3D User Interface Evaluation II

Lecture #14: Example Evaluations

Spring 2023

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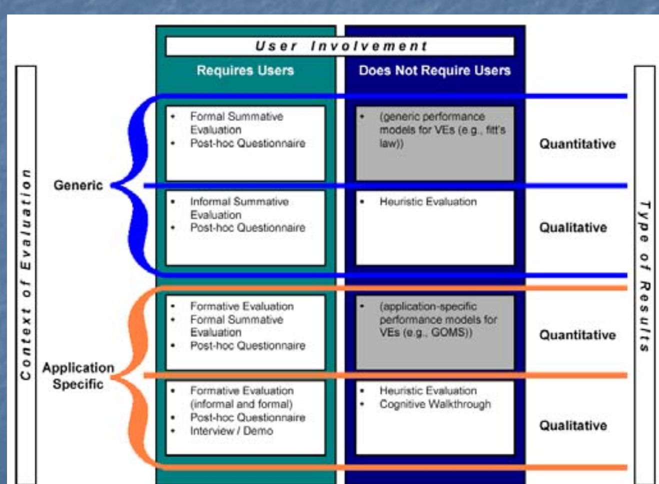
Usability Evaluation in 3DUIs



Example Evaluations

- Non-isomorphic rotation (3DUI 07)
- Visual interface study (SIGGRAPH Video Game Symposium 2009)

IEEE Symposium on 3D User Interfaces 2007

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

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Brown University
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

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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

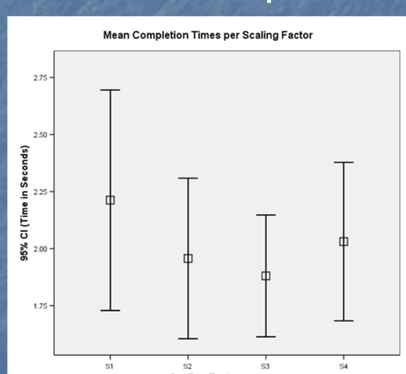
- Repeated measures, three way ANOVA

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	$F_{3,13}=0.73$, $p=0.55$	$F_{3,13}=0.97$, $p=0.436$

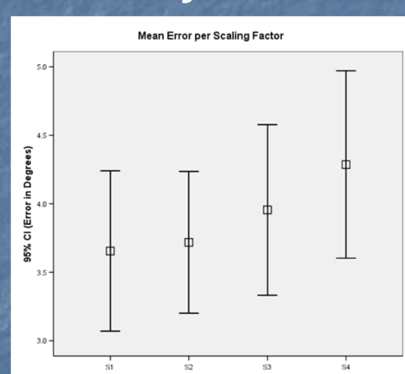
S = scaling factor T = error threshold A = angle

Results - Post Hoc Analysis

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

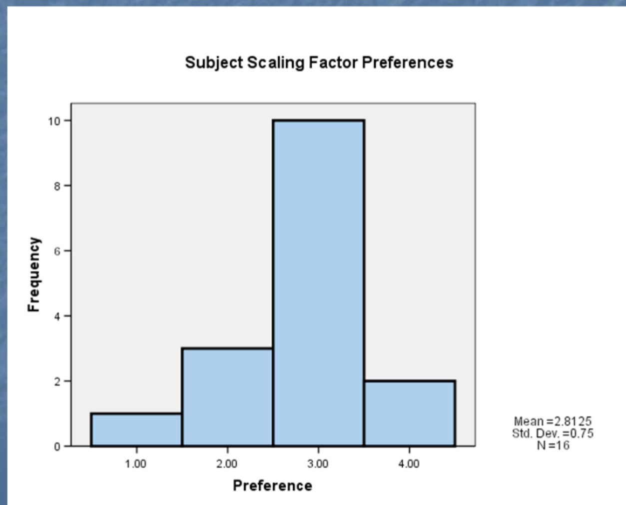


Significant differences between S1 and S2 and S1 and S3



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-isomorphic

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

Understanding Visual Interfaces for the Next Generation of Dance-Based Rhythm Video Games

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Overview

- Problems with Current Dance Games
- RealDance Description
- Visual Interface problems with Dance Games
- Visual Interface Descriptions
- Experimental Design
- Results
- Conclusions

