DEPARTAMENTO DE INGENIERIA DE SISTEMAS Y AUTOMATICA

## ROBOTICS AND MECHATRONICS LAB

UNIVERSIDAD DE
MALAGA

LOCATION:

The ISA department is located at:

Edificio de Ingenierías, Campus de Teatinos, C/ Doctor Ortiz Ramos, S/N, 29071 Málaga.

ROBOTIC GROUPS:

- MECHATRONICS AND ROBOTICS LAB: https://www.uma.es/robotics-and-mechatronics/?set_language=en
- SURGICAL ROBOTICS TEAM: https://www.uma.es/medical-robotics/

- MACHINE PERCEPTION AND INTELLIGENT ROBOTICS (MAPIR) RESEARCH GROUP: http://mapir.isa.uma.es/mapirwebsite/
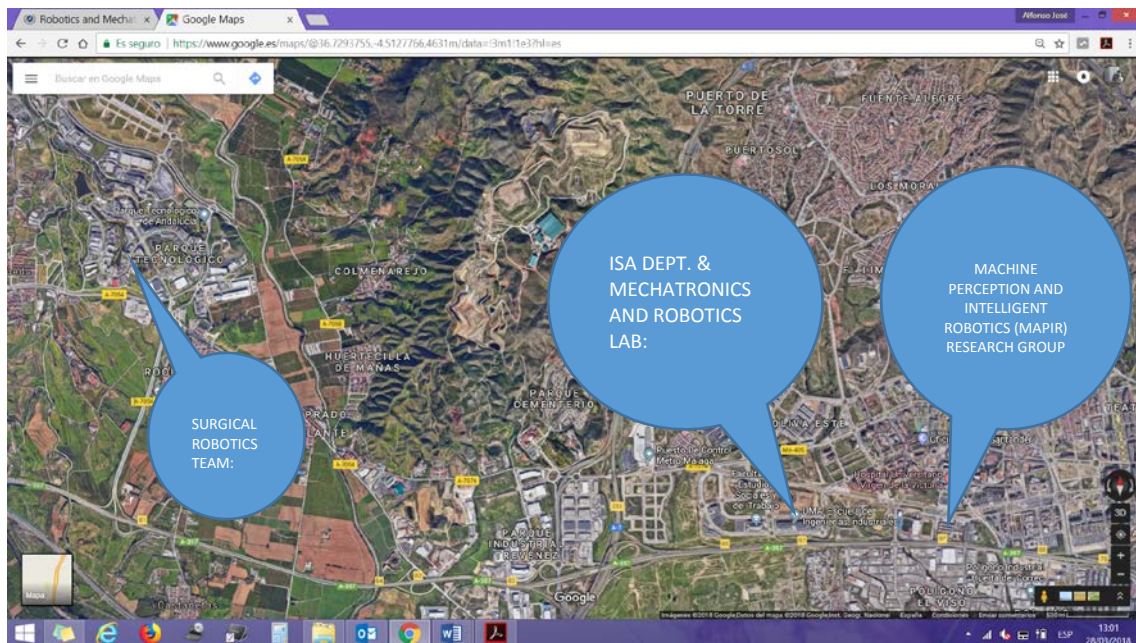
INTRODUCTION

The group of Systems Engineering and Automatics counts with a large number of qualified personnel, numerous patents (product of their research in the field), laboratories Robotics and Automation of Industrial Processes, an aero-hydrodynamics laboratory of unmanned vehicles and equipment necessary for carrying out the different lines of research that they develop. In addition, point out that this group founded the Andalusian Institute of Advanced Automation and Robotics.

RESEARCH TOPICS

- Teleoperated and Autonomous mobile robots for exploration and rescue applications.
- Mobile Robotics in structured environments (hospitals, museums, large buildings,..).
- Robotic Systems for assistance to minimally invasive surgery.
- Processing images (Three-dimensional maps and satellite change detection).
- Control systems for terrestrial, marine and aerial vehicles.
- Intelligent control systems: Fuzzy systems, neural networks, etc.
- Electric vehicles and technologies for sustainable mobility.
- Automation of logistics system and infrastructure.
- Automation of manufacturing systems.

SCIENTIFIC-TECHNICAL SERVICES

- Design and manufacture of mobile robots for industrial applications and services.
- Automation of manufacturing and production systems.
- Design and production of embedded control systems.
- Applications of robotics to medicine.
- Design and production of mechatronic systems (Goniophotometer for luminaire characterization, X-by-wire systems, haptic systems, etc.)
- Developing systems for electric vehicles and sustainable mobility.

SEARCH & RESCUE ROBOTICS.

