Raport stiintific
privind implementarea proiectului PN-II-ID-PCE-2011-3-0**641**

CONDUCEREA AVANSATA A SISTEMELOR DE FABRICATIE REVERSIBILE, DE ASAMBLARE SI DEZASAMBLARE, UTILIZAND ROBOTI MOBILI ECHIPATI CU MANIPULATOARE ROBOTICE
pentru perioada ianuarie-decembrie 2015

Assoc Prof. Ph. D. Eng. Alina VODA-project leader, principal investigator, Ph.D. in Control Systems, Ph.D. supervisor in Control Systems;

Prof., Ph.D., Eng. Adrian FILIPESCU - senior researcher, University “Dunarea de Jos” of Galati, Ph.D. in Control Systems (Contributions to the synthesis of systems with variable structure and adaptive), Ph.D. supervisor in Control Systems;

Assoc Prof., Ph. D. Eng. Eugenia MINCA -senior researcher, University “Valahia” of Targoviste, Ph.D. in Control Systems (Contribution to the supervision of production systems using fuzzy Petri nets: application to the e-maintenance), second Ph. D in Industrial Engineering;

Assistant, Ph.D., Eng. Otilia DRAGOMIR -Postdoctoral researcher, University “Valahia” of Targoviste, Ph.D. in Control Systems (Contribution to prognosis failures of production, by neuro-fuzzy network: control of the prediction error);

Eng. Bogdan DUMITRASCU, - Ph.D. student in Control Systems (contributions to control, navigation and obstacle avoidance of mobile robots and autonomous vehicles), University “Dunarea de Jos” of Galati, Adrian Filipescu is his Ph.D supervisor;pe 29-noiembrie-2012 a susținut public teza de doctoratcu Adrian Filipescu și Eugenia Mincă membri în comisia de susținere publică.

Lecturer eng. Adriana SERBENCU, Ph.D. student in Control Systems (contributions to intelligent control of collaborative mobile robots), University “Dunarea de Jos” of Galati, Adrian Filipescu is her Ph.D. supervisor;

Eng. Adrian RADASCHIN, Ph.D. student in Control Systems(contributions to the intelligent control of mobile robots integrated in flexible manufacturing lines), University “Dunarea de Jos” of Galati, Adrian Filipescu is his Ph.D supervisor, Alina Voda is his Ph.D co-supervisor;pe 29-noiembrie-2012 a susținut public teza de doctorat, cu Adrian Filipescu, Alina Vodă și Eugenia Mincă membri în comisia de susținere publică.

Eng. Silviu FILIPESCU Ph.D. student in Electrical Engineering(contributions to advanced control of mechatronic lines served by mabile platform equipped with manipulatorsusing DSPs and embedded systems), Polytechnic University of Bucharest, Liviu Kreindler his Ph.D supervisor. Eng Silviu Filipescu Replace in the research team Ph.D student eng. Adrian Enache who renounced to doctoral studies and to research team project;

Eng. Cristian VASILACHE, Ph.D. student in Control Systems (contributions to the control of mobile robots equipped with robotic manipulators by biometric techniques), University “Dunarea de Jos” of Galati, Adrian Filipescu is his Ph.D supervisor, Alina Voda is his Ph.D co-supervisor.

Mai jos, se raporteaza rezultate stiintifice obtinute si diseminarea lor la fiecare din cele 3 obiective din anexa IV, parte componenta a actului aditional nr 1 pe 2015:

A fost aprobata nota justificativa de mai jos cu privire la actualizarea obiectivelor proiectului pentru anul 2015

Nota Justificativa,

privind modificarea planului de realizare din actul aditional aferent anului 2015 la proiectul PN-II-ID-PCE-2011-3-0641

