GPS and Physical Activity Monitors: Integrated Tools for Healthy Communities

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Abstract

As obesity levels hit epidemic levels and public health continues to decline, it is imperative to identify what elements of the built environment are contributing to this health crisis. Spatial technology available today allows researchers, health officials, design professionals, and civic leaders to study individual elements of the built environment to determine how these elements affect an individual's interaction with the environment. This presentation will discuss how information collected from physical activity monitors and GPS units were synchronized and analyzed in a GIS to determine how the urban forest, a component of the built environment, may influence an individual's decision to use a particular walking/running route. Attendees will find significance in this presentation by broadening the techniques they use to identifying how and where the built environment impacts physical activity and health. Attendees will also learn tips for selecting equipment, merging GPS and physical activity data and pitfalls to avoid.

Background

The 2002-2003 National Health and Nutrition Examination Survey (NHANES) estimated that 66 percent of U.S. adults were either overweight with a body mass index (BMI) of 25–29.9 or obese, BMI greater than 30. Additionally, data reported in the Center for Disease Control's (CDC) Behavioral Risk Factor Surveillance System (BRFSS) found forty-six of the fifty states had obesity prevalence rates over 20 percent in 2005. Of those, seventeen had prevalence rates equal to or greater than 25 percent, and alarmingly, three states indicated prevalence of 30 percent or greater (CDC BRFSS, 2005). When compared to the prevalence rates of ten years earlier where each of the 50 states had an obesity prevalence of less than 20 percent it is easy to understand why health professionals are concerned with this trend as overweight and obese individuals tend to have an increased risk for high blood pressure, Type 2 diabetes, and coronary heart disease.

The CDC further reports in the *Summary Health Statistics for U.S. Adults: National Health Interview Survey, 2005* that "Sixty-two percent of adults never participated in any type of vigorous leisure-time physical activity" (Pleis JR, Lethbridge-Çejku M, 2006). A decrease in the amount of individual physical activity is considered to be one of the factors contributing to the increase in the percent of the population that is overweight or obese.

In 2002, Humpel, Owen, and Leslie published a review of existing studies related to environmental factors associated with adults' participation in physical activity. Their findings indicated that physical environment factors have consistent associations with physical activity behavior, and that accessibility, opportunities and aesthetic attributes had significant associations with physical activity. The executive summary for the 2004 *Obesity and the Built Environment: Improving Public Health Through Community Design* Conference in Washington D.C. found that the "the rapid increase in obesity over the past 30 years strongly suggests that environmental influences are responsible for this trend."

This brings to question, how can environmental factors that are positively or negatively influencing physical activity be identified and analyzed? While geospatial technologies such as Geographic Information System (GIS) can be used to examine the spatial relationship between demographic data and geographic features commonly found in Census, Health Department and State/City GIS datasets it is necessary to work at a more detailed scale to better understand how items within the built environment affect an individual's physical activity. To work at this scale it is often necessary to collect demographic and health data through a participatory, observational or survey process and to develop higher resolution spatial datasets derived from aerial photography or Global Positioning Systems (GPS).

In a study funded by the National Urban and Community Forestry Advisory Council to investigate the relationship between urban vegetation patterns and walking/running trail preference, a process was developed to collect the data and analyze it along with individual physical activity measurements and meteorological data.

Urban Forestry Study

The objective of this study is to determine the influence of the urban forest and vegetation patterns on user preferences of where to run, walk or jog. Additionally, the study identifies the degree to which physical activity increases or decreases on trails adjacent to wooded or developed areas.

The study tracked forty-nine individuals composed of three population age groups in Ames, Iowa that regularly walk or run at least three times a week, by documenting where they participate in this activity using a GPS. In addition to wearing the GPS, each individual recorded their physical activity using an accelerometry-based physical activity monitor. Weather conditions during the time of the physical activity were recorded by weather stations at local elementary schools and saved to an accessible online data file. All three pieces of data were synchronized and analyzed using a Geographic Information System. The study included four one-week data collection periods occurring during each season.

