Survey of Position Location techniques in Mobile Systems

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ABSTRACT

The growth of mobile technology has made recording of user's location possible. The systems that intent to use location in order to register user's movement and to use the generated data for extracting useful knowledge define a new area of research that has technological as well as theoretical underpinnings. Many location based systems have been developed until now and some first directions and experiences have emerged. In this paper we focus on how some representative examples of these systems collect location information, what parameters use for tracking location and motion, how they model location, and thus tendencies appear on locating persons and objects.

Keywords

Mobile, location, interaction, spatial, context, location awareness.

1. INTRODUCTION

The technological advances in mobile technology have produced a new class of systems that aim at providing support to tasks and interactions of humans in physical space. These interactions differ to those that take place in work spaces characterized by stability in motion and static arrangement of the objects and subjects, such as in a typical office environment. These interactions refer often to places where the positions and the relations of the subjects and objects change regularly. In these usually closed spaces, there may be many persons and the location of each one in space relates to different activities and tasks under different conditions, while often different tasks may take place at the same location.

The systems supporting human interactions in space often need to be discreet and not impose visible technological infrastructure. Also the devices that users carry, are usually light. In most cases these systems can be installed in a place (room, building floor) even when this space is already completed structurally and shaped internally, while the existence of a prebuild infrastructure is not necessary. The basic parts of these systems are the device that the user carries (portable computer, PDA, tag scanner, simple signal transmitter etc.), a server which stores, processes and feeds the user with data, a communication medium, usually wireless, with which data are transferred from the server to the portable device and vice versa, and finally, often, a mechanism for the detection of the user location in space. According to the area range, the systems presented in this work, are mostly indoors, based on network domains [5]. These are usually based on the IEEE 802.11 wireless Ethernet standard and the cells are defined by the range of their WaveLan 802.11 base stations.

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In the mobile systems discussed, the role of the location in space is important. So automatic or not location detection in space in a transparent and convenient to the user way is a key requirement as discussed in the following.

2. USER TASKS AND LOCATION DETECTION

In this section we discuss typical reasons for which systems use location detection mechanisms. The main target of these systems aiming at supporting human-space interaction is to identify the persons and the objects the user aims at, identifying the target task of the user. Knowing where a person is, we can figure out near to what or who this person is and finally make a hypothesis what the user is aiming at.

The designers of systems supporting human-space interaction have been led to use two ways to detect the users' location in space and as a consequence to extract useful information in order to support them:

The first way is transparent to the user, as a location detection mechanism is used to compute spatial relationships of the user with other subjects or objects. Some systems are limited to simply detecting location and do not support mechanisms and algorithms for detecting more complex spatial relationships. These systems are used as the base for building through them other specific domain systems.

The second way is based on user explicit actions. In particular, the user is asked to declare the specific person or object he/she wants to interact with. An example of this case is when the user scans an object with a mobile device in order to receive information about it, to be displayed on this device [12]. Another example is when the user selects from a list of suggested objects or persons, one to interact with. As the main target is interaction with these target objects or actors through mobile devices, there is strong possibility to be in the proximity of them if their location is known [17]. Sometimes the combination of these two ways maybe is more appropriate [6].

We can distinguish three types of systems supporting human-space interaction: a) the systems supporting automatic location detection, less demanding to the user, b) the systems requesting location related information from the user and c) the hybrid systems which constitute combination of them.

3. SPECIFYING LOCATION

In mobile systems supporting human-space interaction, the events of interaction often play very important role. Let us suppose we have a large warehouse, where we import and export boxes. These boxes are registered into a system. An employee confirms import of the new boxes and export of already stored boxes using a scanner that transmits the relative data to a central database. The employee is responsible for the distribution in space of the newly imported boxes to the appropriate groups of the warehouse. Also (s)he has to commit their location in order to know where they are, when it is time for their export. In the case of a simple system supporting the employee using a simple scanner, the need of recording location in the warehouse space seems not so important. In the contrary a more rich system, in addition to recording events such as boxes scanned, it could detect and record the specific location (coordinates x, y) of every box when it is scanned. So that system would be capable of supporting a number of services such as to inform the employee when (s)he forgets to scan some boxes by comparing the box numbers scanned with the number of a certain order. Also on each scan of a newly imported box, it could suggest the appropriate group (location) where the box belongs, using previous data in the central database and criteria such as box volume, weight, days to be stored, fragility etc. Finally an embodied searching mechanism could be supplied on the scanner in order the employee to get instructions how to find a particular box. We can notice in this example that the system needs to know every moment the exact location of the employee and the boxes in order to supply the location sensitive services.

