CENTRE FOR AUTOMATION AND ROBOTICS CSIC-UPM

CENTRE FOR AUTOMATION AND ROBOTICS

Technological offer 2019-2020

CSIC
Consejo Superior de Investigaciones Científicas

POLITÉCNICA

Technological offer 2019-2020

The Centre for Automation and Robotics (CAR) is a joint research center of the Spanish Council for Scientific Research (CSIC) and the Universidad Politécnica de Madrid (UPM). The main objective of CAR is to develop applied research which aims at offering useful results for the society in the field of Robotics and Automation. CAR is vey well positioned in order to lead its ambitious research program, putting research on the areas of Control, Robotics and Artificial Perception at their highest level. Around one hundred researchers work at CAR and their activities are focused on the following scientific-technological areas: Control Engineering, Artificial Perception, Intelligent Robots and Applied Robotics.

The work carried out at CAR is funded by research agreements with private companies and by competitive institutional programs, both national and international, such as the European Commission, National Plan for R&D+I, Madrid Regional Government and AECID, among others. These activities lead to a large number of collaborations with private companies and other research centers.

The research activity of CAR is strategically linked to the training of UPM postgraduate students. It includes Master's Degree and Doctorate Degree Programs in Automation and Robotics.

The Centre for Automation and Robotics (CAR) has two different places of business:

- CSIC headquarters in Arganda del Rey (Madrid), and
- UPM headquarters at the E.T.S. Ing. Industriales, Madrid.

RESEARCH UNITS AND GROUPS

INTELLIGENT ROBOTICS

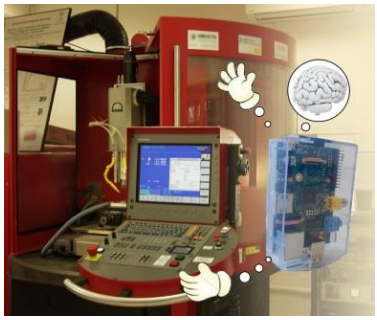
The activities of this research group are oriented to broaden the methodologies for the development and control of robots and special machines by using the know-how derived from artificial intelligence. Its aim is to design and build high-performance robots, machines and systems for different applications.

The research groups focused on this area are:

- **AUTOPIA – Automated Driving of vehicles.**
- **Computational Cognitive Robotics.**
- **Robots and Intelligent Machines.**

APPLIED ROBOTICS

This research unit is focused on the design and conception of new service robotics applications. The main objective is to obtain more efficient solutions in the field of Robotics for different applications of service robots.



Research groups focused on this area are:

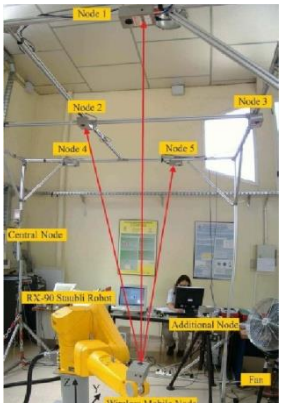
- **Service Robotics.**
- **Robotics and Cybernetics.**

SUPERVISION AND INTELLIGENT CONTROL

The purpose of this research unit is to promote and develop new scientific-technical methods and advanced strategies within the integration of computational science and intelligent control in order to generate new scientific knowledge and techniques. It also aims at the optimization of behavior that will lead to short, medium and long term improvement of wide range of processes and systems.

Research groups focused on this area are:

- **Intelligent Control.**
- **Intelligents Automation of Manufacturin Processes.**



PERCEPTION

The major challenge of artificial perception systems is to process and exploit the vast amount of information about the environment provided by sensory devices. That is the reason why the research unit on Perception involves processing methods using innovative signal as well as designing special sensors that adequately capture reality data of an environment.

Research groups focused on this area are:

- **Computer Vision.**
- **Artificial Perception.**
- **Autonomous System.**
- **Intelligent Systems Localization and Exploration.**

3DLocus: High accuracy 3D positioning with acoustic and ultrasonic technology

3DLocus is a Local Positioning System (LPS) designed and built by the Lopsi group which uses acoustic or ultrasonic technology for high accuracy positioning of mobile objects in small indoor areas. By measuring the time-of-flight (TOF) of spread-spectrum acoustic signals propagating from several static beacons to a mobile node, its position can be computed by multilateration, usually with an accuracy of about 1 cm in a volume of a few cubic meters; the resolution is close to 1 mm.

Key features of the 3DLocus system are:

a) Beacon design with emitting/receiving transducers at each node, enabling bi-directional signal transmission.

b) CDMA encoding of the acoustic signals for high accuracy ranging, using similar principles to the GPS system.

c) Robust positioning algorithms for detection of outliers and compensation of the effects of wind and temperature changes.

3DLocus can be used as a high accuracy positioning sensor in industrial environments, as well as a portable, general purpose positioning device in outdoor applications.

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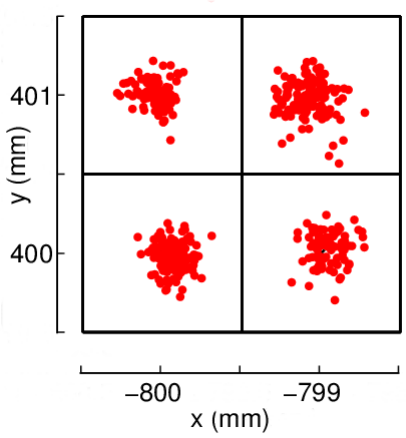
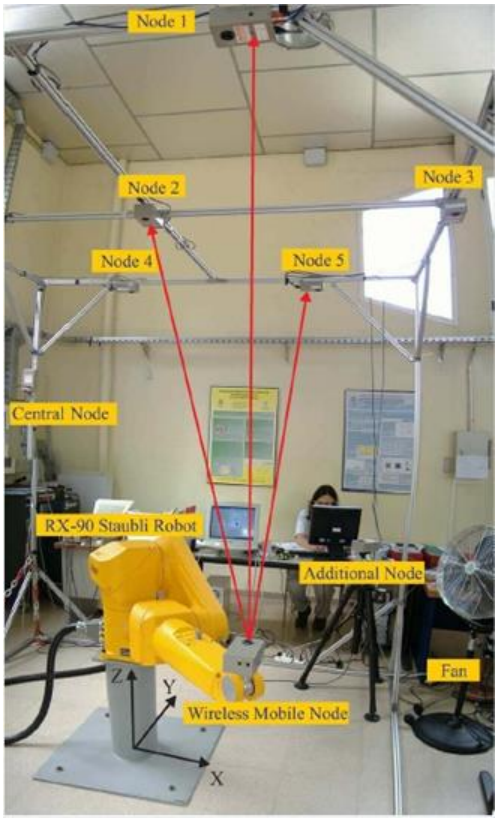
FACILITIES/INFRAESTRUCTURE:

A demonstrator is available at our CAR-CSIC center in Arganda del Rey (Madrid).



3D-positioning estimation with high accuracy and millimetre-level resolution in restricted areas



EXPERTISE AND EXPERIENCE:

LOPSI is a research group specialized in the creation of technological solutions for intelligent environments, which can perceive the presence of people, and offer them useful, location-based services. We perform both basic research and technological development in this area.

Recent projects/activities:

- **LORIS** (M. de Economía y Competitividad, 2013-2015)**: Localization Cooperative Systems for People and Objects in Diverse Environments.**
- **LEMUR** (M. de Ciencia e Innovación, 2009-2012)**. Continuous Location in Wide Areas with Ultrasound and Radiofrequency, with an Application on Personal Guidance Aids.**
- **3D-LOCUS** (Atapuerca, 2004-2006) **Ultrasonic sensor system for positioning and profiling of paleo-archaeological finds.**
- **RESELAI** (M. de Educación y Ciencia, 2006-2009)**. Integration of acoustic, vision and RFID sensor networks for location in smart environments.**

Publications, and/or products, services

- F. Seco, J. C. Prieto, A. R. Jiménez y J. Guevara, **Compensation of Multiple Access Interference Effects in CDMA-based Acoustic Positioning Systems,** IEEE Transactions on Instrumentation and Measurement , vol. 63, no. 10, pp. 2368-2378, October 2014.
- J.C. Prieto, C. Croux y A.R. Jiménez, **RoPEUS: A New Robust Algorithm for Static Positioning in Ultrasonic Systems**, Sensors vol: 9, no. 6, pp. 4211-4229 (2009).
- A.R. Jiménez, J.C. Prieto, J.L. Ealo, J. Guevara y F. Seco, **A computerized system to determine the provenance of finds in archaeological sites using acoustic signals**, Journal of Archaeological Science, vol. 36, no. 10, pp. 2415-2426 (2009).
- J.C. Prieto, A. R. Jiménez, J. Guevara, J. Ealo, F. Seco, J. Roa, A. Koutsou, **Performance evaluation of 3D-LOCUS advanced acoustic LPS**, IEEE Transactions on Instrumentation and Measurement, vol. 58, no. 8, august 2009, pp. 2385-2395.
- J. C. Prieto, A. R. Jiménez, J. Guevara, J. Ealo, F. Seco, J. Roa, F. Ramos, **Subcentimeter-accuracy localization through broadband acoustic transducers**, IEEE International Symposium on Intelligent Signal Processing, Alcalá de Henares, Spain, 3-5 de Octubre de 2007, pp. 929-934.

More information:

http://www.car.upm-csic.es/lopsi

Keywords:

- Acoustic and ultrasonic technology.
- CDMA Signal processing.
- High accuracy localization.
- Portable positioning devices.

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Adaptive & immersive multi-robot interfaces

Multi-robot systems have become a reality and are being applied to current missions, as well as allowing new and more complex missions. However, there are still challenges related to human factors: a current mission involves more operators than robots, and these people face problems of workload and situational awareness.

The Robotics and Cybernetics (ROBCIB) research group is developing a new generation of multi-robot interfaces to address these challenges.

These interfaces use data mining and machine learning techniques to select the relevant information according to the mission state and operator preferences. Additionally, virtual and augmented reality technologies are used to reproduce the mission environment and introduce the operators, improving their situational awareness without increasing their workload.

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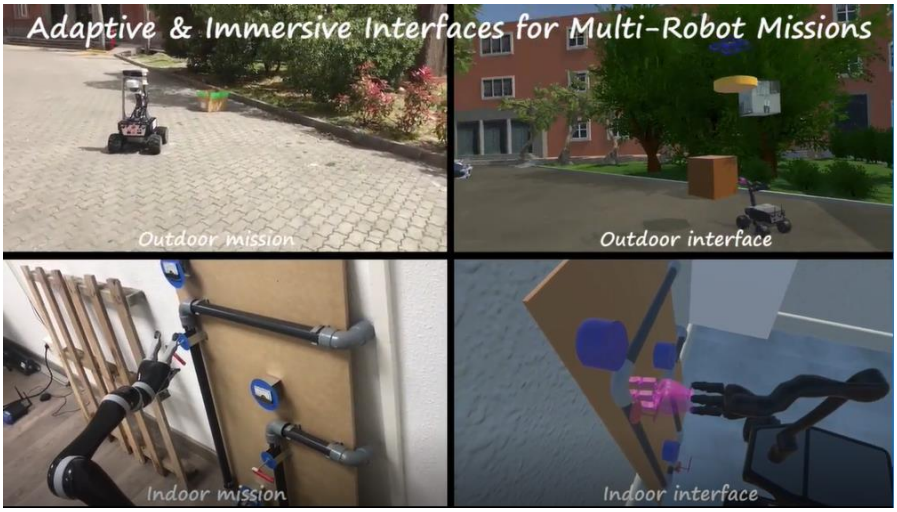
FACILITIES:

ROBCIB has a fleet of both ground and aerial robots, as well as virtual and augmented reality devices.

Multi-Robot Mission Modeling and Virtual Reality Interface



Adaptive & Immersive Interfaces for Single Operator and Multiple Robots Missions

EXPERTISE AND EXPERIENCE:

Our main expertise and experience are related to:

- Adaptive and immersive interfaces.
- Mission and operator modeling.
- Data and process mining.

Recent projects:

Public:

- **PRIC: Robotic Protection of Critical Infrastrures.** National Research Program (DPI2014-56985-R) http://www.car.upm-csic.es/?p=6362.
- **ROTOS:** MULTIROBOT SYSTEMS FOR PROTECTION OF LARGE OUTDOOR INFRASTRUCTURES. National Research Program. Ministerio de Economía y Competitividad (2014-2017).

  http://www.car.upm-csic.es/?portfolio=multirobot-systems-for-protection-of-large-outdoor-infrastructures
- **NMRS.** NETWORKED MULTI-ROBOT SYSTEMS. Cat B. European Defense Agency. http://www.eda.europa.eu/docs/documents/Executive-summary-NMRS.pdf

Private:

- Sistemas robóticos destinados a la evacuación del entorno e intervención tras una situación de catástrofe internacional. SENER.
- **SAVIER:** Situational Awareness VIrtual EnviRonment. Airbus.

Publications:

- Juan Jesús Roldán, Miguel Ángel Olivares-Méndez, Jaime del Cerro and Antonio Barrientos. **Analyzing and improving multi-robot missions by using process mining**. *Autonomous Robots*, 42(6), 1187-1205, 2018.
- Juan Jesús Roldán, Elena Peña-Tapia, Andrés Martín-Barrio, Miguel Ángel Olivares-Méndez, Jaime del Cerro and Antonio Barrientos. **Multi-robot interfaces and operator situational awareness: Study of the impact of immersion and prediction**. *Sensors*, 17(8), 1720, 2017.
- Juan Jesús Roldán, Jaime del Cerro, and Antonio Barrientos. **Using Process Mining to model multi-UAV missions through the experience.** *IEEE Intelligent Systems*, 32(4), 40-47, 2017.
- Mario Garzón, João Valente, Juan Jesús Roldán, Leandro Cancar, Antonio Barrientos and Jaime del Cerro. **A multirobot system for distributed area coverage and signal searching in large outdoor scenarios.** *Journal of Field Robotics*, 33(8), 1087-1106, 2016.
- Juan Jesús Roldán, Pablo Garcia-Aunon, Jaime del Cerro and Antonio Barrientos. **Determining mission evolution through UAV telemetry by using decision trees**. *IEEE International Conference on Systems, Man, and Cybernetics*, 188-193, 2016.
- Juan Jesús Roldán , Bruno Lansac, Jaime del Cerro, Antonio Barrientos. **A Proposal of Multi-UAV Mission Coordination and Control Architecture.** *Robot 2015: Second Iberian Robotics Conference*, 2015.
- J. J. Roldán, J. del Cerro and A. Barrientos. **A proposal of methodology for multi-UAV mission modeling.** *IEEE Mediterranean Conference on Control and Automation*, 2015.

Keywords:

- Multi-robot Interface
- Adaptive Interfaces
- Immersive Interfaces
- Situtional Awareness
- Workload
- Mission Modeling
- Data and process mining

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Aerial Vision-based Navigation & Collision Avoidance

Computer Vision can successfully be applied to **increase the autonomy of Unmanned Aerial Vehicles** (UAVs)* in a similar way as sight is the most powerful sense for human autonomy.

Cameras are cheap and lightweight sensors that provide a huge amount of information which can be processed using the newest Artificial Intelligence techniques in order to extract visual information that allows **UAVs to perform fully autonomous flights** in GPS-denied environments, while providing enhanced situational awareness.

Computer Vision onboard UAVs is essential to provide unmanned navigation with **human-equivalent levels of safety**, which are a requirement for the safe integration of UAVs in our airspace.

* also known as RPAS (remotely Piloted Aircraft Systems) or commonly “drones”

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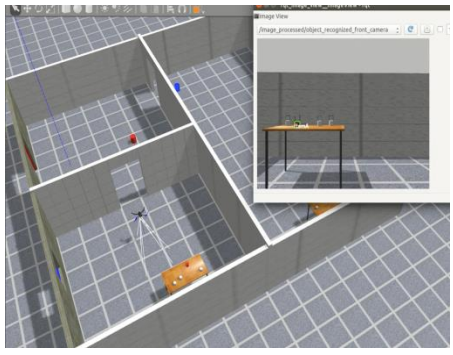
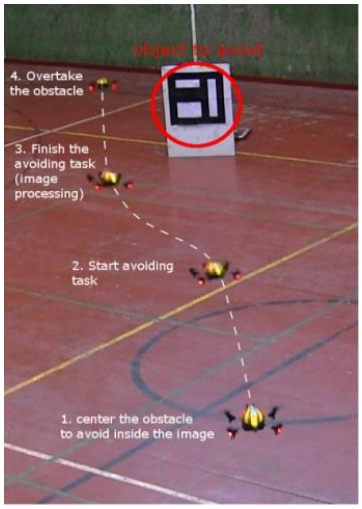
Visual-guided air-to-air refuelling



Fully-autonomous swarm indoor navigation

Automatic object following using on-board vision



Localization & obstacle avoidance using visual markers

Aircraft detection using RGB camera, ADS-B and thermal infrared cameras

Recent related projects:

- **"Visual Autonomy for UAV in Dynamic Environments"** funded by the Spanish Ministry of Economy and Competitiveness DPI2014-60139. 2015-18.
- **"DEO-VAR: Obstacle Detection and Avoidance Techniques development for Rotary Wings Aerial Vehicles"** RIS3 Program contracted by Ixion Industry Aerospace S.L. 2015-16.
- **"TAISAP-UAV: Alternative technologies for enhanced security in UAV precision landing"** AEESD Program TSI-100103-2014-177, contracted by Unmanned Solutions S.L. 2014-16.
- **"MESOANTEN: Security enhancement in the complete operation of aircraft in naval environments"** Program RETOS - Colaboración RTC-2014-1762-8 with Unmanned Solutions S.L. 2014-16.
- **"UECIMUAVS: USA and Europe Cooperation in Mini UAVs"** IRSES Project, coordinating Linköping University (LiU), Sweden, Arizona State University (ASU), USA. 2012-16.
- **"E-Vision I & II: Computer Vision-based detection and avoidance for UAVs"** contracted by Unmanned Solutions S.L. supported by the AVANZA Program Ministry of Industry. 2011-14.

