Medical robotics and Image Guided Therapy (IGT)

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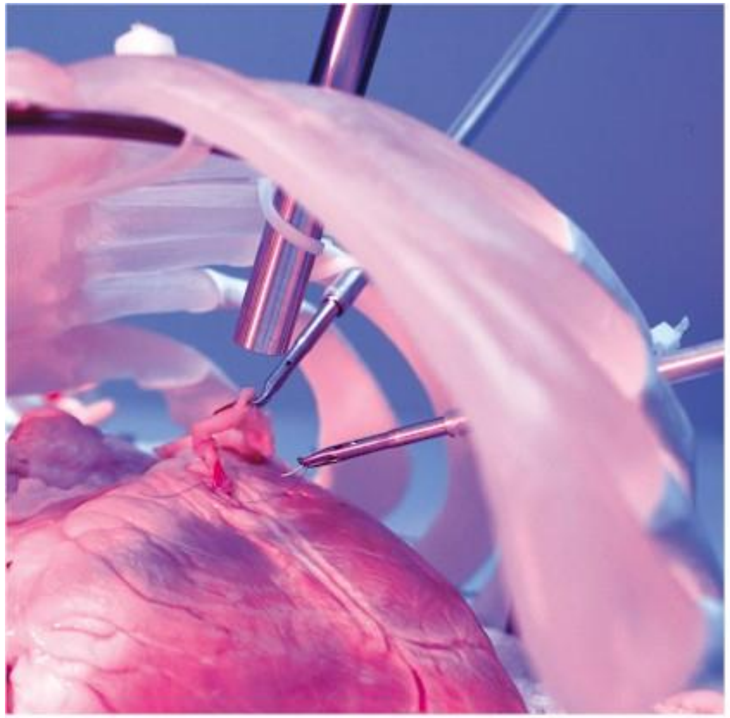
Medical Robotics

History, current and future applications



Robots are…

- Accurate and precise; untiring
- Smaller or larger than people (as needed)
- Remotely operated (as needed)
- Connected to computers, which gives them access to information
- Not always able to operate autonomously in highly complex, unvertain environments
=> need for human interaction

Overview

- Introduction
- Application of Medical Robotics
- Design of Robotic Telesurgery
- Historic Companies and Systems
- Existing surgical systems
- Strengths and Limitations
- Ethical and Safety Considerations
- On-going research projects in Verona
- Challenges, Future and Conclusion

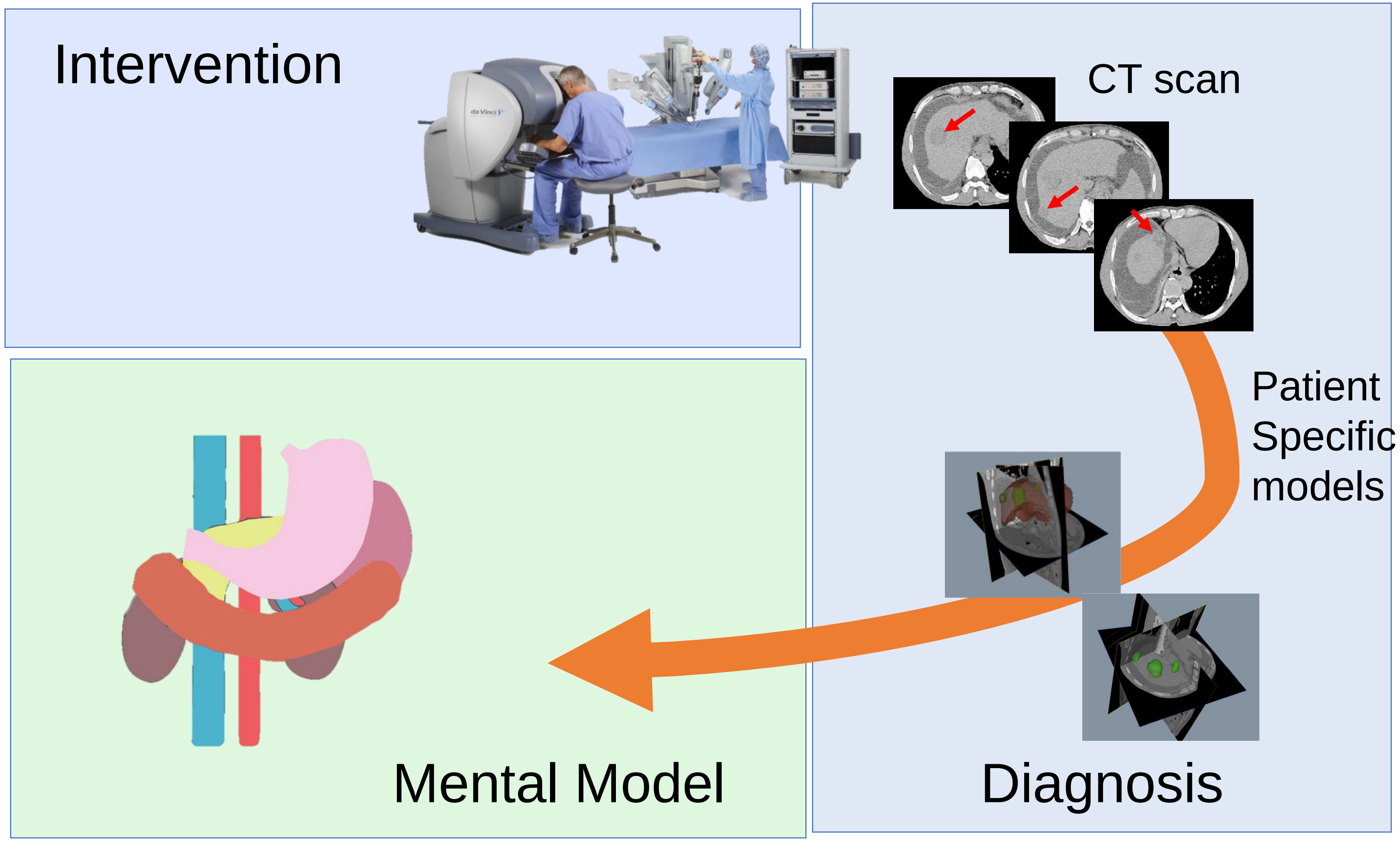
Introduction(1)

- Definition: Robotic systems for surgery
    - There are computer-assisted surgery (CAS) systems first, and “medical robots” second.
    The robot itself is just one element of a larger system designed to assist a surgeon in carrying out a surgical procedure..” [Taylor, 2003]

Computer-assisted surgery is an interdisciplinary research field that builds a bridge between surgery and computer science. It represents a set of methods which use computer technology to support preoperative planning, the actual surgery, and postoperative assessment.

Introduction(2)

