Interactive Multiple Scale Small Multiples

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ABSTRACT

Numerous scientific and analysis problems involve integrating heterogeneous information that is multidimensional, multivariate, and time-dependent. To visualize this data in a 3D environment, we designed a visualization technique called multiple scale small multiples (MSSM), in which each view behaves like an environment in itself. Aggregated multiple views can also form single view visualization. Data from bat flights and flow simulations were used to demonstrate MSSM at work. Users can interact with the dataset at different levels of detail and scale, and access a fairly large amount of data points.

1 INTRODUCTION

Many datasets generated from simulations are time-dependent, include thousands of time steps, and have multiple fields. While mathematical modeling helps users understand the fundamental phenomena, making decisions based on heterogeneous information is non-trivial; the tasks demands interactive visualizations to support complicated data exploration. With this in mind, we have two primary research questions: Can we design effective visualizations to display multifield multivariate datasets? What is needed to support creative data exploration and to foster insight discovery?

Motivated by the complex data generated from bat flight simulations in a wind tunnel [8], we designed interactive multiple scale small multiples (MSSM, Fig. 1, 2) that allows simultaneous viewing of diverse datasets (e.g., kinematics, anatomical structures, and the wake structure behind bat wings). The views are not static; each view is a small environment in itself and can be rotated, scaled, or drilled down to see details. Multiple views can be overlaid or linked. If linked, selected views will behave in the same way, by showing same data properties and changing with other views.

An ultimate goal of this work is to define the mapping between visual encodings, data types, and tasks, so that presenting complex datasets is like operating a mathematic formula. In this paper, we present our on-going efforts to design MSSM. A rationale based approach was used to reason our design in the information layout and interaction in a three-dimensional (3D) environment.

2 RELATED WORK

Guidelines related to multiple views in two-dimensional (2D) information visualization suggested using multiple views if data contains diverse attributes, if correlations and disparities in data can be made apparent, or if a single view is overwhelming [2]. Such guidelines of use still hold for 3D scientific visualization [1, 5]. However, different design issues may arise because of 3D itself. For example, the lack of effective orientation cues could introduce more errors [6]; the mostly discussed context switching problem between views could be alleviated by better user strategies and visual encoding [3, 7]. The study of visual encoding, data attributes, and tasks attributes to design 3D multiple views is therefore important.

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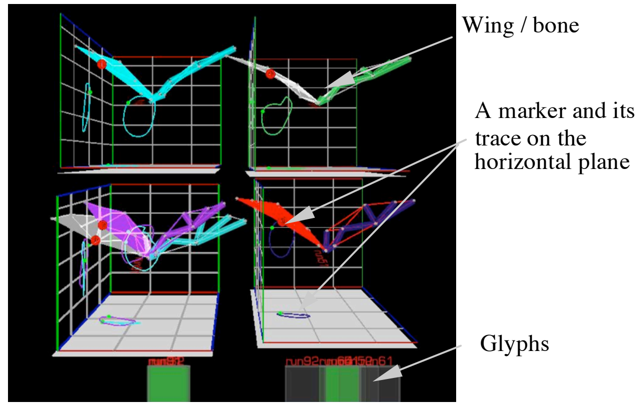

Figure 1. Multiple scale small multiples. An animated view of five small multiples that show bats flying at different speeds. Two multiples are overlaid on top of each other to compare two bat flights. Glyphs stick to the bottom of the screen to provide overview information. Users can drag the glyphs or the multiples to move the bats.

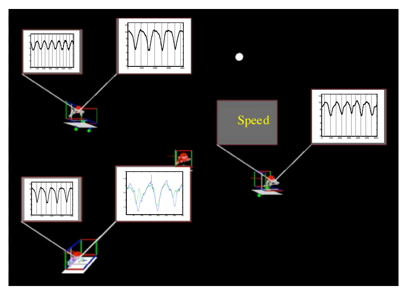

Figure 2. Scale-down visualization allows users to focus on graph analyses. Annotations display biological information associated with the selected marker (e.g., the speed changes during the flight). Users can gesture to link views to associate different types of information. A new graph will pop up to show their relationship.

Previous multivariate visualization in scientific visualization focused either on data (e.g., applying math operations) [10] or the interface modeling [1, 5]. Relationships between datasets are displayed using parallel coordinates or spread-sheet style multiple views [4]. These approaches can be more powerful if appropriate interaction is integrated.

