TECHNICAL AND SCIENTIFICAL REPORT, STAGE 3 (2020)
PROJECT 1
Design, modelling and in-service simulation of distributed configurations of sensors and visual servoing systems on complex autonomous systems (CAS-SI, CAS-ARP, CAS-VAM), intended for personal medical and social assistance technologies, in / out of hospital and at home.

Stage 3 (2020)

Design and functional testing of the integrated sensory system

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Activity 3.1

The design of the sensory system integrated in the management system. Dissemination of results

Tests and experimental determinations led to three main configurations of the sensory system. The comparative analysis of these systems is presented below.

Variant 1 - Kinect, secondary LiDAR sensors, Tobii Eye Tracker

This configuration is recommended for short-distance travel with permanent control by the user and allows travel to the destination point only through linear trajectories (the destination must be visible from the starting point).

Variant 2 - Velodyne Puck VLP-16 LiDAR Sensor, Proximity Sensors, Tobii Eye Tracker

The Velodyne Puck VLP-16 LiDAR sensor is the main sensor in the second variant and allows the creation of a three-dimensional topological map of the visible area, allows the detection of moving objects and the detection of doors or niches for access. The high price of this sensor is offset by the travel safety offered by this system. At the same time, this sensor allows the elimination from the system of several categories of sensors that it replaces: proximity sensors, low range lidar sensors, stereoscopic video sensors.

Variant 3 - ZED camera, secondary LiDAR sensors, Tobii Eye Tracker

The third variant is similar to the first variant. The main change is the replacement of the Microsoft Kinect sensor with a depth camera called ZED that has a higher resolution and acquisition speed.

The system is relatively less expensive compared to "Variant 2 - LiDAR Sensor Velodyne Puck VLP-16, Proximity Sensors, Tobii Eye Tracker", but still allows use outside the building. It is a system that allows a movement on linear trajectories in areas where the destination is visible, and which has a range of up to 15 meters (unlike Kinect 3.5 meters).

Simulare CAD si implementarea reală.

The sensors used in the three configurations are LIDAR type, stereoscopic, optical, Video, respectively: Kinect sensor, Velodyne Puck VLP-16 sensor, RP LiDAR A1, RP LiDAR A2, Scanse Sweep LiDAR sensor, Optical proximity sensor O1D100, Optical sensor proximity O1D102.

3.1.1 The use of Tobii Pro Nano to create custom human-machine interface profiles

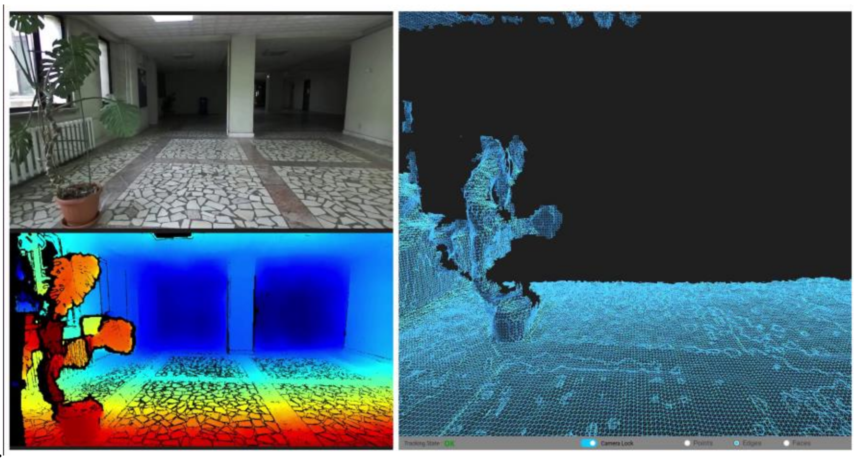
One of the conclusions of previous tests with the eye tracking system Tobii Eye Tracker 4C found that in certain situations (the existence of a complex of medical situations, consisting of both strabismus and Nystagmus) the accuracy of the eye tracking system, and implicitly the accuracy of the given motion commands are low. One possible solution identified by the research team was the use of an advanced eye movement tracking device to analyse and identify the user's eye movement patterns. Based on the information obtained with the advanced device, it will be possible to create customized and compensated profiles for each user, which can be used with the version presented in the previous Scientific Report, of the eye movement tracking system (Tobii Eye Tracker 4C). As an advanced eye tracking device, the Tobii Pro Nano device was identified along with the Tobii Pro Lab software suite.

3.1.2 The use of the ZED stereoscopic video camera to map the three-dimensional space in which the mobile platform evolves

ZED is a 3D camera for depth detection, motion tracking and real-time 3D mapping. The manufacturers of this camera provide the SDK (Software Development Kit) for Windows, Linux and Nvidia Jetson platforms. This kit contains all the libraries needed for development as well as tools that allow us to test the features and settings of the room.

The ZED camera is a multi-sensor platform with built-in positioning and motion assist sensors, accelerometer, gyroscope, magnetometer, barometer and temperature sensor. The SDK provides several classes and interfaces that help

us perform a wide variety of sensor-related tasks such as determining the sensors available on the device, determining the individual capacity of each sensor such as measurement range, resolution and noise, and acquiring data in raw or processed format (calibrated).
The ZED stereo camera reproduces the way human binocular vision works.



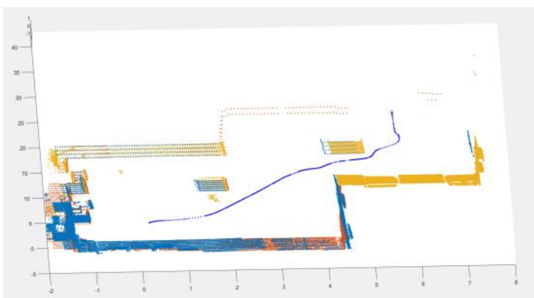
The 3D space cartography using the stereoscopic video camera ZED

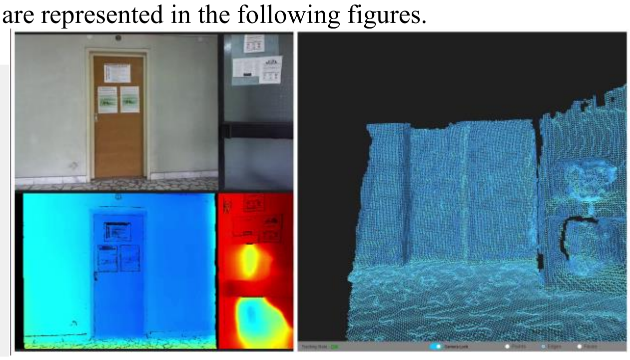
Activity category: A2 - Industrial research
Expected results
Design specifications for the sensor system integrated in the control system
Participation in conferences, workshops, ISI / BDI journal articles;

Activity 3.2.
Functional testing of sensors of the type selected in the previous steps.

3.2.1 Simulation of the movement of the mobile platform in environments with static obstacles, by applying the potential algorithm on a scanned three-dimensional space

Using a LIDAR device (Velodyne LiDAR Puck 16) a series of three-dimensional spaces were scanned inside the Faculty, which also contain static obstacles (structural elements of the building, alveoli and entrances, access roads to other spaces of the building.
Records were obtained and tests were performed for a number of scenarios: moving down the hall of the department, identifying areas of passage from one space to another (such as access roads, doors), or moving to a foyer space. . Acquisitions were made by area, for local navigation in real time, as well as acquisition of mapping data - zonal acquisitions were merged in a mapped region, resulting in a map of the space where the mobile platform moved (figure 3.2.3).
The trajectories of moving the mobile platform in autonomous regime were generated, imposing different pairs of points (start, destination), for different scenarios. Two of the trajectories obtained by applying the control algorithm based on the artificial potential field method for mapped regions are represented in the following figures.

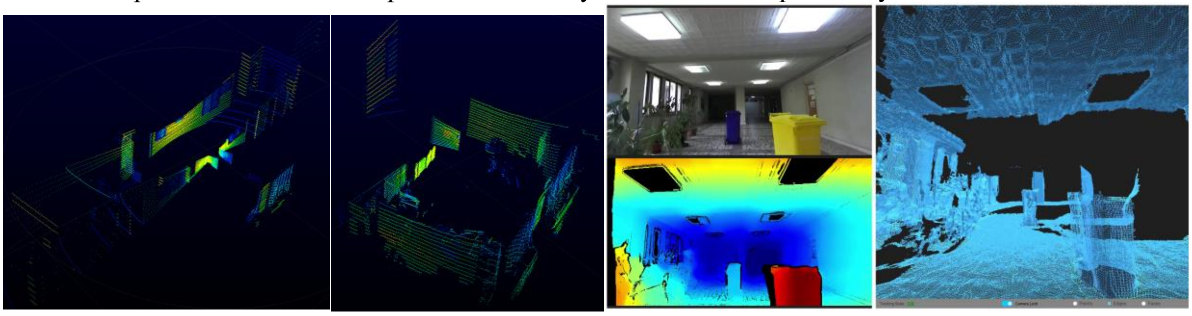




The trajectory of the mobile platform autonomous movement from the point Ps_2 to the point Pt_2. The 3D cartography of the access ways using the ZED stereovision system

3.2.2 The functional testing of the ZED stereo vision system

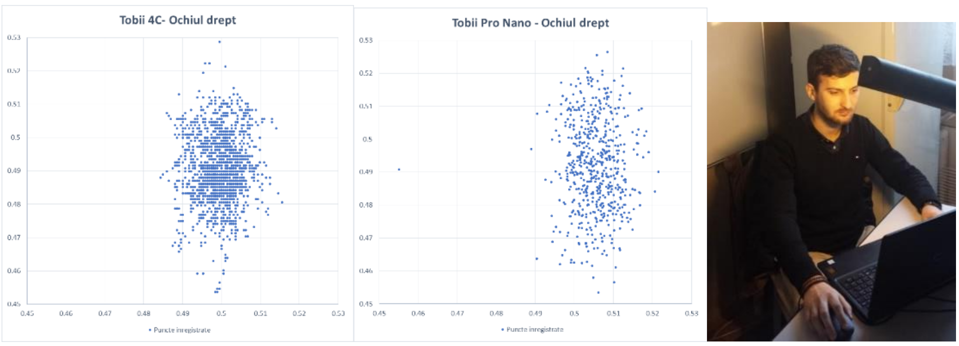
In order to perform a comparative analysis with other devices that allow real-time 3D mapping (Kinect, LiDAR, DJI Guidance) under various aspects (speed of real-time data acquisition, influence of environmental conditions, ease of extraction of relevant data, accuracy , the actual scanning distance in relation to the mobile platform, etc.), a series of data collections were performed in the same spaces of the faculty where data were previously collected with the other devices.



Switching to one space (left image – hallway) into another space (right image – laboratory). 3D mapping of spaces containing various obstacles using the ZED stereovision system

3.2.3 Functional testing of sensory detection systems

The development libraries provided by the manufacturer of these devices were used to test the two direction detection sensors. A .NET library was chosen for the Tobii 4C sensor, while a Python library was selected for the Tobii Pro Nano sensor. The use of two different libraries does not affect the test result due to the fact that these libraries have been optimized for each programming language. Another reason why we have selected two different programming languages is to test the level of difficulty when it comes to programming devices and at the same time to test the response time. Following these tests, we concluded that there are no differences between the two programming methods and that it is strictly a preference for each developer. At the same time, it is worth mentioning that although there are no differences in the case of programming, the two devices are limited by their own sampling frequencies (Tobii Pro Nano - 60Hz, Tobii 4C - 90Hz).
The structure of each program is the same, the only difference being the programming syntax.
The third test was performed outside, with sunlight beating in the directions: left, right, front, back. The results in sunlight proved that the accuracy of the Tobias is influenced by the infrared light emitted by the sun, so when the sunlight hits the device or the eyes directly, the Tobias can no longer track eye movements or detect their presence or lose their precision.
A series of recordings were made using both Tobii Eye Tracker 4C and Tobii Pro Nano. The research team analyzed the results obtained individually for the individual tracking of the movements of the left eye, respectively for the right eye. The analysis of the records showed that although the recordings made with the Tobii Eye Tracker 4C device seem to provide better grouped data than those made with the Tobii Pro Nano device, the data group still has an offset from the target area at the coordinates (0.5; 0.5).
The third test was performed outside, with sunlight beating in the directions: left, right, front, back. The results in sunlight proved that the accuracy of the Tobias is influenced by the infrared light emitted by the sun, so when the sunlight hits the device or the eyes directly, the Tobias can no longer track eye movements or detect their presence or lose their precision.



Comparison of the recordings made for the right eye with the Tobii Eye Tracker 4C device (graph on the left) and Tobii Pro Nano (graph on the right). Tests with artificial light

Activity category: A2 - Industrial research
Expected results
Functional test results

Activity 3.3.
Functional testing of the integrated sensory system
The Kinova Gen3 lite support robot for people with personal needs
The use of human-machine interfaces (HMI) has seen an extraordinary increase in usage in recent years. Movement tracking tools such as Kinect, Tobii, LIDAR, are some devices that can be used to assist people with special needs. The use of portable sensor networks as a means of measuring and tracking body movements also provides interesting possibilities in terms of human-machine interface technology

(Figure 3.3.1).
Often, the design of human interfaces dedicated to people with disabilities is based on mechanical tools, such as head-mounted switches, dedicated keyboards, trackballs, joysticks, sip-and-puff tools, etc.
fi comutatoare montate pe cap, tastaturi dedicate, trackball-uri, joystick-uri, instrumente de tip sip-and-puff etc.

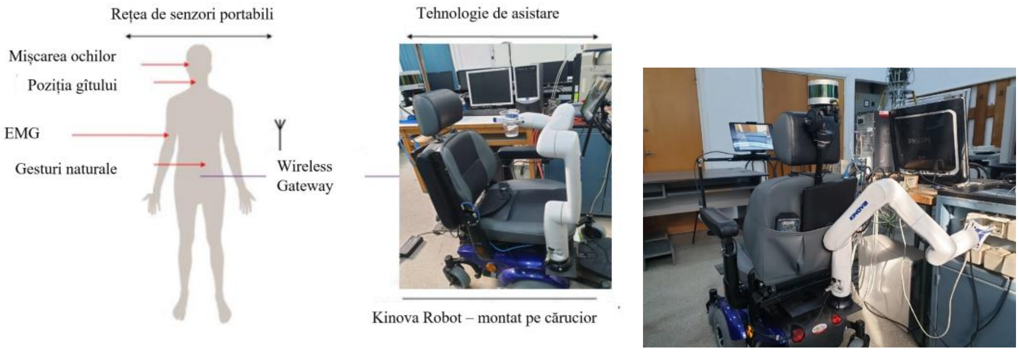


Fig. 3.3.1 Man-machine interface technology.

Automated Modular Architecture with Cooperative Facilities

On the Internet of Things (IoT), cyber systems communicate and cooperate with each other, as well as with real-time people inside, but also between organizational services provided and used by value chain participants. The fourth industrial revolution - Industry 4.0 - is the name given to the current trend of automation and data exchange in manufacturing technologies. As Industry 4.0 (I4.0) works, computers are connected and communicate with each other to make decisions in the end without human involvement. This includes cyber-physics, the Internet of Things, cloud computing and cognitive computing. In the experiments performed, two ways of implementing communication for CCAGV mobile platforms (cheap cooperative vehicles automatically guided) were verified. To obtain results of greater accuracy and accuracy, in current systems, several types of sensors are used in the same project. This process of integrating data from multiple sources is called Data Fusion. For a 3D perception of the environment, additional sensors and additional computing power are needed to be able to process data in real time.

Decision Making using Data Fusion for Wheelchair Navigation

Driving the wheelchair independently or semi-autonomously requires the acquisition and processing of data describing the environment in which the movement takes place. Using the results of the data obtained from the processing of the sensors, it is possible to determine the limits of the environment, the free lanes / free zones, the identification of the destination and the waypoints, etc., which will be used to determine the optimal trajectory.

