Haptic Interface for the performance of a remote echography examination

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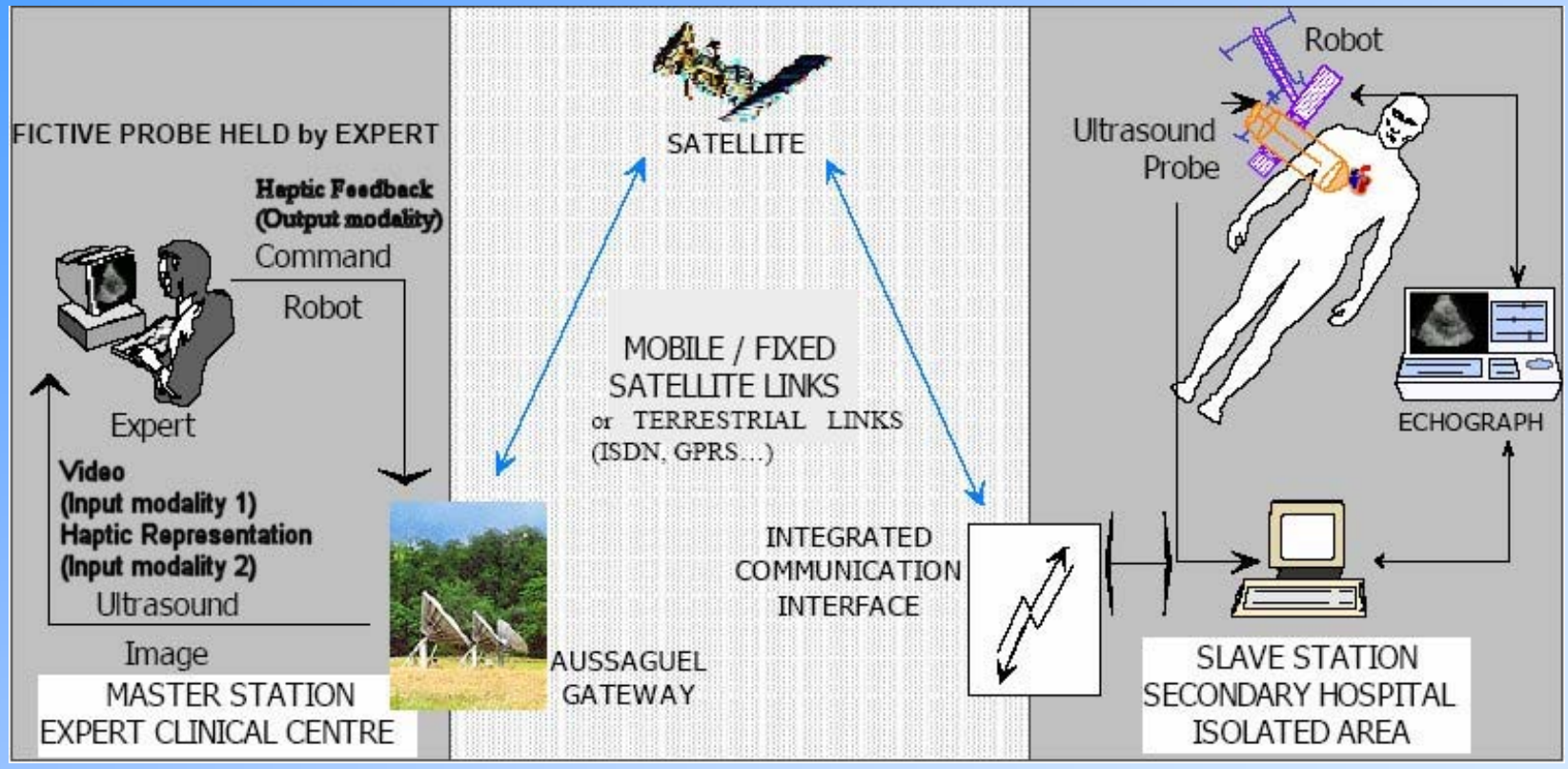
Overview