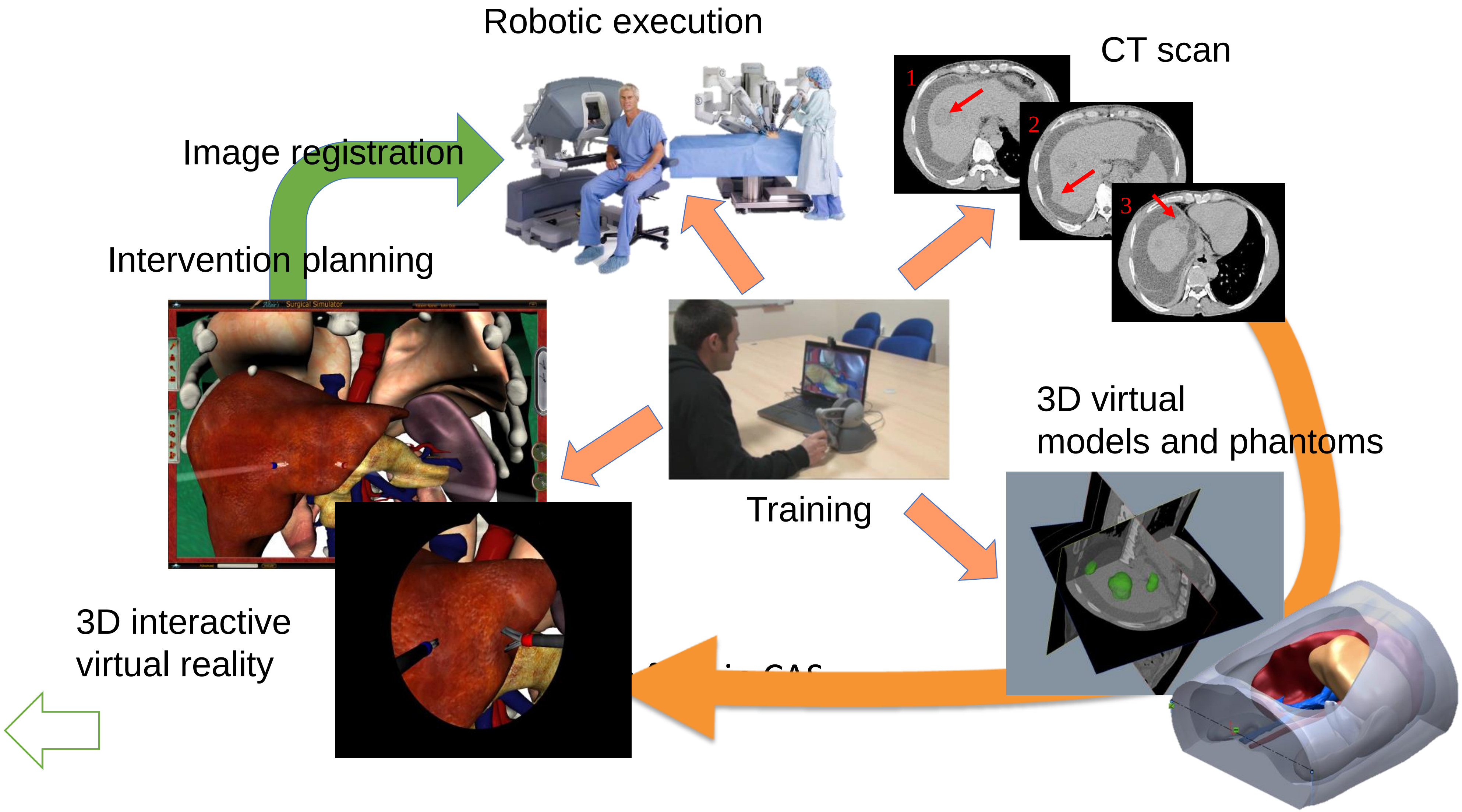
- CAS



- Information flow in CAS

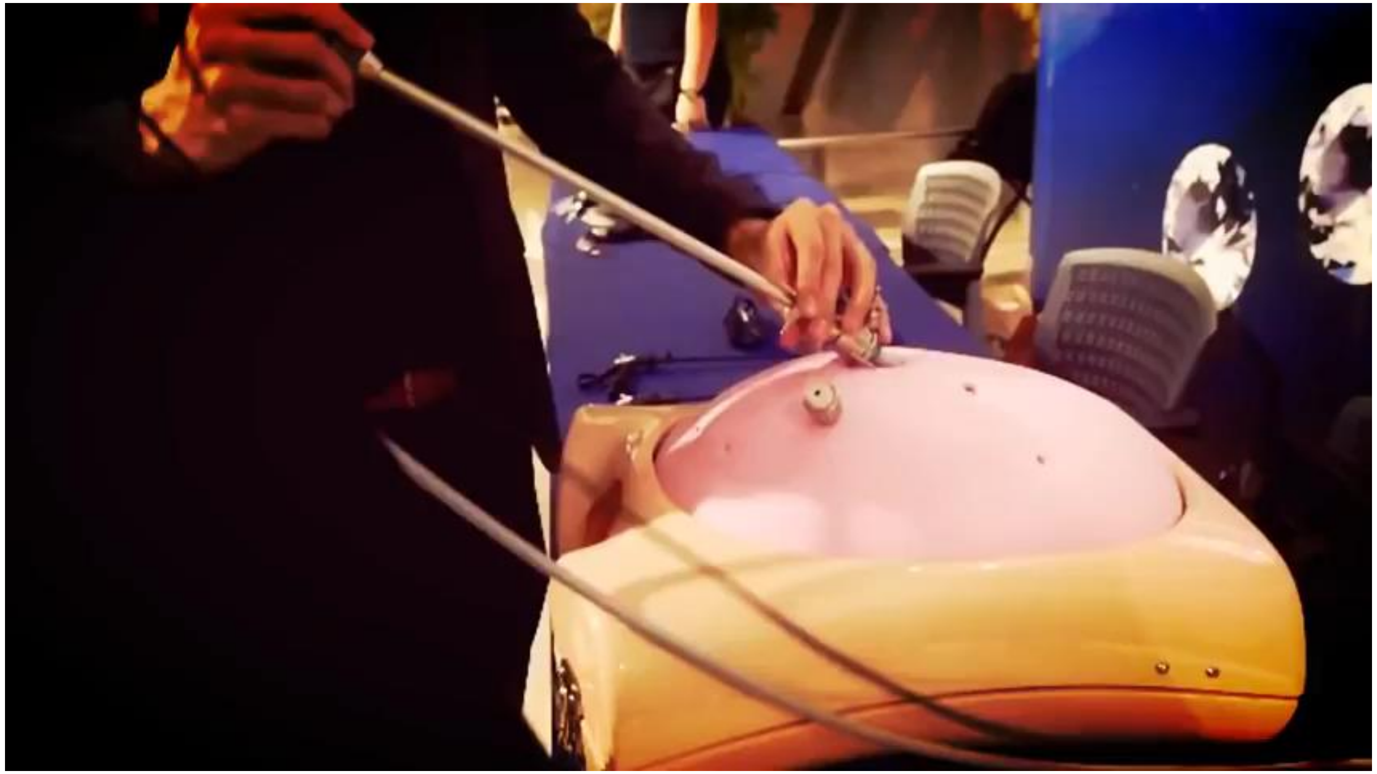
Introduction(3)

- Ideal CAS



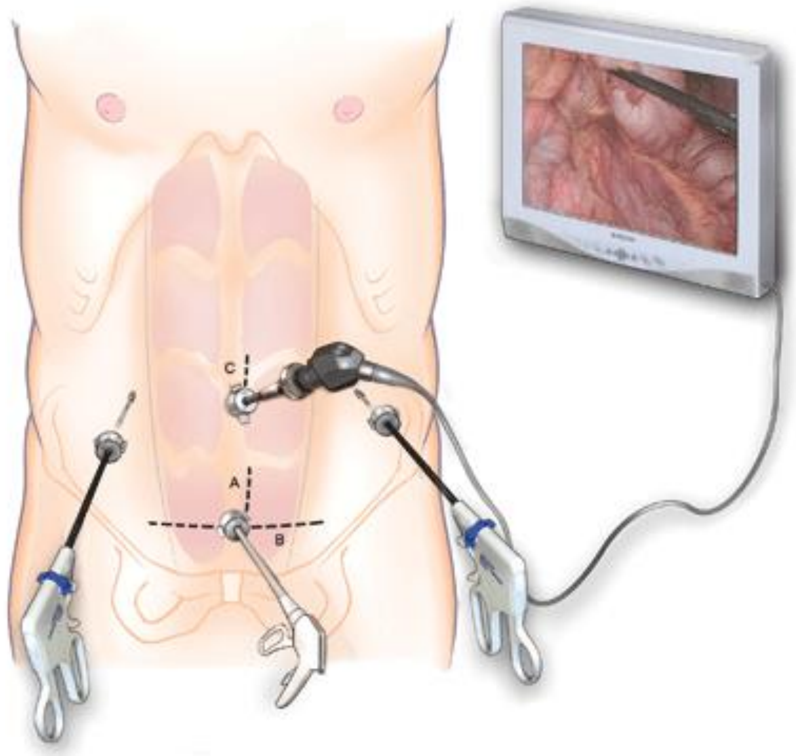
Introduction(4)

- MIS
  - Minimally invasive surgery uses techniques of surgical access and exposure that significantly reduce trauma to the body compared to traditional incisions.



