



→ Integration. Practical Examples

Some examples to illustrate system integration in multi-level aspects



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1

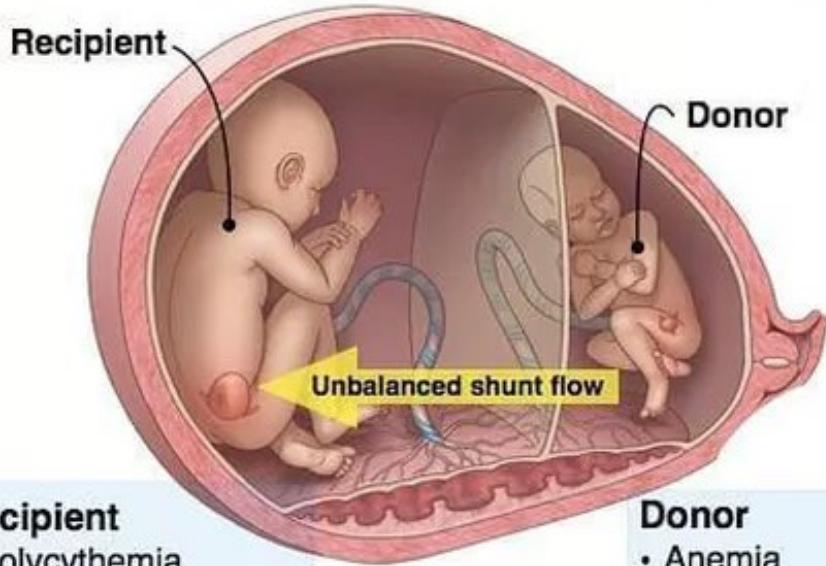


Introduction to Twin to Twin Transfusion Syndrome (TTTS)

TTTS. Description

Twin-Twin Transfusion Syndrome

Serious complication of monochorionic multiple gestations

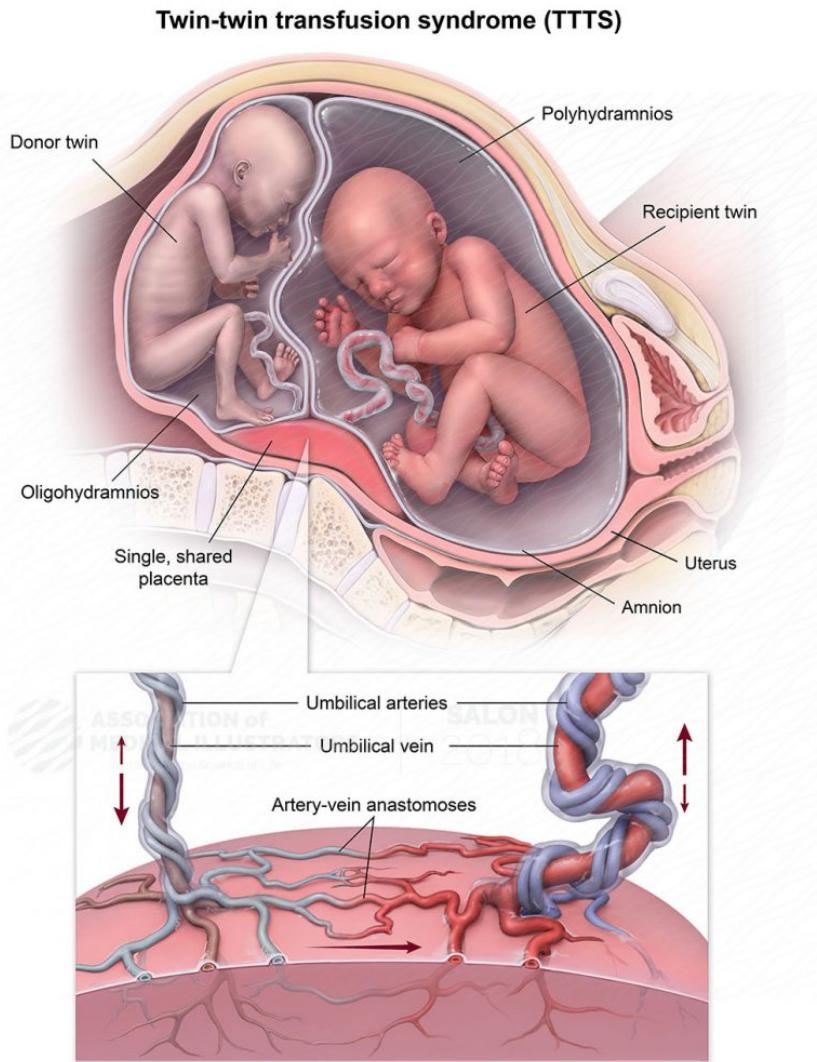


Recipient

- Polycythemia
- Hypertension
- Polyuria
- Polyhydramnios
- Circulatory overload
- Heart failure
- Hydrops fetalis
- Fetal demise

Donor

- Anemia
- Hypotension
- Oliguria
- Oligohydramnios
- Circulatory insufficiency
- Growth restriction
- Renal failure
- Fetal demise