Recent awards:

- **"Best Obstacle Avoidance Award"** and **"Best Trajectory Controller"** special awards at the International Aerial Robotics Competition **IARC-2014.**
- **"First Prize in the Indoors Autonomy"** at the International Micro Air Vehicle Competition **IMAV 2013**
- **"Best Automatic Performance" and "2nd prize in Indoor Flight Dynamics - Rotary Wing MAV"** at the International Micro Air Vehicle Competition **IMAV 2012 .**

Recent related publications:

- ***"A vision based aerial robot solution for the Mission 7 of the International Aerial Robotics Competition"***, Unmanned Aircraft Systems (ICUAS), International Conference on, 1391-1400. 2015.
- ***"A reliable open-source system architecture for the fast designing and prototyping of autonomous multi-uav systems: Simulation and experimentation"***, JINT 1-19, 2015.
- ***"SIGS: Synthetic Imagery Generating Software for the Development and Evaluation of Vision-based Sense-And-Avoid Systems"***, Journal of Intelligent & Robotic Systems, 1-16, 2015.
- ***"Computer vision based general object following for GPS-denied multirotor unmanned vehicles"***, American Control Conference (ACC), 1886-1891, 2014.
- ***"Robust real-time vision-based aircraft tracking from Unmanned Aerial Vehicles"***, Robotics and Automation (ICRA), IEEE International Conference on, 5441-5446, 2014.
- ***"A system for the design and development of vision-based multi-robot quadrotor swarms"***, Unmanned Aircraft Systems (ICUAS), International Conference on, 640-648, 2014.

Main Keywords:

UAV, RPAS, Drones, Computer Vision, Image Processing, Control, Pattern Recognition.

Specific Keywords:

Visual control, pose estimation, v-SLAM, See & Avoid, Swarming, Autonomous navigation, Trajectory planning, Object detection and recognition, GPS-denied.

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www.vision4uav.com

Algorithmic solutions for complex problems

This line of research is the result of more than a decade of work on hard combinatorial problems, which are computationally intractable due to the combinatorial explosion of possibilities. Particularly successful has been research related to fundamental NP-hard graph problems such as vertex coloring or clique.

Combinatorial optimization problems appear in many real life problems such as computational biology, computer vision— in particular image analysis—, planning, deployment, network analysis and optimization and many others. When these hard problems appear in Industry they are usually solved approximately. We are particularly interested in **EXACT** solutions for very hard real problems with the proper structure.

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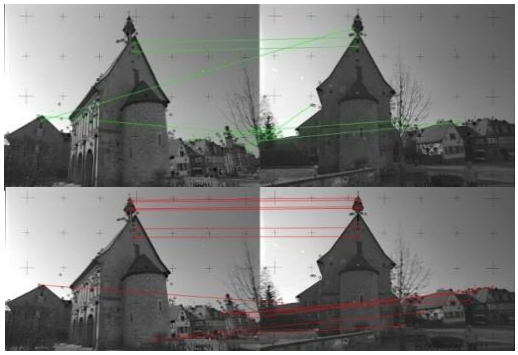
PROBLEM EXAMPLES AND APPLICATIONS



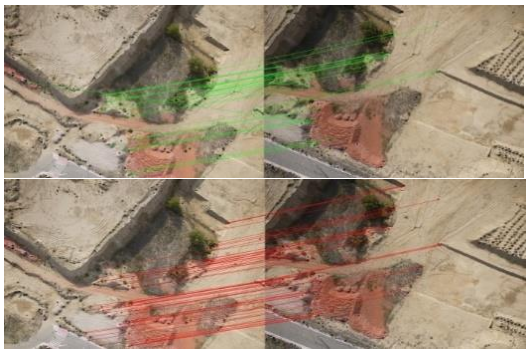
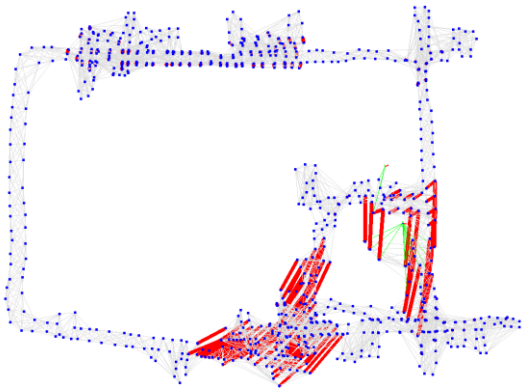
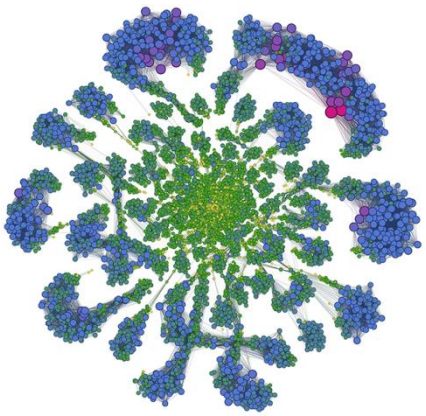


Image analysis and reconstruction



Mobile robotics (SLAM)



Network analysis

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Classical search problems in Artificial Intelligence.
- Combinatorial Optimization problems: Clique, SAT, Vertex Coloring etc.
- Problem reduction.
- Constraint Satisfaction Problems.

Related projects:

- **ROBINT:** Integration of Intelligent Behaviors for Guide Robots (2005-2007), DPI-2004-07907-C02.
- **ROBONAUTA:** Integration of Knowledge Models for Autonomous Deployment of an Interactive Mobile Robot (2007-2010) DPI-2007-66846-C02-01.
- **ARABOT :** Integration of Knowledge Models for an Autonomous Rational Robot (2011-2014) DPI 2010-21247-C02-01 (http://intelligentcontrol.disam.etsii.upm.es/arabot/).
- **NAVEGASE :** Navigation assisted by Natural Language (2015-2017) DPI 2014-53525-C3-1-R.

Recent Publications:

- San Segundo, P., Rodriguez-Losada, D., Jimenez, A.; ***An exact bit-parallel algorithm for the maximum clique problem*.** Computers & Operations Research, 38(2), 2011, 571-581.
- San Segundo, P.; Matia, F.; Rodriguez-Losada, D.; Hernando, M. ***An improved bit parallel exact maximum clique algorithm,*** Optimization Letters, 7(3), 2013, 467-479.
- San Segundo, P.; Tapia, C.; ***Relaxed approximate coloring in exact maximum clique search*,** Computers &Operations Research, 44, 2014, 185-192.
- San Segundo, P.; Rodriguez-Losada, D***.; Robust Global Feature Based Data Association With a Sparse Bit Optimized Maximum Clique Algorithm.*** IEEE Transactions on Robotics, 29(5), 2013, 1332-1339.
- San Segundo, P., Artieda, J.; ***A novel clique formulation for the visual feature matching problem*,** Applied Intelligence, 2015, Online (doi: 10.1007/s10489-015-0646-1).
- San Segundo, P., Rodríguez-Losada, D., Matía, F., Galán, R.; ***Fast exact feature based data correspondence search with an efficient bit-parallel MCP solver.*** Applied Intelligence, 32:3, 2010, 311-329.
- San Segundo, P. ***New decision rules for exact search in N-Queens.*** Journal of Global Optimization (JOGO). Springer, 51(3), 497-514, 2011.
- Komosko, L., Batsyn, M., San Segundo, P., Pardalos, P. M***.; A fast greedy sequential heuristic for the vertex colouring problem based on bitwise operations,*** Journal of Combinatorial Optimization, 2014, Online (doi: 10.1007/s10878-015-9862-1).
- San Segundo, P.; ***A new DSATUR-based algorithm for exact vertex coloring*.** Computers & Operations Research, Elsevier, 39 (7), 2012, 1724-1733.

Keywords:

- Combinatorial Optimization.
- Algorithms.
- Search.
- Graphs.
- NP-hard problems.

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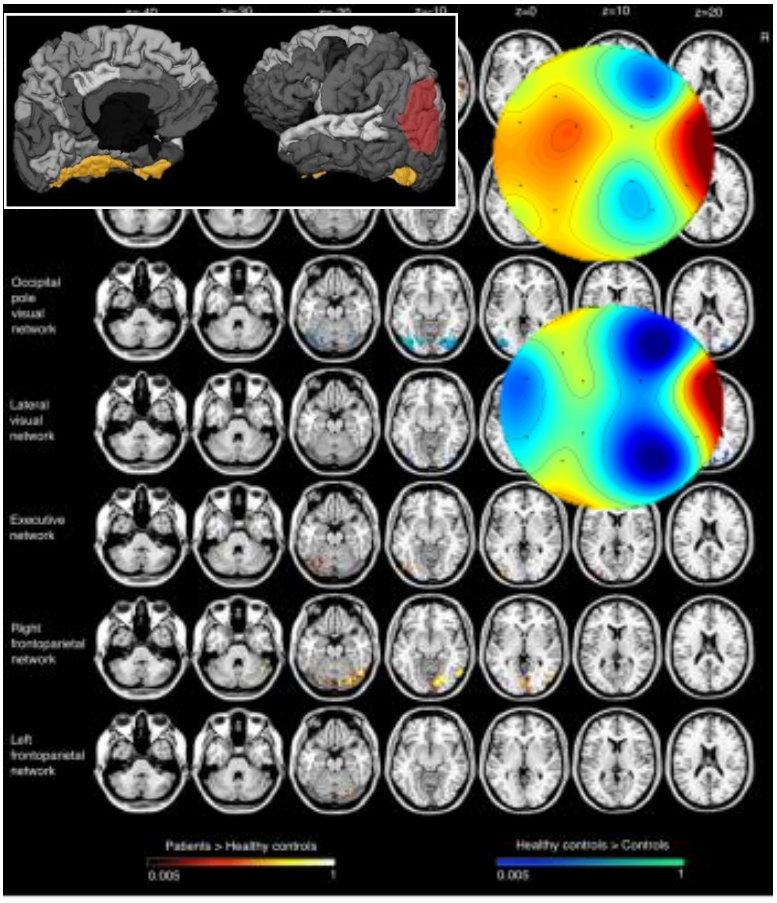
Cognitive and Movement Neurophysiology

The Neural and Cognitive Engineering group (gNec) has a growing interest in understanding the neurophysiological mechanisms responsible for movement and cognitive functions in healthy and pathological conditions. We intend to identify biomarkers that allow for a better diagnosis of motor disorders, as well as novel strategies to manage their motor symptoms through robotics and/or electrical stimulation and also to study neurophysiological and neuropsychological evolution in cognitive training to identify cortical brain plasticity. The integration of neuropsychological, cognitive and clinical data can lead to generate "machine tools" to support neurodegenerative disease diagnosis.

EXAMPLES OF RECENT PROJECTS:



Altered Resting State Brain Networks in Essential Tremor

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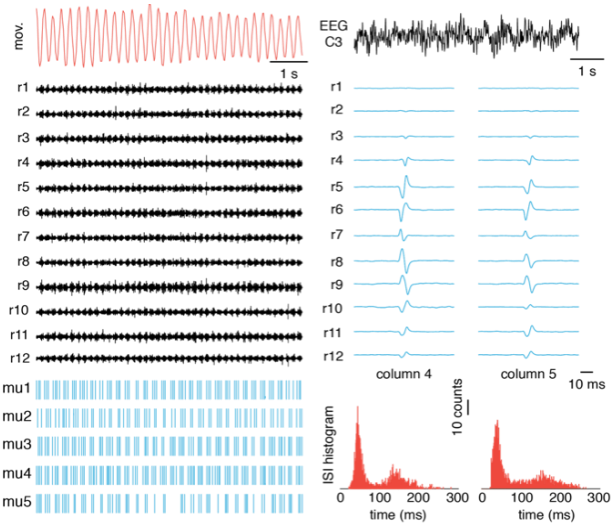
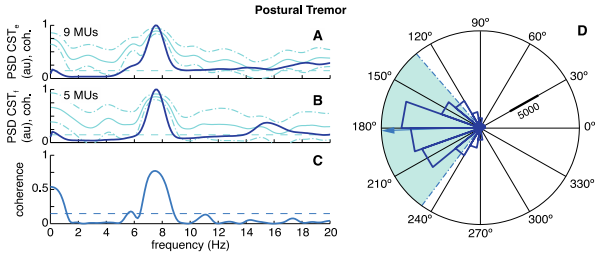


Corticospinal coupling in pathological tremors. Example of EEG and multichannel EMG recordings (r1-12), and some of the concurrently detected motor unit spike trains (mu1-5).



Relationship between neural drives to antagonist muscles in tremor. A,B: tremor synaptic input to the motoneuron pools, C: shared common synaptic input across pools, D: phase difference between them

EXPERTISE AND INTERESTS:

Main expertise and experience are related to:

- Analysis of high-density surface EMG, EEG, MEG, fMRI and kinematic data to elucidate the common and differential mechanisms causing neurodegenerative diseases.
- Investigation of the supraspinal and spinal mechanisms that generate tremor in essential tremor and Parkinson's disease.
- Analysis of fMRI data to elucidate changes in brain connectivity in people suffering from neurodegenerative diseases.
- Development and validation of multi-scale models of neurodegenerative diseases, these comprising: 1) neural activity, 2) limb biomechanics, and 3) EMG.
- Analysis of volumetry and corticometry MRI data and/or neuropsychological data to find discriminant patterns in neurodegenerative diseases.
- Brain Plasticity: neurophysiological studies of cognitive function in ageing and analysis of the evolution of EEG signal and of neuropsychological variables in working memory training.

Recent projects

- **NeuroTREMOR,** A novel concept for support to diagnosis and remote management of tremor. FP7-ICT-2011-7-287739 (2012-2015), http://www.neurotremor.eu
- **NeuroPlast**, Implementation of a Novel Brain Machine Interface to Restore Limb Movement and Promote Recovery from Partial Spinal Cord Injury: Basic Studies and Clinical Application, FP7-PEOPLE-2013-IOF-627384 (2014-2017)
- **NEUROMOD**, Desarrollo y validación clínica de una plataforma de rehabilitación basada en neuromodulación para pacientes con trastornos del control motor, DPI2015-68664-C4-1-R. 2016-2018.

Publications:

- J.I. Serrano, J.P. Romero, M.D. del Castillo, E. Rocon, E.D. Louis, J. Benito-León. **A data mining approach using cortical thickness for diagnosis and characterization of essential tremor**. Scientific Reports, 7(1) 2190, (2017).
- Julián Benito-León; Elan D. Louis; Juan Pablo Romero; Juan Antonio Hernández-Tamames; Eva Manzanedo; Juan Álvarez-Linera; Félix Bermejo-Pareja; Ignacio Posada; Eduardo Rocon. ***Altered Resting State Brain Networks in Essential Tremor***, *submitted to Brain* (2015).
- Gallego, J.A. et al. ***Influence of common synaptic input to motor neurons on the neural drive to muscle in essential tremor***. J Neurophysiol.;113(1):182-91. doi: 10.1152/jn.00531.2014 (2015).
- Ibáñez J., González de la Aleja J., Gallego J.A., Romero J.P., Saíz-Díaz S., Benito-León J., Rocon E. ***Effects of alprazolam on cortical activity and tremor in patients with essential tremor.*** PLoS ONE 9(3), e93159 (2014)
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- del Castillo, MD., Serrano, J.I., Ibáñez, J., Barrios, L. ***Metodología para la Creación de una Interfaz Cerebro-computador Aplicada a la Identificación de la Intención de Movimiento***. Revista Iberoamericana de Automática e Informática Industrial 8(2):93-102. doi: 10.4995/RIAI.2011.02.12 (2011).
- J. Ibáñez, J.I. Serrano, M.D. del Castillo, E. Monge, F. Molina, F.M. Rivas, I. Alguacil, J.C. Miangolarra, J.L. Pons. ***Upper-limb muscular electrical stimulation driven by EEG-based detections of the intentions to move: a proposed intervention for patients with stroke***. EMBC 2014 (2014).
- M. D. del Castillo, J. I. Serrano, S. Lerma, I. Martínez, E. Rocon. ***evaluación neurofisiológica del entrenamiento de la imaginación motora con realidad virtual en pacientes pediátricos con parálisis cerebral,*** RIAI, 15(29), 174-179, (2018).