Participants were trained on how to use the GPS and physical activity monitors during the initial meeting with the group in November 2005. Participants were instructed to wear the GPS monitor on their wrist much like an oversized wrist watch and to wear it only during bouts of outdoor physical activity. The physical activity monitors were to be clipped to the participant's waistband above the hip and worn throughout the day to record all physical activity. In addition to the two devices, each participant was asked to fill out a paper data log sheet where they recorded the day's activity and any anomalies to the protocol or equipment that may have occurred.

Each of the study weeks began on a Wednesday morning and concluded on the following Tuesday evening. After one week of use the equipment was returned and the data was downloaded for analysis.

Participant Data Collection Devices

<u>GPS</u>

Selection of an affordable, small form and reliable GPS was critical to the study. The selected device had to be accurate to within twenty-five feet and allow thousands of points to be saved to the track log. The selected device was the Garmin Foretrex 101 (Figure 1). The device measured 3.3" x 1.7" x 0.9" (8.4 x 4.3 x 2.3 cm), weighed 2.75 oz and cost under $125.00 per unit. The Foretrex 101 offered Wide Area Augmentation System (WAAS) making it much more accurate than other devices available on the market at the time. With WAAS turned on, the Garmin Foretrex 101 was accurate to approximately three to five meters when tested at a known point. The Foretrex also provided storage for 10,000 points in its memory, sufficient for the thirty second track period used for this study. Using the freely available DNR Garmin software from the Minnesota DNR, the tracklog was easily downloaded and saved as text file and point shapefile that could be plotted directly over a map. Each tracklog file contained the latitude, longitude and time for each point recorded during a physical activity session. The only limitation of the Fortrex 101 was the short battery life of 12 – 15 hours. This limitation required that the device only be used during bouts of physical activity as it was inconvenient to have the study participants change the two AAA batteries every day. Additionally, during extremely cold temperatures the battery life was reduced very quickly and the device would stop recording data until the batteries warmed up or were replaced.

Fig. 1 Garmin Foretrex 101

Physical Activity Monitor

The accelerometry-based activity monitor selected for this project was the IM Systems BioTrainer-Pro (Figure 2). The Biotrainer is a uniaxial monitor that records the amount of physical activity a participant has acquired between predefined periods of time. For this study, data was collected every thirty seconds. The Bio-Trainer uses standard AAA batteries and can record data for over a week when using this setting. Windows based software is used to download the data saved by the device. The downloaded data includes a count value representing the amount of physical activity and a date/time feature counting the amount of time passed since the device was initialized.

Fig. 2 IM Systems BioTrainer-Pro

Built Environment Base Data

To evaluate the vegetation in the areas the participant walked or ran, it was necessary to create two base maps. The first map was created in the field using an iPaq PDA, Trimble Pocket Pathfinder GPS and ArcPad 6 (Figure 3). Two research assistants walked each of the trails in the study area stopping every 100 meters to record the type of vegetation adjacent to the trails. To simplify the data collection process, a form for entering information about each GPS point was created using ESRI ArcPad Studio 6. The form included six pages organized by content. The first page, adjacent land setting/landuse use, included pull down menus for selecting the correct characteristic of the trail's adjacent environment. Because the land setting and landscape can be different for each side of the trail, both sides were included as separate attributes. Side 1 represents land setting and landscape that is North and East from the trail and side two represents land setting and landscape that is South and West from the trail. The additional form pages included vegetation cover, tree characteristics, trail surfaces, amenities and notes (Figure 4).