Obiectivul 5.2, prevazut initial pentru 2015: Conducerea în timp real şi echilibrarea liniei de mecatronica, reversibile, de asamblare/dezasamblare HERA&HORSTMANN şi conducerea sliding-mode a următorilor roboţi mobili deservind linia reversibilă în procesul de dezasamblare: Pioneer 3-DX echipat cu manipulatorul Pioneer 5-DOF Arm;PeopleBot(2DW/1FW) şi PatrolBot (2DW/2SW) echipaţi cu manipulatorul 5-DOF Cyton Premium; PowerBot (2DW/2SW) si SEKUR (4DW/SW) echipat cu manipulatorul 5-DOF Adept Arm. Implementarea in timp real a sistemelor servoing vizuale pentru manipulatoarele Pioneer, Cyton si Adept

Obiectivul 5.2 actualizat pentru 2015: Conducerea în timp real şi echilibrarea liniei de mecatronica, de asamblare/dezasamblare HERA&HORSTMANN. Conducerea sliding-mode a doua sisteme roboce autonome deservind linia reversibilă în procesul de dezasamblare: Pioneer 3-DX (2DW/1FW) echipat cu manipulatorul Pioneer 5-DOF Arm şi PatrolBot (2DW/2SW) echipaţi cu manipulatorul 5-DOF Cyton Premium.

Justificare: Bugetul alocat proiectului in anul 2015 nu permite achizitionarea a doua manipulatoare Cyton. Se renunta la a deservi linia de mecatronica de catre robotul mobil PeopleBot care nu mai poate fi echipat cu manipulator.

Bugetul alocat proiectului in anul 2015 nu permite achizitionarea a doua manipulatoare Adept. Se renunta la a deservi linia de mecatronica de catre robotii mobili PowerBot si SEEKUR care nu mai pot fi echipate cu manipulatoare.

Obiectivul 5.3 prevazut initial pentru 2015: Conducerea în timp real si echilibrarea liniei de prelucare/reprelucrare FESTO-MPS, şi conducerea sliding-mode a următorilor roboţi mobili care deservesc linia in procesul de reprelucrare: Pioneer 3-DX echipat cu manipulatorul Pioneer 5-DOF Arm; PeopleBot(2DW/1FW) şi PatrolBot (2DW/2SW) echipaţi cu manipulatorul 5-DOF Cyton Premium. Implementarea in timp real a sistemului servoing vizual pentru manipulatoarele Cyton 1500 si 300.

Obiectivul 5.3 modificat pentru 2015: Conducerea în timp real si echilibrarea liniei de prelucare/reprelucrare FESTO-MPS. Conducerea sliding-mode a doua sisteme robotice autonome care deservesc linia pentru procesul de reprelucrare: Pioneer 3-DX (2DW/1FW) echipat cu manipulatorul Pioneer 5-DOF Arm şi PatrolBot (2DW/2FW) echipat cu manipulatorul 5-DOF Cyton Premium. Implementarea in timp real a sistemului servoing vizual pentru manipulatoarele Pioneer si Cyton.

Justificare: Bugetul alocat proiectului in anul 2015 nu permite achizitionarea a doua manipulatoare Cyton. Se renunta la a deservi linia de mecatronica de catre robotul mobil PeopleBot care nu mai poate fi echipat cu manipulator.

Mentionam, ca obiectivele prevazute pentru anul 2016, 6.1 si 6.2, impreuna cu activitatile aferente, s-au introdus in accord cu modificarile aduse obiectivelor 5.2 si 5.3, din 2015. Atat modificarile obiectivelor pe 2015 cat si obiectivele si activitatile prevazute pentru 2016, nu schimba cu nimic sensul proiectului.

20.03.2015 Director proiect

Alina VODA

OB1) Conducerea în timp real şi echilibrarea liniei de mecatronică, de prelucrare/reprelucrare FESTO-MPS şi conducerea sliding-mode a robotului mobil Pioneer 3-DX echipat cu manipulatorul Pioneer 5-DOF Arm care deserveşte linia în procesul de reprelucrare. Implementarea in timp real a sistemului servoing vizual pentru manipulatorul Pioneer 5-DOF arm.

