PROJECT 3

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

Stage 4

Objectives

The integration of complex autonomous systems SAC-ARP and SAC-VAM in hybrid technologies serving flexible precision, laboratory, mechatronics, P / R, Festo MPS200 manufacturing lines

Activity 4.3

The control structure is designed for the system composed of:

- Flexible cell, CF, with 6-DOF ABB RM IRB120 - station used for assembling, disassembling and repairing parts as follows: with buffer, handling, processing and transport capacity. CF is a controlled assembly / disassembly unit PLC Siemens S7-1200 PLC, which deals with the supply of workpieces for product type 1 workpiece and disassembly, repairs for workpiece type 2;
- A / DML 6-WS Hera & Horstmann ML - based on a mechatronic laboratory system, used for assembling and transporting workpieces with verification and storage facility. A / D / RML, is characterized by a modular structure. The hardware structure consists of 2 PLC controlled subsystems / modules with specific tasks for all stages of manufacturing
- SAC ARP is a system composed of the PeopleBot WMR robot equipped with a 7-DOF Cyton 1500 RM equipped with the VSS eye in hand system, used for recovery and transport / return of the disassembled workpiece / reprocessed components (to the warehouse).

The proposed control structure is a hybrid, distributed and centralized / decentralized architecture, with two main features:

- Distributed structure, through separate PLCs for each of the 2 subsystems, to automate the respective areas with visualization or operation facilities.
- Centralized / decentralized architecture, in which CF PLC (Siemens S7 1200), in addition to the role of local control, acts as a master PLC for central control of both subsystems of the entire ML A / D / R process, and operating facilities, thus

coordinating and control tasks with synchronization of SAC operations. The system is equipped with a KTP 700 hardware interface (HMI) that provides the function of viewing running tasks and operator control.
In addition, scientific papers were developed to disseminate the final results.

1. The control structure

The control structure is designed for the A / D / RML assembly / disassembly / reprocessing line, which is shown in Figure 1. The basic components of the assembly / disassembly / reprocessing line are:

- Flexible cell, CF, equipped with ABB RM IRB120 6-DOF manipulator. This machining station is used for assembling, disassembling and repairing parts.
- Mechatronic assembly / disassembly / reprocessing line A / DML 6-WS ML - based on a mechatronic laboratory system, used for the assembly and transport of workpieces with verification and storage facility;
- SAC PeopleBot WMR equipped with a 7-DOF Cyton 1500 RM used for recovery and transport / return of the disassembled workpiece.

The A / D / RML line represents a system characterized by a modular structure. The hardware structure consists of 2 PLC controlled subsystems / modules with specific tasks for all stages of manufacturing.

- CF is a controlled assembly / disassembly unit PLC Siemens S7-1200 PLC, which deals with the supply of workpieces for product type 1 workpiece and disassembly, repairs for workpiece type 2;
- The 6-WS Hera & Horstmann ML line of stations is also a PLC controlled subsystem (Siemens S7-300 series) which has a predefined role as a logistics unit that assembles individual workpieces, transports between modules and stores the processed parts in place of final storage.
- The hardware and software structure based on PLC is a hybrid, distributed and centralized / decentralized architecture, with two main features:
- Distributed structure, through separate PLCs for each of the 2 subsystems, to automate the respective areas with visualization or operation facilities.
- Centralized / decentralized architecture, in which CF PLC (Siemens S7 1200), in addition to the role of local control, acts as master PLC for central control of both subsystems of the entire A / D / R ML, process and operating facilities, thus coordinating and control tasks as a synchronization of SAC operations that includes a KTP 700 hardware interface (HMI) that provides process monitoring and visualization of the current process status as well as operator control.

Flexible cell (CF) with ABB IRM

- CF is an integrated workstation equipped with an ABB IRB120 robot, shown in Figure 3, which consists of the following major components:
  - manipulator with 6 degrees of freedom 6-DOF ABB IRB120 MRI with electrical outlet;
  - PLC Siemens S7-1200 series-CPU 1214C;
  - HMI Siemens KTP700, Color Basic PN;

- Siemens SCALANCE XB005 switch;
- Conveyor belt with Sinamics V90 servomotor;
- Compact storage and unloading units corresponding to each five-part workpiece to be assembled.

