Ubiquitous Networking Robotics in Urban Settings

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Abstract - **In this paper we will present the objectives of a Network Robot System project denominated URUS, a European IST-STREP project of the FP6 program. The general objective of the project is the development of new ways of cooperation between network robots and human beings and/or the environment in urban areas. The focus of the project is in urban pedestrian areas, an important topic in Europe where there exists a growing interest in reducing the number of cars in the streets and improving the quality of life. In the paper we present the objectives and the goals to be achieved.**

I. INTRODUCTION

European ancient cities are becoming difficult places to live due to noise, pollution, lack of quality facilities and security. Moreover, the average age of people living in large European cities is growing and in a short period of time there will be an important community of elderly people. City Halls are becoming conscious of this problem and are studying solutions, for example by reducing the areas of free circulation of cars. Free car areas imply a revolution in the planning of urban settings, for example, by imposing new means for transportation of goods to the stores, security issues, new ways of human assistance, etc. In this project we want to analyse and test the idea of incorporating a network of robots (which include robots, intelligent sensors, intelligent devices and communications) in order to improve quality of life in such urban areas.

Given the broad spectrum of an initiative like this, the URUS project will focus on designing and developing a network of robots that in a cooperative way interact with human beings and the environment for tasks of guidance and assistance, transportation of goods, and surveillance in urban areas. Specifically, our objective is to design and develop a cognitive networked robot architecture that integrates cooperating urban robots, intelligent sensors (video cameras, acoustic sensors, etc.), intelligent devices (PDA, mobile telephones, etc.) and communications. The main scientific and technological challenges that will be addressed in the project will be: navigation and motion coordination among robots; cooperative environment perception; cooperative map building and updating; task negotiation within cooperative systems; human robot interaction; and wireless communication strategies between users (mobile phones, PDAs), the environment (cameras, acoustic sensors, etc.), and the robots. Moreover, in order to facilitate the tasks in the urban environment and the human robot interaction, commercial platforms that have been specifically designed to navigate and assist humans in such urban settings will be given autonomous mobility capabilities, as well as a simple but friendly robot head.

Proof-of concept tests of the hardware and the software systems developed will take place in a pedestrian area of a city quarter of Barcelona.

The initiative of this project comes from the European Group inside of the Research Atelier on Network Robot Systems (NRS) (part of EURON) which is producing a Roadmap of Network Robots in Europe, one important company on communications and sensors, one SME company to augment the urban robot sensory capabilities to produce a versatile robot, and one company related to organizational studies for the city of Barcelona in conjunction with the Barcelona City Hall and the Government of Catalonia.
This Urban application has been selected to focus the principles of Network Robotics tackled in this project. However, the major contribution is scientific and technological, and in principle can be applied to any other ubiquitous robotic domain.

II. OBJECTIVES

The general objective of this project is the development of new ways of cooperation between network robots and human beings and/or the environment in urban areas, in order to achieve efficiently tasks that in the other way can be very complex, time consuming or too costly. For example, the cooperation between robots and video cameras can solve surveillance problems in urban areas, or the cooperation between robots and wireless communication devices can help people in several ways. The focus of the project is in urban pedestrian areas, an important topic in Europe where there exists a growing interest in reducing the number of cars in the streets and improving the quality of life. Network robots can be an important instrument to address these issues in the cities.

Network robots is a new concept that integrates robots, sensors, communications and mobile devices in a cooperative way, which means not only a physical interconnection between these elements, but also, for example, the development of novel intelligent methods of cooperation for task oriented purposes, new communication languages between the different elements, or new mobility methods using the ubiquity of sensors and robots. We have identified several scientific and technological challenges, when thinking on network robots for urban areas, which have been taken into account to define the objectives of this project.