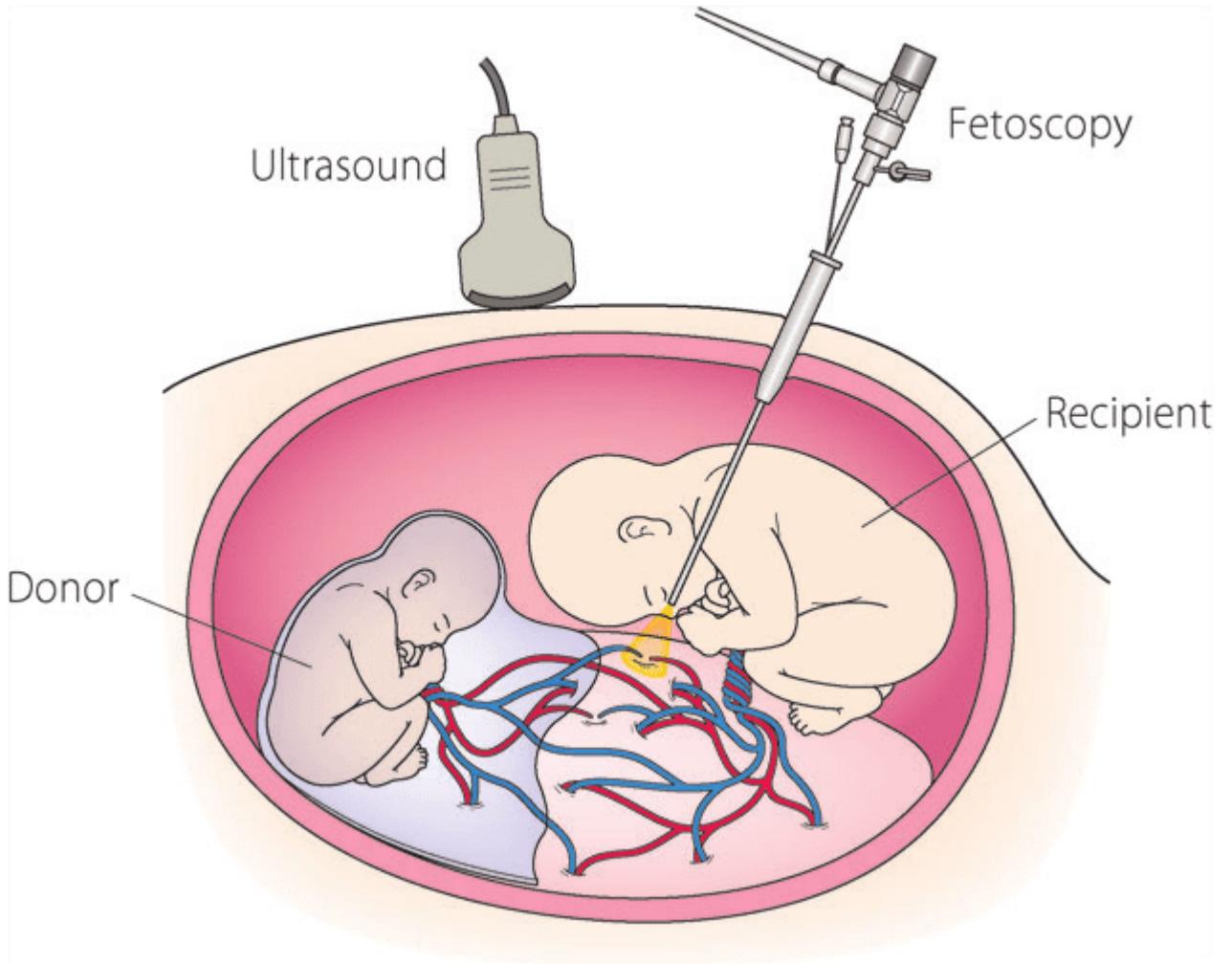


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TTTS. Minimally invasive surgery approach



TTTS. Minimally invasive surgery: main challenges

- Low precision: long tool with restricted movements (trocar)
- Collisions/penetration of fetoscope into placenta: placenta movements (pseudo-periodic and asynchronous)
- Low ergonomics during surgery: Crowded workspace shared with several medical staff (e.g. surgeon controlling optical fiber, sonographer)
- Low image quality, reduced field of view: Difficult to locate/re-locate anastomoses, high probability of leaving anastomoses without coagulation
- Rupture of amniotic sac due to multiple punctures: Undesired trocar exit (friction between trocar and fetoscope)
 - etc





TTTS. Minimally invasive surgery: did you say “bad image quality?”





2

Robotic Minimally Invasive Surgery for TTTS



TTTS. Robotic Minimally invasive surgery: improvement

Discussion:

Improvements that robotics can provide to minimally invasive TTTs surgery



TTTS. Robotic Minimally invasive surgery: improvements

- Increase precision & decrease tremor: motion scaling, filtering
- Improve precision: Motion stabilization using image analysis, motion scaling
- Prevent collisions/penetration of fetoscope into placenta: active control of placenta <> fetoscope relative position, automatic optical fibre control
- Improve economy of movement and execution time: automatic fetoscope navigation and POIs relocation and fine tracking
- Decrease coagulated surface: ROI stabilization and tracking, force feedback guidance



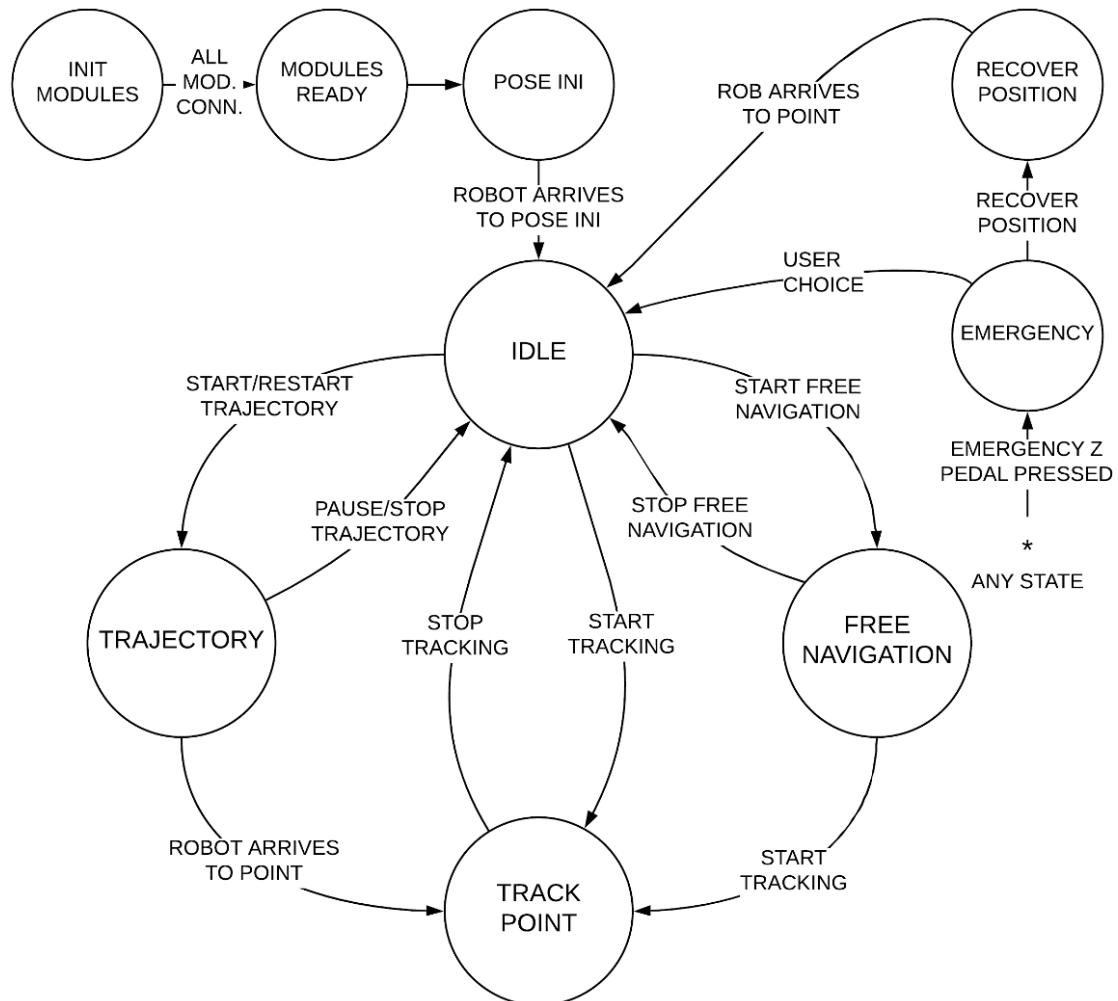
TTTS. Robotic Minimally invasive surgery: improvements