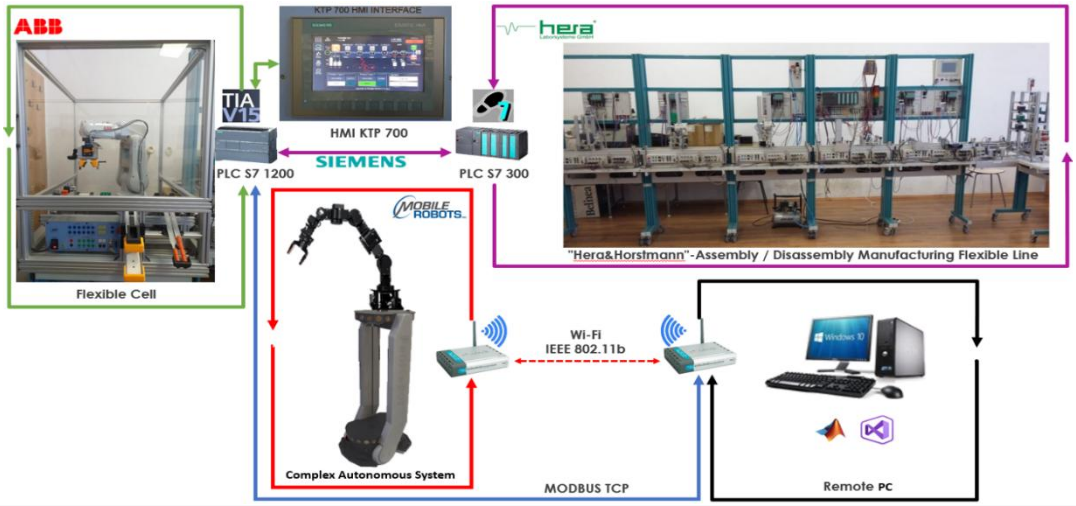

Figura 1 SAC control structure consisting of A / D / R line, CF manufacturing cell and SAC-ARP

The Profinet communication link is used to interconnect and control all the CF devices mentioned above. For the CF hardware structure, the following Profinet profiles are applicable:

• Profinet-IO, distributed I / O (remote I / O), in which user data on field devices is periodically sent to the control system process model. This can be considered an advanced Profibus protocol on the TCP layer. Profinet-IO is used to connect HMI, CPU PLC and ABB robot controller (Figure 2);

• PROFI unit - implemented for drive application scenarios, covers from simple frequency converters to intelligent servo drivers. This Profinet profile is used in the flexible cell station to control the conveyor belt with Sinamics V90 servomotor (Figure 2).

ABB Robot Controller has the hardware capability to communicate with third party devices through the Profinet protocol. For this, a dedicated AnybusCC Profinet slave board (DSQC 688) is inserted into an expansion board above the main computer unit in the ABB robot controller. This Profinet Anybus device, DSQC 688, requires the DSQC1000 robot controller (mainframe). With the Profinet Anybus Device option, the ABB Robot controller can act as a slave module in the Profinet network.

The mechatronic line (ML)

The flexible mechatronic line (Figure 4) includes six individual workstations with different tasks, each task ensures the performance of operations for different stages: transfer and transport, pneumatic workstations, conveyor belt, sorting unit, test station and warehouse.

