

A photograph of a person wearing AR glasses, looking at a blue, translucent, 3D model of a mechanical part overlaid on a real-world machine. The person is in a workshop setting with various tools and equipment visible in the background.

# Augmented Reality in the Psychomotor Phase of a Procedural Task

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PRESENTATION FOR “CURRENT RESEARCH IN AUGMENTED AND VIRTUAL REALITY”

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# OUTLINE

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**01** **INTRODUCTION**  
A Brief Explanation about “Procedural Tasks” and “Psychomotor Phase”

**02** **RELATED WORK**  
Important Previous Work that use of AR to Assist the Completion of Procedural Tasks

**03** **PROTOTYPE**  
The AR Prototype System that Built by the Authors

**04** **USER STUDY**  
Comparing the Performance and General Acceptance of the AR Prototype System

**05** **RESULTS**  
Analysis the Evaluation Results in terms of Completion, Accuracy, and Questionnaire

**06** **DISCUSSION & CONCLUSIONS**  
Discussion about the System, Results, and Future Work

# INTRODUCTION



## Procedural Tasks

Involve People Performing Established Sequences of Activities, while Interacting with Objects in the Physical Environment, to Accomplish Specific Goals [1].



In the **Psychomotor Phase** (or **Workpiece Phase**), the User Performs Physical Manipulations, Including Comparing, Aligning, and Adjusting Configurations of Components [2].

The Psychomotor Phase is Complemented by the *Informational* or *Cognitive* phase.

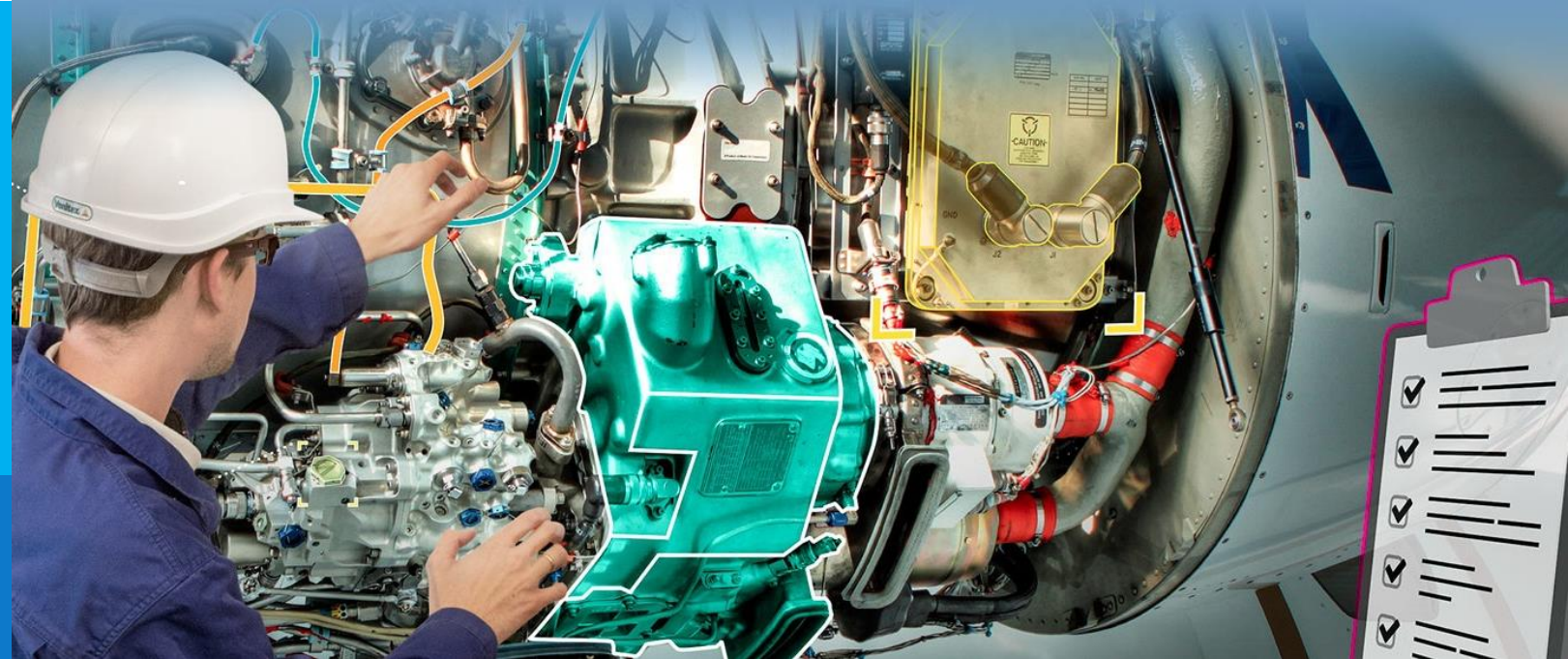
[1] R. M. Gagné and W. D. Rohwer, "Instructional Psychology," *Annual Review of Psychology*, 20(1):381–418, 1969.