The designers of systems, using the spatial location of the user in order to support interaction, need to capture the location paths by modeling location and motion. The philosophy they may follow is similar with that of describing the navigation path in a web site using the web log files. So a group of parameters needs to be defined in order to define the exact location of the user. These parameters may be recorded in various ways. Either by recording them like events when their values change or by recording them periodically through sampling. In the following section we present typical parameters being used by a group of typical systems we have examined that aim to support human-space interaction. These parameters are divided in three groups: a) physical parameters, b) motion parameters and c) symbolic parameters. Many mobile systems use a set of single parameters from these categories in order to achieve the desired location awareness level.

3.1 Physical Parameters

The coordinates x, y and z are being used by many systems to define physically the location of an object or person in space. Defining physical location, according to [10], we mean the use of a group of measures with which we specify the location of a point solitarily in an application field. For example according to the GPS technology a car is at location 50º 11’ 33’’ N and 99º 39’ 25’’ W. The systems using the parameters x, y and z usually refer to small or large closed spaces (e.g. in a warehouse, in the floor of a large building). One positive characteristic of these parameters is that we can compute the distance between two points in space and so we can extract conclusions about their relationship (e.g. “John is near to the printer”). The distance between two points can be computed by knowing their physical (absolute) locations except of systems having a location detection mechanism that supports direct computation of their distance [11]. However any conclusions arising from the distance between two points is not valid if there is no direct physical path between them, like in the case that a wall is in the way.

The coordinate z, in addition to x and y, is being used by less systems because its practical meaning is until now limited. Coordinate z is usually used in closed spaces where the height of a point refers to the floor level or specific point in space. For this reason in most cases is meaningful to record the parameter z for objects and not for persons whose distance from the floor stays the same.

3.2 Motion Parameters

Direction and speed parameters are used by some systems in order to describe motion. Motion parameters consist of a way to describe the rate of change and the future value of the location of an object or person.

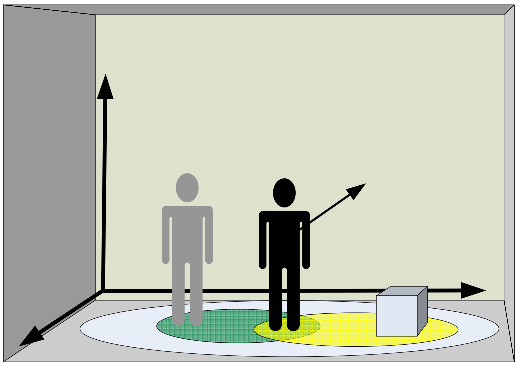

Figure 1. Physical, symbolic and motion parameters.

Direction refers practically to persons because their motion, in contrary to the motion of objects, is not deterministic. This parameter is used as a “compass” and the information we want to extract from it is to determine to which objects and persons the user is aiming at, while moving in space. Direction is usually used with parameters x and y in order to have more specific conclusions. For example to confirm if two persons, being in the same room, interact with each other, we have to detect their locations (x, y) and then compute their distance. If this distance is small (e.g. 1 m) and the persons have approaching directions, then we have strong reasons to believe that they are communicating. The direction parameter is supported by just few systems.

The parameter of *speed* is also used by just a few systems supporting human-space interaction because of its limited practical meaning. As with direction, also speed refers usually to persons because their motion is not predictable. The reason of using this parameter is to extract conclusions for the interaction of a person with other persons or objects. For example when a visitor moves in the room of a museum with a certain speed, the possibility to observe an exhibit is low, even when he moves near and towards to it, because we know that the observation of an exhibit is effective for most people only by staying still.

3.3 Symbolic Parameters

Another way of specifying location is using more abstract description of where something is. These abstract parameters may refer to place, persons or objects. For example "John is in the kitchen", "Peter is near to Andrew", "Mary is next to printer" etc. We describe these parameters as symbolic descriptions of location and according to [10] the position of a user is symbolic when predefined designations are used to specify that an object or person correlates to a place, person, or object. These designations can be either code words (e.g. "John is in room B18") or words from the common vocabulary (e.g. "John is in the office"). Systems appear to have two directions on supporting symbolic parameters. In particular the automated systems which detect the spatial location of the user tend to record the place where an interaction takes place, while the systems that need explicit information from the users about their intentions tend to record the persons or the objects the user wants to interact with.

