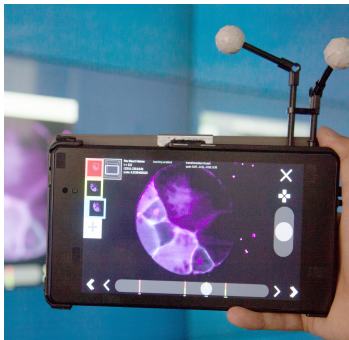


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# Exploring Time-dependent Scientific Data Using Spatially Aware Mobiles and Large Displays



**Figure 1:** Current prototype showing biological data using a spatially aware mobile and a large interactive display.

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## Abstract

Scientific Visualization is generally based on very large and often high-dimensional data sets. In many cases (e.g., in the biomedical domain), high-resolution 3D data that changes over time and multiple data sets are involved. One important task in making sense of this data is finding interesting 2D views in the 3D space and additionally finding ways to handle changes over time. We explore how the combination of spatially aware mobiles and large displays can be used in this context. Specifically, we contribute both a precise selection technique for 2D cross sections and a concept for time-dependent 4D bookmarks that follow a point of interest over time. We implemented these techniques in a prototype application that visualizes biological Light Sheet Fluorescence Microscopy data and report on initial user feedback.

## Author Keywords

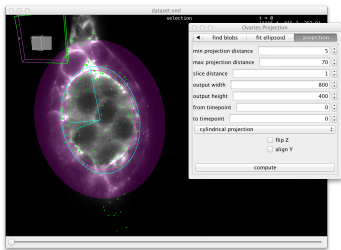
Tangible views; large display; display wall; multi-display environment; spatial interaction; information visualization

## ACM Classification Keywords

H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces - Input devices and strategies; Interaction styles.

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**Figure 2:** Conventional user interface based on Big-DataViewer [7] showing LSFM data.

## Introduction

Exploration of time-dependent 3D data is an important topic in scientific visualization, e.g., in the biomedical field [7] and in fluid dynamics [2]. Challenges include finding 2D cross sections in 3D and in time that display salient features of the data [6]. The combination of a spatially aware mobile display and a large contextual display has been shown to support interaction with cross sections of 3D data well [2, 9]. In these cases, the mobile display's position and orientation in space are used to specify a cross section to show and the large display serves to provide context and a frame of reference. We extend this to cover effective selection using three-way clutching and contribute a novel concept for selection and bookmarking in time-dependent data. Our interaction concepts are based on observations of and discussions with developmental biologists, and our prototype (Figure 1), which displays microscopy time-series, reflects this.

## Related Work

Our work builds on previous work on tangible displays for infovis. A salient example is Spindler et al.'s work on Tangible Views [9], which used projection onto passive tangible surfaces tracked in 3D space for information visualization (later expanded to spatially-aware mobile devices [8]). More recently, Besancon et al. [2] investigated hybrid tactile/tangible interaction in the context of fluid dynamics visualization, again using a spatially-aware mobile device to specify cutting planes. Both these works included an additional stationary display for context visualization. Closer to our application domain, Bertelsen et al. [1] investigated medical volume visualization using a larger display mounted on a movable mechanical arm. None of these works specifically consider time-dependent 3D data or bookmarking.

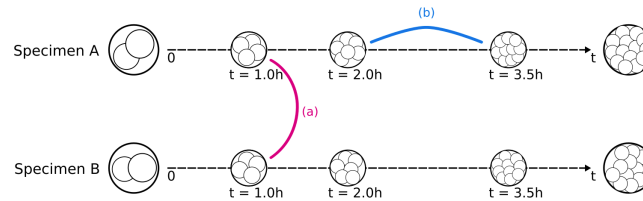
Additionally, there are several overviews that consider the use of novel user interface techniques in the context of scientific visualization. Keefe and Isenberg's 'Reimagining the Scientific Visualization Interaction Paradigm' [6] gives a good concise introduction, including an overview of low-level interactions that these systems should support. Two overviews covering specific modalities are van Dam et al.'s report on VR in scientific visualization [4] and Isenberg et al.'s paper on the use of data visualization on interactive surfaces [5].