[2] U. Neumann and A. Majoros, "Cognitive, Performance, and Systems Issues for Augmented Reality Applications in Manufacturing and Maintenance," In *Proc. IEEE Virtual Reality (VR '98)*, pages 4–11, 1998.

## Augmented Reality (AR)

Combining Interactive Media, such as Graphics, with our Perception of the Real World in Real Time [1].

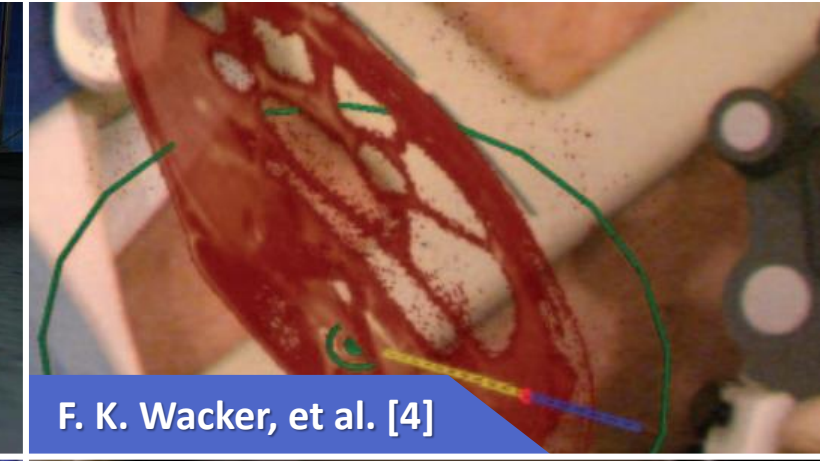
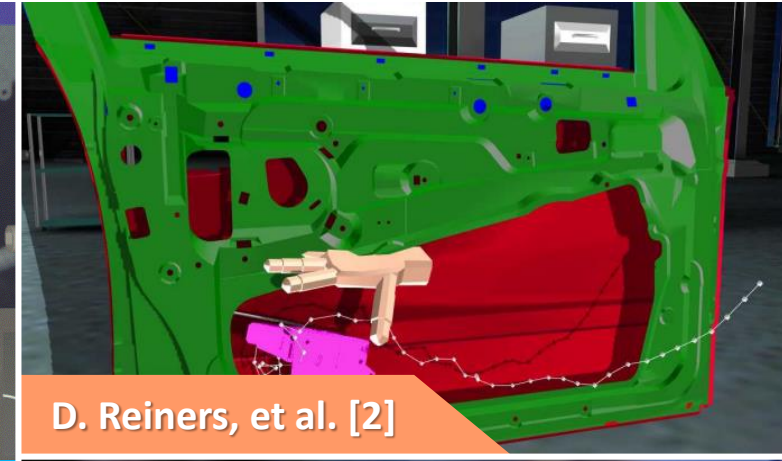
Applying AR to Psychomotor Phase of a Manufacturing and Maintenance Task



### ✓ Present a Research Prototype that:

1. Tracks Multiple Independent Physical Domain Objects and the User's Head Relative to the World.
2. Provide an AR User Interface that Offers Dynamic, Prescriptive Feedback and Instructions.
3. Validated with a Formal User Study.

# RELATED WORK



D. Reiners, et al. [2]

F. K. Wacker, et al. [4]

## S. Henderson and S. Feiner [1]

AR Prototype Assist with Maintenance Activities Inside an Armored Personnel Turret.

Show the Benefits of AR Assistance in the Informational Phase and **NOT** in the Psychomotor Phase.