Interface Problems with Dance Games

- Among rhythm games, dance still doesn’t feel like dancing
- Full body interface games are now mainstream
- Initial Research Goal:
  - Create a video game that feels like dancing
  - Detect more specific movements
    - To teach better
    - To prevent cheating
  - Make fitness gaming more fun

RealDance Overview

Real Dance (Charbonneau et al, 2009)

- Dance Game Prototype
  - No buttons
  - No cameras
  - No wires
- Gesture Scoring
  - Impact
  - Impulse
  - Freeze

Visual Interface Trouble

- Icons scrolling along a path
- Goal to make as many different moves as possible
- But how to display it without being confusing?
  - Current rhythm games have 4-6 colored shapes
  - More specific icons get more confusing

Image of All Star Cheer Squad from thq.com

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Visual Interfaces in Video Games

- Surveyed 76 rhythm related games from about 10 years
- Current and previous rhythm game needs:
  - When to press button
  - What button to press
- 3DUI requires three things
  - When to move
  - Which body part to move
  - Where to move it to

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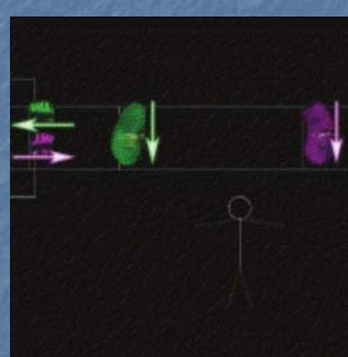
Visual Interface: DDR and Rock Band

- Almost every rhythm, music and dance game uses a variation of this
  - Icons stream along path
  - A perpendicular line indicates when to press
  - Color, position and shape used to assist in deciding between actions
- Our first prototype as well!

Images from konami.com and rockband.com

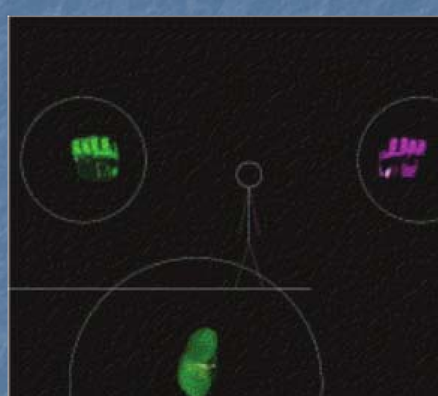
Visual Interface: Timeline



Visual Interface: Elite Beat Agents

- A.K.A. Osu! Tatakae! Ouendan
- For Nintendo DS
- Uses touchscreen and stylus
- User taps the number circle when the outer circle shrinks to it
- For some notes they trace along a path
  - Only three other games with this UI
  - Image from Nintendo.com

Visual Interface: Beat Circles



Visual Interface: We Cheer

- Wii game using two Wiimotes as pompoms
- Player follows characters and arrow paths
- Timing is done by ghost image
- Color for different hands
  - Only two similar games
  - Image from Namco Bandai

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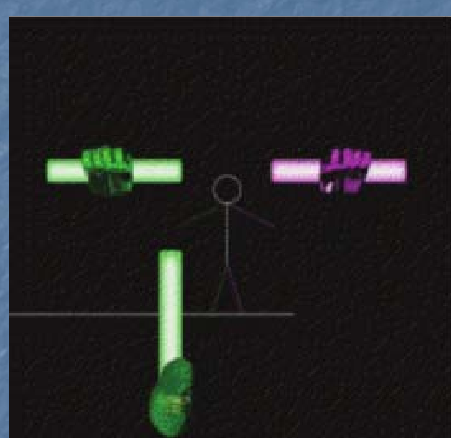
Visual Interface: Motion Lines



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Experimental Hypothesis

- Run a user study comparing three visual interfaces
- Users play RealDance with all of them
- Study their preferences and performance

- Our hypothesis: players will prefer Motion Lines or Beat circles over the Timeline interface, because the streaming icons must present too much information

Subjects and Apparatus

- Participants
  - 24 participants: 13 male, 11 female
  - Ages 18-29
  - 19 had no formal dance experience
  - 17 play video games > once a month
  - 14 familiar with Dance Dance Revolution
- Apparatus
  - Implemented in C# using XNA on a PC running Windows Vista
  - 50 inch Samsung HDTV, 1920 x 1080 resolution

