Augmented Reality Enabled Collaboration

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ESA Contract No. 4000108961/13/NL/GLC/al

Outline

- Problem Definition
- Action Schedule
- Related Work
- Solution: AR for Inflight Maintenance Training (by virtual co-location)
- Distributed Collaborative Augmented Reality Environment (DECLARE).
- Short videos of AR collaboration system
- Usability Study
- Evaluation of Constraints for AR Collaboration support for LEO operations
- Future work

Problem definition

- Work scenario: **Inflight maintenance training** environment
- In modern work environments, even more **complex technologies, protocols and scenarios** are required not only to increase the productivity of workers, but also to fulfill basic work tasks. Often, typical work scenarios demand for **mixed teams of workers** that have **different levels and types of expertise**
- **Inconsistency typically rises serious problems** further leading to the **temporary inability to perform optimally** the assigned tasks.

- Such problems may refer to situations when:
  - The documentation is not sufficient/complete,
  - The expertise is not ready on time/on the spot,
  - The complexity of the problem/solution restricts the transfer of knowledge between the local worker and a potential remote expert using standard means of communications (e.g. audio channels by mobile phones)

Project Schedule

Task Description:

Task 1 (**T1**). Analysis of Scenarios

Task 2 (**T2**). Augmented Reality Collaboration Specification

Task 3 (**T3**). Augmented Reality Collaboration Design and Road-map

Task 4 (**T4**). Evaluation of constraints for applying augmented reality collaboration support for LEO operations

Outputs:

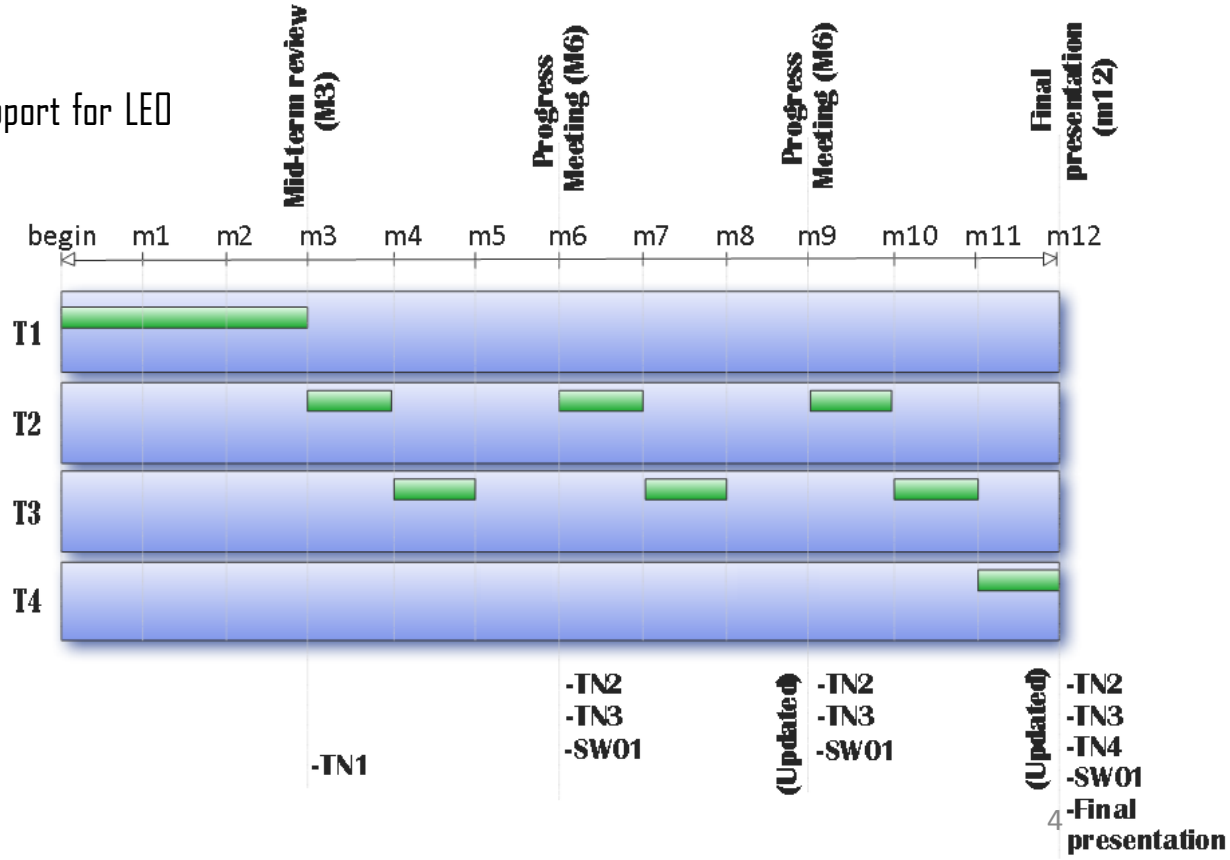
TN1: Augmented Reality technology for Astronaut Training and Operations