Introduction(5)

- Motivation:
  - Started with the weaknesses and strengths of minimally invasive surgery (MIS)
  - Smaller incisions, shorter post-operative time, reduced infection, faster rehabilitation, lesser pain, better cosmetics, ...
  - Eye-hand coordination, difficulty in moving arms, degree of motion



Application of Medical Robotics(1)

- Telemedicine and Teleconsultation
  - Telecommunciation channels to communicate with other physicians/patients
  - Control an external camera which in turn controls an endoscopic camera – used to share images with a remote surgeon

Application of Medical Robotics(2)

- Surgical Training
  - Robots used as surgical training simulators
  - Used for medical resident students
  - Residents lack expertise and this helps in avoiding legal, social and economic problems

Actaeon Robotic Surgery Training Console

“Actaeon Console is the answer to what is currently missing in Robotic Surgery education: an easy trasportable and easy setup console which perfectly simulate the feedback of a da Vinci® console. With it you can trasform your standard computer classroom into an hi-tech robotics surgery training classroom, where every student can find his space to train and practice on this exciting Surgery field.”

Application of Medical Robotics(3)

- Rehabilitation
  - Assistive robots
  - Wheelchair with intelligent navigational control system

Application of Medical Robotics(4)

- Telesurgery
  - Surgeon sits at a console
  - Has controls to move the robotic arms
  - Does not operate on the patient directly
  - Mainly used in minimally invasive surgeries

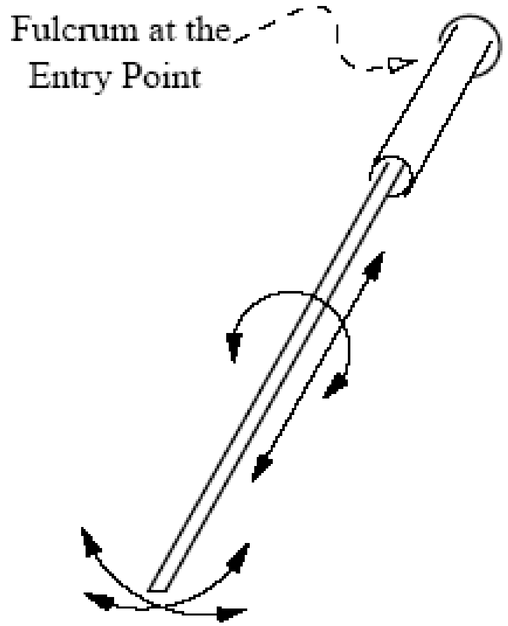
New York

Strasbourg

Lindbergh operation was a complete tele-surgical operation carried out by a team of French surgeons located in New York on a patient in Strasbourg, France (over a distance of several thousand miles) using telecommunications solutions based on high-speed services and sophisticated Zeus surgical robot. The operation was performed successfully on September 7, 2001 by Professor Jacques Marescaux

Application of Medical Robotics(5)

- Laparoscopic Surgery
- Traditional laparoscope instruments have limitations
  - Has 4 DOFs - Arbitrary orientation of instrument tip not possible
  - Reduction in dexterity
  - Reduction in motion reversal due to fulcrum at entry point
  - Friction at air tight trocar – reduction in force feedback
  - Lack of tactile sensing

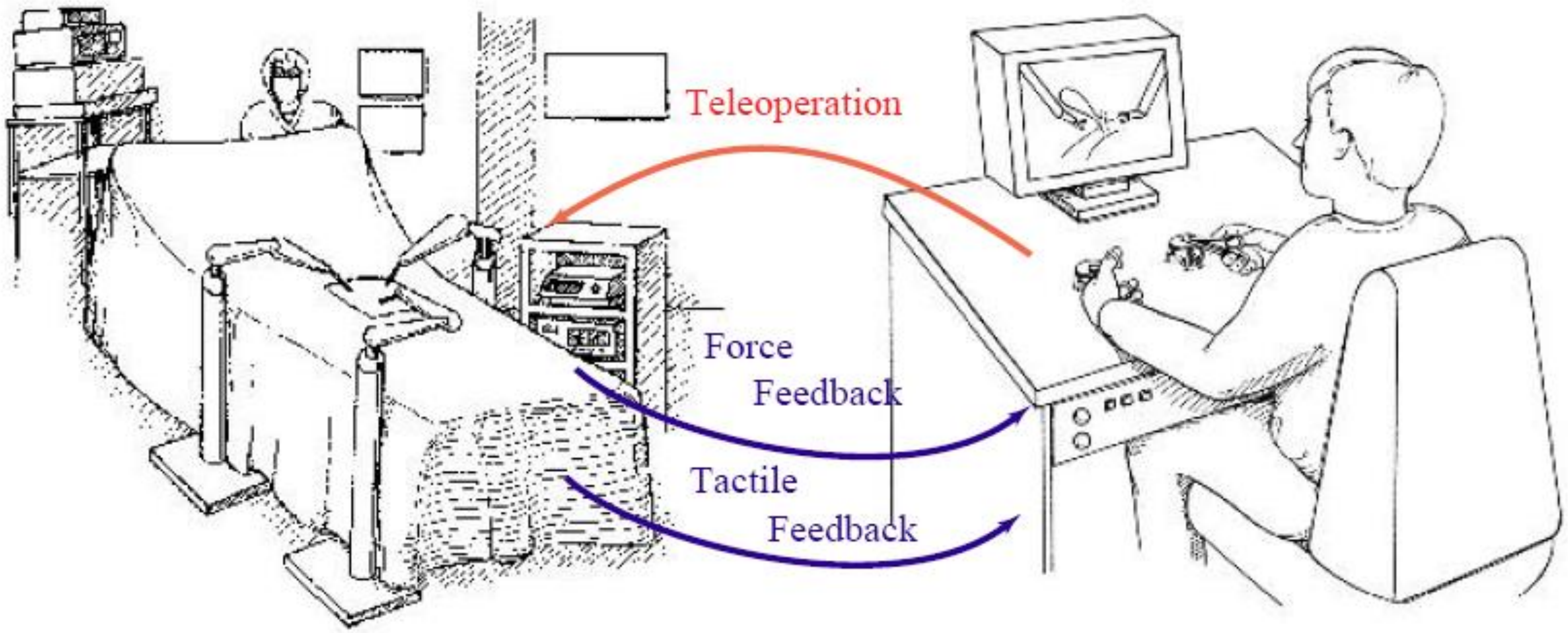


Design of Robotic Telesurgery(1)

- Minimally Invasive Surgery
  - Surgery performed by making small incisions < 10mm dia
  - Reduces post-operative pain and hospital stays
  - Form of telemanipulation
  - Instruments have a camera attached to transmit inside image to the surgeon

Design of Robotic Telesurgery(2)

- The Concept



- Telesurgical system concept

Design of Robotic Telesurgery(3)