The objectives of this project are the following:

1. A scientific and technological objective: Develop an adaptable cognitive network robot architecture which integrates the following functionalities (sub-objectives)
    a. Cooperative localisation and navigation.
    b. Cooperative environment perception.
    c. Cooperative map building and updating.
    d. Human robot interaction.
    e. Multi-task negotiation.
    f. Wireless communication with hand held devices, ubiquitous sensors, and other robots.

2. An experiment objective: Test the cognitive network robot architecture in two different urban tasks :
    a. Guiding and transportation of people and goods.
    b. Surveillance.

The **first main objective** of URUS is to develop an adaptable cognitive network robot architecture which integrates the basic functionalities required for the network robot system to do urban tasks.

- ***Cooperative localization and navigation***: The **specific objective** is to extend the navigation capabilities of the robots by using cooperative localisation, perception, maps, short-term-planning robot navigation and cooperative control in unstructured and dynamic environments, in particular for urban settings.

- ***Cooperative perception environment*****:** The **specific objective** here is to create and maintain a consistent view of the urban world containing dynamic objects, i.e., pedestrians, vehicles (autonomous or conventional small transportation vehicles), by means of the information provided by the robots and sensors embedded in the urban environment. Cooperative surveillance tasks including the fleet of robots and the embedded sensors will be addressed, including cooperative event detection and identification. The cooperation not only includes the fusion of data, but also the development of adequate actions for developing these tasks. Also, decentralized cooperative tracking techniques for the estimation of the people flow and other moving objects in a certain area will be considered.

- ***Cooperative map building and updating*****:** The **specific objective** is to augment the classical static Simultaneous Localization and Map Building (SLAM) problem to deal with dynamic environments, and to be cooperative using not only a troupe of robots, but all the different elements of the NRS, where the static (background) and moving elements (foreground) must both to be taken into account, at all times during map construction. For urban areas, one could take advantage of a GIS (Geographic Information System) for background information and rely on state of the art cooperative SLAM for dynamically updating such map, and for detecting the foreground.

- ***Human robot interaction:*** The **specific objective** is developing a series of tools to have a robust communication interface between robots and persons and a simple but friendly head for the urban robots. A person will communicate to a robot by means of mobile phones, voice and gestures. The robot will communicate to a person by voice, a robot screen or through the mobile phone. The mobile phones will be the main communication interface that will allow the human beings to ask for assistance, help or any other order, and moreover they will be used to have the first location approximation of the person in the urban site. That means that we will define a bidirectional language communication using mobile phones. The robot touchscreen will be an interactive device to interchange information. The human gestures will be used for two actions: to express very simple commands and to locate a person in a specific urban point. An important issue will be to locate precisely a person by identifying its gestures. Finally, we will develop a simple but friendly head for the urban robots which will include the elements described in this work package.

- ***Multi-task negotiation*****:** The **specific objective** is to use general optimal or suboptimal techniques to achieve multi-system task allocation among the members of the system, that is, the robots and the sensors and other systems of the environment. In this project, we will consider a set of heterogeneous robots with capabilities of interaction with the environment and with humans. The team of robots will be heterogeneous due to their motion capabilities (kinematic, dynamic), the type of sensors on-board, their visibility and the communication constraints between robots and the environment.

- ***Wireless communication with hand held devices, ubiquitous sensors, and other robots*****:** The **specific objective** is to extend the localisation of human beings fusing information from typical communication systems (mobile phones, embedded and mobile sensors) and detecting hand human movements; improve the communication recovery with robots and humans; and establish a common wireless interactive language and protocol for the communication between humans (by means of mobile phone), robots and ubiquitous sensors.

Fig. 1. Guiding and transportation of people and goods.

The **second main objective** is to test this cognitive network robot architecture with the specific goal of achieving the deployment of a network of robots, sensors and communication devices for the following urban oriented tasks that will become experiments in the URUS project:

- Guidance and transportation of persons and goods.
- Surveillance.