B. Schwerdtfeger, et al. [3]

A. Tang, et al. [5]

- [1] S. Henderson and S. Feiner, "Evaluating the benefits of augmented reality for task localization in maintenance of an armored personnel carrier turret," In *Proc. ISMAR '09*, pages 135–144, Oct. 2009.
- [2] D. Reiners, D. Stricker, G. Klinker, and S. Muller, "Augmented reality for construction tasks: Doorlock assembly," In *Proc. Int. Workshop on Augmented Reality (IWAR '98)*, pages 31–46, 1999.
- [3] B. Schwerdtfeger, R. Reif, W. A. Gunthner, G. Klinker, D. Hamacher, L. Schega, I. Bockelmann, F. Doil, and J. Tumler, "Pick-by-Vision: A first stress test," In *Proc. ISMAR 09*, pages 115–124, 2009.
- [4] F. K. Wacker, S. Vogt, A. Khamene, J. A. Jesberger, et al., "An Augmented Reality System for MR Imageguided Needle Biopsy: Initial Results in a Swine Model1" *Radiology*, 238(2):497–504, Feb 2006.
- [5] A. Tang, C. Owen, F. Biocca, and W. Mou, "Comparative effectiveness of augmented reality in object assembly," In *Proc. SIGCHI Conf. on Human Factors in Computing Systems (CHI '03)*, pages 73–80, 2003.

# PROTOTYPE

## Realistic Maintenance Domain: Rolls-Royce Dart 510 Turboprop Engine

Disassembly, Re-Assembly, Installation, and Removal of the Dart Engine's Combustion Chamber



### SOFTWARE

Goblin XNA

<https://goblinxna.codeplex.com/>

Includes Two Assistance Phases



### HARDWARE

NVIS nVisor ST60 Head-Worn Display (HWD), OptiTrack FLEX IR Cameras, Firefly MV IEEE Camera, and etc.



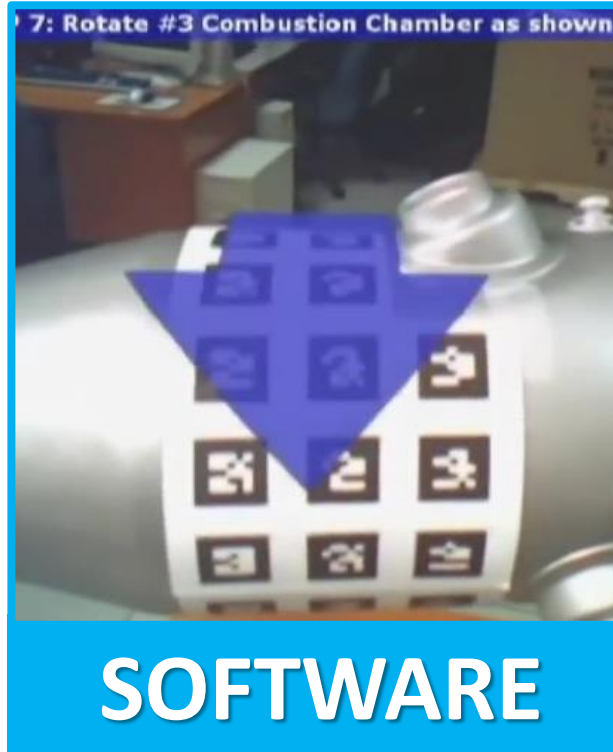
### AR ASSISTANCE

Virtual Labels, Arrows, Help and Error Messages with Different Colors, Alignments, and etc.

