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TRACKING TOURISTS IN THE DIGITAL AGE

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Abstract: The question of mobility is of immense importance in tourism research. Yet the current methods used to collect data on spatial and temporal activities are limited in accuracy and validity. Recent developments in the field of digital tracking technologies have produced a range of widely available systems, including land-based tracking, satellite navigation, and hybrid systems. The study reported here summarizes both the conventional and the new methods used to collect data on the spatial and temporal activities of tourists. It offers an account of three experiments in which tourists were tracked using the aforementioned technologies. **Keywords:** spatial and temporal activity, tracking, Global Positioning System, land-based tracking systems, cellular triangulation. © 2006 Elsevier Ltd. All rights reserved.

Résumé: Le pistage des touristes à l'époque numérique. La question de la mobilité est d'une importance énorme dans la recherche de tourisme. Pourtant, les méthodes que l'on utilise actuellement pour cueillir des données sur des activités spatiales et temporelles sont limitées en termes de leur précision et leur validité. Des développements dans les technologies de pistage numérique ont produit une gamme de systèmes généralement disponibles, comme le pistage terrien, la navigation par satellite et des systèmes hybrides. La recherche présentée ici fait le bilan des méthodes conventionnelles et nouvelles pour cueillir des données sur les touristes. L'article fait un compte rendu de trois expériences dans lesquelles on a pisté des touristes avec ces technologies. **Mots-clés:** activité spatiale et temporelle, pistage, GPS, systèmes de pistage terrien, triangulation cellulaire. © 2006 Elsevier Ltd. All rights reserved.

INTRODUCTION

David Fennell concluded his study of tourists' spatial behavior in the Shetland Islands by noting that in the future information about the behavior of tourists in time and space would be best "accomplished by adopting and modifying the 'radiotelemetry' technology used for many years in the natural sciences... for the purpose of tracking specific animal species in parks and protected area environments" (1996:827–828). While exploring the behavior of tourists in time and space, Fennell, like others before him, encountered a number of problems motivating this observation. The traditional methods most commonly are deficient in the level of accuracy and/or the validity of the data

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collected. As a result, despite the proliferation of research into tourism over the past few decades, and even though it is a fundamental feature of the tourism phenomenon, little attention has been paid to the spatial and temporal behavior of tourists (Dietvorst 1995; Shaw, Agarwal and Bull 2000; Shaw and Williams 2002; Thornton, Williams and Shaw 1997).

Given the methodological complexities involved in investigating this issue, the paucity of studies on the subject is hardly surprising. It is also unfortunate because such inquiries could contribute immensely to the more academic side of tourism studies, and to policymaking, planning, and management. For example, if the spatial and temporal behavior of tourists is better understood, it would be possible to tailor transport systems, adjust the way in which attractions are run, and perfect marketing strategies, all in line with their actual needs. It would likewise help to ensure that tourists are more widely dispersed both within and, more importantly, beyond, what were assumed to be their traditional haunts. All of the above would allow, indeed encourage, them to spend more money, thus usefully filling the town or country's coffers (Thornton et al 1997:1849–1850).

Fortunately, recent technological developments, together with the American Federal Communications Commission's E911 regulations (FCC 2004) and the European Union's E112 program (Ludden, Pickford, Medland, Johnson, Bandon, Axelson, Viddal-Ervik, Dorgelo, Boroski and Malenstein 2002), have produced a range of widely and readily available tracking technologies. Yet, these advances notwithstanding, researchers have, on the whole, failed to take advantage of the growing number of them to study the spatial and temporal behavior of tourists. This is, to say the least, ironic in that tourism proved a veritable goldmine when it came to developing commercial applications, including location-aware mobile information systems or location-aware electronic guidebooks (Schilling, Coors and Laakso 2005; Ten Hagen, Modsching and Kramer 2005). Indeed, it would seem that as mobile phones and other portable devices become progressively smaller and increasingly sophisticated, they will offer both tourists and the industry a range of ever more useful and practical services.

This state of affairs is not just related to the area of tourism research; in other fields such as geography, transportation research, and urban studies, there has been a marked contrast between the widespread use of the geographic information systems and other such systems (Harvey and Taylor 2000), and the fairly limited use of advanced technologies for research on human spatial and temporal behavior. Investigations into pedestrian spatial behavior using tracking technologies such as the Global Positioning System (GPS), have to date been few and far between. There have been several studies that used the system to plot pathways for visually impaired and blind pedestrians (Golledge, Loomis, Klatzky, Flury and Yang 1991; Golledge, Klatzky, Loomis, Speigle and Tietz 1998). There have also been some studies in which the system was employed to trace pedestrians' exposure to toxic materials (Elgethun, Fenske, Yost and Palcisko 2003; Phillips, Hall, Esmen, Lynch and Johnson 2001). Other than that, these technologies have for the most part been limited to transport studies tracing the spatial routes of motorized vehicles (Quiroga and Bullock 1998; Wolf, Guensler and Bachman 2001; Zito, D'Este and Taylor 1995).

