ETH zürich

Turbulence ahead – Using JavaScript to Design a Web-based 3D Turbulence Simulator

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1 Motivation

This thesis is motivated by the potential for improvements in pilots' spatial awareness by using a 3D representation of weather forecast data for pre & in-flight processes.

Pilots are preparing for flights by looking at weather forecasts to estimate expected turbulence areas along the flight path. Currently, those forecasts are distributed as black-and-white 2D maps that do not represent the state-of-the-art of digital (web) maps and available weather data.

2 Research Questions

Performance: How fast can pilots make decisions based on how the weather information is visualized?

Cognitive Load: How difficult is it for pilots to extract information from what is presented to them?

Usability: How does dimensionality and the way of displaying weather information affect usability?

Spatial Awareness: How does the way of displaying weather information impact a pilot's spatial awareness?

3 Methods

The web-based 3D prototype was developed with the **ArcGIS API for JavaScript**. The source data (2D maps) has been digitized and extruded to 3D objects with ArcGIS Pro and published to an ArcGIS Portal. The final interface of the prototype can be seen in figure 1.

An **online user study** with 64 pilots has been conducted in order to compare the two different representations (conditions):

- 2D Significant Weather Chart (current)
- 3D Significant Weather Chart (new)

The study was designed as a counter balanced **within subject** experiment.

4 Application / User Interface

Fig. 1. A screenshot of the 3D web-based prototype displaying weather forecast data for a flight from Zurich to Singapore

5 Results

Performance was measured by tracking the completion time for 8 questions that required the use of the map (2D/3D) in the user study. The questions reflected the steps taken by pilots to prepare for a flight.

The statistical analysis (*Wilcoxon Signed Rank-Test*) has shown that there were significant differences for 4 out of 8 questions ($p < 0.01$) with three questions indicating that the 2D map allowed for faster information extraction and one question where the 3D map allowed for better performance. However, for 3 out of 8 questions, group effects were found.

Cognitive load was assessed with a NASA TLX questionnaire. Five out of six measurements showed significant differences (⭐), all indicating that the 3D map was less difficult. On average, the cognitive load could be reduced by 18.3%.

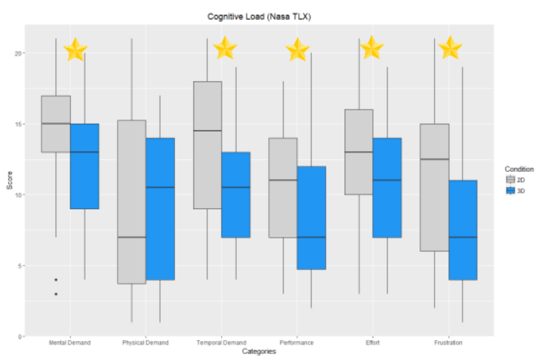

Fig. 2. Cognitive load results from the user study.

Usability was measured with a System Usability Score (SUS) with standardized questions. The results showed that pilots rated the 2D map with an overall 60% score whereas the 3D prototype was rated with a 78% score on average which showed to be significant ($p < 0.01$).

Spatial Awareness was assessed with a drawing task where participants had to draw what they recalled from the map that they previously looked at. A similarity measure was introduced that compared the drawings with ground truth (see fig. 3).

Fig. 3: Ground truth (left-side) vs. drawing (similarity of 80.6%)

The results show that spatial awareness was improved by the 3D condition and that statistical differences ($p < 0.01$) between the similarity measures were found.

6 Conclusion

The user study showed that the novel 3D prototype performed better for three out of the four research questions (usability, cognitive load and spatial awareness) when compared to the current 2D maps.

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