INTRODUCING ARTIFICIAL DEPTH CUES TO IMPROVE TASK PERFORMANCE IN ITER MAINTENANCE ACTIONS

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Introduction

ITER maintenance is largely performed by Remote Handling (RH).

Overcoming limited visual and haptic feedback is an important challenge to achieve effective execution of real ITER RH maintenance tasks.

Operators regard lack of 3D perception as primary factor hindering remote maintenance [1].

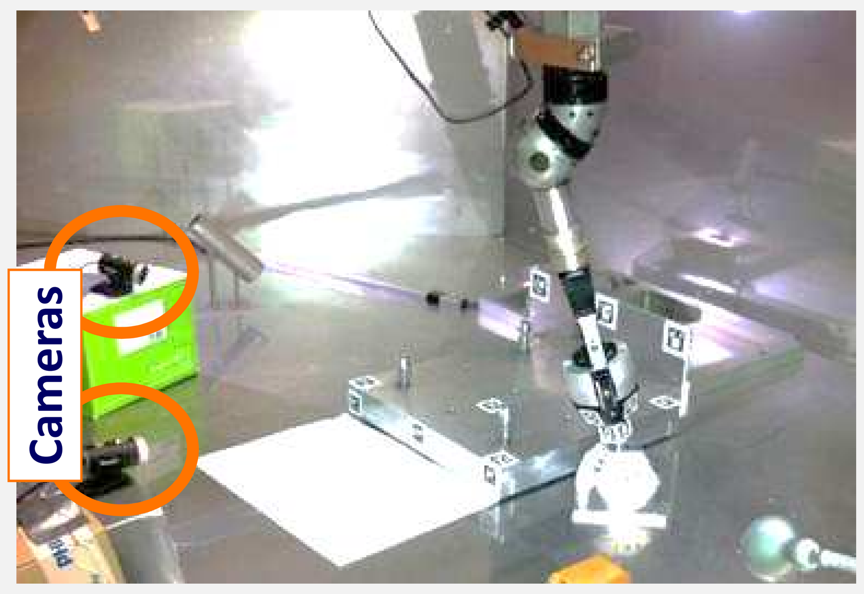
Promising techniques to improve depth perception are depth gauges and stereo vision

[1] G.Y.R. Schropp et al., "Influence of visual feedback on human task performance in ITER Remote Handling", 10th International Symposium on Fusion Nuclear Technology, September 2011, Portland, Oregon, USA

Experiment with artificial depth gauges

Hardware Test setup

Standard mechanical through-the-wall master-slave arm, in a configuration similar to a classical Hot Cell laboratory setup. The manipulator arm provides direct, mechanical, one-to-one scale haptic feedback.



Slave manipulator holds bolt runner. Front and side view cameras observe the scene. A single camera shows a frontal close-up view of the test setup on the workbench.

Second camera placed at a 45 degree viewing angle to generate reliable real time depth information for the artificial depth cue. Second image not shown to the operator.

Test performed on task board with 4 ITER pop-up bolts. Tracking markers are placed on tool and task board.
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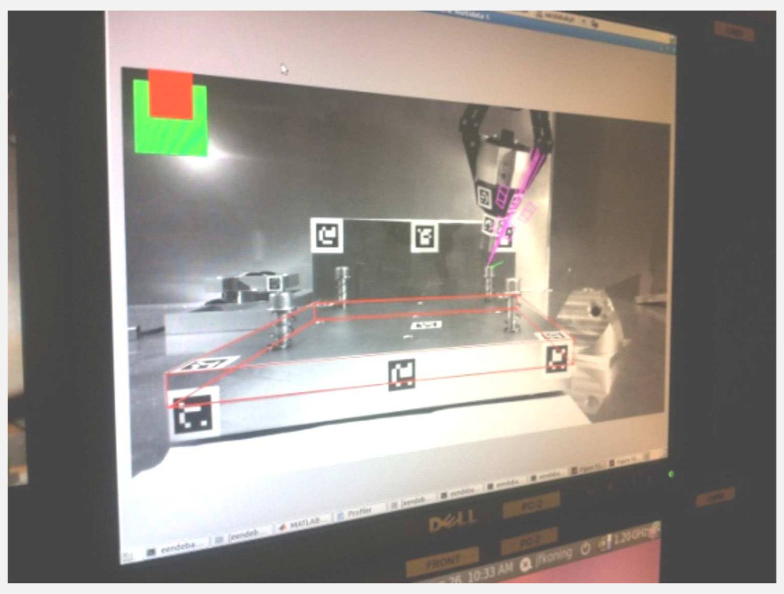
Experimental Procedure

