Multi-Agent Intelligent Planning Architecture for People Location and Orientation using RFID

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Abstract

The new advances in the Information Communications Technology (ICT) allow expanding the electronic communication networks into an objective environment. These techniques can be used to help users that have to go to a building with several floors, corridors and departments, to get its right location and orientation. The problem gets more complicated when there are a high number of visitors with temporal constraints. Typically the lack of information and signs to guide the user complicates this task. A typical example is a hospital where the patients have scheduled doctor's appointments and in some cases severe movement difficulties. A possibility for solving this problem is to equip the building with an intelligent system for user detection and orientation.

In this paper we present a solution that uses a detection and a location system based on wireless technology and Artificial Intelligent techniques to plan and inform about the paths the user can follow.

1 Introduction

The development of new Information and Communication Technologies has originated new posibilities for changing the traditional way of performing business, commerce or education. The consequence of the application of such technologies is a change on the way of thinking, living or working. One of the recent research areas is focusing on the integration of different technologies to the environments where we live. Places such as the houses, the offices or public institutions will be able to recognize us and to adapt to our taste, needs and preferences as soon as we come inside them.

When the Artificial Intelligence (AI) is framed in the environment of the Ubiquitous Computing [9] (also called Pervasive Computing or Ambient Intelligence), to its characteristics and habitual challenges one must add an additional function, the experience of the user. To the typical objectives of an AI approach one must add the maximization of this new function. It is a highly subjective function, very related to the comfort and the perception of the user. The processing of the problem is even more interesting when we apply this kind of technologies not to a user, but to a group of them, many times with completely different needs.

Although the concept of Ubiquitous Computing can seem futuristic, there are already some academic and industrial initiatives that begin to show the strong current tendency to incorporate this type of techniques. Among the objectives it intends to obtain, we can mention:

- Facilitate the use of devices to people that find some difficulty in using them. One of the barriers that most of the person of average and high age have is the difficulty to use the ICTs. The Ubiquitous Computing intends to facilitate its use by means of the voice or the view as replacement to the keyboards.
- Offer greater comfort to the users incorporating new technologies.
- Offer security thanks to the fact that the environment is capable to recognize them. It can guarantee the security set against possible intrusions.
- Personalization of their inclinations: the environment adapts to them and not the other way round.

One of the main problems that one has to face when visiting large surfaces of high affluence level of people, as for example hospitals or public administrations, is the lack of information and signs that can guide them in a customized, efficient, and fast way to the place they have to go. Generally, the user has to face by him/herself an immense and unknown environment in which he feels unprotected. The queues around the information desk as well as the frequent stops along the way to ask the location of the place, they are sure in the mind of all. In this paper we present a solution to this type of problems.

The application to solve this problem, called SIGUEME (Sistema Inteligente de GUiado para Entornos Multiusuario Extensos - Intelligent Monitoring System in Big Multiuser Enviroments)[1] integrates both software and hardware elements. We have used the RFID passive technology [4] and AI techniques, in particular planning and a scheduling [13] for the orientation and the guiding of the patients. All these elements are combined within a global system that coordinates and controls all the assembly of elements. This system has been implemented satisfactorily in a scale prototype that has successfully proved its viability and good performance.

The paper is structured as follows. Section 2 describes the scenario where we have tested our system. Then, section 3 presents basic concepts of the RFID technology. Next, section 4 describes the philosophy we have followed to located the RFID sensors. In section 5 the architecture of our system is presented. Then, experimental results are shown. Finally, related work and conclusions are outlined.

2 The Scenario

We have chosen a concrete example of a big surface with people going back and forward: a medical centre. This framework covers most of the situations than can be found when testing with people inside a building.

From a general point of view the scenario is as follows. When a patient arrives to the medical centre, he usually goes directly to the information desk. There, the receptionist identifies him and verifies in the computer the appointment(s) for the day. Once checked, the user data are introduced into the system and the patient is provided with an individual RFID card. He is informed about the path he has to follow to get to the corresponding waiting room. The user is also pointed out on the different elements in the building, for helping him to reach the destination (usually a waiting room). At the same time, the system generates a track for the visitor to get his objective in the best way

[1] In Spanish SIGUEME means Follow Me

possible.