Activitatea 1.1: Realizarea compatibilităţii hardware şi a sincronizării între linia de prelucrare, şi sistemul robotic.
Activitatea 1.2: Realizarea interfeţei pentru monitorizarea evenimentelor şi a conducerii
Activitatea 1.3: Diseminare rezultate
Conducerea în timp real şi echilibrarea liniei de mecatronică, de prelucrare /rerelucare FESTO MPS-200 deservita numai de robotul mobil Pioneer 3–DX echipat cu manipulatorul Pioneer 5-DOF Arm (Fig. 1, Fig.2, Fig. 3, Fig. 4) s-a facut pe baza modelului SHPN (sincronied hybrid Petri nets) iar sincronizarea dintre linia de mecatronica si platforma mobila echipata cu manipulator s-a facut pe baza semnalelor provenite de la senzori si a unui system servoing visual, cu video camera fixa instalata pe statia de depozitare a sistemului de mecatronica. Conducerea plataformei mobile pentru transportul pieselor care necesita reprelucrare s-a facut cu o metoda sliding-mode, bazata pe modelul cinematic.

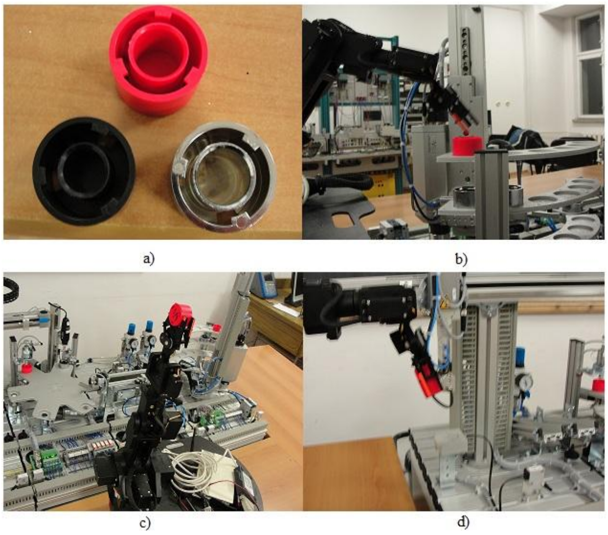

Fig. 1 Linia de prelucrare/reprelucrare FESTO MPS-200 deservita de robotul mobil Pioneer 3-DX echipat cu manipulator