Simulation of the emotional states using a biomimetic structure

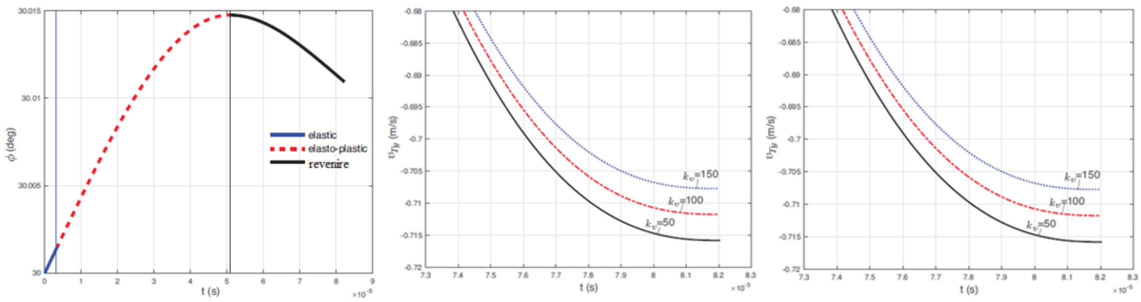
One of the most popular theories of emotion is that of the American psychologist Plutchik, who proposed a detailed classification of emotional responses. He proposed a set of eight basic emotions, which are divided into four pairs of opposite states: joy-sadness, acceptance-disgust, surprise-anticipation and anger-fear. All these emotions are considered innate. These can be used for the perception of patient satisfaction, respectively for the efficiency of the driving algorithm and the overlapping of the results over the initial requirements.

Simulation model for designing the power lines

A simulation of an electrical or electronic system can take the design to a higher level, improving its reliability and efficiency, revealing design defects before the actual production of the device. This design stage can highlight the behaviour of the system under different conditions, bringing to the surface design defects that present various hidden problems. In particular, for expensive and complex systems, manufacturing tools are expensive, test boards are not practical, and testing the behaviour of internal signals is extremely difficult. Therefore, almost all projects for such systems are largely based on component modelling and simulation.

Mechanical impact study

Using the computer-controlled wheelchair, people with special needs can also be supported by a robot arm that lifts objects, turns on or off switches, opens or closes doors, makes tea, and pulls drawers. Considering the particularities of such applications, it is necessary to consider the mechanical impact in the design of robotic structures. In this way an adapted mechanical structure will be obtained, but it will also be possible to design and implement a more efficient control system. For the assessment of the real situation to be as effective as possible, the consideration of friction is an important factor. We proposed a model for mechanical impact, designed to support a more precise design procedure for mechatronics and robotics systems.
The aim of our research was to provide a solution that can support the design process of robotic structures. These structures have applicability in several areas, which have also been presented above.



Impact angle, in degrees, during the impact. Normal bounce rate of the point of impact as a function of the viscous friction coefficient. Angular bounce rate of the bond as a function of viscous friction coefficient.

Study of uneven terrain, slopes or stairs

One of the studies carried out within the project, resulted in a solution for moving the chair on uneven ground, or for moving on stairs. It requires a relatively simple solution that requires the replacement of the drive wheels of an electric seat with a set of wheels with variable geometry based on rheological fluids.

Seat for uneven terrain, on slopes or stairs

Study on the evaluation of the functional qualities of the motorized wheelchair from the point of view of a user with special needs

After the development and testing of the previously presented solutions, a study was developed to evaluate the qualities of the obtained product, from the point of view of some users with special needs. To carry out this study, an evaluation form was developed that covers all the areas covered, listed above.

This study addressed the following issues:

A. Evaluation of the functional qualities of the motorized wheelchair from the point of view of a user with special needs.

B. Evaluating the impact of the intelligent driving system on the initial functional qualities of the wheelchair - durability, strength, stability and efficiency.

C. Evaluating the effects of wheelchair reconfiguration for people with special needs.

D. Evaluating the efficiency of wheelchair prescribing

Expected results: Functional test results

Activity category: A2 - Industrial research

CONCLUSIONS

The detailed scientific report highlights the scientific solutions that the Project 1 work team offers for the requirements of Stage 3. In the detailed scientific report uploaded on the P1 project platform (http://cidsactech.ucv.ro/data/_uploaded/Documente/RAPORT%20CIDSACTEH%20P1%202020%20UCV.pdf), you can view the solutions / results for research related to Stage 3. Project 1 Intelligent and distributed management of 3 complex autonomous systems integrated in emerging technologies to personal medical and social assistance and service lines flexible precision manufacturing".

DISSEMINATION

Articles (ISI or BDI) - http://cidsactech.ucv.ro/index.php/Publicatii

1 **ISI- Paper**

1) Dorian Cojocaru, Dan B. Marghitu, "Impact Behavior of a Rotating Rigid Body with Impact and Viscous Friction", Mathematical Problems in Engineering, ISSN: 1024-123X (Print), ISSN: 1563-5147 (Online), Vol. 2020, Article ID 5471629, 11 pages, 2020. https://doi.org/10.1155/2020/5471629, ISI Web Of Sciences CiteScore 1,800. Impact Factor 1,009 - work in progress.

BDI - IEEE XPLORE

2) 1. Marghitu D.B., Cojocaru D. (2020) Nonlinear Dynamics of a Spatial Two Link Chain. Advances in Service and Industrial Robotics. RAAD 2020. Mechanisms and Machine Science, vol 84. Springer, pp 466-475, ISBN 978-3-030-48988-5, https://doi.org/10.1007/978-3-030-48989-2_50

3) Andrei Dragomir, Liviu Florin Manta, Alexandru Mariniuc and Dorian Cojocaru, Interisciplinary technical competitions - a case study. EAEEIE 2020 - 30th Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEEIE), ISBN 978-1-7281-9327-4 / 20/2020 IEEE - paper accepted for publication.

4) R. I. Cristian, A.C. Trasculescu, F.L. Besnea (Petcu), S.I. Cismaru and R.D. Antohi, Simulation Model for Designing the Power Lines for Low-Frequency ;„ 2020 24th International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania, 2020, - in progress

Presentations at national events organized in 2019:
1. Presentation of the CIDSACTEH project within the event "Researchers' Night - Doing Research Midnight in Romania - DoReMi-Ro" November 27, 2020 organized at the University of Craiova. http://cidsactech.ucv.ro/index.php/Noaptea-Cercetatorilor

RESEARCH AND TECHNOLOGICAL SERVICES
Name
- Structural and architectural analysis of mobile platforms for people with disabilities
- Analysis and selection of solutions for integration and interfacing of sensory systems in management architectures for mobile platforms for people with disabilities
- Study on "Integration of Intelligent Sensors in Robot Control Structures"
- Assisted design services for mobile platforms for people with disabilities
- Services for the integration and interface of sensory systems in management architectures for mobile platforms for people with disabilities
Link: https://erris.gov.ro/Computer-Aided-Design-CAD--C

PROJECT 2

"Modeling, simulation and implementation of distributed configurations of sensors and visual servoing systems for hybrid technologies for reusable products on flexible, precision, laboratory (mechatronics lines) and industrial manufacturing lines, with complex integrated autonomous systems"

Stage 3 (2020)
Development and testing of manufacturing management algorithms through the integration of advanced technologies
Stage summary

In this stage, four activities were carried out, according to the Plan for the realization of the component projects:
Activity 3.5: Modeling of visual servoing systems (SSV) used in the control of precision mechatronic lines and comparative analysis by simulation of SSV performances.
Activity 3.6: Design and implementation of an algorithm for encapsulating the different basic models of the dynamic behavior of a system in a module defined as a software resource (asset). Integrating blockchain technology with cloud computing technology, by creating a software resource library accessed in the cloud at Software as a Service (SaaS) level.
Activity 3.7: Integration of hardware-in-loop technology in modeling production lines. The association of a Real-in-loop (RIL) architecture that allows access to visual servoing systems through a multi-modal interaction mechanism attachable to a specific behavioral model. Design and validation of control mechanisms specific to collaborative environments.
Activity 3.8: Laboratory testing in simulation mode of the complex autonomous systems SAC-ARP and SAC-VAM. Valorization of the test results in order to optimize the management of the assembly / disassembly lines assisted by collaborative robotic platforms from the SAC-ARP and SAC-VAM categories.

Scientific and technical description

Activity 3.5: Modeling of visual servoing systems (SSV) used in the control of precision mechatronic lines and comparative analysis by simulation of SSV performances.
3.5.1. Characterization of basic processes
In this activity we considered the identification of complex methods by which the trajectory of an electrical manipulator to be adjusted in real time, through iterative corrections calculated based on a control model that uses as feedback features of the images extracted at each iteration. Regarding the application mentioned on the flexible assembly line, the visual servoing systems (SSV) are necessary to improve the verification / removal procedures of the parts resulting from the assembly / disassembly, executed with the robotic arm of the workstation no. 3. The research and implementation of the proposed system were done both by experimentation on the robotic laboratory line and on a Digital Twin type model of the main robotic station. The results of the analysis led to the development of a robust method for extracting features from images for SSV management.
For example, in FIG. 1 is a screenshot of Station 3 from the CIROS simulator. The ABB-IRB120 manipulator ensures the taking over of a type C part from the warehouse and its assembly in the pins of the type B part. The assembly is made in the indexing position of the conveyor belt, considering the current assembly recipe - assembly on part B.

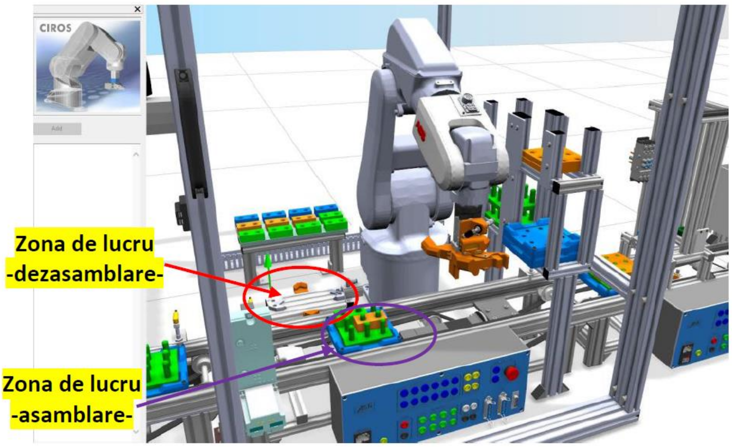


Fig. 1. Station 3 - assembly C type pieces –CIROS Simulator

In the current approach, the verification at the end of the assembly of type C parts was followed, considering the following stages:

1. Main detection routine: checking the number of type C parts mounted on support part B;
2. Assembly error detection routine: checking the pins of part type B.
3. Detection - optimization routine: validation of type C parts
4. IBVS routine: calculation of coordinates and rotation angle for invalid type C parts.

3.5.2. Image processing procedures

Two industrial video / photo cameras are used for image analysis in the parts pickup station. The first camcorder contains a CMOS image sensor with a resolution of 5 Mega pixels with 1 / 2.5 inches optical format. The Arecont® Vision camera is a compact, IP video device that supports the H.264 video compression protocol. It offers dynamic images at a maximum resolution of 2560 × 1920 pixels and 14 fps. The second video camera, the O3D303 produced by IFM®, evaluates the distance, level and volume for the purchased image. The 3D visual sensor is capable of emitting many values of the distance measured in infrared in a single operation. The sensor output data represents distance (depth) 3D images and amplitude images at a resolution of 352 × 264 pixels. Figure 2 highlights the assembly line, computing server, and all communication server components, IP addresses, and other useful descriptions. The computing server is a computer with Matlab® R2019a and Matlab® RT v96 software installed. The IBVSViewer software application, which includes the image analysis algorithm for IBVS, is installed on the computer and processes commands received from the assembly line through the existing Modbus server. The computing server has four main routines: an Arecont® Vision camcorder calibration routine, a primary detection routine for different colours of type C parts, a secondary detection routine for validating type C parts in the assembly process, and a IBVS routine for calculating type C part parameters in order to be manipulated by the robotic arm. The purpose of the secondary detection routine is to validate the type C parts for the assembly process, depending on the rules and constraints of the robot manipulator. The colour segmentation procedure is like that for the main calibration and detection routine, the difference being given by a larger number of properties evaluated by the region analysis function.

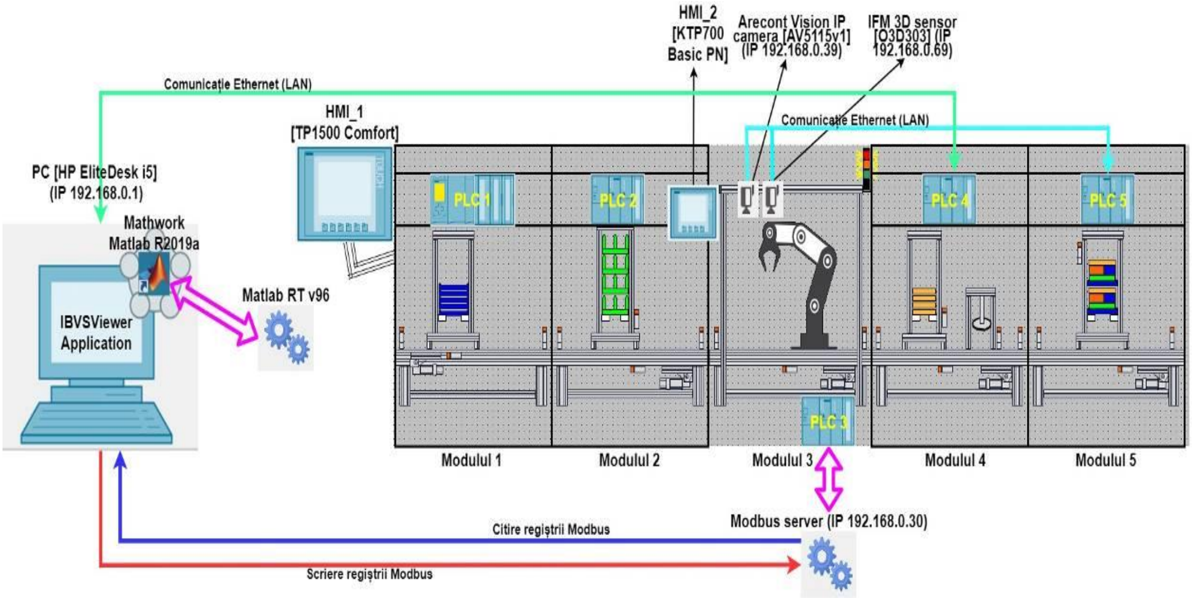


Fig. 2. Schematic of flexible assembly line and computing and communication servers

To calculate the horizontal or vertical footprint of type C parts, it is only necessary to evaluate the properties of the centroid and their framing box. Thus, the coordinates of the fingerprint points for the type C part are obtained from fractions of length or width of the framing box minus the coordinates of the centroid.
Table 1 presents the temporal results for the four routines of the image analysis algorithm for IBVS, in different configurations: Matlab® software application with and without GUI elements (IBVSViewer and IBVSCmd) and Matlab® application compiled with and without GUI elements (IBVSViewer and compiled IBVSCmd). The best values for the average execution times from several experiments of the proposed algorithm for IBVS are highlighted in the grey table.

Table 1. Temporal results of the proposed algorithm for IBVS in different configurations

Rutina	***IBVSViewer* (*s*)**	***IBVSCmd* (*s*)**	***IBVSViewer* compiled (*s*)**	***IBVSCmd* compiled (*s*)**
Calibration	0.76	0.13	0.342	0.096
Main detection	0.43	0.092	0.241	0.074
Secondary detection	0.518	0.232	0.476	0.224
IBVS	0.385	0.128	0.286	0.106

3.5.2. Real-time assembly error detection algorithm

The proposed algorithm for real-time detection of assembly errors incorporates simple but efficient routines for image analysis, with the role of ensuring fast processing. Figure 3 describes the functional diagram of the proposed algorithm for detecting assembly errors. In the color segmentation process, a strategy for converting RGB color space to YCbCr is used.