Two visual conditions tested: No depth cues (N) and Depth Cues (D). In both conditions, the operator has to rely on the mono (front) camera view; no direct view on the scene is provided. The experiments were done with expert operators using alternating conditions. Sequence:

- Lift up bolt runner
- Move to specific bolt
- Engage the bolt runner
- Repeat according to sequence
- Replace bolt runner.

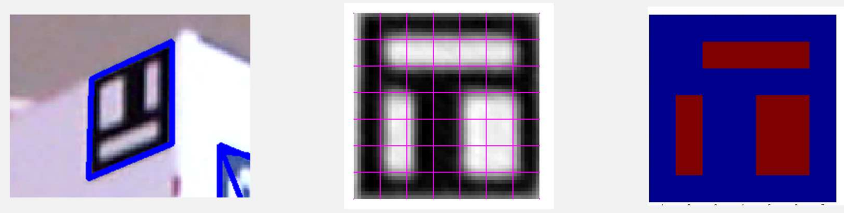


Operator view of the 4-bolt benchmark shows artificial depth cue: the red bar on the top left, and artificial task cue: a green line and magenta circle indicating the target location at the bolt head.

Results

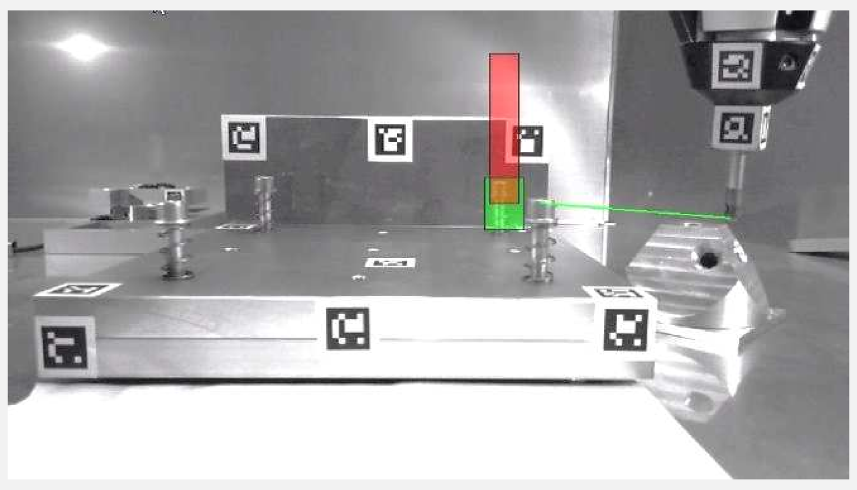
Robust real-time image processing was achieved with marker-based objects.

However: No significant difference was found between the 'no depth cues (N)' and 'depth dues (D)' conditions, ($F(1,3) = 2.442$, $p=0.216$).



Conclusion

Artificial depth gauges need to be designed with care: Operators commented on the artificial depth cue (placed too far away in the corner) and on their view of the bolt head being "obstructed" by the task cue. Depth cues were redesigned accordingly.



