3D User Interface Evaluation III

Lecture #16: Example Evaluations

Spring 2008

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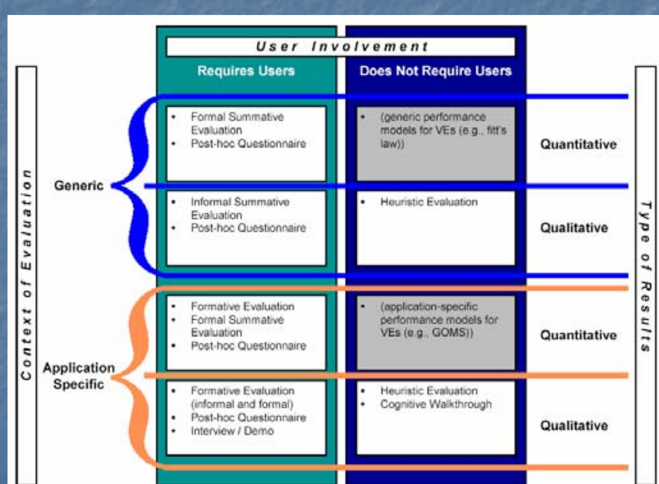
Usability Evaluation in 3DUIs



Example Evaluations

- Non-isomorphic rotation (3DUI 07)
- Interaction Offset (3DUI 07)

IEEE Symposium on 3D User Interfaces 2007

An Exploration of Non-Isomorphic 3D Rotation in Surround Screen Virtual Environments

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March 10, 2007

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Talk Outline

- Motivation and Goals
- Non-Isomorphic Rotation
- Related Work
- Experiment
- Results
- Discussion
- Conclusion

Motivation and Goals

- Rotating objects in 3D space is a fundamental task
- Want to understand how 3D rotation techniques perform
- Isomorphic and non-isomorphic approaches
- Explore these approaches in SSVE
  - extend and augment existing knowledge
  - does existing knowledge transfer?

Non-Isomorphic 3D Rotation

- Human-Machine interaction
  - input device
  - display device
  - transfer function (control to display mapping)
- Non-isomorphic – scaled linear/non-linear mapping
  - manual control constrained by human anatomy
  - more effective use of limited tracking range (i.e vision-based tracking)
  - additional tools for fine tuning interaction techniques
- Isomorphic – one-to-one mapping
  - more natural

Non-Isomorphic Rotation Technique

- Quaternion – four-dimensional vector (v, w) where v is a 3D vector and w is a real number
- Let q_c be the orientation of the input device q_d be the displayed orientation, and q_o be the reference orientation then

$$q_q = q_c^k, \quad q_d = (q_c q_o^{-1})^k q_o, \; k = \text{CD gain coefficient}$$

- Using relative mapping

$$q_{d_i} = (q_{c_i} q_{c_{i-1}}^{-1})^k q_{d_{i-1}}$$

Related Work

- User performance with different 3D rotation techniques (Chen 1988, Hinckley 1997)
- Rotating real and virtual objects (Ware 1999)
- Framework, design guidelines, non-isomorphic effectiveness (Poupyrev 2000)
- Non-isomorphic head rotations (LaViola 2001, Jay 2003)
- GlobeFish and Globe Mouse (Froehlich 2006)
- Hybrid haptic rotations (Dominjon 2006)

Experimental Study

- Further explore non-isomorphic rotation of virtual objects
- Systematic evaluation of different rotation amplifications
- Understand benefits of non-isomorphic in SSVE
  - head tracking
  - stereoscopic vision

Experimental Design

- 16 subjects (13 male, 3 female)
- Conducted in Brown "Cave"
- Based on Poupyrev 2000 → Hinckley 1997 → Chen 1988
- 4 x 2 x 2 balanced, within-subjects design (16 conditions)
- Independent variables
  - amplification (1,2,3,4)
  - rotation amplitude (20-60, 70-180 degrees)
  - Error threshold (6, 18 degrees)
- Dependent variables
  - completion time
  - orientation error

Experimental Procedure

- Task – rotate house from random to target orientation
- Pre-questionnaire
- 16 practice trials
- 16 sets of 10 trials each
- Ordering was randomized
- Post-questionnaire

