Where Were We: Communities for Sharing Space-Time Trails

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ABSTRACT

We consider trails to be a document type of growing importance, authored in abundance as locative technologies become embedded in mobile devices carried by billions of humans. As these trail documents become annotated by communities of users, the resulting data sets can provide support for a host of services. In this paper we describe our socio-technical exploration of the devices, scenarios, and end-user interactions that will come into play as these tools become widespread. We couch this work in a discussion of the sociological impact of a shift from hyperlinks to "hyperties" -- links that bridge the gap between computational media and physical world interactions. We describe a prototype hardware device for location and other sensor data capture. This device links to a complementary website for querying, sharing, and distributing the resulting route datasets. The web application allows users to find related community members via shared attributes of their contributed or annotated routes. These attributes may be generated in part by route analysis performed by systems for activity identification and classification.

Categories and Subject Descriptors

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Keywords

Routes, mapping, social computing, community, sports

1. INTRODUCTION

Mobile devices are gaining locative technologies that can place a user on a map with increasing accuracy and declining cost. Some commercial (e.g., [3, 16]) and research (e.g., [1, 8]) efforts and many map "mashups" (e.g., [2, 14]) are starting to explore these technologies. Looking ahead, what kind of new document types emerge from these capabilities? What kinds of applications are needed to author, manage, edit, and share these kinds of documents? What opportunities exist for communities to leverage the imminent explosion of this new form of document type?

A comprehensive set of capture, editing, publication, and search tools for temporal-spatial data will help users and communities leverage the emergence of location data as a common attribute of most user's daily computing experience. In the following, we describe a set of new devices and applications that offer compelling services based on these new space-time trails. End user scenarios include:

- Runners, bikers, skaters, skiers and other outdoor sports enthusiasts carry their location-enabled mobile device to track their performance and compare it against their own personal best and the records of their exercise or sporting community.
- Vacationers return from their trips with highly annotated trails that track their movements and display holiday snapshots anchored to a map that can be shared with friends or the public. While on their trip they navigated by waypoints contributed by their friends, community organizations, and the general public.
- Everyday experiences generate data as people travel between home, work, and 3rd places, allowing devices to recommend and advise users as they move through space and time.

The main opportunities are to move beyond the "push-pin" or "point-level" data structures that are now widely appearing across the internet and to incorporate both collections of points with relationships to one another along with sensor and community authored annotations. These annotations include:

- Media such as photographs and audio recordings
- Environmental sensor data like temperature, pressure
- Biological attributes like heart rate
- Movement-based sensor inputs like acceleration
- Community contributed comments, tags or other digital media

Additionally, we argue that space-time trails, or routes, include an intentionality on the part of the user that contains more information than a collection of points. A route has a start and finish, as well as properties like time, distance, speed, directional orientation, numbers of stops, and so on. When browsing, retracing, mining, recommending, and searching, these collective and relational attributes can be leveraged for a significantly richer end-user experience than could a collection of points.

1.1 Hyperties

As these locative and sensor technologies proliferate, a new form of hyperlink is emerging: a "hypertie" that bridges the gap between links created in computational media and those authored in the physical world when people interact with one another and the objects around them. The hypertie is an innovation in the "interaction order" [5], the space defined by human interaction. Hyperties are the product of the merger of existing social practices of association with the technical affordances of mobile networked information systems and mobile location and other sensors. It could be argued that a shift in social life is occurring when the ties that bind people can be inscribed with decreasing effort into forms similar to the ways hyperlinks create connections between resources on the Internet. New mobile devices represent a novel innovation in the historically slow-to-change realm of social interaction—face-to-face encounters. The result could be a shift from a social world in which much is ephemeral to one in which even the most trivial of passings is archival.

The sociologist Erving Goffman coined the term "interaction order" to label the realm of face-to-face naturally occurring social interaction [5]. Most social life takes place in this medium through various means of self-presentation and perception. Body posture and adornment, speech, inscription, and proximity are resources used to present oneself and interpret the presentations of others. Goffman studied this realm as a distinct domain of sociological inquiry and found within it a range of structural properties and practices. In Goffman's eyes, people actively produce and perform presentations to one another, laboring with costumes, sets, and props to give a particular kind of impression to other people. Simultaneously, in slips and gaffes, through involuntary responses like blushing or eye motion, people also give-off impressions that others are highly attuned to discovering and interpreting. Symbols—authored intentionally and not, exchanged between actors in shifting roles with shifting audiences—are the setting for much of Goffman's vision of the social world. He highlights a complex landscape with sophisticated signalling and practices.