## Application Scenario: Visualization of LSFM Microscopy Data

Although we designed them to be generalizable, our interaction concepts are based on the analysis of the workflows of a specific group of users: Developmental Biologists working with Light Sheet Fluorescence Microscopy (LSFM) data. LSFM produces high-resolution, 3D time-series recordings of the development of living biological specimens, enabling scientists to examine anatomical structures close enough to observe miniscule details as small as cell membranes or nuclei in motion during cell division. Our concepts and prototype were developed in an iterative fashion, involving several meetings with prospective users and observations of their work using current tools (e.g., Figure 2). The following user scenario is derived from these observations:

*A developmental biologist, Alice, wants to analyze the effects of different treatments on the development of *Platynereis*, a marine ragworm. Accordingly, her goal is to compare certain biological aspects of these **specimens**. These aspects emerge in certain spatial regions of the embryo and at certain times in the development, so Alice selects appropriate views (called **samples**: 2D cross sections at a point in time, i.e., a 2D plane in 4D space)*

for comparison (Figure 3a). Additionally, to demonstrate the expected development of a specimen, she compares the same aspects in different stages of development of the same specimen (Figure 3b). In both cases, the samples she selects must be located both in time and in space.

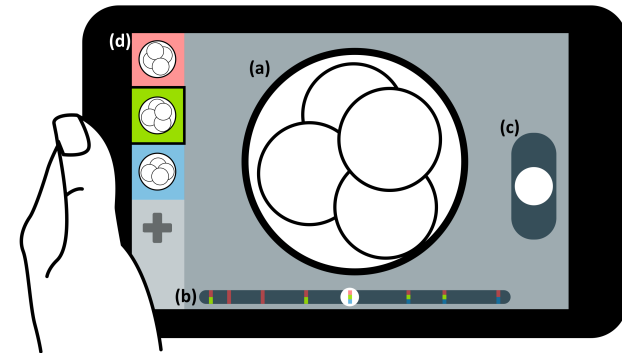


**Figure 3:** Comparing two samples: (a - red line) two specimens at the same stage of development or (b - blue line) two stages of development in the same specimen

Selection in time is aided by the fact that *Platynereis* development is stereotypic and roughly synchronous across specimens, but the location in space involves precise selection of a **cross section** that involves three translational and three rotational degrees of freedom (DOF). This is more difficult, especially if using a 2D input device such as the mouse. An additional issue appears when she needs to be able to follow the aspects over time: With the development of the organism, the interesting points move in space. She therefore needs to be able to adjust cross sections accordingly. Further, when she compares different specimens, it helps if she can transfer sample locations from one specimen to another to have an initial starting point.

After selecting samples for comparison alone, Alice wants to present and discuss her analysis with colleagues. For this stage, Alice would like to have a larger screen for better overview of the data, as well as easy access to bookmarks.

Thus, challenges are the precise yet intuitive and quick selection of a cross section to display and seamless support of time-dependent data, including bookmarking of areas of interest that move over time.



**Figure 4:** Mobile user interface concept. (a) Sample (2D view), (b) Timeline showing current point in time and bookmark keyframes, (c) Clutch for positioning in 3D, (d) Bookmarks.

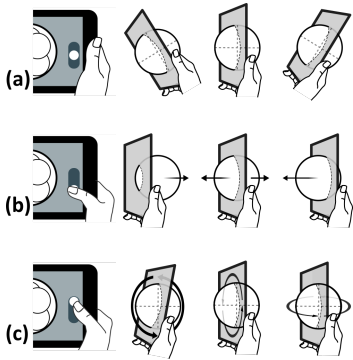
## Interaction Concept

Our interaction concept supports the user scenario above and involves a spatially-aware mobile device as well as a large touch-sensitive display. Users can intuitively select cross sections and in general work with a single sample on the mobile device, while the larger screen enables work with multiple samples and specimens, comparison of samples, and group work.