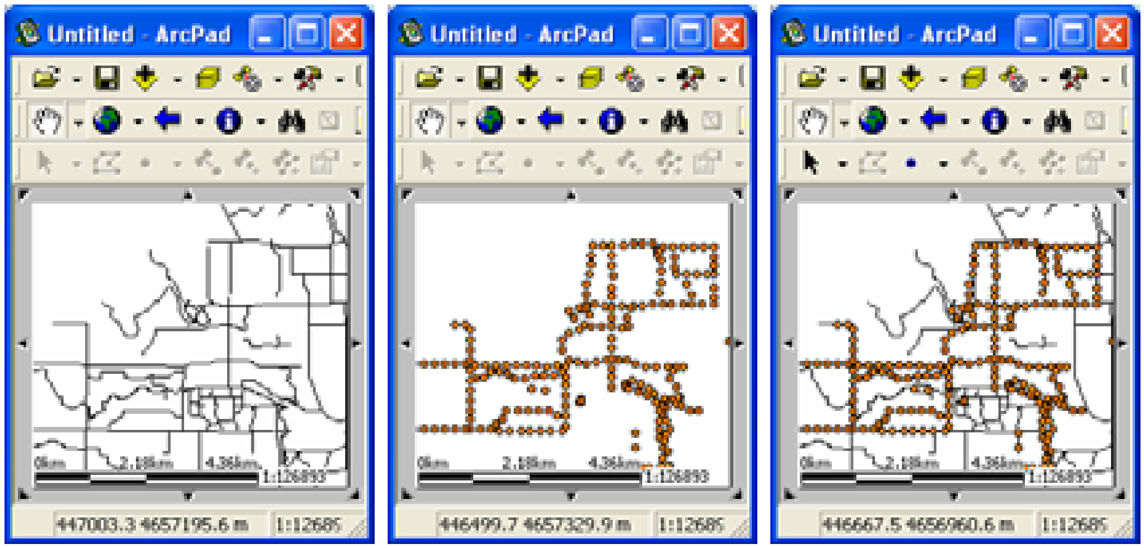

Fig. 3 iPaq PDA screenshot of ArcPad displaying road network and collected points.

