An Integrated AI and RFID System for People Detection and Orientation

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ABSTRACT

A common problem that visitors have to face in big buildings, with several floors, corridors and departments, is their accurate location and orientation. The problem gets even worst when there are a big number of users and they have time constraints. A typical example is a medical centre where the patients have got scheduled doctor's appointments and, in some cases, severe movement difficulties. A possibility for solving this problem is to provide the building with an intelligent system for user detection and orientation. In addition, this strategy would allow to find and locate all the people inside the building and to carry out an individual search if it were necessary. This is the framework we have chosen in this article. We have developed a complete hardware and software system for people detection, location and orientation in this scenario. The hardware part of the system is based on the RFID technology and it has been successfully implemented in a fully operational prototype. The software uses artificial intelligence techniques, specifically planning and scheduling.

Keywords: Artificial Intelligence, Detection, Monitoring, Planning techniques, RFID.

1. INTRODUCTION

In this work we present an application containing software and hardware elements, which gives a solution to the problem expounded in the abstract. The whole system includes four different subsystems and a database. Figure 1 shows its layout.

For detection and location of the users in the building we use a hardware subsystem based on the RFID (Radio Frequency Identification) passive technology [2]. This is called detection subsystem. Added, and in parallel with this first one, we place the orientation subsystem. This part of the application employs the techniques of artificial intelligence [8], more concretely a planning and scheduling tool [3,7], for orientation and guiding of people [9]. A third element, the information subsystem, is made up of a set of screens take care of informing the visitors. All these elements are combined within a global system, the central subsystem, which coordinates and controls all the assembly of elements. The database stores all the information about the patients and their interactions with the system. It is divided in two linked parts: the general or main database and the daily one. The general piece stores all the relevant information about the patient personal and medical data. The daily one is generated every day. When it is created it contains the foreseen doctor's appointments for that particular day. Besides, all the interactions of each patient with whole system throughout the day will be also saved into it. That is: the operators' actions, all the signals generated by the detection subsystem, the plans generated by the orientation one, the messages appeared on the screens and the medical actions. At the end of the day some of these items will be saved into the general database.

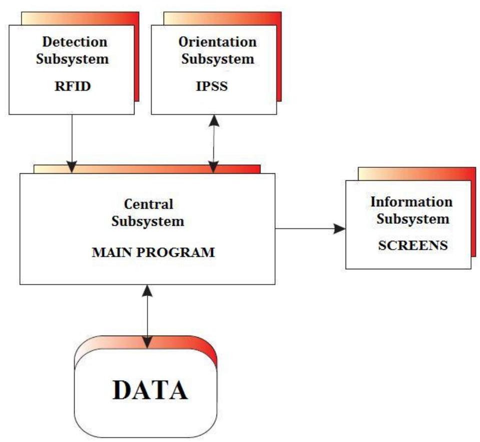

Figure 1. The whole system.

This layout has been implemented satisfactorily in a scale prototype that has successfully proved its viability and good performance. We have chosen a concrete example of a big surface with people coming and going: a medical centre. This framework covers most of the situations than can be found when trying with people inside a building.

From a general point of view the system works that way. When a day patient arrives to the medical centre he usually goes directly to the admissions office. There the receptionist identifies him, looking into the main database, and verifies in the computer for his doctor's appointments in the daily one.

When checked, the user arrival is registered in the system. At the same time, the patient is provided with an individual RFID card. From that moment on the program will keep an eye on him until the moment he leaves the building. Moreover, he is verbally informed by the clerk about the route he has to follow to get his medical service waiting room. He is also pointed out to the different elements (mainly the screens) in the building, for helping him to reach his destination (normally a waiting room). Simultaneously, and behind the scenes, the planner program generates a track for the visitor to get his objective in the best way it will be possible. Usually, the best means the shortest one.

After that, when the person walk in the hospital, he goes across the doors, corridors, stairs and so on and he passes through the different RFID detectors without be aware of them. But, every time he goes through a RFID arch the system detects him and calculates his position and, considering the sequence of detections, the system gets his movement's direction and checks whether it is adequate or not according with the plan generated by the orientation subsystem. Since the program knows the position of the patient it can provide him with the information necessary to reach successfully his destination. This information is displayed on several screens located at geographically strategic points.

When a person gets his destination (the right waiting room) the system warns of his arrival to the corresponding medical service and incorporates him into the correct patient waiting list. From that moment on the system will assume the user will stay there until the nurse called for him to be seen by the doctor. That is, the program will wait for the patient leaving the practice room with a new objective in the building and will be ready either to direct him again to a new surgery room or in the way out.

