How Do Visualization Techniques Improve Construction Decision-Making

PhD qualifying exam
Winter 2000
Kathleen Liston

Overview

• Motivation
• Vision
• Opportunity and Objectives
• Questions
• Point of Departure
• Methods and Plan
• Contributions
• Risks
Motivation: Observations of Project Meetings

Does information support decision-making tasks?

Would 4D technologies help?

Analysis of Current Practice

DESCRIPTIVE (40%)
When do we have access to Area C?
What are the wall sections these numbers refer to?
Where are you placing the crane for erection of XXX?

EXPLANATIVE (20%)
What is driving the finish times for the rides?

PREDICTIVE (10%)
Can we get access to the lagoon a week earlier?

EVALUATIVE (30%)
Does this meet contractual milestones?

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Example of Current Practice

When do we have access to Area C?

Conclusions:
Independent unrelated views, must mentally relate information.

Example of 4D practice

Conclusions:
Fewer views, but still need to look for relevant information and relate it.
Analysis of 4D Practice

- Predictive (10%)
- Descriptive (20%)
- Explanative (40%)
- Evaluative (30%)

Current practice \rightarrow Current 4D practice

Research Vision

Use annotative visualization techniques to relate information

- **Highlight**: visually relate information in different views
- **Overlay**: visually relate information in same view
research vision: highlight example

research vision: overlay example
**Research Scope**

- Front-end of workspace
- No implementation, prototype only

**Workspace Environment**

**Scope of Research**

**Research Opportunity**

**Information Visualization**
- Characterize use of visualization for construction tasks

**Construction Information Visualization**
- Apply CS/HCI research to AEC: information visualization and workspace technologies
- Improve effectiveness of 4D technologies
**Research Opportunity**

**Evaluation of Visualizations**
- Extend and apply ‘fit’ model

**AEC Data Models**
- Validate need for representing relationships and drive representation from use

Adapted from Vessey (1991), Dennis and Carte (1998), and Pervan (1995)

**Research Objectives**

1) to empirically assess the usefulness of
   - overlay and
   - highlight visualization techniques
   for AEC decision-making tasks
2) to characterize the ‘fit’ between these visualization techniques and AEC decision-making tasks
Research Questions

1) What metrics assess the usefulness of visualization techniques for decision-making task performance?

2) What is the fit between visualization techniques and decision-making tasks?

Explanation of Questions

- task characteristics
- visualization techniques
- performance metrics

Cognitive Fit or Fit Model
Adapted from Vessey (1991), Dennis and Carte (1998), and Petron (1995)
## POD: Task Characteristics

### Survey of Decision-Making Task Characteristics

<table>
<thead>
<tr>
<th>Type of Decision-Making Task</th>
<th>Domain-specific typologies (Jarvenpaa and Dickson 1988) [Babiker et al. 1991]</th>
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<td>Low-level domain independent typology (Wehrend and Lewis 1990) [Sebrechts et al. 1999]</td>
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<td>High-level decision-tasks (Newell and Simon 1972) [Winograd and Flores 1987]</td>
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<td>Information-Processing Typology (Lawrence 1999)</td>
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### Level of Decision-Making
- Phases of Decision-Making
- Task Difficulty (task complexity, task clarity, task knowledge requirements)
- Task Complexity
- Task Knowledge Requirements
- Task Clarity
- Task Interdependence
- Task Importance
- Task urgency
- Task size

## POD: Task Complexity

- Task complexity as a function of information requirements [Parvan 1995]
  - **information type**: quantitative, more data types - higher complexity
  - **visual form type**: graph, network [Lohse et al. 1994; Card et al., 1999]
Proposed Task Typology

Criteria
- observable
- scope of usage for visualization technique
- similar information requirements

Proposed Task Typology: Detailed

Matrix to Define Task Input Relationships
Example of relationship for: When do we have access to XXX?

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<th>Temporal</th>
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task type: spatial-temporal-semantic
Proposed Task Complexity

Function of:
- # of types of information requirements (assumed = # of visual forms)
- # of information requirements

POD: Visualization Techniques

Techniques to relate same items across views:
- SDM [Chuah et al., 1995]
  Lifelines [Plaisant et al., 1996]
  Filmfinder [Ahlberg and Schneiderman, 1994]
- Brushing: highlighting same item in multiple views X Gobi [Buja 1996]

Techniques to relate items in one view:
- Visage: drag and drop different types of information [Roth et al., 1997]
Proposed Visualization Techniques

- Highlight: relate same or different items across and within views
- Overlay: relate items in one view ‘snapped’ to base form

POD: Task Performance Goals

Common Types Performance Metrics
[Preece et al. 1995]
- accuracy: high
- task completion: high
- time: low
- quality: high
Overlay and Highlight techniques will:

• reduce time spent performing descriptive, evaluative, and explanatory tasks

• reduce effects of task complexity on accuracy, time, and task completion

Metrics to Assess Performance

- time
- accuracy
- task completion

Adapted from Vessey (1991), Dennis and Carte (1998), and Pervan (1995)
Metrics to Perform ‘Fit’

- information type
- relationship types
- # of information
- visual form types

Adapted from Vessey (1991), Dennis and Carte (1998), and Pervan (1995)

Example of Performance Metrics

Analysis of Observed Decision-Making Task

When do we have access to XXX? 

Accuracy: low 
Completed: no 
Time spent: 5 minutes 
Task complexity: medium 

Information relationship

2D text temporal chart
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**Method: Charette Test Trials**

- **Observe Current Practice**
- **Define Metrics & Design Test Trials**
- **Prototype CIW**
- **Test CIW**

**Interactive Catalog**
- **Baseline Metrics**
- **Set of Performance Metrics and Formalization of Test Methods**
- **Demonstrations of CIW Visualizations**
- **Documentation of Test Results Mapping Techniques to Tasks**

**Test**

- **Groups of 2-3**
- **1 hour**
- **20 questions**
  - 4 each, increasing task complexity
- **Variables:**
  - Visualization technique
- **Pre-Defined Variables**
  - Task types
  - Task complexity (information requirements and information relationships)

**Sample Test**
Test Plan

- Test Trial #1: No Annotation vs. Highlight
- Test Trial #2: No Annotation vs. overlay
- Test Trial #3: Highlight vs. Overlay

Initial Characterizations

Test characterizations

Research Risks

- Note: Technology not a risk
- Note: Outcome is interesting whatever the cognitive fit
- Validation of Metrics
- Test case is not representative of broad class of AEC problems
Expected Contributions

• Validated Set of Performance Metrics
• Empirical results and analysis
  - performance results
  - cognitive fit matches (if any)
  - suggestions for types of overlay and highlight mappings

![Diagram of data flow](image-url)