- Avoid multiple punctures (probability of break amniotic sac) : **Automatic trocar compensation**
- Decrease probability of leaving anastomoses without coagulation:
Interactive map and POIs information, check list in GUI
 - etc



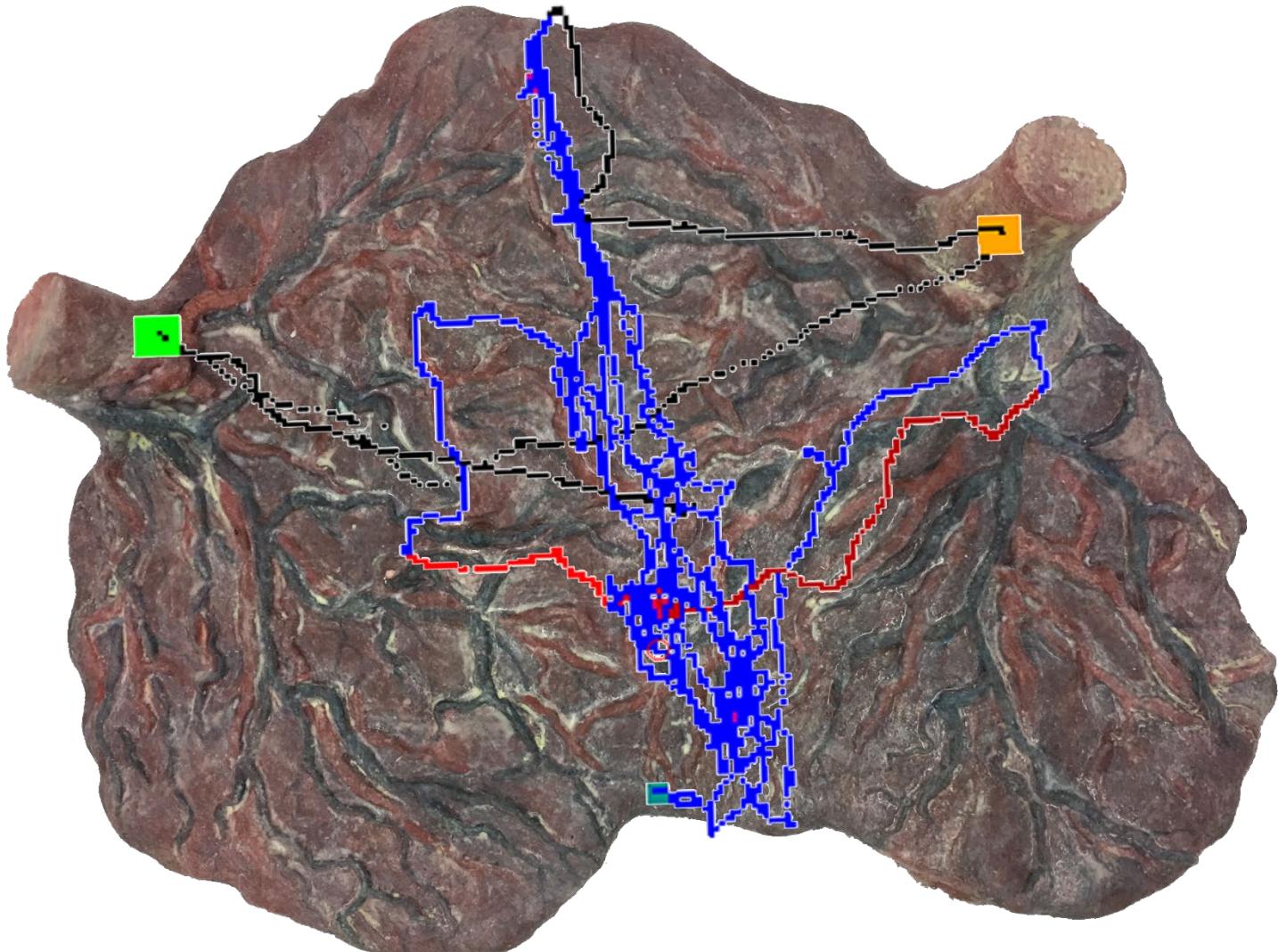
TTTS. System State Machine

- The system has 3 principal modes:
 - Free Navigation
 - Tracking: The system tracks a point in the image and gives force feedback towards that point and compensates the placenta movements.
 - Trajectory: The system creates a trajectory between the current position and the selected location using the paths used in the exploration process.





TTTS. Example of placenta's map





3

Teleoperated/co-manipulated robotic system for RMIS fetoscopy



TTTS. System Requirements

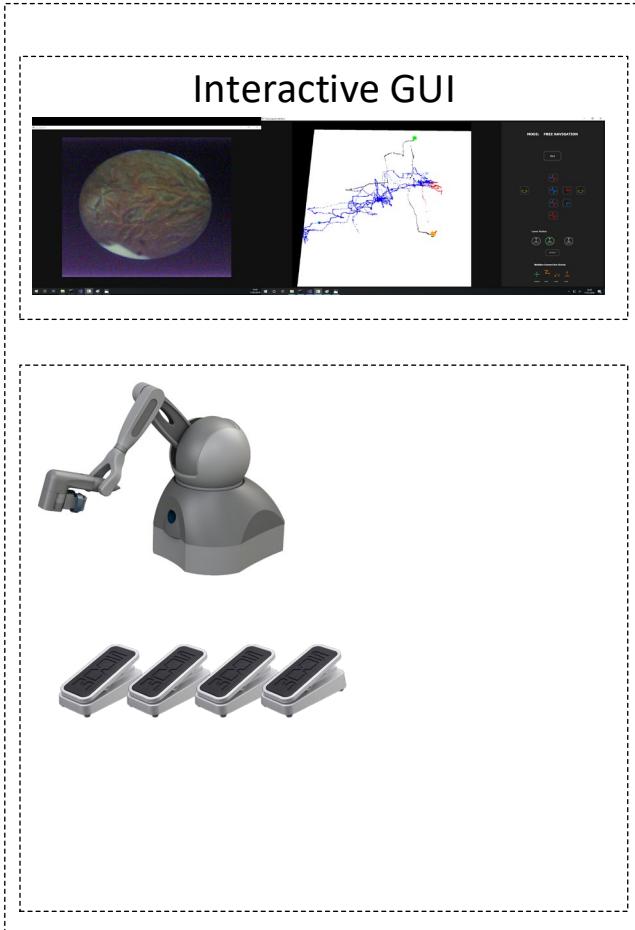
- Teleoperated system with a single robotic arm guiding the fetoscope
- Co-manipulation to accelerate system set-up
- Automatic optical fiber control to extend and retract
- Trocar <> fetoscope depth compensation
- Placenta mapping with POI registration: type, status, pre-post coagulation images, etc.
- Automatic navigation to POIs using safe (free collision) paths (using optimized pre-defined user paths)
- Active collision detection based on tool <> placenta distance
- Adaptive task oriented UI