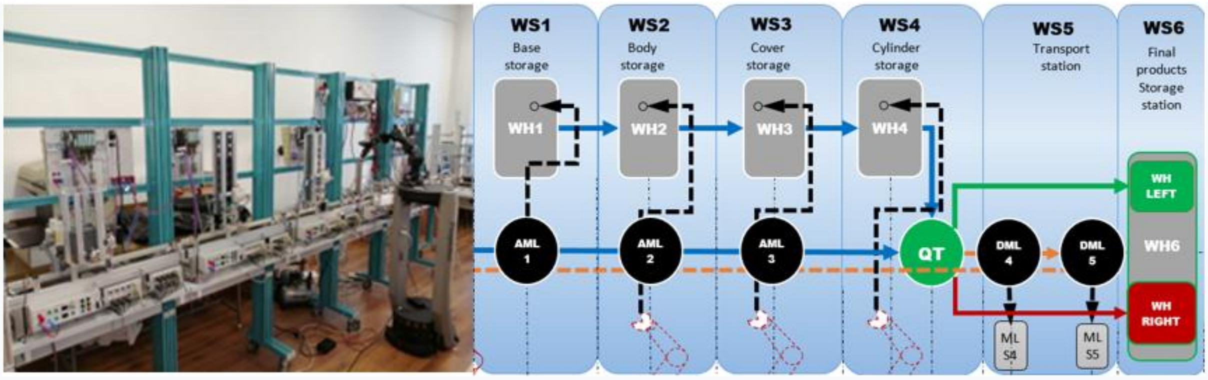

Figura 3. Linia mecatronica Hera&Horstmann si SAC, ARP-PeopleBot WMR cu manipulatorul Cyton 1500 RM

The hardware structure of SAC

The SAC, shown in Figure 7, consists of the following elements: a Cyton 1500 RM 7-DOF manipulator equipped with a visual VSS eye-hand servoing type using a high-definition camera, both being connected to a computer via USB and synchronous communication with A / D / R ML via Wi-Fi. RM is placed on the SAC ARP Peoplebot, which is a WMR with two drive wheels and a freewheel (2DW / 1FW). SAC ARP is used to transport recoverable parts taken by Cyton 1500 RM to the appropriate warehouses if the assembled part has not passed the quality test and has been disassembled or repaired.

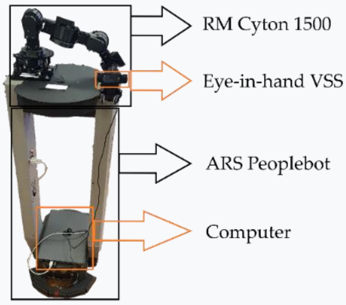

Figure 7. SAC compus din ARP, manipulator mobil (RM), *eye-in-hand* VSS si calculator

The SAC control is performed wirelessly using a router that is placed inside the WMR, through dedicated functions from ARIA (Advanced Robotic Interface for Applications) that run on the same computer to which Cyton RM is connected.

Visual servoing VSS *eye in hand*

VSS eye-in-hand is a system in which the video sensor is placed on the last link of the RM, also known as the final effector. For this type of VSS, 2D image information is used to control the robot's movement in the workspace. Object tracking and robot positioning are done using the comparison between current visual characteristics, extracted from images captured by the camera and the desired visual characteristics. The difference obtained is used to minimize the error between the current position of the part and the anticipated location. Also, eye-in-hand VSS indicates that the RM movement also induces the movement of the mounted camera. One of the most used components in detecting and classifying objects is called image moment. These image moments are commonly used in the fields of robotics due to their efficiency and simplicity in implementation. The moments of the image contain information about the region of interest, the coordinates of the center of gravity of the piece and the positioning of the image.

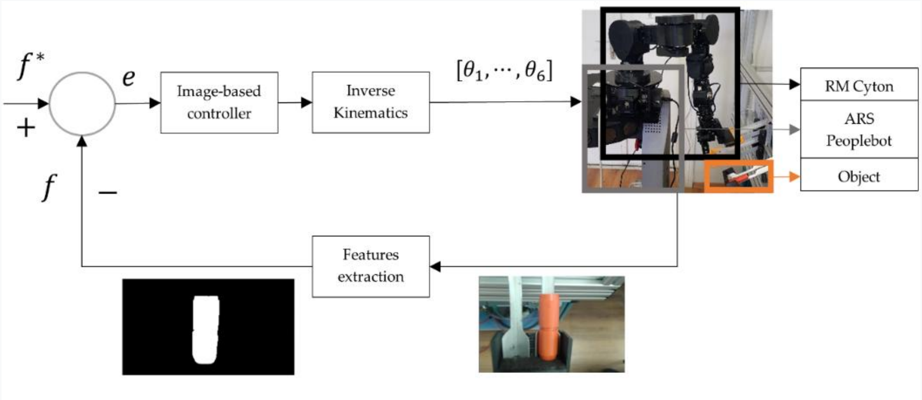

Figura 8. Bucla de reglare a poziției manipulatorului robotic (RM) Cyton bazată pe VSS eye-in-hand