One possible reason for this imbalance may be that it is more complicated to gather data from pedestrians by this means than from motorized vehicles. In essence, for a tracking device to be effective it must not affect the nature of the data collected; and while it is fairly easy to meet this requirement in cars, with advanced tracking system simply one more accessory, which once installed will go about its business, such is not the case with pedestrians. For a tracking device to neither disrupt nor influence the actions of the individual under scrutiny, it must be both small and passive: two prerequisites far from easy to fulfill until recently. This paper considers whether and to what extent the various new digital tracking technologies can help further research into the spatial and temporal behavior of tourists.

TOURISTS TRACKING METHODS

The method of direct observation can be summed up in the words: ‘‘identify, follow, observe and map’’ (Thornton et al 1997:1851). In practical terms, this ‘‘participant-observer method’’ involves the researcher accompanying the individual under scrutiny in person. Alternatively, the observer may follow the subject(s) at a distance, recording the pattern of their activities over time and space, or ‘‘nonparticipatory observation’’. When studying the spatial and temporal behavior of American tourists in Munich, Hartmann (1988) used both techniques, but was happy with neither, which were, he noted, incredibly time-consuming. Nor were these the only problems Hartmann encountered. While the nonparticipatory technique yielded a mine of information, it failed to unveil the purpose and meaning underlying the subjects' decisions and activities. It also posed various ethical questions, particularly when pursued in covert form (Hartmann 1988:94–101). These were less of a problem in the participant-observer procedure. The observer, thanks to his or her intimate contact with the subjects, was constantly aware of what the subjects were doing and, possibly, why. But there was in this case the risk of the subjects tailoring their behavior and explanations, albeit subconsciously, to the presumed expectations of their observer-companion.

Keul and Küheberger (1997) used the nonparticipatory technique to analyze the spatial behavior of tourists in Salzburg, Austria. Hoping to resolve the problem of motivation and fill some spatial gaps, the two followed up their observations with a series of interviews of the tourists observed. However, as the nonparticipatory technique can be applied only for very short time periods, they limited their surveillance to 15 minutes out of what were, on average, four-hour-long walks.

Aware of the technique's restrictions, Murphy (1992), who conducted a similar nonparticipatory type observation study in the city of Victoria, British Columbia, put his subjects under surveillance for an average of 23 minutes, the longest period lasting 87 minutes and the shortest four (Murphy 1992:206). Another drawback to this technique is that beyond a simple visual estimate as to the subjects' socioeconomic background, it cannot, in those cases where interviews are not used, render nonvisual data such as the total length of visit; the subject's next destination, and the like. It is also a hugely expensive, time-consuming, and labor intensive procedure.

A less expensive nonparticipatory technique is remote observation, which is used to record and analyze aggregate tourist flows. Hartmann (1988), in Munich, positioned a camera atop the city hall's 80-meter-high spire and took aerial pictures of the crowds gathering below to watch the Glockenspiel in the old city's main square. He then used the pictures to estimate the percentage of young North American tourists among the total number of people watching the ten-minute display. Some several years earlier, the same technique was used to track the routes selected by pedestrians through a busy office parking lot, in this instance by setting up an observation point in a tall building overlooking the lot (Garbrecht 1971). However, as Hill has noted, these ''eye in the sky'' techniques, though effective for studying the behavior of individuals within a restricted spatial setting, are of little use once the pedestrians step beyond the observation point's line of sight (1984:542). This is true of most other fixed-point observation studies, whether using time-lapse photography, video recorders, or the increasingly ubiquitous closed circuit television (Hill 1984). Moreover, as Hartmann commented, remote observation techniques, though providing an objective snapshot of the subjects' behavior, cannot, by their very nature, reveal the motivations underlying the activities thus documented (1988:100). This, he claims, is the technique's principal drawback, one it, as seen, shares with other nonparticipatory procedures.

At present, the most commonly used method for gathering information on human time-space patterns in the social sciences in general and in tourism studies in particular, is the time-space budgets technique. This method is a nonobservational one. A time-space budget is the systematic record of a person's use of time over a given period. It describes the sequence, timing, and duration of the person's activities, typically for a short period ranging from a single day to a week. As a logical extension of this type of record, a space–time budget includes the spatial coordinates of activity location. (Anderson 1971:353)

Based mostly on time-space diaries, the time-space budget technique records behavioral patterns, which, owing to their spatial and/or temporal nature, are impossible to observe directly (Thornton et al 1997). Other than this all-important asset, the technique has all the advantages of questionnaire type surveys: it is relatively cheap, provides comparatively large samples, and affords the speedy collection of data and prompt analysis.

Of the various studies employing this technique, the most notable are Murphy and Rosenblood's (1974) work on the spatial activities of tourists and daytrippers in British Columbia's Vancouver Island; Cooper's (1981) investigations into the behavior of tourists in the Channel Islands; Lew's (1987) study of tourist spaces in Singapore; Pearce's (1988) analysis of the spatial behavior of tourists in the island of

Vanuato in the South Pacific Ocean; Debbage's (1991) examination of tourists' behavior in Paradise Island in the Bahamas; Dietvorst's (1994,1995) research into the time-space activities of tourists in the small historic city of Enkhuizen in the Netherlands; Fennell's (1996) work, based on time-space diaries, in the Shetland Islands; and Thornton et al's (1997) investigations into the spatial behavior of tourists in the Cornish resort of Newquay. This impressive body of work apart, most researchers in the field have tended to shun the time-space budget method, owing to its various shortcomings, most of which center on the difficulty of keeping accurate records (Hall and Page 2002:46).

