Time Geography Rediscovered: A Common Language for Location-Oriented Services

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ABSTRACT

We propose that the concepts of Time Geography be evaluated as a framework for use within location-oriented services. Originally conceived as a system to describe patterns in human migration, Time Geography is ideally suited for providing the common language and concepts necessary for dialogue within this evolving area. Location-oriented services have been the focus of a great deal of attention, but with research occurring in many disparate disciplines, the lack of a common model that can conceptualize these ideas has not received appropriate attention. To demonstrate its applicability within location-oriented services, we present a research activity which makes explicit use of concepts from Time Geography, with the hope that it can be seen as a tractable and practical solution for several difficulties facing this fast growing area of interest.

Categories and Subject Descriptors

H.4.m [Information Systems]: Information Systems Applications: miscellaneous; K.4.2 [Computers and Society]: Social Issues

General Terms

Human Factors, Theory

Keywords

location-oriented services, time geography, tracking

1. GENERAL PROBLEM DEFINITION

We have no obvious and well-ordered perspective or generally accepted system of concepts available for the interpretation of what is at stake. We do not know how to treat a "whole" of such tremendous complexity [9:194].

When discussing location-oriented services, it is tempting to focus purely on the technical issues involved. However, there are several other areas which must be considered if these nascent ideas and products are ever to be brought into everyday use.

To accomplish this, a common framework must be established. Most importantly, a shared understanding and vocabulary in this emerging field would facilitate dialogue between scholars, thereby fostering new development.

In this paper, we first offer an overview of several current efforts to track individuals. We next propose as a common framework, Time Geography (TG), ending with a discussion of a current research activity that utilizes the proposed framework.

2. CURRENT WORK WITHIN THIS AREA

There are a number of initiatives underway in a variety of industries that focus on directly tracking the habits, patterns and locations of individuals. As an example, customized web advertising, based upon observed online behaviors such as search histories, banners clicked, etc., provides a large percentage of Internet revenue.

2.1 Commercial

Many attempts have been made to commercialize location-oriented services. While not exhaustive, this listing is meant not only to highlight various commercial examples, but also to connect them with a common thread—that of direct tracking and the study of individuals—as well as to contrast the approach we adopt.

Customized web advertising, based on observed online behaviors, is powering Internet growth. Google's success depends on its ability to successfully direct advertising to customers, based on various behavioral aspects that they track (e.g., search histories, banners clicked, etc.). Taking that a step further are two companies, UK-based Phorm and US-based NebuAd. Each company operates in a similar fashion—software installed at the ISP-level monitors and then analyzes customer online behavior.

A second area of interest is hardware-based. Various methods have been proposed as ways of directly monitoring individual behavior, among them sensors and RFID.

- A 2002 patent (US Pat. 9935774) by Procter & Gamble, describes how to use heat sensors to track and record "where a consumer is looking, i.e., which way she is facing, whether she is bending over or crouching down to look at a lower shelf."

- A 2006 patent (US Pat. 7076441) by IBM has the stated purpose to collect information that could be "used to monitor the movement of the person through the store or other areas." Once a cus-

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tomer enters a store, a sniffer "scans all identifiable RFID tags carried on the person," and correlates the tag information with sales records to determine the individual's "exact identity." A device known as a "person tracking unit" then assigns a tracking number to the shopper "to monitor the movement of the person through the store or other areas."

2.2 Current Research

A large amount of research has taken place in the field of tracking individuals. Various location-oriented systems have been proposed, from WiFi access points [14] to FM radio stations [11]. A unique low-fidelity study from 2006 used information from www.wheresgeorge.com to track the dynamic spatial redistribution of individuals who had self-reported serial numbers and locations from currency notes in their possession. The authors concluded that “human travel on geographical scales is an ambivalent and effectively super-diffusive process” [3:462].

A study similar to what we are conducting was reported in June, 2008 [7]. Human mobility patterns were deduced from a data set developed from 100,000 individuals taken from a sample set of 6 million anonymized mobile phone users. Over a 6-month period their position was tracked by recording the time and location each time a call or text message was initiated or received. The researchers discovered that, as opposed to previous studies which show randomness, human trajectories show a high degree of temporal and spatial regularity with a significant probability to return to a few highly frequented locations. The final conclusion was that, despite the diversity of their travel history, humans follow simple reproducible patterns.

Privacy is an important concern in this area and sometimes threats to it are not obvious. For example, America Online (AOL) released search logs from 650,000 subscribers in August, 2006. Although they created anonymous identifiers for each person, the nature of the data released was such that it was easily traceable to individuals [18]. Indeed, the New York Times did just such an investigation [1], contacting the individuals directly to confirm the accuracy of their own study.