# PROTOTYPE

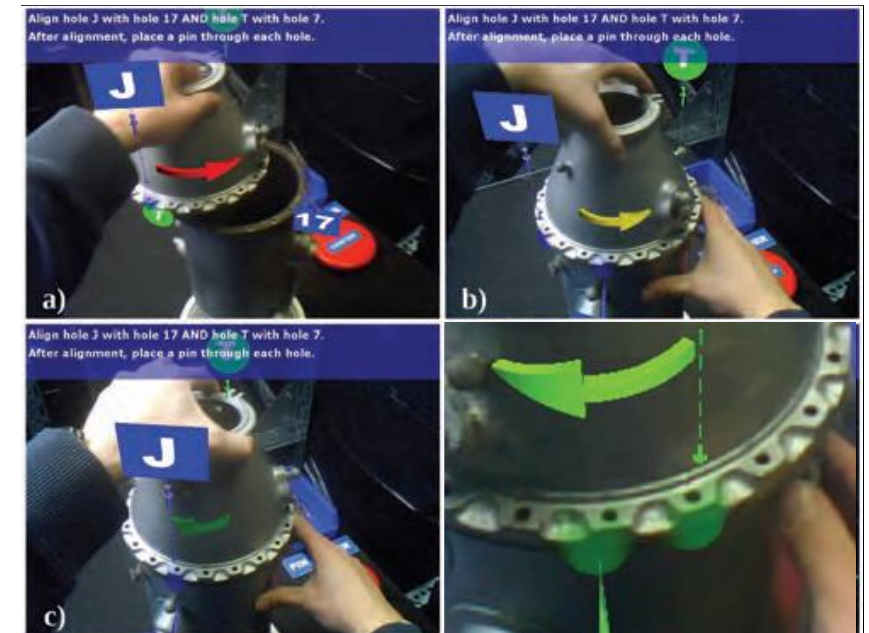
## Informational Phase Assistance

1. 2D Text in a Screen-Fixed Head-Up Display (HUD).
2. A Screen-Fixed Arrow to Orient the User in the General Direction of the Target Task.