In Relations in Public, Goffman introduces the idea of "Tie signs", social practices that indicate linkages between actors and artifacts that signal the nature of their relationship [6]. Holding hands with someone is a good signal that you know them. Less explicit links are also widely recognized as marks of a common bond or prior history. Shared costume, language, mannerism, and insignia are all good ways to tell if someone is from "around here" and is expressing a tie to a geographic region or social status. Related work from Edward Twitchell Hall defined and explored a realm he labelled "proxemics" – the study of proximity and orientation among social actors [7]. Hall highlights the ways cultures generate norms about how far different types of people should stand apart from one another, who has rights to look at whom, and how and when physical contact is permitted.

The web hyperlink encodes a tie between resources or entities represented in computational media. These links, in aggregate, now affect most areas of commerce and culture. They are a new means of inscription of relationships, making visible connections that were previously latent or represented in ways that could not be aggregated and searched easily. When these ties are inscribed in computational media, new applications become possible for building connections, evaluating others, and gaining status and value from the accreted history of prior relationships. Historically, in contrast, many forms of social tie-signs have been ephemeral or stubbornly physical. Bridges (and the traffic over them), contracts, handshakes, and shared opinions have been hard to catalogue, aggregate, analyze, and track in near real-time. In contrast to the digital qualities of hyperlinks, a vast amount of our social ties remain mostly analog in nature.

That is beginning to change. The growth and widespread adoption of computer-mediated communication channels illustrates a major way that the social world is becoming "machine readable." The realm of social networking sites like Facebook, MySpace and Orkut along with the wealth of web discussion boards, email lists, private instant message and email conversations and emerging channels like VOIP and graphical worlds are all examples of the expansion of the interaction order into machine readable media. They also illustrate the limits of these tools for impacting the primary interaction order of face-to-face encounters. Some edge towards the interaction order, as when people use mobile phones or laptops to SMS or IM or email one another while in the same meeting or room, but much of the activity of the face-to-face interaction order is not inscribed in a systematic and widespread manner.

Social network systems have become a rapidly growing form of computer-mediated social space. Systems like SixDegrees and subsequently systems like Friendster, Linked-In, Plaxo, Orkut, Facebook, MySpace, flickr and increasingly most end-user content creation systems, have features that provide a means for individuals to link to other users of the same or related systems. The results are webs of associations that trace the connections between tens of millions of users, all explicitly authored at keyboards with mice and (relatively) big screens. Studies of these systems have revealed highly structured behaviours, or roles, being performed by users who occupy positions within an ecosystem of actors [17]. The interaction order is changing as mobile devices sense more of the social world and integrate with existing social networking systems so that computation is extended into site of face-to-face interaction, the "synapse of society", the gap between people when they associate.

1.1.1. The Hypertie

The hypertie encodes relationships in a form that is similar to the hyperlink and is different in kind and quality from the ways such social ties have previously been expressed. Social ties are widespread, created whenever people or other entities share or exchange resources. In some cases these exchanges leave behind durable artifacts that represent the previous or continuing existence of the tie. A bridge is a good example, but so are artifacts like trade contracts, shared languages, and written citations linking one textual work to another. Simple behaviors towards common objects, like two people emerging from a swimming pool at different times and using the same sun tan oil, can indicate the presence of a linkage between two people [6].

The mobile digital device, the replacement for the "cell phone," is a recent and emerging innovation in the interaction order that enables novel forms of tie signs to be created and displayed. The mobile device is the first artifact that is aware of events in the interaction order to any extent. Its awareness takes place through the use of a number of sensors such as analog and digital radios, GPS, WiFi, Bluetooth, infrared light, and sound. These sensors can allow the detection of other similarly enabled mobile devices in some proximity. Given the intimate association of many mobile devices with individuals (or closely linked small groups), these technologies allow for the mechanical sensing of the presence of people and the creation and inscription of ties, perhaps better thought of as hyperties, in increasingly implicit, passive, automatic, and pervasive ways.

When mobile devices, in the forms of cell phones, PDAs, MP3 players, cameras, personal video players, portable gaming devices and personal GPS navigation devices, are widespread there are a number of ways that social ties can be authored and inscribed. Machines accomplish this sensing in two broad ways. First, they can directly link to one another, sensing the presence of other radios, light beacons, or sound sources. Second, machines can independently determine their location using a variety of technologies from GPS to terrestrial radio and other location beacons, and share that information with a common repository such that their proximity can be calculated from the joint data set and reported back to the mobile devices.

When these data are stored and analyzed the result is an increasingly self-documenting social world in which casual encounters are noted with the same detail as long term relationships. Projects like the "Jabberwocky" [13] system from Intel Research along with commercial systems like nTag.com and SpotMe.com already explore and implement this hypertie concept. These and other related projects and products are described below.