Head: Prof. Dr. Alfonso García-Cerezo. Contact info: ajgarcia@uma.es

Developing new technologies to assist emergency response teams is crucial to save human lives in the aftermath of catastrophes. Particularly, mobile robotics can contribute not only to   reduce reaction time but also to make difficult operations feasible by reaching unexplored areas that could be extremely hazardous for human search & rescue teams. This is a demanding application for robots because effective solutions require coping with a rough and unstructured working environment.

From a research viewpoint, the challenges posed by search & rescue Robotics include the following:

□   Designing and building robust vehicles that can move on difficult terrain, such as rubble.
□   Incorporation dexterous and heavy load manipulation capabilities.
□   Improving maneuverability and vehicle control on rough terrain.
□   3D perception and modeling of unstructured environments.
□   Path planning strategies in natural and irregular terrain.
□   Tele-autonomous navigation strategies.
□   Appropriate HMI solutions for search & rescue teams.

Our research group at the University of Málaga has had an interest in mobile robotics for natural environments that dates back to the AURORA robot for agricultural operations in the 1990s. In the ALACRANE project we developed a robotic assistance for search & rescue operations that consists on a powerful two-arm manipulator on a skid-steer tracked vehicle. Futhermore, QUADRIGA has been built as a lighter exploration wheeled robot to team up with ALACRANE in search & rescue operations. These robots have participated in Spanish annual emergency response drills organized with the collaboration of the University of Málaga. Our developments in environment perception include a compact 3D laser rangefinder which is commercially available as UNOLaser.

1996

1999

2003

2006

2008

2012

2018

THE CUADRIGA-II MOBILE ROBOT

The CUADRIGA-II mobile robot is a redesigned of our CUADRIGA robot as a member of a group of robots in the frame of RAMBLER project. Cuadriga-II is a 4-wheel skid-steer mobile robot.

General characteristics:

-Dimensions: 0.82m length, 0.64m width, 0.81m height.
-Vehicle weight: 83.1 kg.
-Payload: 120 kg.
-Distance between the front and rear wheel contact points is 0.475m.
-Wheels: pneumatic tires of 35.5 cm diameter. Rigid suspension.
-Distance between left and right wheel contact points is L = 0.5m.
-Maximum linear speed: 1.2m/s.

Motors are controlled by an embedded board that integrates a microcontroller (µC) and two independent H-bridge power stages. Power is supplied by a 36V battery pack, which is composed of six 12V lead-acid batteries connected in a series-parallel configuration.
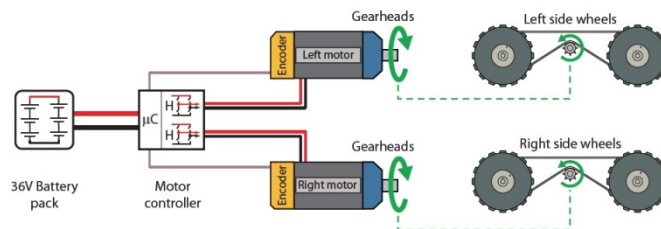
Data acquisition and high level motion control are performed by a compact onboard computer using a LabVIEW program. This computer interfaces with the embedded motor controller and the current sensors through two serial links. Manual operation is possible through a wireless joystick.

The Quadriga's sensorial system also includes hall Effect current sensors to measure the instantaneous power consumption of each motor, a three-axis inertial measurement unit, a 3D thirty meter range laser finder, an ethernet camera and a RTK GPS receiver,

Communication with a teleoperation station is done using a wireless router (2.4Ghz), bluetooth, zigbee, 3G and 900Mhz radio.

THE ALACRANE MOBILE ROBOT

The Alacrane mobile robot has been designed as a mean to help in Search and Rescue Operations (SAR). Unlike current systems, which are usually limited to exploration, Alacrane's arms are powerful enough to rescue victims.

Alacrane's arms are designed around a main arm ending in twin human-sized arms including force and tactile feedback. The whole system (mobile robot plus arms) is hydraulic powered.
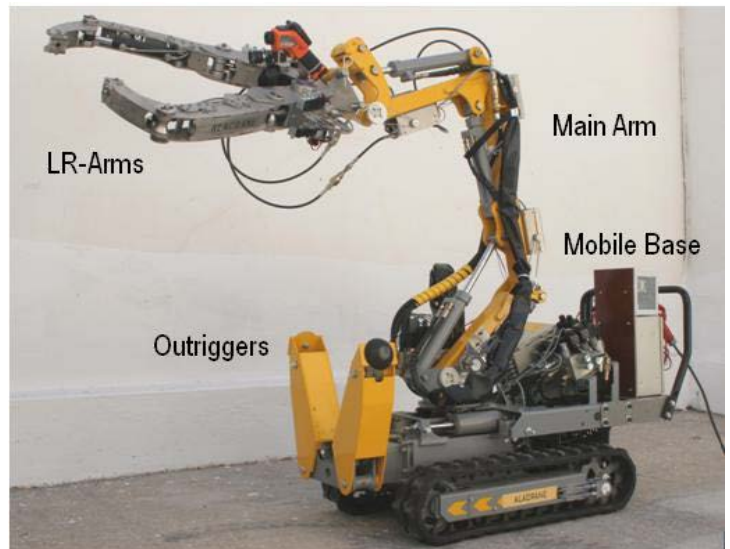
ALACRANE CHARACTERISTICS

