RFID-Based System for Tracking People: Approaches to Tagging Demented Patients

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Abstract. RFID technology has proven to be an effective solution in many applications for monitoring demented patients. However, its wider acceptance is still limited by prohibitive deployment costs, technological limitations and privacy concerns. In this paper, an RFID-based indoor tracking system was analyzed regarding an additional barrier of RFID's acceptance which is an issue of choosing an appropriate strategy for tagging patients. This includes making the trade-off between technological constraints, healthcare staff's routines and the fact that patients with dementia may tend to remove foreign objects.

Keywords: RFID, indoor tracking, monitoring patients, tagging patients.

1 Introduction

Rapid development of technology and medicine in the last decades allowed for significantly higher life expectancy thus shifting median age of population. These trends are predicted to occur in the future – by 2030 the predicted number of people over 65 years will be approximately 71.5 million only in the US [1]. As an inevitable consequence of this growth it is reasonable to expect an increasing number of patients suffering various diseases that are typical of old age, and as such increasing care provisioning demand. In particular, prevalence of dementia is doubling every five years in patients over age of 65 [2]. Dementia causes a deterioration of cognitive functions endangering independence and quality of life, while at the same time making it an expensive disease to monitor and treat.

Addressing the aging population needs there is an increasing body of research initiatives aiming to monitor patients with dementia by exploiting technological solutions. As computational capabilities continuously improve and sensing devices shrink in size, the use of technology is allowing monitoring many aspects of patients' life, from their activities up to various physiological parameters, while increasingly becoming more and more integrated into the living environments. The ultimate goal is development of an unobtrusive system capable of reliable operation while being cost-effective; however, typically there is a trade-off between these requirements.

Although not initially intended for monitoring demented patients, RFID (Radio Frequency Identification) technology has proved to be an effective solution for this purpose, owing to its design (differently sized and shaped tags that can be identified

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without a direct line of sight from antennas) and innovative applications. Using solely RFID or combining it with other technologies, significant results are achieved in analyzing numerous activities of daily living, an important monitoring aspect for demented subjects. For instance, Wu et al [3] achieved a high recognition rate in 16 kitchen activities using RFID, Woodward Laboratories developed the system for monitoring hand hygiene [4], RFID-based design for controlling medication intake is addressed by Ho et al [5] while our previous work [6] tackles the problem of automatic monitoring of steps in dressing activity exploiting the fusion of RFID and the video machine system. With an RFID reader embedded in a glove Philipose et al. [7] recognized 14 everyday activities based on objects manipulated by subjects. Using RFID for identification and localization in addition to other sensors intended for capturing activity patterns, Kaye [8] detected trajectories of change, recorded over many years and analyzed variability in patients' behavior, aiming to dementia prevention. Relying on active RFID-based system for positioning, Kearns et al. [9] correlated patterns of subject's movements and levels of cognitive impairment. In addition, RFID technology proved to be suitable in a number of other healthcare systems, due to the possibility of quickly retrieving patient information and monitoring patient's location [10].

However, RFID implementation in healthcare applications is still behind earlier optimistic expectations of its wide acceptance and according to Yao et al. [10] major barriers lie in prohibitive deployment costs, technological limitations and privacy concerns.

The authors of this paper, in turn, identify and analyze an additional barrier of RFID's acceptance: tagging objects of interests, subjects and the fact that patients with dementia may tend to remove foreign objects. In order to track subjects, we have designed a RFID-based system that is able to track transitions between rooms of interest and we have evaluated tagging different parts of patients' clothes both with respect to the acceptance of healthcare facilities and to the recognition rate of identification and moving direction.

2 System Setup

In order to identify patients and detect their transitions from one room to another we used OBID ID ISC.MR101 mid-range RFID reader [13], multiplexer and two antennas for each door. Antennas are connected to the RFID multiplexer which is connected to the reader that ultimately connects to a PC. Each antenna has a reading range of approximately 30cm and is mounted on the left and right side of a door using free-standing supports that allow changing their height easily. Patients' clothes are tagged also on the left and right side such that moving direction could be recognized (going in or out), deduced by readings on the corresponding antennas (left antenna reads left tag and/or right antenna reads right tag) indicating the direction of passing through the door. In all our experiments (three different locations) door-width was 0.9 – 1m making the reading range of antennas of 30cm suitable fit for the following reasons: a) if the range was considerably larger, the direction of moving is likely to be lost since one antenna might read both tags at the same time, b) if the range was considerably shorter, the antennas might miss both tags. Since the recommended door

opening for care facilities may be up to 1.22m [11], the reading range could be adjusted either by using bigger tags (physically larger tags have a greater reading range) or by using the equipment with a slightly bigger reading range.

Clearly, tagging only one side of patients' clothes would be sufficient for detecting the moving direction; however, as expected, the experiments yielded a significant increase in the recognition rate when both sides of clothes were tagged. In the case of a passive RFID system that we used, tags are able to communicate with the reader when in the reading range of antennas and since they do not have a battery, they are smaller in size and less costly than active RFID tags. In the experiments, we used plastic tags with dimensions 8.5x5.5cm affixed on clothes with double sided adhesive tape while for permanent use they might be sewn in the clothes.

