Eurographics Conference on Visualization (EuroVis) (2013) *Short Papers*
M. Hlawitschka and T. Weinkauf (Editors)

Visits: A Spatiotemporal Visualization of Location Histories

Alice Thudt[1], Dominikus Baur[2] and Sheelagh Carpendale[1]

[1]InnoVis Group, University of Calgary, Canada
[2]Independent Researcher, Munich, Germany

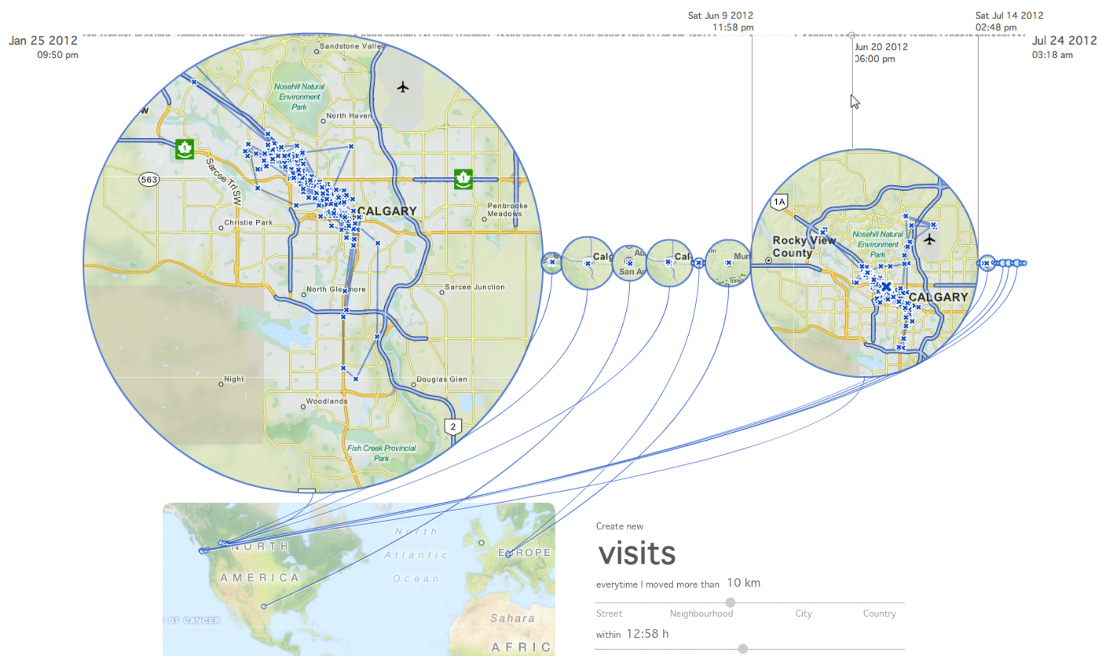

Figure 1: Visits *showing a location history of six months using a* map-timeline *approach. This map / timeline hybrid segments the data into stays at places, revealing more information about the temporal aspects of the data.*

Abstract

Location histories are rapidly becoming easily collectable and offer new opportunities for personal reminiscing. However, while location history data contains both temporal and location information, maps provide the location content while downplaying temporal aspects and timelines focus on the temporal sequence, minimizing the spatial aspects. In contrast, autobiographical memories incorporate both time and location. To address this gap, we present Visits*, a visualization system that puts time and location on equal footing. Our hybrid visualization technique,* map-timelines*, shows location histories as a sequence of visited places represented as map segments on a timeline. This shows the chronological order and the duration of stays, reveals repeated visits of the same place and preserves the fine-grained location information of the underlying data. We demonstrate a possible use of* Visits *for both main types of location histories, long-term lifelogging data and short-term travel logs.*

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Computer Graphics]: Graphical User Interfaces (GUI)—

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1. Introduction

Our personal experiences are important factors by which we define ourselves. A rich source of these experiences are our journeys and trips to foreign places. To reinforce these important memories, we often take photos, collect souvenirs and write travel diaries. Today, our sensor-laden portable devices provide new opportunities to collect fine-grained records of personal movement. Many apps and services exist that collect location data either continuously (e.g. Google Latitude [Goo13] and OpenPaths [The13]) or check-in-based (e.g. Facebook Timeline [Fac13], Dopplr [Dop13] and Foursquare [Fou13]). However, in its raw form, the automatically collected timestamped location data does not reflect the way people remember their trips. While timestamps, latitude and longitude are easy to collect and store, human memory captures trips as narrative-like causal sequences of events [BS98]. To bridge this semantic gap, the low-level sequence of numbers needs translation into a higher-level semantically comprehensible representation.