TN2: Specification for a Space Collaborative Solution based on Augmented Reality Technologies

TN3: Design of an Augmented Reality Collaborative Solution for Space Missions

TN4: Evaluation of constraints for augmented reality collaboration support for LEO operations

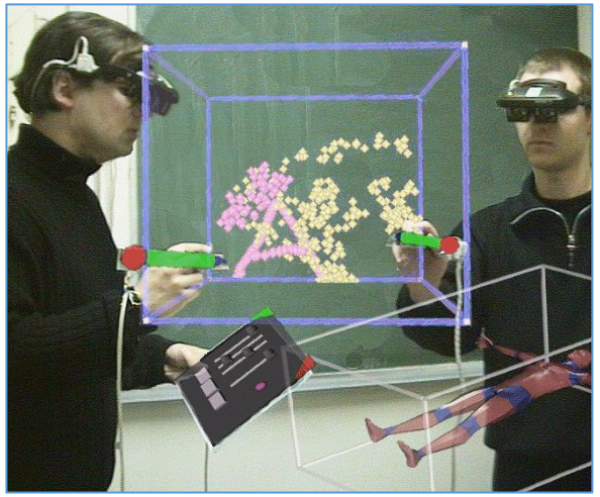
SW01: Software Demonstrator for augmented reality collaboration support.



Final Presentation

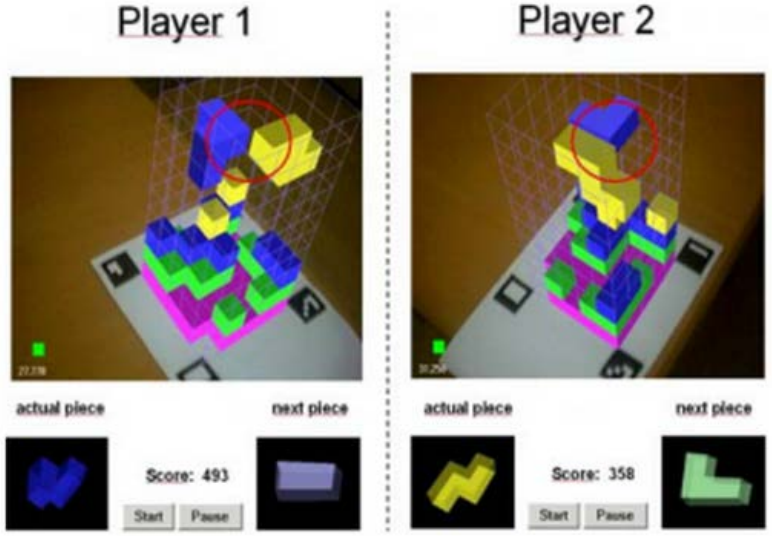
Related work

collaborative



"Studierstube" (Schmalstieg et al., 1996, 2002)

" Arthur" (Moeslund et al., 2003)