Activity 3.6: Design and implementation of an algorithm for encapsulating the different basic models of the dynamic behavior of a system in a module defined as a software resource (asset). Integration of block function technology with cloud computing technology.

3.6.1. Defining the concept of block function software resource

The construction of the models that will be run on PHS_SVF involves the use of predetermined block functions that will be assembled based on a design strategy that depends on the user experience. These strategies are stored in the database, in a standardized modular form, similar to an independent device defined as a software resource, represented as a functional block (FB), as proposed by the IEC 61499 standard. FBs can be used to describes the decentralized control logic and the properties of the devices, such as their interfaces, as illustrated in FIG. 4. In order to further extend the interoperability of the proposed solution and to provide the necessary support for the creation of a solid exchange platform for professionals in the field, all software resources are placed in an open online library. The library access is based on a dedicated system architecture, defined below with the BIB code. The BIB system has a hierarchical architecture, designed to highlight the concept of distributed self-adaptive software services, necessary in the automation of industrial processes.

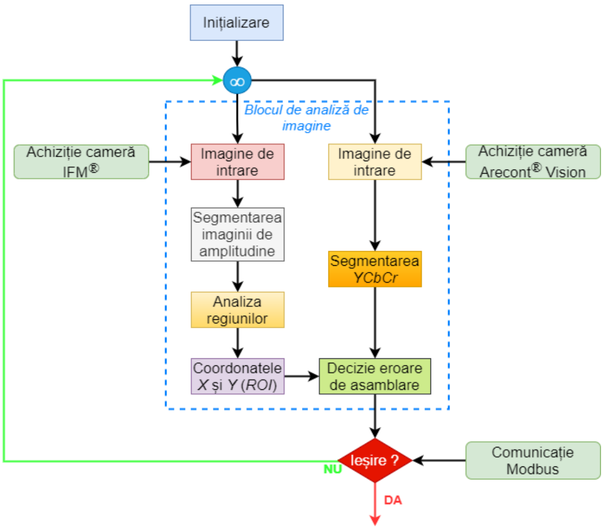


Fig. 3. Functional diagram for the real-time detection error of assembly errors

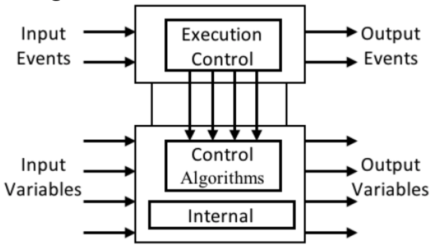


Fig. 4. Representation of a block function according to IEC 61499

3.6.2. BIB system architecture

System components

The system is designed as a web-based application that allows industry users to access and execute various complex algorithms or strategies based on stored process data and optimize process parameters based on these results. The web application is edited on a cloud platform, where two storage services are defined, Data as a Service (DaaS) and Algorithm as a Service (AaaS), as well as two execution services, Model as a Service (MaaS) and Control as a Service (CaaS).

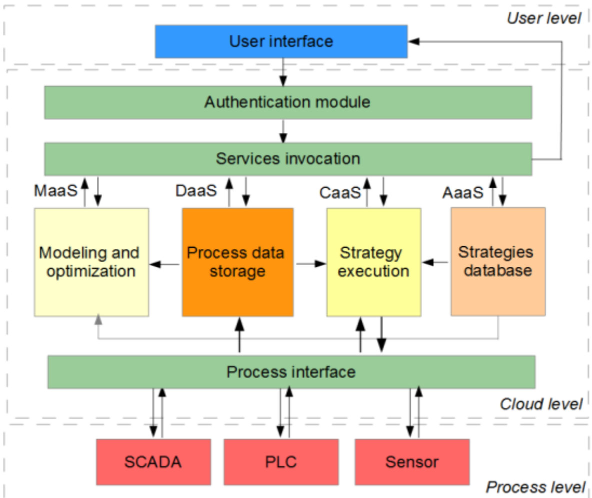


Fig.5 BIB system architecture

The architecture of the system is shown in Fig. 5. A user can access the web interface to request one of the available services. The Authentication module restricts a user's access only to general information and personal information. The available services are organized in four modules: the Modelling and Optimization module provides MaaS, the Process Data Storage module solves DaaS requests, the Strategy Execution module implements CaaS, and the Strategy Database module is responsible for AaaS.

Technologies used

The free FBRT tool, based on Java, was chosen as the runtime execution environment of the IEC 61499 block functions. To make execution results available as services, thus enabling inter-module communication in the cloud, RESTful interfaces have been defined that use web services over HTTP for data transfer. When selecting the best cloud infrastructure for advanced autopilot applications, we chose Docker, an open source technology that offers virtualization at the operating system level. Docker makes it possible to automate the process

of including an application in containers (encapsulation) and provides a high-level interface for container management.
Implementation details
The system comprises four basic modules that are instantiated according to the number of users and the services and applications requested by them. The components of each module, data processing and interaction with other system components are shown in Fig. 6. The CaaS data flow between the components of the Strategy Execution module is illustrated in red. The green part is the administration of DaaS requests using the components of the Process Data Storage module. The blue lines connect the Modelling and Optimization module to other system components. The purple lines provide access to the Strategy Base module.

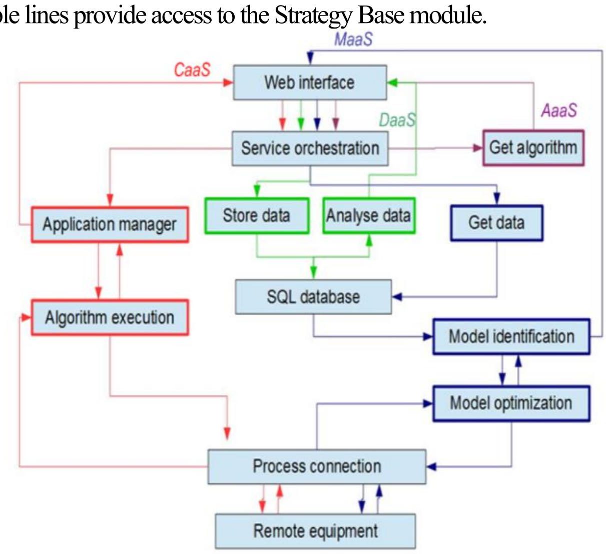


Fig. 6 The interconnected system modules.

3.6.3 Technical specifications for the integration of system components
The conceptual model of services
To implement the project, a web services-built SOA environment is required to provide an interface for IEC 61499 devices and distributed automated control systems. These automated systems can be abstracted through virtual devices and interfaced with a REST interface in order to provide the building blocks for basic services and complex driving algorithms.
The structure of algorithms
The algorithms are delivered in the form of * .fbt files, compatible with all development environments that implement the IEC 61499 standard. Each algorithm will be accompanied by a short description detailing the functionality performed by it. Algorithms that implement more complex functions (modelling, optimization, analysis, etc.) will be able to be executed in the library and then the result will be sent to a remote equipment.

Activity 3.7: Integration of hardware-in-loop technology in modelling production lines. Design and validation of control mechanisms specific to collaborative environments.

3.7.1. Defining the concept of block function software resource
In the particular case of the CIDSACTEH project, the integration of hardware-in-loop technology in the modelling of production lines had in view the elaboration of a real-time simulation architecture (concomitant with the development of the technological process) called Real-in-loop (RIL), which allows access to visual servoing systems through a multi-modal interaction mechanism attachable to a specific behavioural model. The performance of this architecture was validated by two case studies, one aimed at verifying the video control method in the loop (videoservoing), the other designed to detect defects or anomalies in the assembly / disassembly flow and possibly avoid them.

3.7.2 Evaluation of the control procedure.
Specification of the evaluation method
When performing the tests, three working variants were considered: 1) the use of a DTA (DT Aggregate) that integrates all components; 2) C-HIL simulation, through which the hardware architecture of the controller is interfaced with a model of the industrial process that is executed on the simulation platform; 3) integration of two different DTI (DT Courts), SIL-DT and HIL-DT respectively. The final tests were performed for variant 3, which allows the simulation of any type of scenario. For the analysis of the overall performance, a general control structure was considered that aims to compensate for errors caused by behavioural uncertainties and changes in context through active control of Disturbance Rejection Control (DRC). This type of controller is a variant of the classic PID controller, which can be associated with a Nonlinear State Error Controller (NLSE). The DRC controller will be the subject of the C-HIL simulation. A *Reinforcement Learning* (RL) algorithm was used to simulate SIL.
Integration of the RL algorithm in HIL simulation
The association between RL and HIL is facilitated by the similar way in which the control loop testing process takes place. This resemblance can be traced on the diagrams in Fig. 7. Thus, in Fig. 7a is the principle scheme of the HIL simulation (we preferred to avoid the DT notation, to keep the generality, in the sense that HIL can be performed in the hybrid version), but of course HIL simulations are used as the core of DTs. Fig. 7b shows the principle diagram of an RL algorithm, and in Fig. 7c illustrates a composite scheme in which

the simulation is the RL medium itself. The agent can use the same strategy as the one already built for the HIL simulation, noting that additional sensors are used to determine rewards.

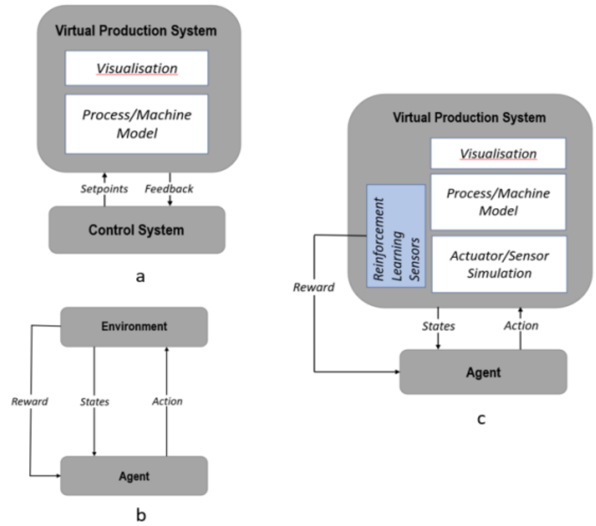


Fig. 7. Comparison between HIL and RL: a) HIL simulation b) RL scheme c) RL scheme on a HIL simulation

Experimental results

The logistic support for performing the tests is the laboratory model for a flexible assembly line of industrial products with 5 workstations (modules), presented in fig. 2. The combination of RL and HIL simulation tools has been tested in different scenarios consisting of monitoring the flow of parts on the conveyor belt. Thus, in the technological flow we have two control procedures - one for operating the conveyor belt (made as a DRC system with discrete events), the other for controlling the robot arm (videoservoing). HIL simulation is used to test and evaluate the first procedure (for the future it is considered to add a SIL simulation for an NLSE controller), and for the second procedure a combination of an RL algorithm with a HIL simulator is used. As for the conveyor belt, the speed is pre-programmed and is kept constant, and the automatic control system (implemented on a PLC) decides only the moment of triggering the initial event of the movement from one station to another. Table 2 presents some comparative results. For example, in the simplest scenario with a maximum of 3 actions, the agent needs approx. 400 states to find the optimal strategy, and in the case of a scenario with 5 possible actions, the duration increases by about 30%.

Table 2. Training duration

Aplicatie	Număr de stări de proces	Număr de stări de antrenare
O singură piesă tip A, B, D	3	420
O singură piesă tip C	5	560
Două piese de tip C+A/B/D	10	680
Toate tipurie de piesă A, B, C, D	24	820

3.7.3 Procedure for improving robustness by injecting artificial errors into a virtual environment.

The method proposes the use of a virtual environment for injection and evaluation of the impact of artificial errors on the robustness of the system. This method uses the representation of FSM (Finite State Machine) of the process correlated with the analysis of the mode of production and the effect of a failure - FMEA (Failure mode and effect analysis) to dynamically quantify this impact. The method involves two steps: 1) building a model of behavior in the virtual environment and 2) analyzing the model under artificial error injection.

Behavior modeling (Fig. 8) is a DT representation of the system, with all phases, nodes and dependences. This can be done through an FSM in which different diagrams capture different levels of detail of the industrial installation, as well as dependencies between different nodes, allowing a top-down (top-down) approach.

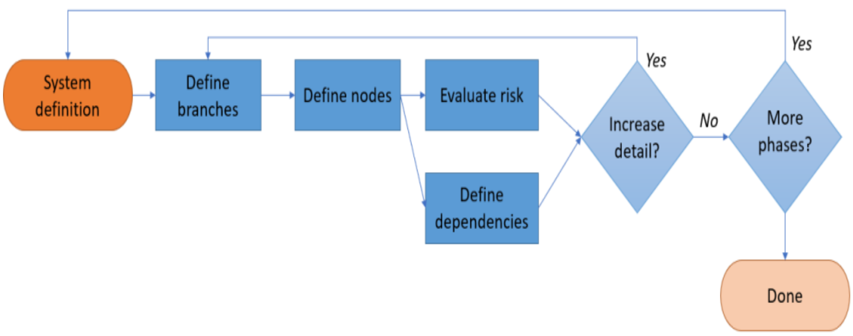


Fig. 8. Building the behaviour model

An WSF representation was built for each station of the production line. The FMEA analysis was applied on this station taking into account for each element possible ways, causes and effects of failure and assigning a risk considering a factor between 1 and 10 for the severity of the event, the probability of occurrence and ease of detection. Multiplying these indices, we obtain a risk factor that varies from 1 to 1000. The value of the risk is called RPN (Risk Priority Number). By superimposing the risk indices on the elements represented in the WSF diagram, we can calculate the global risk factor as the sum of all possible risks of all related elements.

Activity 3.8: Laboratory testing in simulation mode of the complex autonomous systems SAC-ARP and SAC-VAM. Valorization of the test results in order to optimize the management of the assembly / disassembly lines assisted by collaborative robotic platforms from the SAC-ARP and SAC-VAM categories.

For this activity, tests were performed to allow the validation of procedures for driving a mobile autonomous robot that can provide parts transport operations as an auxiliary to the assembly / disassembly operations performed on the flexible laboratory line. In fig. 9 represents the block diagram of the basic functional modules: i. The route creation function; ii. Current position playback function; iii. Obstacle bypass function; iv. Mapping function

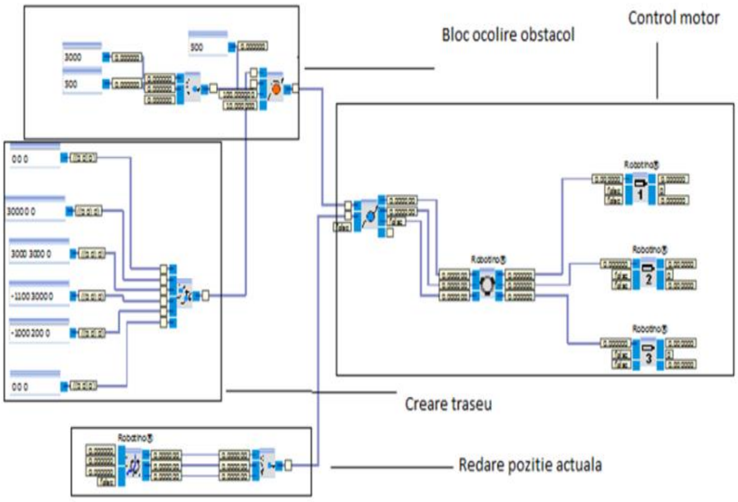


Fig. 9. Interconnection of program modules

CONCLUSIONS

The scientific report highlights the solutions that the Project 2 work team offers for the requirements of Stage 3 (2020). In the detailed Scientific Report uploaded on the P2 project platform (http://cidsacteh.upb.ro/index.php/ro/rezultate/19-rapoarte), you can view the solutions and results for research related to Stage 3. Project 2 „Development and testing of manufacturing management algorithms through the integration of advanced technologies ”.

