Atvis: A New Transit Visualization System

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Abstract This chapter presents Atvis, a system to visualize transit data. Atvis is capable of representing bus route and traffic information at an abstract level. Compared with the traditional map-based geographical information system, Atvis focuses more on ridership, visualizing traffic data at or between stops, and interstop relationships, disregarding information that may not be essential to a user. This chapter describes the design and implementation of the Atvis visualization system and discusses how it can be used to observe transit patterns.

Keywords Transit · Visualization · Bus · Route · Traffic · Public transportation · Abstract data

1 Introduction

Due to urbanization and an increase in private vehicles, most cities are becoming extremely crowded. Moreover, with rising awareness of environmental conservation, people are looking for more economical and eco-friendly ways to travel. As of 2011, there were 7,100 public transportation providers in the United States

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(American Public Transportation Association 2013). These providers range from single-vehicle response servers to large multimodal systems. The largest among them, Metropolitan Transportation Authority's (MTA's) New York City Transit, provided 3.3 billion trips covering 12.2 billion miles in 2011. Cumulatively, bus transportation accounts for more than one-half of the 10.3 billion total trips taken, and 36 % of passenger miles covered for the year, making it the most popular form of public transportation. As a result, optimization of bus routes and stop allocations is crucial in helping public transportation providers meet the needs of people in rapidly developing cities.

Visualizing traffic and route data allows urban planners to observe bus systems and to draw conclusions. Deciding upon a suitable visualization model is one of the greatest challenges in developing an effective visualization. A variety of such models for map and route data exist, ranging from highly abstract (e.g., one-dimensional route maps Wolff (2007)) to highly representational (e.g., 3D models Kwan (2002)). Representational visualizations provide more detail and fidelity but do not necessarily offer greater usability. Agrawala (2002) states that "usability peaks near the abstract end of the spectrum." Nevertheless, many existing visualization methods for bus route data involve some geographical component (Sadahiro et al. 2015; Krause et al. 2012).

Although such map-based visualizations are widely used, alternative visualization methods for discrete data, such as public transit routes, should be considered. First, map-based geographic visualization systems often struggle with the issue of readability, especially when large-scale data are presented (Mashima et al. 2011). Second, the discrete nature of bus routes and stops marginalizes the importance of geographical features. Oftentimes, the unnecessary geographical detail of such systems can distract decision makers from observing individual and systematic traffic patterns. A well-designed bus visualization system must have the appropriate level of abstraction to provide maximal usability.

This chapter presents Atvis, an abstract system for visualizing public transit information. Atvis proposes a system of arc and bar diagram representations of bus route data on a one-dimensional line map. Arc diagrams commonly have been used to visualize "the connection between different parts of a set of objects" (Xiao and Chun 2009, pp. 183–191) for data in graph theory (Saaty 1964), e-mail threads (Kerr 2003), and musical sequences (Wattenberg 2002). We extend such existing implementations of arc diagrams by manipulating arc thickness and height to represent bus ridership levels and distance between bus stops. Additionally, we associate a bar diagram with the arc diagram, which provides more detailed information regarding the boarding/alighting of bus passengers. Atvis visualizes key traffic statistics, allowing decision makers to observe the flow of passengers along a given transit route.

2 Atvis Visualization Model

Atvis provides a more efficient way to visualize spatial and temporal transit data. With the combined use of arc and bar diagrams, decision makers can not only observe the passenger flow between stops but also focus on the number of passengers at each individual stop.

2.1 Goals and Objectives

The primary objective of Atvis is to provide decision makers with an intuitive representation of bus data in order to explore spatial and temporal relationships and to observe systematic traffic patterns. Specifically, one can observe visually

1. distance between stops;
2. passenger allocation throughout a system for any time interval; and
3. boarding and alighting at each stop, individually and cumulatively, at any time interval.

We first explored traditional visualization methods using a map-based data presentation. However, this adds a high level of geographical detail, creating more distraction than information. Figure 1 summarizes our process in transitioning from a geographic information system (GIS)-based model to an abstract data visualization.

2.2 Atvis Model Design

Atvis allows users to view and analyze trends and information for customized bus routes and datasets. Our system offers three major advantages:

1. multidimensional data profiles in a two-dimensional format;
2. seamless integration of spatial and temporal information; and
3. a combination of local and global information in one view.

