MARCH 5, 2009

"Empirical Study on the Merit of Web-Based 4D Visualization In Collaborative Construction Planning and Scheduling"

Julian H. Kang, Stuart D. Anderson, and Mark J. Clayton
By: C. Brooks Herman

Can web-based 4-D construction visualization be useful

in collaborative construction planning and scheduling?

Introduction

Making a Schedule

- Break into work packages
- Build a logical network
- Estimate the time duration
- Identify the critical path
- Illustrate as a bar chart

Reviewing for Logical Errors

- Construction planner reads architectural drawings and schedule
- Step-by-step process does not allow for detections of:
  - Omissions,
  - Conflicts, or
  - Logical Errors

4-D Construction Visualization

- Traditionally Designers made 2-D drawings from 3-D idea, then…
- The Constructors took the 2-D drawings and made a 3-D structure.

- This required a great deal of education, acquired skill, & practical experience on both sides.

- 1980s brought 3-D CAD to Architects/Engineers/Construction

- Later being integrated with timetables to now be coined as 4-D visualization.

Web-Based Project Management

- "Collaboration in construction projects is essential to generate and exchange project information."

- Internet has made collaboration and frequent updates possible
- Programs used to model information online:
  - Virtual Reality Modeling Language (VRML, Original 3-D Modeling)
  - Java 3-D Application Program Interface (API, 3-D Modeling)
  - Java Database Access (Provides 4th Dimension Integration)

- "…,Web-based 4-D construction visualization is expected to improve the process of collaborative construction planning and resolving schedule conflicts."

The Experiment

Research Design and Methods

- Merits of Web-based 4-D visualization evaluated best with real construction planning and scheduling
- Complexity led to reduction of size and scope of study

Computer Simulation

- Experiment designed to test effectiveness of web-based 4-D construction visualization
- Teams broken into two randomly selected groups (A and B)
- Viewed four tasks of assembly at two different levels of graphical representation
  - 1st Level – 2-D drawings showing floor plans/sections and schedules
  - 2nd Level – 4-D construction simulations (3-D models plus schedules)
- Team tasks, role-playing, and graphical resources were distributed, rotated, and counterbalanced among the teams.

The Experiment

Participants

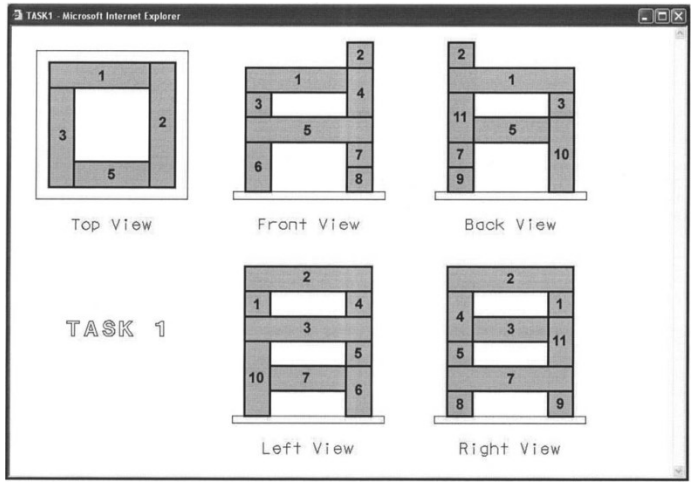
- Data Sample: 84 undergraduates
- Teams sorted by random generator
- Teams divided into random groups
- Given a sequence of four tasks (either 2-D or 4-D graphical resources)

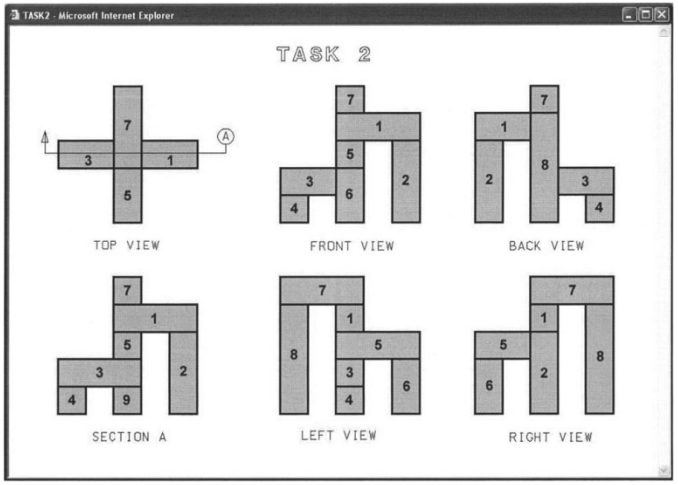
Roles of Individual Participants

- Each member randomly assigned a role (Owner/Contractor)
- Owner
  - Detect logical errors
  - Obtain acknowledgement
- Contractor
  - Acknowledge logical errors quickly