Experimental Design

- Experiment takes place in an enclosed space
- Consent form, Pre-questionnaire, Icon sheet
- Suited up into Wiimote sleeves
  - One each wrist, one each ankle
- Experimental Task
- Post Technique Questionnaire
  - 16 questions, 4 open answer
- Post Questionnaire
  - 10 questions, 8 open answer

Experimental Task

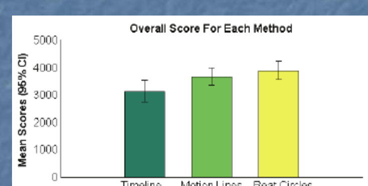
- For each interface
  - Two practice sessions to Ghostbusters theme
  - Gameplay session to Thriller
    - RIP Michael Jackson ☹
- Scored based on timing if correct movement
  - Each move either 100, 75, 50, or 0
  - Compound moves scored per limb
  - Max score 6700

Results: Learning Effects

- Each participant received one of six arrangements
- Even though order was randomized, choreography was identical
- Repeated measures one way ANOVA
  - $F_{2,22} = 0.306$, $p = 0.738$
- No significant improvement from game play session order

Results: Score Analysis

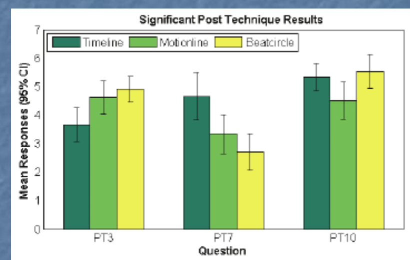
- Participants performed better at spatial interfaces
- Holm's sequential Bonferroni adjustment with three comparisons at $\alpha = 0.05$
  - ML > TL
    - ($t_{23} = -4.38$, $p < 0.0167$)
  - BC > TL
    - ($t_{23} = -3.26$, $p < 0.025$)
  - No significance between ML, BC
    - ($t_{23} = -1.20$, $p < 0.243$)



	Hand	Foot	Compound
Timeline	48.39 (17.48)	52.32 (16.46)	40.69 (15.95)
Motion Lines	59.29 (16.27)	64.58 (14.65)	44.40 (14.13)
Beat Circles	64.18 (18.87)	60.93 (14.93)	52.44 (16.12)

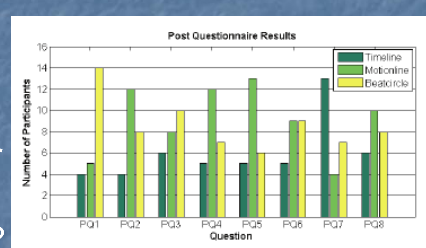
Results: Post Technique

- Easy to Follow?
  - BC > TL (Z = -2.69, $p < 0.0167$)
  - ML > TL (Z = -2.39, $p < 0.025$)
- Position of the icons confusing?
  - TL > BC (Z = -3.08, $p < 0.0167$)
  - ML > TL (Z = -2.38, $p < 0.025$)
- Score matched how you felt you did?
  - BC > ML (Z = -2.50, $p < 0.0167$)



Results: Post Questionnaire

- Only question 1 was found significant:
  - Which interface did you perform the best in? (Beat Circles)
- Worth noting that Timeline was least chosen interface for each question except for question 7:
  - Which did you like the least?
- Spatial nature of Motion Lines and Beat Circles may have divided choices



Discussion

- Timeline
  - Liked to see the approaching moves ahead of time
  - Still found it hard to know when to start moving
- Motion Lines
  - Much better sense of where to go, which body part to use
  - Repeated movements were harder to see
- Beat Circles
  - Icon position defined ending position, timing was easier
  - Overlapping circles made repeated movements confusing

Conclusion

- So far, the Timeline interface has worked well for rhythm dance games
- But as video game consoles explore 3D user interfaces, they can now create new gameplay experiences
  - Nintendo, Sony, and Microsoft all made interface announcements at E3 2009
- In our study spatially designed interfaces were easier and preferred overall
- Identified pros and cons for each design

Next Class

- Future of 3D UI
  - 3DUI Book – Chapter 12