The control architecture of SAC

The mobile part of the A / D / R ML, called SAC, consists of an autonomous robotic system (ARP), Peoplebot WMR equipped with 7-DOF Cyton 1500 RM and an eye-type VSS system, for lifting parts from CF in the case of a repair / disassembly process and transport them to the appropriate storage depots (Figures 11, 12 and 13). The control of the moving part is based on 3 control loops:

1. Control loop for synchronization between CF Modbus PLC and Cyton RM;
2. Cyton RM control loop with eye-in-hand VSS for precise positioning to pick up objects from the FC and place them in storage;
3. PeopleBot WMR control loop based on sliding mode control to track trajectory in set time with obstacle avoidance (Trajectory Tracking Sliding Mode Control (TTSMC)).

All three control loops communicate through a computer that contains GUI and ARP commands, eye in hand VSS, Cyton 1500 RM and manages synchronization with CF. Specific software packages and libraries were used with Microsoft Visual Studio to drive the entire system. As can be seen in Figure 12, the communication between Cyton RM, eye in hand VSS and computer is done with USB connections, while the communication with and CF is done wirelessly using a TCP / IP protocol. Coordination between control loops was achieved using the open-source library specialized in image processing, OpenCV and defined command input, functions from Aria Mobile Robots, a synchronization with the FC Modbus PLC, all combined in Microsoft Visual Studio with the language C ++ programming.

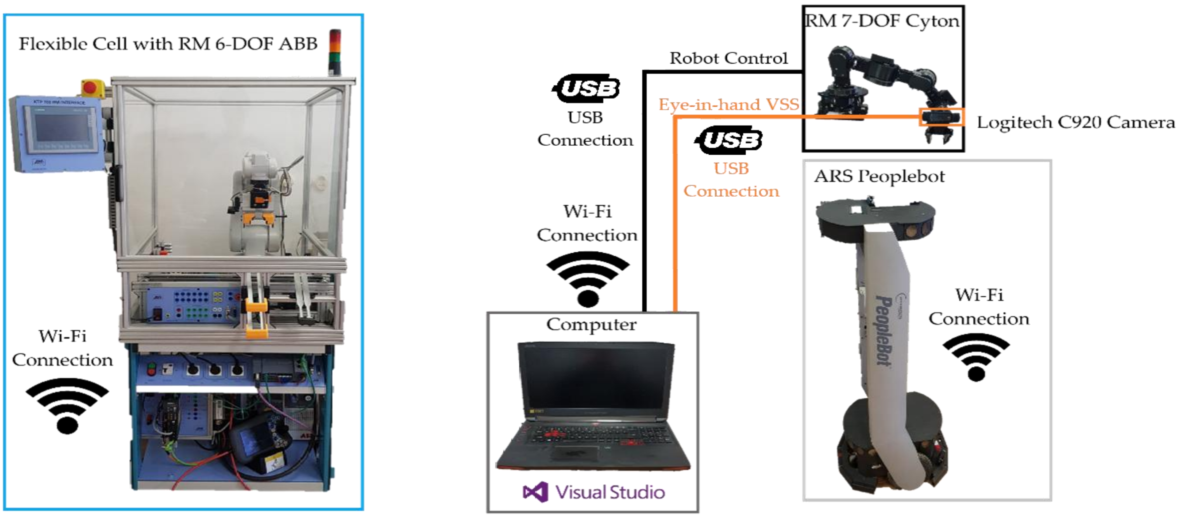

Figura 11. Structura blocurilor de comunicație intre CF ARP PeopleBot echipat cu manipulatorul Cyton RM si VSS *eye-in-hand*

All the three control loops communicate through a computer that contains GUI and ARP commands, eye in hand VSS, Cyton 1500 RM and manages synchronization with CF. Specific software packages and libraries were used with Microsoft Visual Studio to drive the entire system. As can be seen in Figure 12, the communication between Cyton RM, eye in hand VSS and computer is done with USB connections, while the communication with and CF is done wirelessly using a TCP / IP protocol. Coordination between control loops was achieved using the open-source library specialized in image processing, OpenCV and defined command input, functions from Aria Mobile Robots, a synchronization with the FC Modbus PLC, all combined in Microsoft Visual Studio with the language C ++ programming.