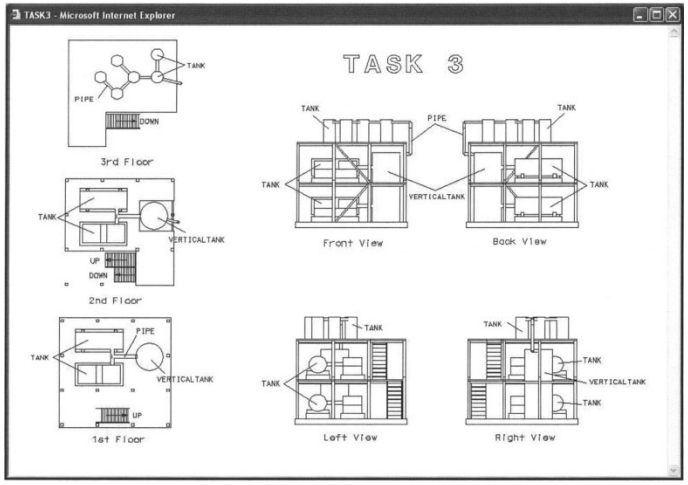
The Experiment

Task 1





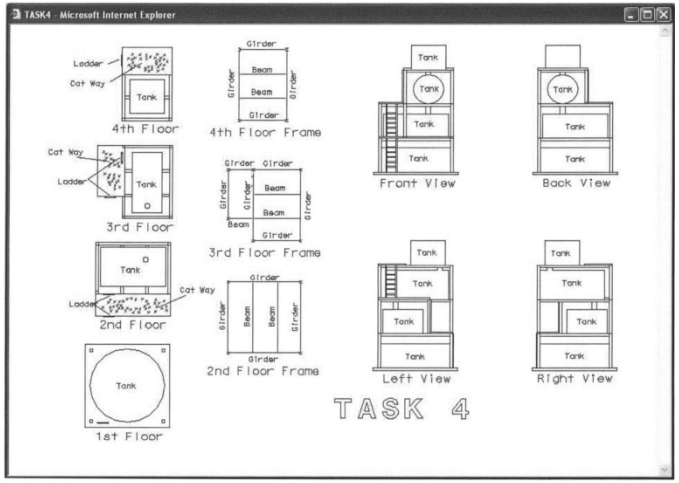
Task 2

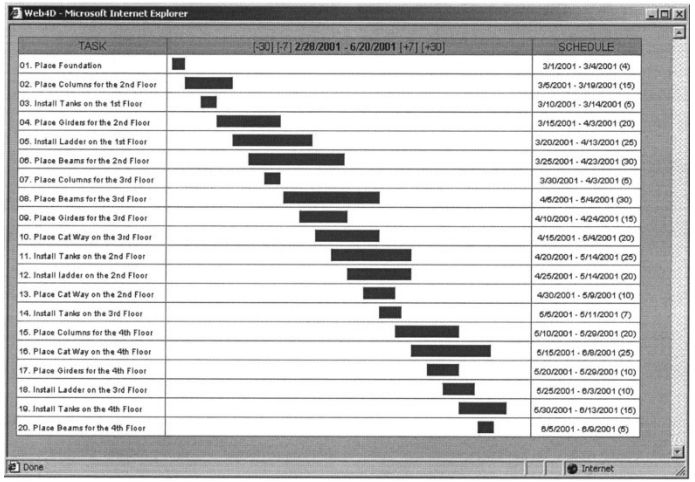


Task 3

The Experiment

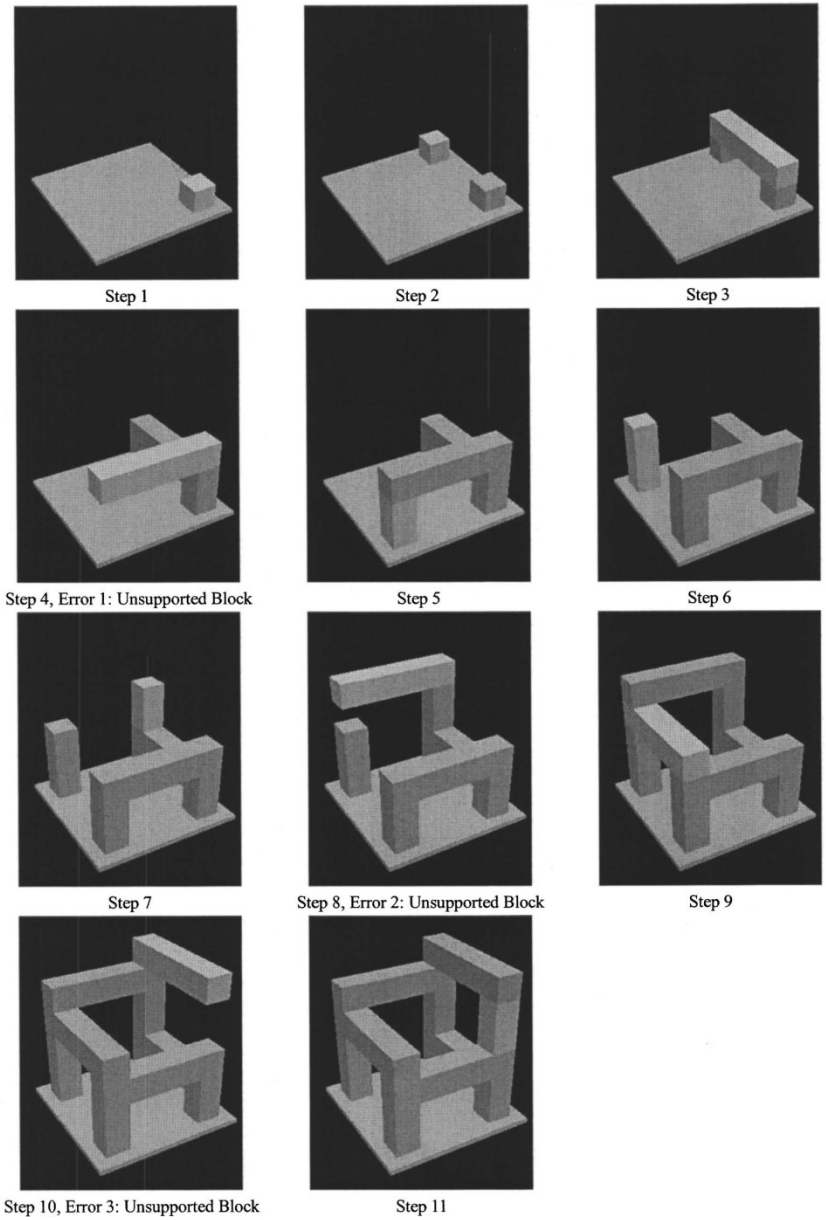
Task 4



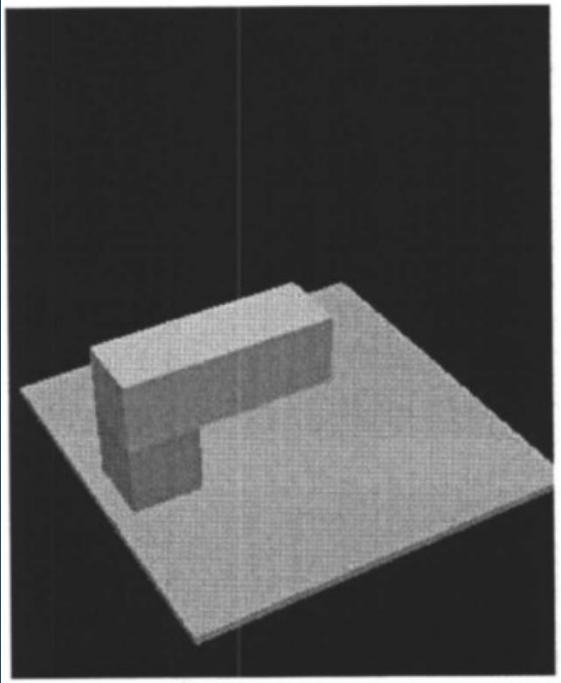


The Experiment

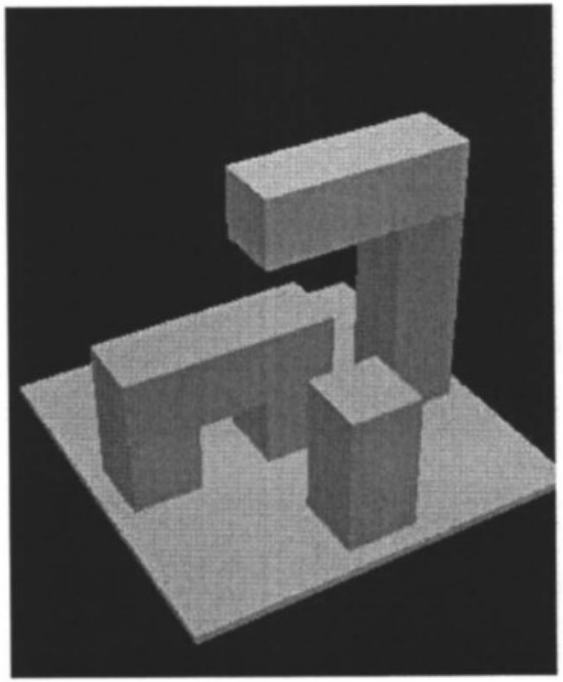
Steps/Errors for Task 1



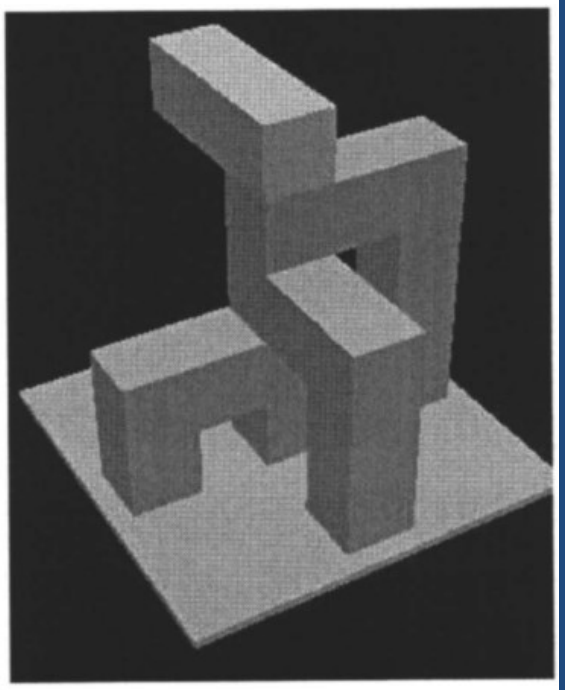
The Experiment



Error 1: Unsupported block