The mobile UI is structured around a rendering of the currently selected sample (Figure 4a). In addition, it displays a timeline at the bottom (b) that allows selecting the point in time to view. At the right and left sides of the screen – easily accessible by thumb if the device is held in two hands – are further interface elements: A

clutch that controls cross section selection (c), and a list of bookmarks (d).

The contextual display (Figure 7) is large and therefore capable of displaying numerous samples (from the same or different specimen) in multiple views. The individual wall views are similar to the mobile UI: They have the same timeline and bookmark selection functionality (but no facility for specifying cross sections). In addition, they can display a volumetric view of the data that visualizes the positions of the currently configured cross sections. The contextual display also supports a comparison view that superimposes two samples.



**Figure 5:** Clutch usage: (a) In neutral state, the dataset does not move in relation to the tablet's screen, (b) Clutch down: Translation of the cross section within the dataset by moving the tablet along its z-axis, (c) Clutch up: Rotating the selected cross section by tilting or rotating the handheld.

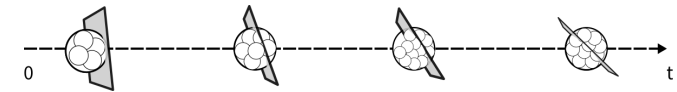
#### Cross Section Selection

Cross section selection – configuration of the 2D cutting plane in the 3D volumetric data – is performed via spatial input (Figure 5). In essence, the position and rotation of the mobile device in 3D space represents the cross section the user wishes to view, and movement of the device changes the cross section (as in [2, 8]). However, it must be possible to enable and disable these view changes. Further, it is not effective to control 6 DOF at once.

We approach both issues by using a three-way clutch (Figure 5) that disables cross section changes when in neutral position (a). Two other modes can be enabled by sliding and holding the clutch down or up, respectively enabling translation (b) or rotation (c). This separation of DOF allows more effective interaction [6]. Additionally, if more precision is needed, it should be straightforward to combine three-way clutching with a mechanism that modifies control-display (CD) gain or with nudging.

An additional issue appears when the current cross section is visualized both on the mobile and the large stationary screen: While looking at the mobile, users expect the

plane to move through a stationary virtual object (the *egocentric* view [3]). However, when looking at a stationary screen, users expect the inverse, with the mobile representing the virtual object while the cross section remains stationary in space (the *exocentric* view [3]). Thus, displaying the moving cross section on both displays is confusing, and one view should be disabled during the interaction.



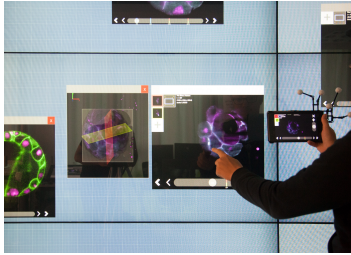
**Figure 6:** Single bookmark with four keyframes at different points in time

#### Bookmarking

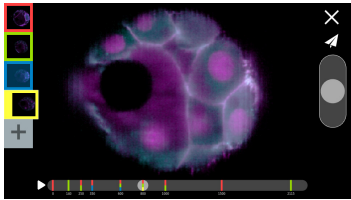
The interface described in the previous section allows specifying cross sections for single points in time. However, one of our goals was to support working with points of interest that move over time. Our bookmark concept (Figure 6) enables this. Besides supporting traditional bookmarks that reference single samples, it allows the user to specify multiple cross sections for different points in time. These are then used as *keyframes* for interpolation. An interface at the left side of the screen (Figure 4d) allows the user to manage bookmarks. It supports adding and removing bookmarks and highlights the currently selected bookmark. Keyframes are displayed and configured on the timeline (Figure 4b), with color coding used to identify different bookmarks.