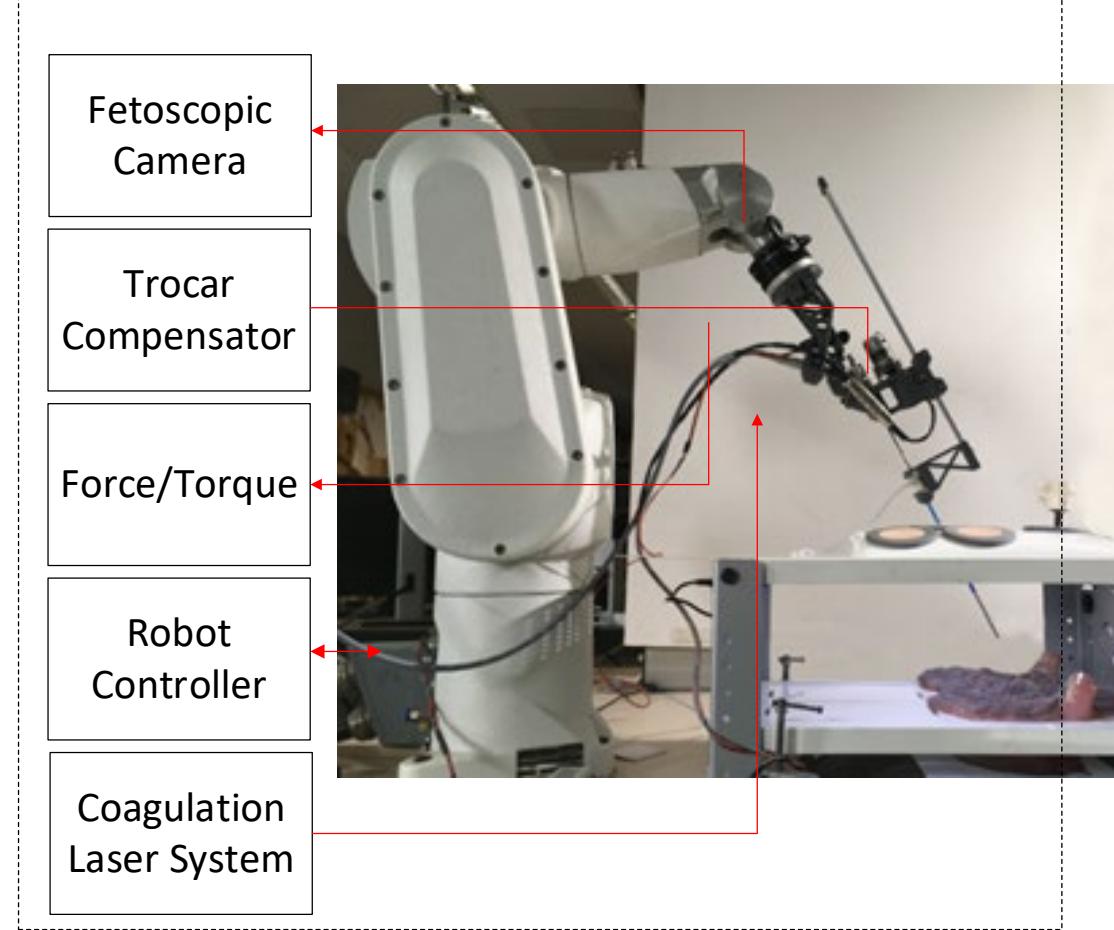
Example of integration system: Fetoscopy TTTs



