haptic Feedback

Minimal Invasive Surgery

Current Scenario

Haptics in RMIS

Goal

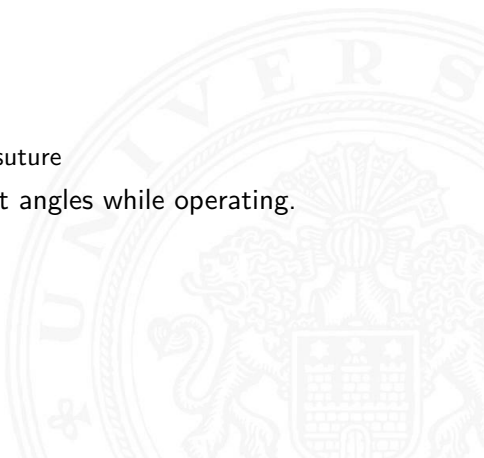
Robots for MIS

Conclusion

- ▶ Performed using thin-needles and an endoscope to visually guide the surgery.
- ▶ MIS reduces trauma to the human body.

Robot Assisted MIS

- ▶ Benefits to the patients
 - ▶ healing time of wounds and suture
- ▶ Surgeons can also see different angles while operating.





Current Scenario in MIS

Haptic Feedback

Minimal Invasive Surgery

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Haptics in RMIS

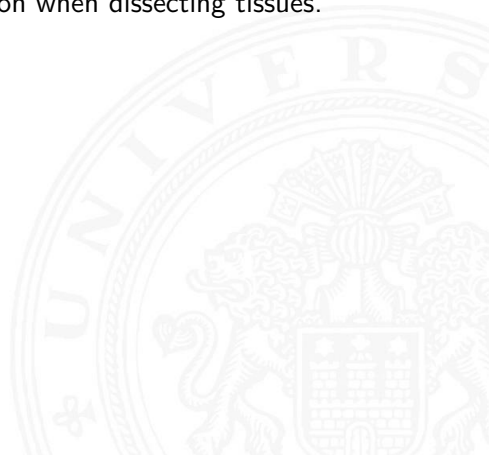
Goal

Robots for MIS

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The surgeon in 'normal' non-robotic surgery uses his fingers to

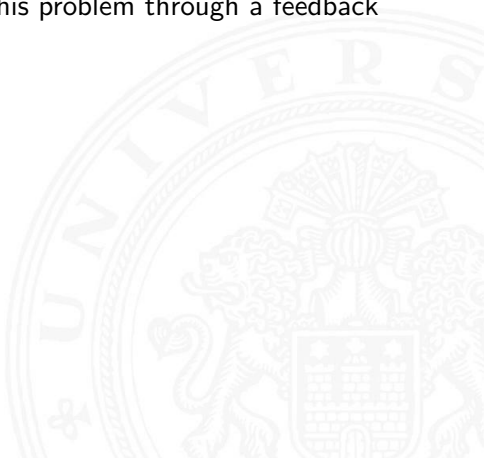
- ▶ feel the tissues.
- ▶ can differentiate between firm tissues and normal tissue.
- ▶ Using the fingers, helps surgeon when dissecting tissues.





Why do we need Haptics in RMIS?

- ▶ In MIS, all the natural Haptic Feedback was lost because the surgeon was not controlling the system directly.
- ▶ Haptic technology can solve this problem through a feedback system





Haptics in RMIS cont.

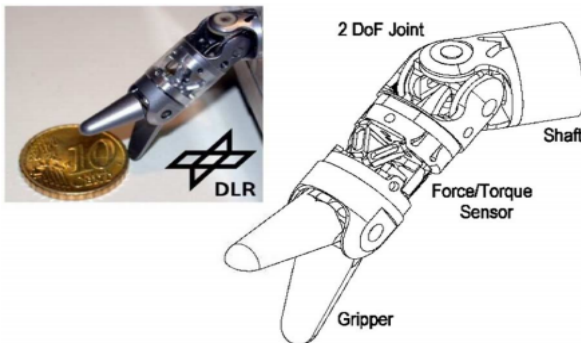
To get the haptic feedback from the robot there are two ways by which we can measure forces.

1. Direct Force Sensing
2. Indirect Force Sensing



Haptics in RMIS cont.

1. Direct Force Sensing — the sensors are located in the point of interaction between the tool and tissue.



A DLR instrument equipped with a six-axis force-torque sensor

Fig. 3.

Fig. 3: <http://bme240.eng.uci.edu/students/10s/sgupta1/DLR.bmp>

2. Indirect Force Sensing — all the electronics are moved apart from the patient.



Fig. 4. HeroSurg Sensor Instrument



Haptics in RMIS cont.