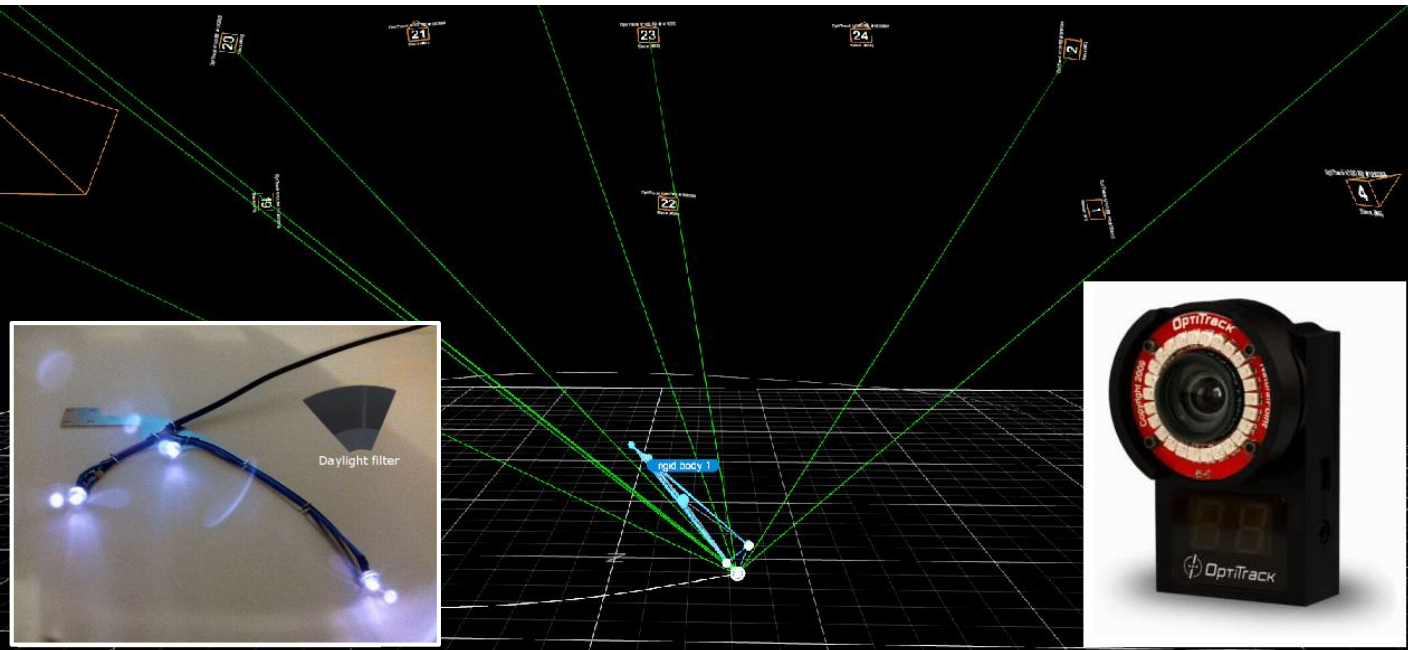


## Psychomotor Phase Assistance

1. Dynamic 3D Arrow.
2. Dynamic 3D Highlights for Connection Points.
3. Dynamic Billboarded Labels.



# PROTOTYPE



**HWD:** NVIS nVisor ST60

**IR Cameras:** NaturalPoint OptiTrack FLEX V100(R2)

**VGA Camera:** Point Grey Firefly MV IEEE 1394a

**Graphic Card:** ATI Radeon HD 5770 (1 GB DDR3/5)

**CPU:** Quad-Core 3.4GHz AMD Phenom II 965

**RAM:** 8 GB

**OS:** Windows 7 64-bit

- ✓ The 3D Position and Orientation of the HWD (with 3 Retroreflective Sphere Markers), Cones, and Cans (each One with 4 Markers) are Optically Tracked Using a Cluster of 11 OptiTrack FLEX IR Cameras [1], Mounted Around the Work Area.
- ✓ Using Printed Fiducial Markers and VTT ALVAR Optical Tracking Library [2] to Track Large Objects Held in the User's Hands by a 640x 480 Resolution Point Grey Firefly MV IEEE 1394a Camera [3] that Attached to the HWD.
- ✓ Calibrate the AR Application and the HWD (Using 10cm x 10cm Patterned Target) by the OptiTrack, and the Camera for Fiducial Marker Tracking. The User is Requested to Align the Real Target with a Series of Virtual Targets, Projected at Eight 3D Locations Per Eye.

[1] NaturalPoint OptiTrack, <http://optitrack.com>

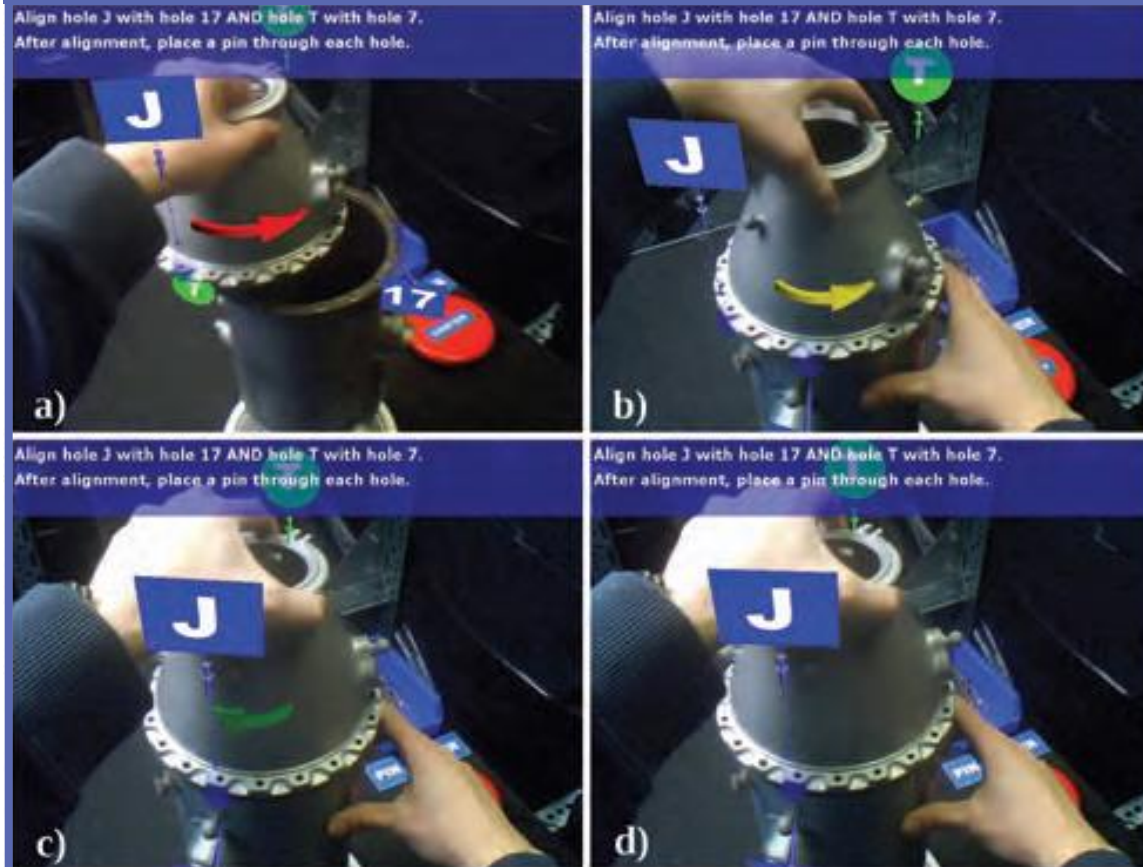
[2] ALVAR, <http://virtual.vtt.fi/virtual/proj2/multimedia/alvar/index.html>