Master Console



Single-Robot Slave Unit



4

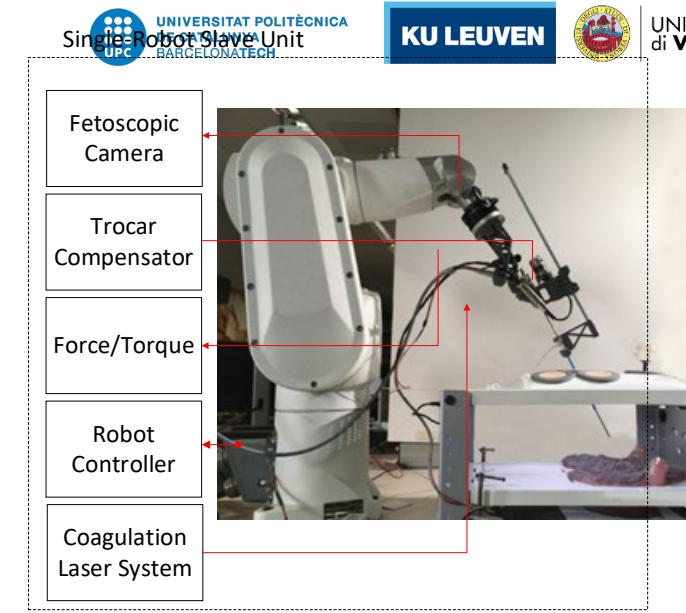


Hands on: Integration

→ Hands On: Integration

ToDo

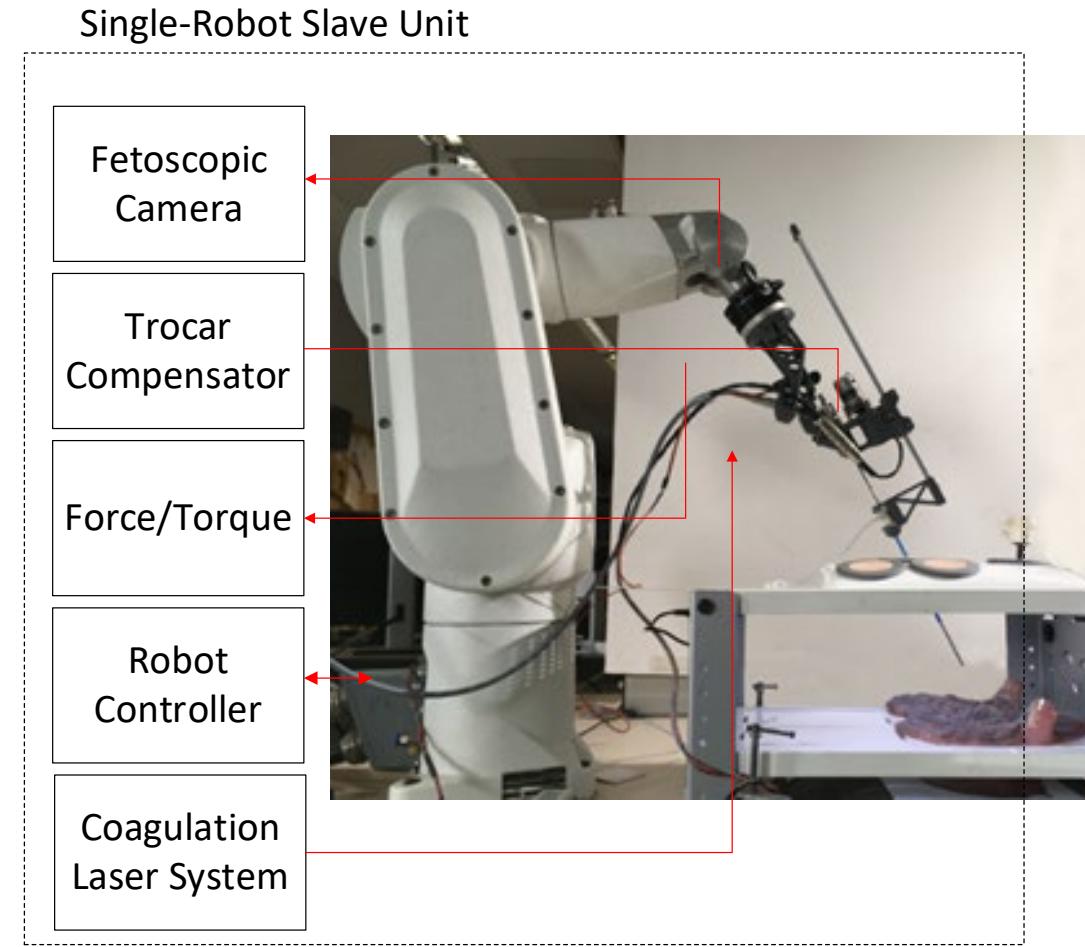
- Define modules controlling each sub-system.
- Define interaction between modules (communication data)
- Define main control modules to full-fill with system requirements.
- Define a safety policy indicating which modules are involved and their role
- Design a centralized control system (block schema) that receives data from master and send an incremental movement to the fetoscope tooltip.



Best practices in programming



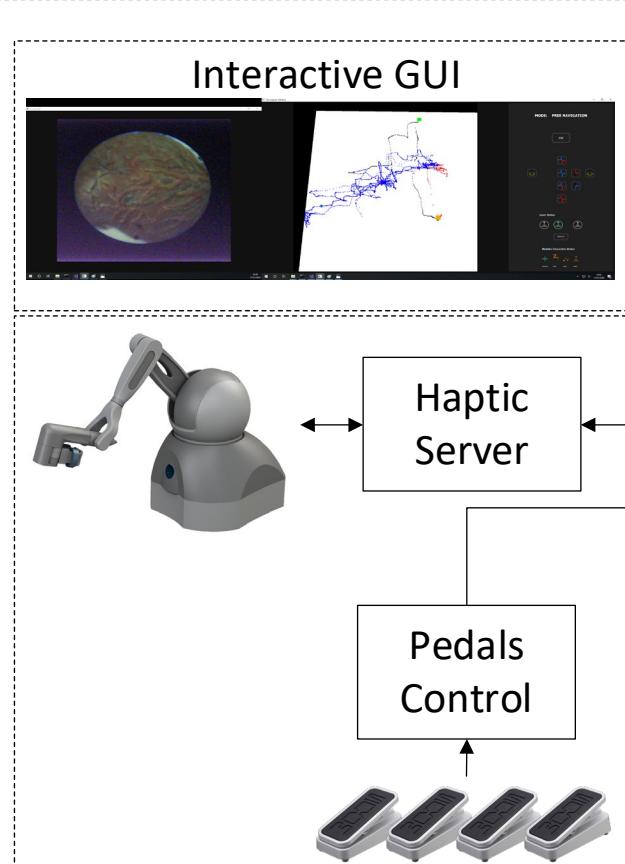
ToDo



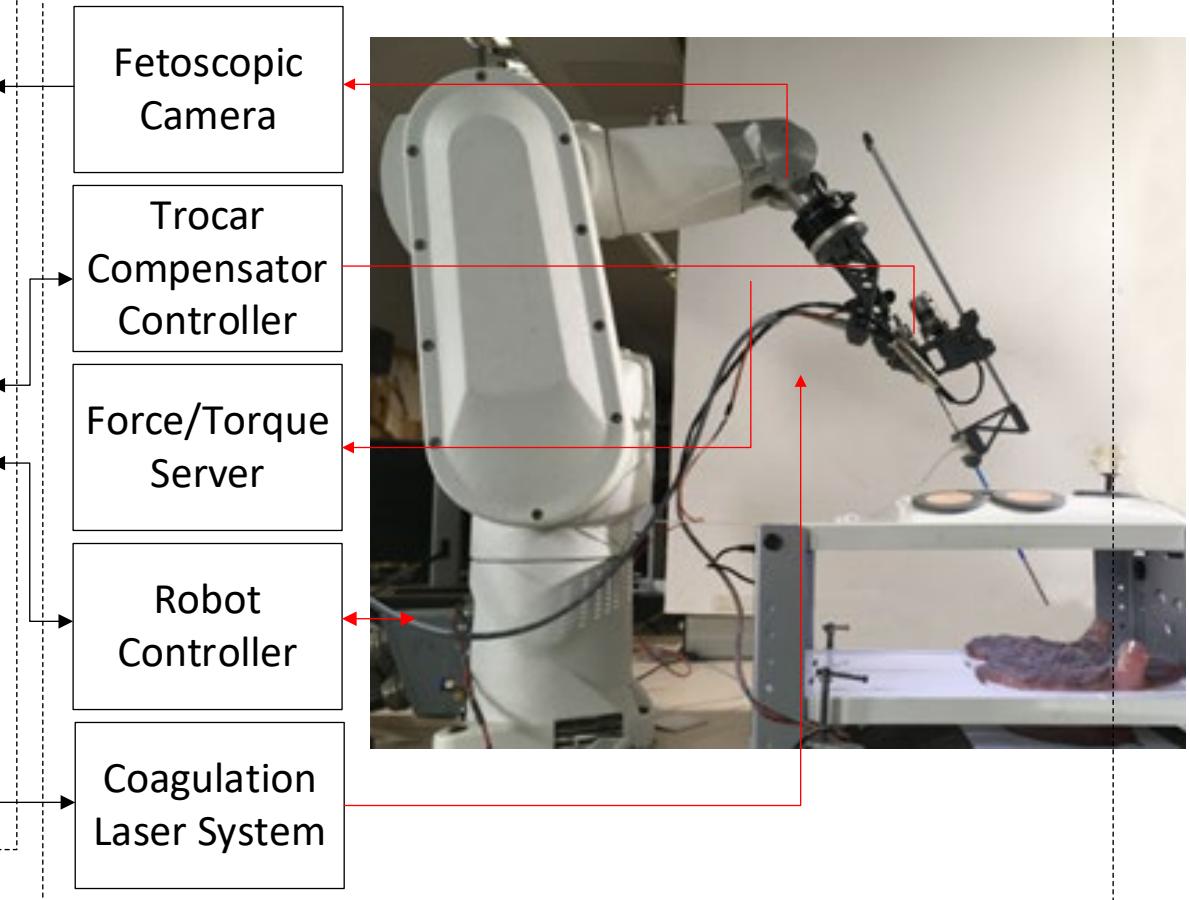
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Real system solution

