Relative Positioning

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ABSTRACT

Positioning of mobile devices is a core requirement in many mobile computing applications. Typically, such applications use external infrastructure installed in the environment to obtain position information. Several different technologies have been investigated such as ultra sound, magnetic fields or inertial systems. In contrast to most of the established location systems, a promising approach is to avoid the need of any infrastructure and to gather location information in a distributed and peer-to-peer manner.

LOCATION SYSTEMS

In the past few years, a reasonable number of location systems for small objects have been published. Different technologies have been investigated and brought to a concrete implementation, some even to a commercial product. Initial research projects were e.g. the Active Badge System [5], a system using ultrasound for location estimation and SpotOn [3] using RF field strength measurements. These systems use mainly the theory of triangulation like the GPS system. Measurements are made between mobile objects on one side and a well positioned and known infrastructure on the other side. The measurements give the distances between the concerning objects and data is collected afterwards in order to combine the measurements to a complete location estimation of the objects. This estimation can be done in the object itself, like in GPS, or in the infrastructure, like in the Badge System. In some cases, the measurements include more than just the distance but also give orientation in terms of axis-angles between objects and the infrastructure.

These system -and other similar approaches- have one important thing in common: They are all in the need of an infrastructure in order to fulfill the task of localization of objects. The infrastructure in most cases consists of beacons sending out position information or complex receiver circuitry. The used physical measurands are in all cases either the time of flight or the received intensity of a physical signal. To use those physical values it is either necessary to establish a synchronization (for a system using time of flight) or having calibration concepts for electronic components (in a system using received signal strength for localization).

The installation of the infrastructure is in many cases a long and elaborate task that included precise measurements and various interconnection between infrastructure components. The infrastructure normally works as a whole and not with independent components. But the most important thing to say about those location systems in this context is that the functionality is *dependent* on the infrastructure. That means, the localization of objects is only possible when and where the enabling infrastructure is available. Applications that rely on positioning of their objects are as well limited to spots where the supporting infrastructure is present.

Further on, infrastructure based location systems often centralize the location algorithms and all necessary computing into one central processing unit. All applications and objects are then dependent on the performance and reliability of this unit. That limits the design and implementation of application in a reasonable extend. Applications that work on distributed objects including the need of a position statement of those objects would never work outside the coverage of the localization enabling infrastructure.

Most of the applications built on those location systems are as well infrastructure related. Such as surveillance of the presence of documents in offices or people in a plant to track their movements and find their current position. Such surveillance systems normally collect all the data from the objects that are being tracked and combine them with knowledge from databases and e.g. floor plans to generate maps or log the history. Such a scenario strongly depends on a centralized analysis and is therefore anyway in the need of an infrastructure that brings together location information and databases.

Based on the badge system, e.g. interactive user interfaces have been built that use the location of general trigger devices like a mobile button to trigger events in a backend system to fulfill e.g. home automation tasks. Other applications automatically control the environment depending on the present people like switching displays nearby a person to their personal desktop or adjust interactive panels to a users' profiles when they come in close range. Those application are back-end centric and need an established infrastructure not only for the location algorithms but as well for the applications themselves. In those cases, arguing for an infrastructure-based location system seem rational.

In contrast to this, application that are not backend centric should not depend on any infrastructure. Applications that work on a peer to peer basis must be freed from the limitations of the infrastructure. That is where relative positioning plays an important role.

RELATIVE POSITIONING

Relative positioning in this context means that objects determine their spatial relation not using an underlying infrastructure. Necessary sensing and measurements such as time of flight of signals or intensity of emitted fields are taken only between enabled objects not including a central access point or any external support. The objects containing the enabling technology can determine their relative position only depending on the partner object that as well is enhanced with the positioning technology. This means, an active collaboration between the objects is intended.

This approach brings in some new challenges special to the distributed and intercommunicative design. First, scalability is an important issue. If objects e.g. measure their spatial parameters in a pair-wise way, the scaling of the whole system is pretty poor as the number of necessary measurements increase strongly with an increasing number of active objects. Concepts for efficient measurements must be developed that several objects can determine their spatial relationship at the same time – ideally using the same emitted signal from one partner object. Secondly, the choice of technology plays an important role. Technologies that rely of a line-of-sight connection between the corresponding objects have a special weakness for the possible target scenario. It's much easier to guarantee a line-of-sight connection between a mobile object and an installed infrastructure than between two mobile objects. The infrastructure could cover e.g. complete walls or floors and ceilings in buildings which clearly increases the probability of having line-of-sight to the infrastructure components. Mobile objects in contrast will not have line-of-sight connection between each other in many cases. Thirdly, as the relative positioning should work in an independent way, all computation must be done within the object. This requires all sensing and computation hardware to be included in the mobile objects and can significantly influence the size and weight of objects that are subject to localization. On the other hand, especially the distributed and self-sustaining computation brings excellent scalability. The more objects participate, the more computation power is available. A positive side-effect of robustness appears when sensing and localization of partner objects is done in a distributed and decentralized way: The drop out of one object will generally not affect the functionality of the remaining ones.

