ODINS: On-Demand Indoor Navigation System RFID Based

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Abstract. This paper presents an On-Demand Indoor Navigation System (ODINS) based on RFID technology. ODINS is a distributed infrastructure where a set of information points (Fixed Stations - FS) provides the direction to a user who has to reach the destination point he/she has previously selected. ODINS system is proposed for residencies hosting people with mild cognitive disabilities and elderly but it can be also applied to structures where people could be disoriented. The destination is configured at some reception points or it is a predefined (e.g. the bed room or a selected "safe" point). The destination is associated with a RFID disposable bracelet assigned to her/him. The path is algorithmically computed and spread to all FSs. Every time the user is disoriented, she/he can search for the closest FS that displays the right direction.
FSs should be located in strategic positions and provide a user-friendly interface such as bright arrows. The complexity is "system-side" making ODINS usable for everyone.

Keywords. RFID, Cognitive disability, Indoor Navigation, way-finding.

1. Introduction

ODINS was developed thinking of people with mild cognitive impairment, elderly and anyone visiting "environments" they do not know.
Mild cognitive impairment (MCI) is an intermediate stage between the expected cognitive decline of normal aging and the more serious decline of dementia. It can involve problems with memory, language, thinking and judgment that are greater than normal age-related changes.
For people with these issues, the way-finding task can be particularly difficult but at the same time of the utmost importance in ensuring a minimum level of independence in those that can be ordinary activities, such as go to hospital. So, assistive technology for wayfinding will significantly improve the quality of life.
Normally the way-finding encompasses all of the ways in which people orient themselves in physical space and navigate from place to place. Sometimes, the environment is unfamiliar and the people need to find a goal without the help of a previously acquired mental map. They depend on external information or what Norman [1] calls knowledge in the world. Such knowledge resides in the environment and is communicated through signs, guidance systems, and architectural clues. The ability to maintain orientation within the spatial environment varies widely between individuals. This depends greatly on the capacity of the individual to use the environmental information that has to identify a reference system. This is known as people's spatial ability and it depends mainly on the following four interactive resources: perceptual

capabilities, fundamental information-processing capabilities, previously acquired knowledge, and motor capabilities [1]. This ability is a necessary prerequisite for people to find a way from an origin to a destination.

However, for people with cognitive impairments (from week to severe) and elderly people – our target - the first three resources are generally limited. According to Lawton [2], the experience of disorientation might be expected to enhance anxiety about performing way-finding tasks.

The easiest way to assist people in way-finding task is the use of fixed signboards, which provide information for orientation. This approach shows some well-known disadvantages: it could be difficult or confusing to choose the direction within a set of possibilities written on the same panel, the final destination is not reported on the panel, the indications are coarse grains with respect to the details the user needs and do not report the detailed destination the user is looking for. Another issue related to this system is its maintainability, i.e. adapt the signs to changes in the dislocation of the rooms.

Technologies such as RFID, High Sensitivity GNSS, Bluetooth, and WiFi have been used to address this goal but they usually require the final user to deal with an application running on a mobile device. In this case the problems are related to the maintenance and power consumption of the mobile devices and above all to the usage of them and their software. This second issue is particularly critical for our target because of the cognitive impairments and/or for poor habit of using technological devices, as is in general the case for elderly people. In particular the user interface of this kind of assistive technology is as crucial as the underlying implementation and localization technology [3].

Our proposal aims to get over all these barriers providing an on-demand service which peculiarity is the usability.

2. Previous Work

The problems of indoor navigation and indoor way-finding have been widely discussed in literature from the technological point of view by focusing in general on the accuracy of localization rather than simplicity and usability of the proposed systems. A lot of researches have been done in systems that require the user to use mobile devices such as smartphone, PDAs or similar to process signals coming from the sensor network in order to compute and visualize the path [4] [5]. These approaches make related systems almost inconvenient by our target users because of the ability to use the device that is required to them.