- Description of the tele-echography examination system
- Communication scenarios
  - Examine application requirements and various communication scenarios
- User Interface
  - Application GUI
  - VR environment
- Synchronization of master and slave probes
  - Time, position and force feedback scaling issues
- Conclusions

Overall system architecture



Remote ultrasound examination

- Master station:
  - Expert
  - Haptic device handled by the expert
- Slave station:
  - Patient
  - Paramedical stuff
  - Robot structure
  - Echograph

Master Station

- At the master station
  - A virtual reality environment is used in order to provide the doctor with visual and haptic feedback
  - The expert controls and tele-operates the distance mobile robot by holding a force feedback enabled fictive probe
  - The Phantom fictive probe provides data to control the mobile robot

Slave Station

- At the slave station
  - The paramedical stuff localizes the robot structure on the anatomical region of the patient guided by the expert
  - In order to receive the correct contact force information of the ultrasound probe, the haptic interface at the master station is properly associated to the slave robot. Important if video is not transmitted.

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Communication Scenarios

- The communication scenarios examine the application requirements in terms of:
  - Data transmission
  - Bandwidth
  - Quality of the channel
- Selection of the appropriate communication model is based on these characteristics

Data transmission priority

- Priority of data that must/should be transmitted.
  1. Ultrasound Video (from the remote site to the master site)
  2. Probe position data (from the master site to the remote site)
  3. Force feedback and robot position feedback data (from the remote site to the master site).

System usability

- The system is considered usable if it provides at least real-time ultrasound video and probe position data communication
- In case of significant delay, the force feedback data are not transmitted, but calculated locally from the 3D parametric model

Communication Models

- Communication Models used :
  - Video + Position
  - Video + Position + force feedback
- Selection of the appropriate communication model depends on the available communication channel
- Trials using packet erasure channels with variable packet error rate (PER) and bandwidth have been performed

Communication channel selection for PER=10%

Channel bit rate Kbps (PER=0.1)	Video (bit rate) Kbps	Position (bit rate) Kbps	Force/position Feedback (bit rate) Kbps	Average Delay /minute (sec)
56	30	26	-	0.46
64	35	29	-	0.32
96	35	30	31	0.87
128	40	40	48	0.06
>128	40	40+	48+	~0

Communication channel selection for PER=1%

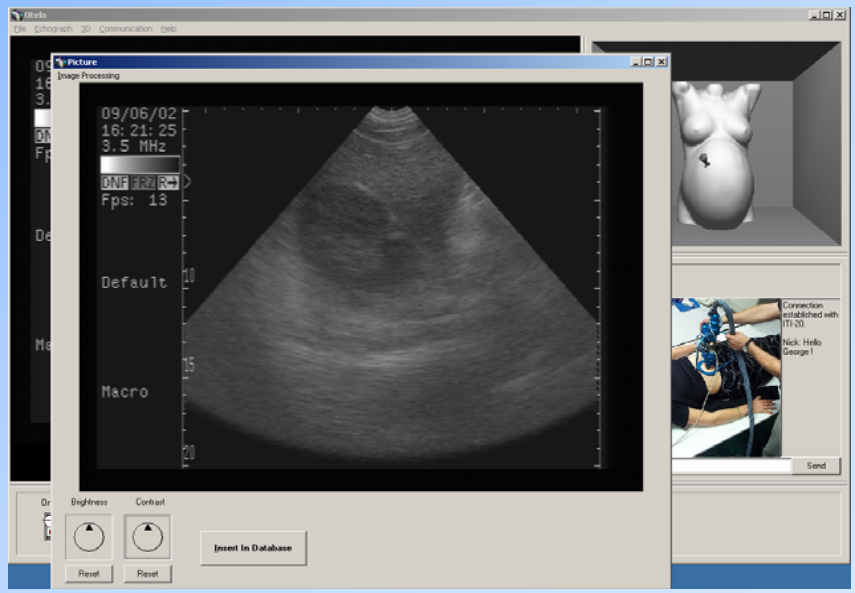
Channel bit rate Kbps (PER=0.01)	Video (bit rate) Kbps	Position (bit rate) Kbps	Force/position feedback (bit rate) Kbps	Average Delay /minute (sec)
56	30	26	-	0.0
64	35	29	-	0.0
64	30	12	22	0.73
96	35	30	31	0
128	40	40	48	0
>128	40	40+	48+	0