Figure 17 illustrates the desired and actual trajectories of the PeoplePot ARP obtained with the command given by the closed loop TTSMC to switch from CF to storage and back to CF in the desired time. In (a) the complete path is shown, in (b) separately on the X axis, (c) separately on the Y axis, (d) the angular trajectory so that the differences between the actual and the desired trajectory can be more easily perceived. There are 2 observable deviations, one after a 90 ° rotation to advance to the depot, as shown in Figure 17 (c) and 17 (d) between seconds 40 and 56 on the X axis, and the second again after a 90 ° rotation to move back to the FC, shown in Figures 17 (c) and 17 (d) between seconds 78 and 90 on the X axis.

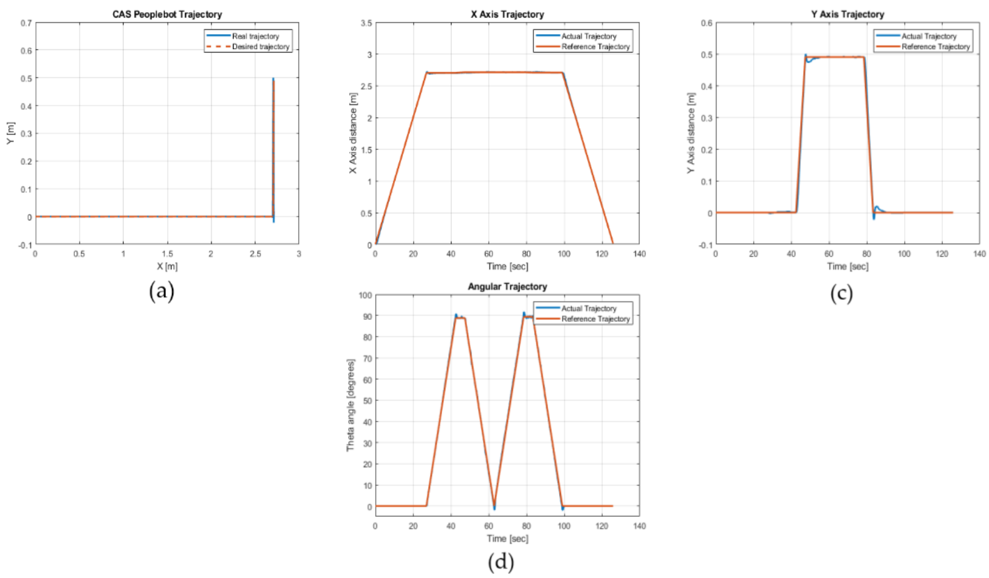

Figura 17. Traiectoriile dorite si reale ale ARP Peoplebot bazate pe comanda Trajectory Tracking Sliding Mode Control: (a) Traiectoria completa, (b) Traiectoria pe axa X, (c) Traiectoria pe axa Y si (d) traiectoriile unghiulare