RESULTS STAGE 3

1. Procedure for encapsulating virtual models as block function software resources.
2. Open library of software resources implemented in the cloud
3. Experimental HIL model in the Digital Twin environment to evaluate the performance of the control system
4. The risk factor evaluation procedure in the robotic assembly / disassembly processes
5. Optimized robot arm control structure that equips SAC-ARP by visual servoing.
6. Robust method of extracting features from images for driving visual servoing systems.

PERFORMANCE INDICATORS ACHIEVED

Activity 3.5.

- Procedure for real-time adjustment of a manipulator's trajectory through corrections calculated with a control model that uses as feedback features of the extracted images at each iteration (New software product)
- Method for extracting features from images for SSV management (New software product)
- Real-time assembly error detection algorithm

Activity 3.6.

- Online library of software resources implemented as block functions (New computer product)
- Algorithm for automating the process of encapsulating FB in containers with Docker technology

Activity 3.7.

- Real-in-Loop hybrid architecture that integrates in the DT simulation environment HIL (Hardware-in-Loop) and SIL (Software-in-Loop) test schemes - (in tests, possible patenting)
- Procedure for real-time elimination of parametric uncertainties of visual servoing systems by an adaptive control method sensitive to context changes - (in tests, possible patenting)

Activity 3.8.

- Procedures for driving an autonomous mobile robot in an environment with obstacles for parts transport operations at the mechatronic assembly / disassembly laboratory line.

DISSEMINATION
Works elaborated by the team in 2020
Articles in journals (ISI)
1. J.I.R. Cojocaru, D. Popescu: "Image Analysis Algorithm for Image Based Visual Servoing of a Robotic Assembly Line", U.P.B. Sci. Bull., In evaluation.
2. R. Dobrescu, S. Mocanu, O. Chenaru, M. Nicolae, G. Florea, Versatile Edge Gateway for improving manufacturing supply chain management via collaborative networks, International Journal of Computer Integrated Manufacturing, 2020, Manuscript ID TCIM-2020- IJCIM-0166 (under evaluation)
Papers published in the volumes of international scientific events:
1. J.I.R. Cojocaru, D. Popescu and L. Ichim, "Real-time Assembly Fault Detection Using Image Analysis for Industrial Assembly Line," 2020 43rd International Conference on Telecommunications and Signal Processing (TSP), Milan, Italy, 7-9 July 2020, pp. 484-487, doi: 10.1109 / TSP49548.2020.9163544.
2. D. Popescu, V. Mihai, J. -I. -R. Cojocaru, C. Drăgana and L. Ichim, "Visual Servoing System for Local Robot Control in a Flexible Assembly Line," 2020 28th Mediterranean Conference on Control and Automation (MED), Saint-Raphaël, France, 16-18 September 2020, pp. .927-932, doi: 10.1109 / MED48518.2020.9183096.
3. O. Chenaru, R. Dobrescu, G. Florea, G. Geampalia, Test Methodology for Hardware-in-Loop Assessment of Control Architectures, 24th International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania, October 8-10, 2020, (being indexed)
Note: The underlined authors are part of the UPB team for the CIDSACTEH project

JOBS SUPPORTED BY THE PROGRAM, INCLUDING NEW EMPLOYED HUMAN RESOURCES
The project team that contributed to the research in Stage 1. Project 2 consists of 11 (eleven) researchers (included in the staff list of project 2). Among them are two young researchers (PhD students) employed full time at the UPB partner, in the position of Research Assistant.
PRESENTATION OF THE STRUCTURE OF THE RESEARCH AND TECHNOLOGICAL SERVICES OFFER WITH INDICATION OF THE LINK FROM THE ERRIS PLATFORM
RESEARCH AND TECHNOLOGICAL SERVICES
Name - Flexible precision and reversible manufacturing line, served by SAC-ARP (Complex autonomous system - Personal Robotic Assistant) and SAC-VAM (Complex autonomous system - Mobile Autonomous Vehicle)
Description - The transfer procedure in the virtual environment data collected in real time from the assembly / disassembly processes. The implementation of the service is based on two new products:
e / 20-images).
Equipment - SMART Flexible Assembly System, Manufacturer: ASTI Automation SRL
Link to the ERRIS platform: https://erris.gov.ro/PRECIS-UPB
Research services: Position L9: Innovative Products and Processes to Increase Life Quality
Equipment: Position SMART Flexible Assembly System

PROJECT 3

The intelligent control, of the of the Complex Autonomous System -SAC-ARP Personal Robotic Assistant and Complex Autonomous System -SAC-VAM Multidirectional Autonomous Vehicle integrated in medical-social assistance and line service technologies flexible manufacturing of precision, laboratory (mechatronics lines) and industrial, with advanced techniques and navigation based on high-performance sensors and visual servoing systems

STAGE 3 (2020)

The testing of the control and navigation structures of the complex autonomous systems, SAC-ARP and SAC-VAM, in laboratory regime; Integration of SAC-ARP in intra / extra hospital personal assistance technologies; Integration of complex autonomous systems SAC-ARP and SAC-VAM in hybrid technologies serving flexible precision, laboratory, mechatronics, A / D, Hera & Horstmann manufacturing lines; Integration of complex autonomous systems SAC-ARP and SAC-VAM in hybrid control technologies to serve flexible precision manufacturing, laboratory, mechatronics lines P / R, Festo MPS200

The researches of Stage 3 meet the research objectives related to Activities 3.9, 3.10, 3.11, 3.12 of the implementation plan of the complex project, and ultimately led to the implementation and laboratory testing of real-time management of an Integrated System for Flexible Manufacturing (SIFF), served by complex autonomous systems, SAC-ARP and SAC-VAM. In this stage, the hardware structure of the production system was finalized, ie the existing system was completed, intended for flow manufacturing, with a flexible disassembly cell equipped with ABB industrial manipulator and the management structure was realized and implemented in real time to ensure capability. of processing / reprocessing of the manufacturing line using the complex autonomous systems SAC-ARP and SAC-VAM, which equipped with driving algorithms that give autonomy, can be used in intra and extra hospital applications.

RESULTS OBTAINED
-Mobile visual servoing system placed on the manipulators that equip SAC-ARP and SC-VAM;
- SAC-ARP and SAC-VAM integrated in the technology of personal intra / extra hospital assistance:
-SAC-VAM tested in rescue actions in rough terrain;
-SAC-ARP and SAC-VAM integrated in a hybrid service technology on precision manufacturing lines f, A / D and P / R, in laboratory

mode;

- Results of laboratory testing of the management of flexible manufacturing lines integrated in hybrid precision flexible manufacturing technologies, assisted by SAC-ARP and SAC-VAM

Act 3.9 -Testing the management and navigation structures of the complex autonomous systems, SAC-ARP and SAC-VAM, in laboratory regime; -Dissemination of results

The structures from Stage2-2019 for the Pioneer 3Dx and PeopleBot robots involved in taking over the parts recovered from the disassembly station were tested. For navigation, obstacle avoidance and time travel algorithms have been validated, in order to ensure synchronization with the production line and / or with the requirements imposed by the hospital user. The management and navigation structures of the complex autonomous systems, SAC-ARP and SAC-VAM, were tested in a laboratory regime. SAC-ARP systems have been equipped with navigation systems for bypassing obstacles and with trajectory tracking algorithms for time travel. These management structures have been integrated into in-hospital and out-of-hospital personal care technologies, hybrid technologies serving flexible precision manufacturing lines, laboratory, mechatronics, A / D, Hera & Horstmann, and hybrid technology serving lines. Flexible manufacturing, laboratory, mechatronics, P / R, Festo MPS200.

Figure 1

SAC-ARP considered at this stage is the assembly consisting of the mobile robot (WMR) (PeopleBot), robot arm (Cyton) and camera (Logitech). The video camera is placed on the last section of the manipulator (next to the final effector). WMR has the task of moving the robotic manipulator with component P4-R from S0 to the storage of workstation S4.

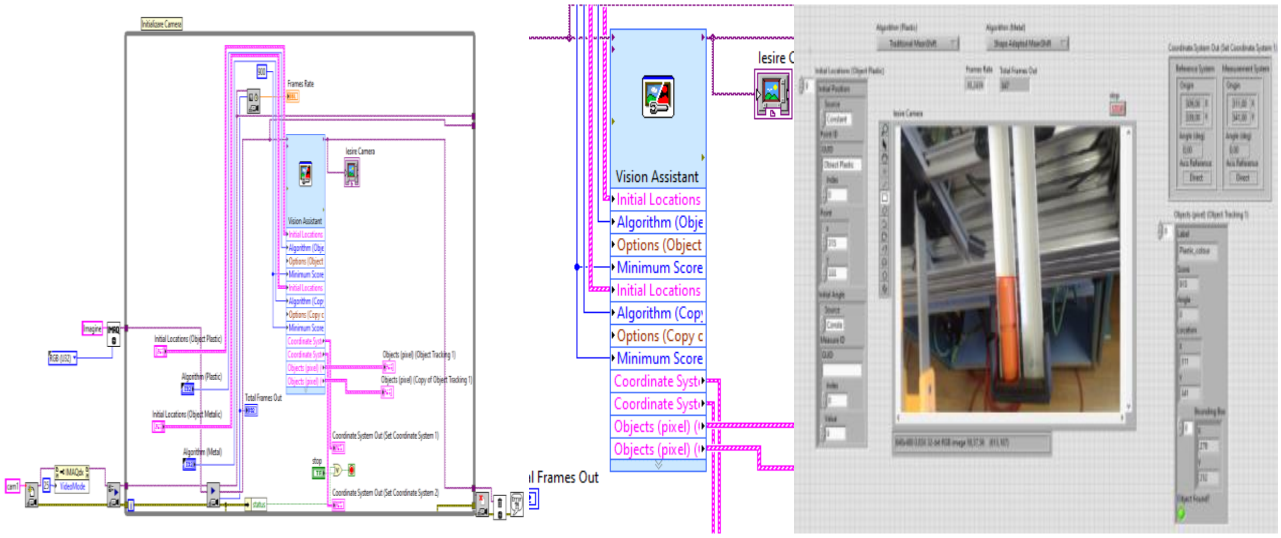


Figure 2

The movement of the WMR is controlled by a trajectory tracking algorithm: this means that the WMR moves in a desired path in a given time, without exceeding the restrictions (for example, the speed / acceleration limit). To retrieve the P4-R component from the S0 workstation, an algorithm is proposed to detect the exact position of the component, using LabView (Fig.1). It is still used to control the final effector of the manipulator, based on the data purchased from the camcorder. This is how the mobile visual servoing algorithm works.

This algorithm is useful because the WMR with the robot arm is not always in the same position (at the same point) in front of the disassembly workstation (S0). This is due to model uncertainties, WMR slips or possible surface unevenness.

Act 3.10 - Integration of SAC-ARP and SAC-VAM in intra / extra hospital personal assistance technologies; -

Dissemination of results

For the integration of SAC_ARP and SAC-VAM in in-hospital and extra-hospital assistance technologies, navigation algorithms have been improved, bypassing fixed and mobile obstacles, developed in Stage 2 and algorithms for moving through narrow spaces (doors, or narrow color). These were complemented with object retrieval algorithms using algorithms based on visual servoing, algorithms used in complex systems for serving flexible manufacturing lines. Object retrieval algorithms are strictly necessary for the development of personal assistance techniques.

The visual servoing system of SAC-ARP or SAC-VAM

The main steps of the control algorithm are:

1) extract useful visual information to calculate the characteristics of the object;

2) uses this information as inputs for the control loop (knowing that the error is calculated between the current visual characteristics and the desired values of those characteristics);

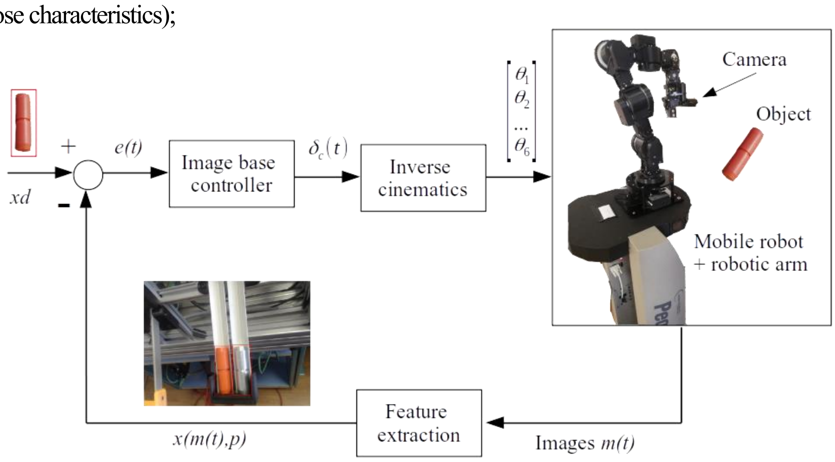


Figure 3

3) the controls (outputs) (for example, the speed of the robot arm) are calculated to reduce the error, as seen in Fig.3 in which the block diagram of the driving structure based on visual servoing is represented.

The real-time implementation aims to identify the objects and transport them to the corresponding points (each of the 4 objects has an associated destination point). To accomplish this task, the SAC-ARP must identify and retrieve the object from station S0 (this is the control algorithm based on visual servoing) and deliver it to the destination station by traversing a desired path. Navigation management based on Trajectory Tracking must ensure not only the planning of the road on which the trip is made (as can be seen in the "path" desired in Fig. 4 of the extended report), but also the speed profiles (time dimension - see Fig. 5).). Fig.5 and Fig.6 graphically show the results obtained after real-time implementation on SAC-ARP (consisting of WMR PeopleBot and Kyton manipulator equipped with visual servoing system). The results of the real-time experiment are presented in Fig.4, where the path followed by SAC-ARP is displayed. The navigation management controller is used to solve the path tracking problem with minimal errors. Fig.5 and Fig.6 graphically show the experimental results of the "sliding-mode" driving algorithm used for SAC-ARP in terms of error dynamics and linear and angular velocities. It is very easy to see how the designed controller can accurately follow the trajectory of SAC-ARP or SAC-VAM. The solution to the minimum time navigation problem (Trajectory Tracking) is based on the design of a "Sliding Mode" type controller.

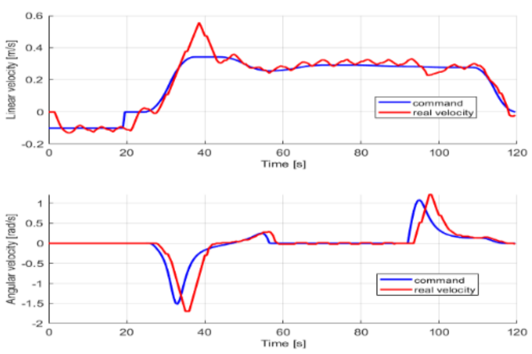


Figure 5

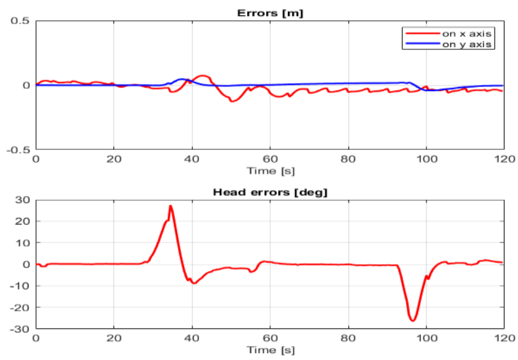


Figure 6

The results of the real-time experiment are presented in Fig.4, where the path followed by SAC-ARP is displayed. (http://cidsacteh.ugal.ro/documente/Raport%20Proiect%20P3%202020.pdf)

The navigation controller is used to solve the path tracking problem with minimal errors. Fig.5 and Fig.6 graphically show the experimental results of the "sliding-mode" driving algorithm used for SAC-ARP in terms of error dynamics and linear and angular velocities. It is very easy to see how the designed controller can accurately follow the trajectory of

SAC-ARP or SAC-VAM. The solution to the minimum time navigation problem (Trajectory Tracking) is based on the design of a "Sliding Mode" type controller.