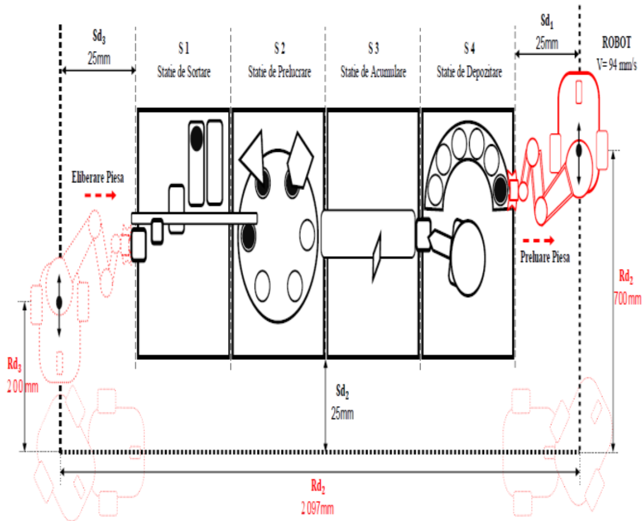

Fig. 2 Triectoria si distantele parcurse de platforma mobila

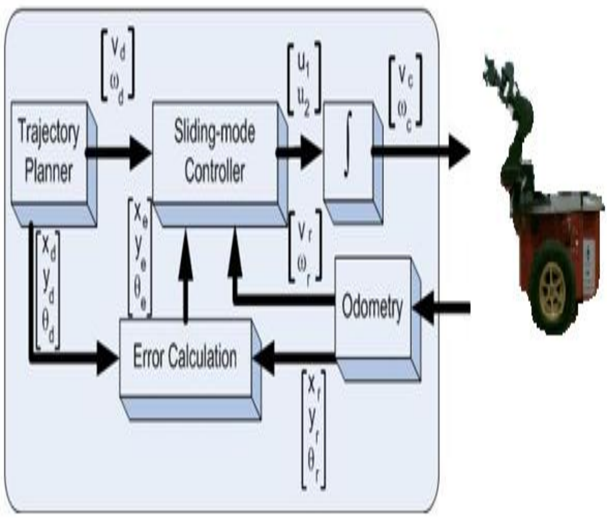

Fig. 3. Structura de conducere a platformei mobile

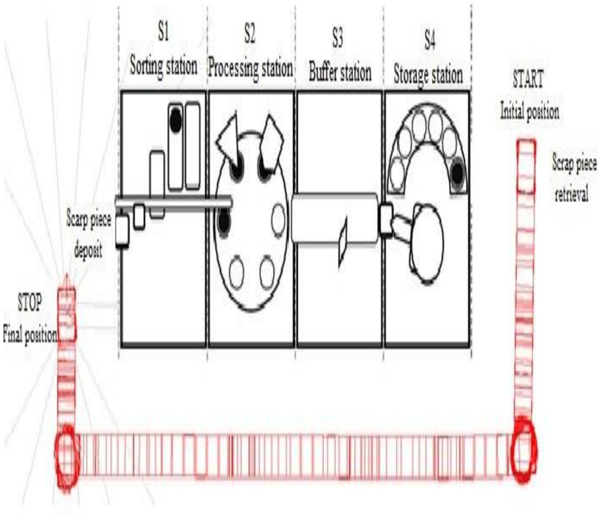

Fig.4. Traiectoria simulata in Mobilesim

Conducerea liniei de mecatronica de prelucrare/reprelucrare FESTO MPS-200, cu supervizorul implementat in Labview face obiectul unui articol trimis spre evaluare la revista Elsevier, Robotics and Computer Integrated Manufacturing (impact Factor:2,305), Visual servoing and sliding mode controller for a mobile robotic systemintegrated in a processing/reprocessing mechatronics line, Autori: George Petrea, Adriana Filipescu, Adrian Filipescu, Razvan Solea

Sunt specificate mai jos realizarile si rezultatele privind modelarea , simularea si conducerea in timp real:

Structure of the SHPN model

The SHPN structure, in Fig. 5 is obtained by modelling processing/reprocessing and continuous service assistance, for reprocessing, performed by a mobile platform equipped with a manipulator. SHPN structure results from integration of three PN models, each of them having a specific functionality: TPN (Timed PN), SPN (Synchronised PN), and THPN (Timed Hybrid PN). These models describe the following automatic operations:

- Processing (TPN functionality);
- Reprocessing of pieces (TPN functionality);
- Service assistance, during the recovery and transport of the piece that needs to be reprocessed, performed by the mobile robot equipped with a manipulator (SPN +TPN functionality).

Fig. 5. Structure of the SHPN model.

Simulation of the HPN model

The proposed model, HPN, has been tested, analyzed and verified through simulation package Sirphyco. HPN model was useful to find maximum speed of the mobile platform that provides minimum cycle time of transporting for reprocesing. This speed should be set respecting the physical limitations of the mobile platform, which ultimately is the optimum displacement speed. The SHPN global model is an exclusive relationship between TPNs associated with the process and elementary THPN modules associated with WMR service assistance.

In figure 1 and 2 are presented the results after simulating the developing of both discrete and continuous actions of the P/RML and robot. First, in figure there are the timed discrete transitions where mechatronics line takes the required actions: handling, sorting, boring, drilling, transporting, etc. According to the time assigned in the model presented in figure 10, the duration of each action can be seen represented in figure 5.

