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# ChronoViz: A System for Supporting Navigation of Time-coded Data

**Adam S. Fouse**

University of California, San Diego  
9500 Gilman Drive  
La Jolla, CA 92093 USA  
afouse@ucsd.edu

**Nadir Weibel**

University of California, San Diego  
9500 Gilman Drive  
La Jolla, CA 92093 USA  
weibel@ucsd.edu

**Edwin Hutchins**

University of California, San Diego  
9500 Gilman Drive  
La Jolla, CA 92093 USA  
ehutchins@ucsd.edu

**James D. Hollan**

University of California, San Diego  
9500 Gilman Drive  
La Jolla, CA 92093 USA  
hollan@ucsd.edu

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**Abstract**

We present ChronoViz, a system to aid annotation, visualization, navigation, and analysis of multimodal time-coded data. Exploiting interactive paper technology, ChronoViz also integrates researcher's paper notes into the composite data set. Researchers can navigate data in multiple ways, taking advantage of synchronized visualizations and annotations. The goal is to decrease the time and effort required to analyze multimodal data by providing direct indexing and flexible mechanisms to control data exploration.

**Keywords**

Interactive visualization, Digital paper, Behavioral research, Multimodal interaction

**ACM Classification Keywords**

H5.m. Information interfaces and presentation

**General Terms**

Design, Human Factors

**Introduction**

A new generation of inexpensive digital recording devices and storage facilities is revolutionizing data collection in behavioral science, extending it into situations that have not typically been accessible and enabling examination of

the fine detail of action captured in meaningful settings. For example, researchers from many disciplines[5] are taking advantage of increasingly inexpensive digital video and storage facilities to assemble extensive data collections of human activity captured in real-world settings. The ability to record and share such data has created a critical moment in the practice and scope of behavioral research. While such data are certainly needed, more data cannot be the whole answer, since many researchers already feel that they are drowning in data. One of the main obstacles to fully capitalizing on this opportunity is the huge time investment required for analysis using current methods. This often leads to haphazard and incomplete analyses or, all too commonly, to no analysis at all of much of the data.

When analysis is so costly, few analyses can be done—so datasets are severely underutilized—and researchers come to have a large investment in chosen data segments. Since each analysis may appear as an isolated case study, it can be difficult to know how common the observed phenomena may be. Larger patterns and contradictory cases can easily go unnoticed. Well-known human confirmation biases can affect the quality of the science when each analysis requires so much effort.

This problem is compounded when multiple sources of data are collected. Working with multiple data types can be cumbersome, typically requiring multiple applications, manual alignment of points of interest across different data sets, and requiring researchers to keep information about values and time points from one data set in memory while consulting the corresponding time points in another data set. For example, the researcher might need to consult video data to clear up ambiguities

present in computer logs, eye tracking data or computer vision analyses to disambiguate gaze direction from video, motion or GPS sensors to indicate the temporal or physical locations of interesting activity, and physiological sensors to provide aspects of activity invisible to video alone.

Another issue is that while digital recording is becoming pervasive, researchers also still rely on paper documents and hand-written notes. Sellen and Harper[6] document the many affordances of pen and paper and how they still remain, even in today's highly digitized work environments. Paper is portable, flexible, inexpensive, and supports forms of collaboration and interaction that are difficult to mimic with current digital tools. In observational research, it is standard procedure to take notes to augment other forms of data. Such notes are typically consulted and augmented throughout the analysis process.

During analysis researchers transcribe and code data in a wide variety of ways, creating new representations of the original events[3]. Currently the coordination of multiple representations, consisting of annotations, visualizations, and the results of other analyses, is a major challenge. Since this representation process—including all sorts of transcription, coding system development and implementation, and re-description—is the essence of science[1], even small improvements in navigation, visualization, and coordination of representations can be crucially important.

### **ChronoViz**

We have developed ChronoViz (formerly known as DataPrism), a system designed to address this analysis bottleneck by providing synchronized interactive visual

representations of multiple data streams including paper-based notes. While several systems have been developed to support various aspects of this analysis challenge, ChronoViz is unique in focusing on navigation of multiple diverse data sources. For example, although numerous systems exist for coding and annotation of video, such as ELAN[7], VCode[2], and Diver[4], they are either not designed for analysis or visualization of multiple types of data, or they do not support easily extensible visualization and navigation facilities.

ChronoViz allows researchers to visualize time-based data from multiple sources, navigate this data in flexible ways, and manually or automatically code the data with structured or unstructured text-based annotations. The data sources can include multiple video files, audio files, computer logs, sensor readings, paper notes, and transcriptions. Since these recordings may be created by a variety of devices, they can be difficult to synchronize. ChronoViz offers interactive mechanisms for aligning a wide range of data streams. Researchers can create annotations, define and evolve category structures for annotations, and construct visualization filters. Annotations can also be created automatically by employing an analysis plugin framework that supports custom scripts.