Act 3.11 -Integration of the complex autonomous systems SAC-ARP and SAC-VAM in hybrid technologies serving flexible precision, laboratory, mechatronics, A / D, Hera & Horstmann manufacturing lines

Act 3.12 Integration of the complex autonomous systems SAC_ARP and SAC VAM in the technologies of serving flexible precision manufacturing lines, laboratory, mechatronics, P / R, Festo MPS200

One of the main problems with flexible manufacturing or assembly systems is productivity. There are various ways to address this issue, including ordering tasks, reactively assigning tasks, or attempting to reuse / reprocess nonconforming parts.

At this stage, a real-time management application was developed to ensure the ability to reuse / reprocess nonconforming parts in a flexible Mechatronics (FMML) manufacturing line as can be seen in Fig.7. The flexible manufacturing line, considered for the application, is a HERA & Horstmann Assembly Mechatronics (AML) line. In this stage, the real-time control application of SAC-ARP and SAC_VAM of the mobile wheeled robot (WMR) equipped with a 7DOF manipulator that has a mobile visual servoing system (VSS) was developed. VSS uses the Eye-in architecture. -Hand to perform tasks of taking over and transferring objects with a priori unknown positions. Autonomous robotic systems use visual servoing systems to increase their autonomy capabilities. Mobile robots that integrate visual servoing control to facilitate the grasping and handling of objects on which transfer them autonomously to the destination, are the main topics of the stage. Detailed results can be found in the extended report (http://cidsacteh.ugal.ro/documente/Raport%20Proiect%20P3%202020.pdf).

The structure of the complex system is presented in the figure below: In the flexible assembly / disassembly production system there are several tasks to be performed. The initial Mechatronic assembly / disassembly line (A / DML) consists of 4 workstations WS1, WS2, WS3 and WS4 where the assembly between the corresponding part and the subassembly is processed. For the disassembly load, add a workstation, called “Flexible Cell” in Figure 8, or S0, which contains an ABB industrial manipulator, which performs the disassembly operation. To perform reprocessing, the parts resulting in S0 must be identified and then transported to the appropriate warehouse of the assembly workstation. SAC-ARP or SAC_VAM (a mobile wheeled robot (WMR) equipped with a manipulator) is used for this task. The task of WMR is to deliver the part from S0 to the appropriate warehouse of the assembly workstation in minimum time and bypassing any obstacle. This task is performed using a trajectory tracking algorithm. The task of SAC-ARP or SAC_VAM is to identify the part (with unknown position) and then deposit it in the assembly of the assembly workstation corresponding to the operation in which it is involved. For this task SAC-ARP or SAC_VAM uses a driving application based on visual servoing. The real time implementation of this application is using LabView.

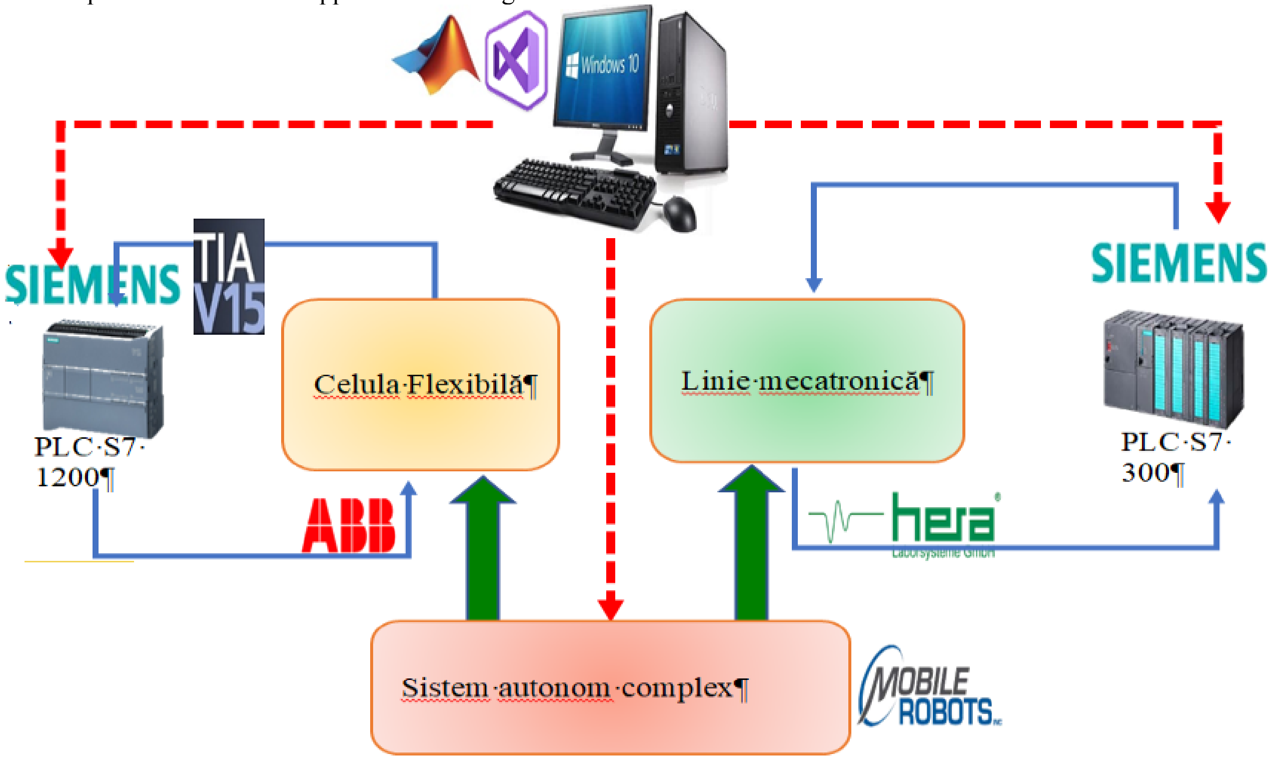


Figure 7

The control of this system means the integration of the 3 subsystems:

- Flexible cell: multifunctional flexible cell (HR) equipped with IRB ABB 6-DOF. Programming the ABB Robotic Manipulator using RobotStudio and the Siemens S71200 PLC
- Mechatronics line: assembly / disassembly control is done strictly through the “Central System” - Siemens S71200 PLC and HMI operator panel

- Complex autonomous system (SAC-ARP or SAC-VAM): RM positioning: trajectory-tracking and sliding-mode control (TTSMC) + Pickup and release of the part: VSS technology "eye-in-hand.

An HMI interface has been designed to drive this system and synchronize operations. Depending on the option chosen in the HMI, namely Product Type 1 or Product Type 2, the location where the product is assembled and its move / transport to the final storage point is determined.

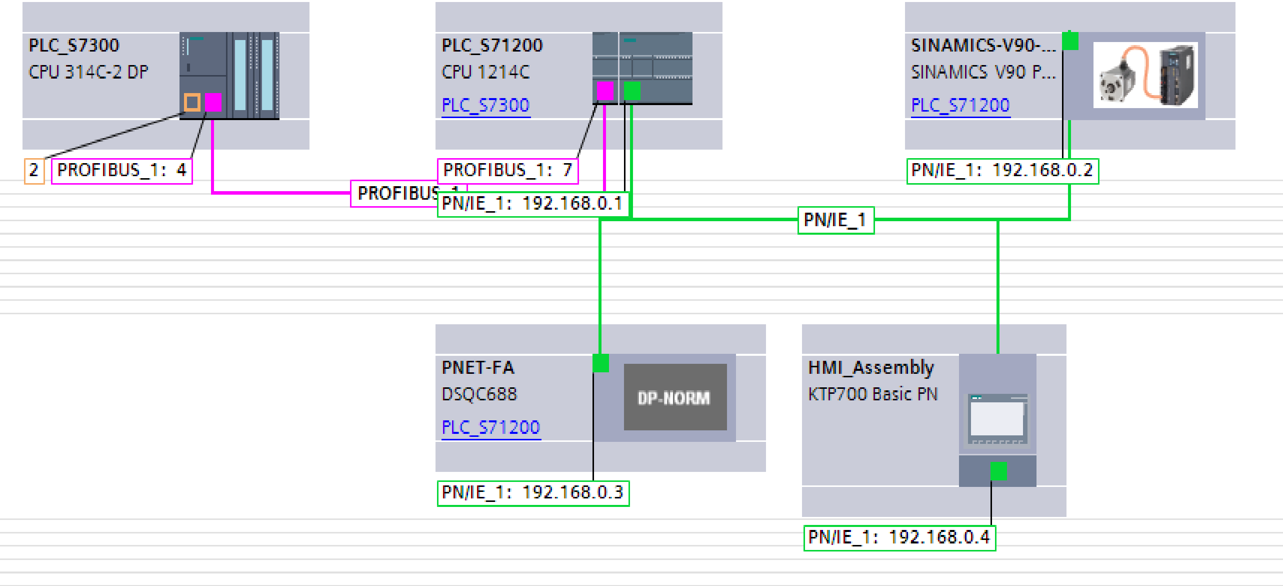


Figure 8

The architecture of the central line management system is represented in the structure diagram below: Central automation system designed. HMI interface

Figure 9

Disemination of the results

-*Improved Image Processing Algorithm for Quality Test on a Flexible Manufacturing Mechatronic Line*, Marius-Adrian Păun, Eugenia Minca, Adrian Filipescu, Octavian Gabriel DUCA, Adriana Filipescu, 24rd International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania during October 8-10, **2020,** *(in curs de indexare)*

- *Optimal control of a flexible assembly technology on a mechatronics line with integrated industrial robotic manipulators*, Octavian Duca, Eugenia Minca , Adrian Filipescu , Henri-George Coanda , Florin Dragomir , Adriana Filipescu, Journal: Sensors, Manuscript ID: SENSORS, 981733, **2020**, pg.921-926, 978-1-7281-9809-5/20/$31.00 ©2020 IEEE
-*Manufacturing Technology on a Mechatronics Line Assisted by Autonomous Robotic Systems, Robotic Manipulators and Visual Servoing Systems*, Adrian Filipescu, Eugenia Mincă, Adriana Filipescu, Henri-George Coandă, Journal name: Actuators, Manuscript ID: actuators-991918, (*in evaluare*), **2020**
- *Hybrid Control Application Using Mobile Visual Servoing for Flexible Manufacturing Mechatronics Line*, Daniela Cernega, Razvan Solea, 24rd International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania during October 8-10, 2020, pp 636-641 *(in curs de indexare)*.

PROJECT 4
Real-time modeling, simulation and control of production lines assisted by complex autonomous systems (SAC-ARP, SAC-VAM) integrated in hybrid technologies of flexible precision manufacturing, laboratory (mechatronics lines) and industrial, for reusable products
Stage 3(2020)
The real time implementation, in laboratory regime, of the integrated technologies of medical-social assistance and service of flexible precision manufacturing lines. Integration of complex autonomous systems SAC-ARP and SAC-VAM in hybrid technologies serving flexible precision, laboratory, mechatronics, P / R, Festo MPS-200 manufacturing lines;

STAGE SUMMARY

The researches of Stage 3 respond to the research objectives related to activities 3.13, 3.14, 3.15, 3.16, from the realization plan of the complex project, and finally led to the implementation and laboratory testing of the real-time management of the Integrated System for Flexible Manufacturing (SIFF), served by complex autonomous systems, SAC-ARP and SAC-VAM.
In this stage, the hardware structure of the production system was finalized, respectively the completion of the existing system, intended for flow manufacturing, with a flexible cell equipped with ABB industrial manipulator. Thus, the production system becomes an integrated system for flexible manufacturing, in which manufacturing is done through two parallel flows: manufacturing in flow and manufacturing in the cell. The production system now has seven stations, equipped with industrial robotic systems - ABB manipulator, FANUC manipulator in which products are assembled or disassembled in order to recover components. The implementation / testing research required the establishment of a production planning procedure on the two flexible manufacturing systems working in parallel. A generalized algorithm for optimizing production planning was developed and tested on the laboratory system. Thus, at the end of this stage, the following indicators are reached: 1) Flexible precision manufacturing line with integrated complex autonomous systems; 2) Client / Management Application software package for optimized production planning, for two flexible manufacturing systems working in parallel, 3) SAC-VAM control, Pioneer 3-DX mobile robots (2DW / 1FW) equipped with 6-DOF Arm Manipulator and SAC-VAM, mobile robots (2DW / 2SW) equipped with 6-DOF Manipulator, integrated in handling / transport / storage operations of components recovered from the SIFF disassembly station.

Activity 3.13

Testing of the software platform for synchronization of flexible precision LA / D production lines, integrated in hybrid manufacturing technologies, and the visual servoing system of SAC-ARP and SAC-VAN, under the LabView / Matlab / Visual C ++ platform

3.13.1.Integrated Flexible Manufacturing System (SIFF)

The SIFF hardware structure

SIFF is a flexible production system obtained by developing the SMART ASTI mechatronic line with a new production station, a disassembly station, a SCARA robotic system and mobile robots. Thus, a system of 7 interconnected stations with two parallel production processes was obtained, in station or in flow.
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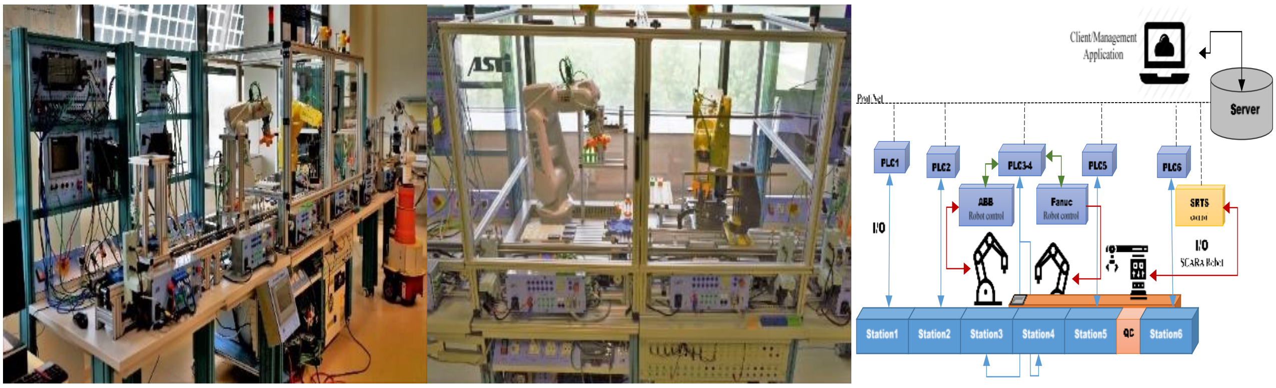


(a) (b) c)

Figure 1. a) SIFF equipped with the robotized systems; b) robot ABB robot (left), robot FANUC si SCARA (right); c) The local control of the workstations and the communication with the Cloud The interaction with the Client-Server/ Management Application

The mechatronic system is designed for assembly by flexible manufacturing and recovery of components by disassembly. In stations: 1, 2, 4, 5, 6 functionally connected in the order of tasks for the successive assembly of components, a complete assembly cycle of a certain product is performed. To adapt line flow manufacturing technology to flexible flow manufacturing (FFF), the system was equipped with the SCARA transport system which was designed to serve the production flow through handling, transport or repositioning operations. In FMC from station 3, equipped with ABB robotic manipulator and with its own component depots, a complete assembly cycle can be performed. In this case, the overall flow production on the mechatronic line is transformed into flexible cross-manufacturing, using a combination of flexible cell / station manufacturing (FMC) and flexible flow manufacturing (FFM). The flexible cell functions as an independent system for flexible manufacturing, operating in parallel with the mechatronic line dedicated to simple assembly and / or flexible manufacturing. The mechatronic system connects the flexible manufacturing in flow with that in the cell, in the quality control station (QT). Flexible production is performed on both systems in parallel and independently, with mutual conditioning only at the initiation of the quality control process.