1.1.2 Hypertie Systems

■ "Life logging," a concept championed by Gordon Bell at Microsoft Research, describes a set of technologies that could allow a large number of people to continuously capture many aspects of their lives from cradle to grave [4]. The resulting data, compiled from video and audio recording as well as from the capture of every keystroke and mouse tap, GPS reading and heart rate data point, would amount to a manageably low number of terabytes. The recognition of people in the resulting data stream is just one of the many applications being considered for exploiting this new data resource. Fragments of this vision are already in demonstration form and a few are already in more stable commercial use.

■ Trace Encounters, deployed at the Ars Electronic conference in Linz, Austria in 2004, was a system built around a small lapel pin computer that contained an infrared mechanism for exchanging data with similar devices. When one person wearing a tag encountered another person who also wore a tag, each transmitted a string of data that represented the wearer's interests and prior encounters. The result is a display of one or more LED lights that indicated to what extent two individuals shared common interests, perhaps encouraging the individuals to engage in interaction to discover their shared interests. When an individual's tag came into range of a base station PC, it also provided information about its previous encounters with people wearing other tags that were then collected and aggregated with information from all other tags that linked to the base station.

■ nTag is a commercial service that extends the core concepts explored in the Trace Encounters system by making the device's display of information far richer. The nTag device was designed to be worn in the same way a name tag at a conference would be displayed, replacing the paper name card with a thin LCD display. The extra signaling space was used to exchange information about the topics that were of possible mutual interest, creating a kind of context aware form of the "ticket to talk" concept described by the sociologist Harvey Sacks [14].

■ The Jabberwocky project explored an alternative RF mechanism, Bluetooth, widely available on millions of mobile devices world-wide, to illuminate the population of social beacons already present in the wilds of the Bay Area of California. The Jabberwocky system processed the aggregate data about past discoveries of Bluetooth radios and presented users with a "familiarity" display that indicated how many people within a close distance were people who ever had been seen previously. Some locations are filled with "familiar strangers" people who often occupy the same spaces but do not create relationships beyond the most minimal recognition.

■ SenseCam [9] is a prototype device developed in the Cambridge, England Microsoft Research laboratory. The device resembles a credit card sized digital camera with significant enhancements in the form of sensors. Accelerometers, thermometers, visible and IR cameras, and Bluetooth radios are combined in the SenseCam to provide the device with the means of recording on-going sensor data and to use that data to determine when to take a picture. The device has programming that selects for volatility events, points of transition between states such as those generated when a walking person comes to a halt or a sitting person stands and begins to walk. When worn from morning to night, the device creates a data set of photographs and associated sensor data of the flow of each user's day. SenseCams are likely to be able to detect one another and, through techniques like facial recognition, to identify people seen by the person's device throughout the day. These sightings could be transformed into the kinds of social reporting services delivered by systems like nTag and SpotMe.

1.1.3 Implications of Hypertie Systems

Some affordances of these technologies are already relatively clear. Co-presence is about to be increasingly automatically documented in such a way that our currently blurry social backgrounds will likely resolve into a focused and detailed pattern of precisely recognized passing profiles. Amidst this detail our primary relationships are documented in the same remarkable detail as our most casual encounters. Casual crossings become increasingly visible as existing patterns that were latent or previously ephemeral are made explicitly visible and available for collection, aggregation and analysis. Once generated in machine readable form, sensor data can be merged with a wide range of other data and correlated with selected collections of traces from other people or groups. From credit and census records, to crop and weather patterns, to web browsing and system configuration patterns, meso- and macro-structural patterns will emerge from the collective behavior of millions of people each carrying mobile networked sensors and computing devices, each moving through the spaces and places they inhabit.

The digital quality of hyperties introduces other implications as well. Once collected within the context of a specific social setting these observations are likely to be available to people a world away. The erosion of control over audience is a critical shift that is already in play as people upload video captured from mobile devices to video sharing sites on the Internet, making the potential audience for an event far larger than the population co-present at the actual occurrence. Given Goffman's observation of the careful crafting of interaction presentations for the specific audience present, loss of control over the boundaries of the potential audience is a significant new challenge in the interaction order. Almost any event can be recast (or "re-keyed") into a less flattering frame, increasing the uncertainty and risk of social encounters.

The sum of these changes could be considered to be a kind of "pervasive inscription revolution", an era in which practices of inscription explode to include almost all human actions and interactions. The signs of the expansion of inscription are visible in the behavior patterns seen in many online services. Early systems, like email, required active contributions of content in order for a user to be visible in the space. A widespread concern was for the disproportionate numbers of "lurkers", read-only users who contributed no visible content.

