Location in the Aware Home

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Abstract. Since the doors were opened in May of 2000, much of the infrastructure and applications in the Broadband Institute's Residential Laboratory [1] has involved trying to locate people. Technologies to obtain location information are almost completely in place, and now we are beginning to look at the issues regarding the management and coordination of this information.

1 Application Space

Our focus is to be able to sense the various activities and whereabouts of the occupants of a house. Technological challenges that this puts forth include the desire to minimize active participation by an individual as well as the need to have robust and reliable systems that can run continuously, collecting the sensed information.

2 Technology

There are two systems that are in stages of development that will soon provide location information in the house. When this occurs, we will very quickly be interested in the problems of fusing the data from these very diverse approaches.

2.1 RFID

Using the TI*RFID system from Texas Instruments [4] and floor-mat antennas we have constructed, we hope to be able to collect room level data about the occupants in the house. Mats are primarily placed in thresholds to rooms while some are used to sense occupancy, such as in front of the refrigerator (see Figure 1.) Subjects wear an RFID transponder attached to their footwear. We have chosen this system due to the relatively simple design, ease of construction, and relatively low cost.

2.2 Computer Vision

Using overhead cameras mounted we are attempting to track people in the house using background subtraction along with blob tracking algorithms.

2.3 Properties of the Location Systems

The two location systems illustrate different types of location sensing which complement each other. The RFID system represents a signpost location approach, where the sensor can provide quite accurately that a subject was at a particular point at a given time. These sensors often provide accurate identity information, but lack in resolution. When subjects discontinue their interaction with these types of sensors, direct information is no longer available. Other signpost-type sensors also include fingerprint scanners, iButtons [3], and standard proximity card readers.

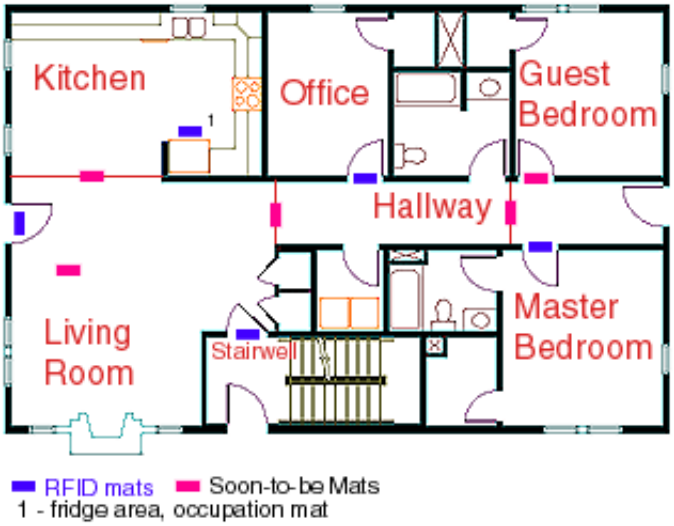

Fig. 1. Overview of house floor plan and placement of mats

3 Modeling

Given the limitations of the RFID system, we need to interpret trajectories from consecutive mat readings in order to provide room level location information. We use the mat where an RFID tag was last seen and the current one to determine if a person is heading towards or coming away from an area. The vision system provides a continuous stream of information about tracked objects, with greater coverage and precision than the RFID system could provide. However, identity is not nearly as easy to determine with only an overhead vision system. Coordination of information is key to generating accurate location information. What we have discussed is a registration system for the location systems, which will be covered after some discussion about location modeling.

Our current focus is room-level location information. As seen in Figure 1, most rooms are defined by the architecture of the house and social convention. However, the kitchen, living room, and hallway don't have much in the way of architectural divisions and must be divided logically by the placement of sensors, furniture and traffic patterns of people working in the house. The choice of room level information was made because it satisfies our current application needs and is a level of location information that is reasonable for the near term, in terms of the technology available to us currently.

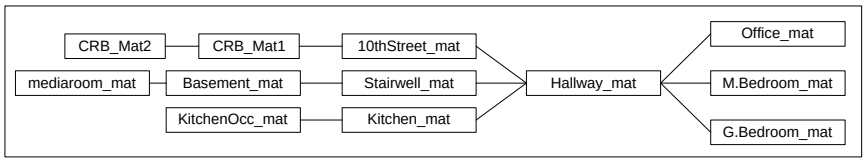

Fig. 2. Mats and the neighboring relationships between them

In the RFID system, locations are currently represented in respect to combinations of mats (see Figure 2). Specifically, a start mat and a finish mat yield a location. As of yet, there is no standardized global representation of location that our systems in the Aware Home (either sensor or application) have used. Such a representation has not been necessary outside of the RFID interpretation mechanism itself, where the relationships are used to determine room level position. We suspect this will change as we start to address different levels of precision in location information.

While room-level information is what we are concentrating on now, there are definitely other levels available. There are at least two resolutions smaller than a room that we will be interested in. There is sub-room, which are areas such as "in front of the refrigerator" or "on the table" that are important not so much because of the location as the context that comes with being in an interesting place within a room. Defining these will, at least at first, be on an as-needed basis. Below sub-room, there is an actual coordinate system. We have taken a preliminary survey of our apartment floors and have recorded locations within 1cm accuracy. The vision system will eventually be publishing coordinate level location information. Less specific than rooms, there are floors (1st, 2nd, basement, attic), buildings (house), and then global coordinates (latitude/longitude/altitude with WGS84, etc.).

4 Registration - providing coordination

One of the topics discussed recently is the need for a system to coordinate location information. Once both the RFID and vision systems are online (as well

as any others) there is the need to combine the information. The result of these discussions has led to the desire to build a registration-based location collector. At startup all location sensing systems would connect and register the coverage area and resolution they can provide to the location collector. What would be registered would be one or more polygons/zone names describing the area being covered by the system, another keyword describing the level of detail they provide (cm^2, room-level, etc..), and possibly the update rate one could expect from that sensor. For example, our RFID floor mat tracking system covers the first and second floors of the Aware Home, and only has room-level resolution. The computer vision system is currently limited to the kitchen, publishing actual coordinates (cm). The location collector would keep an internal map, and particularly the overlap of the different systems. Built using Context Toolkit [2] components, it should be able to easily support sensor fusion at three proposed levels. First, the sensor systems could maintain subscriptions to the systems that overlap in coverage via the location collector and use the data to make its own readings more accurate. Second, one could put some sensor fusion mechanisms into the location collector itself. Finally, a process could subscribe to areas of interest requesting all readings and do its own interpretation of the data.

5 The Future

While much discussion has been made with respect to location, what is being tracked it primarily people, and at some point things. The question then becomes, how do we answer the question of where someone is, given N different mechanisms for doing so. The area of caution here is fusing data too haphazardly. Applications have different requirements when it comes to needing an answer to where someone is. Some may need room-level, others coordinate, and yet others may just want to know if someone is in the building. What if only room level information is available in an area, yet an application requests sub-room level information? Is the application given nothing or some probability that a person could be in that sub-room area? Mechanisms that allow this information to be determined and shared across different sensor systems and applications will be a critical part of future location-aware systems.

References

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