Error 2: Unsupported block

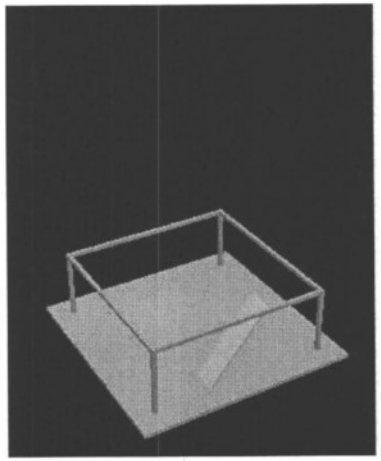


Error 3: Unsupported block

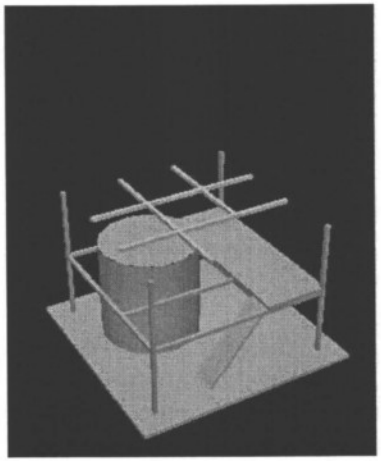
Errors for Task 2

The Experiment

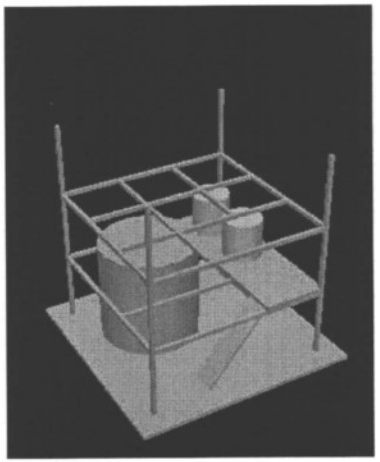
Errors for Task 3



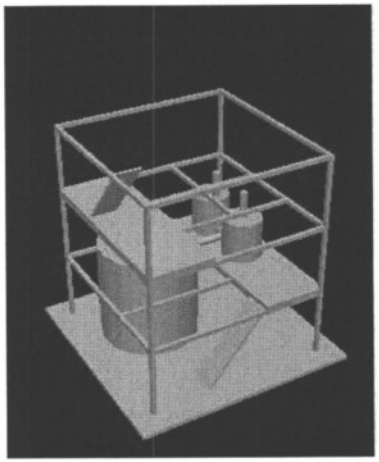
Error 1: No support for the stair



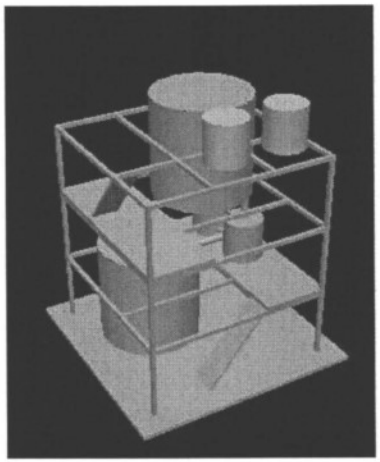
Error 2: No support for the beam



Error 3: No crane can install tanks un derneath the beam

