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TRACKING TECHNOLOGIES *AN OVERVIEW*

There is a growing demand for knowledge about processes in our cities, specifically the understanding of people's actual behaviour. Advanced Tracking Technologies offer the ability to give both actual and detailed insight into both people's individual and collective travel behaviour. The collected information can be used in urban analysis to map behaviour, feed prediction models, for simulation tools and for human behavioural sciences.

The use of emerging technologies such as GPS tracking, mobile phone tracking and RFID is replacing existing methods and adding features to traditional instruments in the field of urban design and planning. Advanced tracking technologies have already been used in other fields – those of sociology, geography, transport planning logistics, and biology have been using tracking technology in their research since the 1990s (Spek, 2006; http://en.wikipedia.org/wiki/GPS_wildlife_tracking, accessed 22 Nov. 2007).

This chapter gives an overview of tracking technologies relevant to urban design and planning. Firstly, the need for advanced technology is explained, followed by an explanation of available techniques. The chapter concludes with examples of the application of tracking technologies in practice

DEMAND FOR TRACKING TECHNOLOGIES

Understanding processes in the city is a pre-requisite for 'good' urban design (Schaick, 2008). Traditional urban planning and city analysis methods only offer partial insight into these processes. Counting, observation and mapping methods such as those developed by Gehl Architects over decades and practiced in cities like Copenhagen, Melbourne, Adelaide, London and Rotterdam (Gehl, 2007) could benefit from new advanced approaches showing the whole picture, including patterns of movement. Melbourne and London have already installed automatic people counters, extending the duration of measuring from several days to '24x7' as presented respectively at Walk21 (Melbourne, Oct. 2006; http://www.walk21.com, accessed 11 July 2008) and by Transport for London at the Connected Cities Conference (London, Sept. 2007; http://www.connectedcities.eu, accessed 11 July 2008). These counters effectively measure the intensity of pedestrian activity at a limited number of locations. However, these studies lack insight into actual, individual travel patterns.

Travel diaries might give insight into actual behaviour, but depend on the accuracy of people's minds (see chapter 11). A case study in Delft showed that the ability of people to reproduce a walked route on a map is inadequate. The actual walking pattern based on GPS tracks deviated repeatedly from the drawn map (Spek, 2006).

Prediction models such as Space Syntax predict pedestrian activity based on 'Centrality' (http://www.spacesyntax.org, accessed 11 July 2008). The structure and form of the street network forms the basis of the hierarchal position in the network. In real estate, these 'hot spots' which attract pedestrians can be recognised on the basis of their functions i.e. the location of fashion & luxury as well as rental prizes as shown by Kickert (2007a, 2007b).

Advanced tracking technologies can add accurate and detailed insight into the actual journey of a person in terms of *location in time and space* and in terms of *duration and distance*, e.g. travelled route, travelled distance(s), mode(s) of transportation, destination(s), departure and return time, time spent travelling and time spent at destinations. Using GPS, Mobile Phones, RFID, Bluetooth or video, it is possible to record individual travel behaviour and even extend it to collective behaviour, namely patterns of use.

ADVANCED TRACKING TECHNOLOGIES

Within advanced tracking technologies, a distinction can be made between two types of tracking technologies, namely global technologies and context-dependent technologies. Context-dependent technologies are limited to a location based on the available infrastructure or the technical limitations of the equipment. Only GPS can be used globally, preferably in the open sky or outdoor conditions. Mobile phones are dependant on the availability of a communication network. Video and infrared are limited to the reach of the sensors and RFID and Bluetooth to the location of the receivers. These tracking technologies differ from context-dependent technologies such as automatic counters based on sound, vibration, infrared or laser. The following paragraphs give an overview of current technologies in use.

GLOBAL POSITIONING SYSTEMS (GPS)

The Global Positioning System

GPS is a system for global navigation and orientation. The system utilises a network of satellites in orbit. These satellites transmit precise microwave signals to earth. A GPS device has the ability to receive these signals and compute its position. At least four satellites are necessary in order to accurately determine a geographical position (http://en.wikipedia.org/wiki/Global_positioning_system, accessed 21 Nov. 2007).

GPS devices are mainly known as navigation or orientation instruments. The devices are the basis for e.g. marine and car navigation systems such as TomTom® or outdoor orientation equipment. Today, GPS devices also function as Location Based Services (LBS) indicating the location of Points of Interest (POI). The GPS technology was developed by the United States military (NAVSTAR/ DOD). Since 2000 when the Selective Availability (SA) was disabled, the technology has been made more widely available to the public. Today, accuracy is around three to five metres in the open field. Russia and India are developing their own GPS system, GLONASS. China is developing COMPASS. In addition, Europe is building its own global positioning system, Galileo (http://en.wikipedia.org/wiki/Global_positioning_system, accessed 21 Nov. 2007). This system should have been completed in 2008 but is facing serious delays. It is now expected to be operational in 2011-12. Technology using external reference points can make GPS far more accurate by disabling atmospheric effects and other errors. These systems are known as GNSS Augmentation, Differential GPS or EGNOS/WAAS (http://en.wikipedia.org/wiki/High_Sensitivity_GPS, accessed 11 July 2008).