Keywords:

Neurophysiology, Neurophysiology of Movement, Electrophysiology, EEG, EMG, Motor Unit Spike Trains, Neuroimaging

Pathologies:

Essential Tremor, Parkinson's Disease, Alzheimer's Disease, Stroke, Cerebral Palsy

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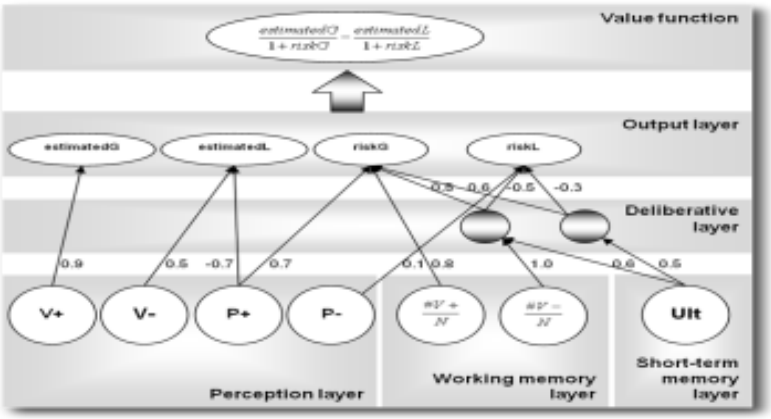
Cognitive Science

The Neural and Cognitive Engineering group (gNec) has a solid experience in the interdisciplinary research and development of plausible architectures of cognitive functions from neurological and psychological evidences explaining brain procedures from perception to output behavior. These architectures optimized to individual subjects produce models that can serve as diagnostic, prognostic and therapy assessment tools for suited interventions. We also work on the application of statistical techniques and machine learning methods to build average descriptive and predictive profiles from human biometric and psychometric data.

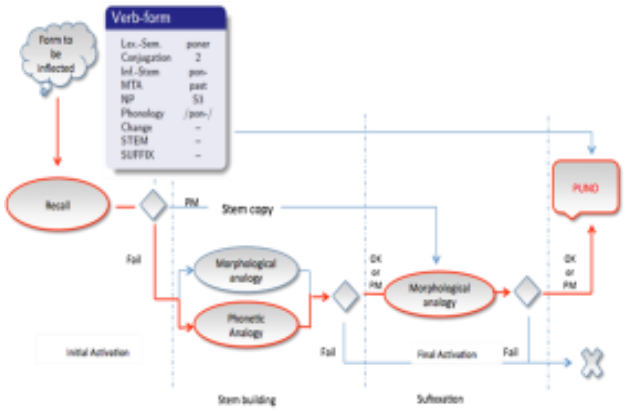
RECENT DEVELOPMENTS:

Technological offer driven by CAR UPM-CSIC

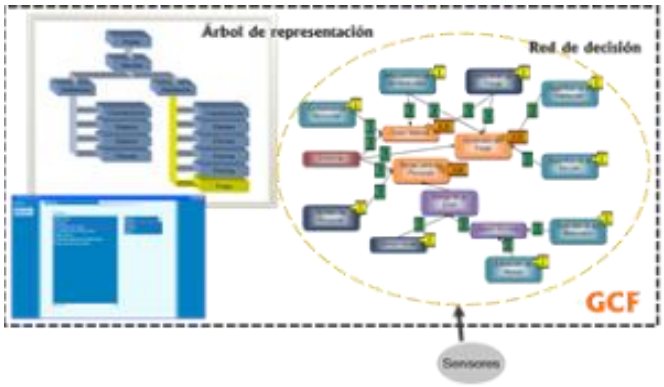
Since 1997, the group has addressed the computational modeling of several cognitive by new developed rational/emotional cognitive architectures. This research have leaded in the decision making field to a decision support system for fire emergencies and cognitive models of drug abusers. In the language field, we have developed models of reading ability in digital search systems and verb morphology production for specific language impairment and Alzheimer's Disease. These models are complemented with data mining methods for dealing with other human biological/psychological information sources.

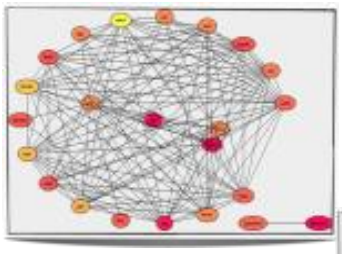


Model of Assessment and Inference of Decisions based on a Net of concepts

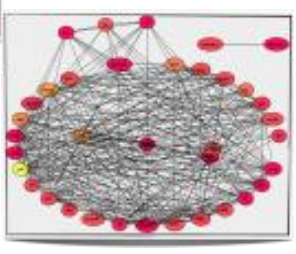


Decision Support System for fire emergencies





Models of language functions



EXPERTISE AND INTERESTS:

Main expertise and experience are related to:

• Computational Cognitive Modeling:

- Individual modeling to identify parameters related to the personalized cognitive abilities of each subject.
- Decision, game and economic theories: normative and descriptive approaches.
- Knowledge-based architectures: multilayer connectionist paradigm.

• Medical Informatics:

- Machine learning methods and statistical techniques applied to knowledge discovery from clinical data.

Recent projects

- **HESPERIA.** Sistema avanzado de ayuda en la toma de decisiones en gestión de crisis y modelado de decisiones. MTIYC-CENIT (2006-2009).
- **TELEMACO**. Sistema de detección y alerta contra el acoso telemático a menores. FIT-360000-2007-65 (2007-2009).
- **SCUBI:** Modelo computacional cognitivo para la optimización de búsquedas digitales. PIE 201050E087 (2010-2013).
- **BCI-0**, Brain Computer Interface for Cognitive Training and Domotic Assistance against the Effects of Ageing. Fundación General CSIC. Proyectos Cero Envejecimiento. 2012-2015.

Publications:

- Iglesias, A., del Castillo, M. D., Serrano, J. I., y Oliva, J. ***A Computational Knowledge-based Model for Emulating Human Performance in the Iowa Gambling Task,*** Neural Networks 33, 168-180 (2012).
- Iglesias, A., del Castillo, M. D., Serrano, J. I., y Oliva, J. ***Knowledge-based Modeling in Dynamic Decision Making***. Proc. 34th Annual Conference of the Cognitive Science Society, 1715-1720. Austin, TX: Cognitive Science Society (2012).
- Iglesias, A., del Castillo, M. D., Serrano, J. I., y Oliva, J. ***A Psychologically and Neurophysiologically Plausible Model for Emulating Human Behavior in Decision Making Tasks***. Proc. Brain Inspired Cognitive Systems – BICS 2012. Madrid (2010).
- Iglesias, A., del Castillo, M. D., Santos, M., Serrano, J. I. & Oliva, J. ***Sistema de ayuda a la decisión aplicado a situaciones de emergencia en tiempo real***, RIAI, 8 (1): 80-88 (2011).
- Oliva, J., Ignacio Serrano, J.I., del Castillo, M.D., Iglesias, A. ***A syntax-based measure for short text semantic similarity***, Data & Knowledge Engineering, 70 (4):390-405 (2011).
- Oliva, J., Ignacio Serrano, J.I., del Castillo, M.D., Iglesias, A. ***A SMS normalization system integrating multiple grammatical resources***, Natural Language Engineering, 19 (1): 121-141 (2013).
- Oliva, J., Serrano, J.I., del Castillo, M.D., Iglesias, A. ***A methodology for the characterization and diagnosis of cognitive impairments. application to specific language impairment***, Artificial Intelligence in Medicine, 61(2), 89-96, (2014).
- Serrano, J.I., del Castillo, M.D., Iglesias, A. ***Human-inspired semantic similarity between sentences***, BICA, 53(11), 1201-1210, (2015).
- Serrano, J.I., del Castillo, M.D., Carretero, M. ***Cognitive? Science?***, Foundations of Science 19:115-31, (2014).
- Oliva, J., Serrano, J.I., del Castillo, M.D., Iglesias, A. ***Cross-linguistic cognitive modeling of verbal morphology acquisition,*** Cognitive Computation, 9(2), 237-258, (2017).
- Serrano, J.I., Iglesias, A., del Castillo, M.D. ***Plausibility validation of a decision making model using subjects' explanations of decisions***, BICA, 20, 1-9, (2017).

Keywords:

Cognitive knowledge-based architectures, Personalized modeling, Machine learning

Application domain:

Language impairments, Decision making, Digital search, Biometric and psychometric data

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Connected and automated driving

Intelligent vehicles technology is advancing at a vertiginous pace. However, the complexity behind some highly uncertain and dynamic urban driving scenarios suggest full automation may have usage limits. AUTOPIA Program was created 15 years ago with the intention of mitigating the potential limitations of fully autonomous driving through the use of shared human-machine control and cooperation with other road agents.

AUTOPIA has a solid experience in providing intelligence to automated vehicle systems in specific situations where communication and interaction abilities may permit to solve understanding/decision dilemmas of isolated self-driving cars. The group has a growing interest in decision-making architectures where driver intentions and skills can be adopted at different assistance levels (from SAE L2 to L4). In this connection, the influence of perception, localisation and mapping on decision-making and road interactions are key research questions that articulate AUTOPIA scientific activity.

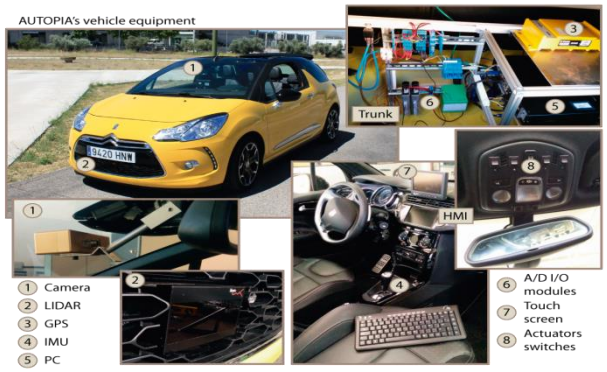
https://autopia.car.upm-csic.es

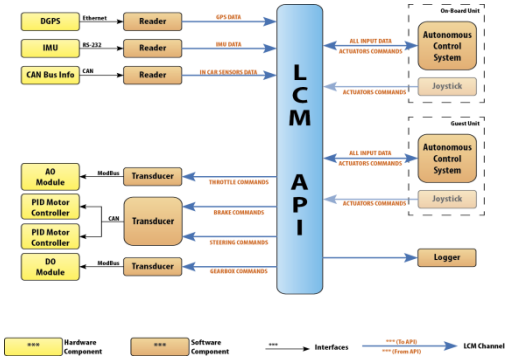
FACILITIES/INFRAESTRUCTURE:

AUTOPIA has a fleet of 5 automated vehicles and a test circuit designed as an inner city area, with a combination of straight-road segments, curves, 90 crossings and a roundabout. Additionally, a traffic light regulation system and RFID/Zigbee sensor networks make our facilities an excellent testing ground to demonstrate the most challenging topics in ITS domain.

Aerial image of the track

Traffic lights, communication tower and control booth





HW and SW architecture of one of our automated vehicles

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Design and implementation of artificial decision-making architectures for autonomous driving.
- Design and implementation of advanced control systems for intelligent vehicles.
- Fail-operational systems in driver-machine interaction.
- Design and implementation of strategies for human-like real-time trajectory planning.
- Modeling, simulation and control of cyber-physical systems focused on vehicles, infrastructures and information systems (weather and traffic information services, etc.).
- Design and implementation of cooperative solutions based on communication among vehicles.
- Sensor data fusion and intelligent processing aiming at safety of the drivers and the other road users.
- Demonstration activities at small-scale on the basis of the private driving circuits at CAR facilities including meteorological stations, traffic signals, five mass-produced vehicles equipped with V2X communications, and even physical temperature sensors installed in the road.

Recent projects:

- **EMC2:** Embedded Multi-Core systems for Mixed Criticality applications in dynamic and changeable real-time environments (2014-2017) http://www.artemis-emc2.eu/
- **TCAP-AUTO:** Familia de Tarjetas Compactas de Altas Prestaciones para Aplicaciones de Automoción (2015-2017)
- **COGDRIVE:** Navegacion de inspiracion cognitiva para conduccion autónoma (2018-2020)
- **PRYSTINE:** Programmable Systems for Intelligence in Automobiles (2018-2021) http://www.prystine.eu
- **SECREDAS:** Cyber Security for Cross Domain Reliable Dependable Automated Systems (2018-2021) https://www.ecsel.eu/projects/secredas

Publications, and/or products, services:

- A. Artuñedo, J. Godoy and J. Villagra, **A Primitive Comparison for Traffic-Free Path Planning**, IEEE Access, vol. 6, pp. 28801-28817, 2018.
- L. Medina, M. Diez-Ochoa, R. Correal, S. Cuenca-Asensi, A. Serrano, J. Godoy, A. Martínez-Álvarez and J. Villagra, **A comparison of FPGA and GPGPU designs for Bayesian occupancy filters**. Sensors, vol. 17(11), p.2599, 2017.
- J. Godoy, J.Pérez, E-Onieva, J.Villagrá, V. Milanés, R. Haber, ***A driverless vehicle demonstration on motorways and in urban environments,*** Transport, vol. 30(3), pp. 253-263, 2015.
- Godoy, J.; Milanés, V; Pérez, J.; Villagrá, J. & Onieva, E***., An auxiliary V2I network for road transport and dynamic environments,*** Transportation Research Part C: Emerging Technologies, vol. 37, pp. 145-156, 2013.
- Tejado, I.; Milanés, V.; Villagrá, J. & Vinagre, B., ***Fractional Network-based Control for Vehicle Speed Adaptation via I2V Communications,*** IEEE Trans. on Control Systems Technology, vol. 21 (3), pp. 780-790, 2013.

Keywords:

- Autonomous driving
- Intelligent vehicles
- V2X communication
- Embedded decision making
- Real-time trajectory planning.
- Cooperative Control.

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Field and Service Robotics

The main objective of the Field and Service Robotics Group is to significantly advance the scientific and technological state of the art of Field and Service Robots towards the achievement of a new generation of both manipulators (human amplifiers, agile bimanual platforms) and mobile robots (legged robots, wheeled mobile robots, robots with caterpillars, humanoid robots, passive robots, bioinspired systems and walking assistive exoskeletons) that open new possibilities and stimulate the resolution of key problems in the industrial leadership and social challenges."

Technological offer driven BY CAR UPM-CSIC

DEVELOPMENTS

Silo6 – DPI 2001-1595 and DPI2004-05824

ROBOCLIMBER - GROWTH G1ST-CT-50160

RHEA fleet – FP7 245986

TIRAMISU – FP7 284747

EXPERTISE AND EXPERIENCE:

Expertise and experience of this group is related to the design and control of:

- Human amplifiers
- Mobile robots
    - Legged robots (Walking and climbing robots)
    - Wheeled mobile robots
    - Humanoid robots
    - Passive robots
- Bioinspired systems
- Walking assistive exoskeletons
- Bimanual manipulation

RECENT RELATED PROJECTS:

- Robot Fleets for Highly Effective Agriculture and Forestry Management (RHEA), European Commission, FP7 245986, 2010-2014.
- Intelligent sensing and manipulation for sustainable production and harvesting of high value crops: crever robots for crops (CROPS). European Commission, FP7 246252, 2010-2014.
- Cucumber Gathering – Green Field Experiments CATCH FP7 (ECHORD++), 2016-2018.
- Detección inteligente y manipulación robótica bimanual para la cosecha selectiva de cultivos de alto valor (ROBOCROP), DPI2017-84253-C2-1-R, 2018-2020.
- Madrid Robotics Digital Innovation Hub (RoboCity2030-DIH-CM), Comunidad de Madrid, P2018/NMT-4331, 2019-2022.