Therefore, the paradigm has been reversed: instead of using a concentrated navigation system, the navigation information is distributed on the field and is made available to the user on demand. In this way, the user does not need to use the any mobile device and he/she can move freely in the environment.

Other indoor navigation systems based on RFID are focused on the estimation of the user's position in order to provide a continuous tracking [6] [7]. The goal of the project is not to track the position but to provide information to the user about his/her specific direction and path.

Some studies have been already done considering our target and/or RFID technology [8] [9] [10]. In [8] the system is based on the use of PDAs and it has been tested on people with different level of cognitive impairments. As mentioned by the author, some participants had difficulty in managing the PDAs and had difficulty in understanding how to interpret a photo shown by PDAs. In addition, most of the participants had a high level of education. This supports our thesis about the difficulties in the use of mobile devices.

In [9] the proposed system is based on NFC (Near Field Communication), which is a bidirectional short range wireless communication technology. NFC technology is based on Radio Frequency Identification (RFID) technology and can operate in card emulation, reader/writer, and peer-to-peer operating modes where communication occurs between a mobile phone on one side, and an NFC reader, a passive RFID tag (NFC tag), or a mobile phone on the other side respectively. The system is an indoor system guiding the user within a building, providing information – e.g. "go straight ahead for 50 meters" - by means of a mobile device, according to the position detected by a set of NFC tags spread along the route. There is a possibility that the user may get out of the route. In this case, the application computes a new shortest path to the destination. Therefore the system requires the use of a mobile device (smartphone, tablet, …) and it could be a limitation. Moreover, this system performs a continuous tracking of the user and so it requires a complex infrastructure.

In [11] the authors proposed the design and development of system based solely on the capabilities of a modern smartphone equipped with accelerometers, compass, camera and Internet connectivity.

Some studies have been done in the context of assistance to blind people [10] [12]. In [10] an RFID-based system for navigation is proposed. This system relies on the location information on the tag, a user's destination, and a routing server where the shortest route from the user's current location to the destination. The navigation device communicates with the routing server using GPRS networks. Finally, the directional information are sent to an external navigation device equipped with a speaker, which is held by the user. Obviously, in this context the usage of a mobile navigation device is required. ODINS is not addressed to people with this disability.

3. The System Architecture and Functionality

An Active Reader Passive Tag (ARPT) system is characterized by four properties: flexibility, low price, low energy and, short range of sensibility [13]. While the first three properties are significant for a vast set of applications, the short range of sensibility is particularly noteworthy only for some of them where the proximity is an important information factor. The proposed system, ODINS, is one of them; in particular, it implements an on-demand service where the "answer" to the user is given when he/she is in contact a fixed information point (**Fixed Station** - FS). In this way the RFID code, univocally associated with an user, is detected only when the tag is very close to the FS reader that, in turn, returns the direction, the position, and any other information the system is programmed to provide. Furthermore, the contact between tag and reader solves the problem of simultaneous requests avoiding false or misleading response.

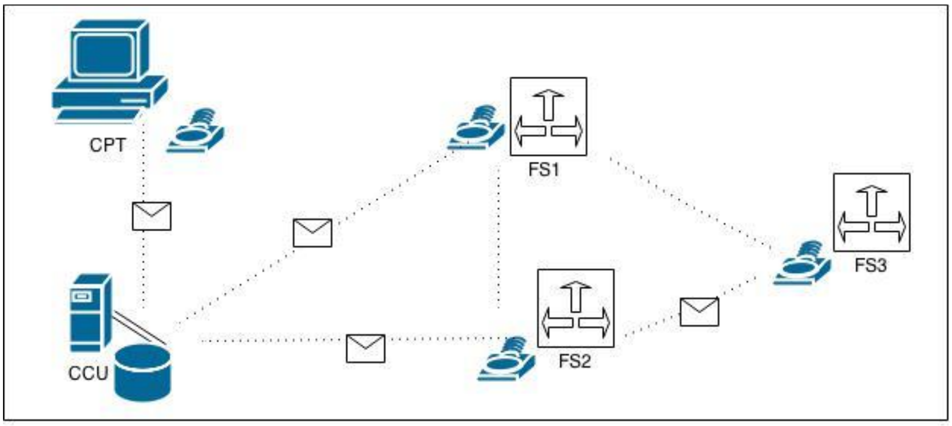

Figure 2. Infrastructure.