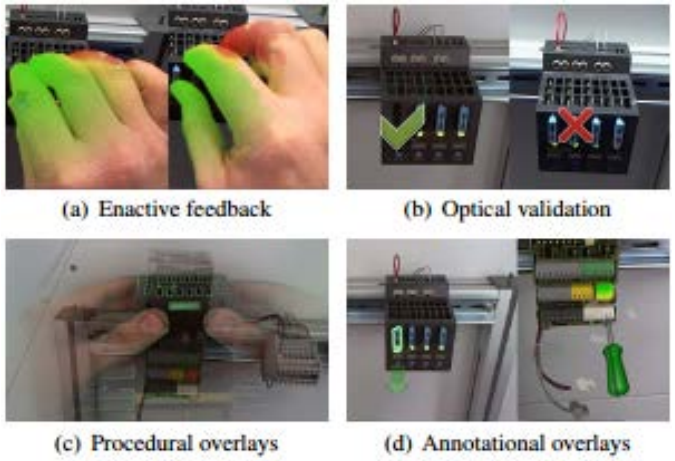
Collaborative environment allows a 3D game like Tetris (Wichert, 2002)

Remote/face-to-face collaboration (Wang and Dunston, 2011)

ReMoTe, remote guiding system - hand gesture communication in mining industry (Alem et al., 2011).

Related work

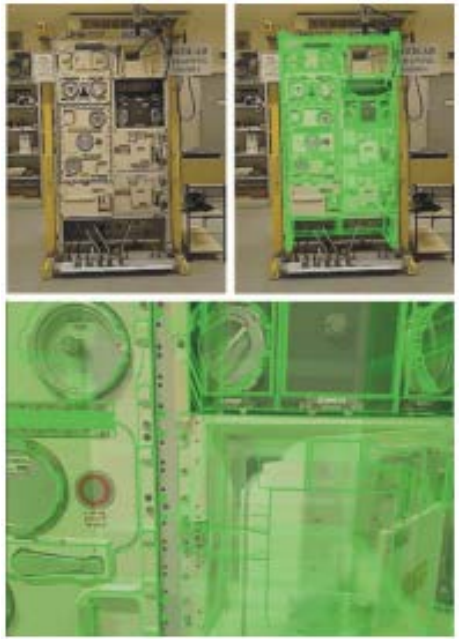
non-collaborative



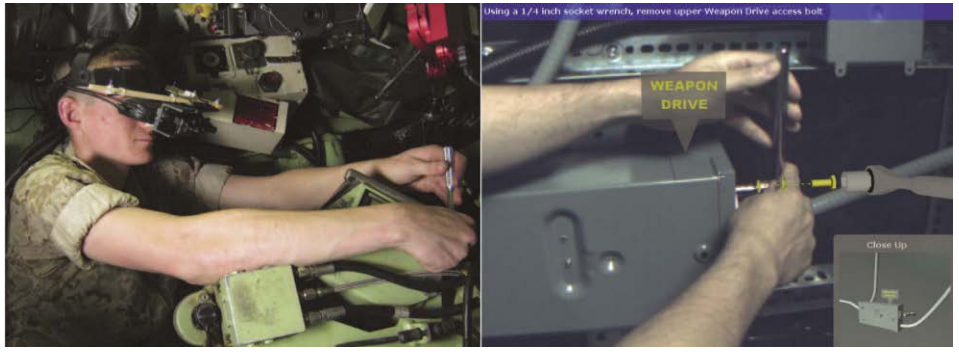
(Petersen et al., 2013)
Fully automatic tool for creating AR manuals from previously observed activity.

(De Crescenzio et al., 2011)
AR system for airplane maintenance.

(Abate et al., 2013) Servicing and repair procedures.



(Markov-Vetter and Staadt, 2013)
MARSOP (Mobile AR for Space Operation Procedures), AR guidelines for astronauts inside ISS



(Henderson and Feiner, 2011)
AR system for military mechanics on maintenance and repair tasks