Over time, computer-mediated interaction systems have evolved smaller hurdles for users to leave traces in systems, allowing the act of "viewing" a piece of content to create a piece of content that is visible to other users. Making objects into "favorites" or adding /someone to a watch list and similar features allow people to browse content and simultaneously leave a series of traces behind that are visible to others. Few systems allow for the unnoticed and unreflected consumption of content. Such behavior is valuable, socially and practically interesting, and cheap to collect. In such a situation privacy issues are sharpened even more than present. The walls have ears and eyes and other's eyes and ears are now high fidelity and archival.

1.2 Devices and Scenarios

We assume mobile devices will gain a small cluster of sensors, most commonly embedded in a mobile phone that is able to capture a range of data about the user and their state: location, motion, contextual variables like altitude and temperature, and biological data such as heart rate will be continuously sampled and stored. These sensor inputs will then be processed and automatically integrated into a route document. This document may inform a number of scenarios, including for example:

- a particular car route is stressful (lots of stop and go and increased heart rate)
- a user is slowly reaching a fitness goal over the course of weeks of working out (average speed is going up while heart rate is going down for a running route that is run frequently over time)
- a runner might want to try a different route that starts near her home but is 10% more difficult than she normally runs (slightly more elevation change, slightly higher max heart rate)
- a less direct route is more scenic

1.3 End-user Interactions and Community

We envision two significant end-user interaction channels for these route documents: a desktop-based and a mobile device interface. The mobile device provides a critical piece of the experience by capturing and uploading route data and other sensor-based data, as well as by downloading routes from the community route server. The web-based (more desktop-bound) interactions figure equally prominently in the community aspects of the system. These web-based interactions fall into three categories:

- *Browsing and searching* A first stop for an end user is to browse and search a database of routes. This process leverages the results of activity categorization algorithms and user tagging activity so that, for example, a user does not see drivers or driving routes when looking for cyclists or bike rides. Such queries can draw on related data sets and services that provide rich annotations so that the user can see that, for example, a potential bike ride includes several segments on roads high in car traffic.
- *Route (and route attribute) visualization* Once narrowed down to a set of routes of interest, the system should present a variety of views of these routes. This is akin to the various 'sort by' options for files in the file explorer, but the nature of the route document enables far greater opportunities for visual presentation. For example, routes can be expressed and compared through graphs of altitude gain/loss by time or by distance. Or a set of routes can be shown as a scatterplot of max heart rate by distance.
- *Manipulation of a route itself* Finally, users will want to manipulate routes, route segments, and route points. Akin to 'cut and paste', users will want to experiment with creating new routes out of pieces of existing routes. The metadata from each initial route can also be pieced together to provide a projected summary of a route that no user has ever actually done in total. Driving and tourist scenarios in particular benefit from this functionality.

Community members benefit from these interactions through the awareness of others' routes (what routes are similar runners running?) and importantly through data annotated on the routes. Automatically captured sensor data (e.g., heart rate) will be useful for finding similar others (those with heart rates similar to mine over similar routes), for recommending routes based on observed measurements (i.e. the route that is 10% harder than the typical route), and for general browsing and search (look for routes that have a desired elevation gain), among other uses. Manually entered annotations allow for humans to also author connections between routes and people that may not be machine observable. For example, text comments on route segments can tell people that the road is under construction or that there is a particularly tasty bakery that makes a good stop during a bike ride.

2. SlamXR: Prototype Trail Sharing System

To start exploring these concepts we designed and implemented a prototype system for route logging, annotating, and sharing called SlamXR (Sharing Location And Media for eXeRcise). Logging takes place via a custom application for Windows Mobile devices and at a minimum a Bluetooth GPS unit. With appropriate hardware, including our custom built sensor configuration (Figure 1), routes are automatically annotated with data such as heart rate and 3-axis accelerometry. Route and any additional data are analyzed for abstracted qualities such as activity and difficulty level. Finally, users can view and share routes using the SlamXR trail sharing community website. On the site, we provide a number of route search and organizational options (tagging), sharing capabilities (RSS feeds from any system query), and community features (people search based on route qualities).

2.1 SlamXR and Hyperties

SlamXR extends the scenarios explored in the other hypertie systems described here in that it incorporates a range of sensors in addition to the radios and IR beacons used in other devices. Sensors like accelerometers, thermometers, altimeters, GPS, and biological sensors like heart rate and blood oxygen levels are increasingly affordable and miniaturized so that they may soon become standard features of many consumer mobile devices. Each sensor has a capability to measure aspects of the user's state in surprisingly refined ways. Accelerometers measure acceleration, which is to say, changes in movement. A 3-axis accelerometer can generate data about the patterns of force applied to it, and by extension, to its owner. Motions like standing, sitting, walking, riding in a variety of vehicles all apply distinct force patterns which can be machine interpreted and identified with high levels of accuracy (e.g., [10]). The forces applied to a person by an elevator versus an airplane ride are very distinct. Recording the output of an accelerometer over time results in a continuous map of a person's (or their device's) motions.