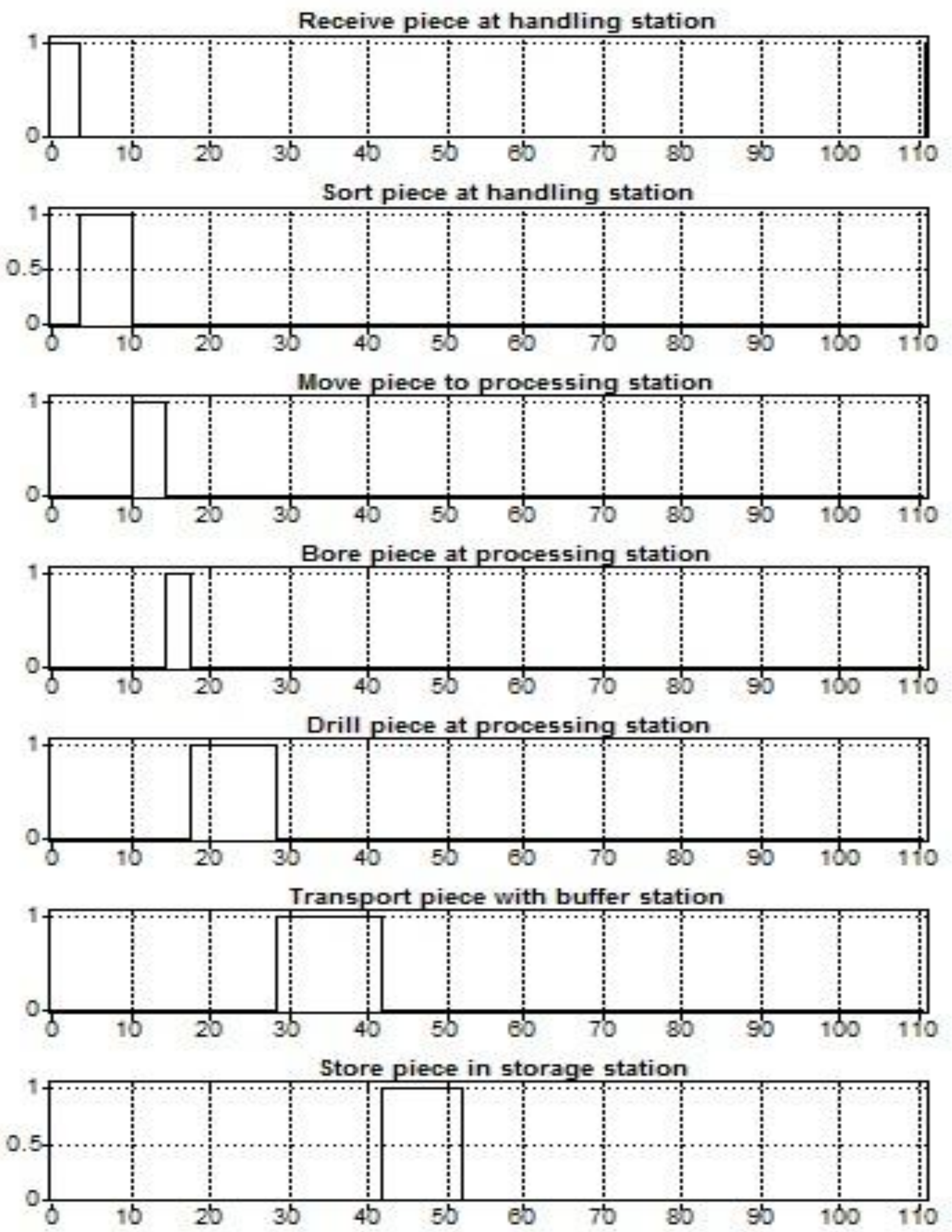

Fig. 6. State transitions of processing piece sorting and storing.

