Exploring Multi-dimensional Data on Mobile Devices with Single Hand Motion and Orientation Gestures

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Motivation

Visualizing, exploring and making sense of large-scale, multi-dimensional data has become a key challenge for researchers and practitioners due to technological advances in sensing, communication, and storage. If such data were navigable on always-online mobile devices, possible applications might include:

- Consumer product search by viewing product specifications
- Advice from off-site medical professionals using patient vital signs
- Monitoring bugs or service problems from server/system error logs

Visualization

- The scatterplot matrix remains widely used by people in different disciplines
- Existing solutions are optimized for desktop computers, which lack in-hand, orientation-aware capabilities

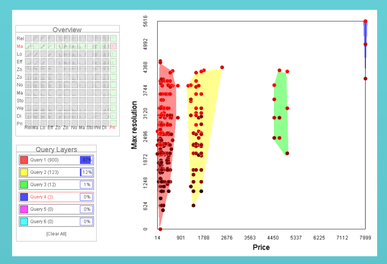
Exploration

- More intuitive visualization techniques can be achieved via in-hand, orientation-aware interfaces
- Existing solutions require additional hardware to achieve such interfaces

Related Work and Approaches

Visualization - ScatterDice

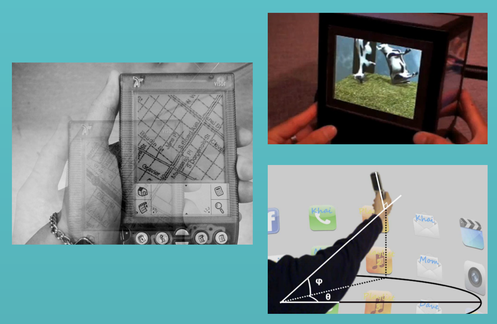
- ScatterDice (Elmqivist et all 2008) combines both the simplicity of scatterplot matrix visualization with 3d visualization between individual scatterplots
- Designed and optimized for desktop computers with large displays, and some techniques require desktop-specific input devices such as a mouse or a stylus with push buttons



ScatterDice uses a focus+context display and a dice-rolling metaphor but requires several interface windows

Orientation-aware Exploration

- pCubee (Stavness et all, 2010), Peephole Display (Yee, 2003), and Virtual Shelves (Li et all, 2009) demonstrate the feasibility and promising interaction scenarios of orientation-aware interfaces
- pCubee and Peephole Display give user single-hand control over some visualization
- All require external, expensive motion capture devices to simulate the intended effects, which makes proposed techniques not yet available for everyday use



pCubee (top-right), Peephole Display (left), and Virtual Shelves (bottom-right) use effective, orientation-aware interfaces

ScatterDice Mobile (SDM)

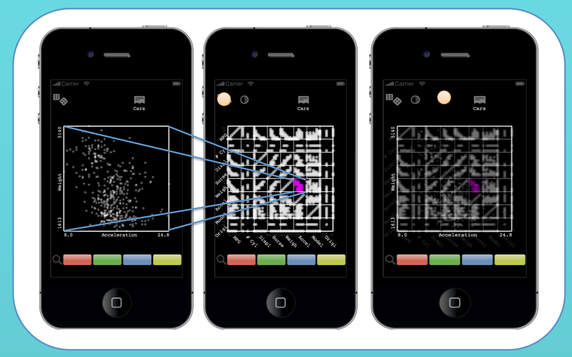
We present ScatterDice Mobile, an interactive visualization system that uses the gyroscope sensor recently available on mobile devices to establish an orientation aware “dice rolling” metaphor for browsing scatterplot matrix visualizations mapped to a cube on mainstream mobile devices without hardware modification.

Overlay-based Mapping

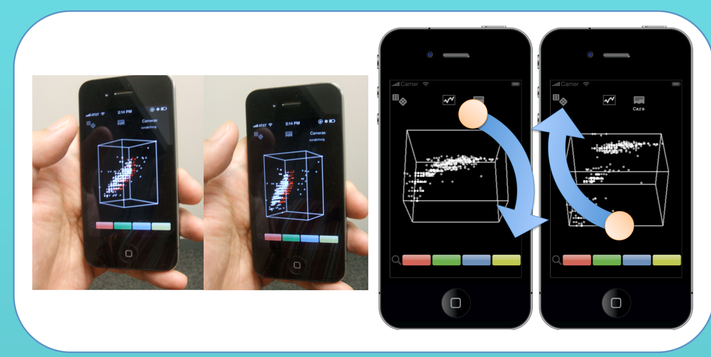
- A scatter matrix provides a global view of multi-dimensional data and can be used for navigation
- Can view local plots alone or with scatter matrix overlay
- 3d scatterplots shown when changing from one local scatterplot to another

Orientation-aware Perspective

- Onboard gyroscope provides orientation-awareness, and 3d visualizations of data are perspective-corrected as user turns the device in his/her hand
- Full, single-axis rotation is possible by combining orientation and touchscreen gestures



The scatter matrix gives a global view of individual scatterplots (left). Local plots are mapped to cells of the scatter matrix (center). A translucent, dismissible overlay allows a simultaneous local and global view (right)

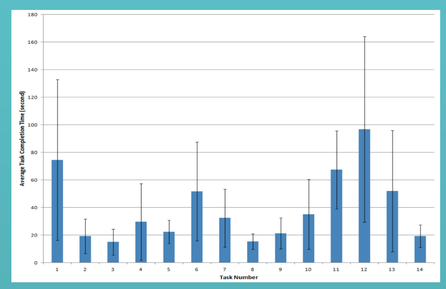


The perspective can be changed by tilting the device in one’s hand (left) and by making swiping the screen with finger or thumb (right)

Pilot User Study

We have conducted a 12-user pilot user study to explore whether the idea of SDM is intuitive to understand and whether users can learn and use SDM efficiently to complete real world tasks. After finishing a brief tutorial, participants completed 14 data exploration tasks involving two data sets (digital camera dataset, 12 dimensions, 1038 samples; and automobiles dataset, 8 dimensions, 398 samples; 7 tasks for each dataset)

Sample pictures were taken during the user study (left), and quotes from users commenting on the SDM visualization and exploration strategies were collected (below).



This table shows the average completion time (with error bar of one standard deviation) of each task. It took most users some time to complete the first task, but their skills improved quickly afterwards. Most users completed the open-ended, final two tasks efficiently.

- *“easy to use and intuitive”*
- *“very cool program and very useful”*
- *“seems useful and well-organized”*
- *“I would not use it, and I did not like it.”* (this user alone gave SDM a negative review)

- *“While manipulating the data initially seemed daunting, I found it easy and even fun to use once the device was in my hands.”*
- *“3D representations (in-between) were very interesting “*
- *“I really liked the cube aspect, and how you can keep one axis while changing the others to find what you need”*