In practice, the time-space budget procedure utilizes one of several techniques. The first involves recall diaries, usually in questionnaire or interview form, which the subjects complete *post facto*. Both Cooper (1981) and Debbage (1991) employed recall diaries during their work. The principal problem with them is that the amount and quality of information gathered depends on the subject's ability to recollect past events with any degree of precision and detail. Furthermore, most questionnaires are, of necessity, phrased rather succinctly, lest the subject lose patience, which inevitably limits the amount of information obtained. Face-to-face interviews, on the other hand, while allowing for more detailed questioning, are again dependant on the subject's memory, and however good that might be, most people will have only the haziest notion, or at best an approximate idea, of the frequency, sequencing, and duration of their activities.

Self-administered diaries, to be filled by the subject in real time, make up another time-space budget technique. Researchers used such diaries when studying the spatial and temporal behavior of tourists (Fennell 1996; Lew 1987; Pearce 1988; Thornton et al 1997). However, while resolving the question of memory lapses, these diaries have several problems of their own. Above all, they demand a considerable effort on the part of the subjects who are required to record in detail their spatial activities all while busy enjoying themselves touring the city or countryside. It is a distracting, disruptive, tiring as well as time-consuming process, which goes far to explain why so few are willing to take part in such studies. Yet, even among those ready to volunteer their services, there will be distinct differences in terms of their commitment and enthusiasm, and, consequently, considerable variation in the quality of the information thus garnered. Moreover, the longer a project goes on, the less keen and thus cooperative most subjects will become (Pearce 1988:113), leading to a sharp fall in the amount and quality of the data recorded (Anderson 1971). According to Pearce (1988:16), a week is the most that one can expect people to compile such a diary in any satisfactory or meaningful manner.

New Methods for Tourists Tracking

There are at present several new digitally based methods that could be used to gather information on the spatial behavior of tourists. Those discussed in this paper are based on the three kinds of tracking technologies: the satellite-based Global Positioning System, land-based antennas, and hybrid solutions. The latter combines elements from the previous two types to overcome their drawbacks while maximizing their benefits.

Global Positioning System. The GPS is basically a series of satellites that orbit the earth broadcasting signals picked up by a system of receivers. By triangulating the data received from at least four satellites, it is possible to determine a receiver's location. Although there is a Russian GPS (Glonass) in operation and in several years there might be a European one (Galileo), the best known and most commonly used is the US Department of Defense's system. Made up of 24 satellites arranged in six orbital planes, it was originally conceived of as a military navigation system. In operation since 1994 (Kaplan 1996), the system was at first available to military personnel only. In order to deny civilians access to the high accuracy of the system, the department used a procedure known as selective availability that deliberately degraded the satellite signals. In May 2000, it ended selective availability, opening the system to individuals and business enterprises across the world. These seized the opportunity, to the point where today its usage is so pervasive that the term GPS has become virtually synonymous with the American system.

The GPS is a one-way broadcasting system: satellite signal, passive receivers. Thus, much like television or radio broadcasting systems, a system can support an almost unlimited number of end users (Zhao 1997). The accuracy of the data supplied by it varies greatly, depending on the nature of the local terrain: exposed rural plains as opposed to dense urban environments; weather conditions; and the degree to which the GPS receivers are exposed to the sky. A receiver will provide an accurate reading only if exposed directly to the satellites' signals. Any kind of obstruction, regardless of whether it wholly or even partially blocks the signal, will produce an inaccurate reading.

As a tool for tracking pedestrian activity, the main advantage of GPS lies in being global, in principle spanning the entire world. An accurate reading requires direct line of sight between receiver's antenna and orbiting satellites. Hence, it provides precise readings only in open terrains, and therein lies its principal disadvantage.

Land-Based Tracking Systems. Although terrestrial radio technology has existed since the mid 20th century, only during the last 10 years or so has it become widely available, a period which also saw a marked rise in its accuracy. Land-based tracking systems, which operate on the principle that electromagnetic signals travel at known speed, are for the most part local, as a series of antenna stations, known as radio frequency detectors, are distributed throughout a given area (Zhao 1997).

There are three main types of land-based tracking technologies. The first is time difference of arrival (TDOA). It consists of a series of antenna stations, which pick up transmissions from end units. By reckoning the time it takes a signal to travel from the end unit to the station, it is then possible to work out the distance between them. This information is passed on the system's central station, which establishes the end unit's location by calculating the point at which the results obtained by at least three stations converge. The second technology is angle of arrival. Like the first type, this consists of a series of land-based antenna stations. In this case, however, the individual stations feature three antennas, each pointing in a different direction. This means that once its antennas receive a signal from an end unit, the station can calculate the angle from which it was sent. It will then pass on this information to the main station, which based on figures obtained from at least two stations, will determine the point at which the two (or more) angles received intersect, thus pinpointing the end unit's location. Unlike the first system, which is dependent on data received from at least three stations, the angle of arrival system requires information acquired from only two stations.