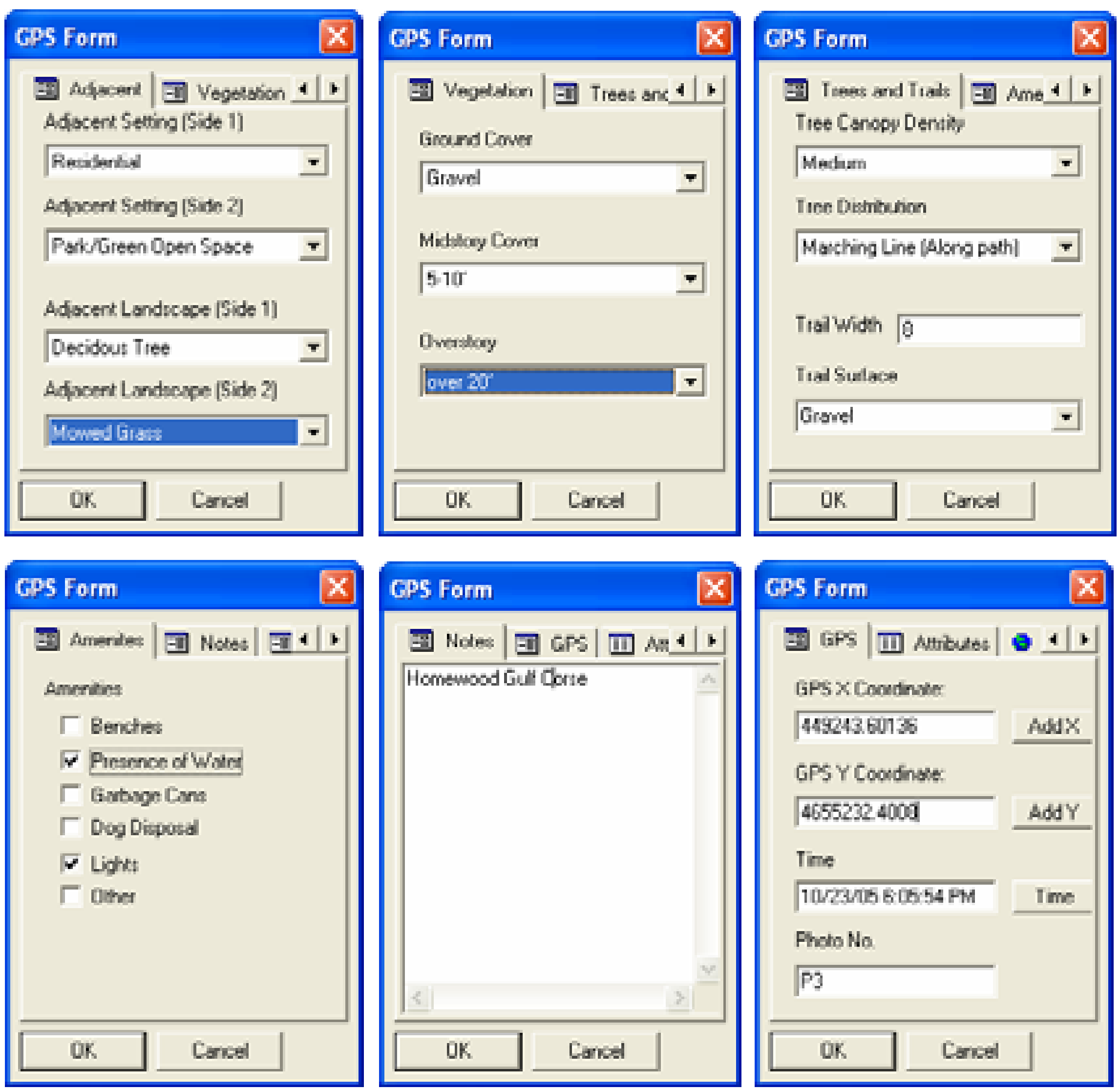

Fig. 4 ArcPad forms used to record environmental data.

The second set of base material used to identify vegetation patterns was created by digitizing the location of vegetation from an aerial photo of the city. To speed up the process of digitizing vegetation from the 1 foot/pixel aerial the study area was overlaid with a series of rectangular polygons creating identifiable zones. Each zone was then exported to a georeferenced raster file and distributed to a team of students that ‘painted’ the vegetation to appropriate layers using Adobe Photoshop. Once the painting was complete, the background aerial was removed and the files were mosaiced back together and then converted to an ESRI GRID file. Each cell in the GRID file contained a value representing the presence of evergreen or deciduous vegetation, water or any agricultural land within the study area. Both base maps were used in the analysis of the participant’s data to determine what type of vegetation occurred along their walking/running route.

Data Synchronization

In order to visualize the data collected by the two devices it was necessary to synchronize the data. Both devices timestamped the data events as they were recorded making it possible to synchronize based on this criteria once the format of the timestamps were standardized. The format of the timestamp on the GPS was based on universal time and was stored in a field as year/month/day-hour:minute:second (2005/11/02-22:02:56) whereas the physical activity monitor time was based on a tabular format where each column represented a unique day and each row contained the physical activity amount for that rows hour:minute (Figure 5). It is important to note that the physical activity monitor’s time was based on the time stored on the CPU used to initialize the device before each study period. Therefore it was necessary to ensure that the time on the computer was synchronized with a network time server (NTS) so that any necessary offsets could be taken into account prior to synchronization.