In *Visits* (see Figure 1) we create a visualization of automatically collected spatiotemporal data that reflects current knowledge about how people naturally remember autobiographical episodes such as their journeys [BS98, Tul72]. To realize this, we developed *map-timelines*, a visualization technique that integrates temporal and spatial information to display histories of trips as a series of visited places. We illustrate *Visits* by applying it to both shorter trips and longer-term lifelogging data. The *map-timeline* concept could also be used to enhance other spatiotemporal data such as historical records of famous journeys or city development.

2. Related Work

Considerable new interest in personal data such as location histories has been sparked by the lifelogging (cf., [CGG*06]) and Quantified Self [Wol13] communities. The location data is commonly represented as pins on a map, which hides the temporal information as well as re-visits of the same place. Efforts such as color-coding the different times of day [The13], showing connecting lines [Goo13] or drawing a curve through a space-time cube [EKHW07] does indicate connections but introduces visual clutter and occlusion that makes the results difficult to read. Using animations [GAL05] limits the overview capabilities. Map visualizations further tend to over-emphasize transit (spreading locations over the map) while understating stays (where all logged locations collapse).

Movement data analysis is also an active topic in the visual analytics community. Topics are summarizing everyday personal movement [AAW07] or clustering location histories of multiple people [AAR*09]. These applications however, are geared towards analysis not personal reminiscing.

Sometimes maps are interlinked with timelines (cf., [AMST11]) for quick navigation: Google Latitude [Goo13] highlights corresponding pins on the map when hovering over the timeline and vice versa. Some systems (e.g. [Fac13], [Dop13]) allow switching between timelines and maps. In *Visits* we offer the first integrated spatiotemporal version.

3. *Visits*

Visits' main goal is reflecting people's episodic memories of trips. Personal experiences and journeys that form autobiographical episodes are organized chronologically and spatially in our memory [Tul72]. *Visits* creates a *map-timeline* that displays location histories similarly to how people remember trips: as a sequence of visited places [BS98] with less memorable transit in between. The *Map-timelines* visualization technique shows spatial and temporal aspects of the data. The goal of this approach is to support the identification of (1) the chronological order of stays, (2) repeated stays at the same place and (3) the duration of stays while (4) preserving the fine-grained location information of the logs.

In *Visits* our intention is to bring to the fore colloquial concepts such as "places" and "stays" that can be part of memories of trips, journeys and everyday life activities. Of necessity from our available data these concepts need to be based on automatically logged locations that contain irregularly measured temporal and location information in form of a timestamp and a location point with a longitude and a latitude value. Working from this we define:

Places are areas that contain one or more location points independent of temporal information. The size of a place can be variable. A place can therefore be a building, a district, a city or even a country, and often in our discussions these places have names such as "home", "the lab", or "my hotel".

Stays are time frames spent in a particular place. Stays have a start time, a duration, and an end time. Internally within a stay there is a consecutive list of timestamped locations whose location points lie within a defined place.

Considering a location history as a sequence of *stays* at different *places* works for travel histories, long-term lifelogs as well as logs of everyday movement.

3.1. Clustering: Identifying Stays

Our distance-based clustering algorithm merges logged locations into stays. The algorithm relies on the assumption that stays are time frames during which there is little relative movement. This notion of relatively little movement can be defined as a distance threshold. In turn the clustering can be based solely on this variable: a settable, adjustable distance threshold. This lets people specify how spatially close two locations must be to be considered part of the same place. No costly requests to external geocoding APIs or intricate manual definitions of places are required.