#### Prototype

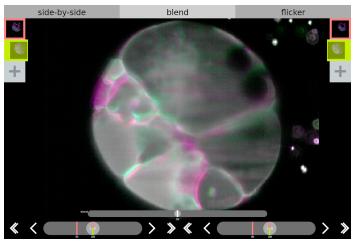
Our prototype implements the bulk of the concepts described above. We tested the prototype using an interactive display wall comprised of twelve 55" displays with a total size of 5x2 meters and a resolution of 24



**Figure 7:** View of complete multi-device prototype.



**Figure 8:** Prototype mobile interface.



**Figure 9:** Comparison view on large display using color coding to show differences between samples.

megapixels running Ubuntu. As mobile device, we used a Google Nexus 7 tablet.

On the large display, the prototype supports multiple cross section views (of the same or different specimen) as well as volumetric views and a comparison view (Figure 9). The mobile device displays the currently selected sample and supports cross section selection using clutching. Currently, we assume that the user looks at the mobile device when specifying a cross section and therefore implement an egocentric perspective. To avoid confusing users, we disable view updates on the large screen as long as the clutch is active. Further, nudging and configurable CD gain are currently not implemented. Both mobile and large display views fully support bookmark management.

The UI of the prototype is implemented in Python using the media application framework libav<sup>1</sup>. It is a single multi-device application: Both display wall and mobile interfaces are rendered on the display wall workstation. The mobile interface is compressed to h264 in realtime and streamed to the device. Conversely, touch data is streamed from mobile to workstation. Mobile location data is obtained using a marker-based optical tracking system, OptiTrack.

For rendering of the actual LSFM images, we use BigDataViewer (BDV), an extensible open source solution for interactive visualization of very large volumes and time series of volumes [7]. Individual image stacks are arbitrarily arranged in global 3D coordinate space, and can be displayed independently or as color composite. The software renders arbitrarily oriented virtual slices through the global space. An intelligent tile-based loading and caching scheme allows smooth navigation in

multi-terabyte image datasets. The data can be provided by both local and remote sources, and is easily extended to handle new data sources such as 3rd party file formats or online data stores.

BDV is implemented as a java library. To make it usable in our context, we implemented a libav plugin in C++ using the Java Native Interface. Using this plugin, an application can request rendered frames from BDV, specifying parameters such as timepoint, transformation, visible channels, etc. On the Java side, BDV fetches and caches the data from an arbitrary backend (in our experiments we remotely access data provided by a server at the MPI-CBG). Rendered frames are asynchronously passed back to libav where they are loaded to textures for display.

## Initial User Feedback

As initial validation of our prototype, we solicited feedback from several domain experts (developmental biologists) who are potential users of our system. For this feedback session we used an LSFM dataset of *Platynereis* that had a size of 1.4 terabytes. The session included a presentation of the interface, informal tests by the domain experts, and a discussion about future directions.

The general reaction was very positive for both tangible-based cross section selection and time-series bookmarking. There were few precision issues in cross section selection with the current three-way clutch. However, users pointed out that this might change for higher resolution data sets. Further, users would like the ability to set a pivot point for rotations, as the current rotation around the center of the specimen causes them to frequently lose their point of interest.

<sup>1</sup><http://www.libav.de>

## Discussion

Based on the initial user feedback, we are confident that our concept is sound and that development is proceeding in the right direction in general. However, there are a number of directions for future work. One very interesting topic is the distribution of the interaction between the mobile and the large display. While the mobile device is clearly more suitable for sample selection, the wall display is good for work with multiple views and presentation of results. However, other interactions can be done on both devices, and sample selection could potentially be done with the mobile device while viewing the results on the wall display in exocentric mode. Aspects such as necessary attention switches, egocentric versus exocentric visualization, and single- versus multi-user interaction all play a role here, so we believe that a good solution requires the exploration of several alternatives.

## Conclusion

We presented an interaction concept for exploration of large scientific time-dependent 3D data sets, validated through a prototype and initial user feedback from domain experts. The presented interactions include both a precise selection technique for 2D cross sections and a concept for time-dependent bookmarks that allows following a point of interest through time.

## Acknowledgements

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