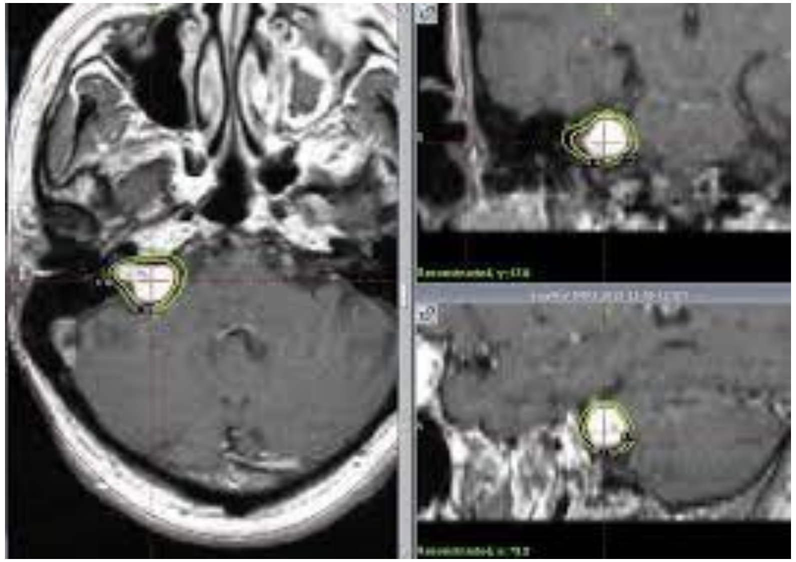
- Considerations:
  - Human-Machine Interface
  - Video system used to capture images inside the patient
  - Backlash-loss of motion between a set of movable parts
    - Choose the appropriate mechanism for the required transmission
  - Choose passive gravity balance over active gravity balance

Design of Robotic Telesurgery(4)

- Haptic Feedback
  - Sensation of touch lost in robotic surgery
  - Receiving haptic information and using it to control the robotic manipulators
  - Needed to achieve high fidelity
  - Types
    - Force (kinesthetic) feedback
    - Tactile (cutaneous) feedback

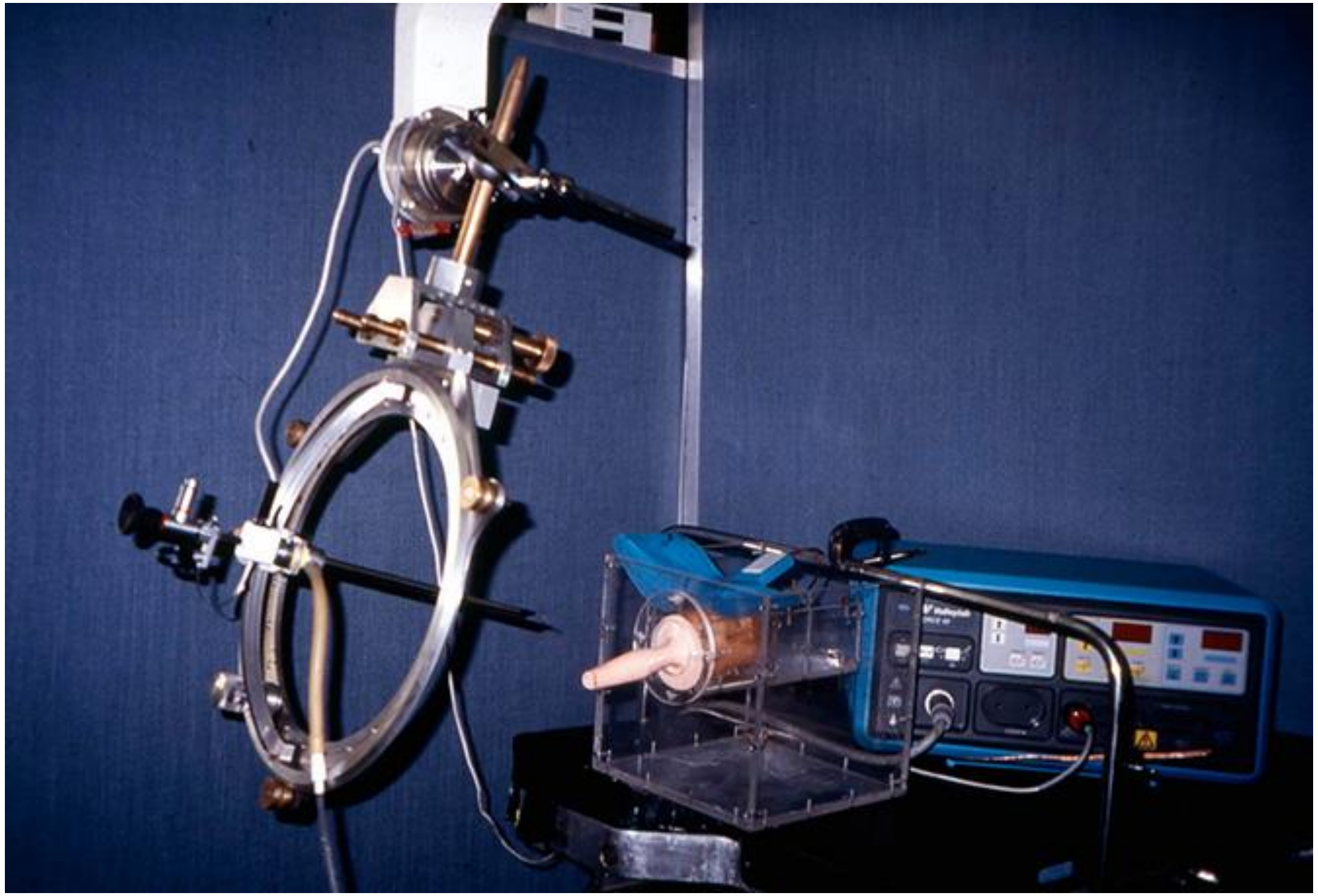
Historic Companies and Systems(1)

- First Robotic assisted surgery 1988
  - – PUMA 560
  - – Light duty industrial robotic arm to guide laser/needle for sterotactic brain surgery



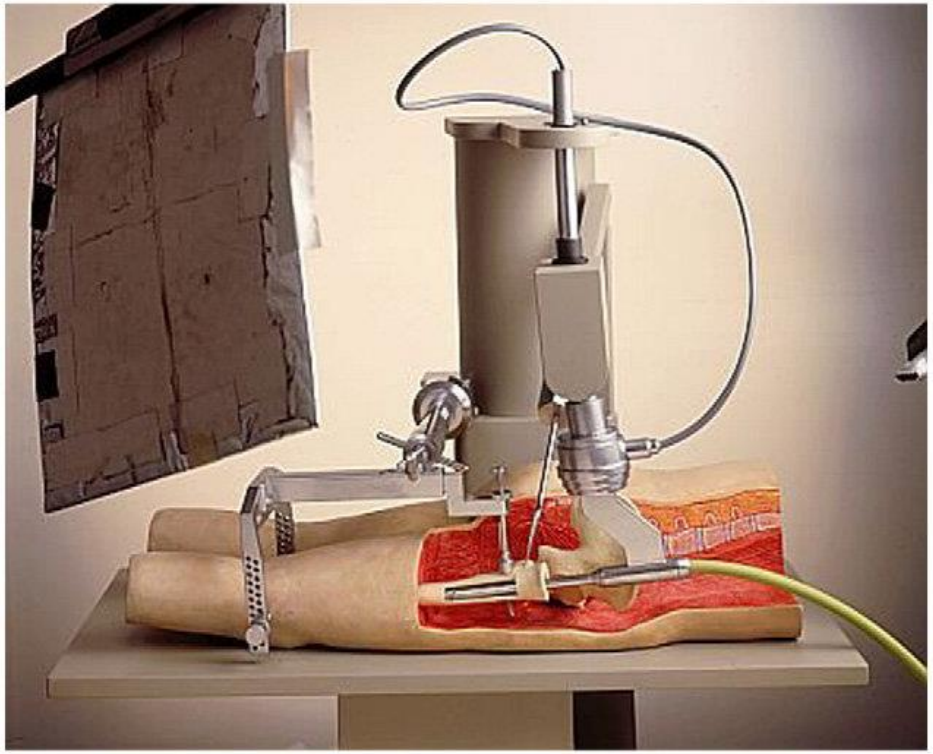
Historic Companies and Systems(2)

- First Robotic urological surgery 1992
  - – PROBOT-assisted TURP in Guy's Hospital in London



Historic Companies and Systems(3)

- First commercially available robotic system, 1992
  - – ROBODOC for orthopaedic hip surgery



