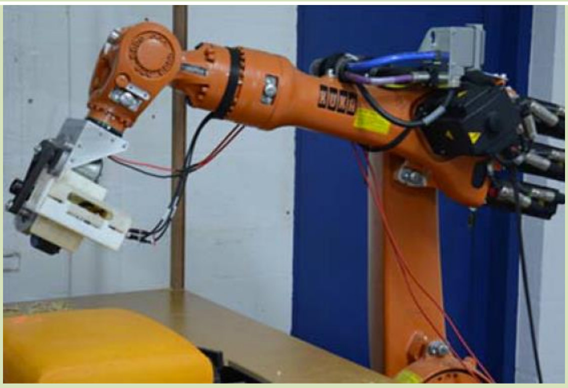
Annex 3: Overview of Experiments in Calls 1 and 2

Call1 Experiments overview

2F

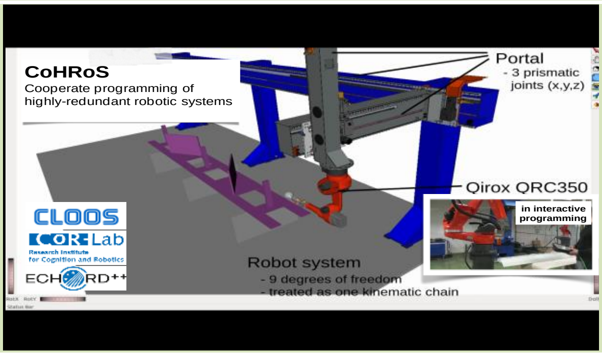
The Flooring Fellow (2F) experiment aims at introducing robotics in construction yards by developing a co-working robot for a specific function related to floor building: grout removing and floor cleaning with acid. The 2F experiment will be introduced to the market in the next years as a new product for the building sector. The use of 2F will impact directly on the entire working cycle related to the flooring realization and the developed co-working robot, together with related accessory range, will increase safety, ergonomics, and eco-sustainability during the specific working phases. More specifically the expected impact is the reduction of construction workers labour time and cost and the reduction of construction worker hazards and risks (noise, vibration and electric shock). The concrete outcome of the Experiment is the conception of a TRL 7 prototype of the robotic platform, and submission of a patent on the technology developed.

3DSSC



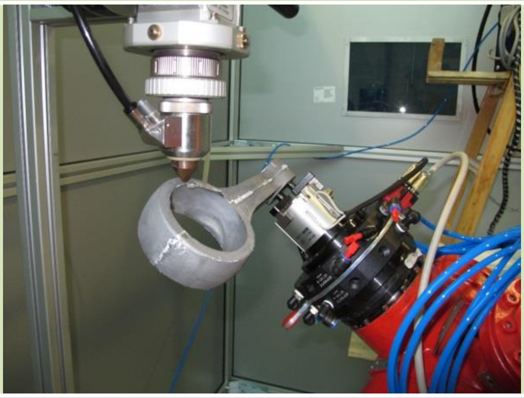
The goal of the 3DSSC experiment was to develop a robot operated cheese peeling solution. With the help of smart 3D sensing, thinner coating of a block cheese is removed resulting in reduced losses. As another objective, the project also targets to increase the speed of cheese peeling. In the current state, the speed of operation is 30% slower than the manual one with comparable losses. However, the system will be optimized to improve upon the current prototype. The demonstrated results have attracted significant commercial interest, in particular with the objective to further develop the demonstrator into industrial implementation. The project also resulted in filing one patent (pending) and a planned journal publication.