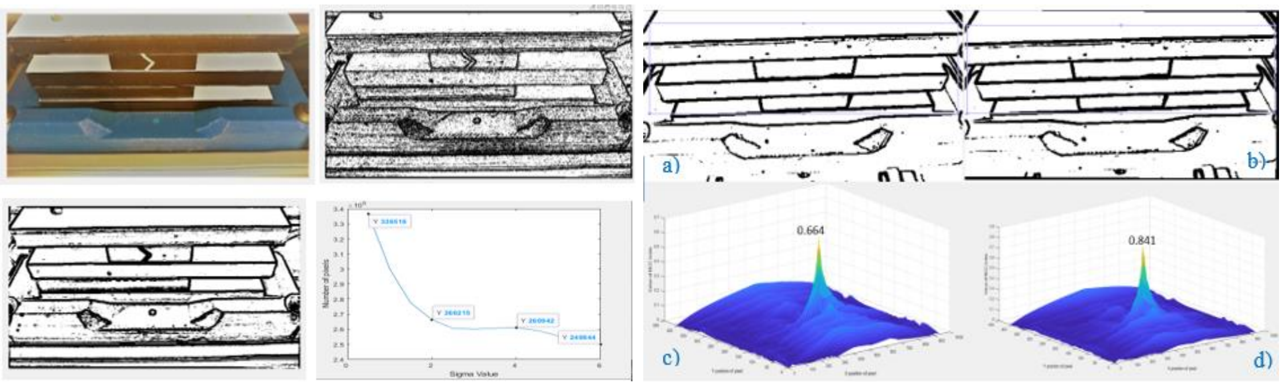
3.13.2. Integrated flexible manufacturing

The control structure

Production control is structured in two parts. A local, decentralized control, represented by PLCs that, based on the information provided by the sensors and based on the production parameters and task diagrams, send commands to the execution elements. The control algorithm of SIFF is also based on global control represented by a Server Application, interfaced with the Client Application, which sends to the PLCs the parameters of the current production. Through the Server Application, based on the customer's order, a sequence of tasks is created for each product. Each sequence of tasks and production information is stored in a query of production orders. From the query, the stations receive a production order after completing the previous order.

Implementation of quality control (QC) functions

At this stage, a dedicated station was designed and implemented to verify the quality of the products. It was placed after workstation 5. Thus, two hypotheses were considered: all assembled components are stored in warehouses and components in warehouses do not show non-conformities. Four scenarios are possible that may arise as a result of the system decision: 1) Product type A declared good in terms of quality, in which case the product is stored in WS6; 2) The type B product declared good in terms of quality, in which case the product is stored in WS6; 3) Product type A declared non-compliant with the required quality standards, in which case the product is sent to WS7 for disassembly; 4) Product type B declared non-compliant with the required quality standards, in which case the product is transported by the SCARA robot to WS2, where it is disassembled by the ABB IRB 120 robot. The algorithm used to detect the defect uses the following image processing techniques: image filtering, edge detection, feature matching and normalized cross-correlation followed by the Gaussian filter for smoothing the two images. The research conducted focused on increasing the performance of contour detection in the image and increasing the performance of defect detection. The difference between the maximum value of the normalized cross-correlation index on which the MASC algorithm was not applied and the value of the cross-correlation index on which the MASC algorithm was applied is between 12% and 30%.



i) ii)

Figura 2. i) Influența parametrului Sigma- abaterea standard a filtrului gaussian, asupra numărului de pixeli detectați; ii) Rezultatele obținute cu privire la implementarea algoritmului MASC și aplicarea corelației încrucișate normalizate: a) imaginea prelevată b) imaginea prelevată asupra căreia s-a aplicat algoritmul MASC c) indicele maxim de corelație încrucișată pentru imaginea prelevată, d)indicele maxim de corelație încrucișată urmat de suprapunerea algoritmului MASC.

Task diagram of integrated flexible manufacturing

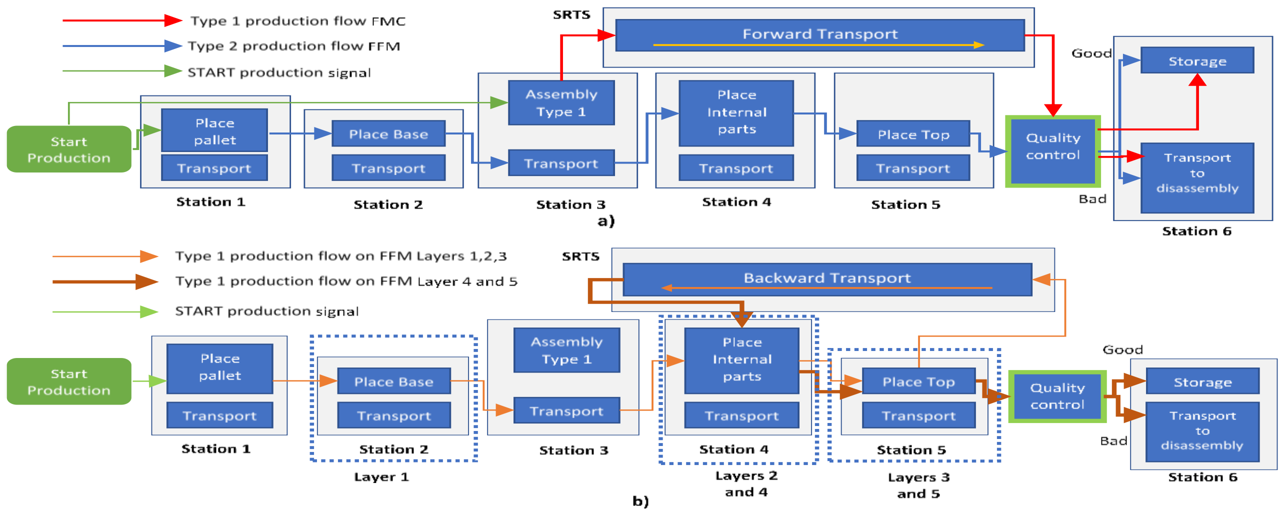


Figure 3. Diagram of tasks related to the two production flows: a) Production of Type 1_single Layers by flexible manufacturing in flow (FFM) and Production of Type 2 by flexible manufacturing in cell (FMC) FFM; b) Production Type 1 - multi_Layers by manufacturing flow (FFM)

SIFF allows the manufacture of two types of products: with several inner layers, called type 1, or with a single inner layer, called type 2. The inner parts of the product layer are placed based on the customer's requirement. For product type 1, several product configurations can be made based on layers. The production process is shown in Figure 3 as a load diagram. The control of the two production processes is based on a planning optimization algorithm. After assembly, the product reaches a quality control point, where it is checked for defects, using an automatic visual analysis process. Good products are stored in station 6 and defective parts are disassembled in station 7. For the type 1 product, the assembly process is different. Complete assembly is performed in station 3. In order not to interfere with the type 2 assembly, the type 1 product is transported to the quality control point by the SCAR system. If the product is defective, the product is transported back to station 3 by the SCARA system. Station 3 is a complete assembly / disassembly workstation that can operate independently or as part of the production line. The flexibility of the production system is given, in this situation, by the possibility of assembling two different products with distinct assembly orders, without the need to change the hardware configuration. The server, based on the volume of products requested by the customer, determines a planning of production tasks, based on the planning optimization algorithm. This information is sent to the SIFF's centralized control system.

3.13.4. PN models for flexible manufacturing system assisted by integrated robotic systems

PN models for flexible manufacturing in the cell (FFC)

PN models for flexible flow manufacturing

Only type 1 and type 2 products will be manufactured on FFM. Only type 1 products will be assembled on FMC. The transport of the finished products from FFM to the quality test (QT) is done by the SCARA system. On FMC, the assembly starts with a signal received from the server (Figure 6.a, Sync signal 1). When signals are received, the ABB robot is assigned to perform this task. After the assembly is completed in the FMC, the SCARA system transports the products to the QT station for verification (Figure 6.a, QT_location). If the product is defective, the SCARA system transports the product for disassembly.

On the FFM system, the type 1 typology will be launched in manufacturing (Figure 6.b). The product has a multi-layer assembly structure that is obtained through recurrent assembly operations. Recurrent assembly operations are controlled by CL1 (control model 1) and CL2 (control model 2), which have a predetermined start / stop state, depending on the product configuration launched in the factory. In the case of manufacturing with recurrent assembly operations, the transport of the product between stations is performed by the SCARA system. After assembly, the finished products that pass the quality test are stored in the warehouse of station 6. Defective products are transported to the next station for disassembly. The quality check is done for both type 1 and type 2 parts, as shown in the model.

Activity 3.14

Testing the software platform for synchronization of flexible precision LA / D production lines, integrated in hybrid manufacturing and navigation technologies based on advanced driving techniques for bypassing obstacles, locating and manipulating SAC-ARP and SAC-VAM, under the LabView platform / Matlab / Visual C ++

3.14.1. Generalized algorithm for optimizing production planning based on synchronization of flow manufacturing

with flexible cell manufacturing

The generalized model of a station as a component part of flexible flow manufacturing

In the generalized model it was considered a station k of a flexible assembly line with $k \in [1, N]$ being the total number of stations of the system. A product p, $p \in [1, P]$ is produced on the considered system, with $T_{transIn_k}$ P the total production volume. In this system can be defined: $T_{transIn_k}$ the duration of transport in the assembly area; $T_{transOut_k}$ transport time at the exit of the assembly area; $T_{assembly\ k}$ assembly time in the station k. Thus, a cycle time can be defined for the production system of the form:

$$T_{cycle_p^N} = \sum_{k=1}^{N} \sigma_{k,p} T_{prod_k} + \gamma_p T_{transport} + \sum_{k=1}^{N} T_{stop_{k,p}},$$

where:

$\sigma_{k,p}$ the number of passes of product p through station k, γ_p the number of product returns for the product *p* $T_{transport}$ the transport time of the returned part, $T_{stop_{k,p}}$ waiting time of the product p located in station k by inserting a piece into the station *k+1:*

$$T_{stop_{k,p}} = \theta_{k+1,p} T_{prod_{k+1}} \quad (2)$$

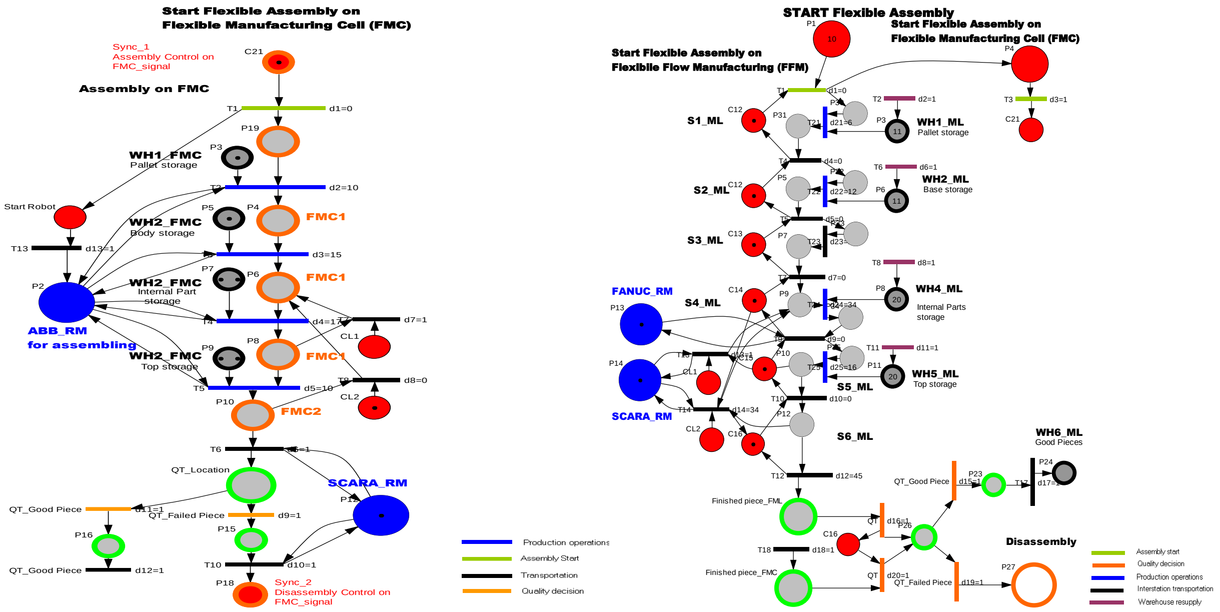
$\theta_{k+1,p}$ represents the number of parts inserted in the station *k+1*.

The generalized model of synchronization of manufacturing in the cell with manufacturing in flow

Based on the production system model can also be defined:

- production time in FFC:

$$T_{prodcell} = \beta T_{prod\,max}, \ \beta \in N, \ \beta \geq 1$$



a) b)

Figure 6. Model PN model pentru asamblarea in a) FMC b) FFM

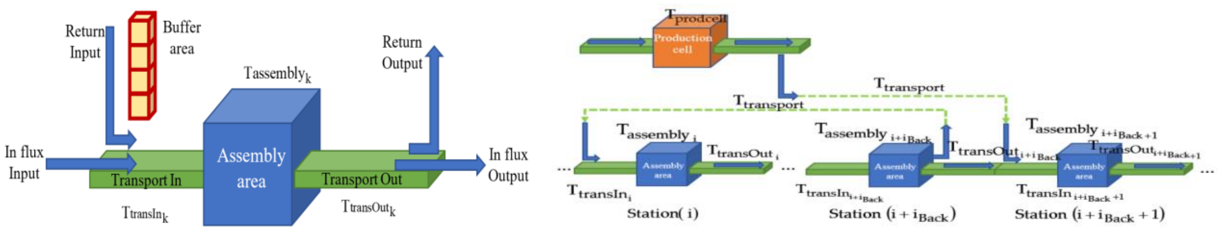


Figure 4. a) Modelul general al unei stații de lucru; b) Model general al fabricației flexibile in SIFF

- return transport time:

$$T_{transport} = \lambda T_{prod\,max}, \ \lambda \in \mathbf{N}, \ \lambda \geq \mathbf{1}$$

- and cycle time in FFC:

$$T_{CycleCell} = (\beta + \lambda + 1) T_{prod\,max}$$

Based on the production times in FFM and FMC we define a form minimization function:

$$J_{IFMS} = \min\left(\left|\left(\sum_{r=1}^{\upsilon_1 - \eta} T_{CycleCell}\right) - T_{prodFFM}\right|\right)$$

Based on these, the number of type 1 products assembled on FFM is determined:

$$\eta = \frac{\upsilon_1(\beta + 1) - \upsilon_2 - N + 1}{\beta + 3}$$

The time between FFM and FMC is also determined as:

$$T_{sync} = c\, T_{prod\,max}$$

where:

$$c = \beta + 1 - (i + i_{Back} + \theta_{i,T1}).$$

Based on parameter c of FFM synchronization with FMC, the following task correlations result:

- production of the Type 1 part on the FFF begins with steps before production on the FFC.
- production on FFF and FFC start simultaneously
- the production of the type 1 part on the FFF starts with c steps after the production on the FFC starts.

3.14.2. Results of the implementation of the generalized algorithm for optimizing production planning on two parallel systems dedicated to flexible manufacturing

Based on the general model, it was considered a production of type 1 and type 2 parts for production, simultaneously on the two streams FFM and FMC. In the case of production, two distinct cases are obtained: process initialization and cyclic repetitive production. Thus, the task schedules for the initialization sequence and for the repetitive manufacturing cycles (Figure 5.a) and minimum durations for the variable “waiting time” (Figure 5.b) were obtained.