Historic Companies and Systems(4)

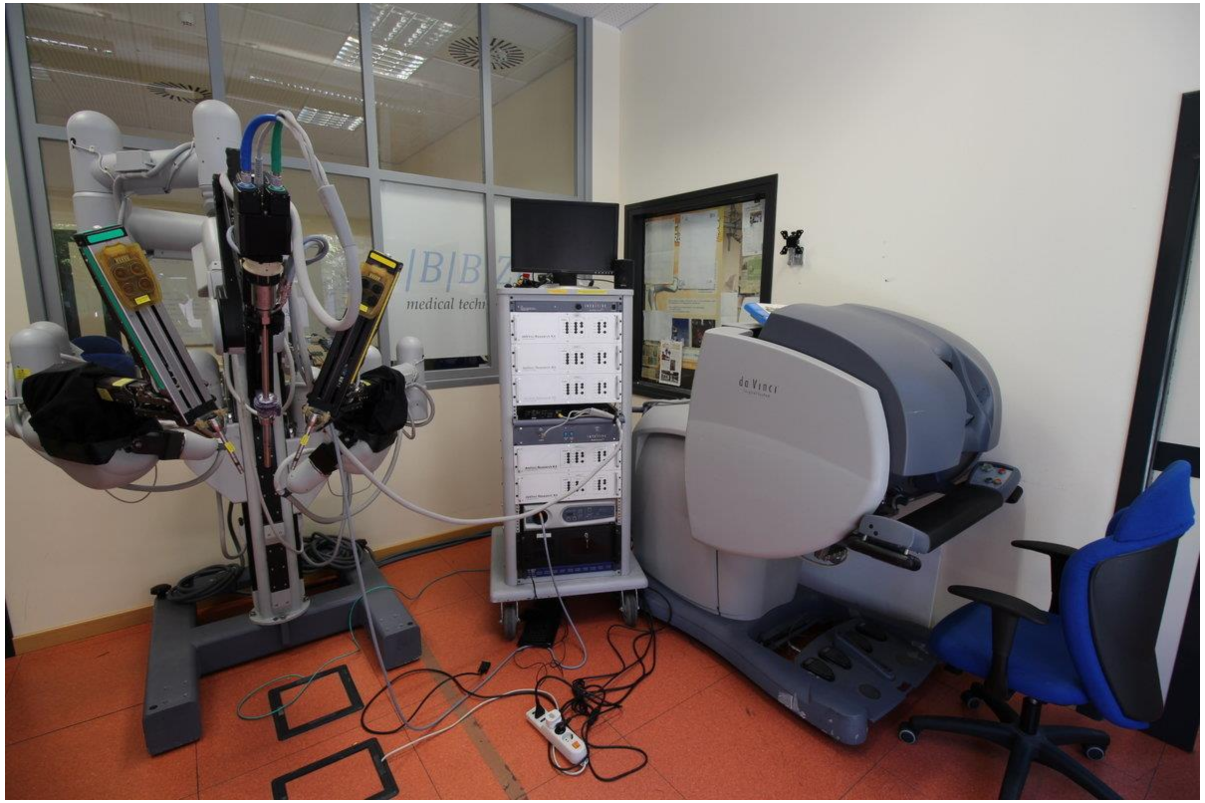
- AESOP (Computer Motion), 1994
  - – Automated Endoscopic System for Optimal Positioning – a voice-activated robotic arm for camera holder
  - – First approved surgical robotic system by FDA

- ZEUS (Computer Motion)
  - – Marketed in 1998

ZEUS Altair Robotics Lab, Verona

Existing surgical systems(1)

- Da Vinci (Intuitive Surgical)
  - – Initially developed by US Department of Defence in 1991
  - – Intuitive Surgical acquired
  the prototype and
  commercialized the system
  - – Approved by FDA in
  - July 2000



DaVinci Research Kit (DVRK), Altair Robotics Lab (Verona)

Existing surgical systems(2)

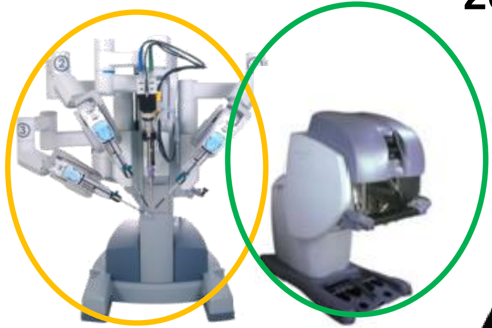
Product Development

da Vinci Xi

da Vinci Si

2009

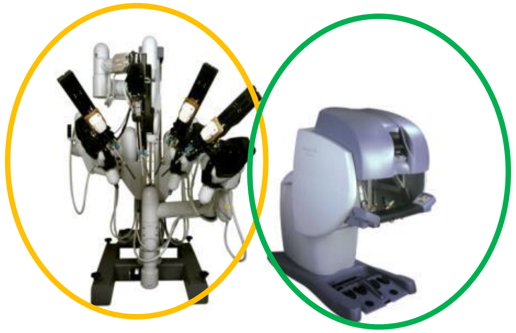
- Collaborative surgery
- Full HD vision
- Better Ergonomicity
- Modifiable Architecture



da Vinci S

2006

- HD Vision (720P)
- Input video
- Multi-Quadrant Access
- Better set-up



da Vinci Standard

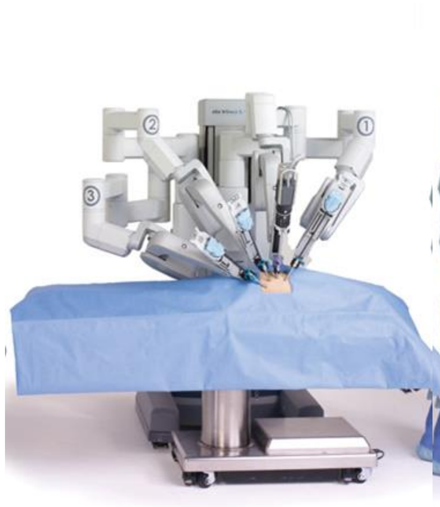
1998

- VISIONE 3D
- 4th arm introduction

Existing surgical systems(3)

Robot daVinci - components

Patient System



Vision System

Surgical Consolle

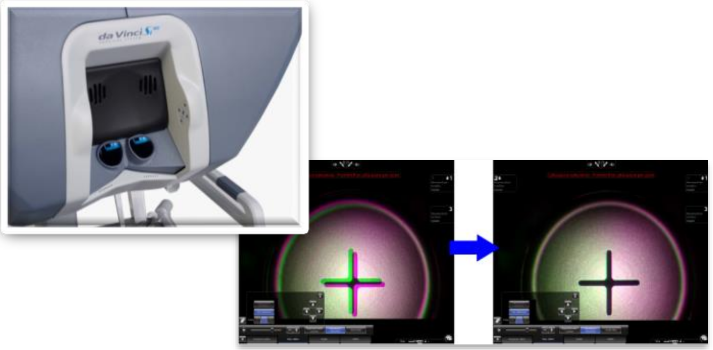
Second Consolle

Existing surgical systems(4)