Weight (no effector)	380 kg
Width	600 mm
Height	940 mm
Length	1200 mm
Speed, max	1.5 km/h
Slope angle, max	30°
Motor power	4 kW

MAIN ARM CHARACTERISTICS

Range	2400 mm
Base angle	±123°
Slewing speed	6,5 sec / 246°

LR-ARMS CHARACTERISTICS

Range	1000 mm
Base angle	±90°
Shoulder angle	+100°L, -100°R
Slewing speed	2,6 sec / 100°

Control system, Communications and Sensors:

Three onboard PC computers connected by Ethernet and a remote base. Low level control on a PXI PC computer. CANopen bus. | IMU (inertial measurement unit) with differential GPS system. | IP cameras (conventional and infrared). | 3D and 2D laser scanners. | Teleoperation with force feedback.

RAMBLER MOBILE ROBOT

The RAMBLER mobile robot is the natural evolution of our CUADRIGA robot. Is the head of a group of robots in the frame of RAMBLER project. RAMBLER is a 4-motor-wheel skid-steer mobile robot, with active suspension.

General characteristics:

-Dimensions: 1.6m length, 1.2m width, 0.66m height.
-Vehicle weight: 370 kg.
-Payload: >320 kg.
-Distance between the front and rear wheel contact points: From 0.95 to 1 m.
-Wheels: pneumatic tires of   50 cm diameter.
-Suspension: Active / Semiactive suspension system. Pneumatic.
-Distance between left and right wheel contact points is L = 1.05m.
-Maximum linear speed: 80km/h, 22.2m/s.

-Battery: (LiFePO$_4$); Range 44,8<V<59,2; 160 Ah (4 cells x 40Ah); Configuration:16S4P. Temperature: 0°C< t < 70ºC. Operative Control: BMS. contactor 600A/80eVdc SPST-NO (Normally Open). Charge Control: External, 59,2V/80A, 4,7 kW.

-Motors: Brushless DC Electric Motor with Outrunner Configuration. Range:36–72 Vdc, 500–3000 W. Nominal speed:300–1000 rpm.

-Arm: AUBO i5. Open source architecture based on CAN bus network and ROS (Robot Operating System) compatibility.

RAMBLER used 4 in-wheel brushless motors. Each motors are controlled by an embedded board that integrates a microcontroller (µC) and an independent H-bridge power stages.

Power is supplied by a 60V battery pack, which is composed of 64 (LiFePO$_4$) cells connected in a 16S4P series-parallel configuration.

Data acquisition and high level motion control are performed by a compact onboard computer using a LabVIEW program.

This computer interfaces with the embedded motor controller through four serial links.
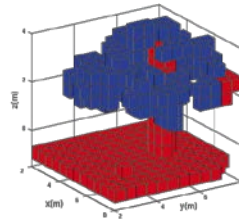
The RAMBLER's sensorial system also includes a three-axis inertial measurement unit, a 3D thirty meter range laser finder, an ethernet camera with pan&tilt and, a RTK GPS receiver.