User Interface

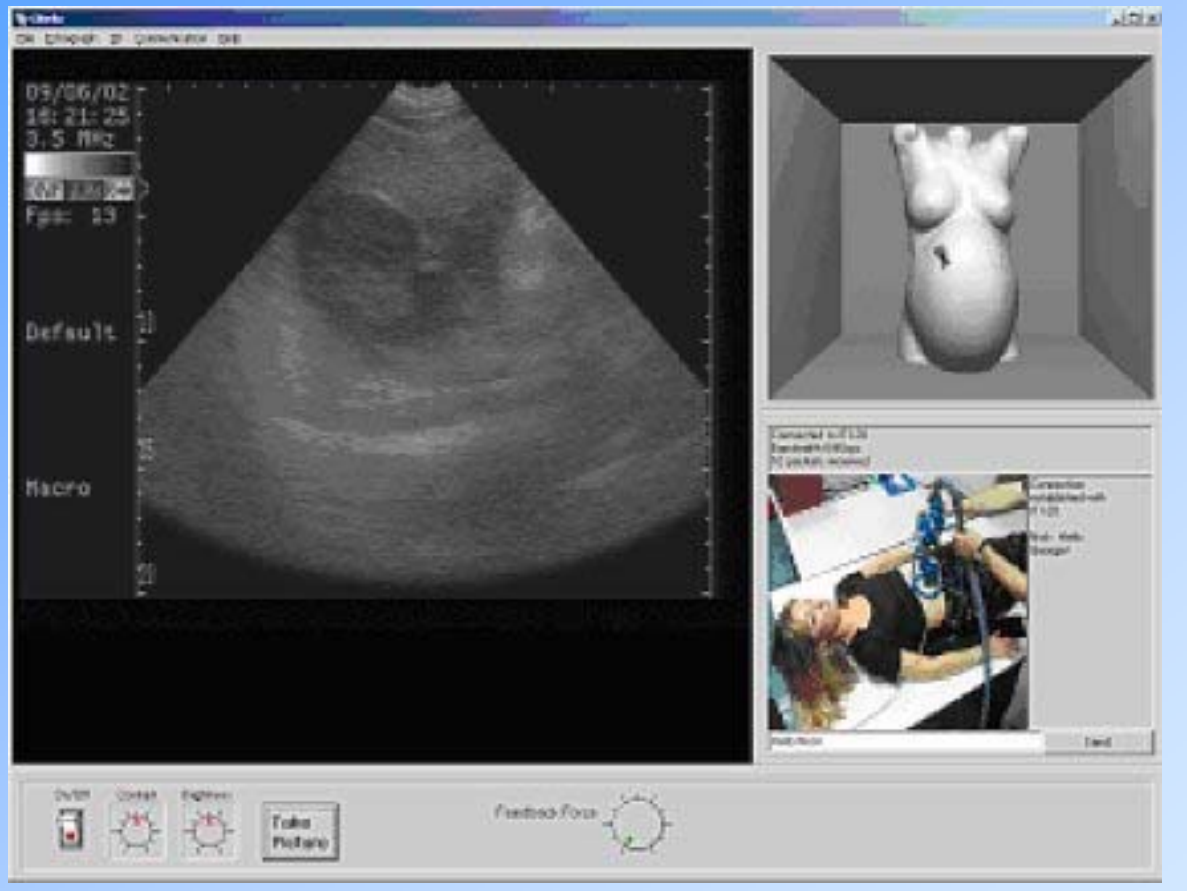
- At the master station the expert's role is to control and tele-operate the distant mobile robot by holding a force feedback enabled fictive probe.
- The medical expert must be able to be in visual contact with the patient and the slave robot positioning during the medical examination. This is possible either through the transmission of an environmental video or a VE simulating the procedure in the remote station. In sequel features of the UI and the VE will be analyzed.