After that, when the person walks inside the building, it goes across the doors, corridors, stairs and so on and it passes through the different RFID detectors without realizing it. But, each time he goes through a RFID arch the system detects him and calculates his position. Considering the sequence of detections, the system gets the directions and checks if it is adequate or not. Since the program knows the position of the patient, it can provide the information needed to help him to reach his destination. This information is displayed on several screens located at geographically strategic points. When a person gets the destination (the right waiting room) the system warns of his arrival to the corresponding medical service and incorporates him into the correct waiting list.

At this point, the program will wait until the patient exits the practice room to point him again to a new surgery room or to the way out. The user will be guided as many times as necessary until he ends all the appointments scheduled for that day. After that, the system will steer the patient to the building exit. There, he will give the RFID card back to the hospital clerk and he will be taken out of the cycle.

During the movements inside the building, the visitor can get lost. In that case, the system will detect this situation and will correct the mistake. In order to solve that problem the system will be called again, and a new plan for the lost patient will be generated. Then, it will be reported in the usual manner.

To deal with all of these tasks, we have developed and tested a complete system. It is composed of five subsystems that are described in section 5. Before that, we describe how RFID works and how we distribute the RFID sensors along a building.

3 RFID

Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders.

An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification using radio waves. RFID tags come in three general varieties.

Passive tags require no internal power source, thus being pure passive devices (they are only active when a reader is nearby to power them), whereas semi-passive and active tags require a power source, usually a small battery. Passive tags have practical read distances ranging from about 10 cm up to a few meters, depending on the chosen radio frequency and antenna design/size. Due to their simplicity in design they are also suitable for manufacture with a printing process for the antennas. The lack of an onboard power supply means that the device can be quite small: commercially available products exist that can be embedded in a sticker, or even under the skin.

Active tags due to their on board power supply, may transmit at higher power levels than passive tags. Communications from active tags to readers is typically much more reliable. In turn, active tags are generally bigger and more expensive to manufacture. Many active tags today have operational ranges of hundreds of meters, and a battery life of up to 10 years.

Active tags may include larger memories than passive tags, and may include the ability to store additional information received from the reader.

Semi-passive tags (also known as battery-assisted), are similar to active tags in that they have their own power source, but the battery only powers the microchip and does not power the broadcasting of a signal. An additional application for the battery is to power data storage. Semi-passive tags have three main advantages: (1) Greater sensitivity than passive tags. (2) Longer battery powered life cycle than active tags and (3) It can perform active functions (such as temperature logging) under its own power, even when no reader is present for powering the circuitry.

RFID is becoming increasingly prevalent as the price of the technology decreases. RFID tags are being used in passports issued by many countries, transportation payments, product tracking as a replacement for barcode tags, inventory systems and supply chain management, and many more. Intensive effort is being put in exploring RFID capabilities as a replacement for barcodes, telemetry applications, and people identification (i.e. patients and hospital staff [5]). There are also some problems and concerns associated with RFID. For instance, the frequencies used in the USA are currently incompatible with those of Europe or Japan and no emerging standard has yet become universal. Also, there is a primary security concern surrounding technology, posing a risk to both personal location privacy and corporate security. A big controversy has been created around implantable RFID tags; now they are used for animal identification and some administrations have approved their use in humans.

4 The Building Description

In this section we present the way we have used to describe a building and how to divide it into different parts. The main idea is to make small rooms in the building and follow the movements of the people across them. Like that, we can know where each person is and what are their moves.

In order to follow the people movements inside a building, we use a set of RFID detectors placed at strategic points. It is very important to choose the suitably detectors locations for covering the whole building. In addition, for economic reasons, it is mandatory that the number of detectors is as small as possible. Figure 1 shows the building layout. When the RFID frame is completely decided and each detector is located at the correct place, the building is divided in zones (rooms between the detectors). Not all the zones are equal. They can have different features and functions. In this work, we have considered three different zones: input zones, transition zones and destination zones.