RECENT RELATED PUBLICATIONS:

- L. Emmi, M. Gonzalez-de-Soto, G. Pajares, P. Gonzalez-de-Santos, "New Trends in Robotics for Agriculture: Integration and Assessment of a Real Fleet of Robots", The Scientific World Journal, Vol. 2014, pp. 1-21, 2014.
- M. Gonzalez-de-Soto, L. Emmi, Isaias García, P. Gonzalez-de-Santos, "Reducing fuel consumption in weed and pest control using robotic tractors", Computers and Electronics in Agriculture, Vol. 114, pp. 96-113., 2015.
- M. Gonzalez-de-Soto, L. Emmi, C. Benavides, I. Garcia, and P. Gonzalez-de-Santos, "Reducing air pollution with hybrid-powered robotic tractors for precisión agriculture", Biosystems Engineering, Vol 143, pp. 79-94, 2016.
- M. Gonzalez-de-Soto, L. Emmi, M. Perez-Ruiz, J. Aguera, and P. Gonzalez-de-Santos, "Autonomous systems for precise spraying – evaluation of a robotized patch sprayer", Biosystems Engineering, 146, pp. 165–182, 2016.
- P. Gonzalez-de-Santos; A. Ribeiro; C. Fernandez-Quintanilla; F. Lopez-Granados, M. Brandstoetter; S. Tomic; S. Pedrazzi; A. Peruzzi; G. Pajares; G. Kaplanis; M. Perez-Ruiz; C. Valero; J. del Cerro; M. Vieri; G. Rabatel and B. Debilde, Fleets of Robots for Environmentally-safe Pest Control in Agriculture, Precision Agriculture, Vol. 18, N. 4, pp.574–614, 2017.
- R. Fernandez, H. Montes, J. Surdilovic, D. Surdilovic, P. Gonzalez-de-Santos, and Manuel Armada, "Automatic Detection of Field-Grown Cucumbers for Robotic Harvesting", IEEE Access, Vol. 6, pp. 35512-35527, 2018.

Keywords:

Walking and climbing robots

Power assists devices

Multi-robot systems

Fleets of robots

Mobile robots

Exoskeletons

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Fuzzy logic & control

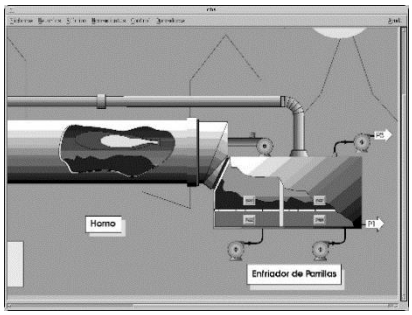
The research started in the early 90's in order to apply fuzzy logic technology in control systems. A lot of theory and industrial applications has been developed since then by the research group. Design methods of fuzzy controllers based on their analogy with PID control, state estimation using fuzzy logic, variable structure control, or fuzzy modeling are examples of the developed know-how.

On the other hand, applications of fuzzy logic have been demonstrated in a wide number of fields, from process control to robotics, in cases where controllers can be designed based on expert knowledge.

Technological offer driven BY CAR UPM-CSIC

PROTOTYPES:

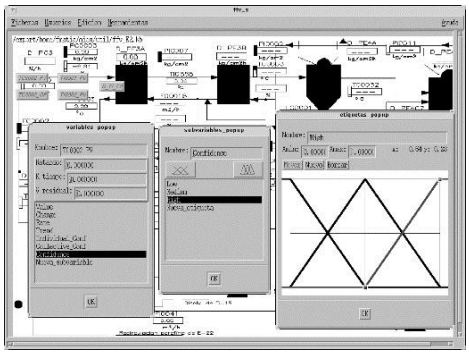
Different applications have been developed for industrial partners, such as ASLAND, REPSOL, VEKA IBERICA, ENUSA or ELIOP. Fuzzy logic is applied in different fields, such as fuzzy control, sensor validation or diagnosis.

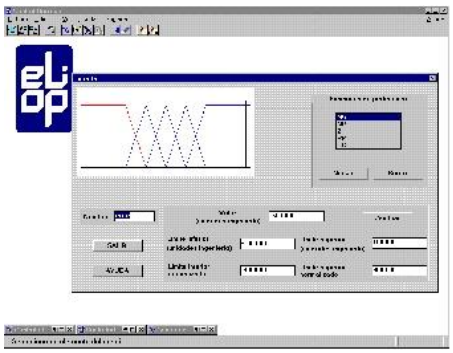


Cement industry

Petrochemical Industry

Extrusion Process





Examples of Fuzzy logic tools developed for REPSOL and ELIOP

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Fuzzy controller design techniques.
- Fuzzy modeling and systems identification.
- Variable structure and fuzzy logic.
- State estimation using possibility techniques.
- Fuzzy diagnosis systems.
- AMFE methodologies.

Recent projects:

- **EXEX:** Intelligent System for Extrusion Control (1995-1998), funded by Veka Ibérica S.A.
- **TOPKAPI**: Application of Fuzzy Logic Techniques to ELIOP Industrial Controllers based on Programmable Logic Controller ELI-4000 (1995-1997). Funded by CDTI.
- **SINCRO:** Intelligent System for the Ceramic Process Control using FMEA Methodology (1995-1996), funded by ENUSA.
- **DIXIT:** Distributed Information Technology for Strategic Muti-objective Process Control (1996-1998) ESPRIT 22130.
- **ROBINT:** Integration of Intelligent Behaviors for Guide Robots (2005-2007), DPI-2004-07907-C02.
- **NAVEGASE**: Navegación Asistida mediante Lenguaje Natural (2015-2017) DPI 2014-53525-C3-1-R.
- **COGDRIVE**: Técnicas de Inteligencia Artificial y Ayuda a la Navegación Autónoma (2018-2020) DPI2017-86915-C3-3-R.

Publications:

- F. Matía, A. Jiménez, R. Sanz y R. Galán, ***Fuzzy Controllers: Lifting the Linear-Nonlinear Frontier,*** Fuzzy Sets and Systems 52 (2), 113-128, DOI 10.1016/0165-0114(92)90044-5 (1992).
- F. Matía, A. Jiménez, B. M. Al-Hadithi, D. Rodríguez-Losada, R. Galán, ***The Fuzzy Kalman Filter: State Estimation using Possibilistic Techniques,*** Fuzzy Sets and Systems 157, 2145-2170, DOI 10.1002/oca.1014 (2006).
- F. Matía, A. Jiménez, B. M. Al-Hadithi, P. San Segundo, ***An Affine Fuzzy Model with Local and Global Interpretations,*** Applied Soft Computing 11, 4226-4235, DOI 10.1016/j.asoc.2011.03.018 (2011).
- B. M. Al-Hadithi, A. Jiménez, F. Matía, ***New Methods for the Estimation of T-S Model Based Extended Kalman Filter and its Applications to Optimal Control for Nonlinear Systems,*** Optimal Control, Applications and Methods 33 (5), 552-575, DOI 10.1002/oca.1014 (2012).
- A. Jiménez, B. M. Al-Hadithi, F. Matía, ***Variable Structure Control with Chattering Reduction of a Generalized T-S Model,*** Asian Journal of Control 15 (1), 155-168, DOI 10.1002/asjc.518 (2013).
- F. Matía, N. G. Marichal, E. Jiménez (Eds.), ***Fuzzy Modelling an Control: Theory and Applications,*** Computational Intelligence Systems 9, Atlantis Press, ISBN 978-94-6239-081-2 (2014).

Keywords:

- Fuzzy Modeling.
- Process Control.
- Intelligent Control.
- Advanced Control.
- Non-linear Control.

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GAMHE 4.0 Lab: Engineering the Intelligence for Industrial Cyber Physical Systems (CPS)

Cyber Physical Systems (CPS) expand a range of possibilities in industrial manufacturing processes through interconnected heterogeneous systems at large-scale ranging from information. In manufacturing environments, the Industrial CPS (ICPS) must be able to continuous update the knowledge generation provide to the users with the possibility to interact in real-time with process and machine indicators.

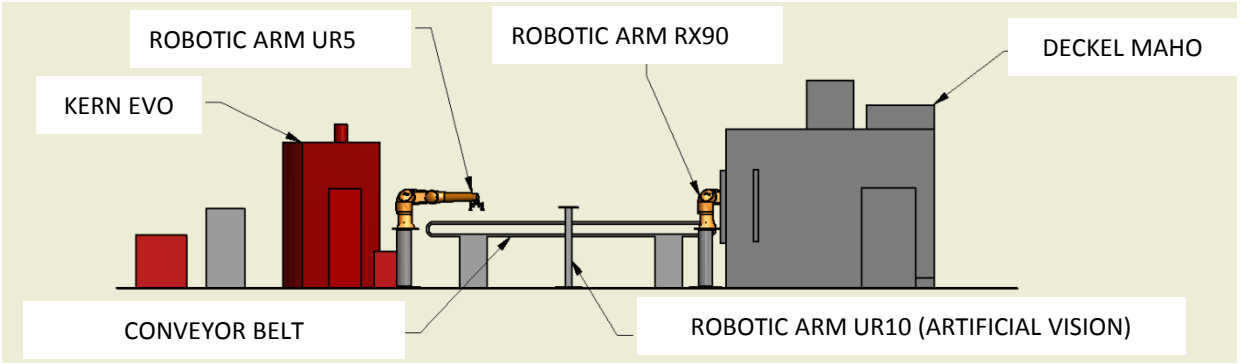
Based on Industrial CPS concepts, GAMHE 4.0 offers technological facilities to carry out R+D projects and for rapid solutions prototyping such as, sensors and a real-time data acquisition platform; real-time processes visualization; machine-to-machine communication interface without human-in-loop; data exchange based on distributed communication networks (Blockchain); production errors minimization (Zero-defect productions); and self-X capabilities (self-optimizing, self-resilience, self-organizing, self-adaptive), optimization methods and decision making strategies based on computational intelligence.

For this, as infrastructure, in GAMHE Manufacturing Lab, 3 Universal Machine Tool Centres fully sensorized and 3 manipulator robots, including an Ultra Precision Micromachining Centre equipped with a laser control Nano NT.

Technological offer driven BY CAR CSIC-UPM

FACILITIES/INFRAESTRUCTURE:

GAMHE Lab 4.0 demonstrator is available at Centre for Automation and Robotics (CAR) in Arganda del Rey (Madrid).



GAMHE 4.0 laboratory for Industrial Cyber-Physical Systems: Testing and Deployment.

EXPERTISE AND EXPERIENCE:

GAMHE is a research group specialized in new emerging fields for networked and embedded systems. The main goal is to evolve intelligent control strategies in order to develop new Artificial Cognitive Control Systems with self-X capabilities (self-optimizing, self-resilience, self-organizing, self-adaptive). Concepts and theoretical methods from neuroscience, philosophy and psychology are the foundations for new control methods. Bio-inspired strategies, Artificial Intelligence, Computational Science and System.

Recent projects/activities:

- **DEMANES: Design, Monitoring and Operation of Adaptive Networked Embedded Systems (2012-2015),** http://www.demanes.eu/
- **IoSENSE: Flexible FE/BE Sensor Pilot Line for the Internet of Everything (2016-2019),** http://www.iosense.eu/
- **EMC2: Embedded Multi-Core Systems for Mixed Criticality Applications in Dynamic and Changeable Real-Time Environments (2014-2017),** http://www.artemis-emc2.eu/
- **AM4G: Advanced Manufacturing 4th Generation (2016-2018).** CIEN Programme. CDTI. Spain (press.danobatgroup.com/am4g).
- **Power2Power: The next-generation silicon-based power solutions in mobility, industry and grid for sustainable decarbonisation in the next decade. (2019 - 2021).**
- **IPAE: Industry 4.0 in Production and Aeronautical Engineering (2019-2020).**

Patents:

- PCT / ES2008 / 070038, **"PROCEDURE AND MODELING SYSTEM FOR DRILLING PROCESSES "**, r03/03/2008,
- PCT / ES2009 / 070375, **"PROCEDURE AND SYSTEM FOR ESTIMATION IN REAL TIME OF SURFACE ROUGHNESS IN MACHINING PROCESSES ULTRA-PRECISION"**, 27/01/2011.
- PCT / ES08 / 070039, "PROCEDURE OF CONTROL BASED ON LOGIC BLURRED FOR DRILLING PROCESSES ",, 03/03/2008.
- PCT / ES2009 / 070374, **"PROCEDURE AND SYSTEM FOR DETECTION IN REAL TIME OF HEAD DISCALANCE IN A ROTATING MECHANISM OF HIGH PRECISION ",** 01/27/2011.
- PCT / ES2009 / 070453, **"INTELLIGENT DEVICE AND PROCEDURE FOR COMPENSATION OF CARNIER FALLS IN TOOL MACHINES ",** 10/23/2009.
- PCT / ES2013 / 070740, **"METHOD FOR MONITORING IN REAL TIME THE ROUGHNESS OF A PIECE DURING A PROCESS OF MACHINING "**, 10/25/2012.
- PCT / ES2013 / 070760, **"PROCEDURE AND SYSTEM FOR MONITORING IN REAL TIME OF A MACHINING OPERATION ",** 03/18/2015.

More information:

http://www.gamhe.eu

Keywords:

- Industrial Cyber-Physical Systems.
- Industrie 4.0 and Cognitive manufacturing.
- Intelligent control and monitoring.

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Human-computer interaction for people with motor disorders

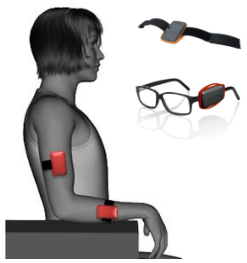
People with multiple physical and cognitive impairments have difficulties for using properly conventional pointing devices, what reduces their possibilities to communicate and improve their cognitive and physical skills through computers. Our research is focused on measuring the human intention to generate control commands using emerging sensor (motion, muscle activity, eye tracking, brain activity, etc.). The group has proven experience – very significant paper record in highly ranked publications and the participation in several national and European projects- in augmented and alternative communication, filtering of involuntary patterns, motor rehabilitation and objective assessment, among others.

Technological offer driven BY CAR CSIC-UPM

Human-computer interaction-based human expressions

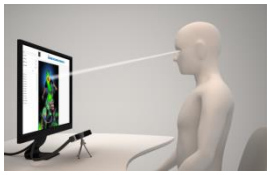
The group develops sensors to measure different patterns of the human behavior. Since we are focused on movement disorders the main device is a Wireless Inertial Measurement Units (WIMU) , which captures the body limb motion. We develop wearable sensor for capturing human expressions and translate them into control commands.

Movement analysis



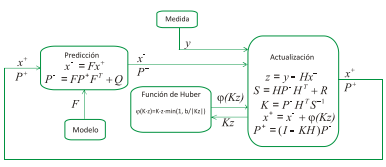
Physiological sensors

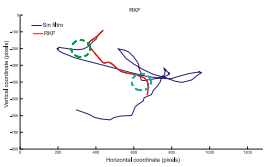
Eye and face tracking



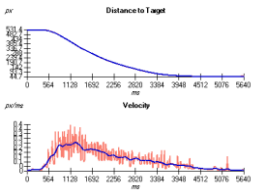
Computer access

Algorithms for enhancing human-computer interaction





Rehabilitation and objective assessment



Foundation of the spin-off for technology transfer in 2015

..werium..

www.weriumsolutions.com

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Design of the hardware and firmware of inertial measurement units for motion capture.
- Design of wearable sensors for capturing physiological signals.
- Implementation of software applications for human-computer interaction.
- Design and programming of filtering algorithms to reduce the effect of motor disorders on the computer control.
- Analysis of captured data from eye-tracking systems.
- Control of assistive technologies using computer-based architecture (e.g. Wheelchairs, special vehicles, etc).
- Design and implementation of Brain-Machine Interface systems and algorithms for natural interaction with rehabilitation devices.

Recent projects:

- **INTERPLAY.** Videoconsola avanzada adaptada a la rehabilitación lúdica de niños con discapacidad neuromotora. 2014-2016. Responsible: E. Rocon. http://www.virtualwaregroup.com/idi/interplay/.
- **CPWalker.** Plataforma robótica para la rehabilitación y el entrenamiento de la marcha en pacientes con Parálisis Cerebral. Plan Nacional. Responsible: E. Rocon. 2013- 2016. http://www.car.upm-csic.es/bioingenieria/CPwalker/.
- **IVANPACE.** Financiado por Obra Social Caja Cantabria, 2012-2014.
- **ABC**—Augmented BNCI Communication. European project FP7. FP7-ICT-2011-7. 2011-2014. http://www.abc-project.eu/index.php.
- **HYPER.** Neuroprothetics and neurorobotics hybrid devices for the functional compensation and rehabiliation of movement disorders. Consolider-Ingenio 2010, Spanish Ministry of Science and Innovation. http://www.car.upm-csic.es/bioingenieria/hyper/index.htm.