Location-oriented services present an even greater need for caution in terms of user privacy. Dobson and Fisher [5] invoke the commonly-hyped fears of Orwell’s 1984 when they point out that while the situations in that novel were indeed horrifying, they were primarily implemented through direct surveillance of humans by humans. The automated systems available today as part of the regular course of our lives can be used for even more frightening ends.

Work has been done in this area to investigate whether this threat is more than theoretical and, if not, what methods might be used to correct it. Krumm [12] among others investigated various methods of obscuring tracking data.

Therefore as a thought experiment, the current work is intended to discover whether useful or desirable results can be produced by focusing on the actual paths of individuals, rather than the behavior of discrete individuals. This leads to an interesting conundrum however, in that the study explicitly violates user privacy. It is highly invasive, constantly following the movements of individuals.

This is necessary however, to prove that such a method for following a persons’ daily transit is technically feasible and scientifically interesting. For example, once we have traced the paths, will we be able to find stations and bundles? Those are the sorts of questions we try to answer with this initial study.

3. INTRODUCING TIME GEOGRAPHY

In his 1953 PhD dissertation, Torsten Hägerstrand first explained the ideas underlying TG, proposing that individuals become the focal point of study by explicitly tying them to time and space coordinates. Translated into English in 1967, the thesis *Innovation Diffusion as a Spatial Process* [6] spawned applications beyond its intended scope, among them Geographic Information Systems (GIS).

TG is not suited for extremely precise measurements of activities; this lack of explicit standards make it inappropriate for some uses within the location-oriented services field. Several attempts to address this have been proposed [4] [15] [16] but none have gained acceptance as a solution to this shortcoming.

What TG does however is deal with the choreography of an individual’s activities, each of these having inseparable components of time and space. Time-space paths can reveal much about individuals. We currently utilize positioning technologies such as GPS and positioning services such as www.dopplr.com, both of which highlight the individual’s whereabouts in time-space.

Mårtensson [17:18] offers the following fundamental conditions that make TG viable and coherent:

1. The indivisibility of the human being.
2. The limited life-spans of living and non-living entities.
3. The limited ability of human beings and other entities to take part in more than one task at a time.
4. The fact that every task has duration.
5. The fact that movements between points in space consume time.
6. The limited capacity of space.
7. The limited size of terrestrial space.
8. The fact that every situation is inevitably rooted in past situations.

In TG terminology, stations and domains occur when two or more individuals meet. A station is the meeting place of at least two people, such as a school corridor, while a domain is an area where people or organizations enforce rules of some sort, such as when a rector provides regulations for a school. The totality of these possible paths for an individual in TG is represented by prisms.

As an example, the last Concorde flight to Paris was the overlap of the time-space prisms of many individuals. Over time, such convergences can produce an activity bundle, an overlap of the histories of individuals [9]. An activity bundle does not occur randomly; rather, many factors direct it, such as resource availability and past activities.

Because of its breadth and flexibility, many fields have tried to adopt TG, either in part or whole cloth, to serve their various purposes. A great deal of criticism has been leveled against these attempts, particularly in the field of sociology and computer simulations [2]. Other critics have come from within the geography community itself [8].

TG has been primarily been used for obvious applications such as trip planning [20] and socioeconomic phenomena [13]. The rela-

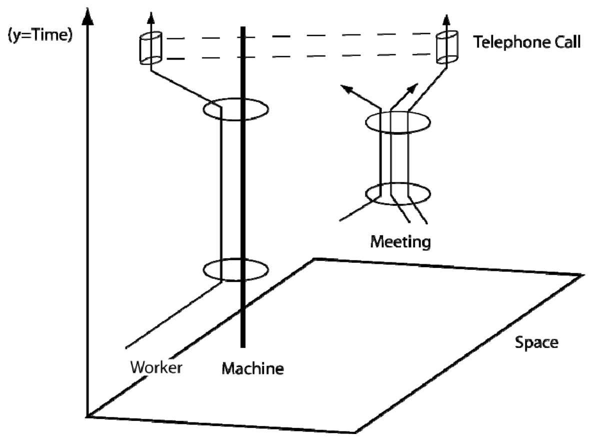

Figure 1. Time-geographical representation of paths being grouped into activity bundles (redrawn from [5:149]).

tionship to location-oriented services is obvious, particularly in the first area. Our hope is simply to re-introduce the themes of TG, providing a method of expressing common concepts among researchers within our field of interest.

4. A RESEARCH ACTIVITY INFORMED BY TG

When viewed through the lens of TG, we propose that people's behavior can yield patterns of significant commercial and research value. This idea is unique, and directly contrasts the current, commonly held notion that value can be only added to services by directly monitoring the behavior of individuals. Additionally, our plan has the express goal of helping develop products which balance the privacy concerns between the law, technology, and society.

4.1 Architecture of System

Our system monitors the daily movements of mobile phone users; their device reports for each base station it connects to throughout the day. This allows us to document their life-path. These life-paths are used to reveal common travel routes, points of intersection and other interesting, yet-to-be-discovered details.