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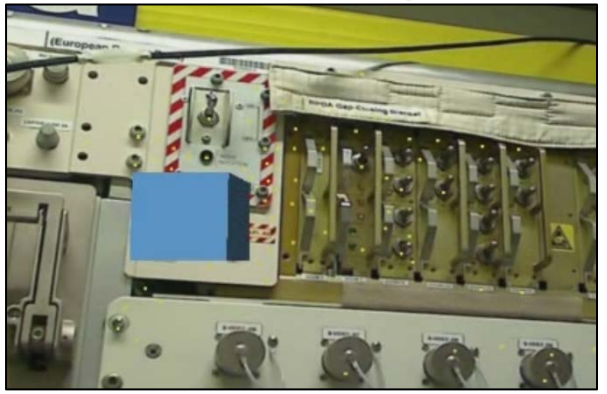
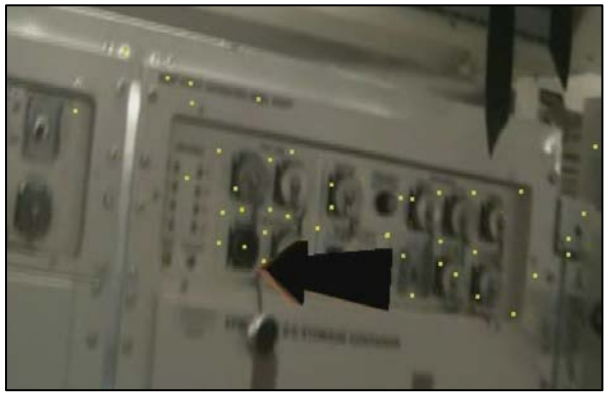
Solution: AR for Inflight Maintenance training

Augmented Reality technology for remote collaboration by virtual co-location





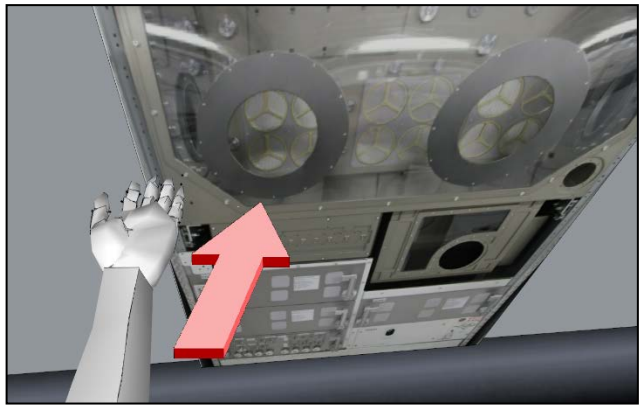
AR technology enabling **collaboration of trainee/trainer (astronaut/payload experts)**.

The AR technology allows for **the co-location in a shared virtual environment for users located at different physical places**.

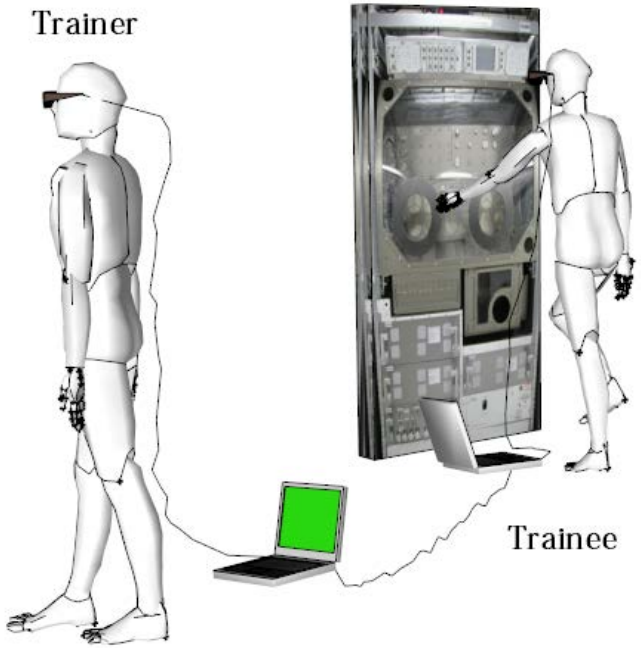
Authoring tool: the remote experts can actively augment the shared view with relevant visual content (in form of t**ext, photos, videos, static and animated objects**).