Publications, and/or products, services:

- M. A. Velasco, R. Raya, R. Ceres, A. Clemotte, E. Rocon, A. Ruiz and T. González. Positive and Negative Motor Signs of Head Motion in Cerebral Palsy: Assessment of Impairment and Task Performance. : IEEE Systems Journal, 2013.
- R. Raya, E. Rocon, J.A. Gallego, R. Ceres and J. L. Pons. A robust Kalman algorithm to facilitate the human-computer interaction for people with Cerebral Palsy using a new interface based on inertial sensors. Sensors, pp. 3049-3067, 2012.
- R. Raya, J.O. Roa, E. Rocon, R. Ceres, J.L. Pons. Wearable inertial mouse for children with physical and cognitive impairments. Sensors & Actuators: Physical, Pp. 248- 259, 2010.
- R. Raya, A. Frizera, R.Ceres, L.Calderón, E. Rocon. Design and evaluation of a fast model-based algorithm for ultrasonic range measurements. 335-341, 2008.
- R.Raya, R. Ceres, E. Rocon. Dispositivo y método para la reducción de los efectos de la discapacidad motora de alta heterogeneidad. Patente. 2012.País de prioridad: España.
- J. Ibáñez, J.I. Serrano, M.D. Castillo, J. Mínguez, J.L. Pons. Predictive classification of self-paced upper-lymb analytical movements with EEG. Medical & Biological Engineering & Computing. 2015 (in press).
- J. Ibáñez, J.I. Serrano, M.D. Castillo, E. Monge, F. Molina, F. Rivas, J.L. Pons. Heterogeneous BCI-triggered functional electrical stimulation intervention for the upper-lymb rehabilitation of stroke patients. Brain-Computer Interface Research: A state-of-the-art Summary, Springer. 2015 (in press).

Keywords:

- Human machine interaction.
- Disability.
- Rehabilitation robotics.
- Biomechanics.
- Brain-Machine Interfaces.
- Virtual reality.

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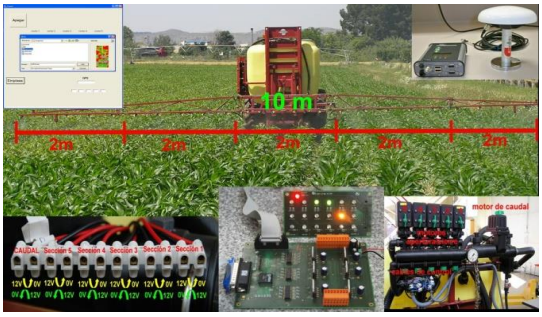
Ict for agriculture

The research focus on the integration of knowledge, methods and systems to design and implement all the processes involved in the optimal resolution of complex problem in Precision Agriculture. An Integrated Pest Management procedure has differential stage intelligent and complex artificial system, which includes:

1. Perception - Detection and identification of natural structures. Crop monitoring and early pets detection.
2. Decision-making - Action plan generation, considering aspects such as the herbicide doses to be applied, information supplied by the perception stage, other additional information available (type of crop and weeds, field history, farmer experience, etc.), and the targets set for the treatment.
3. Intelligent tools and implements for precision pest control
4. Action - Execution of the treatment plan generating proper signals to be sent to the implements.

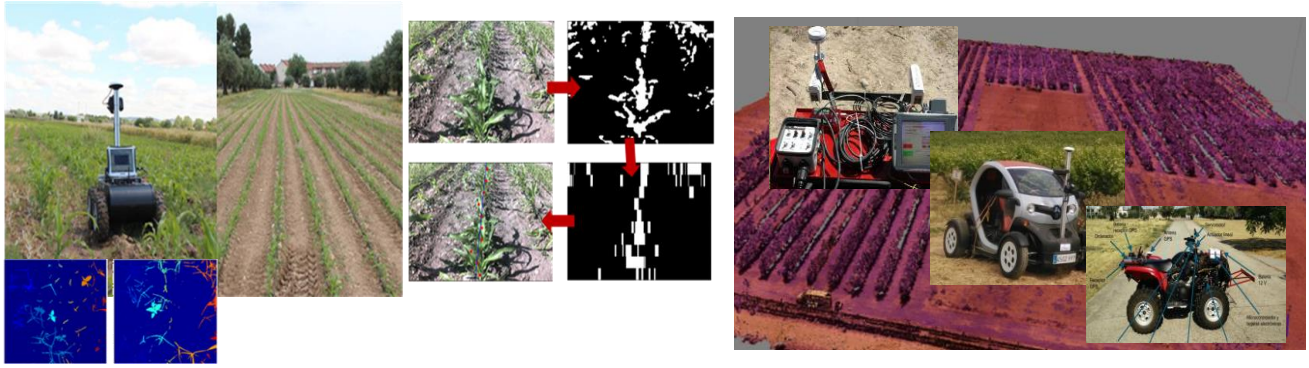
Technological offer driven BY CAR CSIC-UPM

FACILITIES/INFRAESTRUCTURE:



Map-based intelligent spray system for precise weeds control

On board visual real-time crop detection systems and intelligent implements



Autonomous ground-based crop monitoring system that combines several kinds of sensors and location information (RTK-GPS receiver)

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Detection and identification of natural structures (crop rows, weeds, trees, stubble, etc.).
- New tools for three dimensional crop characterization and neural network for plant identification.
- Integration of geo-referenced information to generate maps of pest distribution in crops.
- Plans generation (decision support systems) considering herbicide doses, information supplied by the perception stage, additional information available (type of crop and weeds, field history, farmer experience, etc.), and the targets set for the treatment.
- Actuation systems for executing treatment plans; i.e., generation of proper signals to be sent to the implements (e.g. a sprayer).
- Agricultural autonomous vehicles for crop monitoring and pest control
- Design of intelligent tools for pest control such precision sprayers or mechanical pest control implements
- Methods and procedures designed to obtain operational and profitable devices oriented toward agricultural tasks.

Main projects:

- Diseño, desarrollo y evaluación de sistemas autónomos para la inspección terrestre efectiva y la actuación precisa en cultivos extensivos y leñosos (Ground Autonomous Inspection and Actuation - GAIA). AGL2017-83325-C4-3-R
- Robot Fleets for Highly Effective Agriculture and Forestry Management (RHEA), FP7 NMP-CP-IP 245986-2
- Sistema de inspección terrestre en vehículos autónomos y su aplicación efectiva a la detección de malas hierbas y su control localizado (GROW). AGL2011-30442-C02-02.
- Sustainable Precision Agriculture: Research and Knowledge for Learning how to be an agri-Entrepreneur (SPARKLE) H2020 588241-EPP-1-2017-1-IT-EPPKA2-KA

Publications, and /or products, services:

- Bengochea-Guevara, J.M., Andújar, D., Sanchez-Sardana, F.L., Cantuña, K., Ribeiro, A. A low-cost approach to automatically obtain accurate 3D models of woody crops. 2018 Sensors 18(1),30
- Bengochea-Guevara, J.M., Andújar, D., Sanchez-Sardana, F.L., Cantuña, K., Ribeiro, A. 3D Monitoring of Woody Crops Using a Medium-Sized Field Inspection Vehicle. 2018 Advances in Intelligent Systems and Computing 694, pp. 239-250
- Conesa-Muñoz, J., Bengochea-Guevara, J.M., Andujar, D., Ribeiro, A. Route planning for agricultural tasks: A general approach for fleets of autonomous vehicles in site-specific herbicide applications. Computers and Electronics in Agriculture 127, pp. 204-220
- Andújar, D., Dorado, J., Fernández-Quintanilla, C., Ribeiro, A. An approach to the use of depth cameras for weed volume estimation. 2016 Sensors 16(7),972
- Bengochea-Guevara, J.M., Conesa-Muñoz, J., Andújar, D., Ribeiro, A. Merge fuzzy visual servoing and GPS-based planning to obtain a proper navigation behavior for a small crop-inspection robot. 2016 Sensors 16(3),276
- P.J. Herrera, J. Dorado and A. Ribeiro. 2014. A Novel Approach for Weed Type Classification Based on Shape Descriptors and a Fuzzy Decision-Making Method. Sensors, 8: 15304-15324.
- X.P. Burgos-Artizzu, A. Ribeiro, M. Guijarro, G. Pajares. 2011. Real-time image processing for crop/weed discrimination in maize fields. Computers and Electronics in Agriculture, 75(2): 337-346.

Keywords:

- Equipment of Precision Agriculture.
- Monitoring and detection of pest symptoms.
- Actuators for site specific pest management in crops.
- Decision support systems for effective pest control.

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Intelligent Perception and Dual-Arm Robotic Manipulation

One of the research lines of the Field and Service Robotics Group is focused on the intelligent perception and dual-arm robotic manipulation in unstructured and dynamic environments. The objectives are: (i) the semantic segmentation of scenes; (ii) the analysis of the human strategies used during the execution of bimanual tasks in order to identify primitives of movements and grasping forces; (iii) the development of behaviour-based and learning-based planning algorithms that enable the execution of bimanual operations similar to those carried out by human beings; and (iv) the design and implementation of machine learning and deep learning algorithms that provide to the robotic platform the ability to make decisions in unstructured environments depending on the state of the arms and the inputs acquired by the perception system.

The areas of application in which the group is working are: the selective harvesting in Precision Agriculture, the detection and disposal of explosive devices for Secure Societies, and collaborative robotics for Industry 4.0.

DEVELOPMENTS

Technological offer driven BY CAR UPM-CSIC

CATCH – ECHORD++ - FP7-ICT- 601116

ROBOCROPS – DPI2017-84253-C2-1-R

EXPERTISE AND EXPERIENCE:

Expertise and experience of this group is related to:

- Design of dual arm robotic platforms.
- Design of modular and specialized end-effectors.
- Multimodal sensing and advanced processing in real time.
- Semantic segmentation of scenes with machine learning and deep learning techniques
- Dual arm human motion measurement based on IMUs.
- Bimanual tracking.
- Behaviour-based and learning-based planning algorithms
- Machine learning and deep learning algorithms for reasoning and decision making.
- Design of non-linear actuators
- Design and implementation of non-linear controllers.

RECENT RELATED PROJECTS:

- Detección inteligente y manipulación robótica bimanual para la cosecha selectiva de cultivos de alto valor (ROBOCROP), DPI2017-84253-C2-1-R, 2018-2020.
- Cucumber Gathering – Green Field Experiments CATCH - ECHORD++ (FP7-ICT-601116), 2016-2018.
- Intelligent sensing and manipulation for sustainable production and harvesting of high value crops: clever robots for crops (CROPS). European Commission, FP7 246252, 2010-2014.
- Madrid Robotics Digital Innovation Hub (RoboCity2030-DIH-CM), Comunidad de Madrid, P2018/NMT-4331, 2019-2022.
- Percepción inteligente y manipulación robótica en entornos no estructurados. 201850I037, CSIC (2018-2019).
- Dispositivos robotizados para la manipulación bimanual en cultivos agrícolas (MBCrop), Intramural CSIC (2018-2019).

RECENT RELATED PUBLICATIONS:

- D. Surdilovic, J. Surdilovic, R. Fernandez. Innovative Robotic Application: The experiment CATCH. WT Werstattstechnik 107(9), pp. 600-602.
- R. Fernandez, H. Montes, J. Surdilovic, D. Surdilovic, P. Gonzalez-de-Santos, and Manuel Armada, “Automatic Detection of Field-Grown Cucumbers for Robotic Harvesting”, IEEE Access, Vol. 6, pp. 35512-35527, 2018.
- R. Fernández, J. Gavilanes, H. Montes, C. Salinas, P. González-de-Santos, M. Armada. Scanning Manipulator with Terrain Surface Mapping for Demining Tasks. Assistive Robotics. October 2015, 317-324.
- L. Paredes-Madrid, P. González-de-Santos. Dataglove-based interface for impedance control of manipulators in cooperative human-robot environments. Measurement Science and Technology 24(2), p. 025005, 2013.
- R. Fernández, H. Montes, C. Salinas. VIS-NIR, SWIR and LWIR Imagery for Estimation of Ground Bearing Capacity. Sensors, vol. 15, n. 6, pp. 13994-14015, 2015.
- R. Fernández; C. Salinas; H. Montes; J. Sarria. Multisensory System for Fruit Harvesting Robots. Experimental Testing in Natural Scenarios and with Different Kinds of Crops. Sensors 2014, 14, 23885-23904.
- P. González-de-Santos, E. García, J. Sarria, R. Ponticelli, J. Reviejo. A Power Assist Device for Handling Heavy Loads. 40th International Symposium on Robotics (ISR-2009) 1 (1), 195-200.

Keywords:

Dual arm robots

Analysis of human manipulation strategies

Behaviour-based and learning-based algorithms for bimanual manipulation

Machine learning and Deep learning

Semantic segmentation of scenes

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Multi-robot system in rescue and security misssions

Currently, Robotic systems are capable of playing a important roll both in security and rescue missions due to their refined sensorial capabilities, reducing in this manner the risk for humans and increasing the situational awareness of the facility.

The Robotics and Cybernetics (ROBCIB) research group has focused the research on several fields related to security and safety such as:

- Multi-robot patrolling algorithms that ensure no predictable routes reducing the time among visits by using game theory among others.
- Multi-robot covering area for discovering physical elements.
- Humans detection and tracking under occlusions in presence of several moving targets.
- Following and Interception techniques applied to multi-robot systems in large infrastructures.
- Collaborative remote reconnaissance techniques based on multi-robot support.
- Alternative locomotion systems for travelling across disasters scenarios such as C-leg and spherical robots.

Technological offer driven BY CAR UPM-CSIC

FACILITIES:

ROBCIB relies on a team of different sizes and capabilities wheeled robots endowed with sensors for navigation and detection and communications systems over a muti-master ROS architecture.

Recently, The group has also provided with intervention capabilities to the team by using a six degrees of freedom manipulator. Different locomotion robots such as spherical and C-leg robots have been also developed by the research group.

BACKGROUND:

ROBICB has participated in Networked Multi-Robot System project (Cat B by European Defense Agency) and several National Research Program projects (Multirobot Systems For Protection Of Large Outdoor Infrastructures) among others. ROBCIB participated in Eurathlon 2015 as a member of SARRUS team. More info at : http://www.car.upm-csic.es/about-us/research-groups/robotics-cybernetics/

Eurathlon competition of SARRUS team

Heterogeneous Multi-robot Team during a reconnaissance mission

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Design and development muti-robot architectures.
- Path planning for Area Coverage.
- Patrolling strategies.
- Pedestrians detection, tracking and interceptions.
- Aerial- Ground colaboration for surveillance.
- Sound Anomalies Dectection.

Recent projects:

- **PRIC: Robotic Protection of Critical Infrastrure.** National Research Program (DPI2014-56985-R) http://www.car.upm-csic.es/?p=6362.
- **ROTOS:** MULTIROBOT SYSTEMS FOR PROTECTION OF LARGE OUTDOOR INFRASTRUCTURES. National Research Program. Ministerio de Economía y Competitividad (2014-2017).

  http://www.car.upm-csic.es/?portfolio=multirobot-systems-for-protection-of-large-outdoor-infrastructures
- **NMRS.** NETWORKED MULTI-ROBOT SYSTEMS. Cat B. European Defense Agency. http://www.eda.europa.eu/docs/documents/Executive-summary-NMRS.pdf
- **PRIVATE CONTRACTS**
  - Robotic systems for intervention and evacuation after disasters. SENER.

Publications:

- Garzón, M., Valente, J., Roldán, J. J., Cancar, L., Barrientos, A. and Del Cerro, J. (2015), ***A Multirobot System for Distributed Area Coverage and Signal Searching in Large Outdoor Scenarios***. J. Field Robotics. doi:10.1002/rob.21636.
- Mario Andrei Garzon Oviedo , Antonio Barrientos , Jaime Del Cerro , Andrés Alacid , Efstathios Fotiadis , Gonzalo R. Rodríguez-Canosa , Bang-Chen Wang. ***Tracking and following pedestrian trajectories, an approach for autonomous surveillance of critical infrastructures.*** Industrial Robot: An International Journal 2015 42:5 , 429-440.
- Antonio Matta-Gómez, Jaime Del Cerro, Antonio Barrientos, ***Multi-robot data mapping simulation by using microsoft robotics developer studio,*** Simulation Modelling Practice and Theory, Volume 49, December 2014, Pages 305-319, ISSN 1569-190X, http://dx.doi.org/10.1016/j.simpat.2014.10.003.
- Erik Hernández, Antonio Barrientos, Jaime del Cerro, ***Selective Smooth Fictitious Play: An approach based on game theory for patrolling infrastructures with a multi-robot system,*** Expert Systems with Applications, Volume 41, Issue 6, May 2014, Pages 2897-2913, ISSN 0957-4174, http://dx.doi.org/10.1016/j.eswa.2013.10.024.
- Gonzalo Rodríguez-Canosa, Jaime del Cerro Giner and Antonio Barrientos. ***Detection and Tracking of Dynamic Objects by Using a Multirobot System: Application to Critical Infrastructures Surveillance.*** Sensors 2014, 14(2), 2911-2943; doi:10.3390/s140202911.