daVinci – Master Station

Visor 3D HD

2 independant optical channels



Master

Operator input with tremor filtering

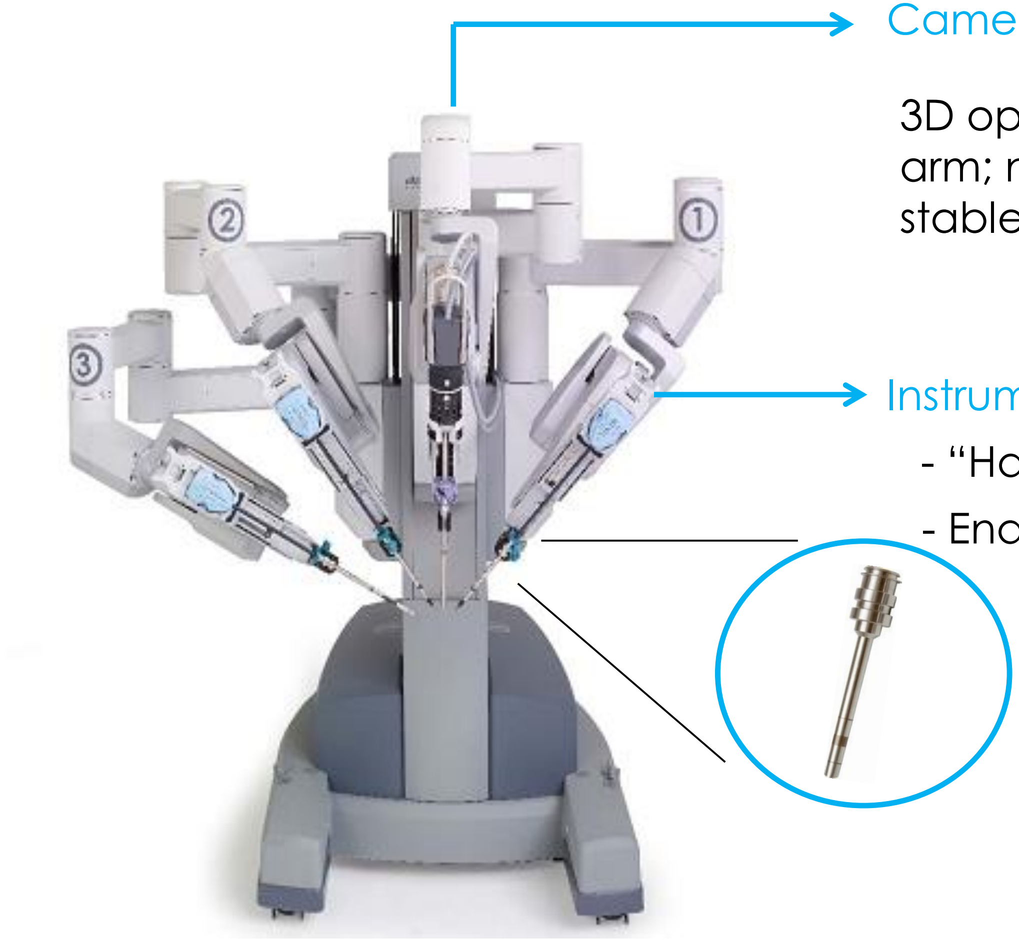
Pedals

Management of vision and tools

Ergonomic settings

Existing surgical systems(5)

daVinci Slave Station

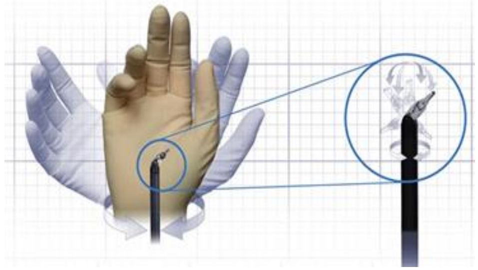


Camera Arm

3D optics installed on the arm; no tremor and stable vision

Instrument Arm

- "Hard" Remote Center of Compliance
- Endowrist Instruments



Existing surgical systems(6)

- Advantages of Da Vinci Surgical®:
  - Technically
    - – Patented Endowrist: 6 degrees of movement
    - – 3-D vision (Dual channel endoscopy) and magnified view (x12)
    - – Tremor suppression and scaling of movement

    Surgeon
    - – Ergonomic advantage
    - – Shorter learning curve
  - Patient
    - – Better outcome

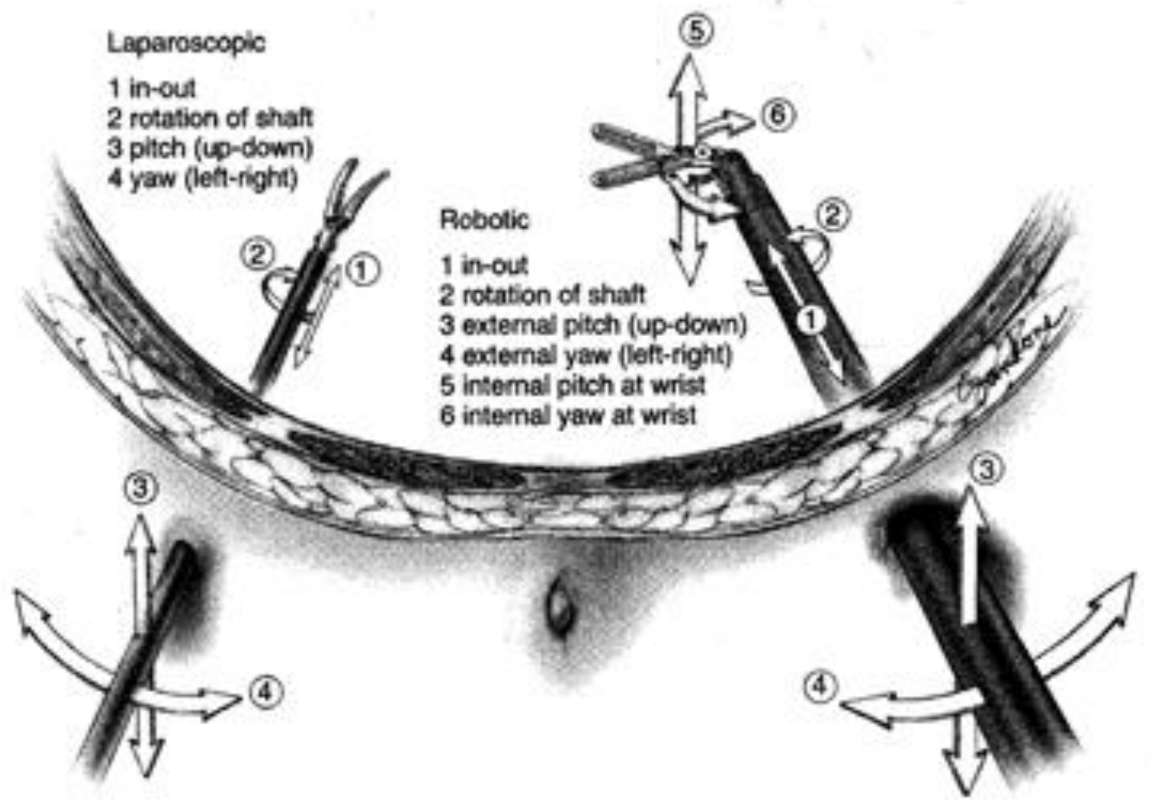
Existing surgical systems(7)

- Advantages:

A surgical robot combines the small instrument size of laparoscopic surgery, with the hand dexterity and visual perception of open surgery. These features allowed a significant improvement in surgical performance especially where laparascopic technique was not too high.