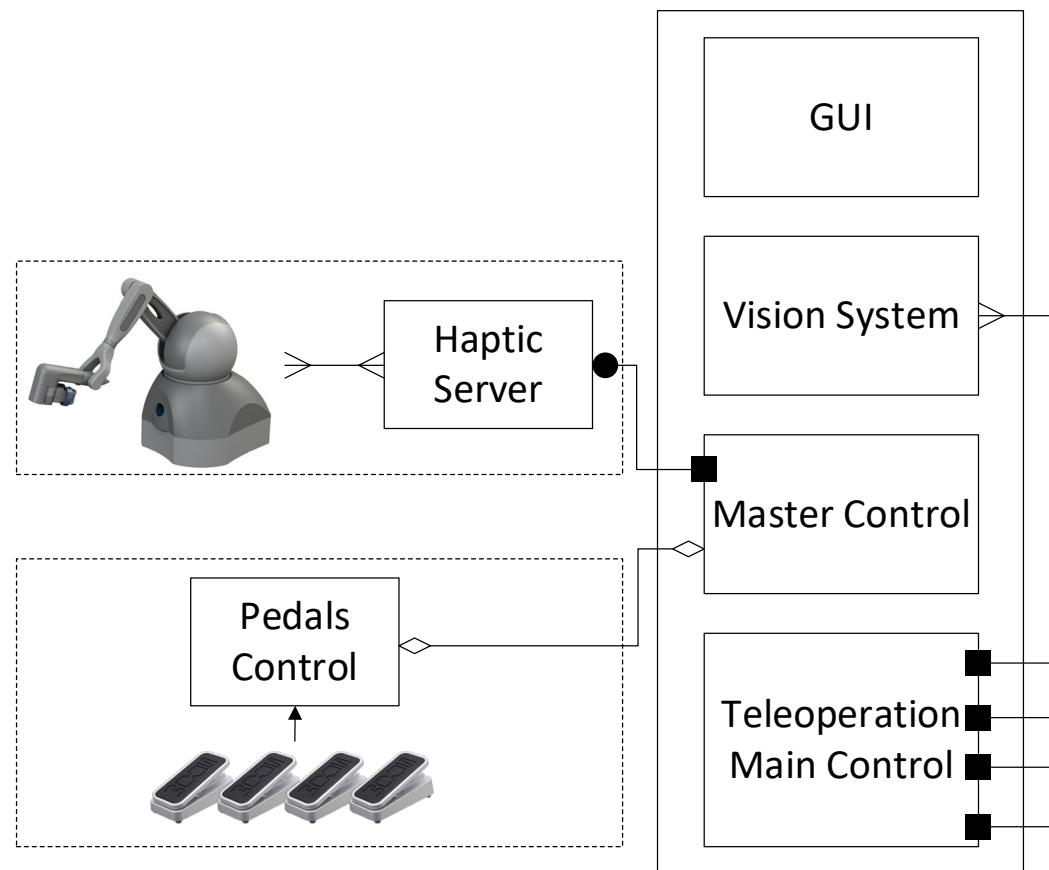
Master Console



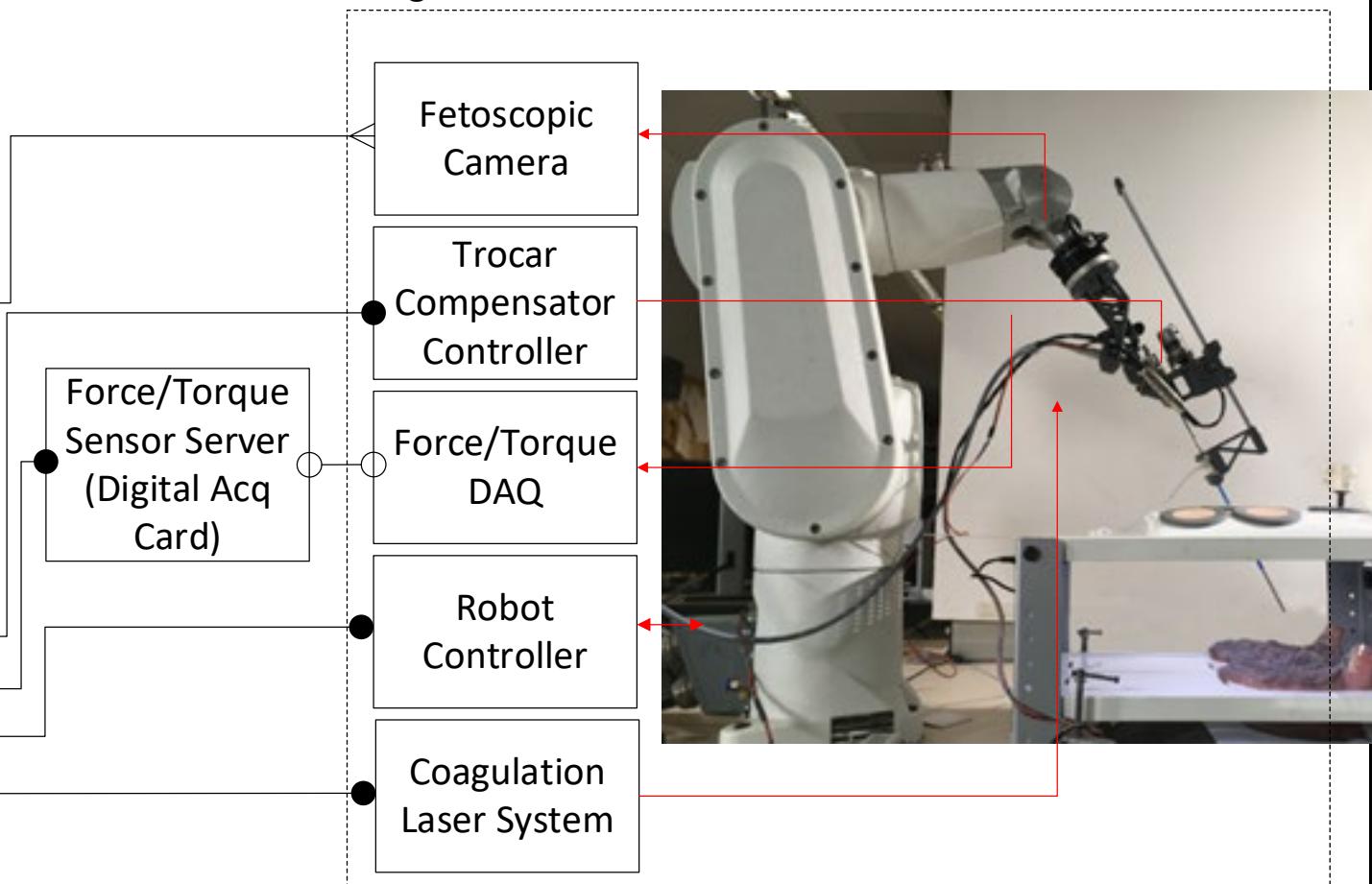
Single-Robot Slave Unit



Master Console



Single-Robot Slave Unit



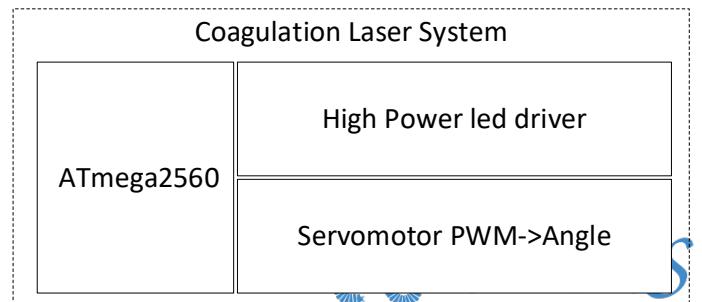
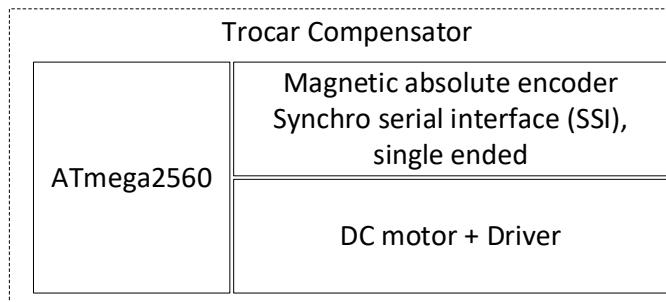
Best practices in programming

● Ethernet Client-Server (TCP Socket)

→ Fast USB (3.0)

◊ Serial/USB (2.0)

○ Device Specific





Haptic Server

C++

Open Haptics: HD/HL API to control Touch Haptic device (Touch POSE, and force/haptic feedback)

WinSock:Server Communications. High level TCP server creation and management

Pedals Control

ARV Libc Provide a high quality C library for use with GCC on Atmel AVR microcontrollers.

Socket Library High level library to create TCP server sockets

GUI

C++

QT 5 Set of high level libraries and development tools oriented to advanced GUIs. Improve usability, modern UI look and feel, ...

OpenGL API for rendering 2D and 3D vector graphics: Placenta's map visualization and interaction

Vision System

C++

OpenCV Library of programming functions mainly aimed at real-time computer vision