The third technology is cell sector identification. It has emerged with the omnipresent spread of cellular communications networks. Based on the same principles as the first type and angle of arrival, it identifies the location of an end unit by triangulating adjacent cells within a single cellular communications network. Using this method, the deviation between the position recorded by the system and the end unit's real location can range from anywhere between several dozen meters, in ideal conditions, to several thousands of meters, in less than optimal conditions. The variation in this method's accuracy is dependent on the number and density of the network's cells and the volume of activity at any given moment. Accordingly, the more active cells there are on the network, the smaller each cell is, thus allowing for greater accuracy. Equally, in that most cellular networks will prioritize the data transmitted by their antennae, the cells closest to the antenna will be the ones used in the triangulation procedure, particularly during periods of low activity.

As a means to study human spatial behavior, land-based tracking technology has several advantages. As there is no need to expose the end unit directly to the radio frequency station, it can be placed in a bag or even carried around in a pocket, hence leaving the subject free to go about business without manipulating the unit. Thus, this technology provides reliable data regardless of the subject's motor skills. Its principal advantage is that it requires the subject to do little other than agree to carry the end unit around at all times. Moreover, with no need for direct line of sight between antennas and end units, this technology can be used in dense urban areas, tracking people as they wander in and out of various buildings. This is a huge advantage in that a significant percentage of all human activity takes place within urban environments.

Hybrid Solutions. This technology combines several geo-location technologies, seeking to reap the benefits of each, while minimizing their various disadvantages. Of the diverse hybrid solutions available today, the leading one is assisted GPS (AGPS). It uses GPS in combination with a land-based antenna network to pinpoint specific locations. It was originally conceived to locate mobile phones within a cellular network with greater accuracy than had been possible with cellular triangulation alone. In this method, the land-based stations are equipped with GPS units, which are used to predict the signals picked up by the radio frequency receivers. This means that end units can be fitted with only a partial, hence much smaller, GPS receiver. This amalgamation of the system and land-based networks has several advantages. It provides much more precise readings indoors. It also solves the problem of having to incorporate unwieldy GPS receivers into today's trendy, miniature handsets (Djuknic and Richton 2001).

Three tests were designed to determine the potential worth of the various tracking technologies for research on tourist mobility. Carried out in several geographical locations and on different geographical scales, the aim was to establish the advantages and limitations of each technology. Accuracy aside, the tests also concerned the problem of the size of the device used, as well as the degree of cooperation demanded from the subject. As noted, if they are to be used for research purposes, tracking technologies must be both small and passive, so as not to disrupt or affect the subject's behavior. The first experiment, set in Heidelberg, Germany, tested the GPS, currently the most commonly used tracking technology. The second experiment, which tracked a subject through Jerusalem's Old City, compared the results obtained using cellular triangulation to those achieved using two different kinds of devices. The third experiment evaluated a land-based TDOA tracking system on a variety of geographical scales.

Experiment I: GPS Tracking

Heidelberg is one of Germany's most popular destinations, its historic center and castle drawing tourists from all over Germany and the world. In 2004, over three million people visited the town, its hotels registering over 900,000 person-night stays (Freytag 2002). In May 2005, one of the paper's authors traveled to Heidelberg. During his visit, acting as the experiment's subject (henceforth, the subject), he carried, in a specially designed harness, an Emtac CruxII BlueTooth GPS receiver and Pocket PC. The receiver, set to record one tracking point per second, was secured by a strap just below the shoulder, thus saving him from having to hold it in his hands, and from having to constantly manipulate it to ensure that it was exposed to the sky. Using wireless Bluetooth technology, the data from this essentially passive receiver was transferred instantly to the pocket PC.

The tracked tour of Heidelberg lasted four hours, during which the subject covered 19.3 kilometers (Figure 1; for an animated version of the track see Shoval 2006). The subject began his journey, accompanied by his host, at the Ibis hotel, situated alongside the town's main train station (1). Leaving the hotel, the two drove to the Heiligenberg Mountain, where they disembarked and climbed an observation tower for a panoramic view of the Old Town's skyline (2). Returning to their car, they took a short trip up the mountain, parked, and climbed a further