Next, in figure 2, are presented the simulation results of the continuous actions of the robots. After the robot in initialized, it waits for the defective piece that can be reprocessed to be stored. Using the camera the system detects the piece (external event) and the robot is triggered.

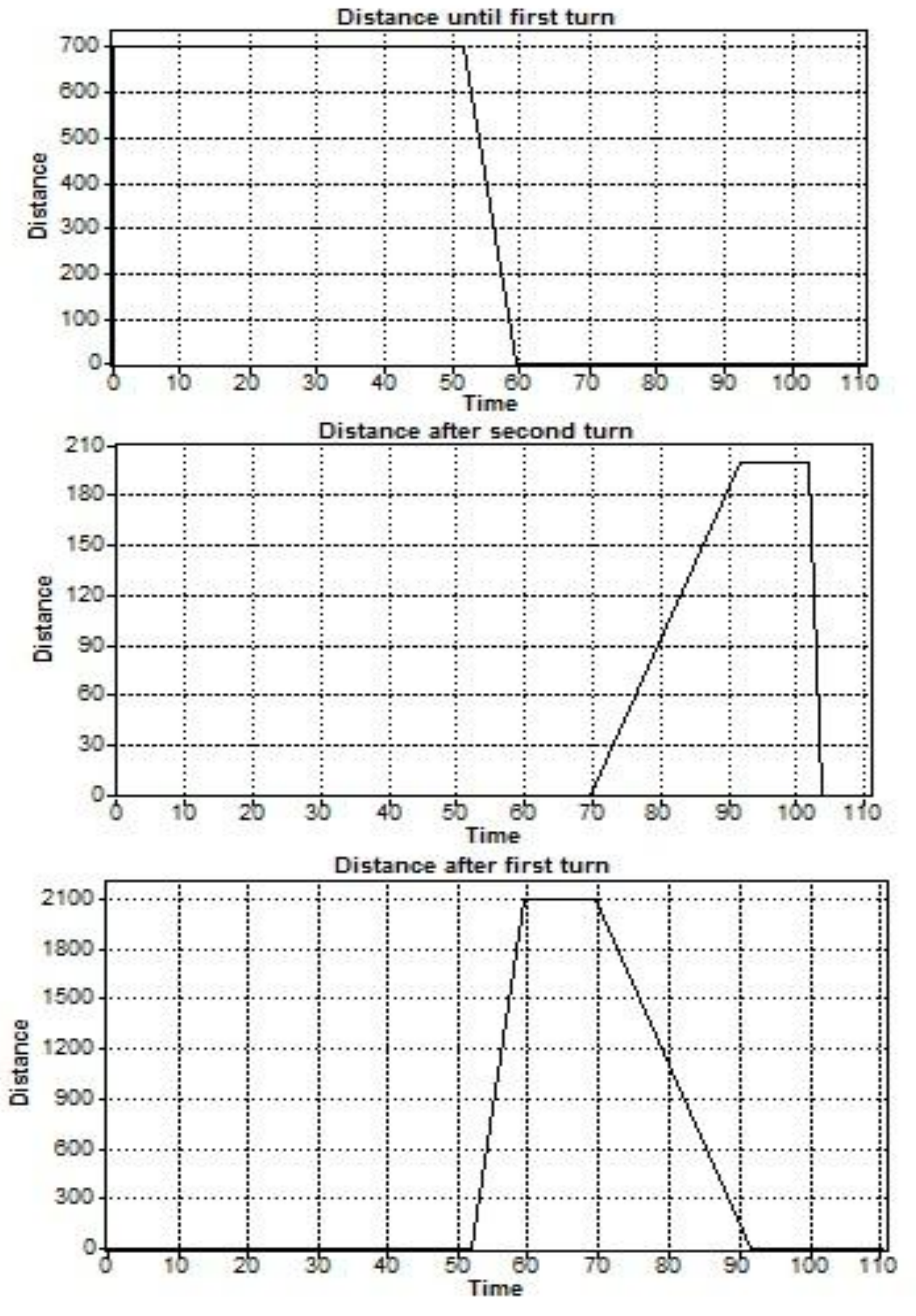

Fig. 7. Variation of the continuous places associated to displacements of WMR with RM for the transporting

Real time control based on SHPN model.