The user will be guided as many times as necessary until he finishes all the appointments he could have. After that, the system will steer the patient to the building exit. There he will give the FRID card back to the hospital clerk and will be taken out the process.

During his movements in the building the visitor can loses his way, in that case, the system will detect this situation and will correct the mistake. In order to solve that problem the planner will be again called, a new plan for the lost patient will be generated and he will be reported in the usual manner by the information subsystem screens.

To deal with all of these tasks we have developed and tested a complete system. It is composed by the four subsystems previously stated. The most important one is the central or global one. It has the control of all the processes and communicates with each one of the three others separately. In fact, it can be considered as the authentic system.

All the subsystems are described in detail next. First we have the detection one which is composed by a set of RFID detectors located at different selected points in the building. They have the mission to detect and identify the patient RFID cards. The second one is called the orientation subsystem. It is a devoted artificial intelligent planner program that calculates, on demand, the best path for each medical centre visitor has to go between two certain points. It is called when either a patient gets into the building or is sent by a doctor to a new destination in the building or loses the way. The last one is the information subsystem. It consists of a set of screens placed in the walls were the users are able to read them easily. All of these subsystems will be described in more detail in the following sections.

2. THE DETECTION SUBSYSTEM

The aim of this subsystem is to detect the persons moving in a building (a medical centre in our case). This is a hardware system and it consists on a group of RFID detectors placed at several points of the public zones. They give a signal when a patient registered at the admission office and with a RFID card passes through each one of them. This signal is decoded and sent to the system central program. There are two relatively significant aspects in the set up of these detectors: the placement in the building and the communication with the central subsystem.

The right location for the detectors is very important because it has to be done in such a way that the whole building be suitably covered. In addition, for economic reasons it is mandatory the number of detector elements to be as small as possible. This is an important optimization problem we are also studying at this moment.

The detector number and placement is also relevant because we have to connect them with the main computer running the central system program. In our first approach we have basically designed two different ways in accordance with the arcs location. The first one is developed for detectors in stable positions and near the central computer. In these cases we use a wired RS232/RS485 connexion. The other one is foreseen when detectors are far from the global system terminal and/or their positions are not finalized. In these cases a wireless Zigbee [1] solution has been found very useful.

When the RFID frame is completely decided (places and communication systems) and each detector is located at this position, the building gets divided in zones (rooms between the detectors). Those are a main element in this paper and in our consistent implementation. The zones are not all equal they are several kinds with different features and functions. In this work we have considered three different types of them.

Input zones

These are the first ones reached for the patients when they get the hospital. They are outside any detector and they house the admissions offices. Our experience recommends only one of these zones and consequently a unique registration desk. 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 him and introduces the user into the system. At the same time, the visitor is provided with a RFID card that will identify him, in a personal way, during his movements in the centre.

The patient must keep this card the whole time he will stay in the building and he will get it back when he definitely leaves. At that moment the patient will be removed from the program and the RFID card will be ready for another person. All the information about each patient activity will be recorded and saved in order to improve the system knowledge. There is not limitation on the amount of RFID cards the program can handle.

There is the chance that a patient leaves the centre carrying the RFID card with him. In that case, the visitor will appear registered in the system and staying at this input zone when the person is actually out of the medical centre. For the time being, the only solution to this problem would be to set another detector just in the exit door.

Transition zones
These are intermediate zones between two or more RFID detectors. Patients have to go across them to get their destinations. They are typically: corridors, stairs or crossing sector. In these zones the system detects the input and output of each RFID card and consequently, the person who carries it. This information allows the program to kwon 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 the right destination. This information is provided to the patient by means of different screens located in these transition zones.

The location of these screens in these zones is very important. They must be installed in places where the patients find then easily and be able to interpret the provided information accurately. Usually an only screen by zone will enough but, if needed by the layout, an intermediate zone can contains more than one. In these cases it will be more useful divide the zone by installing more RFID detectors. In those situations economic reason should be considered as well.

Destination Zones
These areas represent the medical services waiting rooms. Besides, when a user is on his 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 he have reached his destination. Usually these zones are located at corridor ends and only a RFID detector is enough to register the entry of the patients into them. In this case the access control is very easy. Otherwise, two or more arch will be needed.