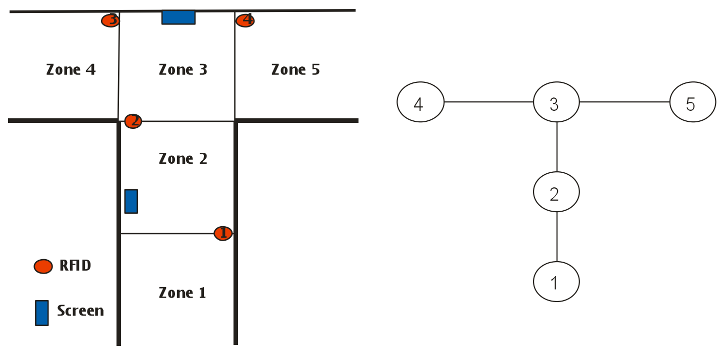
Input zones (Zone 1 in Figure 1) These are the first ones reached by the patients when they arrive to the hospital. They are outside any detector and they house the admission office. Our experience recommends only one of these zones and consequently a unique registration desk. So, in our prototype there is only one input zone with a computer terminal where all the system information and assistance facilities are installed. When a patient arrives at this zone, a hospital clerk identifies the person, provides him a RFID card and introduces the user into the system.

Transition zones (Zones 2 and 3 in Figure 1) These are intermediate zones between two or more RFID detectors and they contain the information screens. The patients have to go across them to get their destinations. They are typically corridors, stairs or crossing sectors. In these zones the system detects the input and output of each RFID card and consequently, can identify the person who carries it. This information allows the program to know the location and even the movement direction of the card owner. These two data are crucial to elaborate the information needed for guiding the user towards its destination. This information is provided to the patient by means of the screens located in these transition zones.

Destination Zones (Zones 4 and 5 in Figure 1) These areas represent the medical services waiting rooms. Besides, when a user is on its way out, the input zone plays the role of a destination one. All these zones should have enough local information so that a patient realizes that he has reached the destination. When this happens, the program adds the user information into the doctor waiting list and the system assumes that the visitor will stay there until the doctor sees him. When the doctor calls the patient, the system provides the whole information about that person. Then, it is up to the doctor to update the patient medical background. Before the patient leaves the practice room, the program will require a new destination. This could be: the hospital exit or another medical service for the same day or another day. If the next destination is the exit or an immediate appointment, the system will provide a new path plan in order to guide the user to its destination. Our system will manage all the data and will control the movements and instructions for each patient. There is not limitation on the amount of RFID cards the program can handle.

Once the building is divided into zones by the RFID detectors we can describe it by a graph. In this graph, zones are the vertexes and detectors are the edges. That is, two vertices/zones are connected if there is a RFID arch between them. The graph is an undirected one and it could not be simple. It has not isolated vertexes and all the vertexes corresponding to transition zones have degree equal or bigger than two. A vertex with degree one is normally the input zone or a destination one. We use the adjacency matrix to store this graph in the system. But, instead of using the number of edges connecting two different vertexes (which is always one), we use the RFID detector number between the corresponding zones.

For example, let's consider the part of the building represented in the right side of Figure 1. The resultant graph is shown in the middle of the figure and the corresponding adjacent matrix on the right.



	1	2	3	4	5
1		R1			
2	R1		R2		
3		R2		R3	R4
4			R3		
5			R4		

Figure 1: The building layout, the graph representation and its adjacent matrix.

5 The Architecture

In this section we describe all the elements of the SIGUEME system [2]. The whole system is composed of the following subsystems:

- The Control Subsystem manages and controls the information and communication with the rest of the subsystems.
- The Detector Subsystem is in charge of detecting the users along the building by means of the RFID cards.
- The Reasoner Subsystem guides the user inside the building.
- The Information Subsystem allocates the information needed for the other subsystems and the users.
- The Visualization Subsystem represents and visualizes the guiding information in the corresponding screens.

Figure 2 shows a diagram of the system architecture and how the subsystems interact among them.

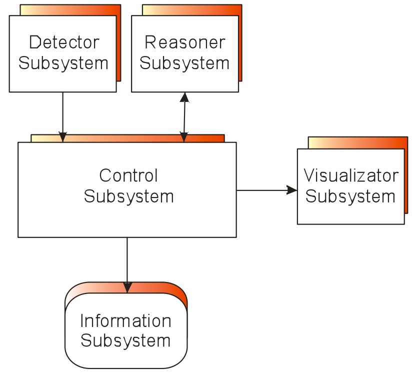


Figure 2: The SIGUEME architecture.

5.1 The Control Subsystem

The Control Subsystem is in charge of controlling the other subsystems. Besides, it has to control the every day patient data and prepare a daily doctor's appointments list. It also knows the RFID available cards and the ones in use at every moment. This subsystem is operated in a computer with its main terminal placed at the admissions office desktop. At the beginning of a working day this program creates a list with all the patients with appointments for that day. When one of these patients arrives to the hospital, this subsystem has already available all its data. At that moment, when the visitor arrives to the admission desk, the operator identifies him and introduces him into the system. Simultaneously, a RFID card, with a unique number, is given to him. The card number is also notified to this subsystem and it identifies unambiguously its owner inside the building. The patient must keep this card the whole time he stays inside the building and he should return it when he definitely exits.