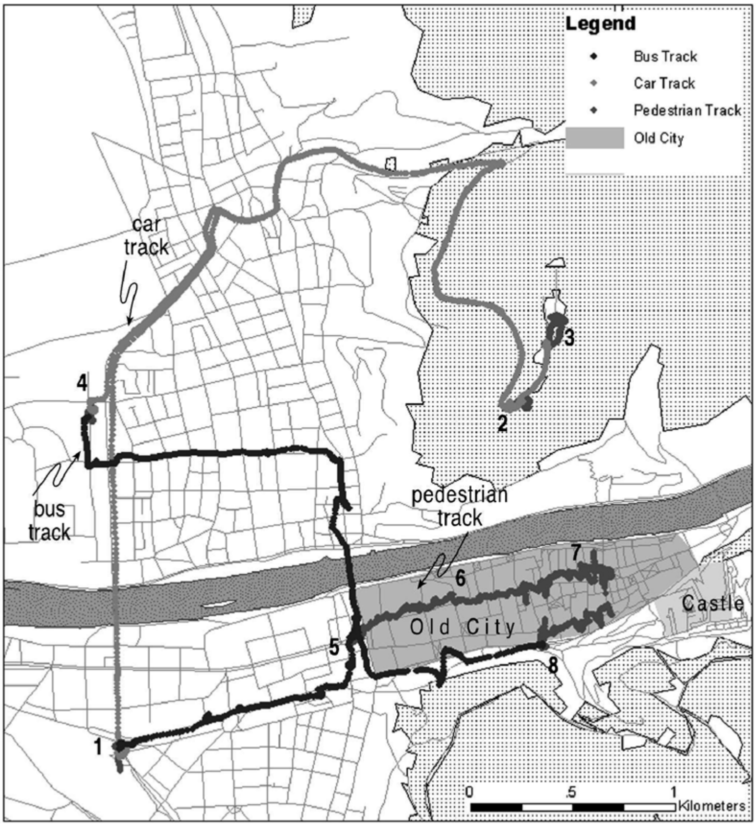

Figure 1. The Heidelberg GPS Track

65 meters to the Heiligenberg's summit. (3) They then traveled back to town to the Im Neuenheim Feld district and the University of Heidelberg's new campus. They parked the car on campus and took a bus to the Old Town (4). Getting off at Bismarckplatz, the subject and his host entered Heidelberg's Old Town through its main gateway (5). From this point onwards, they continued their tour on foot. Having strolled along the Haupstrasse, the Old Town's main commercial street, the two made their way along several of its smaller side streets (6). After 28 minutes of wandering around, they stopped at the Café Burkhardt for one hour and 27 minutes (7). At the end of their walk they boarded a bus (8) back to the Ibis hotel and the trip's starting point (1).

The fact that in the course of his expedition in and around Heidelberg, the subject used three different modes of transport—car, bus, and feet—is clearly marked on the track obtained using the GPS device (Figure 1). As noted, until now researchers have tended to concentrate on tracking vehicles, it being easier to mount such a device on cars. Furthermore, unlike pedestrians, cars have a constant built-in supply of power. Thus, the pedestrian alternative has, until now, been dependant upon the subjects carrying unwieldy devices and a hefty supply of batteries and remembering to change them. Yet the fact that the subject in this experiment, like most tourists, switched means of transport in mid-journey, underlines the importance of tracking the tourist and not the vehicle used. The development of smaller, more efficient batteries in portable electrical devices, and the fact that these devices have, over the last few years, been become smaller and lighter, mean that it is now more feasible to track the pedestrians themselves.

Heidelberg, with its many narrow streets and alleyways, is ideally suited for testing the GPS' ability to provide a clear and accurate track in dense urban environments. As the results of the experiment show, the its receiver remained fully functional throughout the test, and was able to pin down its position with remarkable accuracy. Indeed, neither Heidelberg's dense, maze-like streets nor the roofs of the bus or car were sufficient to render it inoperative. One point worth mentioning is that the density of the tracking points obtained varied according to the type of transportation used. This is not unexpected, as it is the speed at which the subject moves that determines the density of the tracking points. Accordingly, if, as was the case here, the sampling rate (for example, one point per second) remains the same, the more closely packed the points, the slower the motion and vice versa. This allows one to establish whether the subject is traveling by car or moving on foot.

Experiment II: Comparison among Cellular Triangulation, GPS, and AGPS

This experiment compared three kinds of tracking technologies: Cellular Triangulation, GPS, and the Hybrid AGPS. The experiment took place in the Old City of Jerusalem. One of the world's oldest continuously inhabited cities, it is full of narrow, twisting streets and alleyways, some only a few meters wide. In addition, many of its streets are wholly or partially covered. Hence, the Old City's jungle-like density makes it ideally suited to assessing the performance of different tracking technologies when faced with acute physical constraints.

The experiment took place in June 2005, in the course of which a research assistant traveled around the Old City carrying, at the same time, all three aforementioned tracking devices. The 3.1 km tracked journey, took one hour and 26 minutes to complete (Figure 2). Beginning at the Jaffa Gate, the research assistant entered the city. He then continued, on foot, along David Street towards the Church of the Holy Sepulchre. Crossing part of the Roman Cardo into the Jewish Quarter, he walked towards the Western Wall Esplanade. Once there, he hailed a taxi and returned to the Jaffa Gate, via Mount Zion.

The GPS Tracking System used in this experiment was the same as those used in the Heidelberg experiment. The receiver was set to record its location once every second. The AGPS Tracking System embedded in a cellular phone used in this experiment was a Motorola i860 AGPS-enabled cellular phone linked to the MIRS Communications' cellular network, MIRS being a subsidiary company of Motorola, Israel. The cellular phone unit was placed in the breast pocket of a shirt, giving

