

# The Geographic Context Browser

**John Krumm**

Microsoft Research  
One Microsoft Way  
Redmond, WA 98052 USA  
+1 425 703 8283  
jckrumm@microsoft.com

## ABSTRACT

This paper discusses new techniques for enhancing a sequence of (latitude, longitude) points by tagging them with nearby points of interest and associated Web pages. We present a browser that lets a user explore the enhanced tracks by clicking on a map and filtering over aspects of context.

## Keywords

Context, geographic information systems, location

## INTRODUCTION

Viewing a track of (latitude, longitude) points on a map is an interesting way to relive a trip. The map helps trigger memories about locations and events. Such tracks will become more common as more devices become aware of their own location, such as GPS-equipped cell phones.

While a simple track display is useful, it is possible to extract more context from a series of (latitude, longitude) points. For instance, a (latitude, longitude) can be used to find nearby points of interest (POI) from a database. This paper first describes a few simple methods to extract richer context from a track. Then it shows how the extracted context can be used to look through a track to give a richer, more informative browsing experience, including lists of nearby points of interest and associated Web pages.

## LOCATION TRACKS

It is easy to create a location track by carrying a GPS receiver, and even inexpensive GPSs have recording capabilities. Other researchers have investigated the use of such tracks. In Project Lachesis[1], Hariharan and Toyama analyze location tracks to find “stays” and “destinations” and then build probabilistic models of a user’s location behavior. Patterson *et al.*[2] use GPS tracks to help infer a subject’s mode of transportation – walking, driving, or riding a bus. While these projects use location tracks to compute higher level features of the user’s behavior, our work is aimed at enhancing the tracks to help create a richer diary of a user’s travels.

## CONTEXT ENHANCEMENT

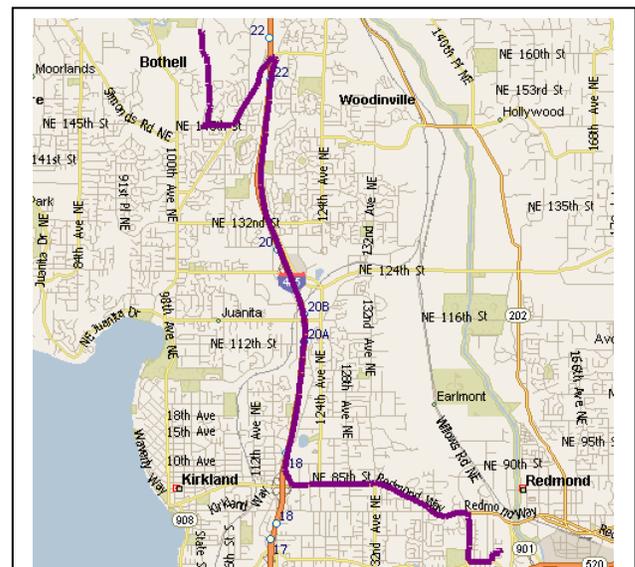
A track is a series of (latitude, longitude) points, which by themselves are not very meaningful to a typical user.

However, there are relatively simple techniques to derive more meaningful information about a track. We have augmented our tracks with a Kalman filter to estimate speed, a POI lookup to find interesting nearby places, and a Web search to find Web pages associated with the POIs. This extra information is stored with the tracks and used as input to our context browser.

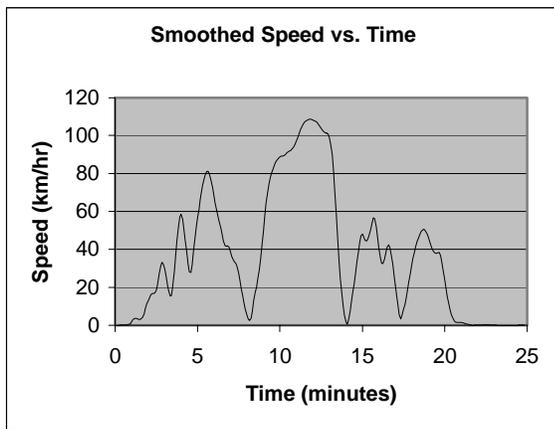
## Kalman Filter

Speed is a valuable feature for a location track, because it can be used to filter salient subsections of the track. For instance, a speed of zero (or near zero) means the subject was lingering at a certain place. Other speed ranges are indicative of walking, bicycling, or riding in a car, train, bus, or airplane.