The clustering algorithm traverses the history of chronologically logged locations. Each pair of consecutive location

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points is checked to assess whether their distance is below the distance threshold. If it is, the logged locations belong to the same cluster. If not, the second logged location marks a new cluster. Each resulting cluster represents a stay. The area covered by the contained location points defines the place of the stay. The time frame of the stay is determined by the first and the last timestamp of the logged locations in its cluster.

3.2. *Map-Timelines*

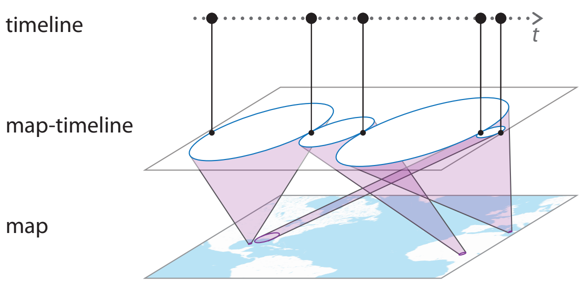

Figure 2: Map-timelines *are a hybrid between timelines and maps: Each map segment in a* map-timeline *has its size determined by the duration on the timeline, while showing a certain section of the map.*

In *map-timelines*, a series of circles each containing a map segment is aligned along a linear timeline (→ chronological order). The circular map-segments are approximated representations of arbitrarily shaped areas and hence facilitate size comparisons. The rounding also prevents erroneous visual connections between neighboring map segments (e.g., two independent roads seemingly being linked). The size of each circle is determined by the covered time span on the timeline (see Figure 2).

As each stay is a combination of a place and time frame, it is represented as one circle on a *map-timeline*. The stay's time frame determines the circle's radius (→ duration), while its place controls which map segment is shown (→ location information). Longer stays at one place result in larger circles that show more detail about the visited place. Locations collected in transit become many places and break down into series of small circles. The same (geographic) place can also appear repeatedly on the *map-timeline* if it is visited several times (→ repeated visits). This approach yields a visual representation that reduces the impact of transit while increasing the prominence of stays.

3.3. The Visualization

Visits consists primarily of two items: the centrally placed horizontal *map-timeline* and the *overview map* in the lower left (see Figure 1).

The *map-timeline* is composed of juxtaposed map circles of varying sizes that represent stays in places. It is annotated with temporal values placed linearly across the top of the display. The left and right extremes of the temporal annotation show the timestamps of the first and last locations that are currently displayed. The location points of logged locations in the dataset are indicated by blue cross-shaped location markers on the corresponding map circle of the *map-timeline* and their timestamps are depicted as small grey circles along the timeline at top of the display.

The map regions — showing visited places — that are visible in the *map-timeline* above are also shown as circles on the *overview map*. Curves connect these overview circles with the corresponding map segments in the *map-timeline*.

3.4. Interacting with *Visits*

Even in its static form, *Visits* already shows an expressive depiction of temporal and location aspects of a location history. Simple interactions enable further exploration of the results:

Moving the mouse over a circle in the *map-timeline* highlights beginning and end of the corresponding stay on the timeline (see Figure 1 for the map segment on the right). Hovering over one of the location markers on a map segment enlarges it and emphasizes the corresponding timestamp marker on the timeline by displaying a label for the time value. The logged locations can be explored in chronological order by moving the mouse along the timeline. This highlights the closest timestamp marker and the corresponding location marker.

Zooming allows focusing on specific sections of the timeline. Dragging the mouse down enlarges all map segments in a fluid animation (see Figure 3 a-e). As this leads to map segments disappearing at the left and right screen borders, the view can be panned by dragging the mouse horizontally. Dragging the mouse up zooms out again.

The lower-right part of the screen shows control sliders. One slider determines the distance threshold used in the clustering algorithm, the other controls the frequency of location measurements (see Section 3.5 below for details).

3.5. Implementation

Visits was written as a Flash application in Actionscript 3.0. The map data is from the OpenStreetMap [Ope13] project via the MapQuest API [Map13]. To create the map circles, the map segments are overlaid with suitable masks. As calls to the API are limited, map tiles are only re-loaded when necessary. While zooming in or out, map segments are treated as images and scaled. When the zooming activity ends, the displayed map tiles are reloaded.