Combined with GPS and related technologies like altimeters (which help correct altitude errors that are often generated by GPS devices), a package of sensors can locate a person precisely on the surface of the planet while simultaneously characterizing the range of forces and motions applied to that person. The recent release of a joint effort between Apple's iPod product and a Nike running shoe is an early intimation of this trend [11]. The Nike+iPod product is intended to measure a runner's foot falls and thus map their exertion over time. This data is recorded on the iPod and can later be uploaded to a shared web application where people can contrast their progress with others. This existing system suggests a future in which these products are combined with biological sensors like heart rate, temperature, and blood oxidation sensors thus generating a detailed picture of where a person is and what their physical state is at reasonably low (and dropping) costs. SlamXR's custom hardware unit incorporates a variety of sensors (see section 2.2 below) that inform the system (e.g., help predict user activity) and the end user (e.g., help find routes with similar elevation patterns). These sensor data are tied to route data with the goal of creating information-rich hyperties between physical space and digital information.

2.2 Route Logging

As mentioned, route logging takes place via Windows Mobile devices and, minimally, an off-the-shelf Bluetooth GPS unit. After pairing the GPS unit with the mobile device, users open our logging application on their Windows Mobile phone and simply press 'Start Logging' on the left soft key, engage in their activity, then press 'Stop Logging', also on the left soft key. At that point, the route and any additional sensor data are automatically uploaded to the SlamXR server over the GPRS network for processing. Alternatively, the user may save a logged route for upload via a computer's internet connection when their phone is connected to the computer. Once a route is uploaded to the server it is available immediately to other users of the system. During logging, the user is shown her current latitude and longitude, altitude, number of fixed satellites, as well as number of data points logged.

To enable and explore more sophisticated automated route annotation scenarios, we built a box (Figure 1) containing pressure, temperature, accelerometer, heart rate, and GPS sensors. Thus, this sensor box performs the standard GPS route logging functions, but also passes the additional sensor data to our phone-based logging application, which in turn combines all sensor inputs into a single XML file for upload to the server. In terms of physical dimensions, the box is approximately 2 inches X 2 inches and is 1 inch thick. The device is light and generally feels like a slightly large Bluetooth GPS unit. The sensor box is powered by a standard mobile phone battery and communicates with the mobile phone via Bluetooth. Not shown in Figure 2 are leads for the wired heart rate monitor. We found that while sufficient for concept testing in a prototype, in practice the wired heart rate monitor was a source of constant frustration due to the leads slipping and subsequently providing erroneous data.

2.3 Trail processing

The SlamXR system implements a number of data analysis steps to translate raw route data into meaningful attributes and categories for later end user consumption. Here we describe the major steps through this process, starting with processing on the mobile device, then on our server, and finally on-the-fly processing as routes are accessed from the website.

2.3.1 On Device Processing

Signal inputs are transmitted over Bluethooth from the SlamXR sensor board to a Windows Mobile device. Some signals require only simple translations, such as converting temperature to centigrade or extracting latitude and longitude from the NMEA string produced by the GPS radio. Others require additional data processing. Primarily this includes extracting heart rate in beats per minute from the heart rate monitor, which uses an algorithm similar to [12], and both absolute and net amount of acceleration along each axis from the accelerometer. After any necessary signal processing, our logging application stores all route and sensor data in an XML file that is then sent to the system server over the GPRS network.