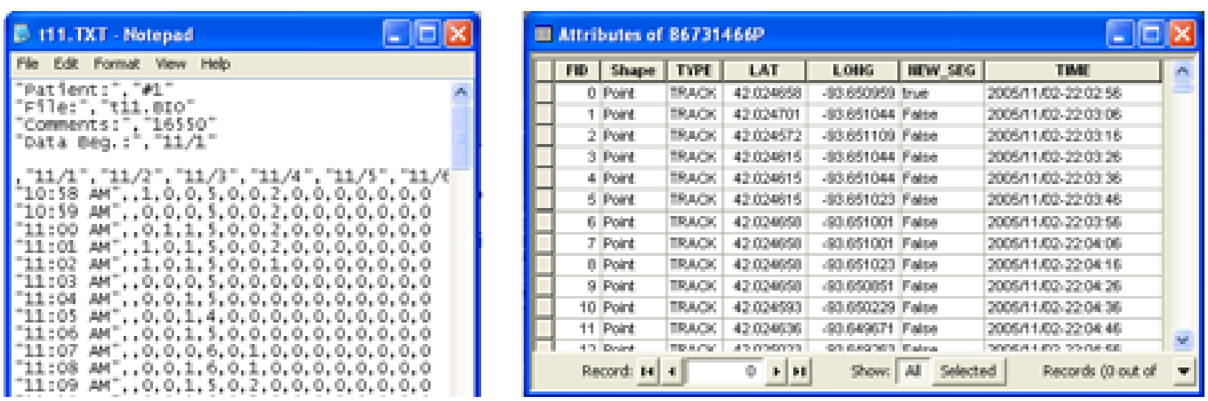

Fig. 5 Physical Activity Monitor and Foretrex GPS timestamps.

To accommodate the difference in time stamps, the collected data was converted to a standard format using Microsoft Excel where individual columns contained the year, month, day, and minutes passed since midnight (7:00 AM = 420 minutes). This format created a unique identification number that facilitated joining the table in ArcMap using a Table Join function. A similar process was used to join the meteorological text file data. Figure 6 shows an example of one participant’s routes during the November study period. The points are symbolized using the values recorded by the physical activity monitor.

Fig. 6 Sample GPS route displayed in ArcMap using symbology of the joined physical activity monitor data where red represents low physical activity and green higher activity).

GIS Analysis

Once the data was synchronized and merged into a single file/related table for each study participant, it was displayed in ArcMap over the aerial photograph and vegetation data layer. Various spatial analysis techniques including proximity, overlap and zonal statistics were utilized to identify the most commonly used routes, existing trails that were underutilized, patterns of vegetation and locations where physical activity values decreased. By project's end, over 180 individual GPS derived shapefiles were created and imported into ArcMap for use in the analysis. To accommodate the analysis of the large number of files, ESRI Model Builder was used to automate several of the geoprocessing functions.

Upon completion of the study, each participant met with the principal investigator to identify on a digital map their most used and favorite walking/running routes (Figure 7). This information was collected using the ArcSketch sample extension for ArcGIS in a minimal amount of time and allowed the research team to identify if the route data collected with the GPS corresponded to the participants favorite or most used route.