3.4 Trends Using Parameters

The *symbolic parameters* related to place, combined with direction and speed, seems to have limited meaningful conclusions if we want to extract conclusions from recording a user's position. As it concerns the combination of symbolic parameters related to place and the coordinates x, y, z, many systems seem to support them both, in order to have more flexibility in the scope of target applicable fields. However no important cooperation is possible between them.

On the contrary information about the objects or persons (symbolic parameters), the user is near to, can be combined with direction and/or speed, in order to come to more specific conclusions. For example it is meaningful to know that a person is near to a printer looking towards it. Also, it is important to know that a person is near to a printer moving with a certain speed and in a direction not towards the printer. From these signs we can conclude that the user has not intention to interact with the printer. Finally many systems support recording both of the symbolic parameters related to persons or objects as references and the physical parameters (coordinates x, y and z), a fact that provides flexibility to these systems. However no further conclusions can be produced from this combination.

4. DISCUSSION OF SYSTEMS USING USER LOCATION AND MOTION

In table 1 we present a number of mobile systems supporting human-space interaction that we have studied in order to find out which parameters for location and motion are used to tackle the problem of recording movement of humans in space. The most recently developed systems tend to use symbolic parameters and

Table 1. Systems using physical, motion and symbolic

System	Description	Physical		Motion		Symbolic	
						Space / Object / Person	
		X, Y	Z	Direction	Speed	Automated	User Feedback
Active Badge [16]	The system provides a means of locating individuals within a building by determining the location of their Active Badge.					●	
Bat Ultrasonic [9]	The ultrasonic system is a room-scaled 3D ultrasonic location system.	●	●			●	
Cricket [14]	Cricket is a location-support system for in-building, mobile, location-dependent applications.	●	●	●		●	
RADAR [1]	RADAR is a radio-frequency (RF) based system for locating and tracking users inside buildings.	●					
Smart Floor [13]	Smart Floor system identifies people based on their footstep force profiles.	●					
Ekahau [7]	The Ekahau Positioning Engine uses wireless network infrastructure to determine location.	●		●	●	●	
Muse [4]	Multi-use Sensor Environment (MUSE) is a middleware architecture for sensor smart spaces employing Bayesian networks.						●
CampusAware [3]	CampusAware is a campus tour for Palm Pilots which uses GPS to find the user's Location.	●					
SpotON [11]	Tagging technology for three dimensional location sensing based on radio signal strength analysis.	●	●			●	
MoteTrack [15]	A decentralized approach to RF-based location tracking based on low-power radio transceivers.	●					
Wireles Andrew [2]	Wireless Andrew uses wireless local area network technology utilizing location based services.					●	
ActiveCampus [8]	An exploration of wireless location-aware computing in the university setting, supporting several location aware applications.					●	
Sotto Voce [17]	An electronic guidebook providing information to individual museum visitors.						●
Marble Museum Application [6]	The location aware system of the Marble Museum of Carrara.					●	
Petrie Museum [12]	The Petrie Museum system is a tag scanner system for organizing and managing exhibits.						●

not physical ones such as coordinates x, y, z. Also most of them, that support symbolic parameters, use automatic sensing techniques and they are not based on user's feedback. In table 2 we can see the effect of applying these parameters to persons and objects, having as guide the systems presented in table 1.

Many systems supporting human-space interaction have been developed until now and have found application in many research areas. In particular systems have been developed to provide services to members of a university campus based on the their location (internal or external) [2, 3, 8]. Systems have been developed to record objects in warehouses, archeological stores [12] etc. Other systems have been used to detect persons inside buildings where many people exist. Specifically these systems aim to help finding doctors between rooms and floors of a hospital. Extensive research has been done on museums in order to provide visitors more accurate and personalized information during their presence in the museum [17, 6]. In addition there are systems supporting human-space interaction aiming at satisfying general purposes by detecting the spatial location of the users [16, 1, 14, 9, 7, 11, 13, 15]. These systems are designed in order to be the supporting technology for other more specific applications.