Keywords:

- MultiRobot systems
- Robots for Rescue missions
- Security Robots
- Pedestrian detection and tracking
- Pedestrians interception
- Area Coverage

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Personal Localization and Navigation in GPS-Denied Areas

We present a solution for accurate localization of people in places where GPS is not operative, like indoors or large buildings such as transport stations. Position is obtained by combining Pedestrian Dead-Reckoning (PDR) estimates and corrections from external RF sources, such as Wifi access points or Bluetooth devices. Position estimation uses a Bayesian fusion scheme, with a typical accuracy of 1-2 meters, and is free from temporal drift.

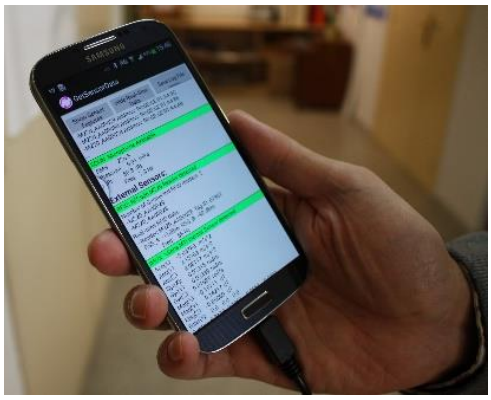
This location approach makes use of the built-in hardware in commercial smartphones: a motion sensor unit and RF receivers for wifi / Bluetooth signals. The current processing power of terminals permits position estimation and display in real time. The method is flexible and allows for integration of additional signals of opportunity, GPS information and open-platform maps, when available.

Applications of this technology include Personal Localization and Guidance, Ambient Intelligence, Location-Based Services, Ubiquitous Computing, First Responder Aids, etc.

Technological offer driven BY CAR CSIC-UPM

FACILITIES/INFRAESTRUCTURE:

Several demonstrators are available using smartphones and laptop computers:



Indoor positioning from data collected from multiple sensor sources (accelerometer, gyroscope, magnetometer, light sensor, WiFi, Bluetooth, GSM,…)

EXPERTISE AND EXPERIENCE:

LOPSI is a research group specialized in the creation of technological solutions for intelligent environments, which can perceive the presence of people, and offer them useful, location-based services. We perform both basic research and technological development in this area.

Recent projects/activities:

- **LORIS** (M. de Economía y Competitividad, 2013-2015): **Localization Cooperative Systems for People and Objects in Diverse Environments.**
- **LEMUR** (M. de Ciencia e Innovación, 2009-2012). **Continuous Location in Wide Areas with Ultrasound and Radiofrequency, with an Application on Personal Guidance Aids.**
- **RESELAI** (M. de Educación y Ciencia, 2006-2009). **Integration of acoustic, vision and RFID sensor networks for location in smart environments.**
- **EvAAL.(** http://evaal.aaloa.org) At the Ambient Assisted Living (AAL) forum, held on 24th September, 2012, in Eindhoven, Netherlands, the CAR-CSIC received an award as **winners of the 2012 EvAAL international competition (track 1: Indoor Localization and Tracking for AAL),** which took place at the Living Lab of the Polytechnic University of Madrid, Spain, in July 2-6, **2012**. This competition is a benchmark test of the accuracy, availability, acceptance, and ease of deployment of a Localization System usable for Ambient Assisted Living applications. CAR-CSIC won with a personal localization system based on a combination of RF-based positioning and Pedestrian Dead Reackning (PDR).

Publications , and/or products services:

- F. Zampella, A.R. Jiménez, F. Seco, ***Improving indoor positioning using an efficient Map Matching and an extended motion model,*** IEEE Transactions on Vehicular Technology, vol. 99 (2015); http://dx.doi.org/10.1109/TVT.2015.2391296.
- A.R. Jiménez, F. Zampella and F. Seco, ***Improving Inertial Pedestrian Dead-Reckoning by Detecting Unmodified Switched-on Lamps in Buildings,*** Sensors vol. 14, no. 1, pp. 731-769, Jan 2014.
- F. Zampella, A. Bahillo, J. Prieto, A. R. Jiménez and F. Seco, ***Pedestrian navigation fusing RSS/TOF measurements with adaptive movement/measurement models: experimental evaluation and theoretical limits, Sensors and Actuators A:*** physical, vol. 203, pp. 249-260 (2013).
- A.R. Jiménez, F. Seco, F. Zampella, J.C. Prieto and J. Guevara, ***Indoor Localization of Persons in AAL scenarios using an Inertial Measurement Unit (IMU) and the Signal Strength (SS) from RFID Tags, Communications in Computer and Information Science*** (Springer), pp. --, 2013.

More information:

http://www.car.upm-csic.es/lopsi

Keywords:

- Indoor personal localization.
- GPS-denied environments.
- Pedestrian Dead-Reckoning (PDR).
- Smarphone applications.

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Robotic aids to locomotion and gait rehabilitation

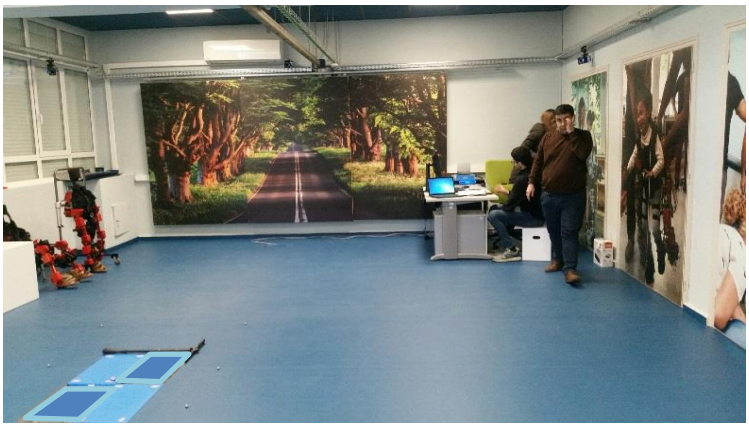
Development of robotic aids to locomotion and gait training. Special focus on wearable lower-limb exoskeletons, ranging from single joint active orthoses to full Trunk-Hip-Knee-Ankle-Foot active orthoses. These exoskeletons make a difference in performance thanks to our patented controllable-stiffness actuation technology. Making use of this technology our exoskeletons personalize the gait therapy, adapting to each patient's needs. The devices provide physical therapy to a number of neurological disorders featuring musculoskeletal complications, such as neuromuscular diseases and neurological disorders.

The technology is continuously transferred to the market through Marsi Bionics SL, spin-off from CAR.

Technological offer driven BY CAR CSIC-UPM

FACILITIES/INFRAESTRUCTURE:

The HUBOTIK Lab is equipped with Motion Capture technology for gait analysis and improvement of the technology, control algorithms and neruro-rehabilitation. Commercial exoskeletons are available for technological research, gait training analysis and clinical research. Safe test area equipped with medical technology.



HUBOTIK Human-Robot Interfacing and Kinesthetic Lab

Pediatric gait exoskeleton ATLAS

MAK Powered Knee by Marsi Bionics

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Design and development of robotic aids to locomotion: Gait exoskeletons, intelligent walkers, active joint orthoses.
- Gait generation.
- Foot-ground interaction control
- Variable stiffness actuation.
- Stable locomotion in natural ground.
- Intention detection and auto-adaptation to patient's needs (assist-as-needed).
- Physical Human-robot interaction control based on Impedance control techniques.
- Adaptation to joint spasticity and other joint dynamic perturbations.
- Gait adaptation to natural ground.
- Dynamic balance control of locomotion.
- Robustness to perturbations.

The above scientific background is being applied to the physical therapy of a number of neurological disorders, in close collaboration with Hospitals and Therapists:

- Spinal Muscular atrophy.
- Muscular Dystrophies.
- Ataxia.
- Stroke.

Recent projects:

- **EXOTrainer** (EC FP7- Echord++ Experiment no. 401): Clinical evaluation of usability of ATLAS2020 exoskeleton for Spinal Muscular Atrophy.
- **KINDER** (DPI2013-40504-R): Exoskeletons for improving quality of life of spinal muscular atrophy and cerebral palsy children.
- **ATLAS** (DPI2010-18702): New actuation and control technologies for empowering humans and robots.

Publications, and/or products, services:

- M. Cestari, D.Sanz-Merodio, J.C. Arevalo and E. Garcia, An Adjustable Compliant Joint for Lower-Limb Exoskeletons, IEEE/ASME Transactions on Mechatronics Vol. 20, No. 2, 2015.
- E. Garcia, M. Cestari, D. Sanz-Merodio" Wearable Exoskeletons for the Physical Treatment of Quadriparesis in Childhood", 2014 IEEE-RAS International Conference on Humanoid Robots, Madrid, Spain, 2014.
- E. Garcia, N. Barraqué "Marsi Bionics' Wearable Exoskeletons for the Daily Rehabilitation of Children", 2014 International Conference on Neuro-Rehabilitaton, Aalborg, Denmark, 2014.
- Sanz-Merodio, D., Cestari, M., Arevalo, J. and Garcia, E. Generation and control of adaptive gaits in lower-limb exoskeletons for motion assistance, Advanced Robotics, Vol. 28 No. 5, 2014.
- Sanz-Merodio, D., Cestari, M., Arevalo, J. and Garcia, E. Exploiting joint synergy for actuation in a lower-limb active orthosis, Industrial Robot, An International Journal, Vol. 40 No. 3, 2013.
- D. Sanz-Merodio, M. Cestari, J.C. Arevalo, and E.Garcia, "A lower-limb exoskeleton for gait assistance in quadriplegia" **Best Paper in Robotics Finalist**", Proceedings of IEEE International Conference on Robotics and Biomimetics, Guangzhou, China, 2012 ISBN: 978-1-4673-2127-3.
- D. Sanz-Merodio, M. Cestari, J.C. Arevalo, and E.Garcia, "Control Motion Approach of a Lower Limb Orthosis to Reduce Energy Consumption", International Journal of Advanced Robotic Systems, Vol. 9, 2012.
- Arevalo, J.C and Garcia, E. "Impedance Control for Legged Robots: An insight into the Concepts Involved" IEEE Transactions on Systems Man and Cybernetics - Part C: Applications and Reviews, Vol. 42, No. 6, pp. 1400-1411, 2012.

Keywords:

- Rehabilitation robots.
- Exoskeletons.
- Gait training.
- Technical aids to locomotion.

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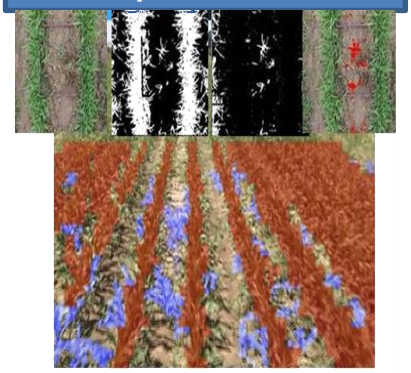
Robotics for agriculture and forestry

Robotics for Agriculture and Forestry is a research line of the Group of Perception Artificial (GPA), focused in developing research in the field of autonomous systems for agriculture and forestry. The group exhibits expertise in national and EC funded projects including the coordination of a Large Integrating Project in the FP7 devoted to the development of a fleet of autonomous robots for agriculture and forestry management.

FACILITIES/INFRAESTRUCTURE:

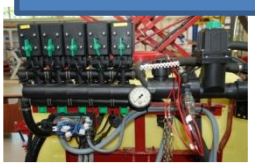
Technological offer driven BY CAR CSIC-UPM

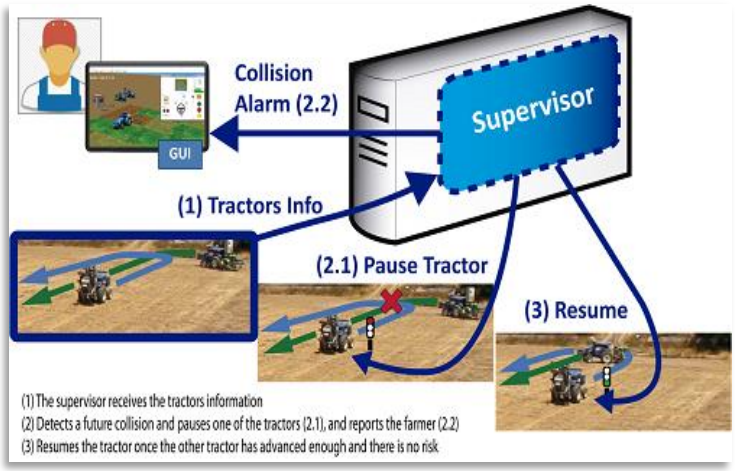
REALTIME DETECTION
Artificial Vision and Deep Learning– Weed and crop row detection.



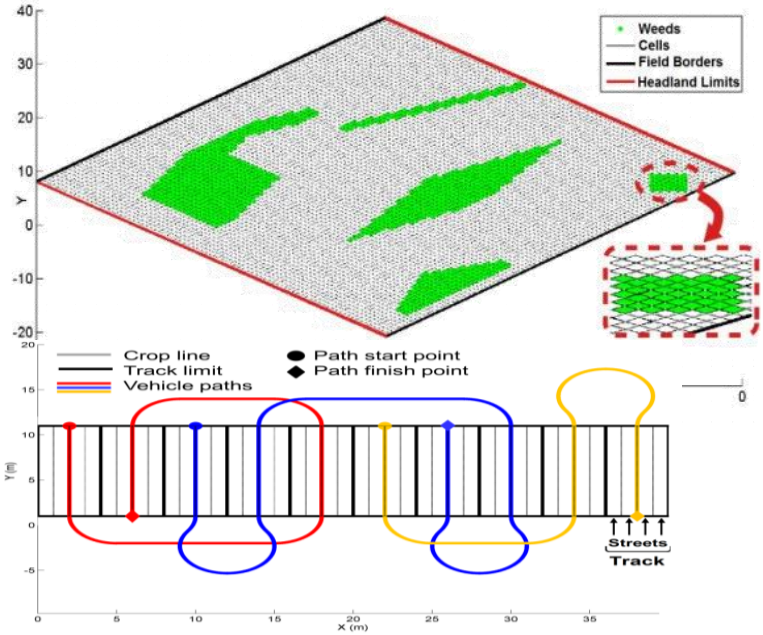
MULTI-ROBOT SYSTEMS
Autonomous navigation Planning and Supervision

SMART IMPLEMENTS
Opening / closing control of nozzles





Mission Supervision System: gathers and analyzes, continuously and in real time, the information provided by subsystems on board the vehicles. Notifies the farmer/other subsystems, the detected failures, sending information to solve them.



Mission Planning System: given a real crop determines the best fleet configuration (type and number of vehicles) as well as the path for each of them (multi-path planning). Constraints, such as the vehicle turning capability and the tanks capacity are considered.

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Controllers for autonomous agricultural vehicles.
- Perception: detection and identification of natural structures (crop rows, weeds, trees, etc.).
- Decision-making system for elaborating plans that consider elements such as the amount of herbicide to be applied, information supplied by the perception stage, additional information available (type of crop and weeds, field history, farmer experience, etc.), and the targets set for the treatment.
- Action systems for implementing the treatment plan; i.e., the generation of the appropriate signals to be sent to implements (e.g. a sprayer).
- Supervision system for fleets of agricultural vehicles.

Recent projects:

- Robot Fleets for Highly Effective Agriculture and Forestry Management (RHEA), FP7 NMP-CP-IP 245986-2, http://www.rhea-project.eu/
- Hacia la automatización integral de la agricultura - (AutoFarmI); CSIC Intramural.
- Sistema de inspección terrestre en vehículos autónomos y su aplicación efectiva a la detección de malas hierbas y su control localizado (GROW). AGL2011-30442-C02-02.

Publications, and/or products, services:

- Jesus Conesa-Muñoz, Mariano Gonzalez-de-Soto, Pablo Gonzalez-de-Santos , Angela Ribeiro, "Distributed Multi-Level Supervision to Effectively Monitor the Operations of a Fleet of Autonomous Vehicles in Agricultural Tasks", Sensors, Vol. 15, pp. 5402 – 5428, 2015, DOI: http://www.mdpi.com/1424-8220/15/3/5402.
- Manuel Perez-Ruiz, Pablo Gonzalez-de-Santos , Angela Ribeiro , Cesar Fernandez-Quintanilla , Andrea Peruzzi, Marco Vieri , Slobodanka Tomic ,Juan Agüera, "Highlights and preliminary results for autonomous crop protection", Computers and Electronics in Agriculture, Vol. 110, pp. 150-161, 2015, DIO: http://dx.doi.org/10.1016/j.compag.2014.11.010.
- Luis Emmi, Leonel Paredes-Madrid, Angela Ribeiro, Gonzalo Pajares, Pablo Gonzalez-de-Santos, "Fleets of Robots for Precision Agriculture: a Simulation Environment", Industrial Robot, Vol. 40 – 1, pp. 41 – 58, DOI: http://dx.doi.org/10.1108/01439911311294246.
- P.J. Herrera, J. Dorado and A. Ribeiro. 2014. A Novel Approach for Weed Type Classification Based on Shape Descriptors and a Fuzzy Decision-Making Method. Sensors, 8: 15304-15324.
- X.P. Burgos-Artizzu, A. Ribeiro, M. Guijarro, G. Pajares. 2011. Real-time image processing for crop/weed discrimination in maize fields. Computers and Electronics in Agriculture, 75(2): 337-346.
- A. Ribeiro, C. Fernandez-Quintanilla, J. Dorado, F. López-Granados, J. M. Peña, G. Rabatel; M. Pérez-Ruiz, J. Conesa-Muñoz, P. Gonzalez de Santos. A heterogeneous fleet of robots: a scalable approach for precise weed control in arable crops. 10th European Conference on Precision Agriculture. July 12-16, Volcani Center, Israel. 2015.