For the study, an applet running on Symbian 9.2 mobile phones and a server with an Apache webserver and MySQL database are used. When the applet is loaded into the phone, it runs in the background, monitoring changes in its connection with the surrounding base stations. When a new connection occurs, the applet requests localization information from a provider of location-oriented services. This information consists of coordinates (latitude and longitude), an accuracy value and a landmark name. To preserve battery life, the localization information is first stored in the phone's local database and every thirty minutes is automatically uploaded to the server. The database can then be queried for selected individuals, delimited by date and time.

GSM localization works when people are indoors (a distinct advantage over GPS) and has an accuracy approaching GPS [19]. While GPS-equipped phones could have been used, allowing for more explicit tracking, we also believed that it was important to focus on using capabilities existing in all mobile phones—the ability to contact a base station. In choosing this approach, no specialized transmitters or sensors were needed, only a small reporting applet. Simply allowing the cell phone to perform its

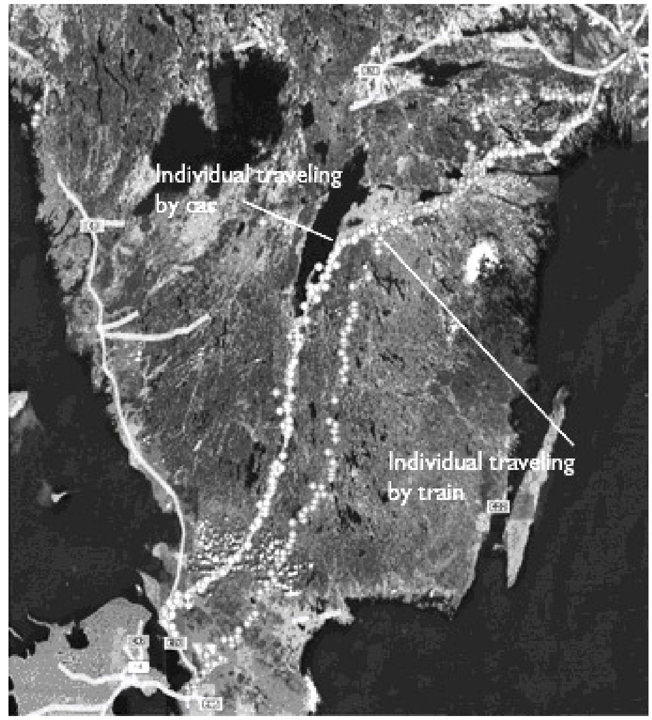

Figure 2. Individuals traveling from Stockholm to Lund, using different transportation methods and routes.

natural duties provided exactly the sort of information that was required.

4.2 Data

Four people participated in the study. Two individuals used the software for a period of at least 17 days, while two others participated for at least 49 days. All the individuals lived and worked within a 75 km radius of Stockholm, Sweden.

The individuals who participated for at least 17 days were in contact with an average of 216 base stations per day whereas the individuals who participated for at least 49 days were in contact with an average of 379 base stations per day. The large discrepancy is largely explainable by one study participant who traveled daily via subway between their homes in a southern suburb, through the dense urban core, to work in a northern suburb which has an advanced network infrastructure. Furthermore, this individual's home lies on a boundary between two base station sectors, causing the mobile device to oscillate wildly between the two. By discounting this user's data, the average number of base stations contacted per day drops to 227.

4.3 Findings

Several interesting concepts of time geography were demonstrated during the course of the study. First, it was quite easy to create paths, even if explicit longitude/latitude information were excluded. The idea of these virtual paths is quite intriguing because often, explicit geographic coordinates are not required to find interesting correlations and correspondences. Rather, if each path is denoted by a particular pattern of base stations, finding bundles becomes a matter of simply matching patterns and timestamps.

However, by adding the coordinate information available from the premium positioning, another layer of richness was added. Paths can be applied to actual geographic areas and landmarks; overlaying a path created by this method showed how two participants traveled to the same meeting several hundred kilometers south of Stockholm—one used the rail system and the other the road system (see Figure 2). By converting raw data to Google Earth's KML format, it was possible to watch the paths and then bundles and stations unfold over a compressed time line.

Place is a matter of context and it is far easier to look at emergent co-incidental occurrences in terms of their geographic, real-world location as opposed to mere points within a database. Thus, adding this concrete layer is important for classifying stations for it allows the researchers to understand that Stockholm's central train station can be designated by a set of particular longitude and latitude coordinates as well as by a particular pattern of base stations. Once these are transposed onto a geographic map, their context and value to study participants becomes apparent.

5. FUTURE WORK

Upon completion of the initial work, we have begun evaluating how to further connect the data to the language of TG. To accomplish this, we hope to add a sociologic component to our work, borrowing from the work of analytical sociology, in particular their ideas of social mechanisms.

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