Experiment with stereo and tracking

HW/VR Test setup

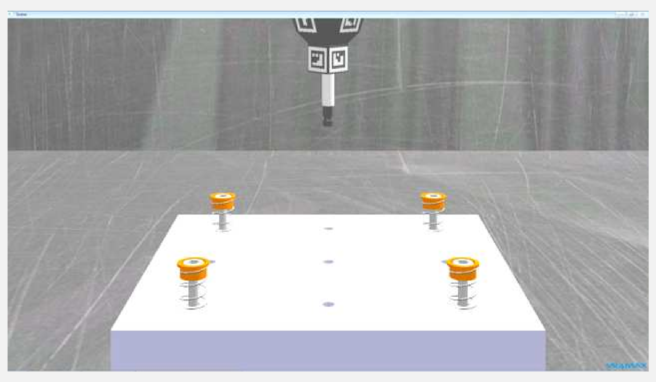
Simple mechanical arm, on pivot joint. The arm provides mirrored, mechanical, one-to-one scale haptic feedback.

Operator wears stereo glasses and/ or head tracking marker, looks at HW scene (in Direct View) or at the VR scene on the monitor, while manipulating the bolt runner via HW arm.

Two cameras observe the tracking markers on the bolt runner and task board. VR software generates mono or stereo view of the scene. Third camera monitors operator head motion and drives view adjustment on the VR display

Experimental procedure

Five conditions were tested: Direct view (DV), Mono VR (MONO), stereo (AS), head tracking (HT) and combination of stereo and head tracking (ASST). Four bolts to be addressed in alternating sequence.



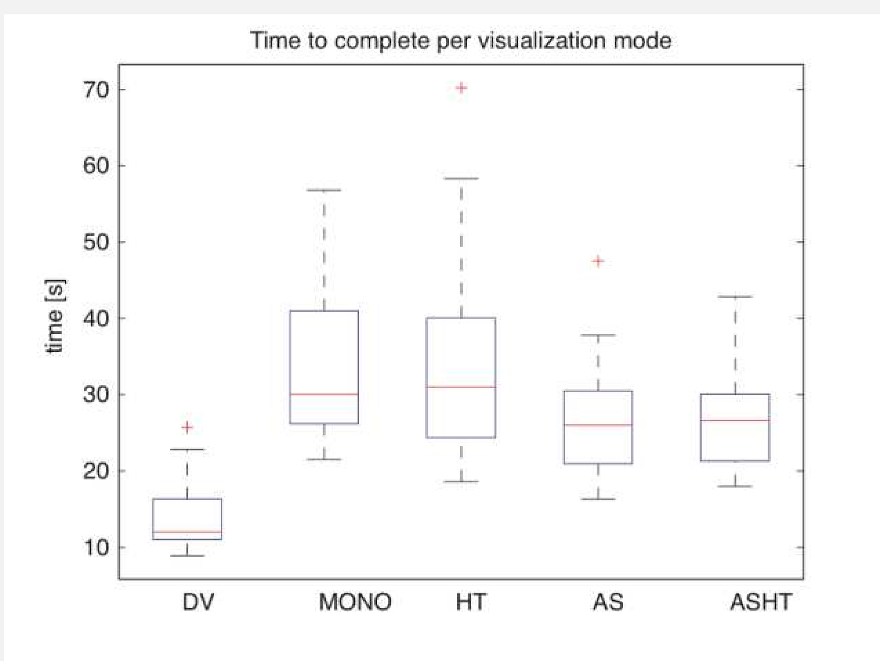
Results

Task execution is significantly faster and with fewer errors using direct view (DV)

If there is no direct view available, stereo (AS) shows a significant improvement ($p=0.0013$) compared to MONO. Also, fewer errors are made.

Head tracking (HT) was expected to show a similar improvement, but this could not be established.

Limitations in tracking performance (delay, resolution) and setup may have had a negative influence on this result.



Conclusion

Artificial depth cues may help to improve task performance in ITER maintenance actions.

Stereo vision does help to improve task performance .

Further work is needed to create simple and reliable systems.

Future Work

In the real ITER hot cell situation it will be possible to derive accurate 3D position information on robots and robot-held tools from slave arm encoders and CAD models.

Further development is needed towards robust 3D object tracking without markers, automatic object recognition, visual detection of deformation, contamination & damage, and possibly real (camera based) stereo depth gauges and stereo vision

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