Communication with a teleoperation station is done using a wireless router (2.4Ghz), bluetooth and zigbee radios, 3G and 902 - 928 Mhz radio link.
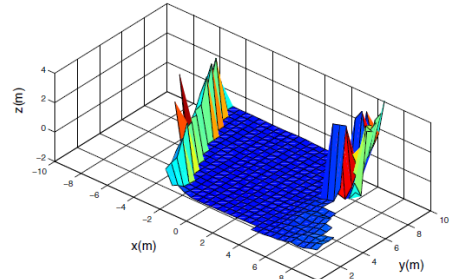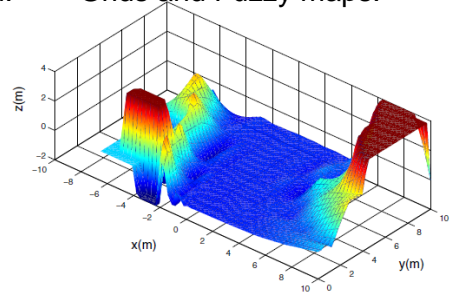
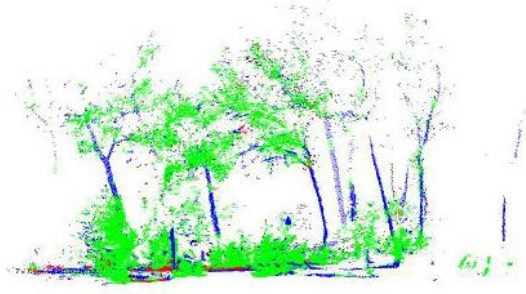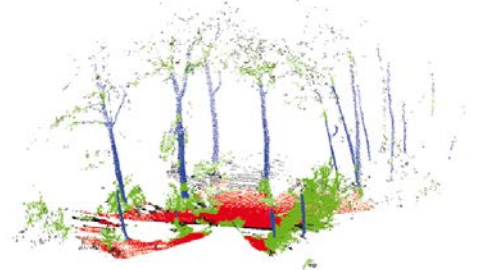# ADVANCED REAL TIME POINT CLOUD ANALYSIS.
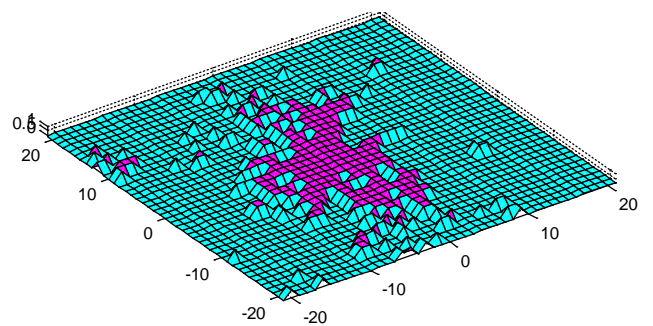

Voxelation.

Grids and Fuzzy maps.
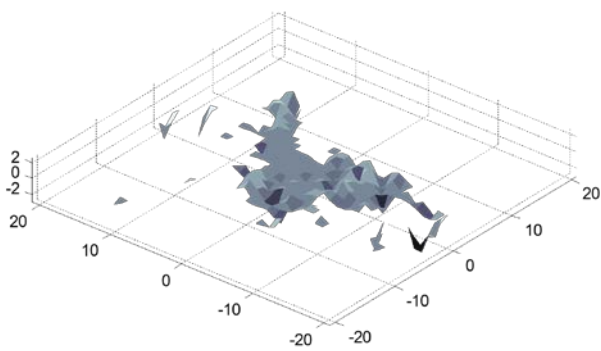

Semantic classification.

Gradient grid maps

Ocupance grid maps

# UNOLaser *Fast and Precise Low-Cost 3D Laser Scanners* **30M135Y**

## Technical specifications:

Product Name	Low-cost 3D Laser Range Finder
Model	30M135Y
Supply voltage	12 VDC ± 10%
Supply current	1.2 A (nominal), 2.8 A (maximum)
Host interface	USB 2.0 (Virtual COM)
Detection range	0.1-30 m
Measurement resolution	1 mm
Field of view	270° x 129°
Minimum scanning time (4.16° pitch resolution)	1.55 s
Maximum scanning time (0.067° pitch resolution)	95.75 s
Dimensions	182mm x 80mm x 191 mm
Weight	850 g