In OpenPaths [The13] location histories are stored as JSON-files (arrays of Javascript objects containing latitude, longitude and timestamps). *Visits* packages a given OpenPaths export into a stand-alone app.

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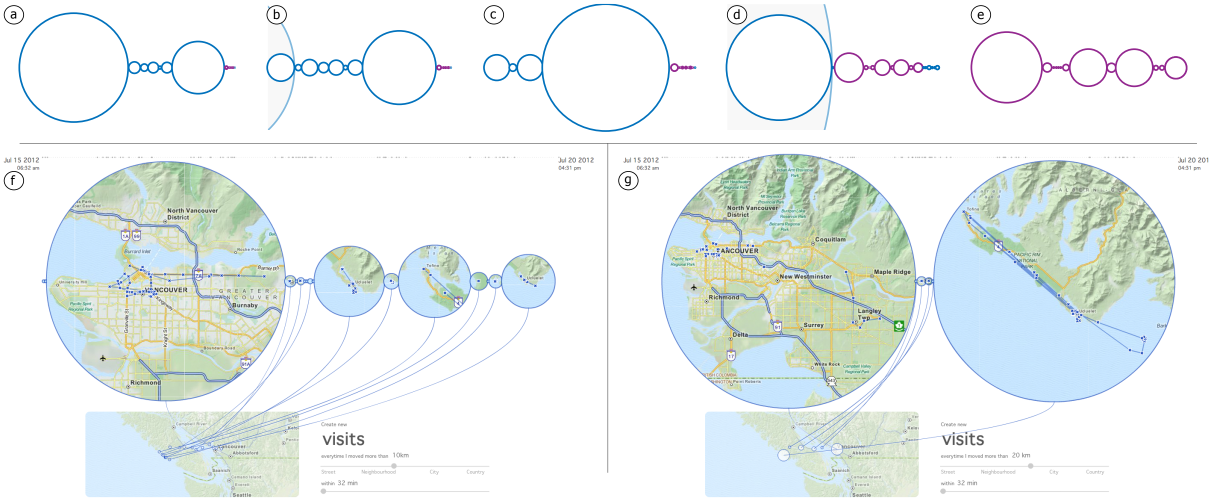

Figure 3: *Interaction with Visits.* a *shows a schematic version of the same* map-timeline *as in Figure 1. The purple circles represent the same map-segments that are shown in* f. a-e *depict the zooming and panning activity that transitions the visualization to the state we see in* f. *Adjusting the distance threshold emphasizes the two main parts of the trip (see* g*).*

To compensate for irregularities and remove unnecessary items the logged data is preprocessed. GPS-logger location histories contain more locations than required to get an overview while smartphone apps usually measure the location irregularly. The preprocessing algorithm uses a time granularity that can be set with one of the sliders in the lower right, creating a fixed-interval raster of timestamps. A coarse granularity allows viewing location histories of several years in *Visits*. Our current research is exploring how irregular timestamps can be fully integrated into *map-timelines*.

4. Scenario

Location histories can contain a great variety of journeying data ranging from shorter trips to longer-term life logs. *Visits* can be used for exploring both types and even allows seamlessly transitioning between the two.

Figure 1 shows Joseph's half-year long location history in *Visits*. The visualization emphasizes his stays in a few different places: Joseph's hometown, Calgary, appears repeatedly with trips to Austin, Munich and Vancouver in between. By hovering, Joseph can explore the time frames of his stays and the underlying logged locations. The connecting lines between overview map (bottom left) and circles on the *map-timeline* also give an idea of the spread of the visited places.

With this overview, Joseph can now dig deeper into specific trips contained in the data. He remembers taking a trip to the Vancouver area in July and navigates through zooming and panning to the respective circles on the right (see Figure 3 a-e). The result shows his three days in Vancouver and his subsequent trip to Vancouver Island decomposed into multiple circles that depict his visits to Tofino and Ucluelet (see Figure 3 f). Joseph wants to print the visualization as a memento and decides to make the two parts (Vancouver, Vancouver Island) stand out more. He therefore increases the distance threshold from 10 to 20 km. This shows Joseph his two main destinations as large map circles and his short transit in between as smaller map circles (see Figure 3 g).