When a person gets to one of these zones and it matches his destination, the main program adds the user information into the doctor waiting list and the system assumes that the visitor will stay there until the doctor will see him, that is, the patient will not leave the room on your own. When the physician calls the patient the system provides him the whole information about the person. Then, it is up to the doctor update the patient medical background.

Before the patient leaves the practice room, the program will require a new destination for him. This could be: the hospital exit or another medical service at the present time or another future day. If the next destination is the exit or an immediate appointment, the system will call the planner to ask for a new plan, in order to guide the user to his current destination.

Nevertheless, if the patient decides to leave the waiting room and even the medical centre, without seen the doctor, the system will figure out the patient has lost the track and it will still guiding him towards the same waiting room. The program won't be aware of that until the building was empty.

All of these zones are suitably enclosed by RFID detectors, in such a way that the user input into any zone and his output is recorder the whole time. This information is sent online to the central subsystem. This main program will manage all data and it will control the situation, movements and instructions for every patient.

3. THE ORIENTATION SUBSYSTEM

This subsystem is based on the application of the artificial intelligent concept. More precisely we refer to the planning and scheduling techniques.

At first sight, the orientation of people inside a building could be considered a planning problem only. Nevertheless in many cases time constrains should be taking into account as well. If we are dealing with a medical centre it is obvious that time is a very important restriction. In a more general hospital case, it may be even necessary to deal with resources constraints. So that, we have developed a complete orientation tool combining planning strategies to represent problems and scheduling capabilities to be in charge of time and resources.

The orientation subsystem is based on the IPSS program [5] which combines a planner and scheduling algorithms. This program creates several plans at the same time and controls each partial plan making the scheduler checks whether it satisfies the time and resource constraints imposed by the problem or not. If so, the planner keeps on expanding the current search brand; otherwise, the planner cuts it and go backwards. The IPSS continues until it achieves a solution consistent with the time and resources. If there are more than one the program will give the first it found.

In our application, the orientation subsystem duty is to generate the best track between two different zones inside a building. In this context, best track means the shortest one. If there are several shortest paths the planner will only found one of them.

Usually these two different zones will be the input one and the medical service waiting room the patient has to reach, but any couple of different zones can be used. To produce a suitable output, the only pieces of information the planner needs are: the initial zone, the target one and the building topology. All of them will be provided by the main program in a special input IPSS file. When the orientation subsystem reaches a solution it gives the answer in another file that sends to the main program.

The system looks at every user in an individual way and it calls the planner for each one when he arrives to the admissions office asking for registration. From that moment on the system will follow the visitor's movements and will inform him about the planner track to reach his destination. The main program will also keep an eye on the movements of each individual patient checking whether he is doing well his track or not. This verification is done every time the patient goes across a RFID detector and changes from one zone to another. If the visitor is moving well, according to the plan, he will be only followed an informed.

Nevertheless, if a person loses his way the system is able to detect this situation just the first time he gets the wrong zone. At that moment, it asks again the planner for a new plan for the lost patient. When the planner gives the answer back, the central program uses it for guiding the person to his destination using the new track and showing the appropriate instructions at the information subsystem screens.

This subsystem is running all the time in the main computer and it is called as many times as needed until each patient gets successfully his destination.

Finally when a patient has accomplished his whole medical schedule, the orientation subsystem will generate the plan to guide him right to the hospital exit. In this case the system will guide the person right to the input zone (the target one in this case). There the patient will give the RFID card back to the clerk before leaving the building.

4. THE INFORMATION SUBSYSTEM

This is the most simple of the individual elements involved in our design. It is constituted by a set of screens located at the building transition zones. The places for installing the monitors must be carefully chosen so that the patients are able find to find them easily. There is no limit in the number of visual devices a zone can contain, it will depend on the zone layout but it should be at least one. In our work we have only used one screen by zone.

There may be screens installed, if needed, in the destinations zones as well. In this first approach we have only considered they are in the intermediate ones because waiting rooms usually have enough static information to report the patients they have arrived to their destination. Nevertheless, it could be possible that a visitor losses the path and gets to the wrong waiting room. In that cases it will be useful some information device to help him.

In these monitors appears the appropriate information for guiding the patients in the zone they are. The messages in the screen will show to each individual user, identified by name, the direction he has to walk according the plan generated by the orientation planner. The concrete instructions for a person will be pointed out in the corresponding screen when he went into the region where the screen is emplaced. At the same time, other indications for the same patient will be deleted of any previous device.