GPS data logging

Using GPS technology it is possible to obtain accurate and detailed insights into the actual behaviour of a person, vehicle or animal with a GPS device attached to them. For tracking research the device should either have the ability to store position data in a log file which can be read out later and projected onto a map in a Geographical Information System (GIS) (http://en.wikipedia.org/wiki/Geographic_information_system, accessed 30 Nov. 2007; see chapter 4), or the ability to send the location data real time to a server or application within a specific time interval.

The technology will give insight into the used route, the covered distance, the visited locations, the speed, the used mode of transportation, the exact departure and return times as well as the time spent on specific locations or destinations.

GPS devices

Although they started out as large, unmanageable devices, today GPS devices are the size of mobile phones or even smaller. New chipsets such as the Sirf III (2006) and MTK (2007) have highly improved their fixation time and accuracy (http://en.wikipedia.org/wiki/SiRFstar_III, accessed 21 Nov. 2007).

Of course, GPS-tracking has its issues too. Firstly, the main issues of GPS devices are the time taken to determine its position (Time to First Fix), the drainage of batteries, their size, weight, accuracy in built-up environments due to multipath effects (e.g. reflection of signals on glass facades) and their lack of reception indoors or underground. (http://en.wikipedia.org/wiki/Global_positioning_system, accessed 21 Nov. 2007)

Secondly, conditions in cities are far from ideal for using GPS technologies. Buildings block the reception of satellite signals, signals bounce off buildings, small streets have limited reception and people naturally enter buildings. Especially slow modes such as walking generate more problems in dense urban environment. (http://en.wikipedia.org/wiki/Global_positioning_system, accessed 21 Nov. 2007)

Finally, carrying GPS devices may trigger other, aberrant behaviour.

Nevertheless, GPS technology is developing relatively rapidly. Software to analyse, filter and map GPS tracks is under constant development too. New hardware and firmware are improving the capabilities of existing devices. This development makes GPS ideal for replacing traditional stalking and observation methods with advanced technology. (http://en.wikipedia.org/wiki/Advanced_GPS, accessed 11 July 2008)

The devices are in development and so far, not specifically designed for tracking research, although some specific data loggers have been recently introduced. These loggers were developed for the automatic positioning of photographs on a map. Other uses are fleet management, e.g. delivery trucks, cabs and emergency services. (http://en.wikipedia.org/wiki/Location-based_service, accessed 13 Dec. 2007; http://en.wikipedia.org/wiki/GPS_tracking, accessed 21 Nov. 2007)

Mobile Phone tracking

Mobile phones can be traced based on the cell tower the mobile phone is allocated to, but also using techniques to pinpoint the phone on a location on the map. Based on the direction of arrival or triangulation, the general position of mobile phones can be determined by comparing the relative signal strength from multiple cell towers (http://en.wikipedia.org/wiki/Mobile_phone_tracking, accessed 22 Nov. 2007). However, this process is time consuming, expensive and there are privacy issues.

Another way of using mobile phones is to determine the intensity of use of the network (see chapter 8), indicating the number of people at a specific location. This method was used in Rome by MIT and was presented at the Biennale in Venice in 2006. The question is whether active calling or sending a text message is representative for the amount of people. So far, mobile phone tracking is less accurate than GPS tracking (Shoval and Isaacson, 2006). Mobile phone tracking works on a higher scale, showing the location of the mobile phone or the densities of mobile phones within an area during a period of time.

Hybrid Mobile Phone: A-GPS and E-GPS

Some mobile phones already have GPS ability onboard or make use of assisted GPS technology (A-GPS; http://en.wikipedia.org/wiki/Assisted_GPS, accessed 11 July 2008). This new technology enables the quick fixation of the position, probably even inside buildings. The Assistance Server is able to roughly position the location of the mobile phone, speeding up the GPS fixation process. Enhanced GPS (E-GPS, due 2008; http://en.wikipedia.org/wiki/Enhanced_GPS, accessed 11 July 2008) will succeed A-GPS using the assistance for augmentation to determine the position even faster and far more accurately. Another advantage of the combination of mobile phone tracking and GPS is that accurate position data can be sent to a server automatically or even real-time.