5. Conclusion and Future Work

Visits reveals fascinating personal information in long-term and short-term location histories. Advances in mobile technology are making this data more and more trivial to collect, and the expectation is that this will continue to proliferate in the near future. *Visits* offers *map-timelines* as an alternative to the pins-on-a-map approach. Temporal aspects are integrated and put on equal footing as the location information. Interaction supports digging deeper into the visualized data.

As personal mementos, *Visits* could be improved through customization or annotation. We are currently experimenting with the integration of photos and personal comments.

In this paper we focus on personal lifelogging data for the purpose of reminiscing since it is a popular form of spatiotemporal data. However, our visualization concept of *map-timelines* can be applied to various types of time and location based data, for example historical travel records of famous voyagers, troop deployments during war, historical exploration of new lands or the territorial development of countries or cities over time.

Acknowledgments

Special thanks go to Paul Lapides and Sarah Tausch for their invaluable feedback. We also thank our funding sources (SurfNet, GRAND, AITF, CFI, NSERC, and SMART Technologies) for their support.

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References

[AAR*09] ANDRIENKO G., ANDRIENKO N., RINZIVILLO S., NANNI M., PEDRESCHI D., GIANNOTTI F.: Interactive visual clustering of large collections of trajectories. In *VAST* (2009), pp. 3–10. 2

[AAW07] ANDRIENKO G., ANDRIENKO N., WROBEL S.: Visual analytics tools for analysis of movement data. *ACM SIGKDD Explorations 9*, 2 (2007), 38–46. 2

[AMST11] AIGNER W., MIKSCH S., SCHUMANN H., TOMINSKI C.: Visualization of Time-Oriented Data. *Human-Computer Interaction* (2011), 105–126. 2

[BS98] BROWN N. R., SCHOPFLOCHER D.: Event Cueing , Event Clusters , and the Temporal Distribution of Autobiographical Memories. *Applied Cognitive Psychology 12*, March (1998), 305–319. 2

[CGG*06] CZERWINSKI M., GAGE D. W., GEMMELL J., MARSHALL C. C., PÉREZ-QUIÑONES M. A., SKEELS M. M., CATARCI T.: Digital memories in an era of ubiquitous computing and abundant storage. *Communications of the ACM 49*, 1 (2006), 44–50. 2

[Dop13] DOPPLR: Dopplr, Feb. 2013. URL: `http://www.dopplr.com/`. 2

[EKHW07] ECCLES R., KAPLER T., HARPER R., WRIGHT W.: Stories in GeoTime. In *VAST* (Oct. 2007), Ieee, pp. 19–26. 2

[Fac13] FACEBOOK: Introducing timeline, Feb. 2013. URL: `https://www.facebook.com/about/timeline`. 2

[Fou13] FOURSQUARE: Foursquare, Feb. 2013. URL: `https://foursquare.com/`. 2

[GAL05] GEMMELL J., ARIS A., LUEDER R.: Telling stories with MyLifeBits. In *Multimedia and Expo, 2005. ICME 2005. IEEE International Conference on* (2005), IEEE, pp. 1536–1539. 2

[Goo13] GOOGLE: Latitude, Feb. 2013. URL: `http://www.google.com/latitude/`. 2

[Map13] MAPQUEST: Mapquest developer network, Feb. 2013. URL: `http://developer.mapquest.com/`. 3

[Ope13] OPENSTREETMAP PROJECT: Openstreetmap, Feb. 2013. URL: `http://www.openstreetmap.org/`. 3

[The13] THE NEW YORK TIMES COMPANY: Openpaths, Feb. 2013. URL: `https://openpaths.cc`. 2, 3

[Tul72] TULVING E.: Episodic and semantic memory. In *Organization of Memory*. Academic Press, 1972, pp. 381–402. 2

[Wol13] WOLF G.: Quantified self, Feb. 2013. URL: `http://aether.com/quantifiedself`. 2

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