Haptic Feedback

Minimal Invasive Surgery

Current Scenario

Haptics in RMIS

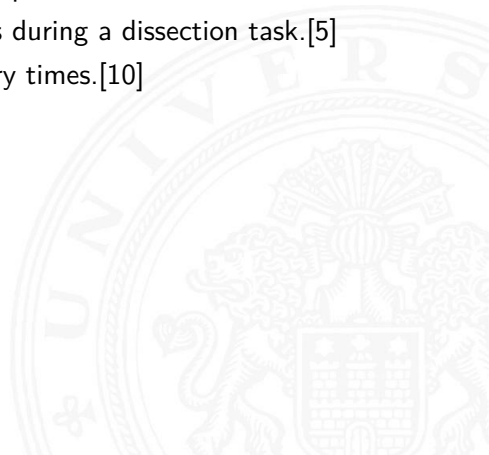
Goal

Robots for MIS

Conclusion

Advantages of Haptics in RMIS

- ▶ Improved tissue manipulation, reducing the breaking of sutures and increase the feeling of telepresence.
- ▶ Reduces unintentional injuries during a dissection task.[5]
- ▶ Less pain, and shorter recovery times.[10]





Haptics in RMIS cont.

Haptic Feedback

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Problems in developing a Good Haptic Feedback for RMIS

1. Measurement of Force
2. Sending back the obtained information to the surgeon.





How the Haptic Feedback can be sent to the surgeon?

1. Visually

- ▶ The feedback from the camera can be displayed on the screen.
- ▶ Plotting of graphs of different types of forces can be done.

2. Aurally

- ▶ Different types of sound feedback can be provided to the remote surgeon

3. Haptically

- ▶ Kinesthetic or Force feedback can be sent back to the surgeon, which should seem that he himself is operating.



What is our Goal for RMIS?

The goal of haptic technology in RMIS is

- ▶ to provide *transparency*,
- ▶ To provide myriad haptic info without sacrificing the maneuverability and dexterity.
- ▶ Feedback of tactile sensing, such as compliance, viscosity, and surface texture.
- ▶ Information should be sent directly to human operator, such as pressure distribution or deformation over a contact area.

But what is Our Main AIM?

- ▶ To make Robot Assisted Minimal Invasive Surgery, Intelligent.
- ▶ Intelligent by the means of *feedback* with less or no delays.
- ▶ Collision avoidance of robot with the patient or bed.
- ▶ Surgeon should feel that he is in direct contact with the patient.



Fig.5.



Robots for Minimal Invasive Surgery

Haptic Feedback

Minimal Invasive Surgery

Current Scenario

Haptics in RMIS

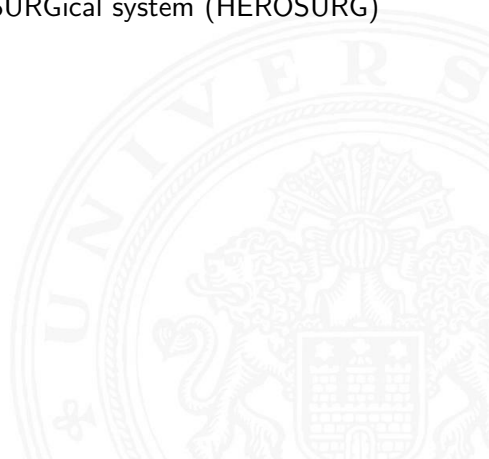
Goal

Robots for MIS

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Robots currently in the market or in research

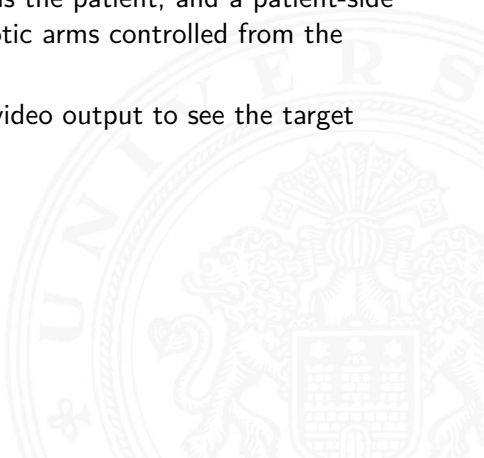
1. Da Vinci Surgical Robot
2. VerroTouch
3. Haptically-Enabled RObotic SURGical system (HEROSURG)





1. Da Vinci

- ▶ Designed for complex surgery using a minimally invasive approach.
- ▶ Controlled by a surgeon from a console.
- ▶ Console is in the same room as the patient, and a patient-side cart with four interactive robotic arms controlled from the console.
- ▶ No haptic feedback, just the video output to see the target anatomy.