Figure 2 depicts the Atvis visualization model, using sample data for two routes (represented in blue and gray) and consisting of 20 stops. The endpoints of each arc in an arc diagram represent stops along a visualized route. These stops are arranged according to the route's stop order. For multiple routes, a single linear order is unlikely to be consistent with all routes' stop orders. For example, we observe in Fig. 2 that stops 1, 5, 10, 15, and 20 are shared by both routes, while the rest are specific to a single route. In these latter cases, we can manipulate the suborder of stops between shared stops to represent accurately each route's stop order. The height of each arc represents the distance between two stops, while the thickness

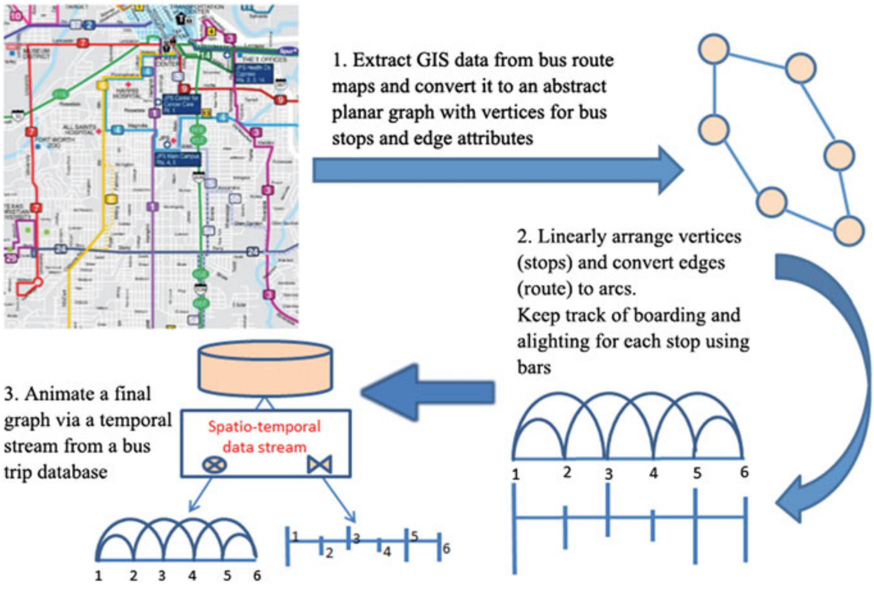

Fig. 1 Geographical to abstract visualization

represents ridership data. The bar diagram consists of bars that correspond to stops in an arc diagram. The component of each bar above the horizontal axis represents the number of boarded passengers, while the component below this axis represents the number of alighted passengers. The combined height of these two components measures the total passenger flow at each stop. Table 1 summarizes how data are represented through the arc and bar diagrams.

3 An Atvis Visualization Demonstration Program

Based on the Atvis model, we created a demonstration program to present the system's representation of actual transit data. Our demonstration contains both a backend component,[1] which allows users to define routes and input ridership data, and a frontend component,[2] which visualizes these data.

[1]http://hpproliant.cse.unt.edu/nctcog/backend/.
[2]http://hpproliant.cse.unt.edu/nctcog/.

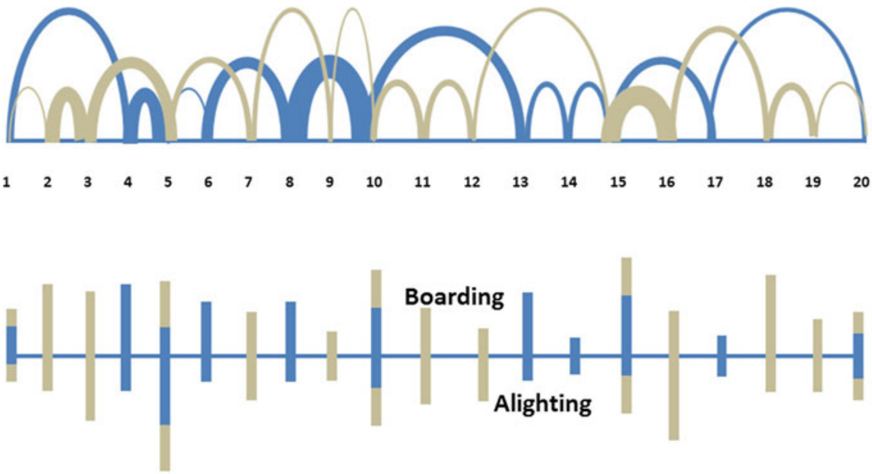

Fig. 2 The Atvis visualization model

Table 1 The Atvis visualization model

Arc legend	Description of arc legend	Bar legend	Description of bar legend
Integer	Bus stop order	Integer	Bus stop order
Arc color	Bus route	Bar color	Bus route
Arc thickness	Number of passengers on the bus	Bar above axis	Number of passengers boarding
Arc height	Distance between stops	Bar below axis	Number of passengers alighting

3.1 Data Description

The bus dataset we used for visualization was provided by the North Central Texas Council of Governments (NCTCOG). It contains 1,827 records from November 30, 1999, detailing bus trips on Route 2 in Fort Worth, Texas. Each record represents a single stop made on a trip along the route. Table 2 offers a detailed description of the NCTCOG bus data, and Fig. 3 is a map of Route 2 provided by NCTCOG.