Tele-collaborative setup

Screen based Interface for Expert

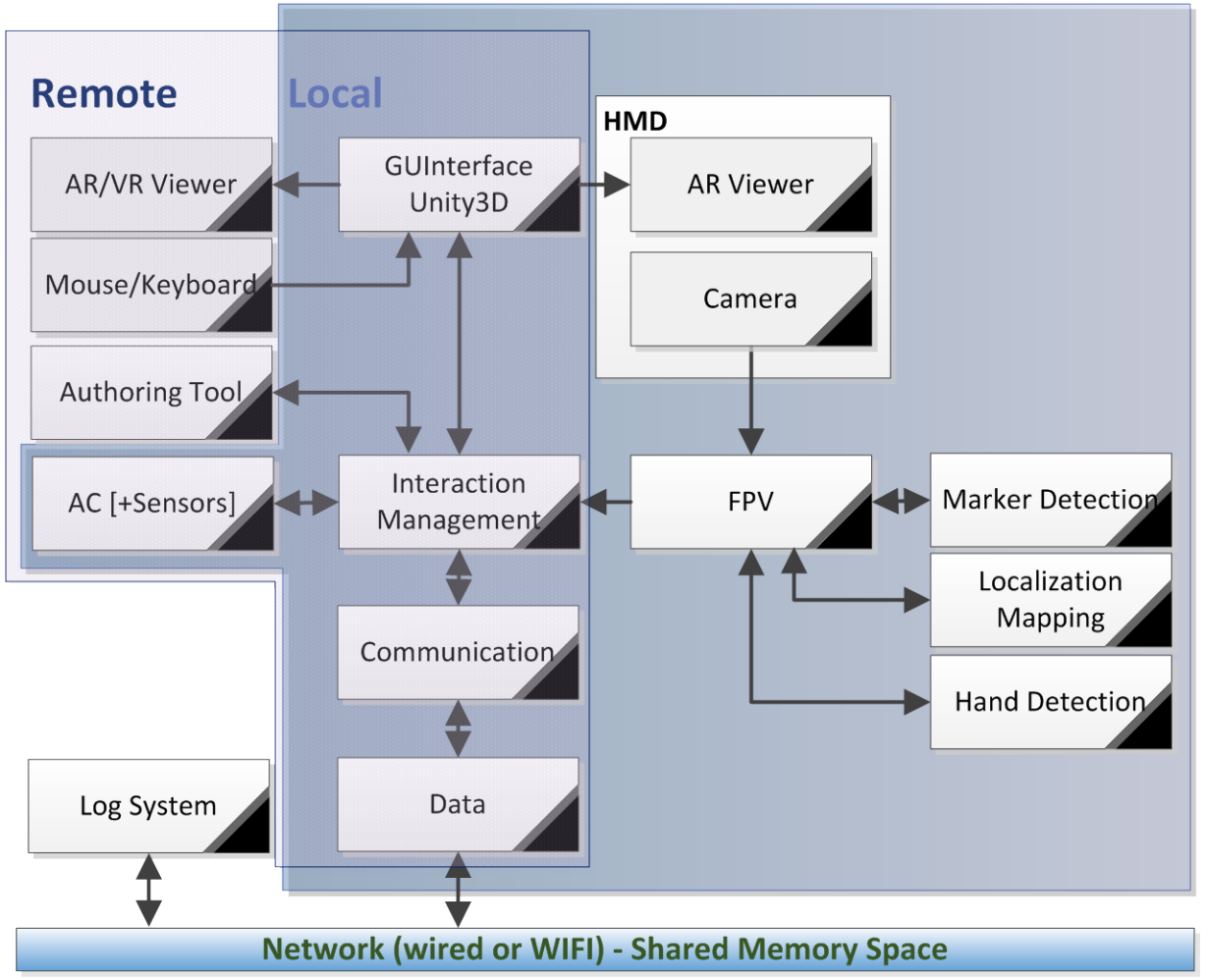


VR HMD-based Interface for Expert



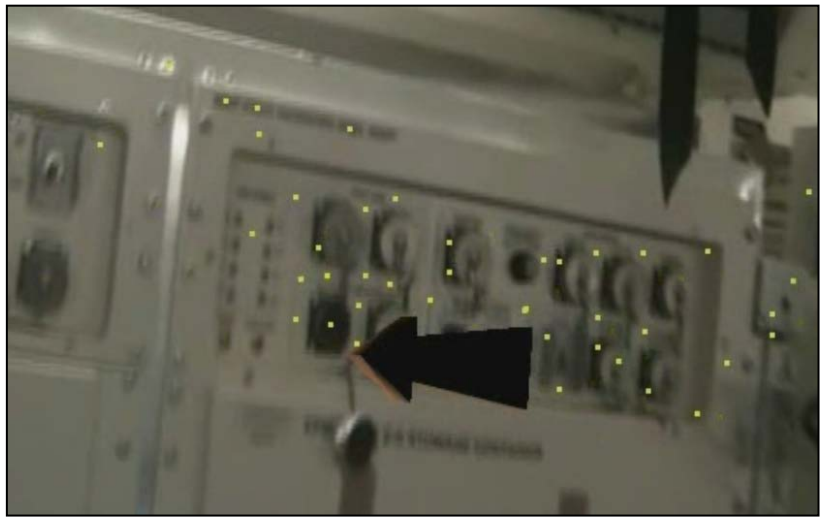
DISTRIBUTED COLLABORATIVE AUGMENTED REALITY ENVIRONMENT (DECLARE)

- supports **virtual co-location** of multiple users simultaneously,
- specialized applications serving both **local and remote roles**.
- network data **communication**
- **shared memory mechanism** to decouple data transfer in time and space
- scalable, distributed and modular architecture, with a range of functional modules e.g. hand tracking and gesture recognition
- data **logging services**, **interaction management** and the implementation of **complex video processing algorithms**
- Unity-based **customized user interfaces** - adapted to the interaction needs of the user



Examples: AR authoring (1)

[VIDEO]



[VIDEO]

AR support points and annotation in form of arrows (placed by the remote expert).

Examples (2)

[VIDEO]

Training scenario: KUBIK Maintenance – at The European Astronaut Centre in Cologne, Germany (experiment February 2014)

Examples (3)

[VIDEO]

Smart Gas Sensor (SGS)

nominal procedure:
- **connecting the payload** to a laptop using a serial port as well as power for both devices.
- the **fuse change protocol**. B. Basically switching off the device, change the fuse and switch it on again to check if it worked
- **troubleshooting procedure** that is fired from one of the previous ones. This basically implies verifying some switches and LEDS

Training scenario: Smart Gas Sensor (SGS) payload – at the ISS Columbus mockup; at ESA/ESTEC, The Netherlands (experiment June 24, 2014)