The system infrastructure is characterized by a **Central Coordinator Unit** -CCU- gathering the information "user-destination". The destination of a user is programmed using a **Configuration Points Terminal** -CPT- (CPTs are in some key points in the center) and forwarded to the CCU which, in turn, broadcasts it to all the fixed stations. It is worth-noting that FSs are located in strategic places of the structure like cross-road, the entrance of each building or points where there are more than one possible routes to choose.

CPT terminal allows the user (or specific personnel) to associate a final destination to the RFID code. Each CPT provides a user interface and it uses an RFID reader: the read RFID number is associated with the selected destination. The data is sent to the CCU (format: <tagID, destinationID>). The CCU receives the data (<tagID, destinationID>) and using a specific routing algorithm, computes the local direction that each single FS has to show, according to the destinationID. The computed information is successively transmitted to each specific FS through the communication infrastructure. Each FS locally stores the information concerning the local direction for every registered tagID and this information is preserved until the ID exists or the information is rewritten. It is worth noting that, depending on the service provided by the system, the suggested direction can be also accompanied by other information locally available (e.g. the name of the building or direction details). After detecting and reading the tagID, the FS looks for the local direction stored in its lookup table and shows the direction to the user.

All the components of system (i.e. CCU, FS and CPT) are connected in a fully meshed network. This type of network is flexible and self-configurable allowing the possibility to add /remove nodes. The FSs can be spread freely in the buildings, as long as each one is within the radio-frequency range of at least one other FS. The network is designed to be self-configured and allows point to point communication using broadcast messages. Currently, system is based on Zigbee protocol. The deployment of the infrastructure produces as output a table where for every FS the areas reachable from it are reported. These areas can be reached directly starting from the given FS. Furthermore, for each FS are reported the other FSs reachable by it. Starting from this information and from those given by the map of the building, the CCU can compute the best path that allow you to reach the final destination starting from the reception. Then the CCU computes the local directions to send to each FS, according to the previous computed best path. The message (payload) that has to be sent to each FS has the following structure:

idFS	idTag	direction

Table 1. Example of message.

where, *idFS* is the id of the FS (2Byte - 2^{16} possible FSs), *idTag* is the id of the Tag (4Byte – 2^{32} possible users in system in the same time), *direction* is normally, just, forward, right, left, back (1Byte - 2^{8} possible local directions).
When a FS receives a message it checks the idFS. If it is equal to FS' ID, then FS stores the message in its table, otherwise it forwards the message in the network.

Considering for example the following study case:

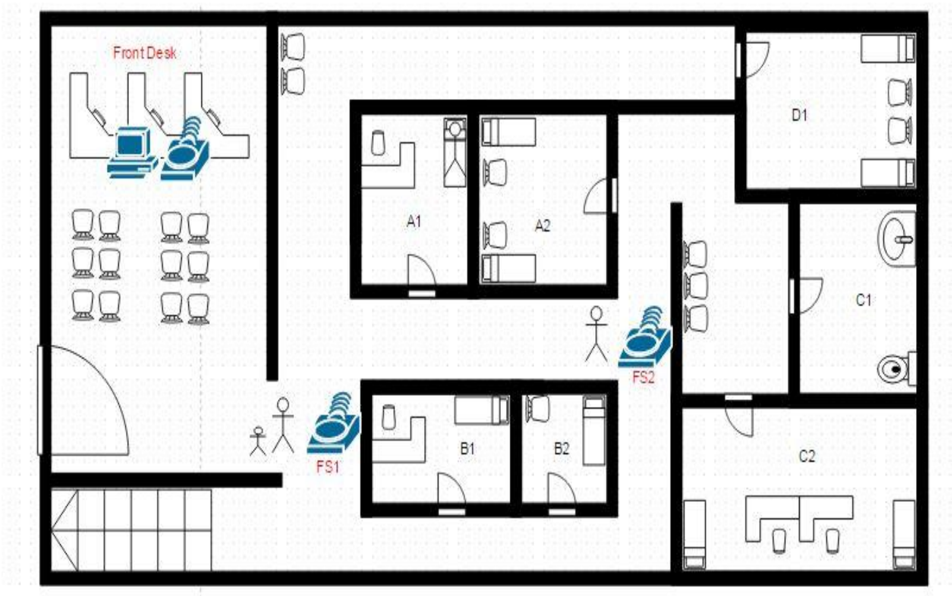

Figure 3. Plan

Dest	FS1		FS2	
	Dir	Cost	Dir	Cost
A1	Fwd	1	Back	2
A2	Fwd	5	Left	1
B1	R	1	Right	5
B2	R	3	Right	1
C1	Fwd	7	Left	4
C2	Fwd	8	Left	5
D1	Left	6	Back	8
FS1	X	X	Back	3
FS2	Fwd	3	X	X
Floor2	Right	3	Fwd	6
BuildB	Back	2	Fwd	5

Table 2. Routing table

To go from FS2 to B1 it is better to pass through FS1 (1+3<5), i.e. indirect local route. If Tag01 wants to go in B1 the following messages will be computed and sent to FS on this floor:

1	FS1	Tag01	right
2	FS2	Tag01	back

Table 3. Result messages

4. Results

The system has been tested in one building of the Politecnico di Milano Como Campus on 12 volunteers both male and female. The average age of participants was 66 years.
A disposable bracelet was assigned to each guest to reach different rooms starting from the meeting area located at the 3rd floor of the building. The overall test was held over two floors and users had no knowledge about the environment.
The installed system consists of 1 CCU, 1CCT and 6 FS.