The monitors are controlled by the central subsystem. They present the patient's name and the direction he has to follow. In our prototype we have chose four different instructions: follow ahead, turn to the right, turn to the left and go backward.

The performance of the screens depends on the number of display lines they have. If there number of patients in a transition zone is bigger than the line capacity of the corresponding monitor, the screen will be properly refreshed so that all people can get their respective information.

The central program will take care about which monitor has to show a determined message, when and where communications needs to be erased from screen and whether a particular screen refreshing is needed or not. It will also be able to send the correct set of messages for all the visitors at their actual places simultaneously.

5. THE CENTRAL SUBSYSTEM

The central or global subsystem is the main program and it has the duty of take the control of the others three isolated subsystem. Besides, it has to control the patient data base and to prepare a daily doctor's appointments list. Finally it knows all the available RFID cards, the ones used in every moment and who carries them.

The global subsystem has a main terminal that will be placed on the desktop at the admissions office and will be operated by a medical centre employee. At the beginning of a working day this program creates a list where all the patients having appointments that day will be included. At that moment, the system assumes there is not any patients in the building and that none of the RFID cards are in use. When one of these patients gets the hospital this program will show all data relating to him. At that moment, the operator will check the visitor doctor's appointments, will introduce the person into de system and will give him a RFID card for individual identification inside de building. This card number will be noticed to the system as well.

Simultaneously, the central program finds out the patient destination in the daily database and asks the orientation subsystem for the track, across the hospital, for this user. When the planner gives its answer the central program records it and, from that moment on, it takes care of guiding the person towards his destination.

To deal with this task the central system registers and distinguishes each one of the RFID card interactions at every RFID detector. This strategy provides the program with the information about where all the persons inside the hospital are located and even what are their movements. That is, the program controls the patient's activity in the medical centre. This way the central program knows which screen is at the zone of each user and it is able to send the right advices to the correct places to help all of the visitors simultaneously.

When a user goes through a RFID detector the central system calculates if he is in the right way or not. If a patient loses is track this program recognizes the situation and generates a new plan by asking the planner for a new one. When the planner sends its answer back, the global program notices the lost person properly by means of the screen located at the zone where the user is. If the patient is able to read and understand the information he will recover the right path towards his destination, otherwise the next time he will cross the bad detector the central system will detect the mistake and a new plan will be generated. This process will go on until the visitor reaches his destination, usually the medical service waiting room of the doctor he has the appointment.

At that moment, when a person gets the waiting room he is going to, the system finishes the orientation job, includes him into the corresponding patient list and it waits for the user to be seen by the doctor. Then the doctor calls the patient, sees him at the practice room, and before he leaves, gives him a new destination. That is, the doctor will register all the actions he has carried out with the visitor and will introduce in the system a new destination for the patient. This new target can be the hospital exit, a different medical service for today or even for another day. In any case the system will call again the planner asking for a new plan for guiding the person to the new medical service or towards the centre way out. At the end of the patient stay in the building, he will get again the admissions office at the input zone. At that moment, before leaving the hospital, 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 data base.

The central subsystem has also in charge the data base maintenance. The first time a patient interact with the medical centre the program ask for his personal details and medical history. From that moment on the system will deal with all the information relative to the person in connection with the centre, especially the doctor's appointments. But, it will also record the data generated by the whole orientation and information system in the building.

6. THE PROTOTYPE

In this section we describe briefly a small prototype we have built in order to check the whole performance of our system.

The prototype reproduces a T shaped-building and it resumes all the special features that a big one could have. Figure 2 shows the building layout. The simulated hospital is divided into five zones by four RFID detectors. It has one input zone (zone 1), two transitions (zones 2 & 3) and two destination ones (zones 4 & 5). That means that we are considering two medical services, namely: traumatology and cardiology. Their respective waiting rooms are the zones 4 and 5 and they are located at both ends of a corridor. This layout make easier to deal with the control of the patients who get to them and no extra information screens are needed. We suppose all the visitors stay at their respective waiting rooms until they are called by the doctor.