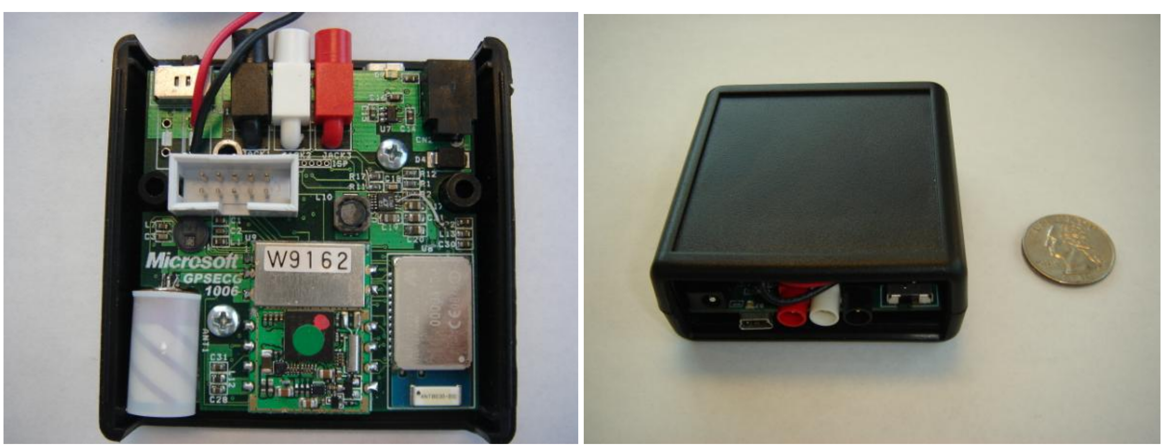

Figure 1. Prototype sensor board that includes GPS, accelerometer, pressure sensor, temperature, Bluetooth, and battery.

2.3.2 Backend Processing

The data arrive at our server in an XML schema containing route data points, with each data point containing latitude and longitude, altitude, absolute and net values for all three axis of the accelerometer, heart rate, and temperature. The goal is to generate higher level metadata descriptions from these raw data that will later be used to support search and organize routes. After storing the raw data, the processing for each input type follows a similar 2-step process. First, a second set of data points is constructed based on point-to-point change for each attribute. For example, altitude is processed to calculate the change in altitude from one route data point to the next. In the second step, a table of metadata points is constructed based on the raw data and these change data points. Metadata points for each route include speed, change in speed, altitude, change in altitude, heart rate, temperature, and total acceleration. We briefly describe the calculation of each metadata type:

- Speed: The result of standard distance calculation from change in latitude and longitude over an amount of time. Since we typically log data points every 5 seconds, the speed at any given point is simply the change in distance over a 5 second period.
- Altitude and Altitude Change: Altitude is taken directly from the altimeter or GPS. Altitude change is the difference in altitude between a given point and the preceding point.
- Temperature: Raw temperature values at a given logged data point in centigrade as logged on the mobile device.
- Heart Rate: Raw heart rate values at each logged data point in beats per minute as logged and processed on the mobile device.
- Acceleration: The summary of the absolute value of each axis of acceleration as logged by the mobile device.

Finally, based on the metadata points, a metadata summary table is generated for each route. This includes: overall distance, distance ascending and descending, overall speed, speed