Existing surgical systems(8)

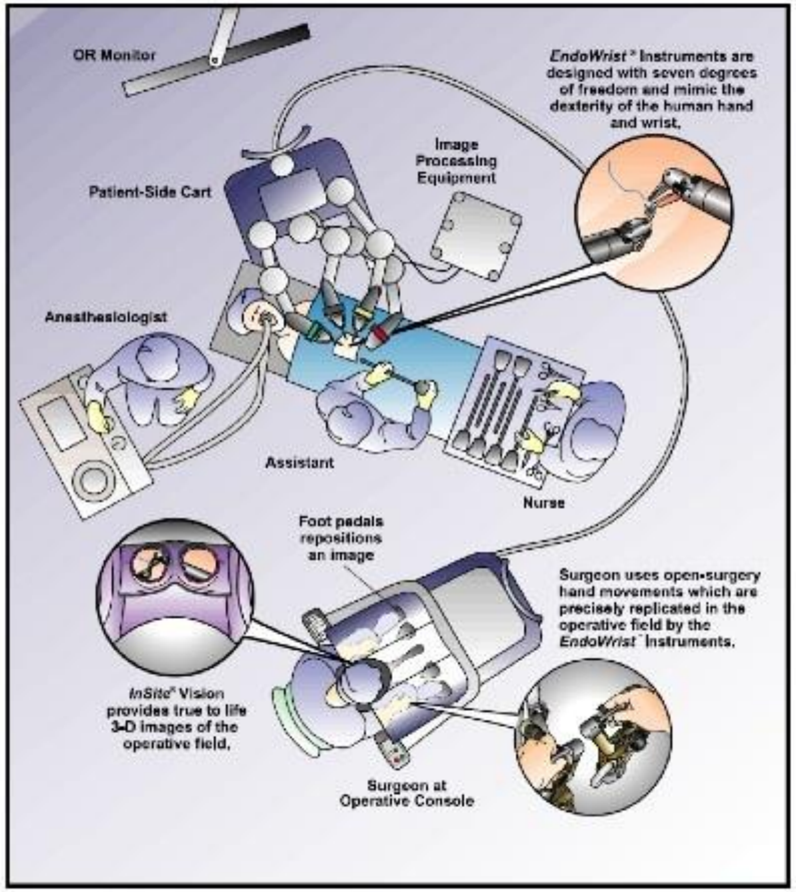
- 6 degree movements



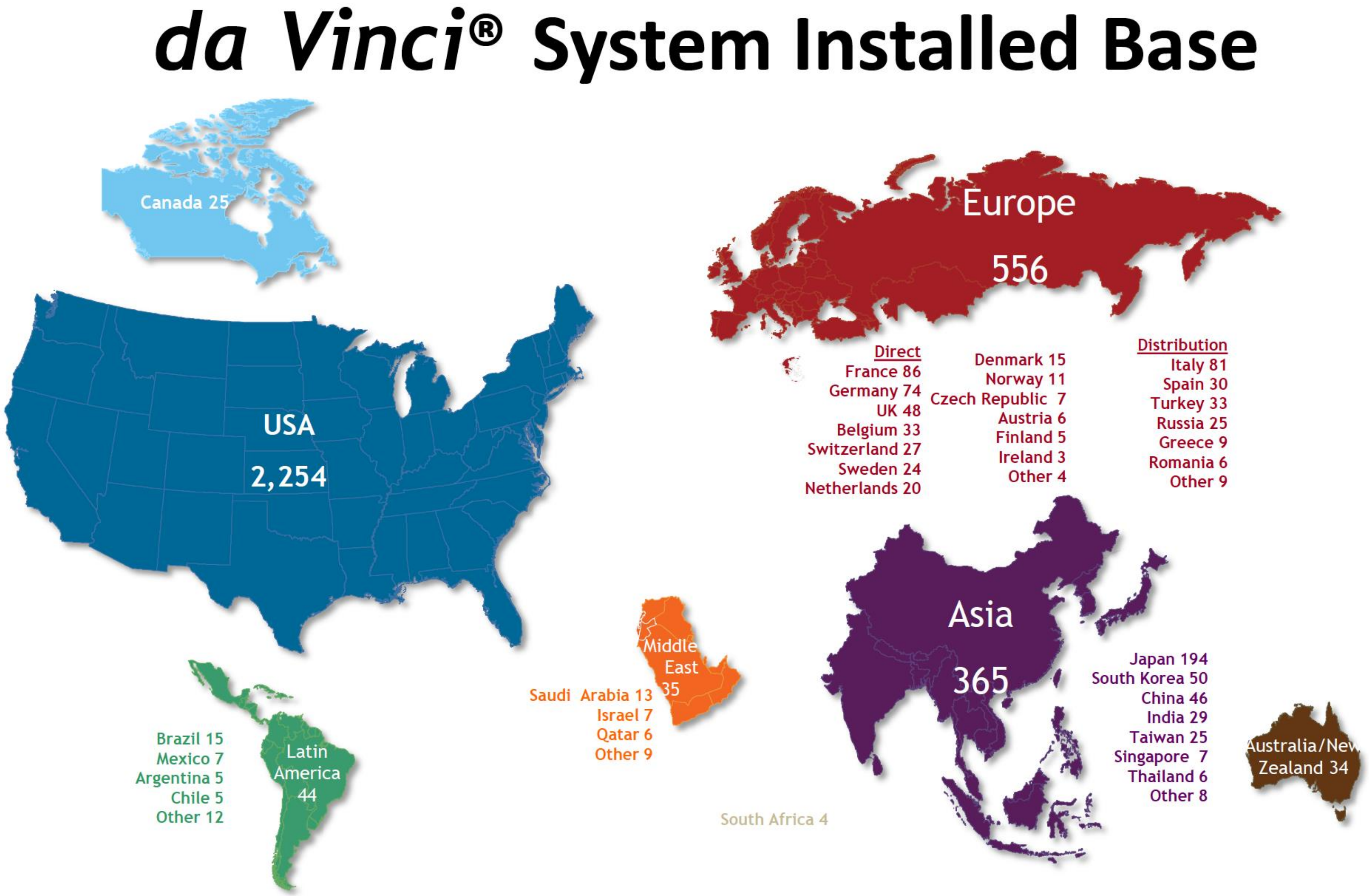
Existing surgical systems(9)

- Da Vinci surgical system in a general procedure setting

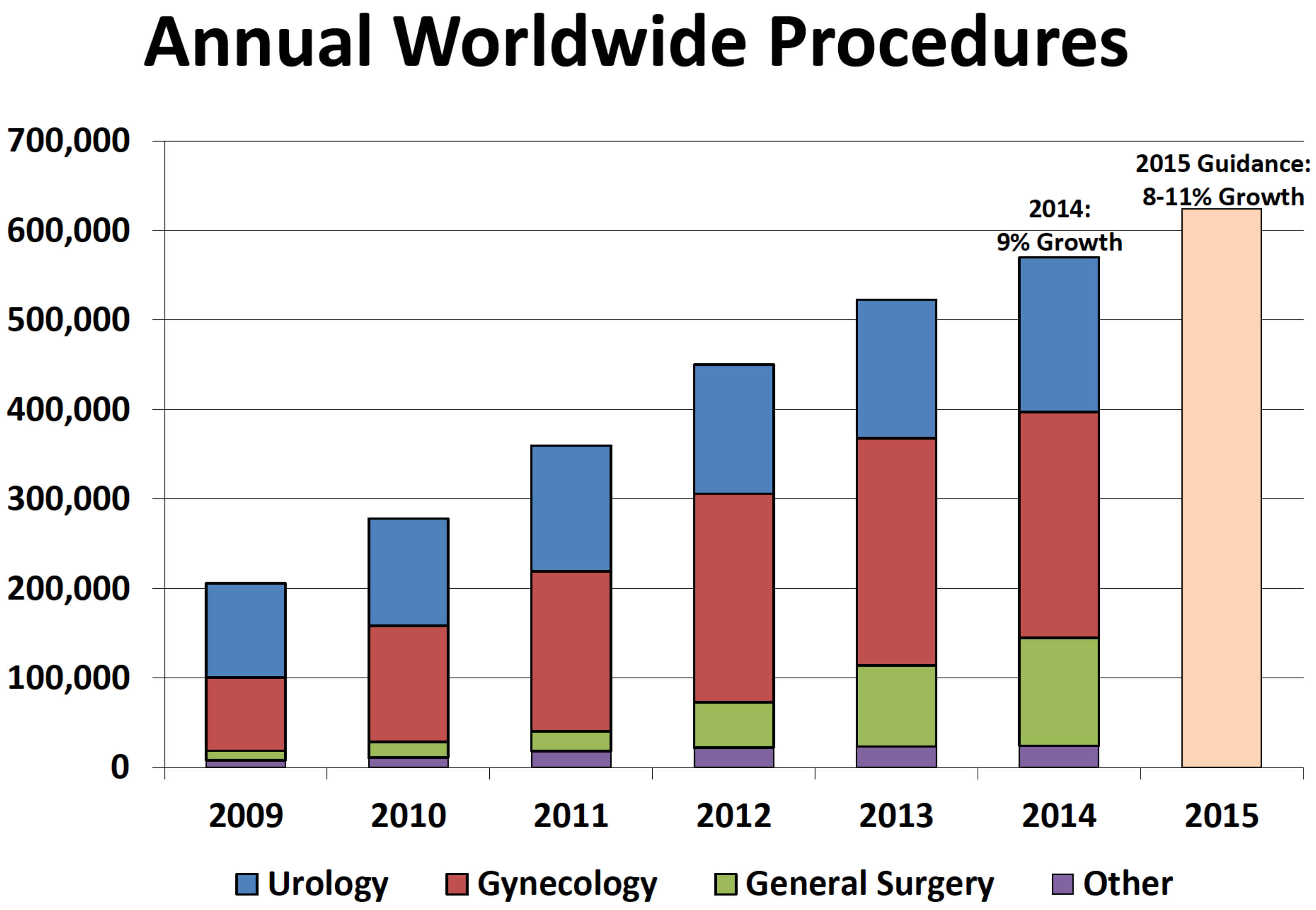
da Vinci® Surgical System in a General Procedure Setting