ChronoViz exploits Anoto digital pen technology<sup>1</sup> to support the integration of paper-based digital notes. It enables paper-based notes to serve as interactive interfaces by linking the notes to digital media such as sound or voice recordings, or triggering specific digital applications on a separate computer. As illustrated in Figure 1, this technology is based on a digital pen and a

unique dot pattern printed on standard paper. The pen includes an on-board infrared camera and tracks its position on the paper in real-time by reading the dot pattern.

ChronoViz supports two types of Anoto-based digital pens. The Livescribe Pulse SmartPen<sup>2</sup> provides audio recording, playback, and an OLED display. It is used in batch-mode to upload written and audio notes to ChronoViz after the note-taking activity has occurred. Notes are taken on standard Livescribe paper or custom-printed forms, using a custom application on the pen. Once uploaded, ChronoViz merges the notes with data from other sources. Custom pen gestures can also be defined enabling users to create annotations in ChronoViz by moving the pen through simple trajectories on the paper. The second type of pen is a wireless Bluetooth Anoto DP-201 pen that can communicate with the computer in streaming mode to provide real-time interaction with ChronoViz.

In the following sections, we describe techniques we have developed to aid data navigation using the visualization and digital pen capabilities of ChronoViz.

### Visualization for Navigation

There are several mechanisms for data navigation with ChronoViz. Since video is often a central form of data in behavioral science, the main ChronoViz interface, shown in Figure 3, consists of a video pane, which can show multiple videos, and one or more timelines from multiple data sources arrayed below. The timelines can be used to visualize annotations, time series graphs of sensor data, audio waveforms, and individual video frames. Annotations can be overlaid on each visualization, as is depicted in the time series graph in Figure 3. The

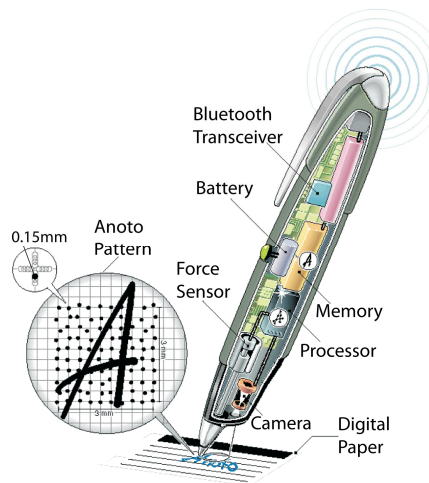


Figure 1: Anoto digital pen and paper technology

<sup>1</sup> <http://www.anoto.com>

<sup>2</sup> <http://www.livescribe.com/smartpen/pulse/>

playhead (visible as a vertical bar near the middle of each timeline in Figure 3) can be dragged to specify the time point shown in the videos, and can also be used to help precisely compare points on the timelines. Clicking on an annotation jumps all of the data streams directly to the beginning time of that annotation.

Geographic position data can be displayed on a map (currently retrieved from Google Maps), as shown in Figure 4. As with timelines, the current time position in the data can be changed by clicking on a route location shown on the map. This allows the researcher to navigate the data by navigating a depiction of physical space that is time-linked to all of the other data representations.

A researcher's paper notes can also be used to navigate the data. Notes can be shown in two ways. First, markers can appear on the timeline that correspond to the time a particular note was written. When the researcher hovers over the marker, an image of the note appears, as shown in Figure 2. Second, the entire note document can be displayed, as shown in Figure 4. Pen traces are initially displayed in gray, but as the researcher moves through the data, the letters darken to indicate notes that were taken at the associated time. As with timelines and maps, analysts can change the current time position in the data stream by clicking on locations in the notes document.

Finally, the set of annotations can be shown as color-coded, sortable, and filterable tables. As with the other ChronoViz visualizations, table entries can be used to

navigate the data. If a researcher is interested in a particular category of activity that has already been annotated, the table can be filtered to show only those annotations, and then a user can click on individual annotations to identify the corresponding data points.

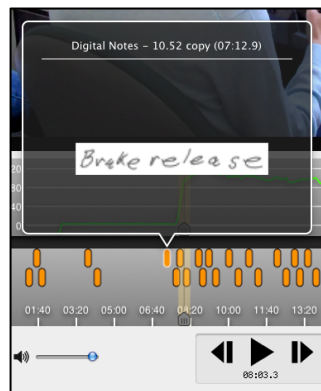


Figure 2: Annotation marker for a digital note, with the actual note displayed in a pop-up window.



Figure 3: Data from a flight simulation. The data, from top to bottom, show: two videos, a waveform of the audio, individual video frames, a graph of the altitude of the simulated flight with overlaid annotations, several categories of annotations.