Results - ANOVA

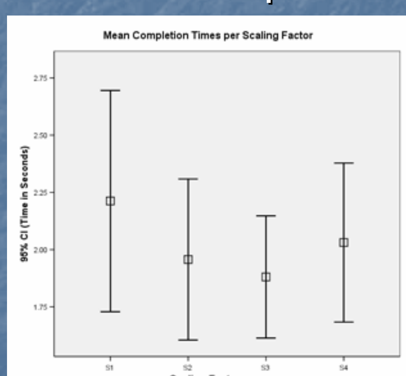
- Repeated measures, three way ANOVA

Effect	Time	Error
S	$F_{3,13}=3.26$, $p=0.056$	$F_{3,13}=4.8$, $p<0.05$
T	$F_{1,15}=13.66$, $p<0.05$	$F_{1,15}=22.96$, $p<0.05$
A	$F_{1,15}=55.46$, $p<0.05$	$F_{1,15}=0.001$, $p=0.98$
S x T	$F_{3,13}=0.29$, $p=0.83$	$F_{3,13}=1.575$, $p=0.243$
S x A	$F_{3,13}=0.87$, $p=0.523$	$F_{3,13}=0.562$, $p=0.649$
T x A	$F_{1,15}=5.03$, $p<0.05$	$F_{1,15}=0.573$, $p=0.46$
S x T x A	$F_{3,13}=0.73$, $p=0.55$	$F_{3,13}=0.97$, $p=0.436$

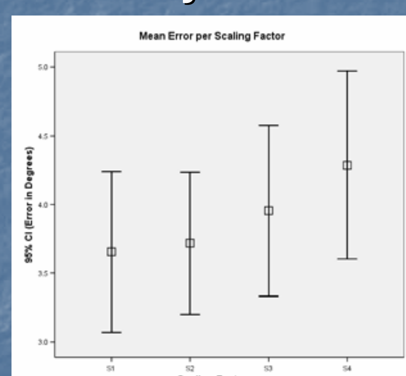
S = scaling factor   T = error threshold   A = angle

Results - Post Hoc Analysis

- Pairwise comparisons on scaling factor using Holm's sequential Bonferroni adjustment

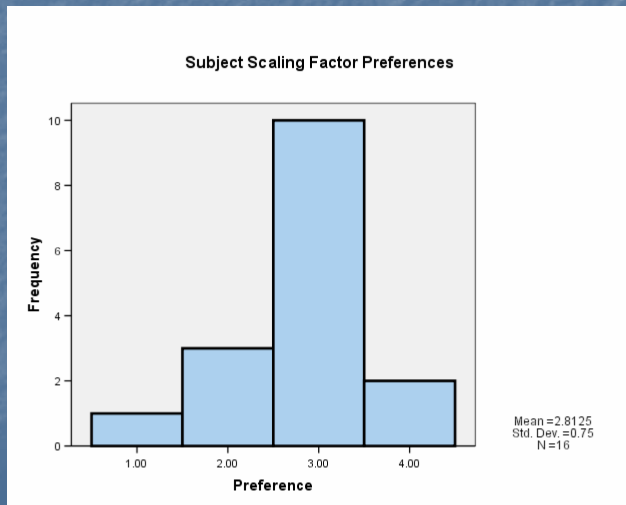


Significant differences between S1 and S2 and S1 and S3



Significant difference between S1 and S4

Results – Subject Preferences



Results - Summary

- Subjects performed 11.5% faster with S2 and 15.0% faster with S3 with no statistically significant loss in accuracy
- Appears to be correlation between subject preferences and mean completion time
  - scaling factor of 3 is preferable amplification coefficent

Discussion - Error

- Interesting differences with previous studies
- Poupyrev – 6.8 degrees
- Hinckley – 6.7 degrees
- Ware (physical objects) -- 4.4 degrees
- Our study – 3.9 degrees
  - threshold of 6 – 3.41, threshold of 18 – 4.4

Discussion – Completion Time

- Poupyrev
  - 5.15 seconds for isomorphic
  - ≈4.75 seconds for non-isomorphic
- Hinckley
  - 17.8 seconds for isomorphic (no training, accuracy focus)
- Our study
  - 2.2 seconds for isomorphic
  - 1.96 seconds for non-isomporhic

Discussion – Implications

- Differences attributed to
  - different hardware configurations
    - previous studies on desktop
    - our study in SSVE
- Poupyrev's amplification factor (1.8)
- Hinckley – "… accuracy of rotation less affected by interface then by difficulties in perception of error…"
  - head tracking
  - stereoscopic vision
- Others – display size, refresh rate, video game proficiency, tracking lag