The **first experiment** will consist in assisting people to find places to go and to transport people and goods from one place to another, using the best path taking into account for example, the map information and the on line street situation obtained by the network of robots. For the purpose of assisting people, some of the community of robots will have special interfaces to communicate with people (special monitor, new generation of mobile phones, PDAs etc.) and the people will use similar devices to communicate with the network robots. In this task, we need an accurate estimate of the position of the person that requires the service, and for this reason sensor integration for localization is of uttermost importance; for example, by tracking the person with vision sensors, by aiding in his/her localization from mobile phone signals, by identifying the person by his/her movements and by referring such data to a map (if such exists). With respect to transportation, some of the robots will be prepared to transport people and goods (small size). Figure 1 shows a virtual view of the Guiding and Transportation of people and goods task.

The **second experiment** will consist in a surveillance task. Some robots in conjunction with the network will navigate the urban area to detect abnormal situations (vandalized urban furniture, big areas with trash, suspicious activity etc.). Moreover the network robots will be used to measure the flow of people in the streets or the flow of mobile elements in the area. For this purpose some of the community of robots will have special sensors and they will have to cooperate to exchange information, and give their location to send an alarm when they detect something strange.

In the two tasks, there will be cooperation among robots, sensors and communication systems. Basically the six functionalities aforementioned must be taken into account, however with different priorities.

The network of robots, sensors and communications will be tested in two different environments: a full experiment will be in the Campus of the Technical University of Catalonia, in Barcelona, which includes streets, passages, and closed environment (shops, restaurants, offices); and secondly a more limited testing will be performed in a selected "Superblock" (Supermanzana) of the city of Barcelona. At present there are several superblock studies in Barcelona, for example in Poblenue, 22@, and Gracia's quarter.

III. Partners

TABLE I
PARTNERS

Partic. Role*	Participant name	Participant short name	Country
CO	Technical University of Catalonia (Institute of Robotics)	UPC	Spain
CR	Centre National de la Recherche Scientifique	LAAS	France
CR	Eidgenössische Technische Hochschule	ETHZ	Switzerland
CR	Asociación de Investigación y Cooperación Industrial de Andalucia	AICIA	Spain
CR	Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna	SSSA	Italy
CR	Universidad de Zaragoza	UniZar	Spain
CR	Instituto Superior Técnico	IST	Portugal
CR	University of Surrey	UniS	U.K.
CR	Urban Ecology Agency of Barcelona	UbEc	Spain
CR	Telefónica I+D	TID	Spain
CR	RoboTech	RT	Italy