CoHRoS



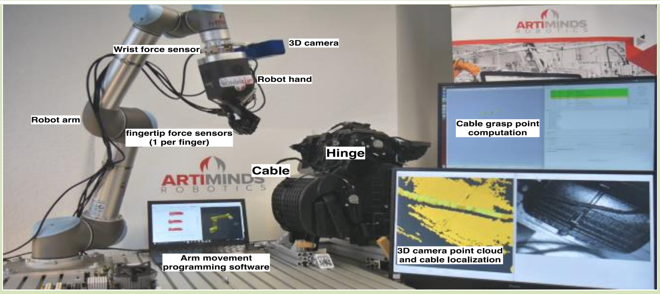
Highly redundant robots with up to ten or more degrees of freedom are commonplace for welding, grinding, or varnishing of large in sectors like earthmoving equipment, agricultural machines or automotive engineering. Programming these systems is tedious, costly and needs highly specialized expertise, which is an important factor to achieve a reasonable return-of investment for automation. The project CoHRoS aimed at redefining and advancing the state-of-the-art in programming for such highly redundant robot systems through developing a practical and robust method for assistive teaching using machine learning techniques. The project has allowed the development and testing of a software solution for such programming tasks. This solution was integrated into an industrial setup, to allow demonstration in an operational environment. Results achieved have led to discussions with a number of interested potential industrial partners.

DEBURR



The overall objective of the experiment was to design and set up an automated robotic station for laser deburring of metal casting 3D parts. The experiment has developed a flexible, low-maintenance and environmentally friendly prototype, able to replace the current hydraulic deburring and manual sanding operations of casting industries, for components with different geometry and burrs thickness (< 2.0 mm). Therefore, it was intended to obtain quality, uniform and low roughness cutting edges, with protrusions lower than 0.2 mm, and without thermal affection, all of them done in competitive cycle times (60 - 90 s for the selected parts). An adaptive cognitive robotic system has been developed, to carry out the process of deburring and manipulating the parts autonomously, and to provide overall process inspection using 2D and 3D machine vision techniques. This system corrects the predefined trajectory, implementing a burr tracking system based on machine vision techniques, and finally determines the optimum cutting path. Building upon the strength of the prototype developed, collaborations with a number of industrial partners is being pursued.

DexBuddy



DexBuddy was mainly a software capability demonstrator experiment. It showed the potential of the combination of 3D-vision, finger-based force sensing and wrist-based force sensing used with online grasp and motion planning as well as force-controlled motions. Furthermore, it showed how concepts of intuitive programming can be used to parameterize arm and finger motions for dexterous manipulation. The overall setup was demonstrated in the context of a dexterous industrial assembly use-case with cables. The work performed in the Experiment has led to a partnership with a large industrial group.

EXOTrainer

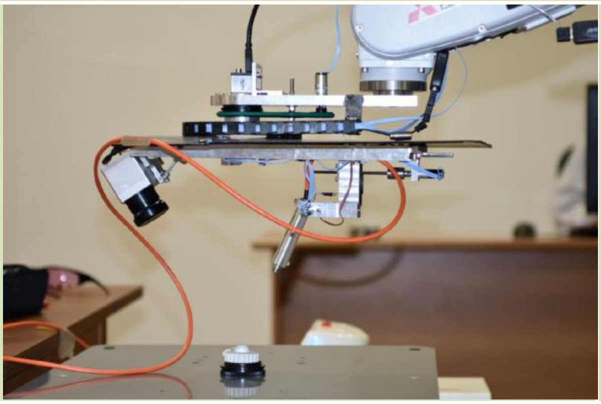
EXOTrainer addresses the introduction of wearable gait exoskeletons for the therapy of children affected by Spinal Muscular Atrophy (SMA). Although a rare disease, SMA is the first cause of child mortality, affecting all countries, races and gender. There is still no known cure for SMA, and treatments mainly focus on maintaining the physical state of the patient, and delay the onset of side effect like scoliosis and loss of range of motion which lead to more serious illnesses. Walking is key to retard these side effects, and EXOTrainer will provide a solution through wearable gait exoskeletons.

EXOTrainer builds over available technology and thus addresses a new target group and new diseases, as current commercial devices are targeted to adult paraplegics. The prototype exoskeleton developed in the project has achieved the level of maturity necessary to provide a walking ability to patients. In the final stages of the Experiment, the technology developed is undergoing clinical trials, paving the way towards CE marking and future series production.