Conclusion

- Presented experiment exploring non-isomorphic rotation in SSVE
- Rotation task completed 15% faster with amplification factor of 3 than with isomorphic rotation
  - no statistically significant loss in accuracy
  - subjects preferred this amplification factor
- Faster and more accurate performance in SSVE in general
  - perception of objects closely matched with physical reality
  - many other factors could contribute
- Further work needed

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An Exploration of Interaction-Display Offset in Surround Screen Virtual Environments

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March 10, 2007

* Now at the University of Central Florida

Talk Outline

- Motivation and Goals
- Display-Interaction Offset
- Related Work
- Experiment
- Results
- Discussion
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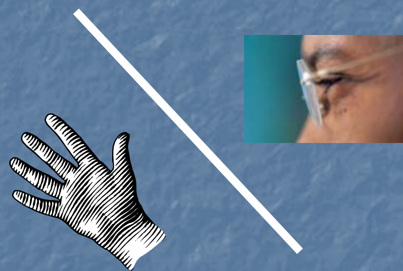
Motivation and Goals

- Want to build effective interfaces in VE applications
- Many different interaction technique choices
  - set parameters to optimize performance
  - guidelines needed
- Techniques centered around user's body are common in VEs
- Where should virtual object be placed with respect to user?

Display-Interaction Offset

- What is display-interaction offset?
  - two frames of reference
    - display
    - interaction
- Display frame of reference
  - perceived location of rendered graphical feedback
- Interaction frame of reference
  - location of physical interaction

Display-Interaction Offset (HMD)



Courtesy of www.5dt.com

Projection surface occludes physical hand

Display-Interaction Offset (SSVE)

Interaction in a SSVE

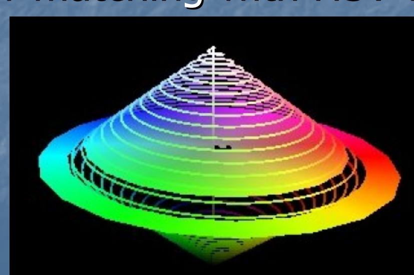
Physical hand occludes projection screen

Related Work

- Virtual object manipulation for docking task
- With HMD – Mine(1997)
  - found users performed faster with collocation over positional offset
- With Responsive Workbench – Paljic(2002)
  - found collocation or minimal offset minimized time to completion

Experimental Study

- Hypothesis – Translational offset between interaction and display frames of reference would improve user performance for 3D widget-based task
- Chose color matching with HSV widget

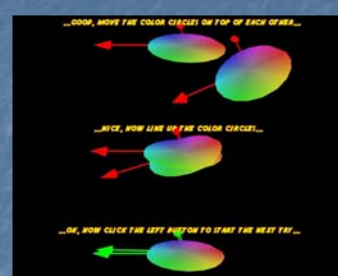


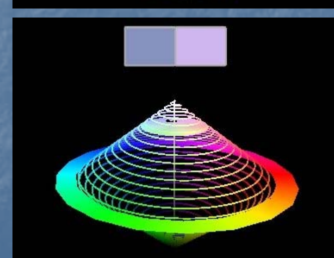
Experimental Design

- 24 subjects (12 male, 12 female)
- Conducted in Brown "Cave"
- 3 conditions of display-interaction offset
  - collocated
  - 3 inches
  - 2 feet
- 15 trials per condition
- Within-subjects design
- Target color used as second factor to control for color difficulty

Experimental Procedure

- Pre-questionnaire & color vision screening
- 6 practice trials
- For each trial
  - centering task
  - color matching
- Post-questionnaire
- 15 more trials with subject chosen offset