[Video DaVinci] Suturing and Surgery

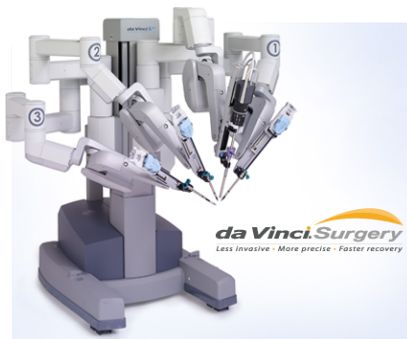


Fig. 6.: DaVinci Robot (Patient Side)

Fig. 6: http://theliverinstitutetx.com/wp-content/uploads/2013/08/img_davinci.png



EndoWrist

- ▶ It provides surgeons with natural dexterity while operating through small incisions.
- ▶ Also provides maximum responsiveness, with rapid and precise suturing, dissection and tissue manipulation.



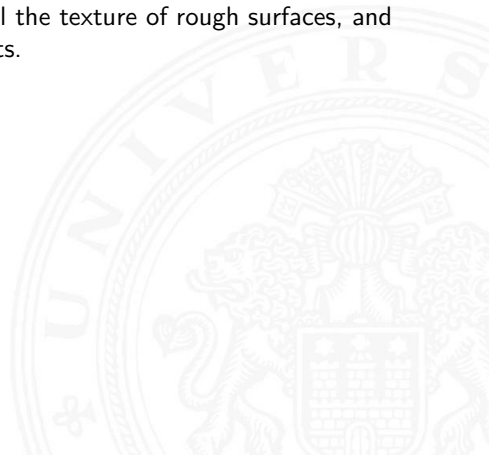
Fig.7. Endowrist

Fig. 7: <http://sofmedica.com/wp-content/uploads/2017/03/xi-instruments-fan.png>



2. VerroTouch

- ▶ VerroTouch was developed for partially restoring the lost sense of touch by DaVinci System.
- ▶ Measures the vibrations and recreates them on the master handle.[9]
 - ▶ It enables the surgeon to feel the texture of rough surfaces, and other important tactile events.



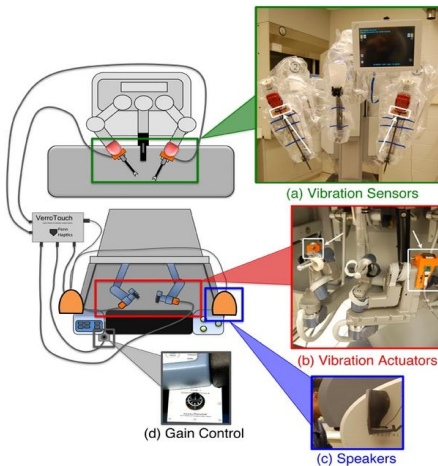


Fig.8. VerroTouch System

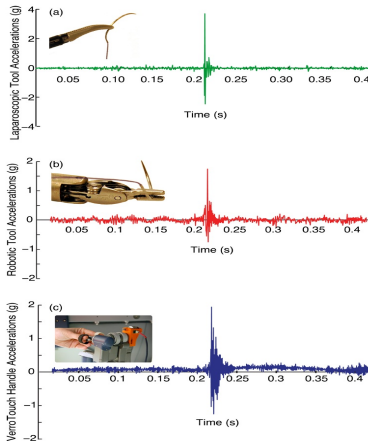


Fig.9 Vibration comparisons

Fig 9: http://haptics.seas.upenn.edu/uploads/Research/similar_recordings.jpg



3. HEROSURG

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Haptically-Enabled Robotic Surgical System (HeroSurg)

- ▶ To restore the sense of touch in robotic-assisted MIS [11]
- ▶ key features — haptic feedback, collision avoidance and automatic bed/patient/tissue motion compensation.
- ▶ It is capable of measuring tip/tissue interaction forces without any sensor at the tip.

- ▶ Strain gauge technology is incorporated into the instrument to measure interaction forces.
- ▶ It is modular.
- ▶ Doesn't lose it's force sensing capability.