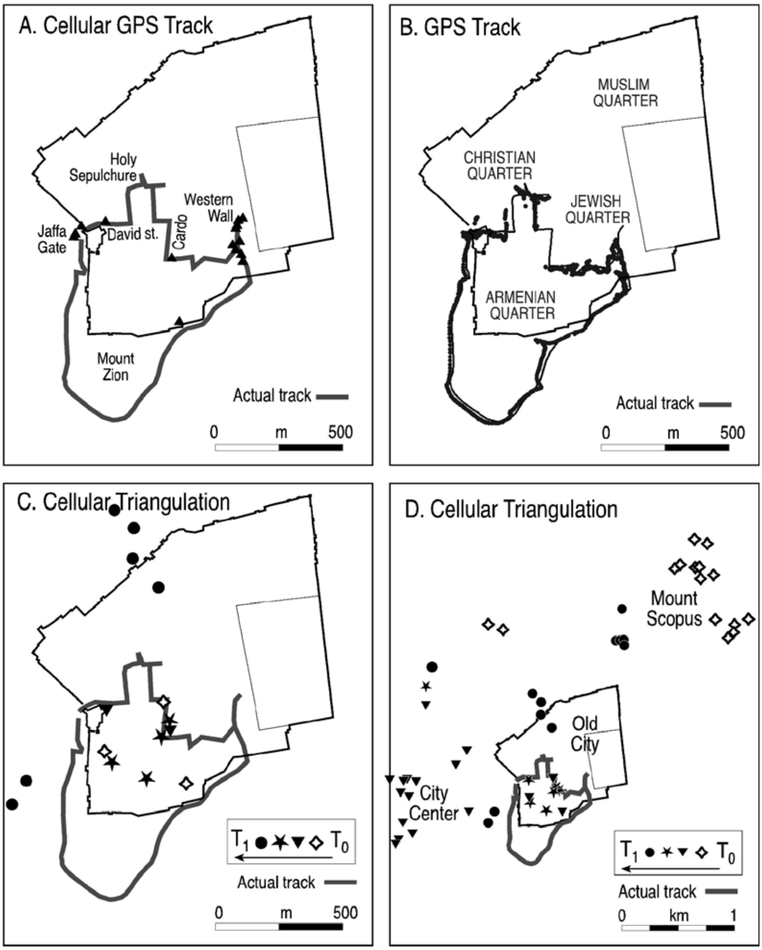

Figure 2. Tracks Obtained Using AGPS, GPS and Cellular Triangulation

it an uninterrupted line of sight to the sky. The MIRS network was instructed to ascertain the device's location once every 30 seconds. Having done so, it logged the device's position on the network's central server, from which the data was eventually retrieved. For the cellular triangulation in this experiment, a Samsung 854 cellular phone linked to the Partner Communications cellular network was used, employing an Internet-based graphical users interface. This particular apparatus was designed specifically to help companies locate their workers during the day. In that it proved impossible to change the procedure's 15-minute location default frequency, the second of the paper's two authors requested a manual location check once every five minutes. The system logged the device's position on the Partner's network's central server that was then accessed through the Internet. The tracking points thus accumulated were eventually transferred manually to a GIS layer. On this occasion the cell phone was placed in a bag.

The results obtained using the GPS receiver were similar to those obtained in Heidelberg. In both cases, the track proved accurate at most points (Figure 2B). There was some difficulty in pinpointing the receiver's position when it was lodged under the Old City's covered streets. However, once it had left such an area, the receiver was able to, once again, promptly fix its location. Given that the system was set to record the receiver's location once every second, the result was a fairly smooth and accurate track.

The tracking results obtained using the AGPS-enabled cellular phone proved rather disappointing (Figure 2A). Unlike the GPS receiver, which was set to retrieve its location once every second, the AGPS unit, owing to the limitations imposed by the cellular network, had a much lower sampling rate. Set to register its position once every 30 seconds, the result was considerably fewer location points. Nevertheless, the points the system did obtain were, on the whole, accurate. It is worth noting that the device found it difficult to log its location during the taxi ride back from the Western Wall area to Jaffa Gate. This was somewhat surprising as it was thought that the system would have no problem in fixing its position while in a car. It is entirely possible that this was the result of this specific AGPS unit being less sensitive than the GPS device used in the experiment and thus incapable of picking up satellite signals through the roofs of cars.

The track obtained using cellular triangulation was, as expected, the least accurate of all (Figure 2C). Indeed, the location points obtained were not only few and far between, but ill-defined, sufficient only to note whether the device was near or in the Old City. It thus proved impossible to reconstruct the path taken by the research assistant. Nevertheless, cellular triangulation should not be dismissed as a research tool. As a means for collecting spatial data, cellular phones have many advantages, including and above all the fact that they are also fully functional phones. This means that tourists would be quite happy to carry them around, using them as ordinary cellular phones. Nor would subjects, for the very same reason, have any problem in remembering to recharge the devices' batteries. While the information they gather may be of little worth in the context of micro-level research, it could prove useful for studies carried out on larger geographical scales (Figure 2D).

Experiment III: Land Based TDOA Tracking

This experiment was designed to determine the value of using TDOA tracking systems to study of the spatial behavior of tourists in a variety of geographical scales. The TDOA technology used in the experiment belonged to Ituran Ltd., a privately run Israeli company, which has built and administers tracking systems at home, in the United States, Brazil, and Argentina. In the course of the experiment, the subject carried around a small tracking device, which in this instance was placed in a bag. The system was programmed to record its location once every minute.