The Kalman filter[3] is a well-established technique for statistical estimation based on noisy data. It is especially suited to noisy time-indexed data such as GPS location tracks. In our formulation, the Kalman filter computes smoothed estimates of location and velocity, balancing the



**Figure 1: The dark segment starting at the lower right shows a sample location track based on GPS. Our goal is to augment this track with local context information.**



**Figure 2: Our Kalman filter computes a smoothed speed estimate for every point in the GPS track. This shows speeds computed for the drive in Figure 1, which had a highway in the middle.**

expected standard deviation in GPS location measurements (10 m) and the expected standard deviation in accelerations (0.1 m/s<sup>2</sup>). Because the GPS gives only location, using a Kalman filter is an effective way to give realistic speed estimates.

After applying the Kalman filter, we store a smoothed speed estimate for every point of the track. For the drive shown in the map in Figure 1, the computed speeds are shown in Figure 2.

### Points of Interest

Points of interest are places like businesses, schools, and cities, normally located with (latitude, longitude). There are POI databases available, some specialized to certain types of POIs. In our project, we use the MapPoint® Web Service, which provides a list of businesses in North America. The businesses are categorized by their North American Industrial Classification System (NAICS) codes. NAICS is a hierarchical classification. For example

NAICS code 72 is the category for “Accommodation and Food Services”, 722 is the subcategory for “Food Services and Drinking Places”, and 7221 is the subcategory for “Full-Service Restaurants”. MapPoint® provides an API to take a (latitude, longitude), a search radius, and a NAICS category and return a list of businesses nearby, including the business’ name, address, and phone number.

There are 2341 NAICS categories available from MapPoint®, including exotic types like “Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing” and “Guided Missile and Space Vehicle Manufacturing”. We use a subset of NAICS categories, shown in Table 1, to find a list of POIs within 100 meters of each point of our tracks. These POIs are stored for use in our context browser. The POIs found for a particular point are listed in the screen shot in Figure 4.

### Web Pages

There are very often Web pages associated with businesses. Unfortunately, these pages are not normally indexed by location, as POIs are. However, we can still find appropriate pages via a Web search using terms from the POIs. For each POI we find, we create a search term consisting of the POI’s name and telephone number and submit this to MSN® Search. An example search term shows the different formats we allow for the telephone number:

```
"TRES HERMANOS" AND ("(425) 827-4422" OR "425-827-4422" OR "425 827-4422" OR "425 827 4422" OR "425.827.4422")
```

The first uniform research locator (URL) found for this term gives a review of this Mexican restaurant, shown in Figure 3. The URLs of the found pages are stored along with the POIs and Kalman filter results.

NAICS	Name	NAICS	Name	NAICS	Name
111	crop production	6111	elementary and secondary schools	61161	fine arts schools
112	animal production	6112	junior colleges	71131	promoters of performing arts, sports, and similar events with facilities
442	furniture and home furnishing stores	6113	colleges, universities, and professional schools	71211	museums
443	electronics and appliance stores	6115	technical and trade schools	71213	zoos and botanical gardens
445	food and beverage stores	6211	offices of physicians	71219	nature parks and other similar institutions
447	gasoline stations	6212	offices of dentists	71392	skiing facilities
448	clothing and clothing accessories stores	7111	performing arts companies	71394	fitness and recreational sports centers
452	general merchandise stores	7132	gambling industries	81211	hair, nail, and skin care services
481	air transportation	7211	traveler accommodation	81221	funeral homes and funeral services
482	rail transportation	7221	full-service restaurants	81222	cemeteries and crematories
483	water transportation	7222	limited-service eating places	485112	commuter rail systems
491	postal service	7224	drinking places (alcoholic beverages)	485113	bus and other motor vehicle transit systems
492	couriers and messengers	8131	religious organizations	512131	motion picture theaters (except drive-ins)
622	hospitals	31212	breweries	512132	drive-in motion picture theaters
4411	automobile dealers	31213	wineries	532111	passenger car rental
4441	building material and supplies dealers	44611	pharmacies and drug stores	561439	other business service centers (including copy shops)
4531	florists	45111	sporting goods stores	611620	sports and recreation instruction
4532	office supplies, stationery, and gift stores	45112	hobby, toy, and game stores	711211	sports teams and clubs
4871	scenic and sightseeing transportation, land	45113	sewing, needlework, and piece goods stores	71212	racetracks
4872	scenic and sightseeing transportation, water	45114	musical instrument and supplies stores	713990	all other amusement and recreation industries
4881	support activities for air transportation	45121	book stores and news dealers	721211	RV (recreational vehicle) parks and campgrounds
5112	software publishers	52212	savings institutions	721214	recreational and vacation camps (except campgrounds)
5312	offices of real estate agents and brokers	52213	credit unions	811192	car washes

**Table 1: This is the list of types of points of interest we look for around every (latitude, longitude) point. These are a subset of the North American Industrial Classification System (NAICS) categories.**

## CONTEXT BROWSER

Our context browser is designed to let a user explore a GPS track. It takes as input the enhanced tracks described in the previous section, including the Kalman-filtered speed, POIs, and URLs for each track point. A screen show of our context browser is shown in Figure 4. The upper left shows a clickable map with each track point marked with a disk.