Radio Frequency Identification (RFID)

RFID makes use of active, passive and semi-passive tags (transponders) in combination with readers (receivers). Passive tags have no power and only reflect information at short distances, less than a few metres. Active tags have a power source for the chip and can broadcast information at greater distances, around 500 metres. Semi-passive tags have a power source for the chip and are ten times more sensitive then passive tags (http://en.wikipedia.org/wiki/Radio-frequency_identification, accessed 21 Nov. 2007).

A recent development in plastic tags makes RFID useful for retailers and tracing objects or people. Examples are tracing goods or people in buildings and public transport chip cards, such as TfL Oyster Card (London), OV-Chip (Netherlands) and Smart Card (Singapore). The use of the system is limited to the location of the receivers and the range of reception (Shoval & Isaacson, 2007; Shoval, 2007); a predefined and prepared environment is required with a view to using RFID for tracking purposes.

Video monitoring

Video can be used for specific locations, only showing the behaviour of people at a determined location. Feasible locations are public spaces such as squares or interior public spaces such as train stations as shown by Arsenal (Vienna) (see chapter 5). Sophisticated software is available for automatic recognition and analysis, e.g. as used by the Faculty of Civil Engineering at Delft University of Technology to monitor and analyse pedestrian behaviour. Video analysis was, for example, used during the 2008 European Football Championship, measuring the distance the football players walked during a match.

Bluetooth monitoring

Bluetooth is a technique for short range communication between devices. Today, most mobile phones, laptops and handhelds are equipped with Bluetooth.

Some cities have installed a network of Bluetooth information systems delivering Location-Based Services (Furbach, Marun & Read, 2008). Using the connectivity logs, it is possible to 'track' the visited locations of Bluetooth devices, similar to tracking mobile phones based on cell towers, and similar to tracing RFID tags based on a network of RFID receivers.

URBANISM ON TRACK?

For years now, tracking technologies have been used in fields other than urbanism for tracking research and other space-time related studies. Nonetheless, tracking is a growing business in the field of urban design and planning.

The first well-known tracking experiment was carried out in Amsterdam in 2000 by Waag Society (Kustermans, 2006; http://www.waag.nl, accessed June 2006) as part of an art exhibition. Participants were equipped with a GPS and information was collected real-time, resulting in a new map of Amsterdam. This project re sulted in 'Sense of the City', Eindhoven 2006 (http://www.senseofthecity.nl, accessed July 2008).

Tracking technologies can be used on different scales for different purposes. On the largest scale, the University of Tartu operates using their mobile phone based technology which measures activity in the phone network throughout the whole country, Estonia (Ahas, Aasa, Mark, Pae & Kull, 2007; Ahas, Aasa, Roose, Mark & Silm 2007). MIT measured the densities of mobile phones in Manhattan (Shoval, 2007), Milan and Rome (see chapter 8).

Well known is the use of GPS tracking technologies in activity pattern research. In this case, people carry a GPS device with them each time they leave the house for a fixed period of time, usually a week. Here the GPS device replaces the activity agenda, offering very accurate and detailed insight into individual movement. Examples of these kind of travel surveys have been carried out by iMOB (see chapter 11), OTB at TU Delft (Verbree et al., 2005; see chapter 10) and Aalborg University (Nielsen & Hovgesen, 2004; http://www.spacetimeman.net, accessed 11 July 2008). Urbanism at TU Delft carried out a small test tracing fifteen families in the Dutch new town of Almere for a period of one week.

On a lower scale, GPS tracking has been used to observe people in an open-air museum in the Old City of Akko and Old Jaffa in Israel by Shoval and Isaacson (2006, 2007; see chapter 2). In Denmark, Hovgesen and Nielsen used GPS tracking to observe people in several parks in Aalborg and in the city centre of Copenhagen (see chapter 6). TU Delft developed a method of using GPS technology to observe pedestrian behaviour in three historic European city centres within the Spatial Metro project - Norwich (UK), Rouen (F) and Koblenz (G) (Spek, 2008; http://www.spatialmetro.org; see chapter 7).

Another interesting project applying GPS- based research in urban design is CityWare (UCL). This project compares the outcome of movement behaviour research to the physical environment and relates it to Space Syntax theory (http://www.cityware.org.uk, accessed 11 July 2008). Finally, the collection of global GPS tracks delivers a unique tool to develop maps based on actual use. An example is OpenStreetMap (http://en.wikipedia.org/wiki/OpenStreetMap, accessed 21 Nov. 2007; http://openstreetmap.com/, accessed 21 Nov. 2007).

CONCLUDING REMARKS

On the basis of this chapter, three brief conclusions can be drawn. Firstly, tracking technologies provide rich grounds offering a wide range of techniques for research in urban design and planning. Secondly, particular types of tracking technologies need to be applied to particular (urban) contexts and particular types of research questions. Finally, the scale of a study, the control of its context and the deployment of tracking devices are the key to selecting a particular technique.

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