At the same time, this subsystem finds out the patient destination and asks the Reasoner Subsystem for the path, across the hospital, for the user. When the Reasoner Subsystem gives its answer, the Control Subsystem records it and, from that moment on, it takes care of guiding the person towards its destination.

To deal with this task the Control Subsystem registers and distinguishes each one of the patient's RFID card. This strategy provides the program with the information about where all the persons inside the hospital are located, and even what are their moves. That is, this subsystem controls the patient's activity in the medical centre. When a user goes through a RFID detector the Control Subsystem calculates if he is in the right way or not. If a patient loses its track, the subsystem recognizes the situation and call the Reasoner subsystem to generate a new plan.

When a person arrives to the destination point, the system finishes its orientation job, includes him into the corresponding patient list and waits for the user to be done with the appointment. After that, a new destination is given to him. This can be the hospital exit or a different medical service either for today or for another day. In any case, the Reasoner Subsystem will guide the person to the new medical service or towards the centre way out. On his way out, he will return the RFID card and the operator will take him out of the system. Finally all the information produced by the person will be recorded. If a new appointment for another day was given to the patient, the system will update its corresponding database. Figure 3 shows the Control Subsystem main window.

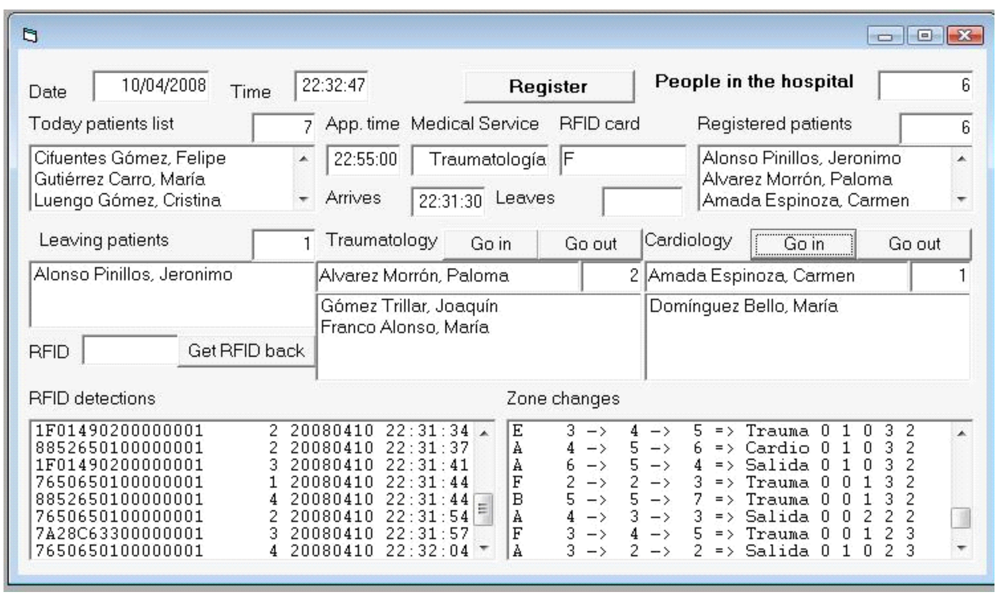


Figure 3: Control Subsystem main window.

5.2 The Detector Subsystem

The aim of this subsystem is to detect the persons moving in the building. It consists of a group of RFID detectors placed at several points in the building and based on passive tags (see section 3 for more information about RFID types). They give a signal when a patient with a RFID card passes closed to them. This signal is decoded and sent to the Control Subsystem.

In this work we have developed two different detector subsystems. The first one is a hardware prototype that scales an actual building with one input zone, two transition zones and two destination ones. This scale model uses four RFID short range detectors and is connected to the main computer by RS232/RS485 port. This allows us to set the detectors a thousand meters away from the Control Subsystem. Reproducing the patient's movements inside the building is as easy as passing the RFID cards over the small detectors and recording the signal produced. The figure 1 shows a sketch of this scale building layout.