UI Features

- Transmission of high resolution Ultrasound Images
- Sequence of Images from the organ of interest
- Communication between users (expert and paramedical personnel) in the master and the slave station

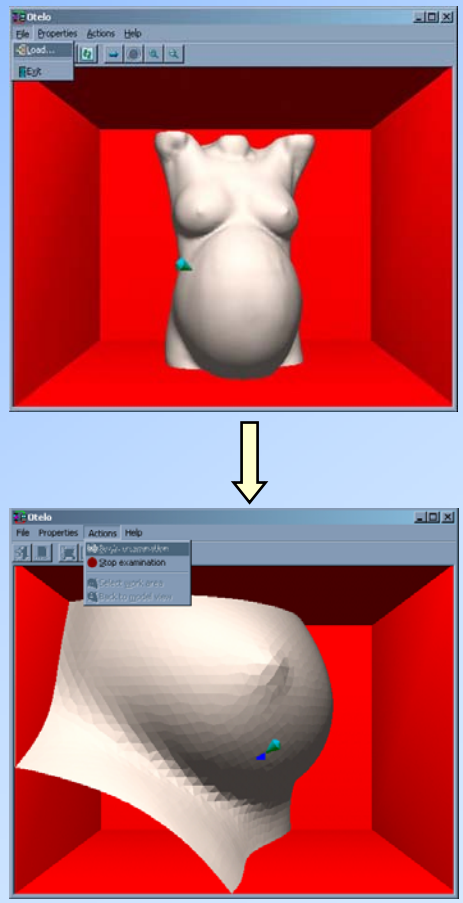


Master Station GUI



VE Features

- Using the VE the expert can:
  - View a representation of the workspace
  - Select the area of the body to be examined
  - Start stop the examination process
- A cone in the workspace represents the position of the probe in the VE and a small cube the position of the remote robot in the remote site



Synchronization

- The use of a master probe and a slave robot brings up the problems
- Different workspaces
- Time delay is introduced in the system

Workspace synchronization

- Use of indexing or scaling can solve the problem of different workspaces
- Indexing means that the movement is not scaled but a variable offset (index) of the master's position within the slaves' workspace.
- Indexing doesn't affect force feedback calculation however it is not very comfortable to stop the operation in order to change the index and examine neighboring areas.

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Workspace scaling

- Scaling is the second solution for the problem of different workspaces
- If scaling is applied only to the positions and forces felt by the human remain the same as measured then the appearing stiffness of the environment changes due to the scaling factor *s*

$$X_{slave} = s\, X_{probe}$$

where *Xslave* and *Xprobe* vectors defining the position of the slave robot and the master probe.

Force feedback scaling

- To avoid changes in stiffness the force feedback can be calculated using the formula.

$$f_{ph}=K_p(X_{ph}-X_{slave}/s)+K_f\, f_{Env}/s$$

- Where
  - f_{ph}: is the force vector send to the haptic device
  - K_p: represents a virtual coupling between the master and the slave system
  - X_{ph},X_{slave}: are the positions of the haptic device and the slave robot, respectively
  - K_f: is a control parameter (usually equal to 1), which can be tuned down if the communication delay affects the stability of the system

Conclusions

- A tele-echography system was presented
- Usability of the system under various communication channels was examined
- A haptic enabled VR environment was proposed that enables the realistic representation and remote handling of the echograph
- Realistic force feedback calculation was proposed

THANK YOU!

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