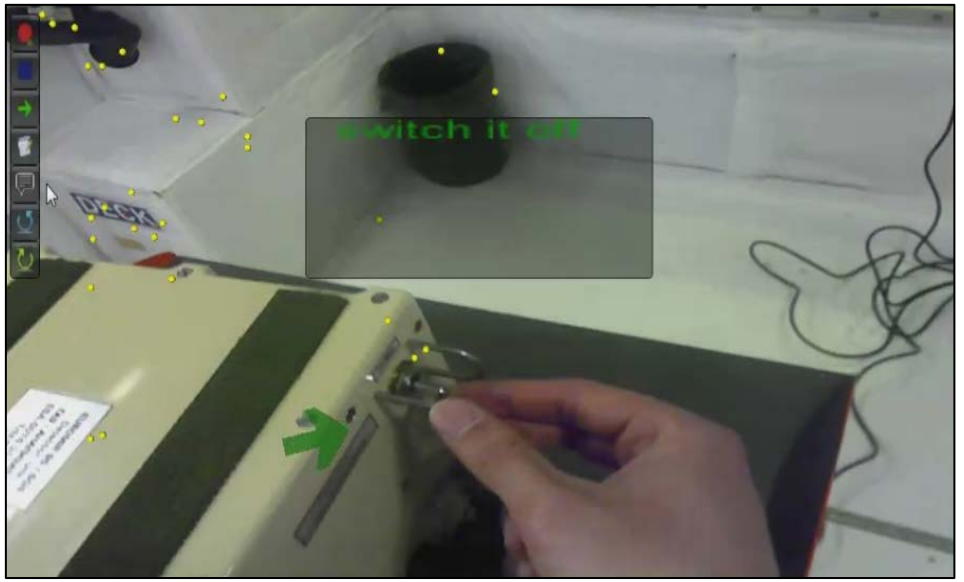
Usability Study

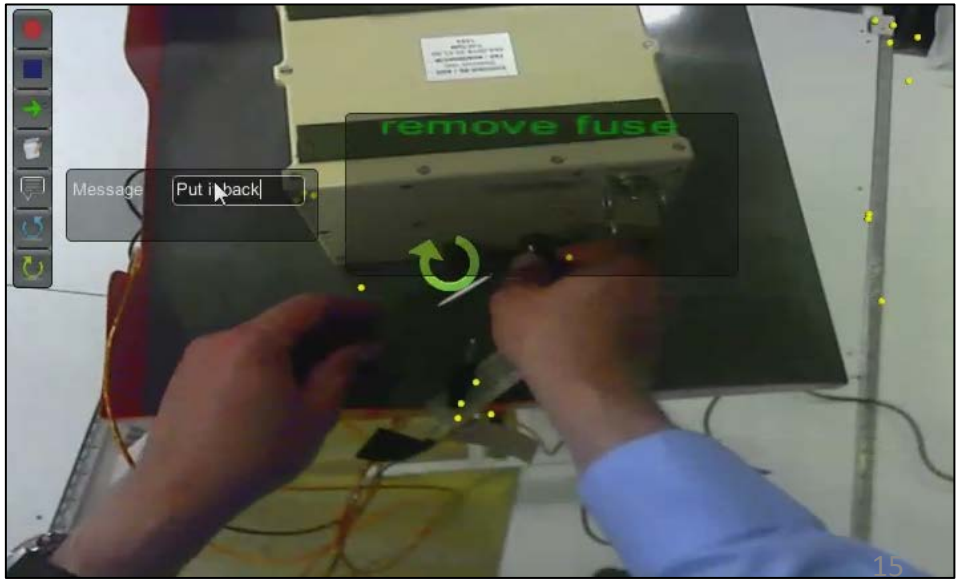
Experimental setup

- 2 users: a local user (trainee), and a remote user (trainer/payload expert);
- The user interface for the trainer provides:
  - Visualization on the laptop screen,
  - Interaction capabilities using the standard mouse device,
  - Visualization of the video stream received from the video camera sensor attached to the Head Mounted Device of the trainee,
  - An authoring tool for the trainer to add and alter visual content in the Augmented Reality layer overlaid on the video stream layer.
- AR displays on the user interface for the trainee's HMD,
- No hand gesture-based interaction for the trainee with the AR system,
- No audio communication support.