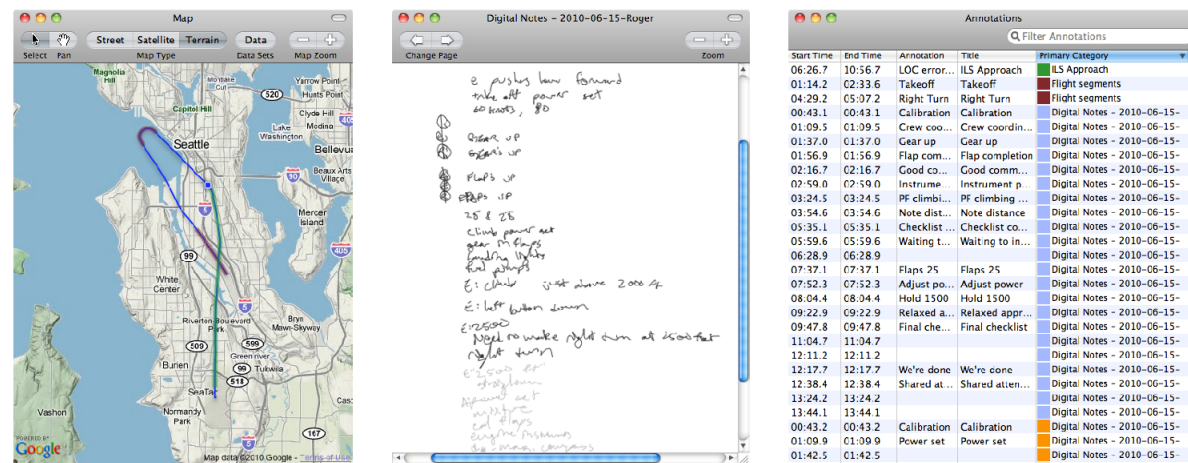


Figure 4: Three visual methods for navigating data. Left: A geographic map showing a path allows for navigation by clicking on spatial points. Middle: A digital version of paper notes allows for navigation by clicking on any note. Right: An annotation table allows for navigation by clicking on individual annotations.

### Interactive Paper Navigation

ChronoViz also supports interactive use of paper-based notes for data navigation. The notes are reprinted to allow for streaming usage with a Bluetooth Anoto pen and to print the overlaid controls shown in Figure 5. This reprinted paper version of the notes can then be used for direct navigation of the data in two ways. First, the researcher can simply tap the pen on any of the notes, and the on-screen representations will move to the corresponding time when that note was taken. This has several benefits. Because the appearance of the reprinted notes is almost identical to their original form, users find it easy to recall the original context for taking particular notes. More importantly, it eliminates the need to display the notes on-screen, so that valuable display space can be used to show more data and additional detail. Since multiple sets of notes and pens can be used simultaneously, this interface also supports collaborative analysis. For example, if data is displayed on a screen using a projector, multiple members of a research team,

each with an Anoto pen, can navigate the displayed data while discussing observations by tapping their own reprinted notes with the pens.

However, tapping notes only allows jumping from point to point. Since important features of data sets might only be seen in the dynamics (e.g., moving video or movements on a map), we have developed controls that can be printed with the reprinted notes, as shown in Figure 5, and used to control playback. These are common video controls, including icons for stop, play, rewind, fast-forward, and fast-rewind. There is also a circle surrounding the rewind, stop, and play buttons that mimics the behavior of a jog dial, such as those that are often employed for precision video editing. By moving the pen in a circular motion either clockwise or counter-clockwise on the printed circle, the video can be moved frame-by-frame forward or backward, at user-controlled speed.



Figure 5: Video playback controls printed on Anoto pattern.

Finally, to support playback while focusing on the notes, there are two additional techniques beyond a simple tap that can be used directly on the notes. First, by double-tapping, the time point will instead be moved to a point a customizable number of seconds before the note was written. In informal testing we found that the delay between when an observer sees an action and when that observer writes down a note often means that tapping on a note will actually move the data to a time after the described action. This shortcut allows the researcher to go to a point before the action, and then play the video to watch. The second additional interaction technique we support allows playing the video at normal speed by holding down the pen on the paper. After a 500ms delay, the video will start playing, continuing until the pen is released. This is meant to support viewing of short clips that are directly related to particular notes.

### Conclusion

We have described techniques for supporting navigation of multimodal, time-coded data that take advantage of multiple representations and existing practices. We believe these techniques have the potential to increase the efficiency of observational research by making it possible to navigate data in more flexible and powerful ways. The synchronized visualization of multiple data streams allows researchers to gain a better understanding of rich data sets. The integration of interactive navigation techniques with existing note-taking practices enables researchers to quickly navigate to moments that were noted during initial observation of the activity.

While these techniques are promising and ChronoViz is already in use by a number of researchers, we are planning a formal evaluation. To assist this evaluation,

the ChronoViz application collects data about its use after obtaining the user's permission. It also solicits user comments. We are also designing new features based on feedback from current users. Two examples are: (1) visualization techniques to support navigating data via representations of the structure of actions and events, (2) additional paper interface techniques to allow users to interactively record annotations directly on their paper notes while simultaneously using those notes to navigate the data sets.

### Acknowledgements

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