The experiment took place in June 2005. The device was carried around by a student while on a fieldtrip to Nazareth and Akko (Acre) in the north of Israel. Akko is most famously known for its underground crusader city, and in 2002 UNESCO added the town's Old City

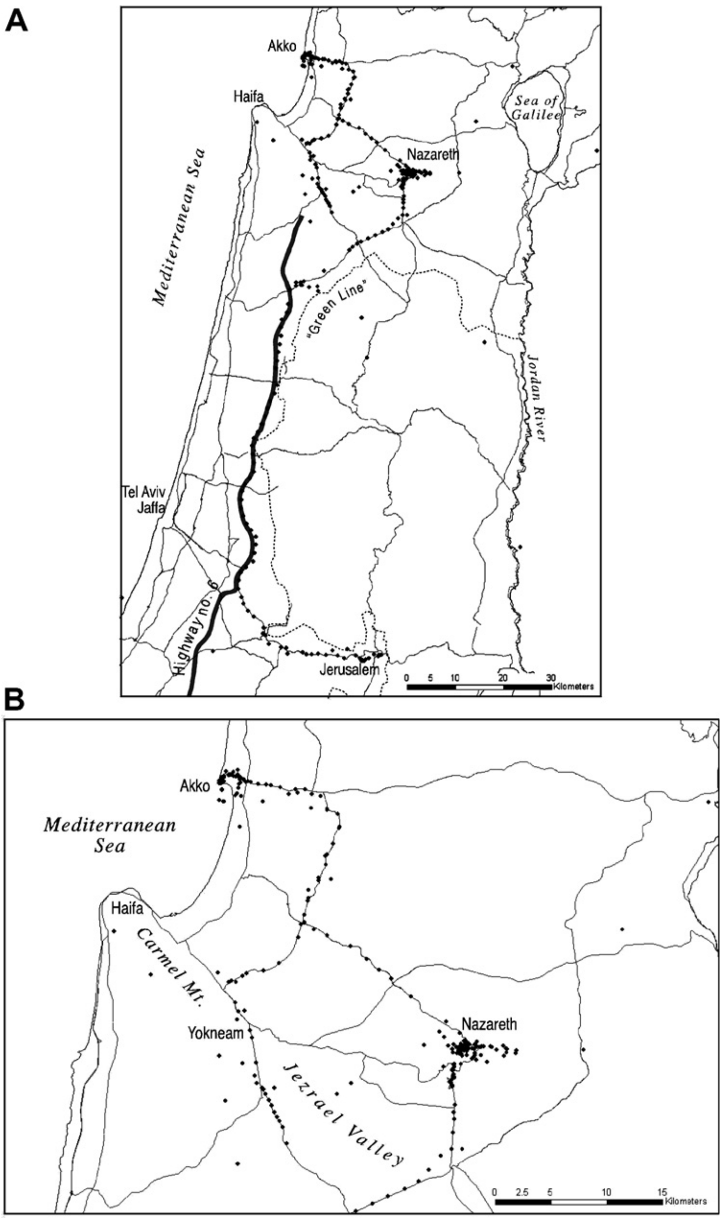

Figure 3. Tracks Obtained Using a Land-Based TDOA System

to its list of World Heritage sites. The town of Nazareth was first mentioned in the New Testament as the town in which St. Joseph and the Virgin Mary lived. It was in Nazareth that annunciation took place and there that Jesus spent his childhood and adolescence. Not surprisingly, pilgrims have, since the dawn of Christianity, flocked to Nazareth.

National and Regional Analysis Using a TDOA System. The fieldtrip began near the town of Yokne'am. From there the group traveled to Akko where they spent most of the day. In the afternoon, they drove to Nazareth, where they stayed overnight in a hotel. Its members spent the following day touring the city, then returned by bus to Jerusalem along Highway No. 6.

As can be seen in Figure 3A (produced on a national scale, using data obtained from the TDOA system) the group spent most of its time in the towns of Nazareth and Akko. The roads used to travel to and from the two towns are also clearly marked on the track. Figure 3B, drawn using the same data, focuses solely on the north of Israel. Offering a more detailed picture, this chart, drafted on a regional scale,