[3] Point Grey, <https://www.ptgrey.com>



# PROTOTYPE

## AR ASSISTANCE



**01** Display Text Instructions in the 2D HUD of the HWD.

**02** Guide the User to the Can's Current Location.

**03** Provide Virtual Labels to Help the User Identify the Can and Other Objects in the Environment.

**04** Display a Dynamic 3D Curved Arrow to bring the Cone and Can into the Desired Alignment and then Secures the Alignment with a Set of Pins.

# USER STUDY



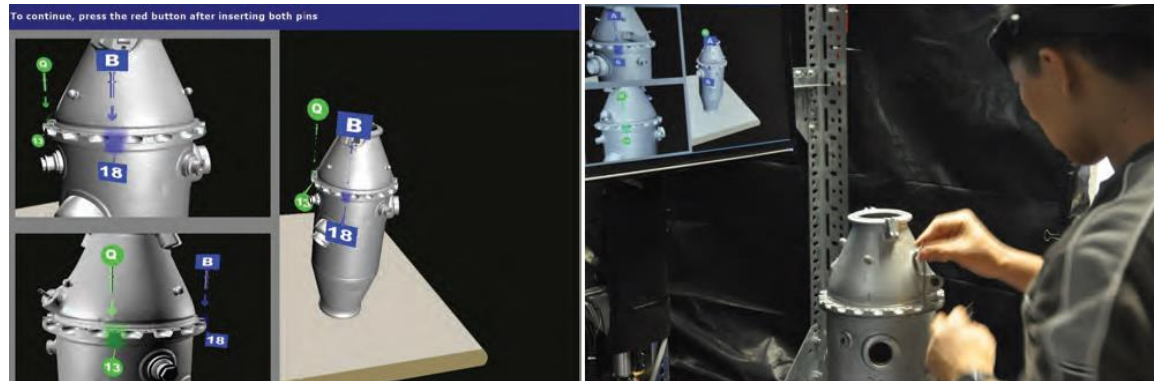
Study Task Environment

## AR Condition

Display 3D Graphics-Based Documentation on HWD.

## Control Condition (LCD)

Display 3D Graphics-Based Documentation on a 22" Diagonal 1920x1080 LCD.



# USER STUDY

## Experiment Design

01



Table 1: Steps of combustion chamber assembly task.

Step	Description	Activity Type
1	Locate Can X in Bin W	Locate
2	Move Can X to Turntable	Position
3	Locate Cone Y in Bin V	Locate
4	Place Cone Y on Can X	Position
5	Align Cone Y with Can X; Insert pins	Align
6	Move assembly XY to Bin Z	Position

**2 Blocks:** AR Condition, LCD Condition  
(Five Minute Break Between Blocks)

**A Trial:** Assembling one of 3 Cones with one of 3 Cans, Aligning the Cone and Can Correctly, and Inserting 2 Pins.  
(Completion Time were Logged Automatically)

(Stereo Optical Co. Stereo Fly Test for each Participant)

## Pilot Testing

02



### 6 Participants

(1 female; Ages 18-40)

Recruited by Mass Email to CS Students at University and by Flyers → Paid \$15 each

### Each Block → 18 Trials

(Changed to 14 Trials)

### 2 (Display Condition) x 3 (Activity Type)

Measure ANOVA on the Mean Completion Time for each Steps in Table 1 Using an  $\alpha$  of 0.05

### Significant Main Effect of Display Condition:

Completion Time:  $F_{(1,5)} = 17.14, p = 0.009$

Accuracy of Alignment:  $F_{(1,5)} = 11.51, p = 0.019$

**Very Few Errors** During Activities

**Strong User Preference for AR vs LCD**

## Hypotheses & Testing

03



### Hypotheses:

1. AR would be *the Fastest Condition* during the Psychomotor Phase of the Task (Step 5 in Table 1).
2. AR would be *the Most Accurate Condition* during the Psychomotor Phase of the Task.
3. AR would be *the Most Preferred Condition*.
4. Participants would Rank *the AR Condition as Most Intuitive*.