Keywords:

- Agricultural autonomous vehicles.
- Planning in agricultural contexts.
- Cooperative autonomous robots for pest control.
- Mission supervision of fleets in agricultural contexts.
- Sensors for autonomous agricultural vehicles.

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Robots applied to agriculture

The Robotics and Cybernetics (ROBCIB) research group is working on multiple applications of robots in agricultural tasks: mapping open fields with aerial robots, measure of environmental variables in greenhouses and tree modeling with ground robots.

In the context of greenhouse farming, a team made up of a small aerial vehicle and a robust ground robot is used for measuring the environmental variables. First, the system is teleoperated to build a map of the facility. Then, it uses this map to navigate autonomously and take measurements. The team is able to travel through the corridors of the greenhouses monitoring the humidity, temperature, luminosity and carbon dioxide and performing detailed 3D maps. The mini-drone acts when the ground robot cannot overcome an obstacle or an anomaly is detected and must be investigated.

In the context of precision agriculture, aerials robots are used to build maps of open fields, detecting weeds and pests. Additionally, ground robots are applied to model trees by using laser scanners and multispectral cameras.

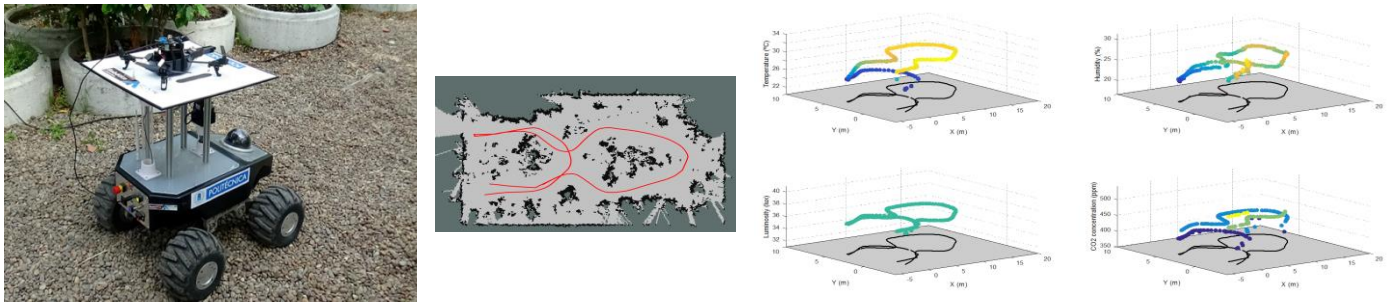
Technological offer driven BY CAR UPM-CSIC

FACILITIES:

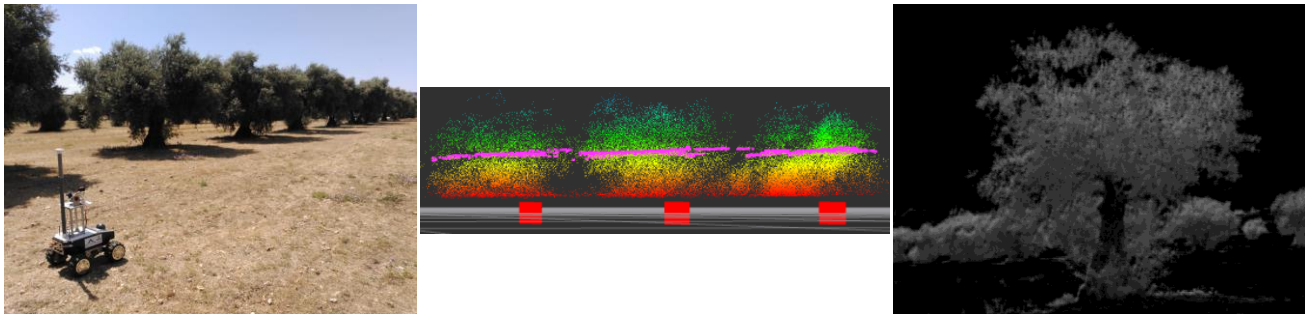
ROBICB applies ground and aerial robots, endowed with autonomous navigation skills and different types of sensors, to measure environmental variables in greenhouses and determine the state of crops in open fields.

More info: http://blogs.upm.es/robcib/2016/10/06/robotica-en-invernaderos/

Video: https://www.youtube.com/watch?v=o6SXPQv9LyU



ROBCIB Robot Team for Monitoring Environmental Variables in Greenhouses



Modeling of trees through 3D reconstruction and multispectral images

EXPERTISE AND EXPERIENCE:

Our main expertise and experience are related to:

- Coverage path planning for aerial photography.
- Environmental monitoring in greenhouses.

Recent projects:

RHEA: Robot Fleets For Highly Effective Agriculture And Forestry Management. 7TH Frame Program. NMP-CP-IP 245986-2 RHEA, http://www.rhea-project.eu

SUREVEG: Strip-cropping and recycling of waste as the basis for biodiverse and resource-efficient intensive vegetable production. CORE Organic Cofund Project.

Publications:

- Juan Jesús Roldán, Jaime del Cerro, David Garzón-Ramos, Pablo Garcia-Aunon, Mario Garzón, Jorge de León and Antonio Barrientos. **Robots in Agriculture: State of Art and Practical Experiences**. *Service Robots*, InTech, 2018.
- Juan Jesús Roldán, Pablo Garcia-Auñon, Mario Garzón, Jorge de León, Jaime del Cerro and Antonio Barrientos. **Heterogeneous Multi-Robot System for Mapping Environmental Variables of Greenhouses.** *Sensors*, 16(7), 1018, 2016.
- Juan Jesús Roldán , Guillaume Joossen, David Sanz, Jaime del Cerro and Antonio Barrientos. **Mini-UAV Based Sensory System for Measuring Environmental Variables in Greenhouses.** *Sensors*, 15(2), 3334-3350, 2015.
- Alberto Ruiz-Larrea, Juan Jesús Roldán, Mario Garzón, Jaime del Cerro and Antonio Barrientos. **A UGV Approach to Measure the Ground Properties of Greenhouses.** *Robot 2015: Second Iberian Robotics Conference,* 2015.
- Leandro Cancar, David Sanz, Juan D. Hernández, Jaime del Cerro, Antonio Barrientos. **Precision Humidity and Temperature Measuring in Farming Using Newer Ground Mobile Robots.** *ROBOT2013: First Iberian Robotics Conference,* 2013.
- João Valente, Jaime Del Cerro, Antonio Barrientos and David Sanz. **Aerial coverage optimization in precision agriculture management: A musical harmony inspired approach.** *Computers and Electronics in Agriculture*, 99, 153-159, 2013.
- Hernández, J.D., Barrientos, J., del Cerro, J., Barrientos, A. and Sanz, D. **Moisture measurement in crops using spherical robots.** *Industrial Robot: An International Journal*, 40(1), 59–66, 2013.
- A. Barrientos, J. Colorado, J. del Cerro, A. Martinez, C. Rossi, D. Sanz and J. Valente. **Aerial remote sensing in agriculture: A practical approach to area coverage and path planning for fleets of mini aerial robots**. Journal of Field Robotics, 28, 667–689, 2011.
- Gonzalez-de-Santos, P., Ribeiro, A., Fernandez-Quintanilla, C. et al. **Fleets of robots for environmentally-safe pest control in agriculture**. *Precision Agriculture*, 18(4), 574-614, 2016.
- Jesús Conesa-Muñoz, João Valente, Jaime del Cerro, Antonio Barrientos and Angela Ribeiro**. A Multi-Robot Sense-Act Approach to Lead to a Proper Acting in Environmental Incidents**. *Sensors*, 16(8), 2016.

Keywords:

- Multi-Robot Systems for agriculture
- Environmental Monitoring
- Frost detection
- Greenhouse Farming
- Aerial Coverage for evaluation
- Ground proprieties monitoring

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Social robots for the elderly, hospitals, museums and trade fairs

The research started in the 90's in order to cover the emerging field in mobile robotics. Since the initial work on navigation control, planning and mapping, with the beginning of the new century the focus switched to guide robots with richer interaction and navigation capabilities, including SLAM.

This kind of social robots are being widely investigated in the robotics field and are appropriate for a number of applications such as medical and elderly assistance, tour guide, commercial exhibitions or entertainment.

Technological offer driven BY CAR UPM-CSIC

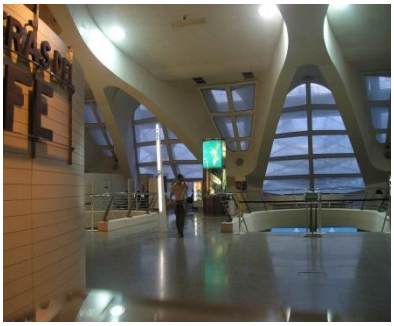
PROTOTYPES:

Three prototypes have been developed till now: Blacky (2000), Urbano (2004), Doris (2014) and POTATO (2018). The main features of most of these robots are autonomous navigation, facial expressions, voice dialogues, emotions and remote operation via web and tablet.

BLACKY at Madrid for Science fair

URBANO

DORIS



URBANO at Valencia Prince Felipe Museum

POTATO

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Safety navigation based on laser and computer vision.
- Sensor fusion techniques for robot localization and environment mapping.
- SLAM using geometric representation and B-Splines.
- Mechanical head and arms with servos for expressing emotions designed ad-hoc.
- Voice recognition and speech synthesis in several languages for human like conversations.
- Remote operation via touch screen and web services, including chat and voice communication.
- Robust software architectures to coordinate the different modules.
- User interaction through touch screen.
- Prototypes have been tested at different places crowded of people, such as: INDUMATICA Fair at UPM, Prince Felipe Museum at Valencia, Madrid for Science Fair at IFEMA exhibition and Belgioioso Castle at Milano.

Related projects:

- **URBANO**: Autonomous Robots Integration in Society by using New Technologies (2002-2004), DPI01-3652-C02.
- **ROBINT:** Intelligent Behaviors Integration for Guide Robots (2005-2007), DPI-2004-07907-C02.
- **CRAWLER:** Autonomous Robot for Carbon Fiber Inspection with Pulse-echo Techniques (2005-2008). Funded by Airbus Spain.
- **ROBONAUTA:** Knowledge Models Integration for Autonomous Start-up of an Interactive Robot (2008-2010), DPI-2007-66846-C02.
- **ARABOT:** An Interactive Autonomous Robot Abel to Reason in an Dynamic Environment (2011-2014). DPI 2010-21247-C02.
- **ROBOCITY 2030:** Robótica Aplicada a la Mejora de la Calidad de Vida de los Ciudadanos (Phase III) (2014-2018). Comunidad de Madrid (S2013/MIT-2748) and EU structured funds.

Publications:

- I. Navarro, F. Matía, ***A Framework for the Collective Movement of Mobile Robots Based on Distributed Decisions,*** Robotics and Autonomous Systems 59 (10), 685-697, DOI 10.1016/j.robot.2011.05.001 (2011).
- I. Navarro, F. Matía, ***Distributed Orientation Agreement in a Group of Robots,*** Autonomous Robots 33 (4), 445-465, DOI 10.1007/s10514-012-9300-5 (2012).
- P de la Puente, D Rodríguez-Losada, **Feature Based Graph-SLAM in Structured Environments**, Autonomous Robots 37 (3), 243-260 (2014).
- P de la Puente, D Rodriguez-Losada, **Feature Based Graph SLAM with High Level Representation using Rectangles**, Robotics and Autonomous Systems 63, 80-88 (2015).
- B. P. Alvarado, F. Matía y R. Galán, **Improving Indoor Robots Localisation by Fusioning Different Sensors**, International Conference on Intelligent Robots and Systems, 1-5 october (2018).
- B. P. Alvarado, R. González, F. Matía, P. de la Puente, **Sensor Fusion for Tour-Guide Robot Localization**, IEEE Access (2018).

Keywords:

- Tour-guide robots.
- Human-robot interaction.
- Artificial intelligence.
- Robot navigation.
- Sensor fusion.

UPM contacts:

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Technologies for human rehabilitation

Neural and Cognitive Engineering group (gNec) has a long track expertise in research studies that generate a new body of knowledge and development of new technological solutions pursuing the comprehension and control of human biological systems and its relation to the environment. gNec is determined to play a leading role in this neurotechnological field, one of the strongest growing markets in the medical technology business. Research activities aims at leading the transition from classic robots to neuroprostheses in the field of rehabilitation robotics.

Technological offer driven BY CAR CSIC-UPM

RECENT DEVELOPMENTS:

Since 2002, the group has developed a number of robotic platforms for the rehabilitation. Our approach is based on investigating and taking inspiration from biological models (in particular from the human model) to the design of innovative, dependable, inherently friendly and highly acceptable robotic systems. The research line is mainly focused on developing the next generation of wearable robots, focused on the rehabilitation of impaired people, growing populations with special needs in the European society.

Upper limb Exoskeleton for tremor suppression

Example of tremor suppression

Wearable neuroprosthesis for tremor suppression

Vehicle for Cognitive Rehabilitation

Robotic platform for the rehabilitation of children with Cerebral Palsy

Neuromodulation for the rehabilitation of stroke patients

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Development of robotic devices for rehabilitation (Hardware): CSIC is a world-class institution in the development and application of intelligent robotics devices in the rehabilitation for the rehabilitation of different pathologies. In particular, CSIC has successfully developed robotics devices (exoskeletons and walkers) for tremor suppression, stroke, SCI, and CP rehabilitation.
- Development of tailored robotic-based rehabilitation therapies. CSIC was the leading technological partner responsible for the control aspects in several Rehabilitation EU projects (DRIFTS, TREMOR, NeuroTREMOR).
- Processing of multi-parametric data: This involves several bioelectrical and biomechanical modalities. Our research group is experienced in EEG analysis by creating predictive models from neurophysiological phenomena to build BCI solutions that guide a top-down in-time functional recovery. Furthermore, we are experienced in EMG patient-end user interfaces and will collectively provide the required expertise in this area; and CSIC master techniques in the area of acquisition and processing of biomechanical data out of inertial sensors (IMUs).

Recent projects:

- **NeuroTREMOR,** A novel concept for support to diagnosis and remote management of tremor. FP7-ICT-2011-7-287739 (2012-2015), http://www.neurotremor.eu
- **CPWalker,** Robotic Platform for Gait Rehabilitation and Training in patients with Cerebral Palsy. DPI2012-39133-C03-01 (2012-2015).
- **TREMOR,** An ambulatory BCI-driven tremor suppression system based on functional electrical stimulation, ICT2007-224051 (2008-2011).
- **HYPER,** Hybrid NeuroProsthetic and NeuroRobotic Devices for Functional Compensation and Rehabilitation of Motor Disorders (2010-2014).

Publications:

- E. Rocon, J.L. Pons, ***Exoskeleton in Rehabillitation Robotics***. Tremor suppression, Springer, ISBN 978-3-642-17658-6 , 168 pages. DOI: 10.1007/978-3-642-17659-3 (2011).
- E. Rocon, J.M. Belda-Lois, A.F. Ruiz, M. Manto, J.C. Moreno, J.L. Pons. ***Design and Validation of a Rehabilitation Robotic Exoskeleton for Tremor Assessment and Suppression***, IEEE Transactions on Neural Systems and Rehabilitation Engineering, 15-3, 367-378 (2007).
- Gallego, J. A, Rocon, E., Belda-Lois, J. M. & Pons, J. L. ***A neuroprosthesis for tremor management through the control of muscle co-contraction***. J. Neuroeng. Rehabil. 10, 1–13 (2013).
- Dosen, S. et al. ***Online Tremor Suppression Using Electromyography and Low Level Electrical Stimulation.*** IEEE Trans. Neural Syst. Rehabil. Eng. 4320, 1–11 (2014).
- Frizera Neto, A., Gallego, J. a, Rocon, E., Pons, J. L. & Ceres, R. ***Extraction of user's navigation commands from upper body force interaction in walker assisted gait***. Biomed. Eng. Online 9, 37 (2010).
- J. Ibáñez, J.I. Serrano, M.D. del Castillo, E. Monge, F. Molina, I. Alguacil, J.L. Pons. ***Detection of the Onset of Upper-limb Movements Based on the Combined Analysis of Changes in the Sensorimotor Rhythms and Slow Cortical Potentials.*** Journal of Neural Engineering 11(5) (2014).
- J. Ibáñez, J.I. Serrano, M.D. del Castillo, J. Gallego, E. Rocon. ***Online detector of movement intention based on EEG - application in tremor patients.*** Biomedical Signal Processing and Control 8: 822-29, DOI:10.1016/j.bspc.2013.07.006 (2013).