Although this strategy reproduces very faithfully the detection process, it is not useful at all if we want a statistically significant amount of data for testing our system. With this aim we have developed a Montecarlo simulation program that generates patient movements across the RFID detectors and works in the same way that the scale hardware model does. It has even the advantage that it can be adapted to a new building topology in a faster and easier way that the hardware prototype (see section 6).

5.3 The Reasoner Subsystem

This subsystem is composed of PIPSS (Parallel Integrated Planning and Scheduling System) [13]. It is a system that integrates AI planning and scheduling techniques. It is based on HPP (Heuristic Progressive Planner) [14] and scheduling algorithms [3]. Its open architecture using object oriented interfaces allows the implementation and execution of different planning algorithms, scheduling methods and planning and scheduling integration schemes. PIPSS has two kinds of planning searches: enforced hill-climbing and greedy best-first search. One type of scheduling algorithm called ISES [3] or the possibility to disable scheduling. And also, two types of planning and scheduling integration schemes: scheduling after planning or scheduling inside planning. Although this planner can perfectly handle temporal and resource constraints, in this first prototype we haven't considered deadlines for the patient appointments.

The Information Subsystems translates all the patient and building information into a suitable format for input to the Reasoner Subsystem. That is, the initial zone, the RFID Id given to the patient, the target zone and the connections between the different parts of the hospital. So, if a person gets lost inside the building, the system is able to detect the situation. At that moment, the Reasoner Subsystem is called and a new plan is generated for the lost patient. This new plan will be translated in new screen messages managed by the Visualization Subsystem to guide the patient. The Reasoner Subsystem will produce as many times guiding plans as needed until each patient achieves the destination target. Finally, when a patient has accomplished its whole medical schedule, the Reasoner Subsystem will generate a new guiding plan to guide him right to the exit.

5.4 The Information Subsystem

This subsystem is in charge of keeping the whole information of patients, destination goals and building information in the format understandable for each subsystem. It uses two data sources: the building description and the patient information. It is very important that these data can be given by means of external files (although it can be introduced/modified by hand to the system), because it makes possible to change either the building or the patients information without modifying the software. The first file basically consists of the graph building adjacent matrix, where all the zones and detectors are recorded. The second one consists of a file with all the information about patients and their doctor's appointments. The application allows importing this file with a predefined structured that will be saved in the database. This database is a stable one and grows when new patients are added.

This subsystem also saves the following data: every signal produced by the RFID detectors, the doctor appointments for each patient, the guiding plans for each patient and the messages given by the Visualization Subsystem. Later on, we can analyze the system behavior and find deficiencies on i.e. the messages sent to the users or in the localization of the detectors inside the building thanks to the saved information.

5.5 The Visualization Subsystem

It is in charge of sending the corresponding guiding information to the screens where the user is close to. It must be able to send the right messages to the correct places to help all the visitors simultaneously. It is composed of a set of screens located at the building transition zones. In these devices appear the appropriate information for guiding the patients within that zone. The messages in the screen show to each user the direction he has to follow according to the guiding plan generated by the Reasoner Subsystem. The information he visualizes is: the patient's name and the direction. In our prototype we have chosen four different instructions: straight, turn right, turn left and go backwards, followed by the corresponding arrow. Any other indications for the same patient will be erased from any previous display devices.

In massive transition zones (i.e. zones very closed to the hospital entrance and used by almost everybody), screens can show information about how to reach the different areas of the building, instead of repetitive specific guidance information of tons of individual patients.

The performance of the screens depends on the number of display lines the monitor has. If the number of patients in a transition zone is bigger than the monitor capacity, the monitor will be properly refreshed so that all people can get their respective information. The Visualization Subsystem will take care of which monitor has to show a specific message and when a particular monitor needs to be refreshed.

6 Experimental Results

In this section we describe the simulator built to test the SIGUEME architecture and the results obtained by PIPSS in the hospital domain when it is compared to other planners.

6.1 The simulator

It is a program that simulates the patient passage through the different RFID detectors located in a concrete set of places inside a building. It is based on the Montecarlo method [15, 16] and it only needs the building subdivision on zones. That is, the building graph adjacent matrix.