### Testing:

**22 New Participants**

(6 female; Ages 18-44)

**14 Trials for each Condition**

# Completion Time Analysis

Table 2: Pairwise comparisons of mean completion time by activity type.

Activity Type	Mean Completion Time (s)		Comparison
	AR	LCD	
Locate	2.66	2.39	LCD 0.27 s faster than AR $t_{(21)} = 1.60, p = 0.124$
Position	1.15	1.15	LCD within 0.01 s of AR $t_{(21)} = 0.12, p = 0.905$
Align	24.23	45.55	AR 21.31 s faster than LCD $t_{(21)} = 6.27, p < 0.001$

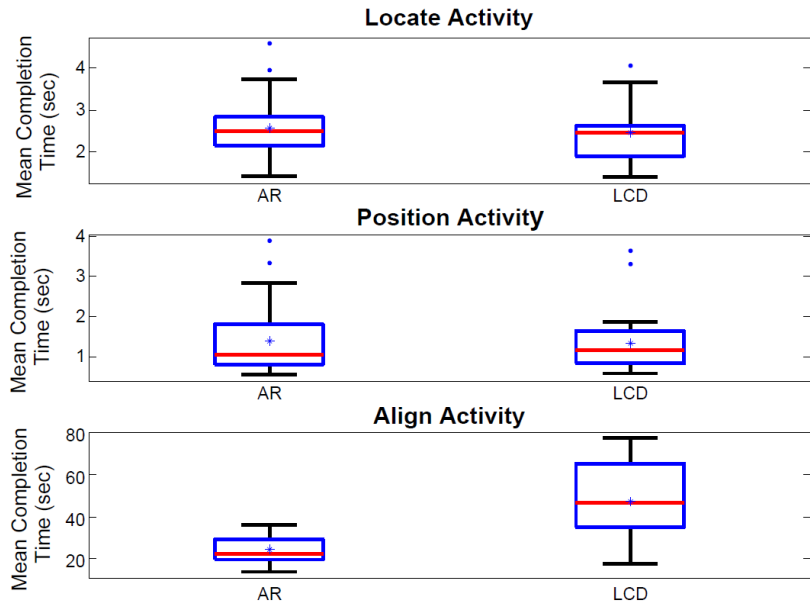


Figure: Activity completion times (s) for AR and LCD. An asterisk marks mean task completion for each condition.

# RESULTS

# Accuracy Analysis

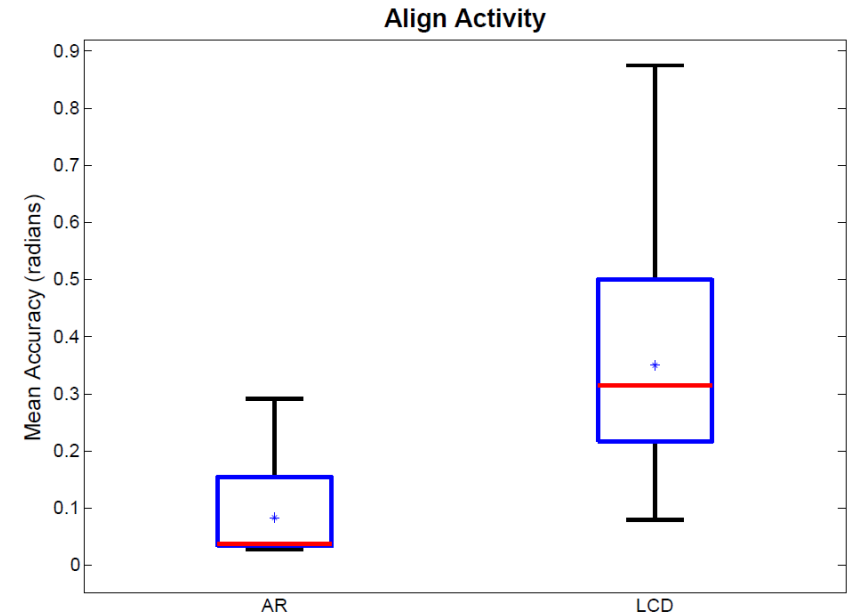


Figure: Mean alignment error (radians) for alignment activity in AR and LCD. An asterisk marks mean alignment error for each condition.