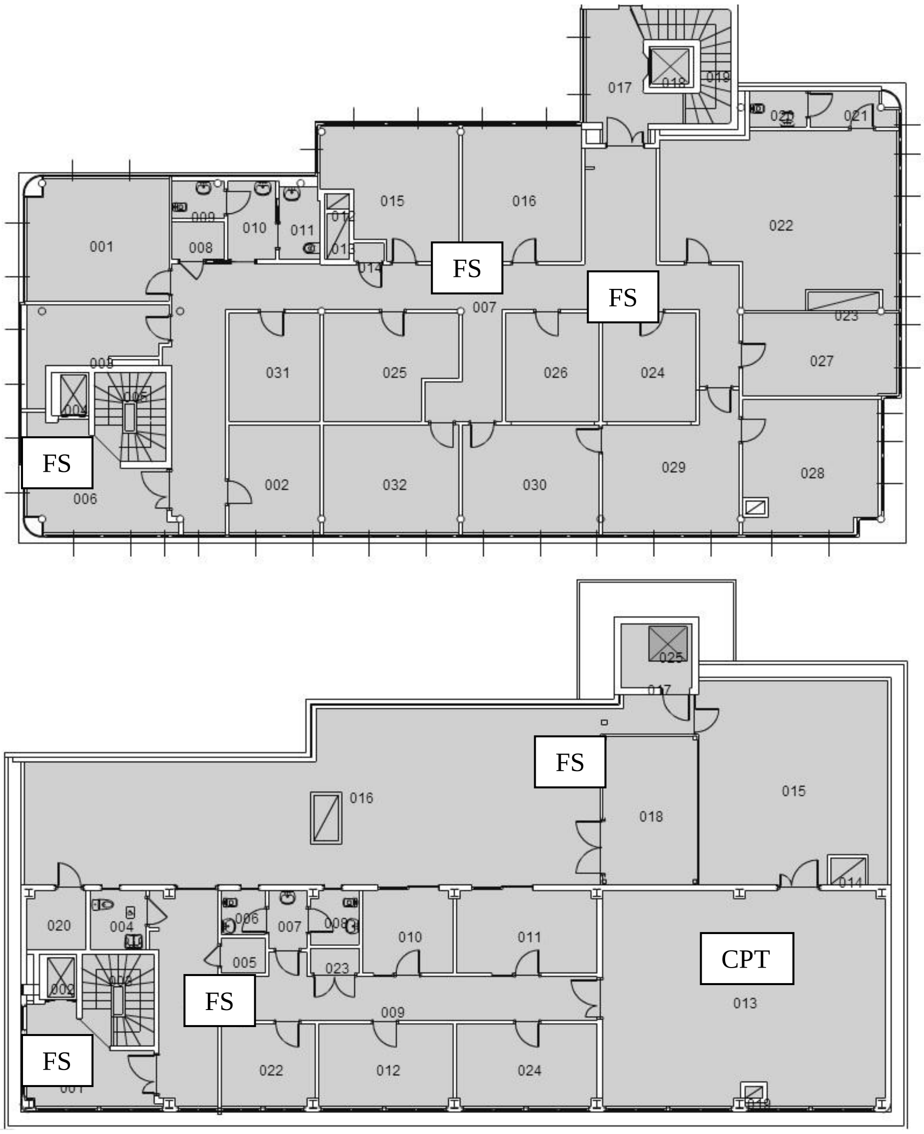

Figure 4. Plans of test

At the end of the day, all participants had to fill out a questionnaire composed by 7 questions giving a score between 1 and 4.

1. Do you think that this system is useful to reach the destination?
2. Do you think that the information shown by the FS was intuitive?
3. Do you think that the system is easy to use ?
4. Was the information provided by the system correct?
5. Were the fixed stations in the right place to help you in way-finding?

All participants successfully reached the assigned destination.

Question	No	Partially	Yes	A lot
1	0%	8%	76%	16%
2	0%	0%	25%	75%
3	0%	16%	42%	42%
4	0%	0%	84%	16%
5	0%	16%	76%	8%

Table 4. Questionnaire results

The results obtained by the test are very positive, however the environment was not as huge and complex as those in which ODINS can work.

5. Conclusions

A new Indoor Navigation System helping people to find the way inside buildings and large areas has been presented. In particular, the system is thought to help elderly and people with mild cognitive disabilities to recover themselves from brief moments of disorientation. The first peculiarity we have introduced is that the system is On-Demand. This means that ODINS is not an intrusive assistive technology, so the user can decide when and where to use it. In fact, to reach the final destination it is not required to ask information to each FS, but only when the user needs it, since each FS has local directions that do not depend on those of the other FSs. In fact each local direction depends only on the final destination that user needs to reach and on the physical position of the FS.
Another important peculiarity is that the proposed system does not require any personal technological device (e.g. a smart phone, a PDA) on/for the final user except a disposable bracelet; this aspect makes the system particularly user-friendly and accessible from everyone. In fact, the bracelet does not require any knowledge about how to use it, the user has only to wear it and bring it closer to the FS when he needs. Furthermore, due to the absence of an external device, the availability of the service does not depend on the user, e.g. the user doesn't need to worry that his device works in order to use the system.
ODINS uses a RFID technology, a wireless infrastructure and a simple and low cost micro controller platforms making the system a cheap solution and easy to install. The only thing to ensure is that every FS has the power supply. The proposed system is easily scalable, because of the use of ZigBee protocol that automatically organizes every wireless module in a mesh network. This allows installing easily new FS, which will be automatically added to the wireless network if it is within range of at least one existing station that will act as a router for the newest one. Obviously, the new FSs must be inserted in the lookup table used by the CCU to compute the path.
To conclude, from all the above-cited peculiarity we can confidently say that the complexity is system-side and it is hidden from the final user: this makes the system easier to maintain and simple to use.

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