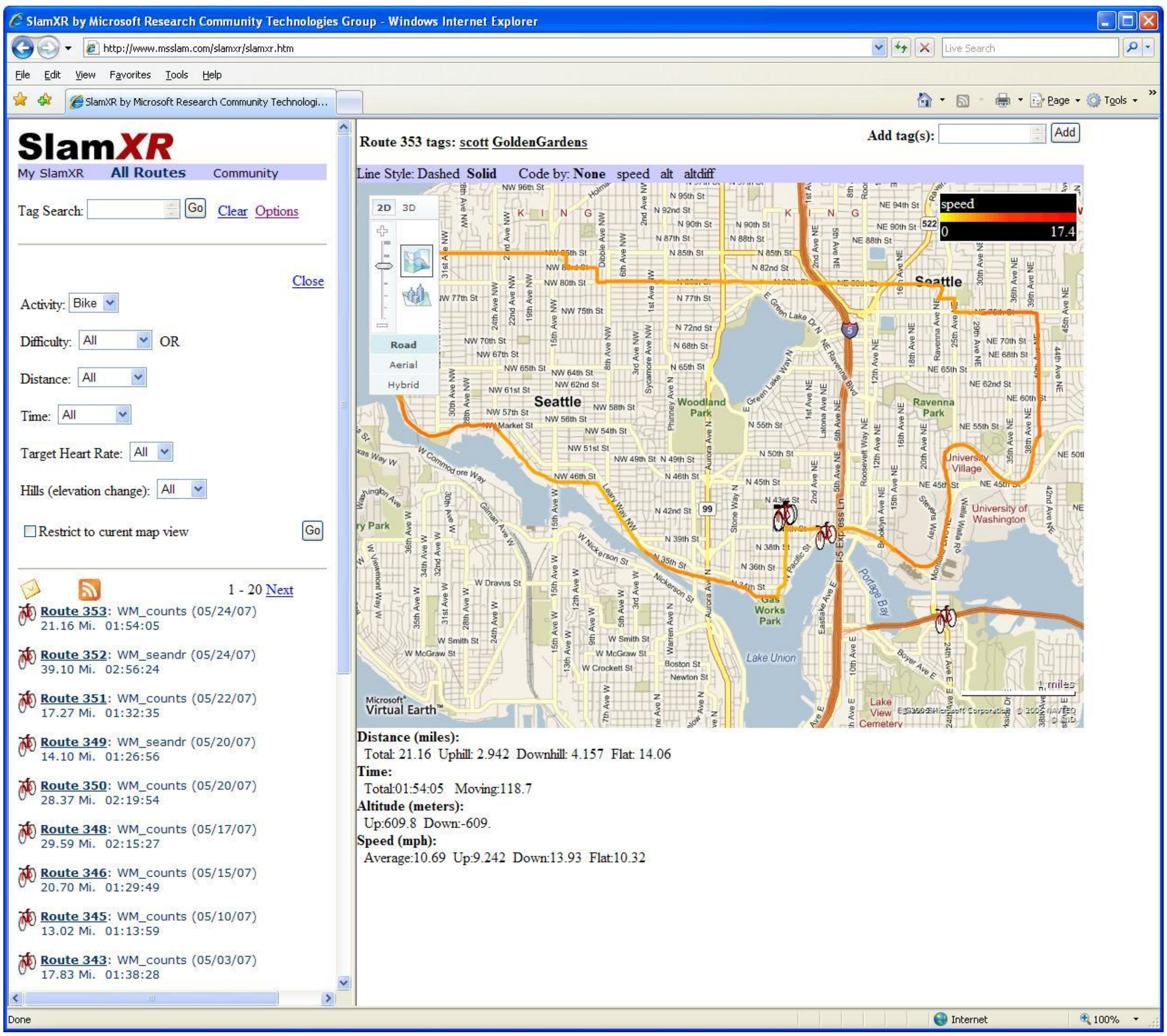

Figure 2. Prototype "SLAM XR" website for annotated trail sharing in support of outdoor sports communities

ascending and descending, overall time of route and time while moving, altitude change ascending and descending, and both average and maximum heart rate.

Every route uploaded to the system is considered a unique route. That is, we do not at this point, test routes for equality. This means that one or more users could in fact log the same route without our system taking advantage of this fact. Scenarios, such as averaging across multiple logs of the same route or route segments for mean speed, which could be attained from such route comparison, are areas for future work.

2.3.3 On-the-fly processing

We further abstract the route data on-the-fly as routes are called to the web interface for later viewing. First we classify the route into one of a number of different activities. There are many ways this could be done, and we are currently employing a decision tree algorithm that looks primarily at properties of speed. Simple distinctions are made based on overall average speed, such as between running and driving. Further distinctions are then made based on maximum speed. This helps distinguish activities such as bicycling from running, such that even if a slow bike ride and fast run have similar average speeds, the bike ride almost surely has a faster maximum speed than any run. We also include speed variability for additional distinction between activities that have similar average speeds. For example, running and downhill skiing have fairly similar average speeds for a given route, but skiing involves much more stopping and starting and thus shows considerably greater variability in speed. We currently support the identification of five distinct activities: running, skiing, bicycling, driving, and flying.

There are many more factors that could be employed in activity classification. For example, altitude or change in altitude could further distinguish running from skiing. Distance to the nearest road would also distinguish between activities like road and off-road bicycling. There will always be edge cases, however, that will prove challenging. For example, one may be tempted to classify activities above 5,000 feet of elevation as skiing, hiking, or some other activity related to being in the mountains. However, in many parts of the world, someone could simply be jogging near their home at 6,000 feet. Or a person, such as a smaller child, could truly have ridden her bicycle as slowly and consistently as an adult would run. Ultimately, a sophisticated probabilistic statistical model will likely be employed that accounts not only for route and route metadata, but for personal factors of the user (age, typical activities) and context factors (road map data).

Next, for each activity, we classify a particular route in terms of its difficulty level. Difficulty levels are unique to each activity and require some level of expertise or knowledge of each activity to calculate. We approximate these levels with a three-level categorization: easy, moderate, or difficult. Distance, speed, and altitude change are all incorporated such that, a difficult bicycle ride, for example, will be longer, faster, and include more elevation change than a moderate level bicycle ride.

A number of issues arise with both the activity and difficulty level classifications, many of which have noteworthy side effects. For example, a poor satellite fix may produce small logging errors from the GPS signal that produce maximum speeds too fast for running, when in fact the user was running. Unfortunately, this route could then be classified as a bicycle ride and will not show up as a run in searches without additional manual annotation. Distinguishing such errors is tricky and some amount of user override is likely necessary.