3.2 Backend System

The demo backend system allows users to manage, define, and upload bus routes and corresponding datasets to be visualized. Figure 4 describes the flow of a route and trip data submission. Users must provide the name of each stop, as well as the distance in miles between stops. Figure 5 is a screenshot of the route creation system.

Table 2 NCTCOG data description

Field name	Data type	Field description
ID	Integer	Unique identifier for each row of data
Route_name	String	Name of the bus route being visualized
Trip_ID	Integer	Unique identifier for each bus trip
Stoporder	Integer	Unique identifier for each stop, based on the order of all stops along the route
Latitude	Double	Latitude coordinate where the bus stopped
Longitude	Double	Longitude coordinate where the bus stopped
Arrival_time	Integer	Time in seconds from midnight to when the bus arrived at the "Stoporder" stop, on November 30, 1999
Departure_time	Integer	Time in seconds from midnight to when the bus departed from the "Stoporder" stop, on November 30, 1999
Dwell_time	Integer	Time in seconds that the bus dwelled at the "Stoporder" stop
Board	Integer	Number of passengers who boarded the bus at the "Stoporder" stop
Alight	Integer	Number of passengers who alighted the bus at the "Stoporder" stop

Datasets are uploaded to a server as a plain text file. Users must also indicate the route with which their dataset corresponds. Figure 6 offers an example of how a dataset is properly formatted. The format must comply with the following requirements:

1. Stop names for each data entry match stop names for the corresponding route.
2. Data entries are separated by a line break.
3. Items in each data entry are separated by a vertical bar.
4. Items in each data entry are in the following order: Trip ID, Stop Name, Time, #Board, #Alight.
5. Trip ID, Time, #Board, and #Alight must be integers.
6. Time must be in seconds.

3.3 The Frontend System

Our frontend system can visualize multiple routes and datasets that are defined in our backend system. Thus, we offer a menu that allows users to select the data they wish to display, as shown in Fig. 7. The system progresses through time in accumulative or real-time fashion and can be slowed down, sped up, paused, and resumed by a user. Changes in passenger flow are reflected when the system clock reaches the time that they occurred. Users can specify start and end times for data

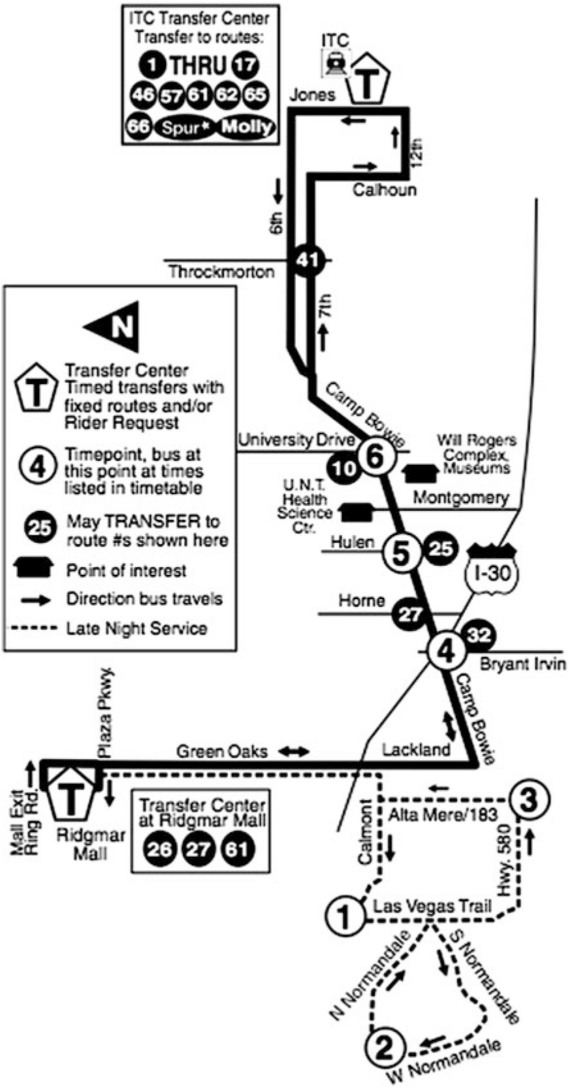

Fig. 3 Map of route 2

visualization, allowing for a more straightforward analysis of bus traffic flow based on the time of day.