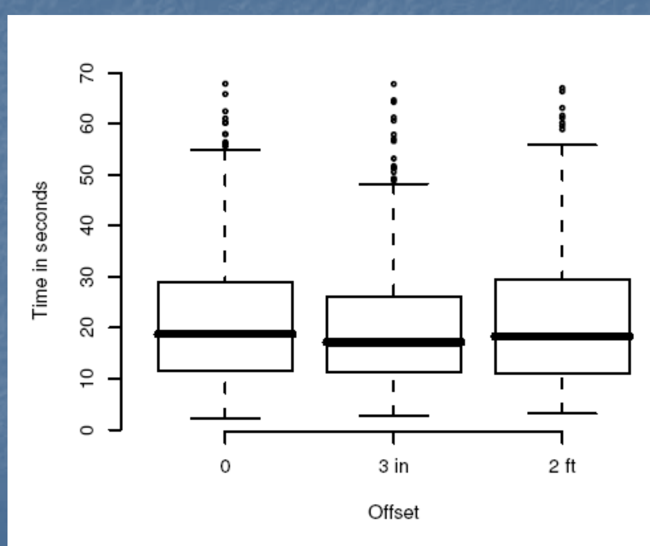




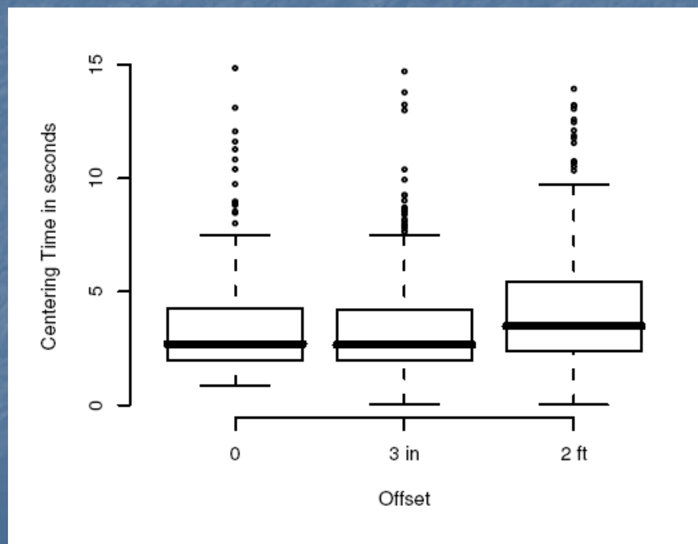
Performance Metrics

- Measurements
  - Time to center hand
  - Time to chose matching color
  - Chosen color
- Derived
  - Distance between target and chosen
  - Accuracy per time

Results – Time to Match Color



Results – Centering Time



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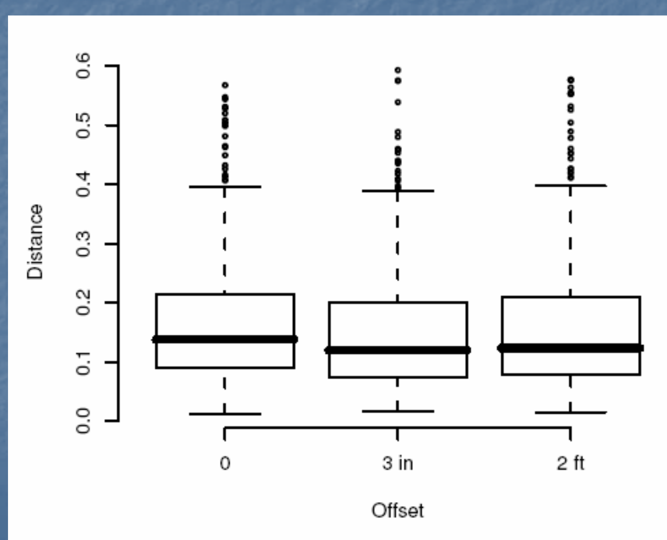
Results – Distance Between Target and Chosen Color



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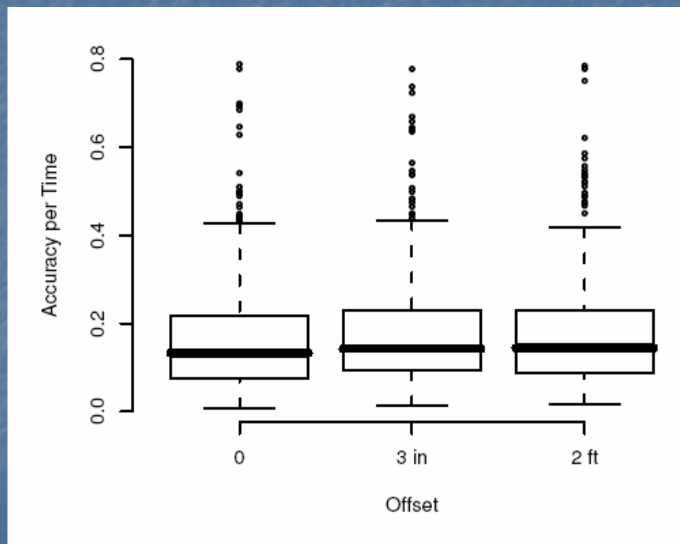
Results – Accuracy per Time