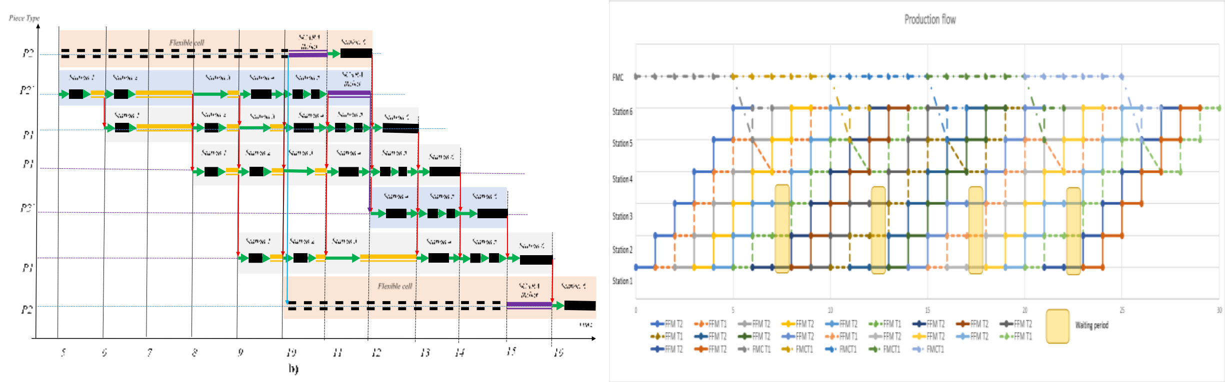


Figura 5: Planificarea taskurilor de producție: a) Producția repetitivă; b) : Fabricație flexibila cu evidențierea timpilor de așteptare

Activity 3.15, Activity 3.16

Laboratory testing of real-time control of flexible LA / D precision manufacturing lines, assisted in the reversible process of disassembly of SAC integrated in assistive technologies, SAC-ARP, SAC-VAM, mobile robots (2DW / 1FW) equipped with Manipulator 6-DOF Arm

3.15.2. Implementation and testing of the production optimization algorithm on SIFF equipped with SAC-VAM industrial robotic systems

SAC-VAM control structure for warehouse recovery / supply with components, based on an inventory optimization algorithm

Figure 6. Linia de fabricație flexibilă de precizie, de laborator, asistata în procesul reversibil de dezasamblare de SAC-VAM (2DW/1FW), robot mobil echipat cu Manipulator 6-DOF, cu conducere integrata în tehnologii de asistare

The recovery and replenishment process presented in Fig.6, Fig.7 is defined by the production and mobile robot parameters. In a non-optimized manner, the mobile robot receives a supply order when stocks in a workstation warehouse are below a set threshold. At the supply order, the mobile robot takes a predefined number of parts and transports them to the station warehouse.

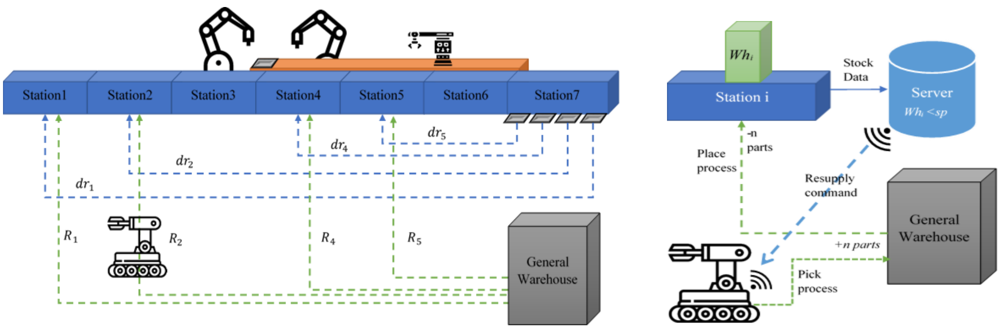


Figura 7. a)Traiectoriile CAS pentru aprovizionare/recuperare componente in magazii; b) Aprovizionare cu componente

The process steps can be viewed in general for a station i in Fig.7.a, where i represents the station number. The sourcing process depends on some parameters of the process and the mobile robot: • it is the processing period of the station and represents the time required for a workstation to finish a product; • represents the supply time and is to a large extent influenced by the time of taking over and placing the robot. The mobile robot is connected to the local network, communicating directly with the production server. The communication between the local server and the mobile robot is done using the local wireless internet network. All provisioning commands processed on the server are stored in the SQL database from where the mobile robot's internal processing unit reads it at a predefined time interval. The mobile robot also transmits the supply processing information back to the database for storage and other processes.

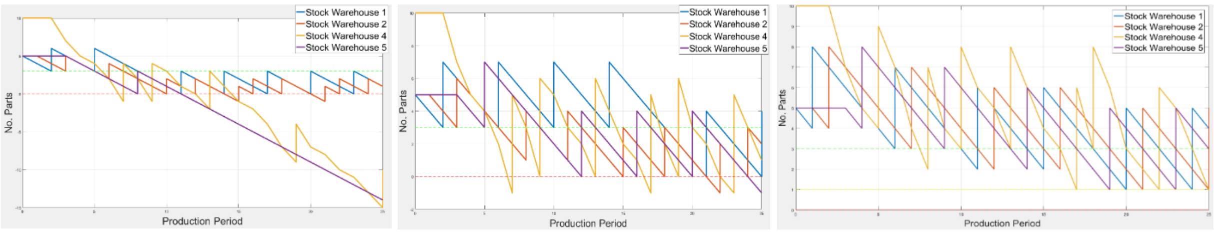


Figura 8. Evoluția stocului in magazii pentru a) aprovizionare insuficienta**;** b) supra-aprovizionare; c) stoc optimizat

The optimization function is defined according to the waiting time for supply and the difference between the stock in a warehouse and the stock demand for production between the production period j, which has values from 1 to N:

$$t_a = \min\left(\sum_{j=1}^{N}\sum_{i=1}^{N_w}\left(Tw_i\sigma_i\left(Wh_{i,j}\right) - D_{i,j+1}\right)\right)$$

After implementation and testing (Fig.8.a, b), it results that in the process of supplying the warehouses, the mobile robot introduces an additional waiting time that accumulates over time. This cumulative waiting time causes a decrease in the level of components in the warehouses compared to the ideal case (Fig.8.c). But even in the case of the introduction of a waiting time by the mobile robot, the level of stocks is kept above the minimum level, without implications in the production process.

CONCLUSIONS

The detailed scientific report highlights the scientific solutions that the Project 4 work team offers for the requirements of Stage 3. The detailed scientific report (http://cidsacteh.valahia.ro/p4/files/Report Stage3_extins.pdf) presents technologies management system of the **Integrated System for Flexible Manufacturing** as well as results of the test sequences of its real-time management, with the integration of algorithms for optimizing the flexible manufacturing and component stocks of SIFF warehouses. Algorithms and technologies have been developed / implemented / tested for the management of SIFF:

- product quality control (QC) based on a new image analysis algorithm;

- SAC-ARP, SAC-VAM control algorithms, mobile robots (2DW / 1FW) equipped with 6-DOF Arm Manipulator for optimizing component stocks in SIFF station warehouses;

- optimizing the planning of production tasks based on a generalized algorithm for optimizing flexible manufacturing;

- Testing the software platform for synchronization of parallel processes, dedicated to flexible precision LA / D manufacturing, integrated in hybrid manufacturing technologies;

- Testing the control structure for precision handling and positioning operations of the SCARA manipulator

- Testing the control structure of two parallel flows for flexible manufacturing, with the synchronization of arrival at the QT quality testing station

- Testing of the software platform for synchronization of flexible precision LA / D production lines, integrated in hybrid manufacturing technologies, and the visual servoing system of SAC-VAM, under the LabView / Matlab / Visual C ++ platform;

- Laboratory testing of real-time management of flexible LA / D precision manufacturing lines, assisted in the reversible process of disassembly of SAC integrated in assistive technologies, SAC-VAM, mobile robots (2DW / 1FW) equipped with Manipulator 6- DOF Arm

Functional test results;

- Results of laboratory testing of the management of flexible manufacturing lines, integrated in hybrid technologies, assisted by SAC-VAM and SAC-ARP
- Results of the laboratory testing of the quality testing process management, on a quality control station implemented in this stage;

- Results of testing the production optimization algorithm, implemented on the flexible manufacturing line with parallel, synchronized flows;
- Results of testing the quality control algorithm implemented in a dedicated station;
- Results of laboratory typing of the hybrid system management, flexible manufacturing line with two synchronized flexible and reversible manufacturing flows, served by SAC-VAM and SAC-ARP;

EXPECTED RESULTS

Within Stage 3 of project 4 the following results were obtained:

1. Validation by testing of the product quality assessment software implemented under the Matlab / Visual C ++ platform;
2. Validation by testing of the production optimization algorithm, implemented on the flexible manufacturing line with parallel, synchronized flows;
3. Validation by testing of the optimized management of the flexible manufacturing technology, with synchronized parallel flows, assisted in the reversible process of disassembly of SAC integrated in assistive technologies, SAC-ARP, mobile robots (2DW / 1FW) equipped with Manipulator 6- DOF Arm and SAC-VAM, mobile robots (2DW / 2SW) equipped with Manipulator 6-DOF

PERFORMANCE INDICATORS

1. SAC-VAM and SAC-ARP research services integrated in hybrid service technologies, on flexible precision manufacturing lines for A / D;
2. Hybrid technology of flexible manufacturing based on the software for synchronizing the management of two parallel processes of flexible manufacturing with synchronized execution, integrated in the system for flexible manufacturing;
3. Hybrid technology for flexible, precision manufacturing, A / D on laboratory (mechatronics) lines with integrated SAC-ARP and SAC-VAM;
4. Two new research jobs supported by the program. The UVT partner employs 2 new researchers in the field of Systems Engineering, in the position of Researcher in Automation, who are included in the staff list of the UVT partner

DISSEMINATION

Articles presented at national and international conferences in 2020:

1. *Optimal Control of Automated Resupply on a Flexible Manufacturing Mechatronics Line* , Octavian Gabriel DUCA, Eugenia Minca, Filipescu Adrian, Petrut Claudiu Bidica, Marius-Adrian Păun, 24rd International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania during October 8-10, 2020
2. *Improved Image Processing Algorithm for Quality Test on a Flexible Manufacturing Mechatronic Line*, Marius-Adrian Păun, Eugenia Minca, Adrian Filipescu, Octavian Gabriel DUCA, Adriana Filipescu, 24rd International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania during October 8-10, 2020
3. *Optimal control of a flexible assembly technology on a mechatronics line with integrated industrial robotic manipulators*, Octavian Duca, Eugenia Minca , Adrian Filipescu , Henri-George Coanda , Florin Dragomir , Adriana Filipescu, Journal: Sensors, Manuscript ID: sensors-981733, (*under review)*
4. *Image processing method based quality test on a smart flexible assembly mechatronic system with component recovery*, Paun Marius-Adrian, Eugenia Mincă, Duca Octavian, Gurgu Valentin, Journal of Science and arts, 2020, (*under review)*
5. *Manufacturing Technology on a Mechatronics Line Assisted by Autonomous Robotic Systems, Robotic Manipulators and Visual Servoing Systems*, Adrian Filipescu, Eugenia Mincă, Adriana Filipescu, Henri-George Coandă, Journal name: Actuators, Manuscript ID: actuators-991918, (*under review)*

Description - The real-time management structure of precision assembly / disassembly lines, integrated in hybrid manufacturing technologies, assisted in the reversible SAC disassembly process, integrated in assistive technologies. Flexible manufacturing line with two parallel production flows, synchronized, and served by SAC-VAM and SAC-ARP.https: //erris.gov.ro/Valahia-University-of-Targoviste

Services

Hybrid technology for flexible, precision manufacturing, assembly / disassembly on mechatronic laboratory lines with integrated SAC_ARP and SAC-VAM

Hybrid technology for flexible manufacturing based on the software for synchronizing the management of two parallel processes for flexible manufacturing, with synchronized execution, integrated in the system for flexible manufacturing; https://erris.gov.ro/Valahia-University-of-Targoviste ,

PROJECT 5

Component project: Pr.5 Intelligent driving, with advanced techniques and navigation based on high-performance sensors, video-biometric system and visual servoing system of the complex autonomous system SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities

Stage 3 (2020)

The results of the laboratory testing of the intelligent driving structure, the navigation structure (based on high-performance sensors) and the real-time visual servoing of the SAC-SI advanced driving structure based on systems integrated in the technology of assisting people with severe neuromotor disabilities

Stage 3 - P5. The researches of Stage 3 respond to the research objectives related to Activities 3.17, 3.18, 3.19, 3.20, from the realization plan of the complex project, and finally led to the implementation and testing in laboratory mode of the real-time management of the complex SAC-SI system, autonomous robotic system consisting of a wheelchair and a robotic manipulator with 7-DOF integrated in the technology of assisting people with neuro-motor disabilities. In this stage, the hardware structure of the management system was finalized, respectively the existing system was completed, with a laser type sensor. The researches for implementation / testing required the establishment of a procedure for planning the trajectory of the complex SAC-SI system. An algorithm for planning the trajectory of the complex SAC-SI system was developed, which can avoid obstacles, and which was tested on the laboratory system. The scientific balance of this stage is the following: 1) Autonomous robotic system consisting of a wheelchair type "Cirrus Power Wheelchair" and robotic manipulator with 7-DOF, integrated; 2) Software package for planning the trajectory of the complex SAC-SI system; 3) Obstacle avoidance software package (based on laser sensors); 4) Real-time management of the complex SAC-SI system, using a video camera; 5) The control based on visual servoing system of the robotic manipulator with 7DOF.

Activity: Act 3.17 - -Implementation and real-time testing of the intelligent driving structure (based on advanced techniques) and navigation structure (based on high-performance sensors) of SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities ;

Achievement indicators:

-Testing in laboratory conditions the management structure and the navigation structure for SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities;

-Reports with the results of SAC-SI testing integrated in the technology of assisting people with severe neuro-motor disabilities, in laboratory mode;

Laboratory testing of the steering structure and navigation structure for the complex autonomous system SAC-SI involved:

- Modification of the “Cirrus Power Wheelchair” wheelchair platform by adding and connecting a video camera that can transmit data in real time, so that a recognition of the user's head movement necessary for SAC-SI driving was possible.
- Integration of the 4th floor map of building Y to achieve / generate the desired trajectory of the complex autonomous system SAC-SI.

During this activity, a management structure of SAC-SI was tested using the head movements of a person with severe locomotor disabilities. By adding and connecting a video camera to the wheelchair, equipped with electric motors and computer equipment needed to perform face detection, the SAC-SI driving (simple, safe and easy to learn for a person with severe locomotor disabilities) was achieved. The application was physically designed and implemented so that it can be easily extended so that in the future it can be used to facilitate the movement of people with disabilities on other types of mobile platforms.

Activity: Act 3.18 - -Implementation and real-time testing of the obstacle avoidance structure (based on high-performance sensors and video system) of SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities;

Achievement indicators:

-Laboratory testing of the obstacle avoidance structure (based on laser and video sensors) of the "Cirrus Power Wheelchair" (SAC-SI) integrated in the technology of assisting people with neuro-motor disabilities severe. During this stage, an algorithm was tested for the automatic determination of a trajectory (which allows to avoid fixed obstacles) for a wheelchair / wheelchair with two wheels using PSO (Particle Swarm Optimization) and a Lidar type sensor.

Activity: Act 3.19 - -Implementation and real-time testing of the intelligent driving structure based on visual servoing systems (for the robotic manipulator with 7DOF) of SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities in conditions of laboratory;

Achievement indicators:

-Testing in laboratory conditions the intelligent driving structure based on visual servoing system of the Cyton 1500 manipulator that equips SAC-SI;

-Laboratory testing of the driving structure and navigation structure for the complex autonomous system SAC-SI involved modifying the wheelchair platform type "Cirrus Power Wheelchair" by adding the robotic manipulator with 7DOF and connecting a video camera that can transmit real-time data (visual servoing system).

-Testing the robotic manipulator with 7DOF was performed in laboratory conditions using various types of objects.