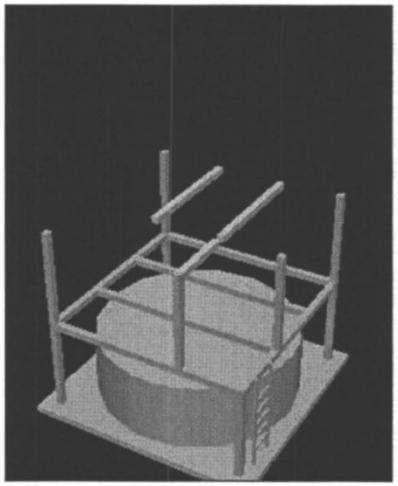


Error 4: No support for the stair

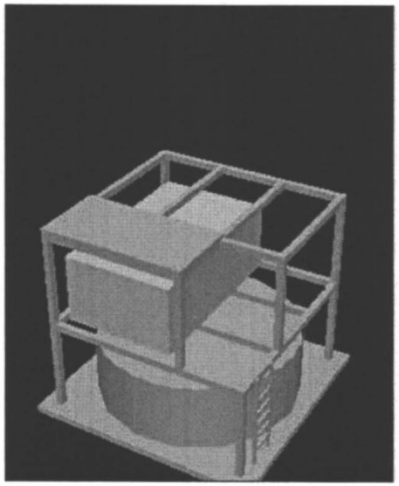


Error 5: No support for tanks

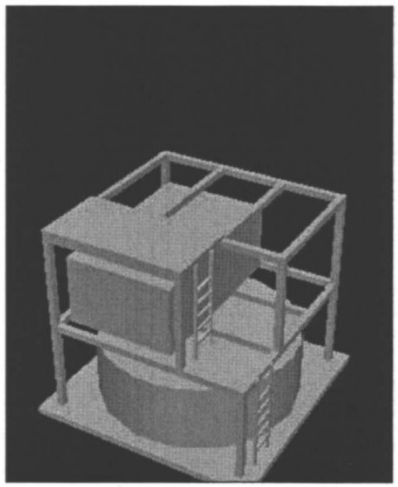
The Experiment



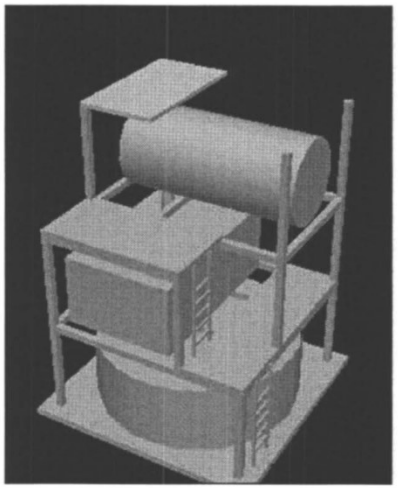
Error 1: No support for the beam



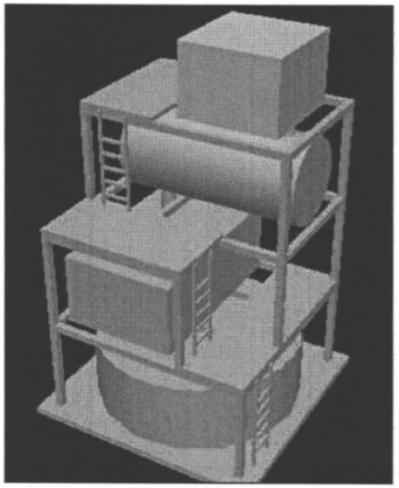
Error 2: Tank should be placed first



Error 3: No support for the ladder



Error 4: No support for the plate



Error 5: No support for the tank