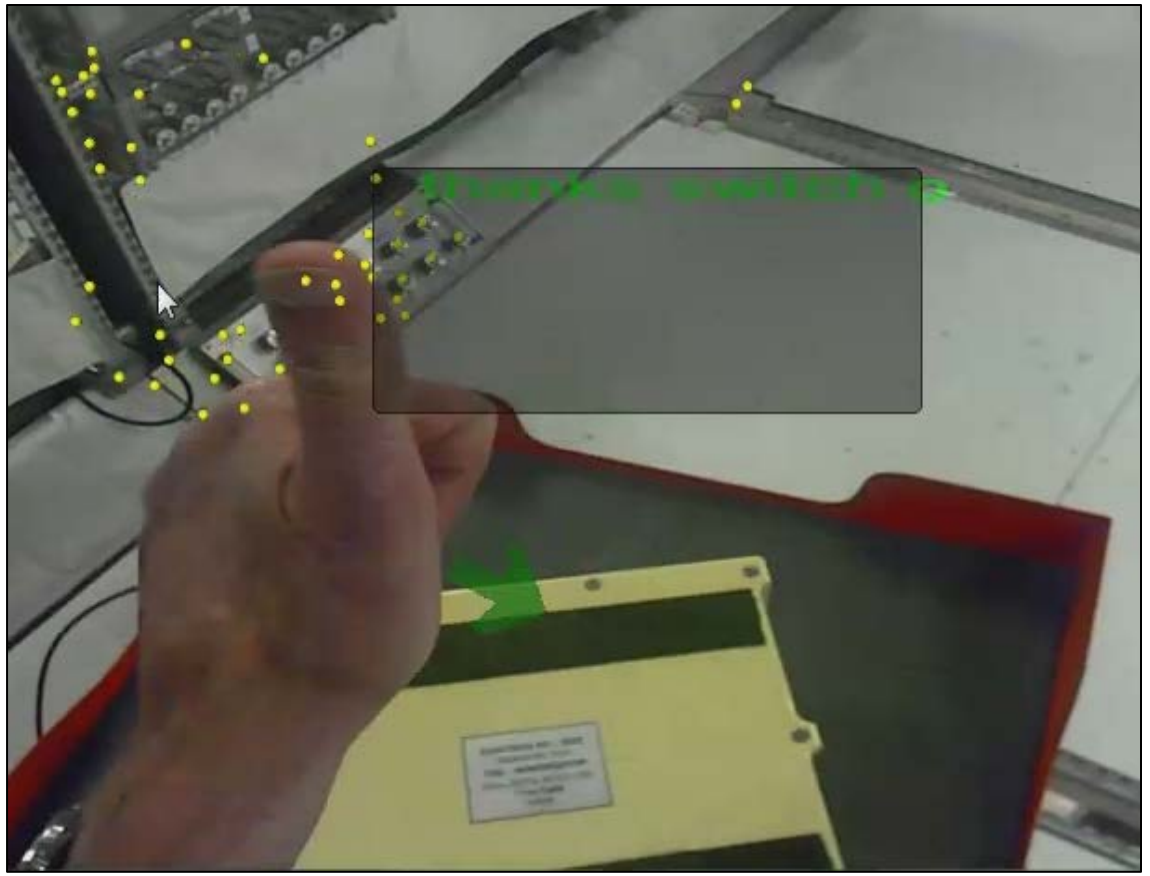
Usability Study

Usability Study





Usability Study



Usability Study

Results (see TN3 for details)

Findings:

- + **Attractively built/realistic scenario**, well prepared for further assignments.
- + Participants felt that **AR system could support remote collaboration** for training in IFM procedures.
- + **Overall good performance (technical, logistics, collaboration).**
- + Factors to support remote collaboration:
  - + **visualization of the trainee's workspace.**
  - + **the communication by text messages.**
  - + **the appearance of the shared AR objects.**

Factors with negative impact on the realism of the scenario (we further address all these in future work):

- Wired connection between the trainer's and trainee's laptops.
- Missing audio communication between the trainer and trainee.
- Limited text capabilities (reduced number of characters).
- "Camera lost" events (+wrong calibration of RDSLAM marker-less tracking), incorrectly placed annotations.

Evaluation of Constraints for AR Collaboration support for LEO operations

Communication channel	Bandwidth	Type
Video data stream	21.97MB/sec (TCP/IP, 25fps, frame size: 640x480, color, 24 bits/pixel, uncompressed)	per session
Tracking	160 bytes per frame=3.9 KB/sec	per session
AR interaction		on demand
- Text	max 78 bytes for fixed text	on demand
- Photo	59 bytes + photo size=900KB	on demand
- AR objects	max 65 bytes	on demand

The Class 3 payload on-board device throttles outbound data flows

Activity	Protocol	Frequency	Bandwidth	Volume
File Transfer	FTPS, SFTP, others	On demand		50 MB
Data exchange	UDP	Continuous	3 Mbps down	
Remote Desktop	RDP	30 min/day	100 Kbps down	
Video (encoded)	MPEG2 TS over UDP	5 hours/month	8 Mbps down	
Remote Shell	SSH	30 min/day		

The Class 3 payload User Application throttles outbound data flows

Activity	Protocol	Frequency	Bandwidth	Volume
File Transfer	FTPS, SFTP, others <TBD04>	On demand		50MB
Data Exchange	UDP	Continuous	100 Kbps up	
Remote desktop	RDP	30 min/day	100 Kbps up	
Video (encoded)	MPEG2 TS over UDP	5 hours/month	1 Mbps up	
Remote shell	SSH	30 min/day		

Future/Current work

- Lightweight AR HMD
- WIFI data communication
- Audio communication
- Improvement of marker-less tracking (+IMUs, other sensors/detectors)
- Hand-based interaction in AR
- Support for multiple local/remote users
- Automatic calibration of RDSLAM
- Robustness to network failures

- Affective Computing

[video]

EPSON MOVERIO BT-200

Questions