Figure 8 is a screenshot of the Atvis visualization demonstration system. Our original model and demonstration differed in a few key ways:

1. Our final implementation allows for the visualization of only one route and dataset at a time.
2. We add interfaces that allow users to control simulation timing and visualization methodologies (described in greater detail in Sect. 3.4).

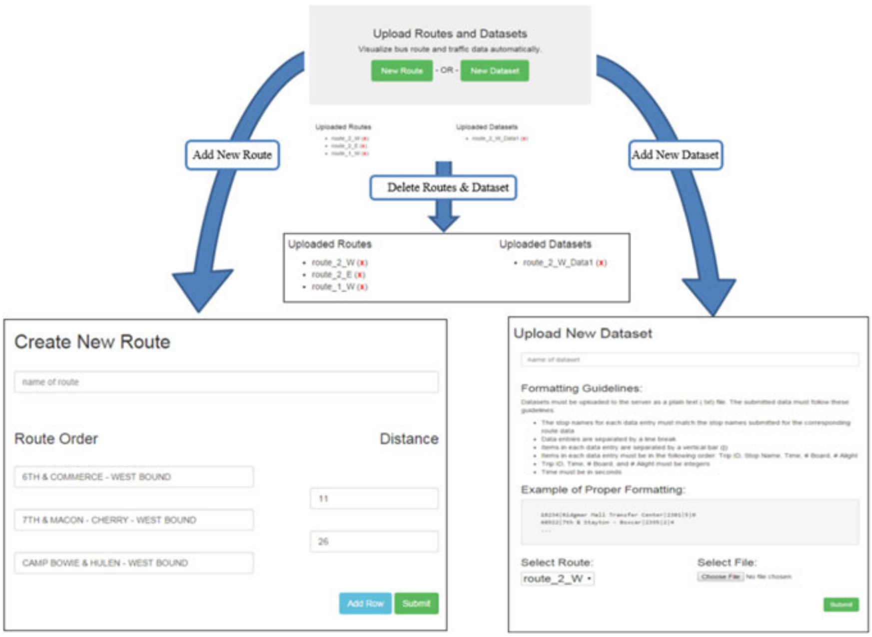

Fig. 4 Atvis backend data management system

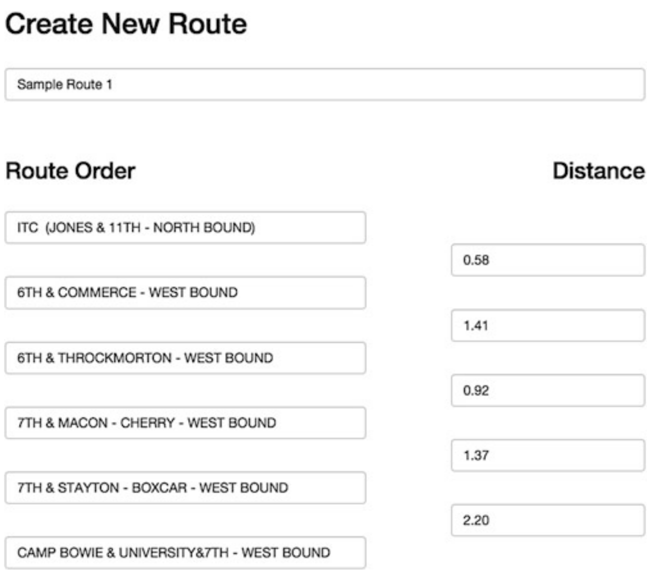

Fig. 5 The backend route creation system

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18234|Ridgmar Mall Transfer Center|2381|5|0
48922|7th & Stayton - Boxcar|2395|2|4
...
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Fig. 6 An example of a proper dataset format