3 INTERACTIVE MULTIPLE SCALE SMALL MULTIPLES USER INTERFACE

We use bat flight simulations to demonstrate MSSM at work, because evolutionary biologists at Brown University would like to use a visualization tool to compare, probe, and analyze their data. In addition, the data are spatial (e.g., kinematics data from 56 markers and proper orthogonal decomposition on 9 of them) and also multidimensional, including pressure, velocity, and vorticity fields from two aerodynamic simulation methods. Such data were collected on bats flying at different speeds.

3.1 Design principles

Two major design principles have guided the design of MSSM. First, *a principle of effective visualization*, aimed for the visualization to convey the exactly intended meaning. For example, because multiple field data can easily overwhelm users, visualization design should exaggerate or complement human cognitive ability. Multiples can show all information on the screen, making less information to be remembered in users' heads. Therefore the views become part of users' working memory that is always available. Users can then focus better on data analysis tasks.

Second, *a principle of effective interaction* facilitates decision-making. Useful information is often derived from interacting and operating on the information with a variety of processing mechanisms. When information is displayed, users should be able to link information spaces to form new visualizations.

3.2 Visualization and design rationale

Small multiples. Each wing-beat cycle of a bat is shown in one small view in a Cartesian coordinate system. The projections on the three planes encoded the trace, the upstrokes and downstrokes (color coded) and the speed (line width coded). Such information serves as the basis for kinematics analyses.

Detailed information on each marker point can be queried by clicking or moving the cursor over the marker, drawn as a gray dot. Annotated notes including all relevant information about the selected marker will be displayed at the nearest location of the marker point. Information conveys the analysis of a joint or bone based on domain knowledge in biology. For example, clicking on the wing tip marker will display the wingspan information and wing beat reversals; clicking on a wrist marker will display the angles between the forearms instead.

Multiple scales for visual perception. Our attention is easily distracted by a moving target, making the analyses of annotated graphs harder, especially when many bats are visible at once. Scaling down visualizations allow users to focus on graphs, while scaling up allows detailed view of the animated motion or wing structures.

Interactive glyph. Users can easily become "lost" when navigating through many multiples that contain much information. We therefore use glyphs on the bottom of the screen to show all available datasets that name the runs. The locations of the glyphs are mapped to the spatial locations of the bats so visual tracking of specific datasets is effortless. Clicking on the glyphs will toggle on (green color-coded) and off (gray color-coded) the associated views.

Aggregated and separated views. Since separated views lead to better performance on detailed tasks while integrated views are good for overview tasks [9], a visualization that supports fluid transition between these two can be more suitable for data exploration. Users can drag small multiples to separate them or overlay them on top of each other. If aggregated, all relevant information, such as the projected view and the information graphs are also integrated into one annotated note to help data comparison of different flights.

3.3 Discussion

MSSM has received much positive feedback from biologists and aerodynamic engineers who study multidimensional and multivariate datasets. To address our research questions, a follow up usability study is to compare our approach and spread-sheet style user interfaces. A major difference between these lies in the parallel or sequential viewing of multidimensional data and interactivity.

The design of MSSM prompts more questions than answers. First, visual encoding might be one of the leading factors that affect the amount of information that can be visualized and understood. When spatial data are displayed in the small multiples, a key question is how to display the annotations without affecting other views? Geographic information systems concerning connectivity, order, and neighborhood, may bring us effective ways to layout the multiples and design new algorithms in 3D visualizations.

Second, multidimensional data analyses often require the study of data relationships to answer questions. Information visualization queries data or uses various techniques so that millions of data points can be encoded. Can scientific visualization do the same? One way might be to move and shrink unrelated spatial information to peripheral views or a better use of depth. Such a layout of the small multiples will be similar to a tree structure. Another way might be to use topology knowledge to map 3D scientific data to a 2D plan view and show relationships.

Third, better interaction techniques are necessary to interact with the rich information space. For example, users will need to navigate in both 3D and 2D annotated notes, and sometimes the combination of the two. Gesture-based interaction may be the most ubiquitous solution to interact with the rich information space.

4 CONCLUSION

A major contribution of this work is to design the MSSM visualizations to visualize multidimensional multivariate data in 3D environments. Critical design issues related to visual encoding, information layout, interaction were discussed.

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