GAROTICS

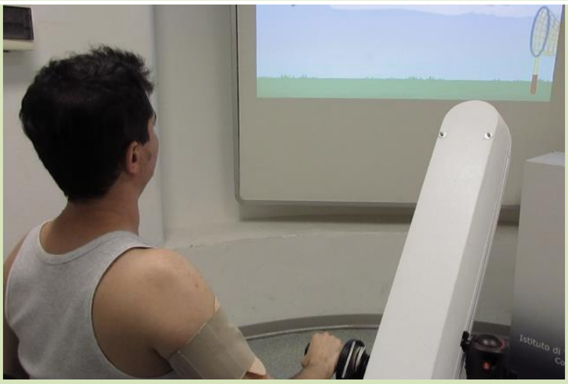
The main goal of GARotics was to improve/redevelop a 3D detection system for green asparagus and the development of a robotic tool for selective harvesting. Both had to reach a reliable success rate of more than 95% under real conditions in order to bring a commercially viable product to market.
The project led to the development of a detection and harvesting device prototype, which was successfully tested in an operational environment. Using a 3D camera and a corresponding image processing program, detection rate of 100% was reached. Using an active cutting and gripping device, 95% of detected asparagus stalks were harvested successfully, in tests on an asparagus field in UK.

LA-ROSES



The LA-ROSES project aimed to develop a robotic platform dedicated to Laser-assisted Keratoplasty (cornea transplantation), with the objective to substitute the laser tip currently handled by the ophthalmic surgeon. The solution proposed offers a tool capable to safely assure the welding (suturing, without needle and stitches) of the cornea in a way not possible with other techniques. The surgeon has an on-line control of the trajectory of the laser and of the temperature of welding, critical to the safe success of the surgical procedure. A robotic arm is used to position the end-effector over patient's eye, then three motors move the laser along the desired trajectory. Work performed in the project has led to the development of a proof-of-concept prototype. Additional work is considered to reach higher TRLs. Possible alternate uses of the developed technology are being pursued, both in the medical field (laser welding of tissues), and for industrial applications.

LINarm++

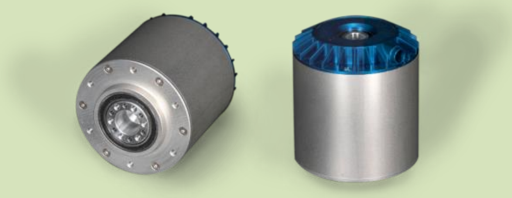


The goal of the project was to realize a technological solution enabling a multisensory, multimodal and patient-oriented neuromuscular rehabilitation of the upper limb, currently unavailable among off-the-shelf devices. The developed solution integrates a variable-stiffness end-effector rehabilitation device, a wearable neuromuscular electrical stimulation system, a virtual rehabilitation scenario, a low-cost unobtrusive sensory system, and a patient model for adapting training task parameters according to the patient. Work performed in LINarm++ led to advances in several areas, including that of unobtrusive measurements of physiological parameters, sensor fusion and interpretation of human data, bio-mimetic and bio-feedback FES for upper-limb rehabilitation, and design of variable stiffness actuators and related control techniques. Building upon the strength of the prototype developed in the project, clinical trials are expected in the coming months.

MARS

The goal of the experiment is the development of swarm-robotic solutions for precision agriculture, targeting automated seeding tasks in particular. The technology developed is intended to **1)** reduce usage of seeds, fertilizers, and pesticides, **2)** reduce soil compaction, and **3)** provide an easily scalable and automated solution. The product developed will address expanding needs in terms of food production in the near future, and significantly reduce the associated environmental impact. In the project, two cloud-connected, small-size ground robots, equipped with precision localization technology and integrated seeding units, were developed to successfully demonstrate the approach. The work performed has led to the development of a strong partnership with the industrial end-user, active work on further development of the technology is being pursued.

MODUL



In the project MODUL a highly integrated series elastic actuator module was developed. To this end, a motor, harmonic drive gear, custom titanium spring, sensors, and specifically developed motor control electronics were compactly integrated in a single joint unit. This drive combines perfect impact robustness with precise torque regulation and is made for operation in harsh environments (IP67). It is well suited for applications involving interaction tasks such as manipulation, rehabilitation robotics, prosthetic devices, or walking robots. Over the last year, the drive was successfully tested in ANYmal, an autonomous quadrupedal robot that is capable of walking and running. Projects achievements have led to the development of a very well defined, conceived, and received new product (attracting significant attention from interested customers), and the creation of a spin-off.