Errors for Task 4

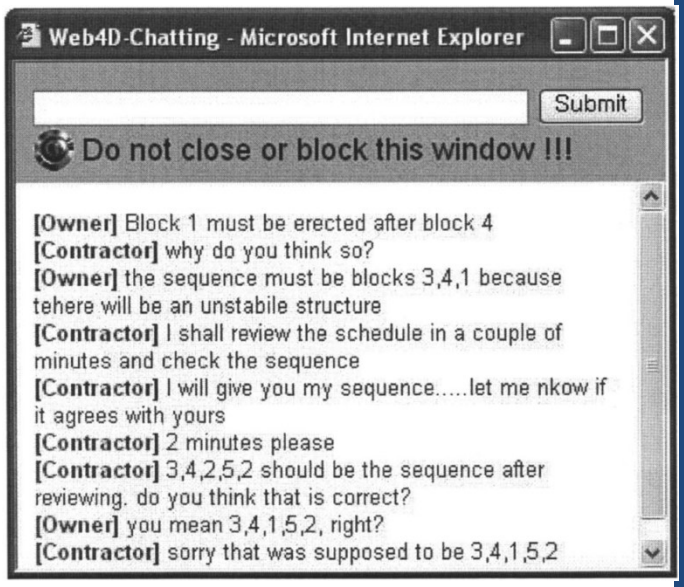
The Experiment

Web-Based 2-D and 4-D Graphical Resources

- 2-D Interactive Web Page
  - Drawings illustrating plans/sections
  - Bar chart represented schedule
- 4-D Interactive Web Page
  - Each task displayed snapshot in 4-D
  - Bar chart represented schedule

Instruments and Setting

- Unique Web-based environment
- Instructions/Communication/Drawings seen on page
- Members sit in different locations
- Chat saved with time stamps



Data Analysis

- Data analyzed on three measures of team performance:
  - Number;
  - Accuracy; and
  - Speed of Detecting Logical Errors.

- After data collection, but before data analysis, Teams A and B, were now Group 2-D and Group 4-D

- Raw data converted into measures of the three outcome variables for team performance, and one measure of the outcome variable of intrateam communication.