UNOLaser 30M135Y

Dimensions:
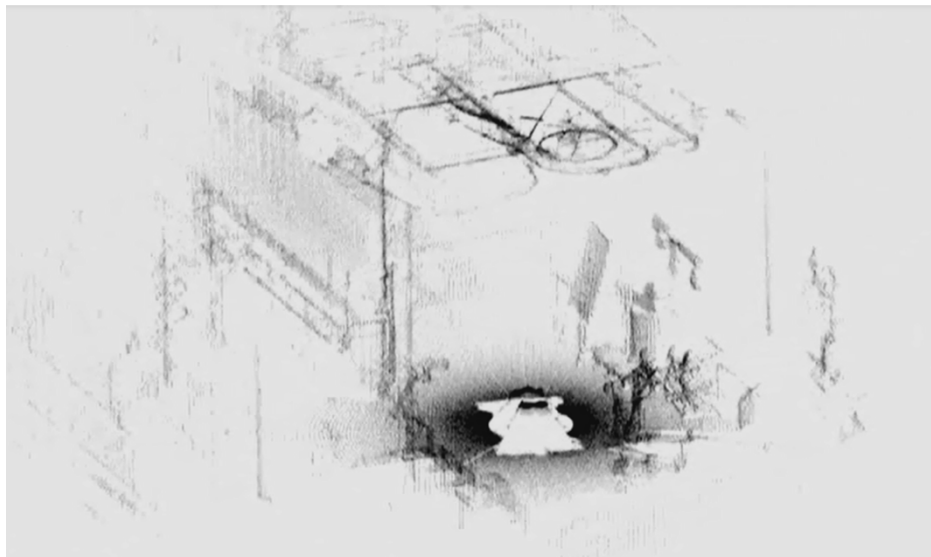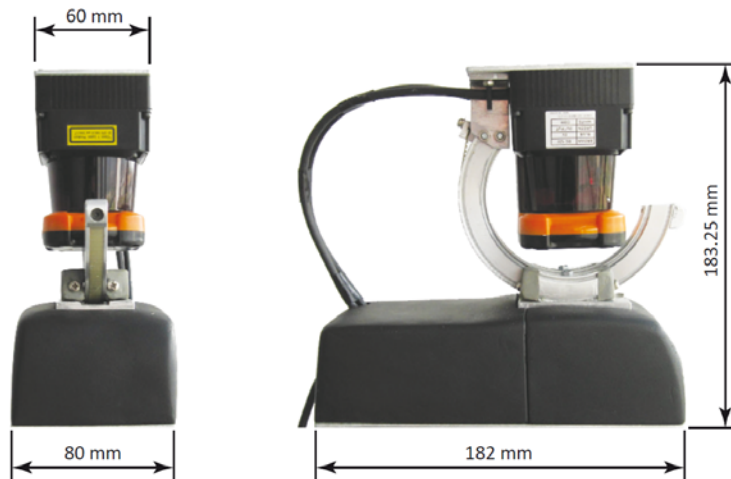
UNOLASER-V2 Cloud Points

INFORMATION SYSTEMS FOR URBAN MOBILITY.

Head: Dr. Jesús Fernandez Lozano. Contact info: jfl@uma.es

Urban traffic is one of the main problems that affect the life quality of residents in cities and metropolitan areas in developed countries, due to the city model, widely distributed, and the raising of urban population. Both factors are coupled, and amplify each other, contributing to increased displacement and length, in an expansive process that has placed the urban environment in a difficult situation in terms of sustainability. Pollution, traffic congestion and accidents are negative externalities producing a strong impact on both the health and the economy of citizens. All these problems suggest the development of new global strategies for sustainable urban transport. Strategies that address not only a wide range of mitigation measures, but also *the use of innovative technologies and infrastructures*. The concept of efficient, effective and safe transport must prevail today in new transport policies.

Our Research Group is involved in the design, development and implementation of a wireless smart sensors to acquire information about traffic and the environment, as well as to communicate with each other and with the outside, resulting in traffic reports available by the user in real time.

We have developed a series of nodes that receive sensory information from the environment:

- Bluetooth Node.
- Ultrasound Node.
- Laser Node
- Gases Node.
- Environmental Node.

All these nodes send the information gathered periodically to a manager node, also called coordinator node.
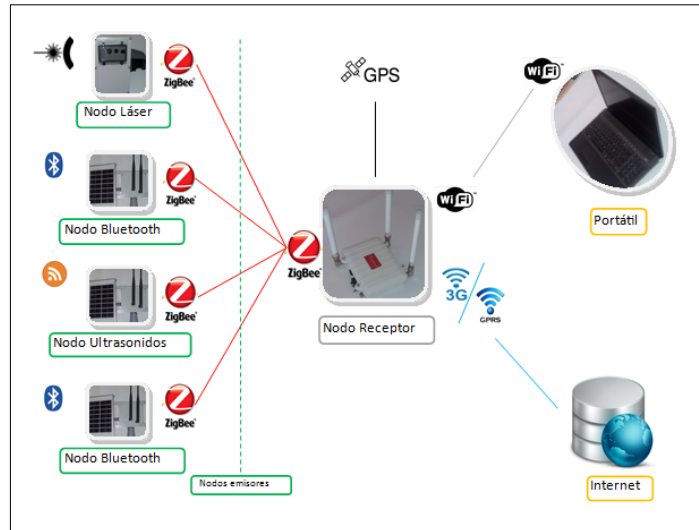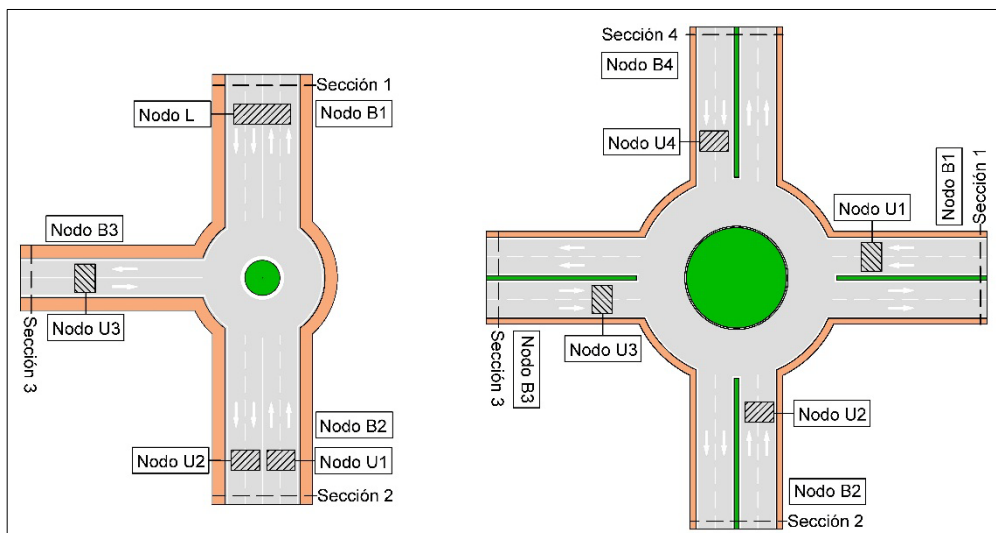
Diagram of the wireless sensor network.