MOTORE++

Stroke is one of the leading causes of adult disability in the world, and is the second cause of death for individuals over 60 years of age. Most of the patients who survive such an accident are left with a severe partial paralysis and need professional help for rehabilitation. It is predicted that expenses for medical care and rehabilitation in this case will grow steadily. The goal of MOTORE++ is to continue the development of a planar rehabilitation robot named MOTORE (MObile roboT for upper limb neurOrtho Rehabilitation) aimed to restore upper limb functionality and to assess performance in patients with neurological diseases. MOTORE is the first robot small enough to be easily carried, it is the first robot really suitable for home based rehabilitation. Proprietary software has been developed with several exercises/games. The core business of humanware is the production of medical devices and MOTORE++ will be the flagship product of the company. CE marking was obtained during the run-time of the project, and the first product sales were recorded.

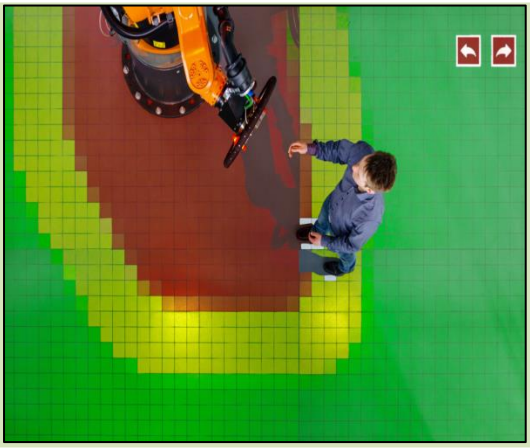
PICKIT

Scape technologies

Fraunhofer IFF

The objective of the experiment was to incorporate tactile sensors into the grippers of an off-the-shelf bin-picking system. A gripper thus equipped introduces an essential modality to a bin-picking system, especially if the object's surfaces are challenging to detect optically and do not allow for a precise position estimation. In this case, the haptic modality, which offers tactile feedback from slight physical contact between the gripper and the content of the bin can be used to support the gripping process. The experiment identified various potentials in bin-picking through use of tactile sensors in the gripper. This applies in particular to the *Grip Monitoring* after picking a part, more precisely detecting collisions, verifying a successful grip operation and an accurate part placement. The presented method reduces the cycle time by up to 36%. Supplementing inadequate optical data by tactile data offers new opportunities for e.g. the detection of transparent parts. We successfully demonstrated our approach for picking glasses and blackened washers, which so far could not be detected by the camera. Commercialization of the technology is to be discussed in the short term, and additional technological developments are being pursued within a new European project.

SAPARO



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PILZ
THE SPIRIT OF SAFETY

Current industrial applications with human-robot collaboration focus on the use of small robots such as the KUKA iiwa, Universal Robots UR5 etc. due to safety considerations. However, many industrial applications where human-robot cooperation would be very beneficial require higher payload capacity and robots with large workspaces. In the SAPARO experiment we propose an innovative and trendsetting solution for safeguarding collaborative human-robot workplaces with high payload robots through a combination of safeguarding technologies. This consists of a tactile floor with spatial resolution together with a projection system to warn the human. The safety zone is dynamically created, according to the relevant guidelines in ISO/TS 15066, based on the velocity and joint angle positions of the robot instead of statically. Safe human-robot interaction is a key strategic area intrinsically related to Industry 4.0 and Factories of the Future. The industrial partner has committed to bringing the product to market, and the sale of an early prototype has already been recorded.

TIREBOT

The goal of the experiment was to build TIREBOT, a cooperative robotic assistant for helping the tire workshop in the heavy part of the tire changing process. By delegating to TIREBOT the low level tasks we aimed at making the work of the operator less tiring and more efficient. TIREBOT employs advanced control, localization, perception and cooperation strategies in order to cooperate with the operator. The operators have experienced a 63% reduction of the efforts compared to the manual exchange of tires. The experiment has led to the development of a TRL 7 prototype. Strength of this prototype has attracted expressions of interest from a number of possible end-users of the developed technology.