DECENTRALIZED COLLABORATIVE SENSING

The decentralized sensing appears to be one of the most challenging issue in this context, as technologies must be found that can be used in mobile and small objects. Research has started to evaluate different possibilities like [1] and [4]. The sensing and measuring of the spatial relation of object must be designed in a way that it works collaborative. This means, objects would not sense their environment and discover other objects which are physically there, but the objects would find each other e.g. through a broadcast communication on a radio frequency channel and then determine their location actively together. That is as well an important condition for the scaling of the whole system. Exchanging existing data to minimize the actual sensing is as well necessary.

Additionally, energy issues and the size will be important considerations for the system implementation. The advantages and new problems of a distributed approach will include independent and ubiquitous operability, cost and set-up time, broad- and multicast communication.

THE RELATE PROJECT

In the RELATE project [1] we investigate relative positioning in the specific context of tangible interfaces that involve spatial arrangement of physical interaction objects on 2D surfaces, such as white board or tables. Relate is an approach that uses dedicated positioning technology to obtain finer-grained relative position, targeted at close-range operation. The research is driven by positioning requirements that we observe in tangible interface systems composed of physical interaction objects. Tangible interfaces have recently attracted considerable research interest, as part of the paradigm shift toward ubiquitous computing, aiming to provide interaction in ways that are intuitive and seamlessly integrated with people's activity in a physical world [6].

We seek to make such interfaces independent of particular environments and fit for deployment beyond lab spaces. We specifically target objects that collectively constitute a tangible interface but the approach applies to mobile devices in general. The embedded technology allows objects to measure distance from neighboring objects as well as the angle at which these are observed. It further foresees wireless communication for the objects to share observations and to collectively establish the overall spatial configuration of the set of objects.

In particular, we discuss the following relevant research issues during the RELATE project: First the enabling technology that includes the actual position sensing. Different technologies are such as infrared light and ultrasound are under evaluation and prototypes are being built. Second, the design of the distributed and decentralized sensing of object in a collaborative manner seams an interesting research issue. Objects, that e.g. create signals for measurements of the location of partner objects expect them to work simultaneously. A pair-wise approach would scale bad and cause slow update rates that might not be useful for the target application: human interfaces.

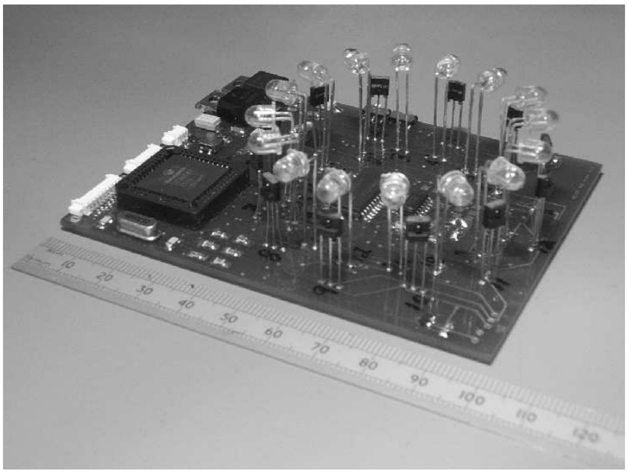

Figure 1

Thirdly, robustness, physical size and weight are properties that are evaluated during the RELATE project. If the enabling technology for acquiring location information is attached to mobile objects or human or even embedded in mobile devices like cell phones or PDAs it must fulfill additional conditions. Those even include energy efficiency and interface definitions. Further, we discuss the theory of combining data from distributed measurements to even draw a complete picture of the united arrangement of objects. In a first step, we focused our investigation on the use of infrared light intensity as basis for relative position measurement. We have implemented a number of device prototypes (see Figure 1) to facilitate initial small-scale experiments to inspect accuracy and robustness of this particular method for relative positioning. Those prototypes can cover a range of distances up to 2.5 meters and work distributed and independently together. The communication for organization and data exchange is processed on the Smart-Its platform [7] which provides an ad hoc networking with a maximum bandwidth of 125kBit/s.

AUTHOR

Albert Krohn has written his master thesis on promoting ideas towards “spectrum pooling”, which involved new concepts for simultaneously running concurrent protocols. During his time as a student at TecO he established his interest in ubicomp research and location issues mainly through the MediaCup [2] project. As a research assistant at TecO he now focuses on a positioning system for ubicomp as well as adaptive ad hoc communication and human computer interaction.

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