Existing surgical systems(10)



Existing surgical systems(11)



Strengths and Limitations(1)

- Strengths:
  - Physical separation
  - Wrist action
  - Tremor elimination
  - Optional motion scaling
  - Three-dimensional stereoscopic image
  - Electronic information transfer (Telesurgery)

Strengths and Limitations(2)

- Limitation
  - Reluctance to accept this technology (trust)
  - Additional training
  - Fail proof?
  - Most of the sensors use IR transmission
  - Highly efficient visual instruments are needed
  - Cannot be pre-programmed
  - Task-specific robots are required
  - Latency in transmission of mechanical movements by the surgeon
  - Longer operating time

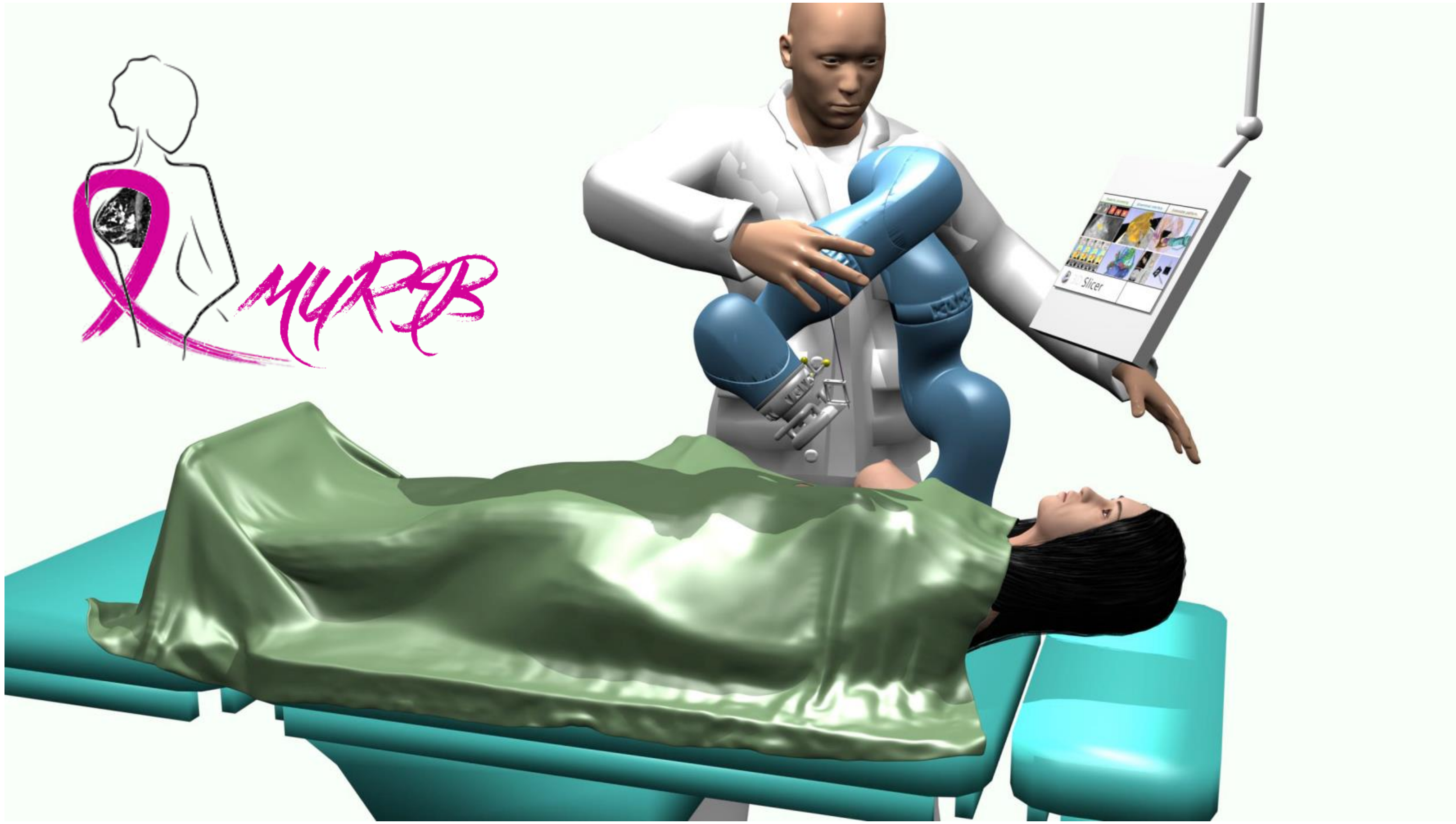
Strengths and Limitations(3)

- Limitation
  - Cost for the Da Vinci system:
    - The average base cost of a System is $1.5 million
    - Approximately $ 160,000 maintenance cost a year
    - Operating room cost, $150 per hour
    - Hospital stay cost, $600 per day
    - Time away from work, $120 per day

Ethical and Safety Considerations

- When there is a marginal benefit from using robots, is it ethical to impose financial burden on patients or medical systems?
- If a robot-assisted surgery fails because of technical problems, is it the surgeon who is responsible or others?

On-going research projects in Verona (1)



"The MURAB project has the ambition to drastically improve precision of diagnostic biopsies and effectiveness of the workflow, reducing the usage of expensive Magnetic Resonance Imaging (MRI) to a minimum and at the same time yield the same precision during samples targeting due to a novel MRI-Ultrasound (US) registration."

On-going research projects in Verona (2)

SARAS - Smart Autonomous Robotic Assistant Surgeon

“The goal of SARAS is to develop the **next-generation of surgical robotic systems that will allow a single surgeon to execute Robotic Minimally Invasive Surgery (R-MIS) without the need of an expert assistant surgeon**, thereby increasing the social and economic efficiency of a hospital while guaranteeing the same level of safety for patients.”

On-going research projects in Verona (3)

“The ARS project aims at making the scientific advances that will enable the autonomous execution of complete procedures in uncertain and partially unknown environments.”

Challenges, Future and Conclusion

- Haptic feedback
- A safe, easy sterilizable, accurate, cheap and compact robot
- Reliable telesurgical capabilities
- Compatibility with available medical equipment and standardizing
- Autonomous robot surgeons

Challenges, Future and Conclusion

Automation:

The ability to carry out a task repetitively, without human intervention. Tasks are well defined, actions are governed by a set of well defined rules, the environment is well known and structured. *Adaptation is bounded and pre-programmed.*

Autonomoy:

The ability to carry out a task without human intervention and to make cognitive decisions about the task. Tasks are defined in general terms, actions are are governed by learning and adapting previous knowledge to current situations, the environment can be changing, uncertain and not predictable a priori. *Adaptive actions are not pre-programmed*.