✓ AR is 0.28 radians More Accurate than LCD.

### Binary Accuracy Rate:

AR Condition = 95.3%  
LCD Condition = 61.7%

# RESULTS

## Questionnaire Analysis

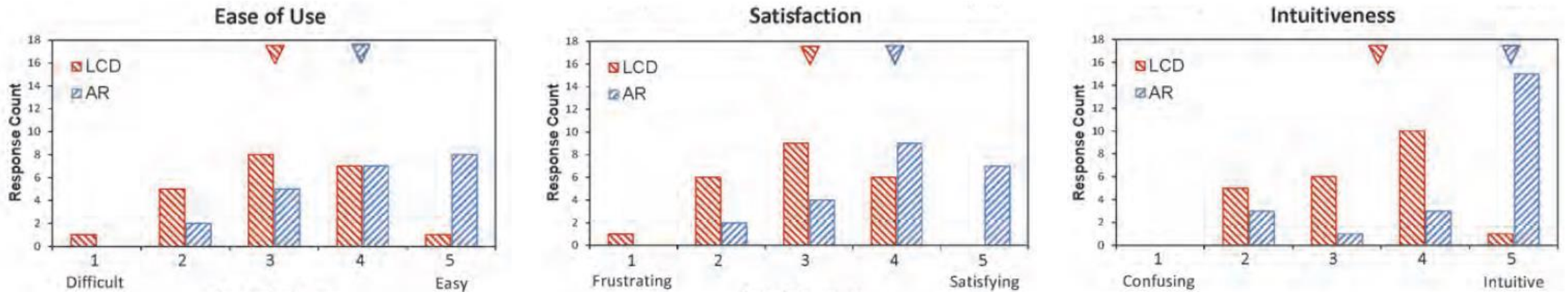


Figure: Survey response histograms by condition for ease of use (top), satisfaction (middle), and intuitiveness (bottom). Median values for each condition are displayed as triangles.

(1 = Most Negative, 5 = Most Positive)

✓ AR Rate is Significantly Better than LCD in Terms of Ease of Use, Satisfaction, and Intuitiveness.

# RESULTS

## Comparison to Physical Labels



### The PRINTED Condition:

- Create a Modified Version of the LCD Condition with Printed and Glued Small Physical Labels to All Possible Connection Points on each Can and Cone.

### Testing:

#### 8 Additional Participants

(All Male, Ages: 19-27), 14 Trials

### Results:

#### Main Effect on Completion Time:

AR = 7.87 s | PRINTED = 7.29 s.

#### The Mean Completion Time for Align:

AR = 20.73 s | PRINTED = 19.42 s.

#### Main Effect on Accuracy:

AR = 0.034 radians | PRINTED: 0.065 radians

#### Binary Accuracy Rate:

AR = 100% | PRINTED = 96.4%

- ✓ Failed to Show Evidence of Significant Main Effect.
- ✓ Ease of Use → No Difference.
- ✓ Preference for Use and the Most Intuitive → AR

# CONCLUSION

## Discussion Future Work Conclusions

### In Summary:

- ✓ Do Assembly Task more Quickly in AR than LCD.
- ✓ AR Condition is the Most Preferred and Intuitive Condition, even with a 1.3 kg Bulky HWD!
- ✓ AR is More Accurate than LCD.
- ✓ AR is Faster and More Accurate for Psychomotor Phase Activities.

01

There is a Need to Formally Explore the Specific Types of Assistance Provided by AR During Psychomotor Activities.

02

Addressing other Realistic Maintenance and Repair Tasks and Exploring More Complex Psychomotor Activities.

03

Test with other AR Engines, such as The Designers Augmented Reality Toolkit (DART) Engine [1].



# ISMAR

Received the ISMAR 2011  
Best Science and Technology  
Student Paper Award

## Augmented Reality in the Psychomotor Phase of a Procedural Task

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# Thank You...

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ANY QUESTIONS?