Each track point is clickable, which brings up a list of found POIs and URLs in the upper right panel. Using this capability, a user can click on various points and immediately see a list of what was nearby and, if available, Web pages associated with that location. Clicking on a URL launches a separate Web browser displaying that URL.

The lower left of the UI is devoted to filtering track points. This allows the user to find which track points meet certain criteria in order to target certain subsections of the trip. One of these criteria is a threshold on speed. Invoking this filter assigns gray to all track points below the threshold and black to those above. This is useful for finding, say, parts of the track where the user lingered (zero speed) or where the user was moving at highway speeds. The low- or zero-speed points are especially interesting, because they indicate where the user stopped, perhaps at one of the POIs in the list.

The other available filter selects those track points that are near a selected type of POI as indicated by a NAICS category. The speed and POI filters can be independently enabled and disabled. Taken together, they allow a user to find track points that, for instance, show where the user stopped (zero speed) near a gas station with a convenience store (NAICS code 447110).

## CONCLUSION

Using relatively simple means, our system enhances tracks of raw (latitude, longitude) to include speed, POIs, and Web page URLs. Our context browser lets a user explore the track points and their associated context by choosing points on a map and by filtering the context based on speed and type of POI. This is a convenient way to explore tracks and to trigger memories of interesting points along the way.

In the future, the geographic context browser could be enhanced with other sources of information. For instance, adding historical weather data would allow a user to query on weather conditions as a trigger to find parts of a trip, e.g. "I remember we were near a movie theater and it was raining." Another interesting set of data to tap is digital photos. Since the GPS creates time stamps for all the (latitude, longitude) readings, it would be easy to find relevant photos from the trip if they were stored on the same computer used to run the context browser. There are also digital photos available via the Web that come with (latitude, longitude) stamps that could be displayed[4].

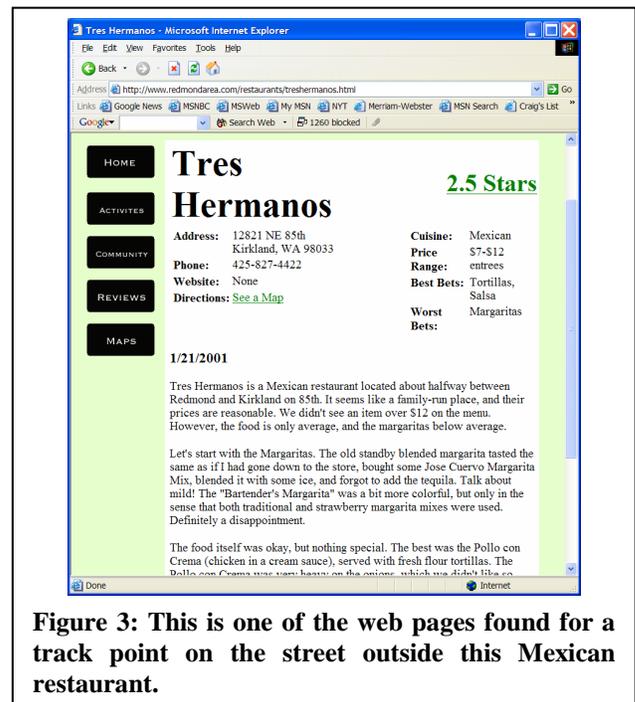


Figure 3: This is one of the web pages found for a track point on the street outside this Mexican restaurant.