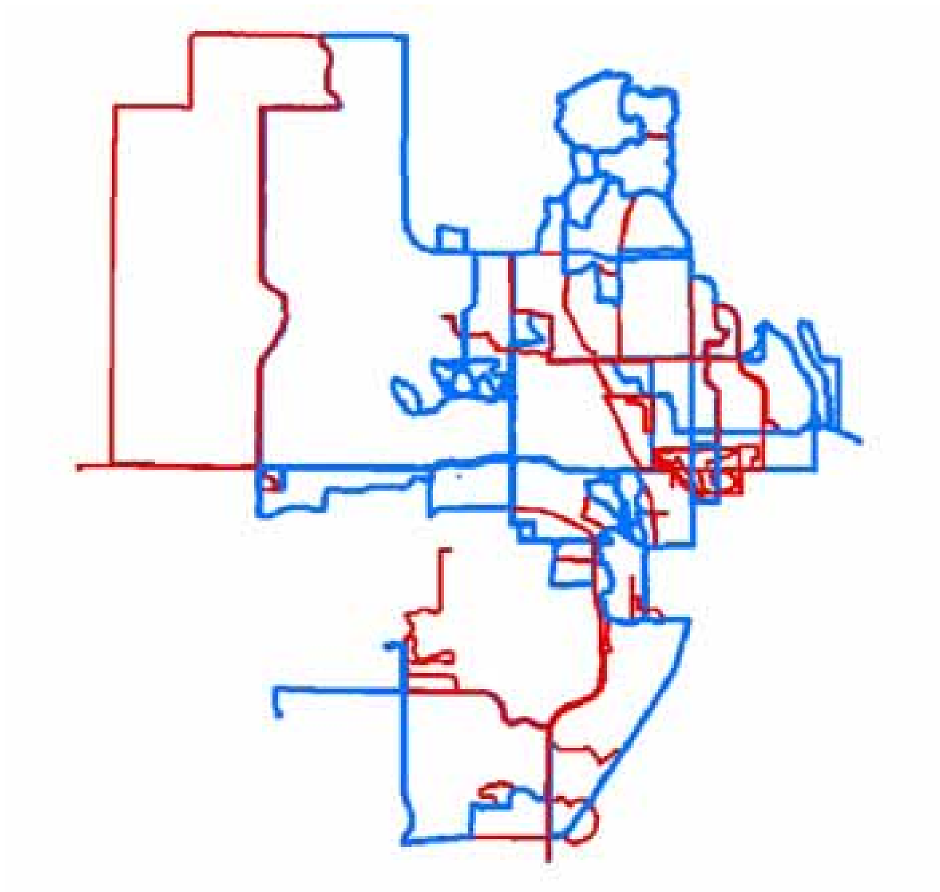

Fig. 7 Participant reported favorite (blue) and most used (red) routes.

Technology Lessons Learned

Throughout the project several things were identified that worked well or could be improved in future studies.

1) The use of a paper log file where the participant could briefly record what they did during the day proved to be helpful on several occasions when the participant mistakenly wore the GPS during a bike ride or left it on while traveling in a car. The log made it easy to identify these records and remove them from the analysis.
2) Erroneous data was occasionally logged by the GPS when the signal was lost or when under dense tree canopy. To identifying these outliers, the average rate and distance of travel was calculated and used to create buffers around the points. These buffers were then used to locate GPS recordings outside of the expected spatial range of the previous point. Because the Garmin Foretrex records in the database when a new route or track is created it was possible to break the data at those points and limit the cleaning process to individual track sessions.
3) Securing the activity monitor to the participant was an unexpected problem. The Biotrainer device include a plastic clip, however it easily slipped off so an elastic band with an alligator clip was used as a secondary method to ensure that the device was not lost. Participants also had to take care when using the restroom as the shuffling of the clothes made it easy for the devices to fall off.
4) The Foretrex GPS included a wrist band extender that worked very well except during the January trial period as it was not long enough to be worn on the wrist over winter clothing.
5) The batteries selected for the study performed poorly during the coldest days during the January study period. While all of the batteries were new at the beginning of the week, several battery

exchanges were required. This problem did not exist in the following two trial periods. Research conducted during cold periods should utilize premium batteries capable of maintaining a charge when exposed to freezing temperatures.

6) The Biotrainer device used during the study included a LCD display area where the count value could be displayed. In some cases the LCD would turn off during the trial and the participant thought the device was not working and an exchange was made. Upon examination it was determined that the device was still recording but was not updating the display for an unknown reason. The end result was that two data sets had to be merged to complete the data set. The recommendation is to turn the display off during initialization of the device..
7) Throughout the study the same GPS units were assigned to the participants. However, it was not possible to utilize the same Biotrainer unit as they were shared between several research projects. To ensure that the collected information could be accurately merged, detailed records regarding the serial number of the device assigned were kept. While on the front end this appeared to be just some basic paper work, it was found to be a time consuming process when synchronizing the data sets.

Closing

Correlations between vegetation patterns in the built environment, climate data and physical activity are currently being reviewed. The results of this study are scheduled to be completed during the first half of 2007 with anticipated publication of the results in late summer 2007.

While the extent to which vegetation and the urban forest influence an individual's physical activity is still to be determined, this project has demonstrated that physical activity monitors, global positioning data, environmental characteristics and weather data can be combined together and analyzed using a geographic information system. As other aspects of the built environment are studied, this technique and similar processes can be utilized to further the understanding of the effect of the built environment on physical activity.

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