Table 2. Usage scope of parameters

Parameters		Person	Object
Physical	X, Y	●	●
	Z		●
Motion	Direction, Speed	●	
Symbolic	Place / Object / Person	●	●

5. CONCLUSIONS

As we have seen there are two approaches for supporting the interaction of humans in space. According to the first one, the system automatically detects the users' location in space and as a consequence builds a hypothesis on their targets and intentions. According to the second one the system request input from the users about what object or person are interested in and then provids them with the relevant information and services. In this case the places the user has visited are considered knowledge, with some use, not necessarily determining users' intentions.

A system that is built for the first approach is [2] which detects users in places like libraries, classrooms or public spaces like a cafeteria. In that case, the target of the user is obvious because of the space he/she is in and the services provided can be very specific and accurate. The second methodology may have very successful results in the case of a museum. There the interest of a visitor about an exhibit is not easily concluded from parameters such as distance from the exhibit, direction and speed, because there aren't specific standards for describing motion and habits in a museum visit. In addition problems like congestion, glass showcases and interdicted rails make things more complicated. An example of a system that follows the second approach is [17].

6. REFERENCES

[1] Bahl, P., Balachandran, A., Padmanabhan, V. Enhancements to the RADAR User Location and Tracking System. Microsoft Technical Report, 2000.

[2] Bennington, B.J., and Bartel, C.R. Wireless Andrew: Experience building a high speed, campus-wide wireless data network. In Proceedings of MOBICOM, September 1997.

[3] Burrell, J., Guy, G., Kubo, K., and Farina, N. Context-aware computing: A test case. In Proceedings of UbiComp 2002, Springer, 2002, 1–15.

[4] Castro, P., Chiu, P., Kremenek, T., and Muntz, R. A probabilistic room location service for wireless network environments. In Proceedings of the 3rd International Conference on Ubiquitous Computing 2001.

[5] Chen, G. & Kotz, D. A Survey of Context-Aware Mobile Computing Research. Technical Report. TR2000-381. Department of Computer Science, Dartmouth College, 2000.

[6] Ciavarella, C., Paternò, F. Design Criteria for Location-aware, Indoor, PDA Applications. Proceedings of Mobile HCI 2003, Udine, Italy, September 2003.

[7] Ekahau Inc., http://www.ekahau.com/.

[8] Griswold, W. G., Shanahan, P., Brown, S. W., Boyer, R., Ratto, M., Shapiro, R. B., and Truong, T. M. ActiveCampus - Experiments in Community-Oriented Ubiquitous Computing. IEEE Computer, To Appear.

[9] Harter A., Hopper A., Steggles P., Ward A. and Webster P. The Anatomy of a Context-Aware Application. ACM/IEEE Mobile Computing and Networking, 2002.

[10] Hightower, J. and Borriello, G. Location systems for ubiquitous computing. Computer, August 2001, 34(8):57–66.

[11] Hightower, J., Vakili, C., Borriello, G., and Want, R. Design and Calibration of the SpotON Ad-Hoc Location Sensing System. UW CSE 01-08-?? University of Washington, Seattle, WA, August 2001.

[12] MacDonald, S. University Museums and the Public: the case of the Petrie Museum. in McManus, P. (ed.) Archaeological Displays and the Public. London: Institute of Archaeology, UCL, 2000, 67-86.

[13] Orr, R., Abowd, G. The Smart Floor: A Mechanism for Natural User Identification and Tracking. In Proceedings of the 2000 Conference on Human Factors in Computing Systems), The Hague, Netherlands, April 1-6, 2000.

[14] Priyantha, N. B., Chakraborty, A., Balakrishnan, H. The Cricket Location-Support system. Proc. 6th ACM MOBICOM, Boston, MA, August 2000.

[15] Robust, A. Decentralized Approach to RF-Based Location Tracking. Konrad Lorincz and Matt Welsh. Technical Report TR-19-04, Harvard University, 2004.

[16] Want, R., Hopper, A., Falcão, V., and Gibbons, J. The Active Badge Location System. ACM Trans. Information Systems, vol. 10, no. 1, Jan. 1992, 91–102.

[17] Woodruff, A., Szymanski, M.H., Aoki, P.M. and Hurst, A., The Conversational Role of Electronic Guidebooks, Proc. of 3rd Int. Conf. on Ubiquitous Computing, (Atlanta, GA, 2001), Springer-Verlag (LNCS Vol. 2201), 187-208