Ultrasound and laser nodes are vehicles counters. The first type detect vehicles crossing the sensors beam, and the second ones sweep the driveway analyzing the existence, and characteristics of vehicles.

Gases and Environmental nodes gather information from the environment. The first type of sensors gets information about the concentration of various gases such as O_2, CO, CO_2 and volatile gases, among others, and the second type gets information concerning noise, dust and brightness.

The information collected by the coordinator node is always available by using two protocols: Wi-Fi and 3G.

Depending of the study area, various settings can be chosen for a wireless sensor network distribution:

Different configurations for wireless sensor network based on the area to be studied.

The information gathered by the sensors is processed by an algorithm designed to obtain the Origin-Destination matrix of the study area. Therefore, it can obtain information about traffic flow in each of the lanes, trips made by vehicles (origin and destination), control sections that are more likely to receive vehicles as their destination, or those lanes that are more likely to be the origin of travel. All information before can be classified according to the hour, weekdays and weekends.

Experimental Results.

The experimental results correspond to the Project "Portable Information System applied to urban mobility" of the "Programa operativo FEDER de Andalucía 2007-2013" in collaboration with the Agency of Public Works of Andalusia Regional Government.

Several tests have been carried out, which can be classified into four groups:

- Calibration tests of the system.
- Testing analysis of visible Bluetooth devices in the system.
- Mobile node testing, including all types of sensors.
- Crossings / urban intersections testing.

About the evidence concerning the analysis of Bluetooth devices detected by the system, the number of Bluetooth devices that the system is able to detect was processed. Consequently, the rate of vehicles has been detected with respect to all vehicles that have passed through the control area of the test. Results show that about 10% of the vehicles counts with some Bluetooth device recognizable by the system.

In addition, wireless sensors have been installed in a vehicle (mobile node) in order to provide information about traffic conditions and environment of the roads. As a result, a maps can be obtained with the information gathered by the mobile node in which citizens and mobility areas staff can observe the traffic situation at any time.

Maps created with the mobile node. Light colors represent low traffic intensities and dark colors high traffic intensities.

The whole system has been tested in two similar intersections, as shown previously. The first is used to validate the system qualitatively, while the second has been used to validate the system quantitatively. Both tests were performed in real urban environments with normal traffic conditions.
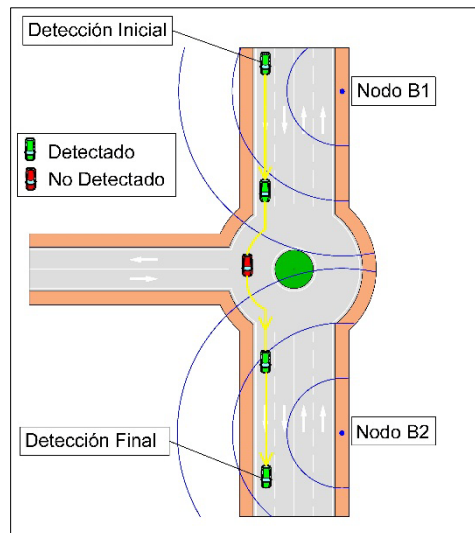
Detection process for Bluetooth device.

The results obtained by manual counting and through the sensor network in the above intersection can be observed in the table:

Origen \ Destino	1	2	3	*4*
1	72	249	125	125
2	39	52	256	1.611
3	170	537	0	59
4	72	872	118	20

Origen \ Destino	1	2	3	*4*
1	0	484	114	110
2	58	0	294	1280
3	316	772	0	42
4	91	592	111	0

Left: Real traffic counted manually during the experiment. Right: Results obtained using wireless sensor network.