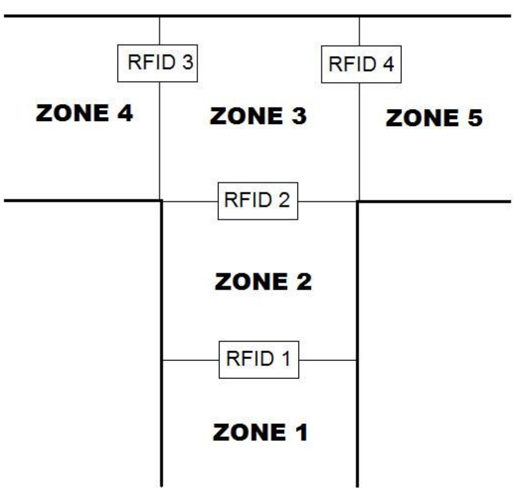

Figure 2. The building layout.

This building can be summarized by a graph where zones are vertex and RFID detectors are edges. This strategy allows us to keep the geographical information of the building structure in the corresponding graph adjacent matrix. More than that, this matrix can record the RFID detector number in the corresponding item so that we condense the centre distribution as much as possible. The related graph relative to our prototype building is shown in the figure 3.

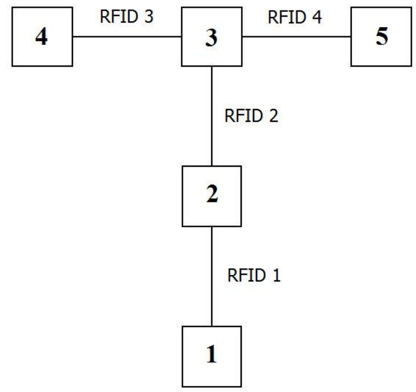

Figure 3. The building graph.

The global subsystem has been written in Visual Basic computer language. This program is the only one the operator should interact with. It works as the main program, communicates with the other subsystems and takes charge of the database updating too. This main system presents the set signals generated by the RFID detectors, the visitor's movement and the number of patients in all the building zones. All this information is shown in two different ways either in text form or graphically.

The set of RFID arch has been physically built in a scale model that reproduces the medical centre. In this case, the real detectors have been implemented by proximity RFID card readers with a read range of up to three inches. We have chosen four 13'56 Mhz. devices RIDEC 5000 and have used I-Code RFID cards. These detectors are able to read the tags by a magnetic loop and without contact. Each one of these detectors is powered in an autonomous way and all of them are connected to the main computer using a RS-485 line. This choice allows us to increase our system up to sixty four RFID devices.
The set of RFID detectors have been physically wired as a star circuit with a logical organization based on the IEEE 802.5 token-ring topology [4]. This strategy together with the RS-485 line offers us high data transmission speed and the chance of use relatively long cables (up to 1200 m.).

The orientation subsystem is based on the IPSS planner and scheduler [5,6]. This artificial intelligent program has been written by one of the authors of this article. The communication between them is done by sending a text file with the orientation problem, from the global program to the planner, and receiving another file with the answer in the opposite direction. The layout of the prototype makes that plans will have a maximum of four steps. These plans correspond with the way from the input to any waiting room.

Finally the information subsystem is a couple of LCD screens placed in the two transition zones. Each screen has four lines whit twenty characters wide and it can show only two advices simultaneously. When there are more than two patients in the same zone the information messages for them are changed in such a way that the information for each person remains on the screen at least ten seconds. These two screens are connected to the same bus for data transmission and control.

We have used a 16 bits microcontroller PIC 18F4520 to connect both the RFID tags and the display screens to the main computer. This is a cheap and versatile device that can be use for many technical applications. We have also developed a special printed circuit card for this device. Figure 4 shows a simplified circuit diagram. This microcontroller houses the program written in C that controls the token travelling around the ring. When one of the detectors has any data to transmit this program takes the information and sends it to the main computer trough a RS-232 line.

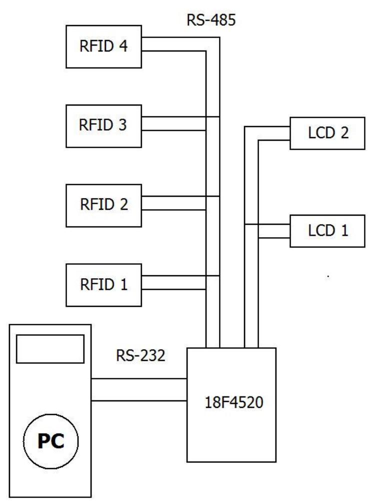

Figure 4. RFID detectors and LCD screens circuit.