It has been developed to provide exactly the same detection data the hardware RFID device would supply. We can very easily collect a statistical significant amount of patient interactions and without moving by hand, the RFID cards over the short range hardware prototype detectors. Software simulation allows us to avoid errors that could occur by hand simulation such as to forget a RFID card during the experimentation or to go across two different not contiguous detectors. In this first approximation we have presumed that there are no lost detections. The program assumes that the patients are able to find and understand the messages supplied by the information screens without demanding any other kind of assistance. Nevertheless, there is a certain chance that the person loses the information provided by the monitors and there is a lack on orientation that, in some cases, could get him out of the planned track. This situation can be tested by the simulation program with several levels of disorientation probabilities.

The simulator takes into account two different orientation sources. (1) The building layout (what we call ”geographical orientation”). This means that if a person is walking along a corridor there is a higher probability to follow the same direction than to go backward. In the same way, when the person reaches an intersection, there will be different probabilities for each possible way. To deal with the geographical source, we have assumed a fixed probability distribution for each building zone that has two or more contiguous one. (2) The set of the information screens. We can easily admit that a patient has a certain probability of misunderstanding the information the system provides him. Obviously, this situation will depend on the particular person and the monitor position. However, in our first model we have assumed that all the patients in all zones have the same probability P of getting the right direction. The two information sources are linearly combined in such a way that when P=0 we only have the geographical probability distribution, and if P=100 the patient never loses his track. The visitor movements are simulated applying the Montecarlo method on that probability distribution.

The simulation program begins when a patient is introduced into the system. A new item in the simulator list is added containing the personal information, the time the person entered the building or passed through the last detector, and the estimation time to pass the next RFID detector. This estimated time is the addition of a fixed minimum time between detectors and a random extra one. When the program achieves this point a new zone is assigned to the patient by the Montecarlo method described previously. Then, the corresponding simulator list item is updated and a new estimated time is calculated. This process goes on until the patient either arrives to the proper waiting room or gets the admission desk before leaving the medical centre. In the former the system will take again care of the visitor's new destination. In the latter, the user will be removed from the simulator list.

6.2 Results

The Hospital domain is a simple path planning domain where people move among the different parts of a building. Then, the building graph adjacent matrix is used to set the problems. The action of moving from one room to another is durative, so all the people can independently move in parallel.

Four planners have been tested against PIPSS. We have also used four different PIPSS settings, so it can be said that there is a total of eight planners. They are explained as follows:

- PIPSS-A: PIPSS with all the possible operators instantiated in the domain, enforced hill-climbing, ISES and sequential search.
- PIPSS-B: PIPSS with the operators instantiated in the relaxed GraphPlan heuristic [10], greedy best-first search, ISES and integrated search.
- PIPSS-C: PIPSS with the operators instantiated in the hadd heuristic [1], greedy best-first search, ISES and sequential search.
- PIPSS-ABC: PIPSS running three threads like the previous three configurations.
- LPG-speed [6]: non-deterministic planner LPG trying to achieve a solution as fast as possible.
- LPG-quality: non-deterministic planner LPG trying to achieve a solution with the lowest makespan (this modality cannot be launched more than once to get a better solution).
- CPT1 [20]: planning system for optimal temporal STRIPS planning with a distinguished Performance in Optimal Planning (Temporal Domains) at IPC'06.
- CRIKEY [8]: a temporal planner written in java.

There are two blocks of problems of ten problems each. In the first block, there is a map formed by a square of zones, with a length of 5 zones per side and they are connected in a such a way that it is possible for any person inside it to move between any two zones needing a maximum of 8 movements, so it can be assured that a solution with this value as its makespan could be found for any problem. The number of people in the first problem is 2 and 2 more people are added to any new problem of the block till there are 26 people in the tenth problem. The second block is similar to the first one, but its sides have a length of 25 zones. In this case, any problem could be completed with a makespan value of less than 49. The number of people in the eleventh problem is 8 and the last problem will have 32 people. All PIPSS modalities and LPG speed found a solution to all the problems, LPG quality solved 75% of them, CPT solved 50% and, finally, CRIKEY solved 45%.

The left part of the Figure 4 shows the accumulated execution times. CPT (until problem ten), PIPSS A and PIPSS ABC are the fastest performers, before LPG speed. Then comes PIPSS C, PIPSS B, LPG quality and CRIKEY.

The right part of the Figure 4 shows the accumulated makespan of the solutions. CPT and CRIKEY do not obtain enough results to be compared to the other planners. In this domain, PIPSS A, PIPSS B and PIPSS ABC are the best. LPG quality is nearly as good as them, but gets stuck in the problem fifteen. Then comes PIPSS C, which is near the first four. LPG speed is the last, getting quite big values. So we can conclude that PIPSS is the best performer (in time and makespan) in the hospital domain.