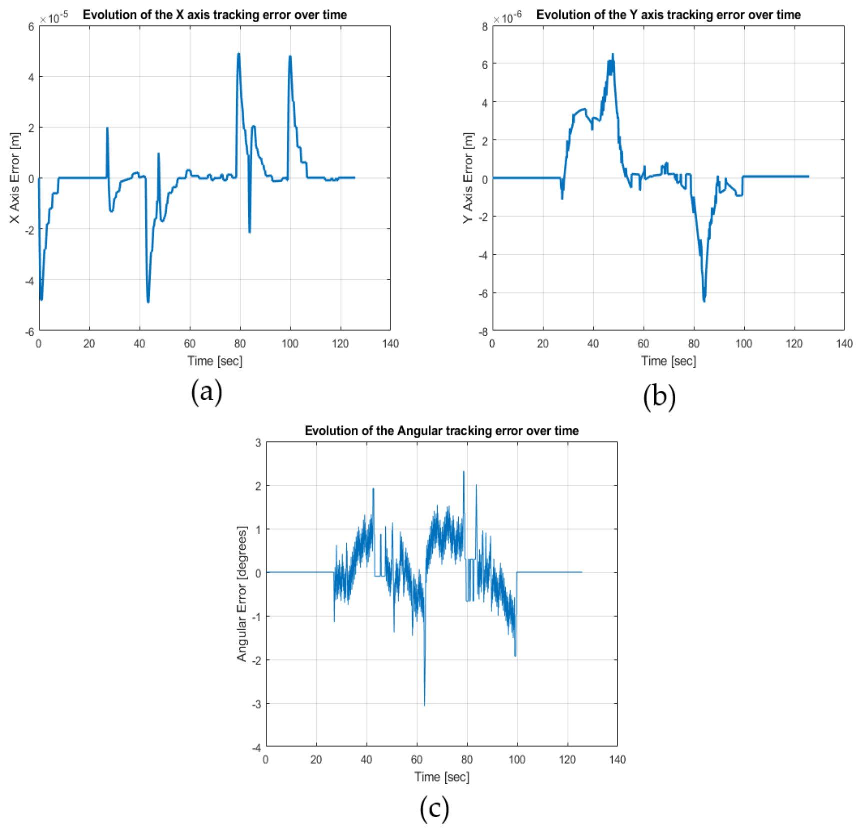

Figura 18. Erorile de urmărire in coordinate absolute (**a**) pe axa X si pe (**b**)axa Y axis , (**c**) eroarea unghiulară absolută exprimată in radiani pe secundă pentru robotul ARP PeopleBot

The proposed and validated control structure at this stage, is easy to implement, does not require additional equipment to the usual ones in the manufacturing systems and ensures the assembly or manufacturing system the fulfillment of the imposed performances.
SAC ARP is equipped with high-performance algorithms for tracking the trajectory in a set time and avoiding obstacles. The use of VSS eye in hand for the positioning of the RM Cyton mobile manipulator, which is equipped with SAC ARP, leads to a considerable reduction in the positioning errors of the parts, in a priori unknown conditions.
The proposed SAC ARP solution, having the two major advantages demonstrated, is an emerging technology that can be used in the industrial environment with very small adjustments.

2. The research services structure offered

The research services structure offered, regarding SAC-ARP integrated in the hybrid technology for servicing flexible precision, laboratory, mechatronics, P / R, A / D manufacturing lines is available at https://eeris.eu/?&sm=module.org.erris.app.infra&ddpN=3245192760&we=a5ba74f6d75889ea8c62a266f3e019f6&wf=dGFCall&wtok=598efa9b52e5b548b3eb15710f55b335b924c1fc&wtkps=JY3bEkMwFEX/Je+MOLk5vibE0aiiSTCj038v+rYe1l7bosBPREAWvWN1RFki45vapDRHguFoXPRvM1bE1y2mKaV5aMkfjyLjuhJ9K7N+hWEM11Yj8xMF+y8JZIJzfUeR7ek5xovhPCBeEgAYB7qRZItWQWm0IVK2LBoSl3dqe3eDQvaa3Tp2+Rz6vAvBx9wuS35/sfr7Aw==&wchk=4252aaa4ab28b8b1fdb3db7fd9588b0e3f8b9349 .

The services structure offered is made of two research services:

- Research for the Autonomous Complex System - Personal Robotic Assistant platform to ensure the medical and social assistance in the hospital and at home
- Research for the Autonomous Complex System- Multidirectional Autonomous Vehicle platform for personal assistance in/out the hospital and rescue in rough terrain

and two technological services:

- Hybrid flexible manufacturing systems control technologies for precision flexible assembly/manufacturing lines for laboratory or industrial use, integrating the Autonomous Complex System -Multidirectional Autonomous Vehicle
- Hybrid flexible manufacturing systems control technologies for precision flexible assembly/manufacturing lines for laboratory or industrial use, Hybrid flexible manufacturing systems control technologies for precision flexible assembly/manufacturing lines for laboratory or industrial use, integrating the Autonomous Complex System - Personal Robotic Assistant.