Keywords:

Rehabilitation Robotics, Top-down functional recovery (Neuromodulation, Neurorehabiliation).

Pathologies:

Tremor, Stroke, Cerebral Palsy.

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Telerobotics, Telemanipulation and Remote Handling

Telerobotics covers all technologies that allow a human operator to remotely control a robot. The most advanced telerobotics systems are based on multimodal interfaces that include haptic interaction, stereoscopic visual perception and voice communication. The role of the human operator varies from mere task monitoring to guiding a robot for the execution of the manipulation task.

Traditionally, telerobotics have been applied in nuclear, space and underwater applications. New fields of Telerobotics, such as telesurgery, inspection and maintenance, and security among others are currently growing.

Technological offer driven BY CAR UPM-CSIC

FACILITIES:

There is a setup for testing and developing new methods for Telemanipulation and the main components are as follows:

- Two hydraulic powered telemanipulators with 6 degree of freedom.
- Several master arms with force feedback.
- Stereoscopic video cameras that reproduce human binocular vision.
- Real-time computers for bilateral controllers.

Telerobotics setup with 2 hydraulic powered manipulators, and several master interfaces

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Design and development of telerobotic systems.
- Definition and evaluation of remote handling procedures.
- Evaluation of interfaces, such as haptic devices and stereoscopic displays.
- Design of new methods for telemanipulation.

Recent projects:

- **TeleScale:** Development of new teleoperation technologies oriented towards human-robot interaction for apllications with highly scaled manipulation, funded by the Spanish National Plan of Research, DPI2012-32509 (2013-2016), http://www.car.upm-csic.es/?portfolio=telescale.
- **PURESAFE:** Preventing hUman intervention for incrREased SAfety in inFrastructures Emitting ionizing radiation, funded by FP7 Marie Curie ITN-GA-2010-264336 (2011-2015), http://webhotel2.tut.fi/iha/puresafe/
- **TEMAR:** REMOTE MANIPULATION TECHNIQUES FOR NUCLEAR FUSION RESEARCH CENTERS, funded by Spanish National Plan of Research, DPI2009-12283 (2010-2012) http://www.car.upm-csic.es/?portfolio=temar
- **GOT-RH:** GOAL ORIENTED TRAINING FOR ITER REMOTE HANDLING MANIPULATORS, funded by Euratom (2010-2013), http://webhotel2.tut.fi/iha/got-rh/

Publications:

- J. Barrio, M. Ferre, FA. Suarez, R. Aracil. "**A Remote Handling Rate-Position Controller for Telemanipulating in a Large Workspace**", Fusion Engineering and Design, vol. 89 (1). 2014. doi: 10.1016/j.fusengdes.2013.11.003.
- Manuel Ferre, Ignacio Galiana, Raul Wirz and Neil Tuttle, "**Haptic Device for Capturing and Simulating Hand Manipulation Rehabilitation**", IEEE Transactions on Mechatronics, vol. 16 (5). 2011, doi: 10.1109/TMECH.2011.2159807.
- Manuel Ferre, Ignacio Galiana and Rafael Aracil, "**Design of a Lightweight, Cost Effective Thimble-Like Sensor for Haptic Applications Based on Contact Force Sensors**". Sensors, 2011, doi: 10.3390/s111211495.
- R. Wirz, R. Marin, M. Ferre, J. Barrio, J.M. Claver and J. Ortego, "**Bidirectional Transport Protocol for Teleoperated Robots**", IEEE Transaction on Industrial Electronics, vol. 56 (9), 2009, doi: 10.1109/TIE.
- Manuel Ferre, Rafael Aracil, and Miguel A. Sánchez-Urán, "**Stereoscopic Human Interfaces**", IEEE Robotics and Automation Magazine, vol. 15 (4), 2008, doi: 10.1109/MRA.2008.929929.

Patents:

- Patent: P201132146. "**Method for telerobotic guidance by switching rate and position control modes**", M. Ferre, R. Aracil, J. Barrio and F.A. Suárez.
- Patent: P200000257. "**Tremor characterization by applying force patterns**", A. Barrientos, M. Ferre, R. Gonzalez, A. Mora, J.L. Martínez and R. García.
- Patent: P9801372. "**Stereoscopic video camera**", M. Ferre and A. Barrientos.

Keywords:

- Telerobotics.
- Remote Handling.
- Telepresence.
- Telemanipulation.
- Bilateral control.
- Haptic devices.
- Binocular perception.

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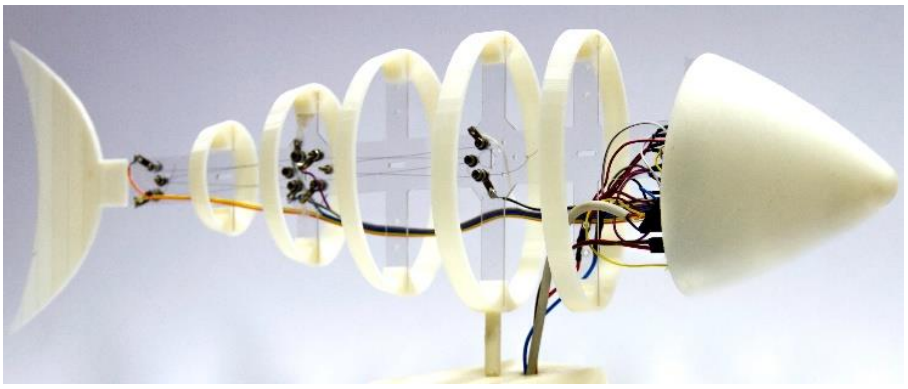
The Bio-Inspired Systems

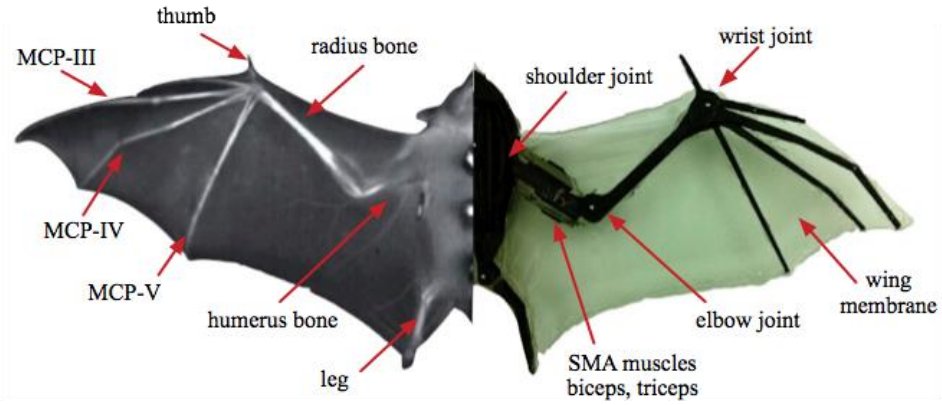
The Bio-Inspired Systems Lab was created in 2009 with the aim of performing research on new actuation mechanisms for *motor-less* and *gear-less* robots, i.e. robots devoid of conventional rotating parts, motors and bearings. We take inspiration from animal biomechanics to design innovative light and simple mechatronic systems, with an eye on future service robots that will share living and working space with humans.

Technological offer driven BY CAR UPM-CSIC

SELECTED PROTOTYPES:



The iTuna, 2010: a bendable continuous structure actuated by Shape Memory Alloys.



BatBot, 2012: the world's first bat-like micro aerial vehicle, equipped with morphing wings

EXPERTISE AND EXPERIENCE:

Main expertise and experience are related to:

- Design and implementation of bio-inspired mechatronic systesm.
- Control of functional materials.
- Evolutionary Computation and Evolutionary Robotics.

Recent projects:

- **CHEMOCONTROL:** Chemical signals for robotics actuators control.
- **ROBOCITY III:** Service Robots for increasing the quality of living of citizens in metropolitan areas.
- **BatBot:** Service Robots for increasing the quality of living of citizens in metropolitan areas.
- **iTuna:** Service Robots for increasing the quality of living of citizens in metropolitan areas.
- Organization of the workshop on smart materials and alternative technologies for bio-inspired robots and systems "ATBio", part of the IROS 2012 conference.

Publications, and/or products services:

- W. Coral, C. Rossi, J. Colorado, D. Lemus and A.Barrientos, ***"SMA-Based Muscle-Like Actuation in Biologically Inspired Robots: A State of the Art Review",*** In G. Berselli, R. Vertechy and G. Vassura (eds.) Smart actuation and sensing systems / Recent advances and future challenges, InTech Open, 2012 ISBN: 979-953-307-990-4
- C. Rossi, A.E. Eiben**,"Simultaneous versus Incremental Learning of Multiple Skills by Modular Robots",** Evolutionary Intelligence, Volume 7, Issue 2, 2014.
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- C. Rossi, W. Coral **"Robot Fishes' Escape from Flatland",** 2nd FitFish Workshop, Barcelona, Spain, October 2014 (invited talk).

Keywords:

- Bioinspiration.
- Biomimetics.
- Functionals materials.
- Smart structures.

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Visual Aerial Inspection and Mapping

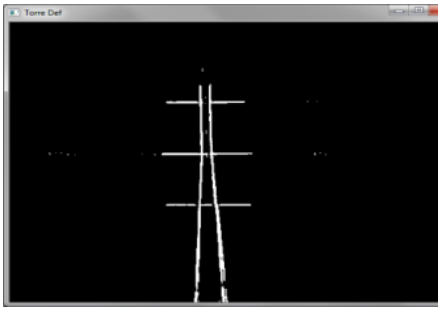
Unmanned Aerial Vehicles (UAVs)* can successfully exploit **Computer Vision Techniques** to provide the desired degree of **autonomy for flying** into inaccessible or dangerous places and coming up with an **extensive and detailed visual information** on spot. Target tracking, environmental mapping, visual control, and object detection and recognition are the key features provided therefore.

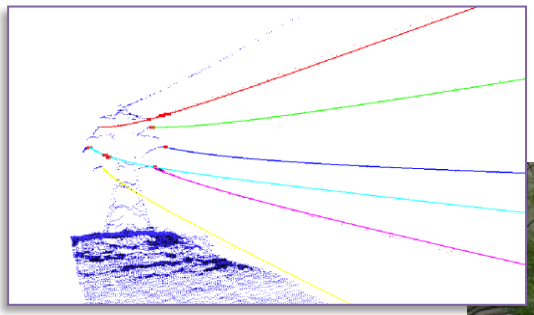
The **Computer Vision Group at U.P.M.** has a large experience of more than 15 years applying Computer Vision to increase the autonomy of UAVs, allowing them to be used for a **wide range of industry-oriented applications**, including Industrial Inspection, Mapping, Precision Agriculture, Safety and Security.

* also known as RPAS (remotely Piloted Aircraft Systems) or commonly “drones”

Technological offer driven BY CAR UPM-CSIC

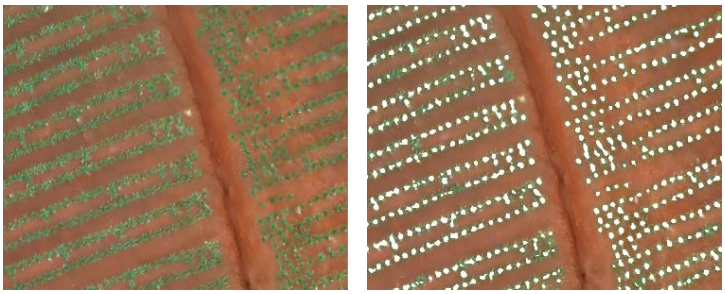
Power line inspection using LIDAR, RGB and IR cameras





Building inspection using RGB and Thermal Infrared cameras

Hydrothermal analysis in volcanic areas



Mapping and automatic plant counting in precision agriculture

Image mosaicing

Recent related projects:

- **"AEROS: Autonomous Working Windmill Inspection"** RETOS-Colaboración RTC-2014-1977-3, with Diagnostiqa, Ixion Industry Aerospace y CENER-CIEMAT. 2014-16.
- **"I2L: Intelligent Power Line Inspection"** INNPACTO IPT-2012-0491-120000, with Unión Fenosa S.A., Diagnostiqa, INTA and Prysma S.A. 2012-15.
- "**AIRBIOTA: Urban Air Biologic Pollution Monitoring"** funded by the Madrid Goverment S2013/MAE-2874 with U.C.M., U.A.M. and CBM-CSIC. 2014-17.
- **"SUPVERT: UAV for Otdoors Vertical Structure Inspection"** AVANZA TSI-020602-2012-43, contracted by Ixion Industry Aerospace S.L. 2102-14.
- **"OMNIWORKS: Omnidirectional vision for human-UAV co-working"** ECHORD Projec FP7, coordinating Skybotix AG (CH) and APIA XXI S.A. (E). 2012-13.
- **"Multi-rotors UAV for hydrothermal alterations in the Costa Rica Volcanic Mountains"** by UPM and coordinating Universidad de Costa Rica. 2011-12.

Recent related publications:

- ***"Towards an Autonomous Vision-Based Unmanned Aerial System against Wildlife Poachers"***. Sensors 15 (12), 31362-3139, 2016.
- ***"UBRISTES: UAV-Based Building Rehabilitation with Visible and Thermal Infrared Remote Sensing"***. Robot-15: Second Iberian Robotics Conference, 245-256, 2015.
- ***"Towards autonomous detection and tracking of electric towers for aerial power line inspection"***. Unmanned Aircraft Systems (ICUAS), 284-29, 2014.
- C Sampedro, C Martinez, A Chauhan, P Campoy. ***"A supervised approach to electric tower detection and classification for power line inspection".*** Neural Networks (IJCNN), International Joint Conference on, 1970-1977, 2014.

Keywords:

UAV, RPAS, drones, Computer Vision, Image Processing, Control, Pattern Recognition. Visual Inspection, object tracking, object detection, object recognition, video stabilization, image enhancement, mosaicing, visual control, mapping.

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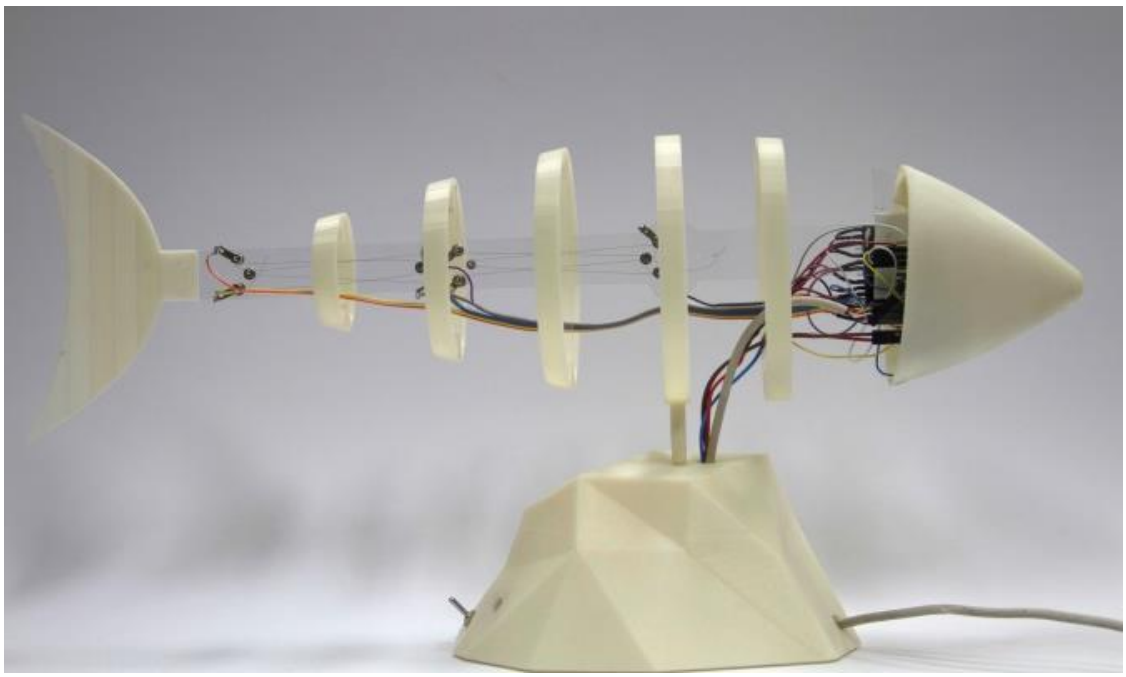

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