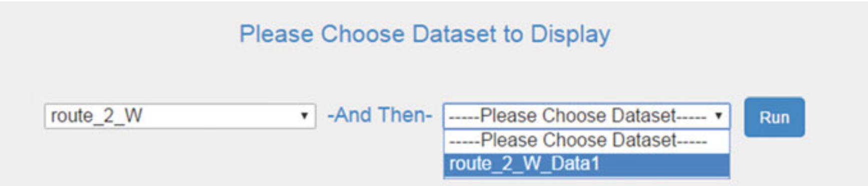

Fig. 7 The frontend data selection

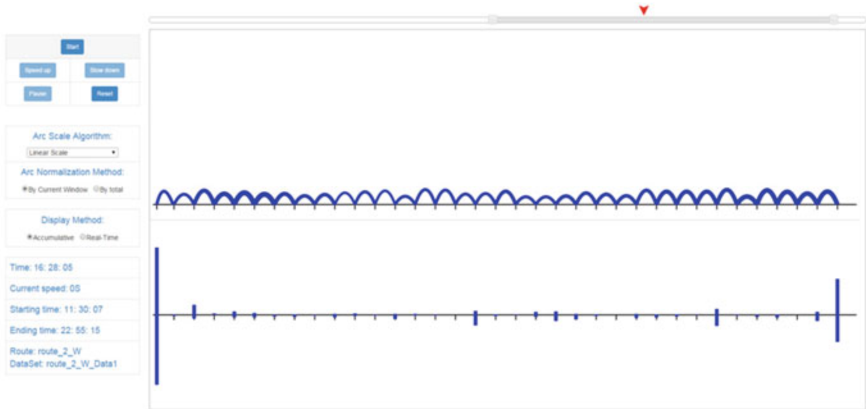

Fig. 8 The frontend data visualization system

3. We add a timeline that allows users to specify the starting/ending time of a simulation and to view current simulator time.
4. Users can mouse over both the arc and bar diagrams to view more detailed ridership information at each stop.
5. Users can zoom in and out of the arc and bar diagrams to view ridership and passenger flow statistics in greater or lesser detail.

3.4 Visualization Methodologies

The Atvis demo supports a variety of visualization options that display different types of information using different algorithms and calculation methods.

3.4.1 The Display Method

We offer accumulative and real-time options for displaying route and traffic data. The accumulative method displays the ridership situation from the start of a simulation until the current time. The real-time method presents the ridership situation at the exact current time in the simulation.

3.4.2 The Arc Normalization Method

Atvis normalizes ridership values as arc thickness using two different methods: by current window and by total. These methods differ based on the scope of data that are presented.

Using the accumulative display option Both methods calculate a normalization factor to use in determining arc thickness, then applied to the arc scaling algorithm (described in Sect. 3.4.3). The by current window method does this based on the range of data from the start time to the current simulator time, while the by total method does this based on the range of the entire dataset.

Using the real-time display option The by current window method determines an arc thickness normalization factor based on the data at the current simulator time. Using the by total method while displaying data in real-time produces a visualization that lacks detail. As a result, we have disabled this option from the demonstration system.

3.4.3 The Arc Scaling Algorithm

The arc scaling algorithm controls the method in which ridership values are presented in an arc graph. Our demonstration system offers three different algorithms for scaling data in this view:

1. Linear scale—the base scaling function utilized by the following two scaling algorithms. A scale is determined for a dataset by linearly distributing thickness values throughout the range of data.
2. Square root scale—takes the square root of all ridership values and then applies the linear scale to them.
3. Relative magnitude scale—takes the square root of the largest ridership value and then uses the linear scale to scale the rest of the values relative to this value.

4 Discussion/Conclusion

Atvis allows a transit planner to observe bus data visually, to pinpoint individual stops and transitions, and to formulate research hypotheses. The following is a list of questions that can be posted to or answered by the Atvis system:

1. Which stop has the highest boarding/alighting level at 8:11 a.m.?
2. How many people ride a bus between stop 2 and stop 3 from 9 a.m. to 10 a.m.?
3. Which two bus stops have the most ridership on Saturday?
4. Does the distance between two stops have any correlation with their ridership levels during rush hours?
5. Do any stops have abnormal boarding and alighting ratios for a given time period?

Atvis excels at visualizing transit data at an abstract level. Our focus on ridership and interstop relationships creates a visualization that emphasizes key bus/route statistics and removes the distraction of unwanted geographical data, allowing for more direct observation of transit patterns. Our innovative use of the arc diagram in conjunction with a bidirectional bar graph offers a holistic representation of transit data in a single view.

Our demonstration system is not currently implemented fully for multiple routes and datasets. Future implementation of this functionality will be useful to transit planners. A simple extension is to add the relationship between trips headed toward opposite bounds but along the same geographical route. A more general extension is to add a multiroute using suborder and multi-dataset visualization to allow users to compare ridership and passenger flow through different bus systems at the same simulator time.

Our system can also be improved by expanding data presentation to allow zooming in on individual bus trips. Doing so allows Atvis to help analysts not only to determine trends in bus data for the overall system but also to itemize ridership and passenger flow information for each trip. This feature would allow users to analyze data from a different perspective while maintaining our visualization's other advantages.

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