7 Related Work

There are several approaches to the problem of people moving inside a concrete environment [7]. Most of them are focused on representing emergency evacuations from buildings, aircrafts, ships or even cities. They are related to different simulation models based on the knowledge we have about

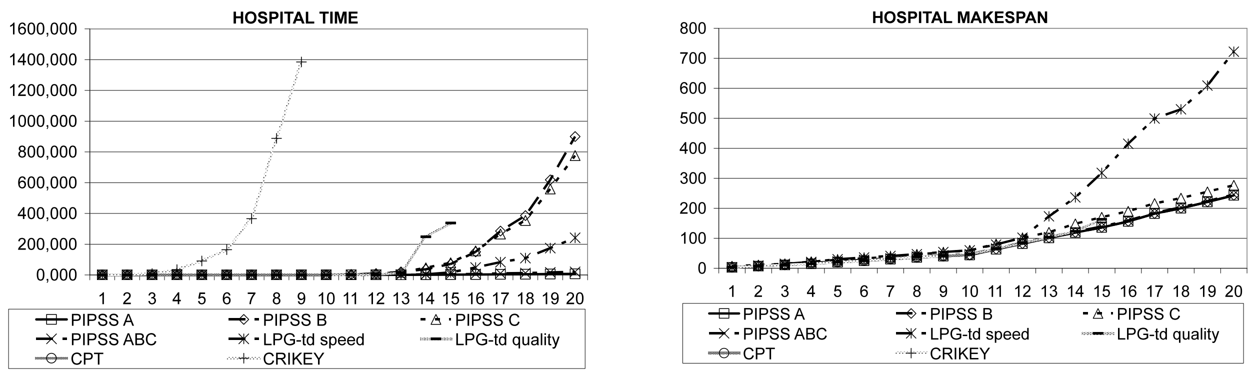


Figure 4: a) Execution time. b) Makespan in the hospital domain.

how humans behave in response to emergency information and/or life threatening events, as fires floods or earthquakes, such that they take protective and predictive actions.

One on these models has been applied to the EVACNET4 [11] system. It employs a flow-based approach that models the density of nodes in continuous flows. In that program the simulated physical environment is represented by a set of nodes that correspond to building structures, such as rooms, stairs, lobbies, and hallways.

Another program for simulated evacuation is EGRESS [18]. It uses a cellular automata approach that involves the discretization of space. It divides the floor in small cells and places each individual person into a concrete one. Then, when evacuation is simulated each person moves by ”step-times” form one cell to another.

The agent-based programming technique has been also used for simulated evacuation programs. One of these programs is SIMULEX [19]. Its advantage is that individualizes the movement of each person in the building. Besides, the program also takes several other factors into account as: the physical proximity of other evacuees, the shape of the building structure, and the influence of sex and age.

All those simulated systems have proved they have a good technical behaviour. However, some critics have been made because they do not incorporate any of the social sciences approaches that could improve them significantly and provide new directions to simulated model of emergency evacuation [17].

One simulated system that incorporates this information about actual human social behaviour is EXODUS [12]. It is a agent-based system that furnishes the most complete set of social psychological attributes and characteristics for each one of its personal-agents. This set includes age, name, sex, breathing rate and running speed, among others. These agents also have a certain degree of familiarity with the building, agility, and even patience. The model deals with the movements of large numbers of persons inside a building towards the exits. It can also take into account the eventual delay of movement due to extreme heat or effect of toxic gases.

Our program is not related to people movements in hazard conditions but it can be adapted to include that performance if it were needed. In that case detecting evacuee movements, planning their paths and informing them about the building egress could be very useful.

8 Conclusions

In this paper we have described an application based on AI Planning and Scheduling techniques to solve the problem of guiding persons through large surfaces of high affluence level of people, as for example hospitals or public administrations. We have used the RFID passive technology to detect the users movements and to know in each instant their positions. This system has been implemented satisfactorily in a scale prototype that has successfully proved its viability and good performance. A simulator based on the Montecarlo method has been used to test the whole architecture.

In the future we want to optimize the problem of the number of detectors inside the building. We want to also add temporal constraints to the patient appointments.

Acknowledgments

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