Outlook of Call 2 Experiments

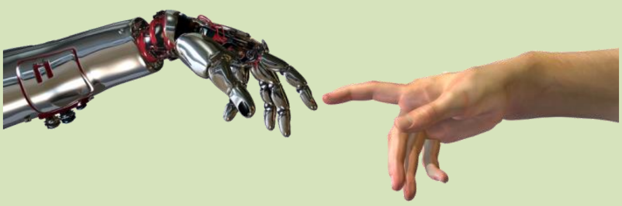
AAWSBE1

In order to address legislation regarding increased reuse of batteries and rare metals in WEEE, the AAWSBE1 experiment aims to sort batteries inside Waste Electrical and Electronic Equipment (WEEE) by using deep learning techniques. It will detect potential battery-containing items from residuals in a WEEE small electronics stream, as well as presort battery streams for more efficient recycling of the batteries. The AAWSBE1 system will be adaptive in order to address changing market values, and changes in legislation. Furthermore, it will employ design strategies from industry 4.0 by learning from process data new prioritizations regarding gripper types and gripping points by measuring success rates and employing a secondary camera to measure changes in the scene in between picks. It will be designed to work as an individual sorting station in a line, with either manual or robot sorting stations, capable of either working alone or of integration into a cognitive factory.

CATCH

Harvesting represents one of the most costly and most critical phases in horticultural value chain production. The advantageous and opportunities of automation of harvesting tasks by means of innovative robotic technologies (agricultural robots, terms also used *agrobots, hortibots etc.*) has been recently widely identified as one of the most advantageous *green-techniques* approaches capable of ensuring improved crops yield and environmental sustainability impacts. CATCH experiments deal with the shortage of flexible, cost-efficient and reconfigurable/scalable *hortibotic* out-door solutions for automated harvesting in difficult natural conditions by addressing critical problems: fruit perception and fast picking actions. The use case of outdoor cucumber harvesting has been selected taking into account the need from relevant end-users, the technological challenges, as well as the economic impact in various European regions.

CoCoMaps



The experiment CoCoMaps uses an expanded version of the existing Cognitive Map Architecture implemented on Honda's ASIMO robot in an environment with more complex tasks than already attempted. This will allow the robot to interact in more complex ways, in particular, to simultaneously interact with another robot and more than one person at a time. Thus, the project aims for a group of 2 robots and 2 humans. These systems will enable social interactions that can coexist with the robots' attention to – and completion of – practical tasks in the workplace. A particular focus is on human detection and tracking algorithms and on an improved dialogue system.

DUALARMWORKER

DUALARMWORKER will solve one of the key issues to the real use of dual-arm robots in industrial applications: the planning and execution of highly-constrained closed-chain dual-arm motions. No industrial software or open source library available today allows these capabilities. The objective of the experiment is to: 1) Transfer the knowledge and algorithms for closed-chain dual-arm motion planning from academic research labs (in particular LAAS-CNRS) to the industry through Tecnalia; 2) Implement them into a cognitive dual-arm robot for flexible assembly operations; 3) Deploy them into an Aeronautics pilot station in AIRBUS Spain to evaluate their performance. The technology will be demonstrated by applying it to deburring process of HTP (Horizontal Tale Plane) and VTP (Vertical Tale Plane) ribs of the A380 airplane. Depending on their size and shaped, ribs have to be manipulated using two arms. This experiment targets to give the means to manipulate the bigger sized ribs with two hands. The experiment will conclude with a robust closed-chain dual-arm planner that will be tested in a pilot station manipulating a selection of bigger sized ribs. A successful result of the experiment will open the doors to many other exploitation opportunities for the automation of aero and non-aero applications where dual-arm coordinated manipulation is required. After the conclusion of the experiment, the dual-arm trajectory planner will be released as a MoveIt! open source plugging by LAAS-CNRS, which will make the results available to be exploited by many other companies and institutions

FASTKIT

The goal of the FASTKIT project is to provide a low cost and versatile robotic solution for logistics using a combination of mobile robots and Cable-Driven Parallel Robot (CDPR). The FASTKIT prototype addresses an industrial need for fast picking and kitting operations in existing storage facilities while being easy to install, keeping existing infrastructures and covering large areas. The FASTKIT prototype consists of two mobile bases that carry the exit points of the CDPR. The system can navigate autonomously to the area of interest and deploy the CDPR at high velocity by controlling the cable tension.