Results - ANOVA

Statistic	Factor	Df	F-value	Pr(>F)
Time	Offset	2	1.297	0.283
	Color	14	7.867	2.27×10^{-14}
Distance	Offset	2	4.13	0.0224
	Color	14	20.7	$< 2.0 \times 10^{-16}$
Accuracy Per Time	Offset	2	1.655	0.202
	Color	14	7.108	7.98×10^{-13}
Centering Time	Offset	2	8.2594	0.0008614
	Color	14	0.7685	0.7033

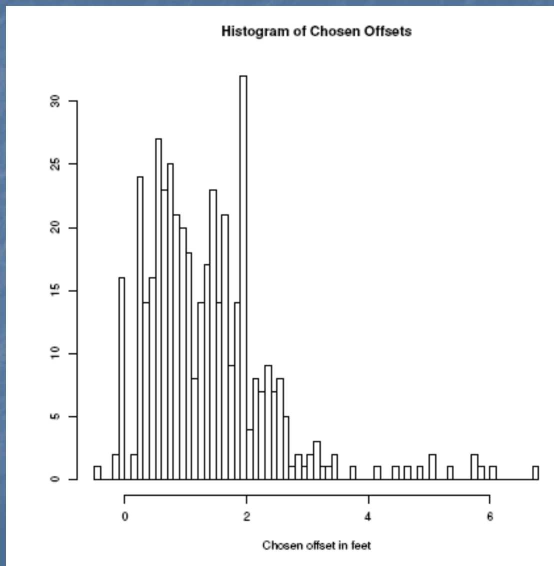
Results – Paired Sample T-Tests

- Bonferroni correction

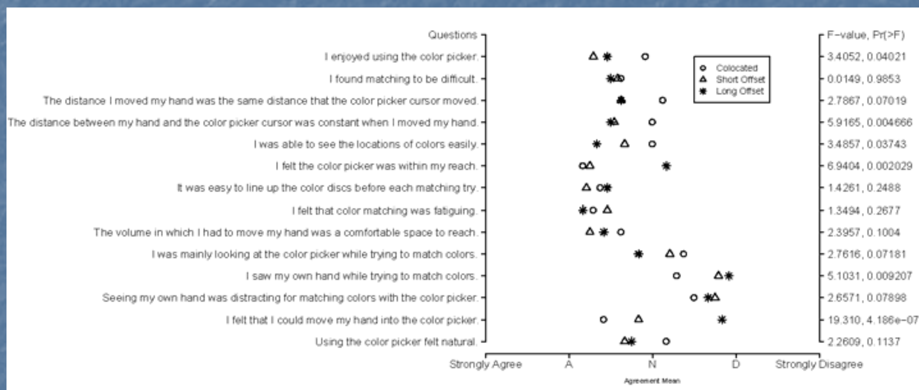
Conditions	Statistic	p-value
Short vs. Long offset	Time Distance Accuracy Per Time Centering Time	2.2635 2.5266 2.1699 1.689×10^{-7}
Collocated vs. Long offset	Time Distance Accuracy Per Time Centering Time	0.19872 0.0026733 0.1221 1.944×10^{-5}
Collocated vs. Short Offset	Time Distance Accuracy Per Time Centering Time	0.3624 0.0027369 0.2526 1.2495

Results – Second Phase

- Chosen offset
  - mean – 1.34 feet
  - SD – 1.026



Post – Questionnaire Results



Discussion

- Both offset conditions were significantly better than collocation
  - distance
  - user preference
- No significant difference between offset conditions
- For centering task
  - most similar to Mine and Paljic
  - collocation and minimal offset significantly faster
- Results agree and disagree with previous work

Conclusion

- Compared effect of positional offsets on user performance in SSVE
  - color matching
  - centering
- Centering task performance in line with previous work
- Color matching performance shows technique does not fit within established guidelines
- Further studies needed

Next Class

- 3DUI and the Real World
- Readings
  - 3DUI Book – Chapter 12