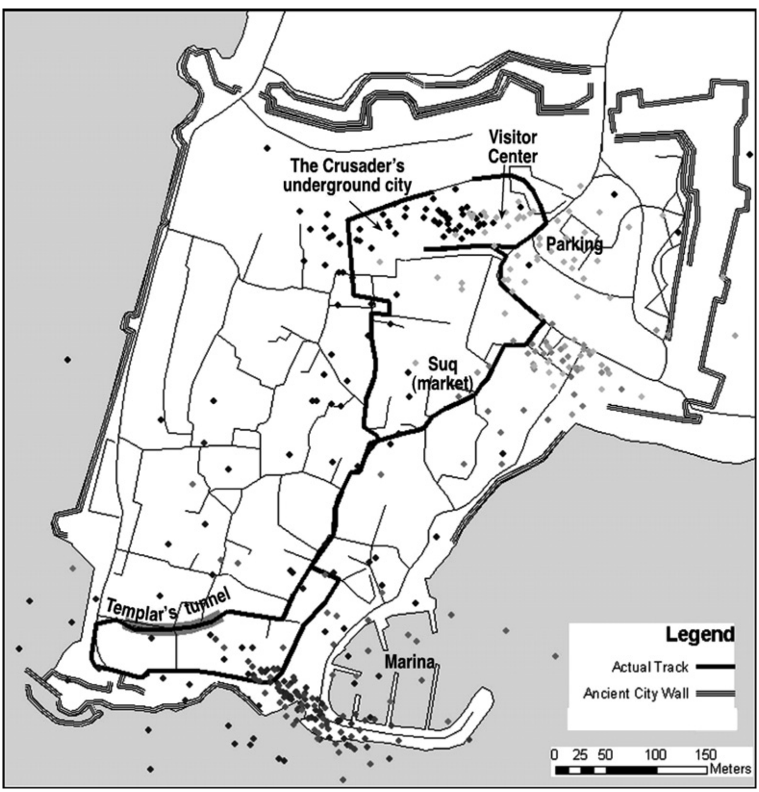

Figure 4. The Akko TDOA Track

shows which parts of Akko and Nazareth the group visited and which routes it took to and from the two towns.

Inner-City Analysis Using a TDOA System. The path the fieldtrip pursued through Akko's Old City is shown in Figure 4. The dots change from dark to light as time advances. Beginning at the visitors' center, the group saw the adjacent archaeological site. It then explored the Templar's Tunnel, having first passed through *Suq* (local market). This done, it stopped for lunch at a restaurant overlooking the Marina. Walking once again through *Suq*, the group returned to its bus, which was parked near the entrance to the visitors' center.

As can be seen in Figure 4, the TDOA system was for the most part unable to track the route followed by the group, and is thus clearly unsuited for micro-level research. If it is to further the understanding of the spatial and temporal behavior of tourists in small towns and sites, the accuracy of the data must be greater than that obtained at a regional or national level. That said, the TDOA system did indicate, albeit somewhat loosely, the group's location and as such can be used for researching tourist activity in larger cities, or in those cases in which the exact position of the tourists is of less importance.

CONCLUSION

This article presented the results of three experiments, each of which used one or more of the three principal tracking technologies currently available. All these technologies could potentially be used as effective tools for analyzing the spatial and temporal behavior of tourists, but only if, as previously noted, the tracking units used do not restrict or alter the subject's behavior. Put simply, they must be fairly light, easy to carry, and able to track the subject reflexively, without forcing him or her into taking any kind of special action. In this respect, the TDOA technique has a distinct advantage over the GPS in that the end units do not need a direct line of sight to the sky, and hence they can be placed in bag. On the other hand, GPS devices have the advantage over land-based tracking methods when it comes to obtaining accurate data. This makes them a suitable means to be used in micro-level investigations, such as studies which record the number and density of tourists visiting historic cities, attractions, theme parks, and the like, all of which demand high-resolution data.

As tracking mechanisms, the new digital technologies raise several moral and ethical questions, all which need to be addressed if they are to become fully functional research tools. Most of these relate to the way these devices may impinge upon people's right to privacy. This is not a new problem. At present, commercial mobile phone companies have the ability to locate and pinpoint the position of cell phone users, information which they can then use to bombard users with unsolicited information about nearby functions and events (Curry 2000). Indeed, as the current legal systems in the United States and elsewhere have yet to tackle the question of privacy in the digital world, it is an issue of considerable and global importance (Renenger 2002). It seems that privacy abuse is less of a problem in the case of research into the behavior of tourists, because the people tracked are monitored for a limited and well-defined time period. However, this gives rise to a new complication of whether tourists, once they know they are being followed, change their behavior, and if so how. This question should be answered by means of further empirical studies. Another general question that still needs to be investigated is if it will be socially desirable to carry the equipment; that is, while the technologies for tracking are already feasible, it is not clear currently how willing are people to be monitored.

In addition to the general questions that need to be dealt with in the future, there are specific limitations with the empirical tests presented in this study. First, the locations for the tests were chosen due to their convenience aside from the fact that they represent typical destinations. Second, just one test was made in each location and with a particular device. This could lead to idiosyncrasies associated with the particular device or location. However, this preliminary and exploratory study aimed to present the available digital tracking methods for tourism research and not to draw any generalizations about the findings.

This paper, while touching upon the challenges and problems that arise when using modern day tracking technologies to scrutinize of the spatial and temporal behavior of tourists, nevertheless established these technologies' potential as tools for gathering data on the spatial whereabouts of tourists at any given time, a potential to be verified and demonstrated by more empirical research. Providing extremely accurate data in time and space, these technologies could open up new, previously unfeasible lines of inquiry. In practical terms, the high-resolution data thus obtained could be used, among other things, to regulate the carrying capacity of tourism sites more rationally, develop new attractions, improve the allocation of accommodation services, and reduce friction between tourists and the local population. All in all, these technologies will not replace questionnaires, diaries, or interviews, which will, of necessity, remain important sources of information on behavior and especially motives underlying it. But they will complement, add to, and enrich the findings of more traditional research tools. This article offered a systematic review of several tracking technologies, which if properly applied could well prove revolutionary, pushing forward the boundaries of tourism studies, as well as improving policymaking, planning, and management. A

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