The SHPN model is transposed via Matlab and LabView platform into a real-time application, obtained by interfacing the HPN model with synchronised signal taken by the video camera. The robot will be initialised and synchronisation will lead to the beginning of transporting the damaged piece to the start of the line. Discrete time and sliding-mode control, in trajectory tracking, based on a kinematic model, is used to control WMR In this way, both the robot and the flexible line are controlled, so as to achieve a minimum time cycle.

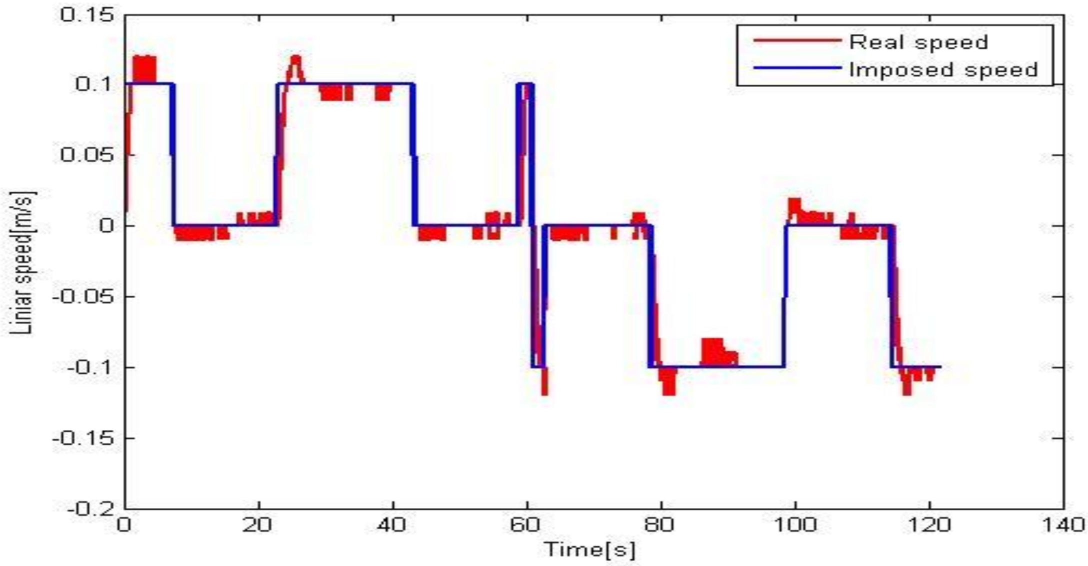

Fig. 8. WMR linear speed during transporting

The robot is initialised by a signal transmitted via a wireless access point mounted on the robot. The gripper is positioned by a visual system so as to grab the piece and store it at the beginning of the line. Linear velocity of the complete WMR transporting cycle in trajectory tracking, real-time, sliding-mode control, is presented in Fig. 3. Sliding-mode control of the mobile platform servicing P/RML does not address issues related to the possibility of uncertainty of type: false information, faulty sensors / actuators and possible route / storage space blockage.

Synchronization based on fixed visual servoing system

The WMR and P/RML get synchronized when the video camera detects a scrap piece in the storehouse. By convention, the piece that is to be reprocessed is red. The video is processed using a Matlab program.

After piece detection is finished, the Matlab program runs and guides the WMR and the RM in order to get the piece for transporting. The robotic manipulator's arms have two red markers used by the video camera in order to detect the position of the robot regarding the piece that needs to be grabbed. By convention, the defective piece is also red. As shown in figure 9, the Matlab program marks the piece and the arms of the gripper and when the RM is positioned correctly, the piece is taken.