2.4 Route Visualization and Interaction

The SlamXR website (Figure 2) is the primary interface for browsing and searching for both routes and the profiles of other users of the system. Upon visiting the site, the user sees the 20 routes most recently added to the system, with the map interface scoped to accommodate their start points. A data summary for the totals across all routes in the route list is provided below the map. That is, distance, time, altitude change, and speed metrics are presented that summarize all the routes in the current route list. Start points and routes in the route list on the left are identified with an icon appropriate to the activity type. In addition to the activity type, the route list populates each route with a few pieces of data, such as date added, total distance, and total time.

A user can then simply click a route to view it on the map. At that point, the metadata summary will change to reflect only that particular route and the map will zoom to show the selected route. In addition to the standard map controls, the user can choose to view the route color-coded by any available annotated data, such as by speed or by heart rate. The color coding is done by drawing multiple polylines on the map control, each color coded to reflect the average value of the chosen metric across that stretch of the route. A small amount of additional on-the-fly calculation is performed here to determine the scale for this color coding, mostly to eliminate any errant data points reflecting noise in the signal data. For example, one data point for speed that clearly is an outlier would throw off the scale such that the rest of the route would look much more uniform than it should.

Users can search for routes by tag, by abstracted route attributes (activity type, difficulty level), by specific route attributes like elevation change, or by combinations of the above. Thus a user can search for routes that are classified as bicycle routes of medium difficulty that are tagged with any arbitrary tag string (“scenic” or “noisy_highway”). Or a user could search for running routes that are of a specified distance and contain a specified amount of elevation change. Once the search is executed, starting points for the result set are populated on the map and the data summary is updated to reflect the new route list. The route data summarization was intended to be used in a variety of ways. For example, if the user wants to search for all bicycle rides that are tagged with the user’s name (“Sarah”) and anything else (“triathlon_training”), she will see relevant distance, speed, time, and altitude metrics for that set of routes.

2.5 Route Sharing and Distribution

We demonstrate several concepts for space-time trail document sharing in SlamXR. Any route can be emailed through a hover menu over items displayed in the route list. More complex sharing can take place through emailing and subscribing to archived queries. Every query in the system is saved for later access. These queries can be emailed or made into RSS feeds. Thus, the person training for her triathlon, or perhaps her coach or team, can add an RSS feed to their favourite reader for the bicycle rides tagged with “Sarah” and “triathlon_training”.

2.6 People Search

As discussed above, hyperties connect people based on digital information collected in the physical world. A critical component of SlamXR is the people search functionality that allows users to query the people who have authored trails stored in the database. Any query that can be made against routes can also be made again people in the system. If a person were, for example, looking for a running partner, she could search for runners in her area who also run at a particular difficulty level. If another person were looking to become a better runner, she could search for runners in her area that were running slightly longer distances or routes with greater elevation change than she is currently running, and then start to run the uploaded routes or try to contact and arrange to run at the same time as these other users. These social connections lay the foundation for the formation of communities, either exclusively online (cyclists who share routes) or online/offline (runners who share routes and also run together).

To date, the system does not offer explicit recommendation of other users based on co-location. Instead the user must browse the map interface for routes in their area of interest in order to find co-located others. Considered more broadly, a “similar to me” stock query for returning people in the system similar not just in terms of co-location, but also in terms of activity and difficulty level represents an interesting next development.

2.7 Usage

We have been using SlamXR to record a variety of route-based activities, from running, cycling, and inline skating, to commuting. We are hesitant to generalize because we are just now beginning to collect usage data from more people, but so far we feel that route documents are simple to collect, are compelling and insightful when viewed later, and can provide an effective way to make social connections.

3. Summary

Routes are becoming an increasingly common document type that is likely to be authored by billions of people every day as they go about their daily lives while carrying sophisticated sensor rich mobile devices. Further, these route documents will be annotated automatically by the analysis of the data generated by a variety of sensors. These machine annotated route documents will then be open to human annotation and will become a new source of social record keeping and signaling. The records can, for example, generate the new social formation of the “hypertie”: links between people and physical world objects and locations that are based on digital data and machine sensing.

In this paper, we presented a prototype system for analyzing, interacting with, and building community around hyperties based on sensor-annotated route data and that connect people with physical spaces and with other people. Very early use provided anecdotal evidence that routes are a compelling document type in that they reveal meaningful data about people: the activities they do and the places they do them. As people being to populate these systems, they will form connections around these activities, whether just to learn from others, to find similar others, or to find partners or groups for activities. This new method for forging social connections represents a next and important step from current mixed physical-digital interaction systems in that it leverages sensors of physical world action and behavior.

4. ACKNOWLEDGMENTS

We thank Jianfeng Zhao and Andy Jacobs for their help with the SlamXR prototype.

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