- Two sample *t*-test or the Wilcoxon rank sum test was used to analyze data

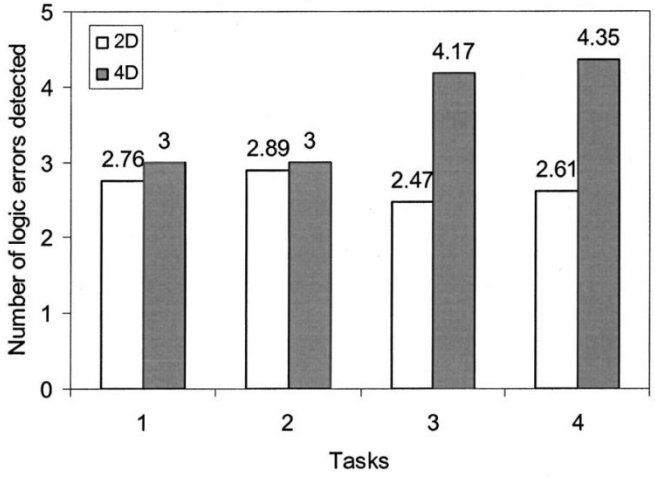
Results

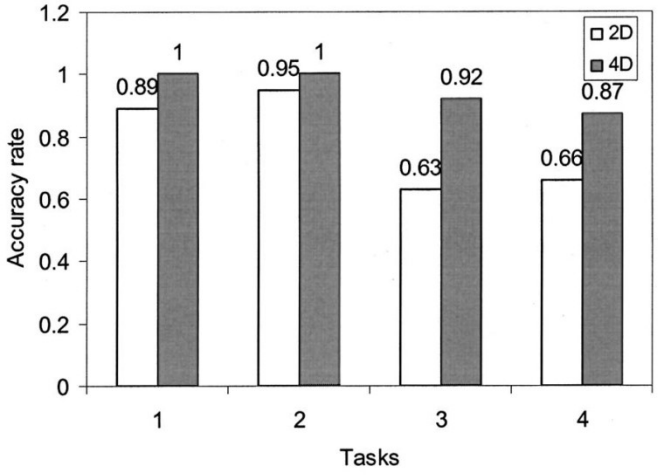
Number of Logical Errors Detected

- Group 4-D detected more for Tasks 3-4
- Wilcoxon showed, less than 1% chance Group 2-D would equal 4-D for Tasks 3-4.
- Task 1: 38% chance 2-D equals 4-D
- Task 2: 59% chance 2-D equals 4-D

Accuracy Rate in Claiming Logical Errors

- Group 4-D more accurate for Tasks 3-4
- Results showed slight tendency for 2-D to make more false claims.
- Task 1: 25% chance 2-D equals 4-D
- Task 2: 41% chance 2-D equals 4-D

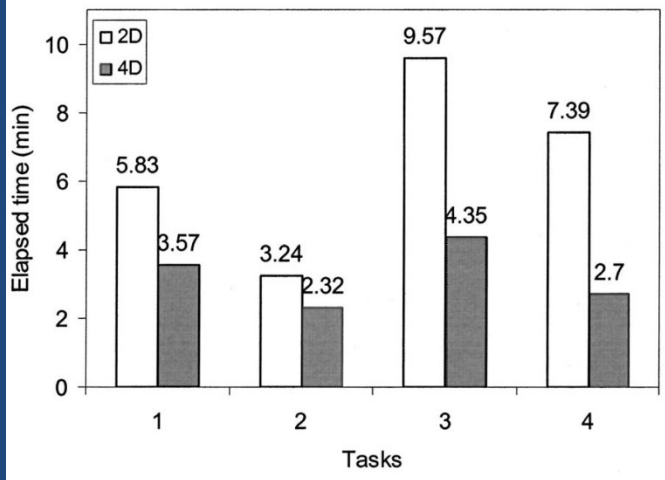




Results

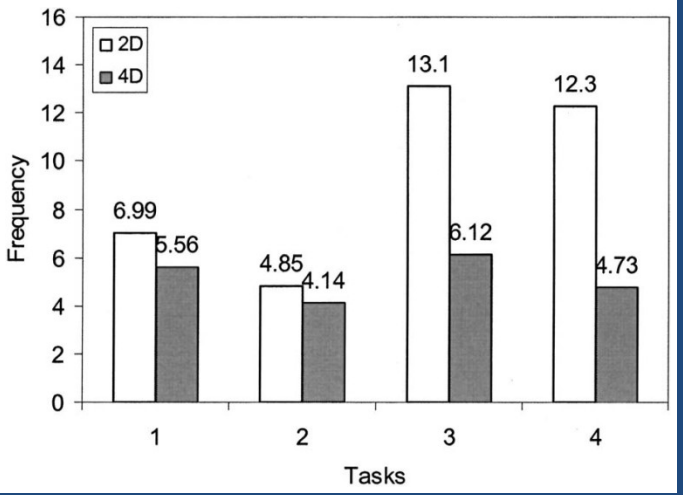
Rate of Speed to Detect One Logical Error

- Group 4-D detected logical errors faster on all tasks.
- 4-D Owners did not explain detected logical errors in detail.



Frequency of Team Communication

- Group 2-D communicated more frequently than Group 4-D, especially during Tasks 3-4.



Results

- All four tasks, teams in Group 4-D detected a larger number of logical errors with higher rates of accuracy and speed.
- Intrateam communication was more frequent among Group 2-D team members in Tasks 1-2.
- Tasks 3-4 significantly increased communication among Group 2-D.
- Group 2-D chatted more frequently, but was very slow at detecting errors.

Findings and Conclusions

- “Results of the research presented here provide empirical evidence of the potential merit of representing a 4-D construction visualization model on a Web browser for collaborative construction planning and scheduling.”

- “In construction planning, effective communication among project participants contributes a great deal toward making proactive decisions that avoid logical errors in the construction sequence.”

Example

http://cbherman.googlepages.com

Question & Answer

Quiz