The origin and destination classification algorithm uses a statistical process, so that increasing the number of vehicles taking a trip between a given origin and a certain destination, more confidence can be expected from the results. According to the rate of Bluetooth devices in vehicles, it will require 200 trips to obtain a confidence value of 95%.

After analysing the results, the main conclusion is that it is possible to make consistent, useful traffic studies with the intelligent sensors network. Among the advantages that the Mobile Information System Applied to Urban Mobility can be enumerated:

- Cheaper traffic Studies and real time results, including useful tools like Origin-Destination matrix algorithm.
- Installing sensors without road closures.
- Possibility to apply dynamic algorithms in traffic control elements (information signs, traffic lights, reversible lanes, etc.) depending on the traffic conditions.
- Increasing knowledge of drivers habits in urban and interurban areas.
- Real-time status of roads in a city using mobile nodes.
- Planning more accurate and efficient road projects.

MEDICAL ROBOTICS

Head: Prof. Dr. Víctor F. Muñoz Martínez   Contact info: vfmm@uma.es
www.roboticamedica.uma.es

Minimally invasive surgery has required the acquisition of new skills on the part of surgeons and the creation of new tools, an area in which robotics is an invaluable help. The Medical Research Group is involved in the development of robotic assistants for laparoscopic surgery. The purpose is defined as the creation of machines which are not intended to replace the doctor in surgical interventions, but to work side-by-side with him. The working method is focus on an early stage of new knowledge creation and a second stage leading to the construction of demonstrator systems. The developed prototypes exhibit a dual function: i) they are useful to experimentally verify the theoretical developments and ii) they facilitate the transmission of research data.

From a research point of view, the specific lines of Medical Robotics group are:

- Design of robotic assistants
- Instrument movement control
- Automatic movements
- Fault-tolerant control architecture
- Human-machine interfaces
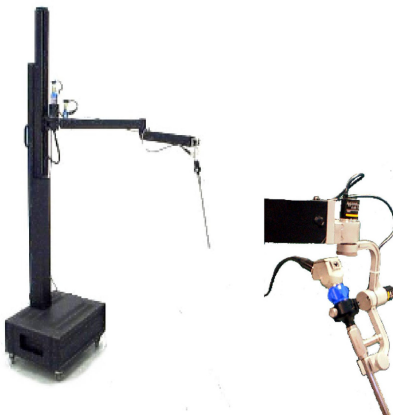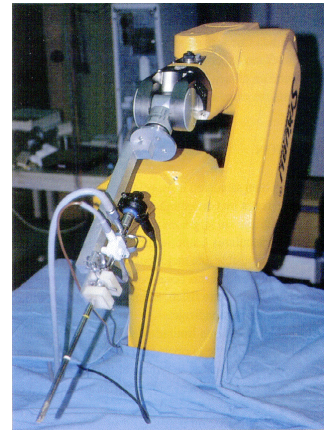- Telerobotics
- Clinical essays

Robotic Assistants

ISA (Intelligent Surgery Assistant). It is the first robotic assistant designed to be used in laparoscopic surgery; it is based on an industrial Stäubli RX60 robot. The robot must fulfil various requirements, such as accessing the entire working area by means of an endoscope without limiting the surgeon's movements. The assistant is handled in response to the surgeon's commands. In the picture, it can be appreciated a clinical trial using animals for experimentation purposes. It was developed under the project framework FIS-00/0050-02

RTUP. The right picture shows the ISA robot adaptation for the transurethral resection of the prostate. The intervention involves passing a narrow metal telescope, attached to the robot end effector, through the patient's penis until it reaches the prostate. The robot is handled by a master manipulator.

ERM (Edoscope Robotics Manipulator). Robotic assistant developed under the project framework PI021708. It is designed to fulfil the kinematic requirements used for the ISA assistant, as well as the real-time needs found in a human operating room. In this sense, there was emphasis on the fact that the robot used here does not require any structural modification in the operating room, and that it does not obstruct the surgeons' movements. In the left picture, it is shown the ERM, version 1.0. This system has been validate by means of human clinical trials.


CISOBOT. It consists of a two-arm robot, one to control the laparoscopic camera and another to help the surgeon operate along the intervention in a semi-autonomous mode. The objective of the CISOBOT system is to help the surgeon operate alone. To that end, the system is provided with a multimodal HMI leading the robot to a higher reaction capacity and a high level intelligence. This robotic assistant has been developed under the project frameworks DPI2007-62257 y P07-TEP-02897.

MARCUS (Micro Abdominal Robot Cooperative System).