The prototype operation has been done in the most real way. We have simulated the admissions of patients into the system and the RFID card assignment using the main program. At that point, the program has communicated with the planner and it has generated a moving plan for the visitor. Then the user's movements across the building have been accomplished taking each card in hand and passing it carefully over the card readers. The computer has read accurately the detectors, has computed the location and patient movement, has communicate with the planner program and it has sent the correct message to the corresponding LCD screen. We have even simulated the surgery times and the case when the patient loses his track and needs to be corrected.

The final version of our simulated system has worked properly for all the possibilities we have tested. There are still some more improvements we consider for future development as we present in the following paragraph.

7. FUTURE DEVELOPMENT

The system and the prototype we present are up to now very simple. He works rightly when the situation is not complicated and the people density is low. So, the capacity for managing more users should be accomplished. To achieve this goal we are now developing an authentic detection and orientation, system with real people and physically located in a building. This system will be made up of big RFID arches with several meters of detection rank.

This actual implementation of our system in real building will have to face a major problem as this is the privacy of persons. In this case the identity of patients must be preserved and this means than we can't use their names in the information screens for identification and communication. One possibility to achieve this would be to provide each patient a unique code that identifies all the time he stays at the medical center. This code will be generated by the main program and given to the visitor when he gets the admission office. This identification key can also be employed to provide the patients with audible information in order to help them to follow their path inside the building.

In our laboratory experimentation we have suppose that the detection process is fair, that is, the users cross through the RFID detectors once every time and there are not hesitations that will make him to cross several times the same RFID arch in a very short period of time. This could be a very realistic situation and it must be considered. In the worst case, when a visitor stops just in the middle of a RFID detector the system will receive a lot of signals from him and the information about the patient location will be probably lost until the person reaches the next detector.

We have also assumed that the system records all the detectors signals with no loses and that two patients never cross the same or two different detectors at the same time. Those are situations that could happen if the number of visitors is important and must be taken into account in the next program version.

Another relevant question we have not considered and that could be relevant is the installation of information screens in waiting rooms. These monitors will help considerably the patients to realize they have got their destinations, and the doctors to keep their waiting lists' control. Obviously these displays will need a different design and a new set of instruction messages.

Relative to the planner let us say that it has been operated in a very ideal framework: short plans and few people at the same time. A more complicated situation will make us to look for better strategies. Among them we can suggest to create a data base of plans, generated in advance, covering the most foreseeable cases between the principal locations in the building. So, we will get them directly without calling the planner. It is possible to generate plans for day patients, before they arrive to the hospital when the system is not too busy, as well.

Finally, we would like mention a more sophisticated system where the patients are provided with an active (not a passive RFID card) device. Let us say, for instance, a Bluetooth terminal allowing the program to send individual information to each terminal. Operating this way the patients will be released of looking for information screens and get the information from them because they will have it in hand.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

[1] Coleri Ergen, S., **ZigBee/IEEE 802.15.4 Summary,** *http://www.sinemergen.com/zigbee.pdf*, 2004.

[2] D.V. Engels, **RFID: The technical Reality**. Workshop on Radio Frequency Identification: Applications and Implications for Consumers. Washington D.C. June 2004.

[3] H. Geffner, **Perspectives on Artificial Intelligence Planning**. In Procs. Of the Eighteenth national conference on Artificial Intelligence. Edmonton, Alberta, Canada, pp: 1013 – 1023, 2002.

[4] Institute of Electrical and Electronic Engineers (1985). **Local Area Network – Token Ring Access Method and Physical Layer Specifications**. American National Standard ANSI/IEEE 802.5, IEEE Computer Society.

[5] M.D.R. Moreno**, Representing and planning task with time and resources,** Ph.D., Universidad de Alcalá, 2004.

[6] M.D.R-Moreno, Angelo Oddi, Daniel Borrajo, and Amedeo Cesta. **IPSS: a Hybrid Approach to Planning and Scheduling Integration**. IEEE Transactions on Knowledge and Data Engineering, 18(12):1681–1695, 2006.

[7] N. Muscettola, G Dorais, C Fry, R. Leviston and C. Plaunt, **IDEA: Planning at the core of Autonomous Reactive Agents.** In Procs. Of The Workshop On-Line Planning and Scheduling, AIPS 2002, Toulouse, France, pages 49-55, 2002.

[8] N. Nilsson, **Problem-Solving Methods in Artificial Intelligence**. Ed. Feigenbaum, E. and Feldman, J. McGraw-Hill., 1971.

[9] J. Werb, C. Lanzl, **Designing a positioning system for finding things and people indoors**. Spectrum IEEE, 35(9), pp: 71 – 78, 1998.