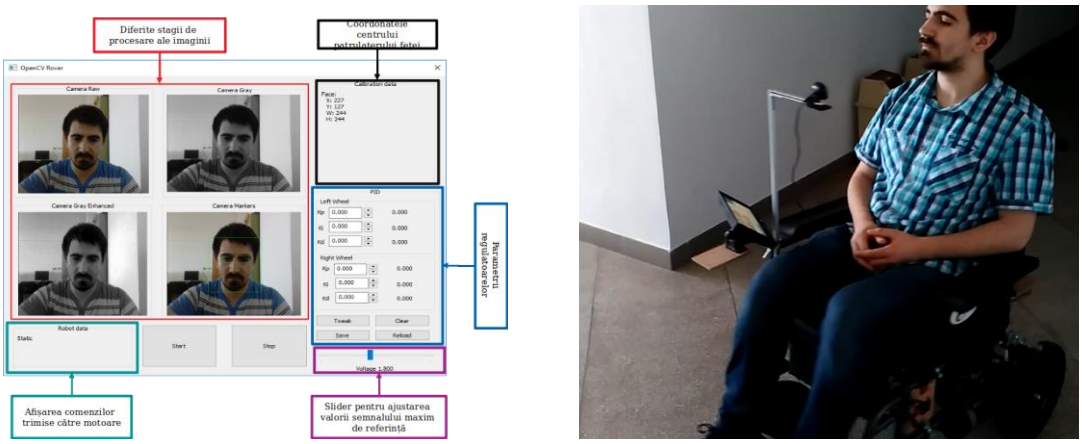
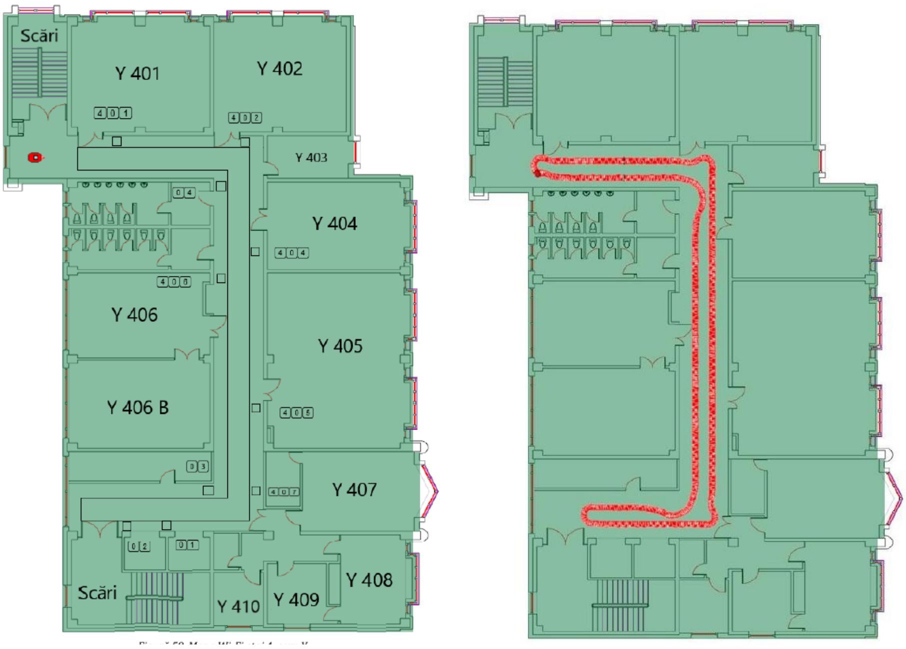
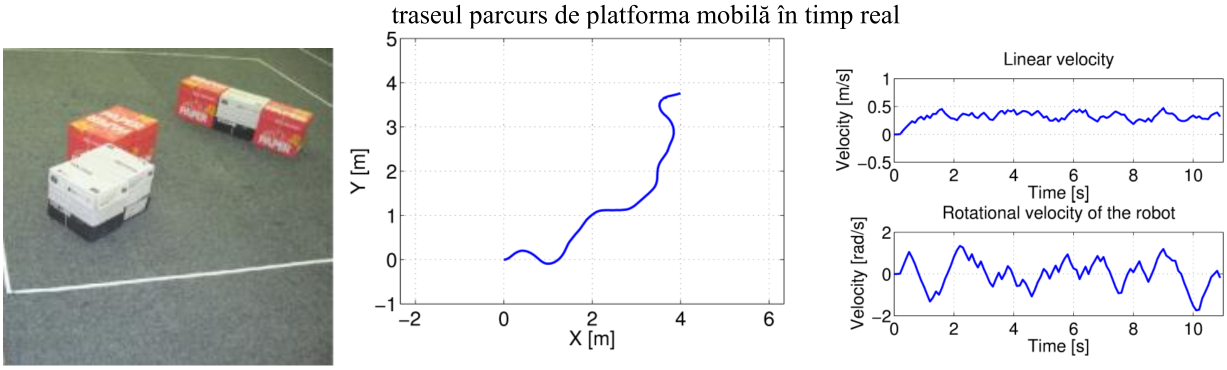


Fig.5.1 Testarea în condiții de laborator a structurii de conducere utilizând mișcările capului unei persoane cu dizabilități locomotorii severe: a) interfața grafică, b) testarea în timp real a SAC-SI



a) b)

Fig.5.2 Testarea algoritmului pe o platform mobilă cu două roți motoare a) harta reală a etajului 4 din corpul Y, b) traseul parcurs de platforma mobilă în timp real



a) b) c)

Fig.5.3 Testarea în condiții de laborator a structurii de evitare a obstacolelor (bazată pe senzori de tip laser), a) tipuri de obstacole, b) traseul urmat de platform mobilă, c) vitezele liniare si unghiulare a platformei mobile.

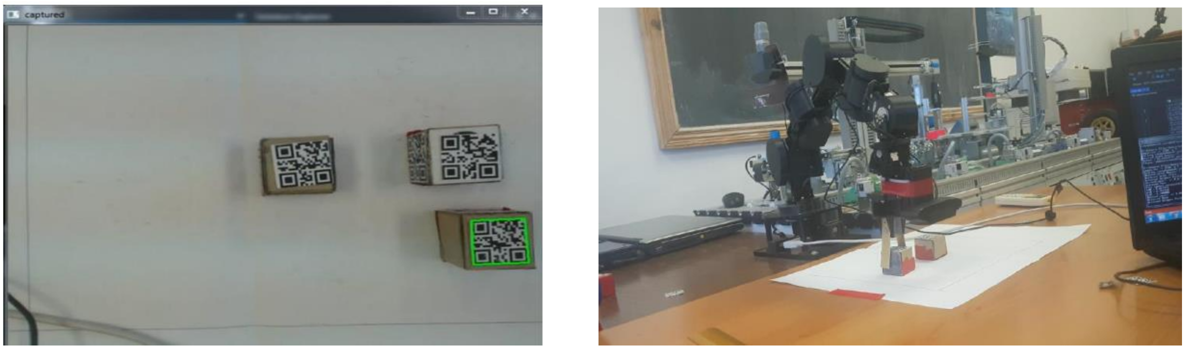


Fig. 5.6 Testarea în condiții de laborator a manipulatorului robotic cu 7DOF utilizând cutii ce au atașate coduri QR.

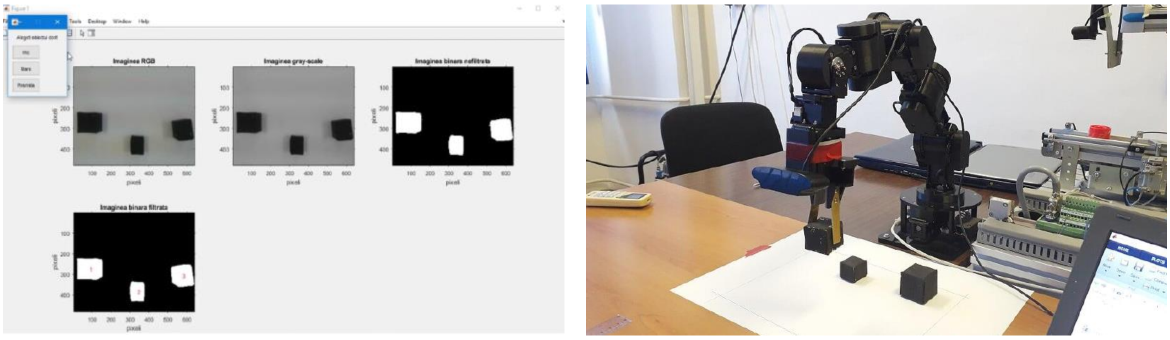


Fig. 5.7 Testarea în condiții de laborator a manipulatorului robotic cu 7DOF utilizând cutii de dimensiuni/înălțimi diferite.

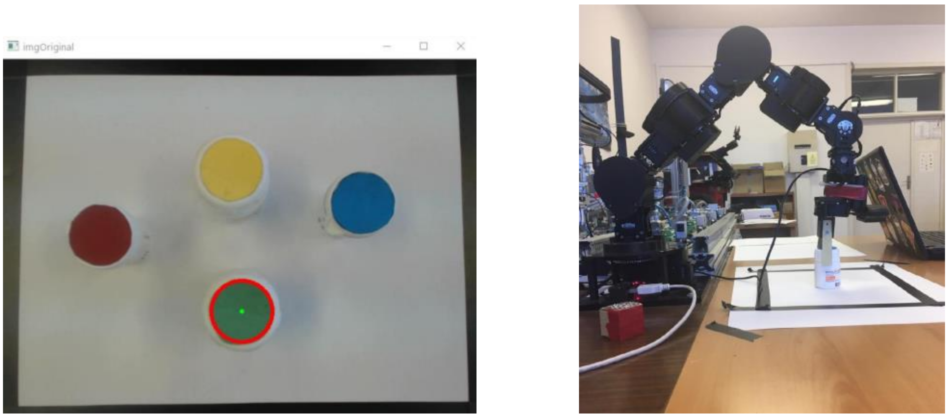


Fig. 5.8 Testarea în condiții de laborator a manipulatorului robotic cu 7DOF utilizând cutii ce au capacele divers colorate.

Activity: Act 3.20 - -Testing the management structure, navigation and obstacle avoidance for the complex autonomous system SAC-SI integrated in the technology of assisting people with severe neuro-motor disabilities in laboratory conditions at UVT and UCV;

Achievement indicators:

A structure of offer of research services regarding SAC-SI integrated in the technology of assistance to people with severe neuro-motor disabilities present in the erris platform of the partner institutions in the consortium was created:

UVT: https://erris.gov.ro/Valahia-University-of-Targoviste

UCV: https://erris.gov.ro/Computer-Aided-Design-CAD--C

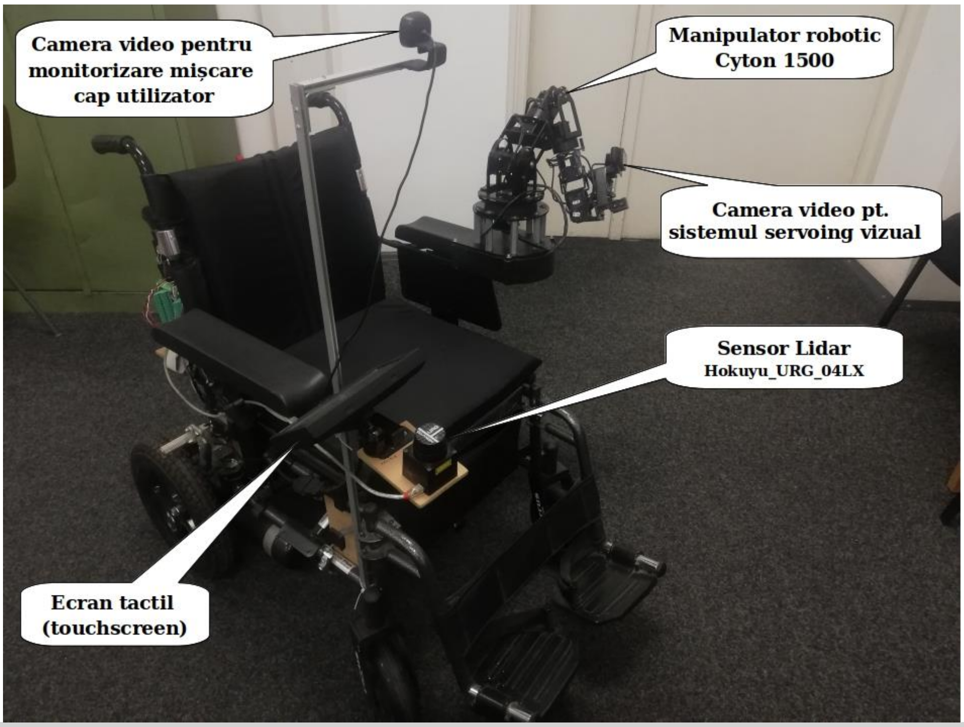


Fig. 5.9 Sistemul autonom complex SAC-SI integrat în tehnologia de asistare a persoanelor cu dizabilităţi neuro-motorii severe (vedere din faţă).

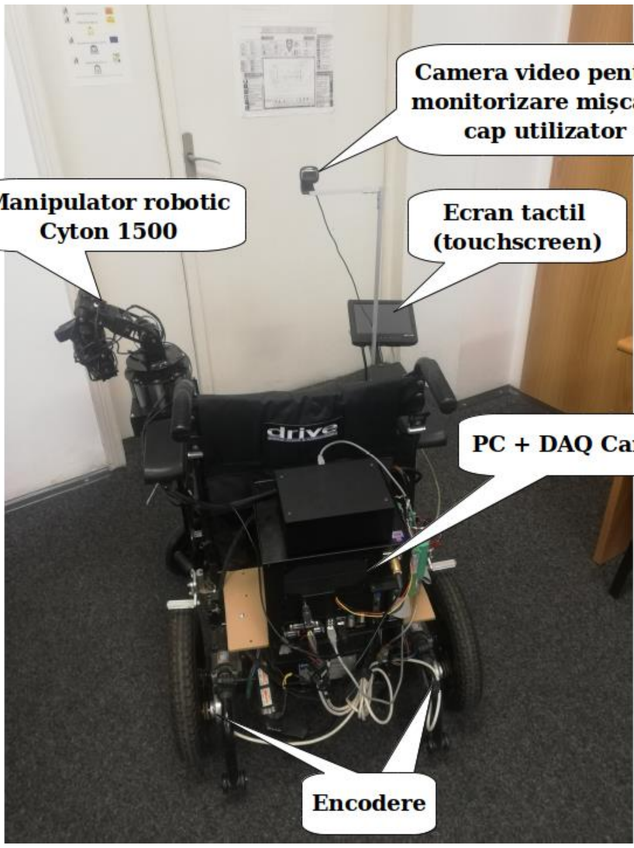


Fig. 5.10 Sistemul autonom complex SAC-SI integrat în tehnologia de asistare a persoanelor cu dizabilităţi neuro-motorii severe (vedere din spate).

CONCLUSIONS

The scientific report highlights the solutions that the Project 5 work team offers for the requirements of Stage 3. In the detailed scientific report uploaded on the P5 project platform (http://www.cidsacteh.ugal.ro), you can view the solutions and results research related to Stage 3. „The results of the laboratory testing of the intelligent driving structure, the navigation structure (based on high-performance sensors) and the real-time visual servoing of the SAC-SI advanced management structure based on systems integrated in people with severe neuromotor disabilities".

RESULTS STAGE 3

The following results were obtained:

- Autonomous robotic system consisting of a wheelchair type "Cirrus Power Wheelchair" and robotic manipulator with 7-DOF, integrated;
- Software package for planning the trajectory of the complex SAC-SI system;
- Obstacle avoidance software package (based on laser sensors);
- Real-time management of the complex SAC-SI system, using a video camera;
- Visual servoing system control of the robotic manipulator with 7DOF.

DISSEMINATION

Articles (ISI Proceedings or BDI)

1. Daniela Cristina Cernega, Solea, Razvan, “Hybrid Control Application Using Mobile Visual Servoing for Flexible Manufacturing Mechatronics Line”, 2020 - 24th International Conference on System Theory, Control and Computing (ICSTCC), Sinaia, Romania, 2020, pp. 636 -641 (being indexed).

Director proiect complex
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