FLEXSIGHT

The FlexSight experiment aims to provide a robotic solution for the "pick&place" class of applications with rigid and deformable objects. The project focuses in building a prototype smart camera - the FlexSigh Sensor (FSS) - which can be integrated in the chassis of an existing robot to empower it with detection and localization capabilities. The main objectives of the FlexSight experiment are: (1) Enable a robot to perceive a large and widespread class of rigid and deformable objects in an accurate and reliable way, with a particular emphasis on the computational speed of the whole system. (2) Implement a prototype of a compact industrial sensor (the FSS), that integrates inside a robust and small chassis all the required sensors and a processing unit suitable to run the detection and localization algorithms. (3) Integrate the FSS inside a working system that will be tested in several industrial and logistic use cases. The FSS will integrate latest generation components, such as high speed, low noise CMOS cameras, laser random pattern projectors, and a compact but powerful computer board with integrated GPU. The experiment will exploit state-of-the-art deep learning techniques for the object detection step. At the end of the project, we plan to produce and commercialize the FSS.

GRAPE

Precision agriculture practices aim to significantly reduce the negative environmental impact of farming due to over-application of chemicals, while still producing enough food to satisfy a growing demand. The introduction of advanced sensing capabilities allows monitoring at plant level, spotting problems before they spread. Furthermore, introducing farming robots, chemicals can be applied with honeybee precision, pesticides and fungicides can be used only when needed and in the smallest necessary amount, or even be substituted by less impacting techniques (e.g., mechanical instead of chemical thinning, biological control instead of chemical pesticides). GRAPE project aims at creating the enabling technologies to develop vineyard robots that can increase the cost effectiveness of their products. The project addresses the market of instruments for biological control by developing the tools to execute (semi) autonomous vineyard monitoring and farming tasks with Unmanned Ground Vehicles and, therefore, reducing the environmental impact with respect to traditional chemical control.

HOMEREHAB

Rehabilitation can help hemiparetic patients learn new ways of using their weak arms and legs. However, reductions in healthcare reimbursement pressures rehabilitation specialists to reduce the cost of care and improve productivity. Service providers have responded by shortening the length of patient hospitalization. Additionally, early home supported discharge of subacute stroke patients has been proved to have a significant impact on motor recovery after stroke, but equires some level of innovation of methods and tools for service delivery to really become a sustainable solution for the healthcare system. The HOMEREHAB project will develop a new tele-rehabilitation robotic system for delivering therapy to stroke patients at home. It will research on the complex trade-off between robotic design requirements for in home systems and the performance required for optimal rehabilitation therapies, which current commercial systems designed for laboratories and hospitals do not take into account.

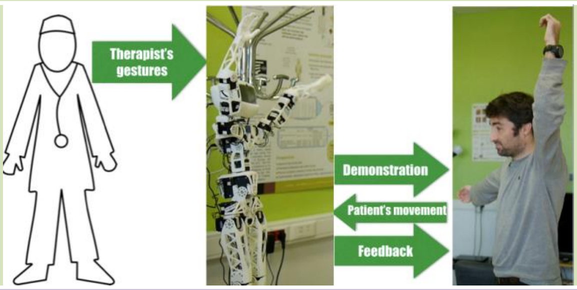
HyQ-REAL

Disaster response and other tasks in dangerous and dirty environments can put human operators at risk. Today's remote-controlled vehicles with wheels and tracks have limited use in such missions due to their reduced mobility on rough terrain. In the wake of recent disasters (e.g. Fukushima power plants) we have witnessed how tracked robots can struggle and eventually get stuck in unstructured environments, such as stairs with rubble. A new generation of all-terrain vehicles, with legs instead of wheels and tracks, is finally reaching performance levels that show superior mobility on rough terrain. The HyQ-REAL experiment will bring IIT's new quadruped robot HyQ2Max from the laboratory to the real world applications. Under the experiment, ruggedization of the HyQ2Max robot and providing it with power autonomy are the main goals.