The current trend in Minimally Invasive Surgery is towards reducing the number of incisions practiced on the patient to a minimum. SILS (Single Incision Laparoscopic Surgery) and NOTES (Natural Orifice Transluminal Endoscopic Surgery) techniques have thus emerged, and these require a new generation of robotic tools. MARCUS in intended to assist and collaborate with surgeons in Single Incision Laparoscopic Surgery (SILS) operations. Specifically, it deals with the design and development of a robotic platform capable of placing a miniature robot equipped with surgical tools within the abdominal cavity to work collaboratively with the surgeon.
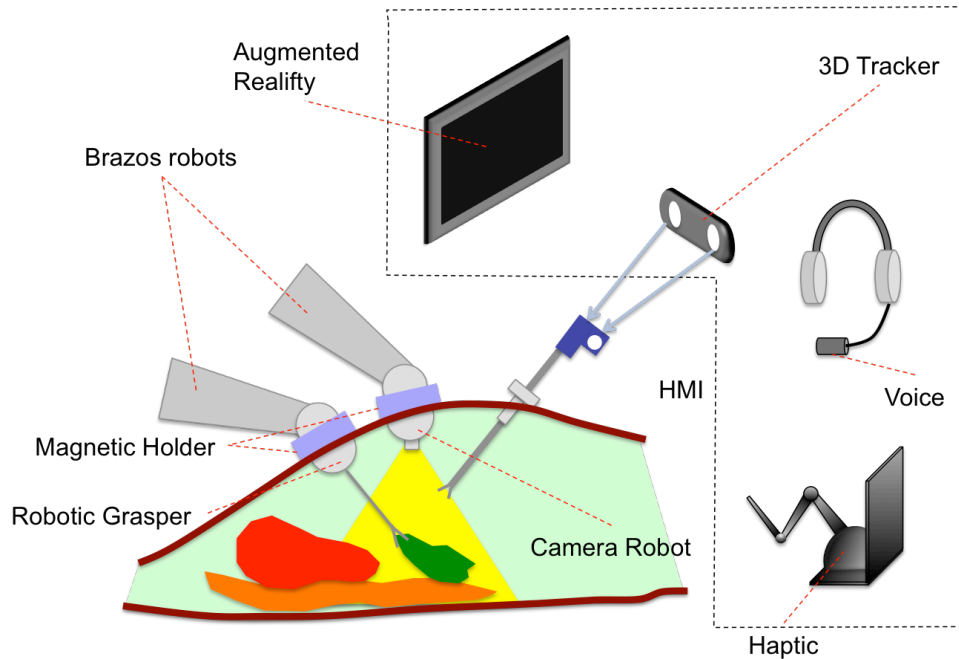
The robotic system itself consists of a lighting robot, a miniature camera robot and a redundant robotic grasper. Positioning of robots inside the patient's abdomen is done by means of magnetic control. External magnetic sources are placed at the end effector of two robotic arms, and permanent magnets are integrated in the robots. Camera robot is provided with three permanent magnets, so both position and orientation can be controlled. Robotic grasper's redundancy makes possible autonomously obstacle avoidance and increases its workspace. The haptic device is designed so as surgeons can handle the grasper as if it were a conventional tool. In order to this aim, augmented reality is used to simulate a traditional tool in the visual feedback system, in substitution of the robotic grasper.
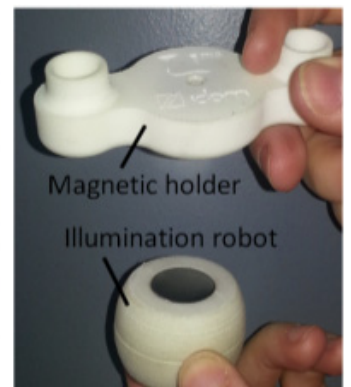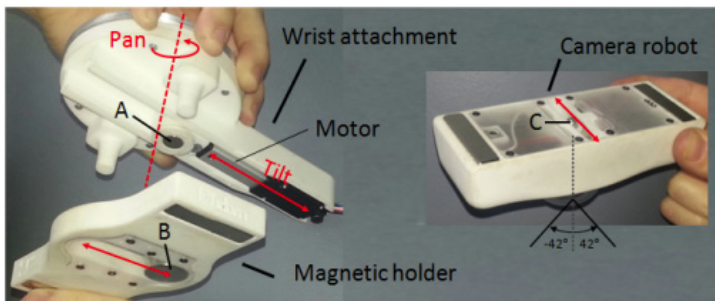
MARCUS Robotic System has been tested bye means of In-Vitro as well as In-Vivo Experiments.

In-Vitro Experiments

In-Vivo Experiments

http://www.roboticamedica.uma.es/marcus