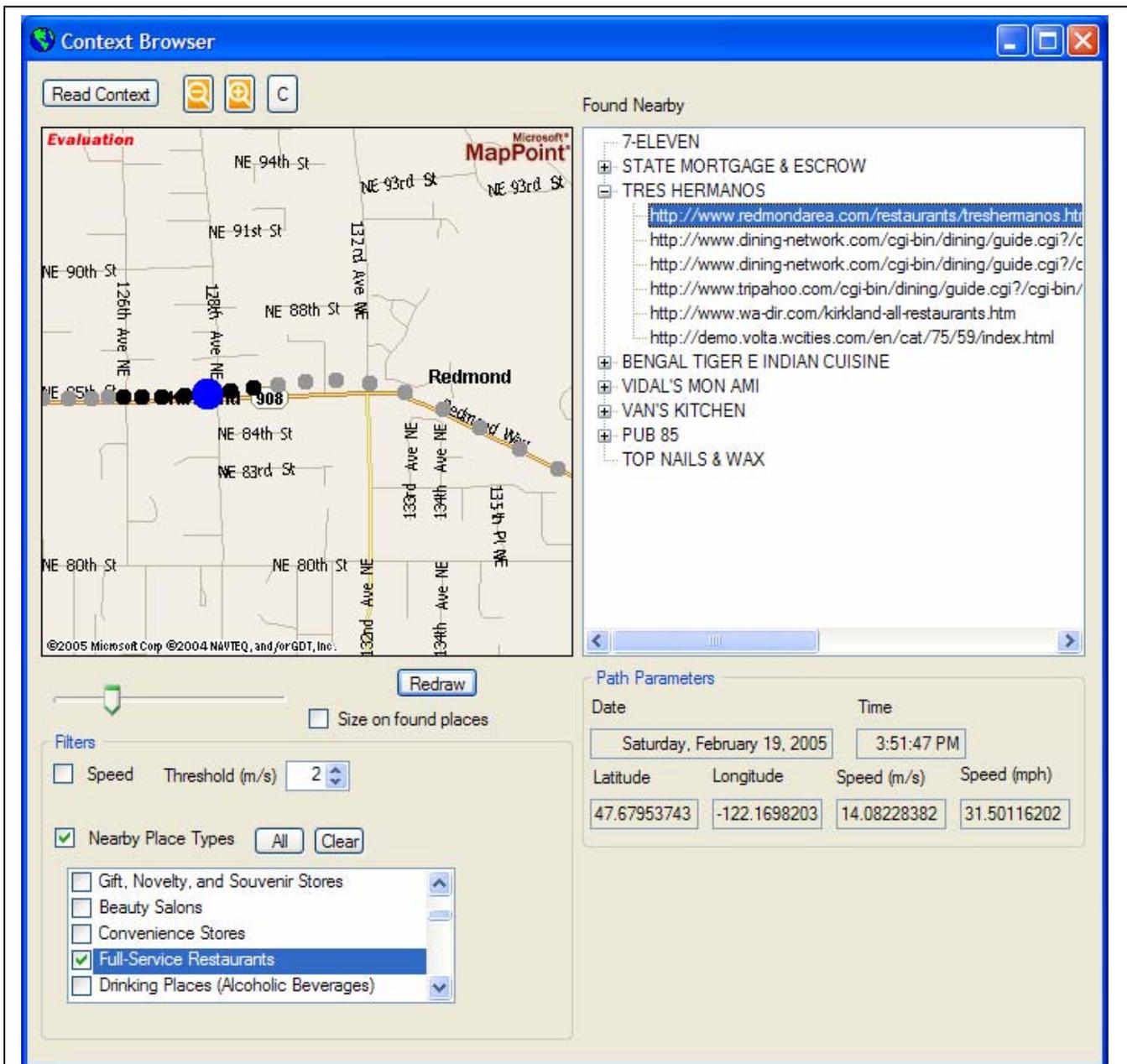
## REFERENCES

1. Hariharan, R. and K. Toyoma. *Project Lachesis: Parsing and Modeling Location Histories*. in *Third International Conference on GIScience*. 2004. Adelphi, MD, USA.
2. Patterson, D.J., et al. *Inferring High-Level Behavior from Low-Level Sensors*. in *Fifth International Conference on Ubiquitous Computing*. 2003. Seattle, WA, USA.
3. Gelb, A., *Applied Optimal Estimation*. 1974: MIT Press.
4. Toyama, K., et al. *World Wide Media Exchange*. in <http://wwmx.org/>.

## BIOGRAPHY

John Krumm graduated from Carnegie Mellon University in 1993 with a PhD in robotics and a thesis on texture analysis in images. He worked at the Robotics Center of Sandia National Laboratories in Albuquerque, New Mexico for the next four years. His main projects there were computer vision for object recognition for robots and occupant detection for cars. Since 1997 he has been a researcher at Microsoft Research in Redmond, Washington, USA concentrating on location tracking of people and devices and on ways of using location data to benefit the user.





**Figure 4:** The context browser shows a series of (latitude, longitude) points on a map. The selected point is shown larger than the others. Black dots are locations that are near at least one “Full-Service Restaurant”, according to the filter parameters set up in the lower left panel, while gray dots are not. The panel on the upper right shows the points of interest found for the selected point and associated Web page URLs. Clicking on a URL brings up the corresponding Web page. The panel of path parameters on the lower right shows the date, time, location, and speed.