INJEROBOT

Grafting in horticultural seedling industry is a common hand-made practice, with the objective to achieve a stronger and more productive plant. Currently, grafting of seedlings is a very important part of the horticultural production industry in Europe, accounting for *solanaceae* (tomato, pepper and eggplant) market up 38% of world production, with more than 200 million of grafted plans annually, and for *cucurbitaceae* (watermelon, melon and cucumber) market up to 47% of world production, with more than 120 million of grafted plants annually. **INJER-ЯOBOT'S** goal is to perform a universal and flexible robotic system to make grafting of horticultural seedlings, based on the cooperative work of two commercial robotic arms supported by artificial vision, and external devices.

KERAAL

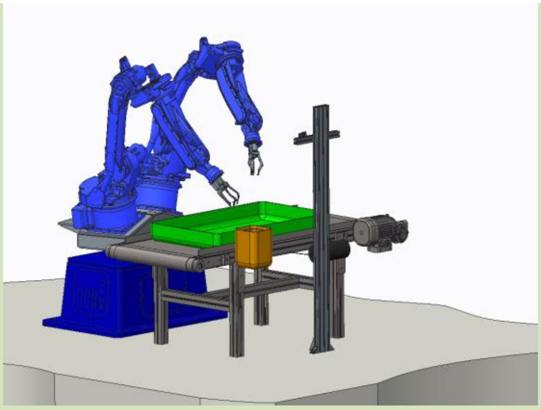


Low back pain is a leading cause disabling people. It particularly affects the elderly, whose proportion in European societies keeps rising, incurring growing concern about healthcare. Assistive technology in general and assistive robotics in particular may help to address the increasing need for healthcare. In particular, it can help people with musculoskeletal conditions that need keeping mobility of joints and increase of muscle force and coordination. In this context, the experiment proposes to develop a robot coach for rehabilitation exercises. The goal is to increase the time patients spend exercising, by alleviating the lack of time a physiotherapist can spend monitoring a patient. With this perspective, the experiment will develop a robot coach capable of demonstrating rehabilitation exercises to patients, watch a patient carry out the exercise and give him feedback so as to improve his performance and encourage him.

MaxES

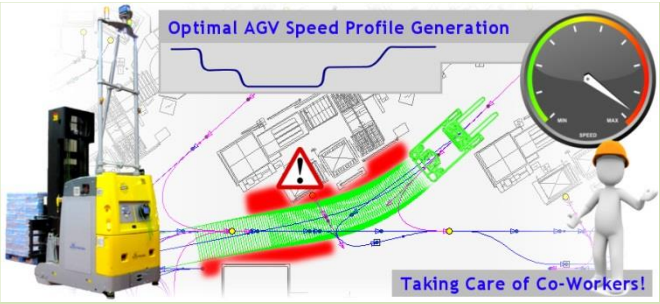
The proposed experiment aims to develop, to implement and to test navigation software for delivery robots in an industrial environment. The experiment is part of the smelter of the future framework, aiming to integrate fully autonomous unmanned vehicles in an industrial process. The integration of unmanned vehicles in a factory raises some very challenging problems such as the robustness of the navigation for indoor and outdoor operations and the safety of goods and people. The proposed experiment is the first of its kind in the world involving a robot for handling and delivering heavy loads in a realistic situation alongside other vehicles and pedestrians. In addition, the experiment will demonstrate the feasibility of implementing an autonomous form of logistic in an existing plant, without guiding infrastructures and while keeping the existing road network.

RadioRoSo



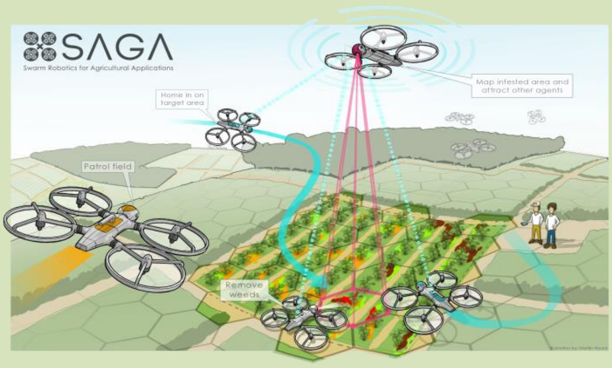
The scope of RadioRoSo is decommissioning operations performed in nuclear waste storage facilities. A significant amount of old and undocumented nuclear waste is buried underground in unused mines in several countries. Many of these facilities, created as far as 50 years ago, pose a safety and environmental risk, and thus several countries have started or considering the decommissioning of these waste in safer facilities. Decommissioning is a complex and expensive process. Large industrial cells are manufactured around the storage silos. Sorting is done manually by using mechanical master-slave manipulators. The process is very slow and tiring for the workers, thus requiring short shifts, a high number of workers and a long time of training. The overall cost is huge. RadioRoSo intends to reduce the costs of the operation by means of intelligent automation of pick-n-place tasks. Specifically the experiment will demonstrate autonomous sorting of Magnox swarf (debris from the deconstruction of nuclear fuel cells) intending to isolate medium radioactivity parts from low radioactivity waste.