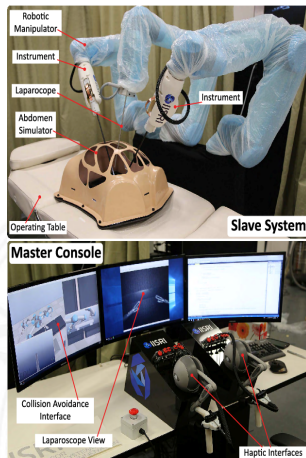


Fig.10. Herosurg



[Video] HeroSurg



- ▶ The lateral tissue interaction forces at the tip produce bending in the sleeve.
- ▶ Each instrument has a sleeve —> integrated with strain gauges.
- ▶ The insert can have any tip type. e.g. grasping or cutting.

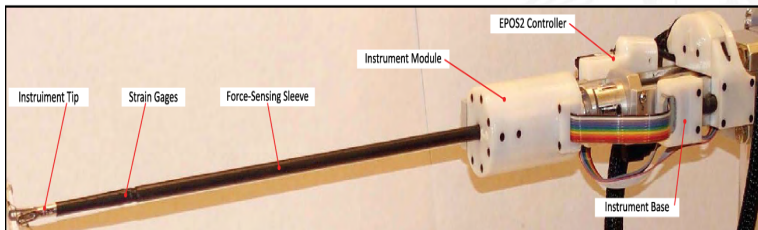


Fig. 11. Herosurg Instrument Sleeve

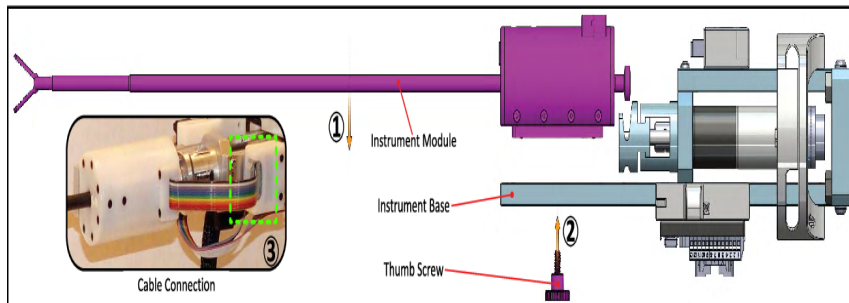
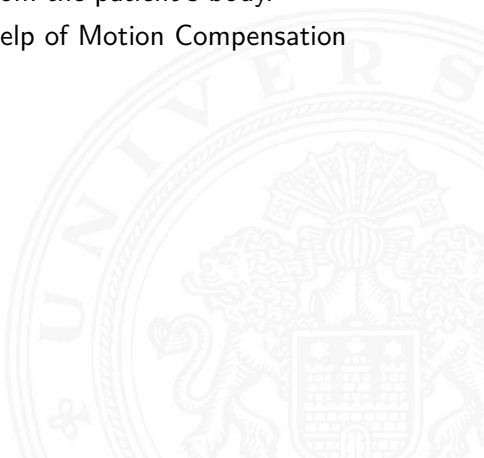


Fig. 12. Attachment of Instrument to Base Module

Fig.12: [11]



- ▶ Position information is sent through wireless transformations.
- ▶ Real time fluoroscopic images are sent to the display.
- ▶ Motion Compensation to & from the patient's body.
- ▶ Collision avoidance with the help of Motion Compensation



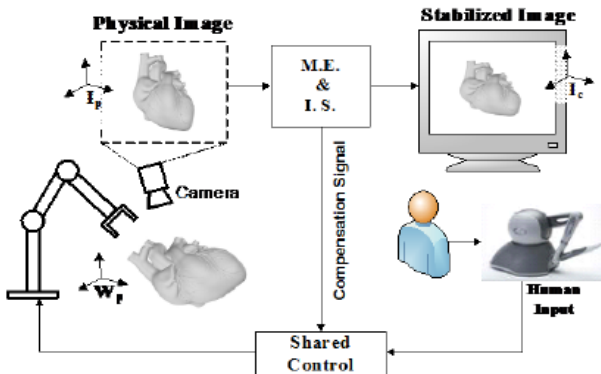


Fig. 13. Motion Compensation and Image Stabilization

Fig.13:

https://www.researchgate.net/publication/261435371_Shared_Control_for_Motion_Compensation_in_Robotic__Beating_Heart_Surgery



Conclusion

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- ▶ Once the major problems are accomplished, a number of exciting clinical and scientific opportunities will arise.
- ▶ These feedbacks can improve a surgeon's sense of telepresence, leading to better performance and eventually better results.
- ▶ The master robot can also use haptic feedback to provide intelligent assistants, generating “virtual fixtures” that support various manipulation tasks performed by the surgeon. [4]



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