3 Evaluation of the Approaches

When it comes to the implementation of RFID-based system for tracking, one must consider various factors that affect the reading accuracy, including tagged objects, tag placement, angle of rotation and reading distance [10]. Moreover, RFID may interfere very often with metal objects in hospital environments. In addition to the technological issues, the key requirement for a system intended for monitoring demented persons is unobtrusiveness, particularly with regards to visible and wearable sensors. Visibility of the RFID equipment is usually a trivial problem (in many cases antennas, readers and multiplexers can easily be hidden from patients) while special attention should be put on tagging strategy since wearable objects may influence patients' activities and they are prone to removing them. However it would be incorrect to consider solely patients as the system's users while not taking into account the healthcare staff. In this respect, choosing the most effective tagging strategy includes identifying the appropriate location for placing tags, their type and size, and a way of attaching tags (permanently or temporarily). The goal is to make an unobtrusive system from the perspective of patients, to minimize the additional workload for healthcare staff and to not interfere with their usual routines while at the same time achieving the highest possible system's accuracy,

The aim of our work was to analyze solutions for tracking demented patients considering the abovementioned constraints and providing an appropriate trade-off between the patient/healthcare staff requirements and the technological limitations. Various possible body locations for placing the tags were examined in accordance with the advices of doctors from a number of rehabilitation centers. According to the caring routines in the centers, doctors' experience with demented persons and the technical constraints, we identified three positions to place passive RFID tags: sole of shoes, hips (pockets of pants) and shoulders of upper garments.

We tested the tracking system in our laboratory, test-bed apartment and a real care facility. The experiments were conducted with two different participants that were passing through the door one after another. The antennas (with a length of 33.7cm) were positioned on the ground, 60cm and 100cm from the ground in the cases of tagging shoes, hips and shoulders respectively. Due to the physical constraints for mounting antennas, the approach of tagging shoes was not tested only in a real care

facility. The recognition rates are presented in Fig.1 (minimal and maximal values relate to the highest and lowest system's accuracy concerning different experimental trials). Since it never occurred that a subject was identified while moving direction was missed (and vice versa), the recognition rates are the same for both cases.

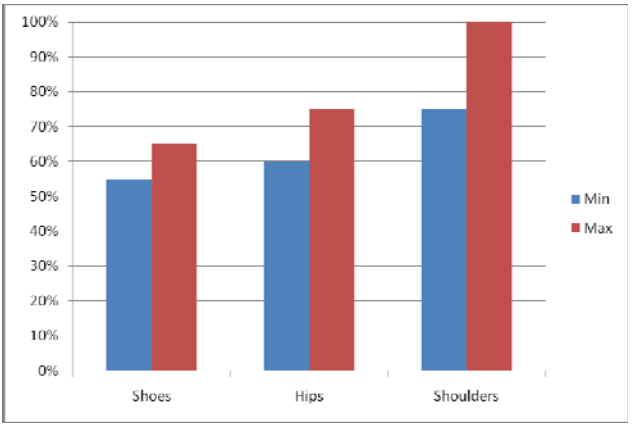

Fig. 1. Moving direction and identification recognition rate

In the case of tagging shoes the system performs at the lowest accuracy mostly due to a higher speed of moving feet than hips and shoulders when a person is walking, providing less time for the RFID reader to identify tags. In addition, in this case the system was more prone to the interference in our experiments, probably because concrete in the floor contained metal objects. On the other hand, tags attached on the shoulders were more parallel to antennas than tags on hips (in most cases in our experiments participants were putting them in their pockets) which resulted in better system's accuracy (putting tags in any other position but parallel with respect to antennas lowers the effective surface for tag-to-antenna coupling).

The type of care facility (daycare or residential nursing homes) can influence the decision of choosing one of the aforementioned places for tagging. In the case of residential care, patients' private clothes can be tagged permanently using waterproof tags (that can be washed with the clothes) sewn in the inner side, in order to be invisible to the patients. Therefore, any of indicated places might suit well so the decision could be based on the criteria of the system's accuracy. Moreover, tagging process may be performed only once which is less time consuming for caregivers. On the other hand, daycare facilities differ more in routines they apply in the sense that some facilities provide clothing (such as shoes or slippers for example) while others allow patients to wear their own. In latter case, it is possible to use tags in form of stickers and attach to patients' clothes upon their arrival. Therefore, in daycare facilities the applied clothing routine should be dominant criteria for choosing an appropriate place for tagging.

4 Conclusion

Tagging shoulders provides the highest recognition rate, being an effective solution for residential nursing homes where it is possible to permanently tag patients' clothes. However, daycare nursing homes differ more in the clothing routines they apply so the tagging strategy depends mostly on this criteria. In these cases, the option is to employ tags in form of stickers that may be attached on hips or shoulders, which provide higher recognition rate for identification and moving direction than tagging the shoes. On the other hand, shoes are often a well-suited place for tagging, since tags remain practically invisible to patients. Therefore, in our future work, we will further investigate the approach of tagging shoes, aiming to increase the recognition rate possibly using different RFID equipment with a higher frequency of reading or multiplexing.

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