SAFERUN



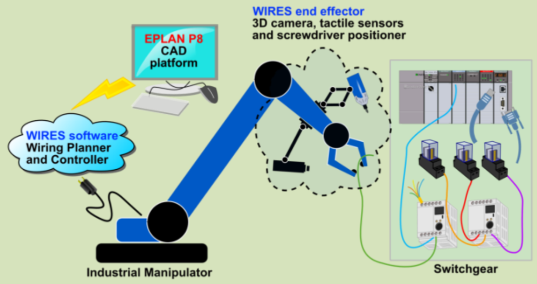
The SAFERUN experiment aims at developing and implementing a new planning methodology for Laser Guided Vehicles (LGV). Such vehicles, which are largely used in industrial environments for the autonomous transportation of huge loads, share their workspace with several independent agents, like other LGVs or humans. For efficiency, but also for safety reason, LGVs move along pre-specified path segments. This implies that they cannot skip unexpected obstacles placed along their route: collisions are normally avoided through the execution of emergency stops. The drawback of this approach is that, in the absence of a thorough study, collisions can only be avoided by greatly reducing the average vehicle speeds: evidently, the plant productivity is negatively affected by such commonly used strategy. The new planning method proposed for the SAFERUN project aims at improving the safety standards in LGV plants -- such to preserve the physical integrity of human coworkers -- by simultaneously increasing the plant productivity.

SAGA



The goal of the experiment is to prove the applicability of swarm robotics to precision farming. The application of swarm intelligence principles to agricultural robotics can lead to disruptive innovation, thanks to the parallel operation of multiple robots and their cooperation. The experiment aims at demonstrating such advantages and compare with the current state of the art within the context of a monitoring/mapping scenario. By exploiting swarm robotics principles, a group of small UAVs will be deployed to collectively monitor a field and cooperatively map the presence of weed. An existing multi-rotor UAV will be enhanced with on-board camera and vision processing, radio communication systems and suitable protocols to support safe swarm operations. The experiment will develop robust on-board vision routines capable of supporting local navigation and discerning weeds from cultivated plants. Collectively, the robots will build a map of the field with semantic tags associated with different areas, so as to convey precise information about the presence and amount of weed in the different parts of the filed. This will facilitate optimal spatiotemporal planning of weeding operations, and autonomous precision weed removal in the future.

WIRES



The experiment aims to improve production quality of switchgears by automatizing the wiring process which is currently handled manually due to high complexity of the involved manipulation tasks. The experiment will contribute in software as well as hardware (grippers) to come up with a robotic solution for wiring. The main challenge is to develop a novel gripper with tactile sensors which can handle deformable objects such as wires and simultaneously operate on screw/clip type connection points. During the WIRES experiment, manipulation strategies exploiting tactile feedback for tolerant wire grasping and handling during connection on electromechanical components in a laboratory setup will be evaluated. For limited simple cases, the applicability of the results to the switchgear production in a realistic scenario will be tested. All the technologies developed within the WIRES experiment aim at reducing the time for switchgear wiring and at improving the product quality. The foreseen reduction of the wiring time is about 40% with respect to the overall wiring time, due to the fact that at least part of the overall wiring process can be executed by the automatic system also overnight. It is clear that the achievement of these objectives will have a very strong impact on product cost and company income. IEMA estimated on its 2016 data that the time saved in the wiring process can generate an additional sales volume of about 4M€, with an increase with respect to the "conventional" manufacturing of about 53%. This estimation can be extended proportionally to all companies, even of different market fields, whose products currently require a long wiring time.