uEye Image Acquisition Interface for IDS uEye Cameras



Teleoperation Main Control + Master Control

C++

OpenGL	API for rendering 2D and 3D vector graphics: Visualization of slave robot and environment
RobLib	Library to control multiple robots and real time distance computation
WinSock:Server	Communications. High level TCP client creation and management
Interpret client library	High level robot control and communications

Force/Torque Server

C++

ATICombinedDAQFT .NET	Library to read calibration files, control NI-DAQmx-compatible DAQ device, and calculates the transducer's force and torque
WinSock:Server	Communications. High level TCP server creation and management

Trocars Compensator Controller

ARV Libc	Provide a high quality C library for use with GCC on Atmel AVR microcontrollers.
Socket Library	High level library to create TCP server sockets

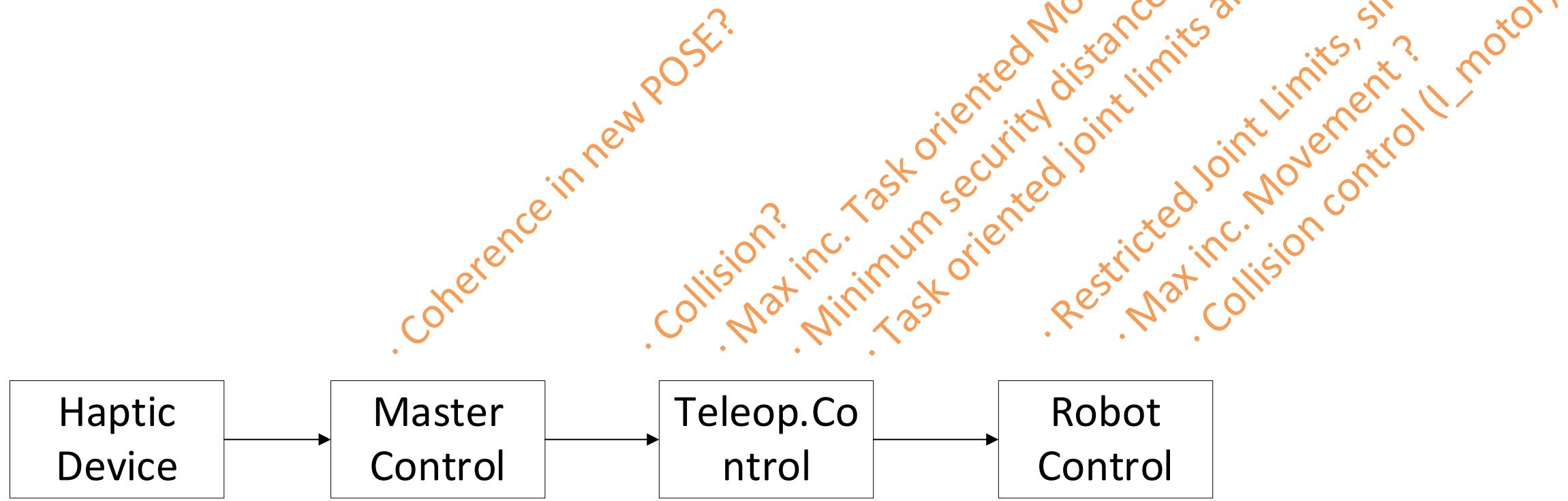
Coagulation Laser System

ARV Libc	Provide a high quality C library for use with GCC on Atmel AVR microcontrollers.
Socket Library	High level library to create TCP server sockets
Servo Motor Library	Servo motors control library (PWM based)