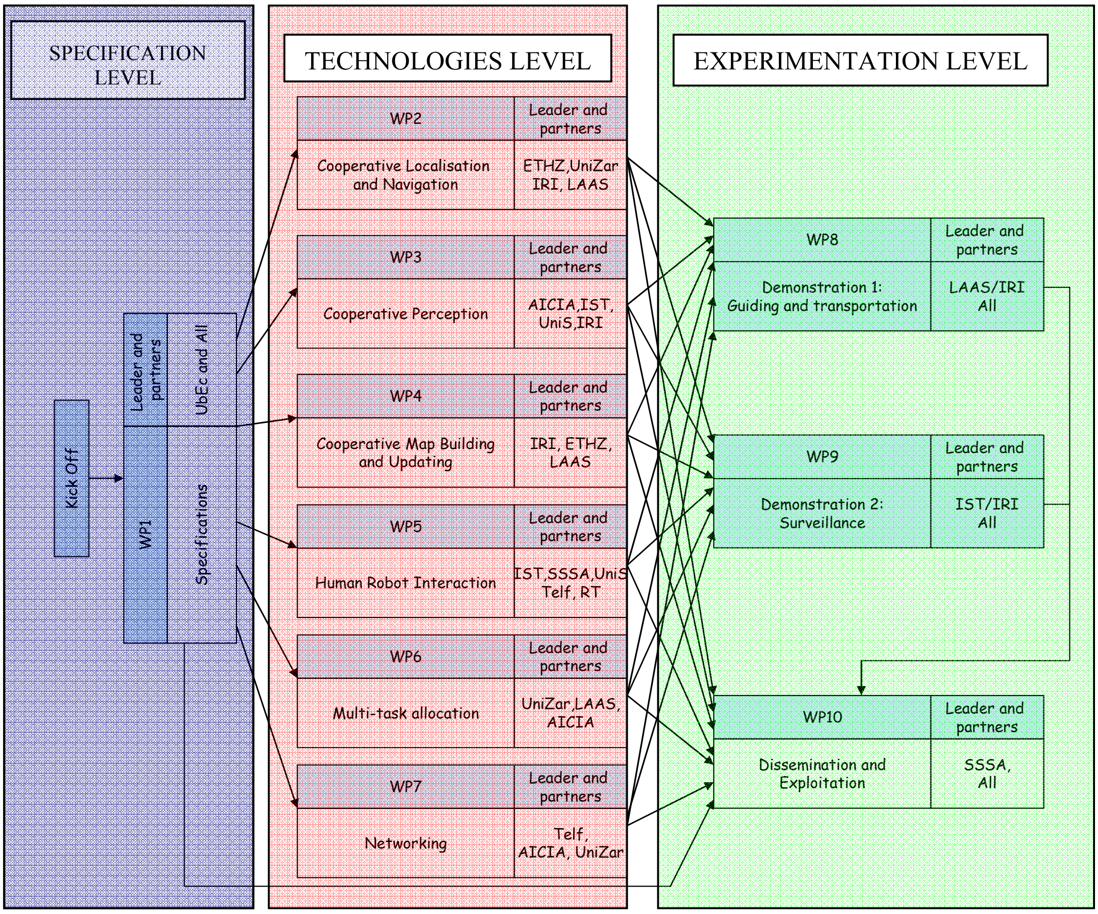

Figure 2: Graphical representation of the WP and their interdependencies

IV. WORKPLAN

In order to accomplish the aforementioned objectives, we have structured the project in the following levels (see Figure 2):

Specification level: In this level we will identify the basic operational requirements for each one of the two experimental situations proposed, the needed hardware, software and communications, and detailed software modules that will be develop in the URUS project. Moreover, we will study the required urban regulations and procedures from the point of view of mobility, deployment of devices, communications, security and monitoring. Thus, the first type of specification is oriented to the technological requirements of the project; whereas the second type is oriented to setting general conditions for the future deployment of network robots in urban settings.

Technologies level: At this level lays the scientific core of the project. It will consist of the development of innovative techniques for networked robots, which will be based on the latest research and development taking place at the university and company research centres from the consortia. This level consists on six work packages, each one developing a specific scientific and technological issue regarding network robotics. The outcome of each one of these work packages will be a set of independent modules that will serve specific functionality within the URUS project. These work packages include localization and navigation, environment perception, map building, human robot interaction, multitask allocation, and networking.

Experimentation level: In this third level, the objective is to set up two experimental settings to show how the networked robots can help humans in urban areas. One work package will be devoted to each of the settings, namely, guiding and transportation, and surveillance. The work packages include system integration of the modules developed within the technological level of the project, as well as experiments, using a distributed set of sensors and robots.

The project will use an estimated set of 10 mobile robotics platforms, coming from the different partners. We will use existing platforms already developed by the partners and we will only include the appropriate sensors needed to extend their capabilities to deal with the challenges posed by cooperative multirobot tasks in urban settings. In addition, in order to obtain a friendly human robot interaction, one of the companies will develop an intelligent robot head for the future urban robots, which will be tested in the experiments. Moreover, the communication companies participating in the project will develop and serve specific needs and techniques to best interconnect our robot network.

V. Conclusions

The URUS is an ambitious project that tries to investigate on the key issues of Network Robot Systems on Urban Sites and make some experiments to verify the scientific and experimental results developed in the project. URUS is a 3 year project that will start on December 2006 and will finish on November 2009.

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