Robot Controller

Val 3, Val+	Low level programming language for Staübli RX60B robot
Interpret server library	High level to low level instructions for robot controller

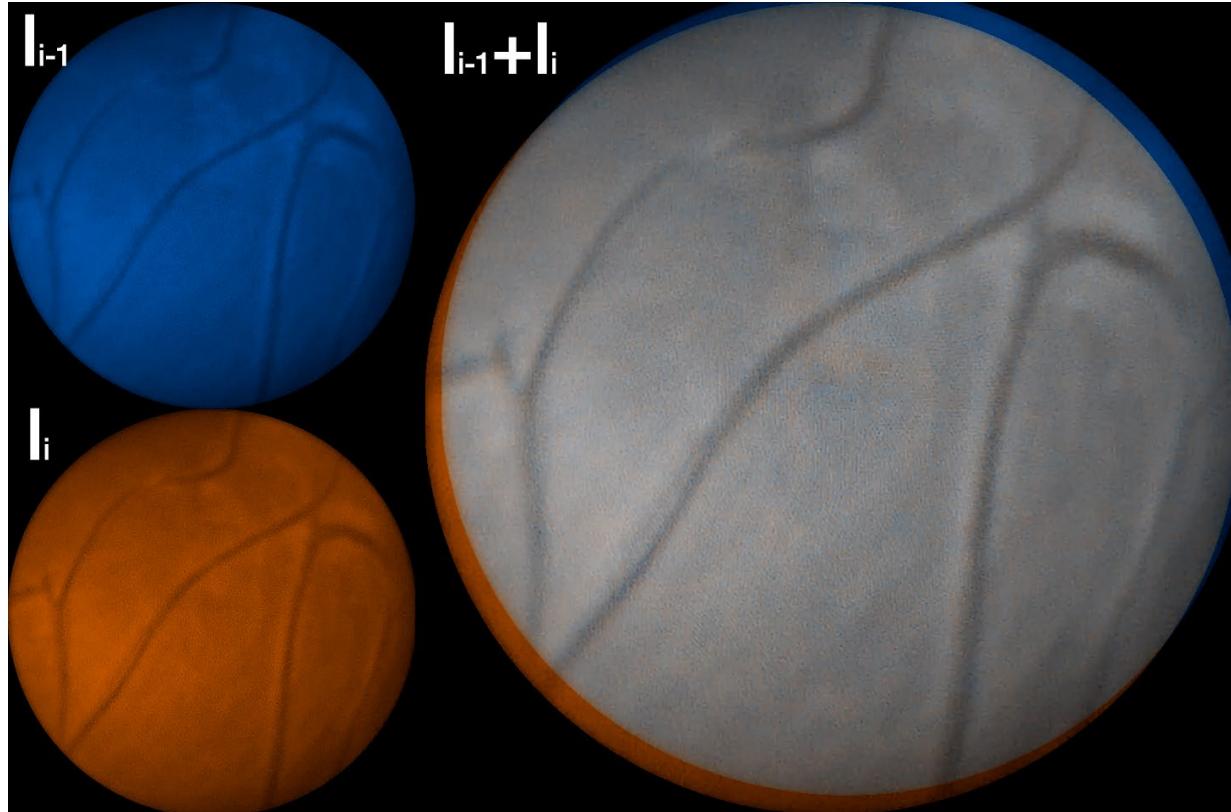
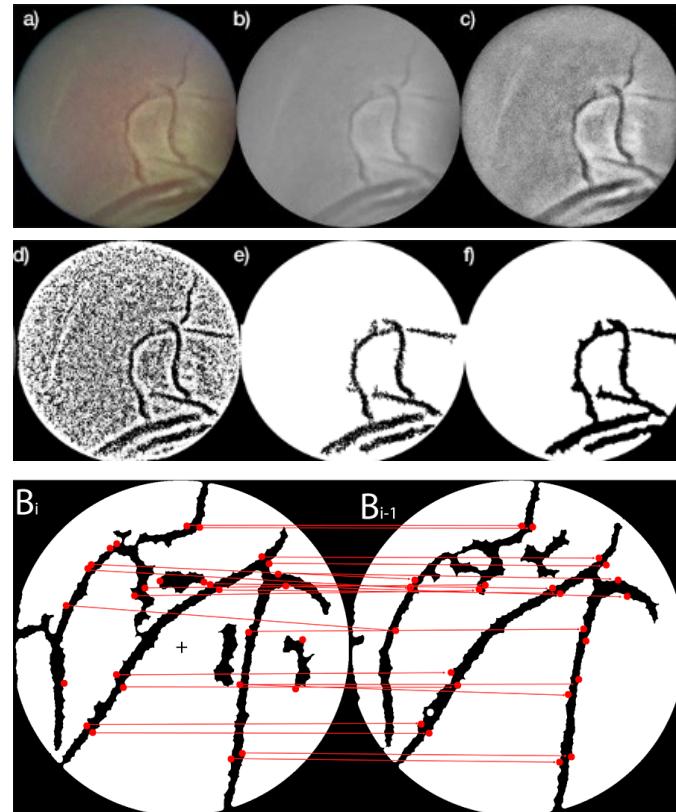
Active Fetoscope Movement Multi-Layer Security



Reactive Anatomy Movement Security

1. Placenta movement based on vascular surface visual information

ROI placenta movement = Robot inc mov – Vascular structures variation





Reactive Anatomy Movement Security

1. Placenta movement based on vascular surface visual information

A Vision based Algorithm for robotic assistance in TTTs Fetal Surgery

ICRA 2019 | Narcís Sayols, Albert Hernansanz, Johanna Parra, Elisenda Eixarch,
Eduard Gratacós, Josep Amat and Alícia Casals



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Reactive Anatomy Movement Security

2. Depth perception using monocular 3D stereo vision (REMODE)