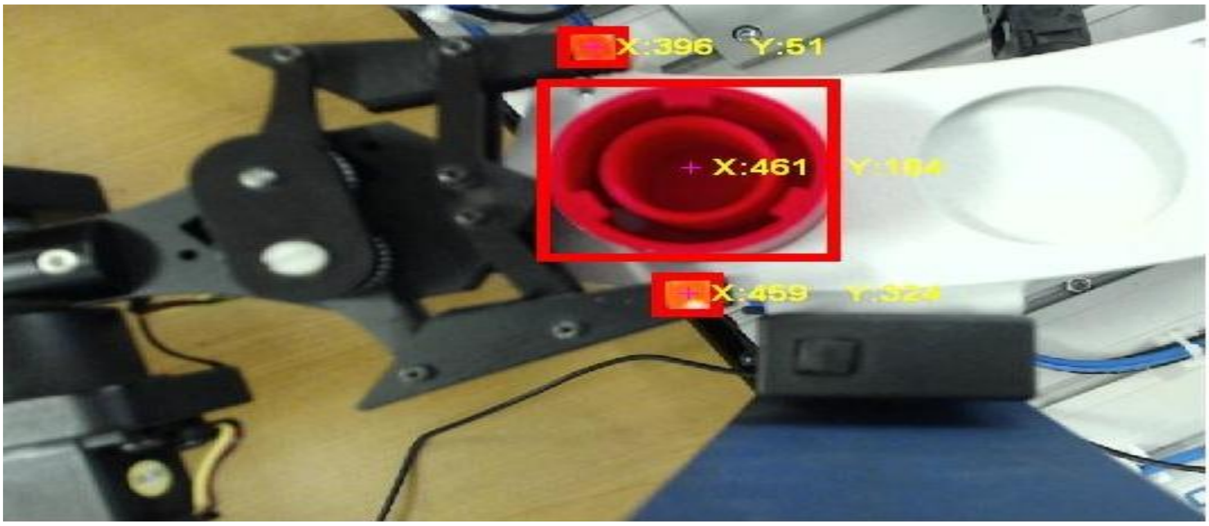

Fig. 9. Camera view of the gripper reaching for the piece

OB. 2) Conducerea în timp real şi echilibrarea liniei de mecatronica, de asamblare/dezasamblare HERA&HORSTMANN. Conducerea sliding-mode a doua sisteme roboce autonome deservind linia reversibilă în procesul de dezasamblare: Pioneer 3-DX (2DW/1FW) echipat cu manipulatorul Pioneer 5-DOF Arm, utilizat pentru manipulare şi PatrolBot (2DW/2SW) echipaţi cu manipulatorul 5-DOF Cyton Premium, utilizat pentru transport; Cele doua sisteme robotice functioneaza in regim sincronizat cu linia de mecatronica.

Activitatea 2.1: Realizarea compatibilităţii hardware şi a sincronizării între linia de asamblare/dezasamblare şi sistemele robotice în vederea sincronizării. Realizarea interfeţei pentru monitorizarea evenimentelor şi a conducerii.
Activitatea 2.2: Inplementarea in timp real a structurii de conducere a acelor doua sisteme robotice colaborative, deservind linia de mecatronica
Activitatea 2.3: Testarea in timp real a sistemelor servoing vizuale.
Activitatea 2.4: Diseminare rezultate

Echilibrarea si conducerea în timp real şi echilibrarea liniei de mecatronică, de asamblare /dezasamblare, Hera&Horstmann deservita de doua sisteme robotice, robotul mobil Pioneer 3–DX echipat cu manipulatorul Pioneer 5-DOF Arm (Fig. 10, 11, 12 si 13), folosit pentru manipulare piese si robotul mobil PatrolBot folosit pentru transportul pieselor, s-a facut pe baza modelului SHPN (sincronied hybrid Petri nets) iar sincronizarea dintre linia de mecatronica si platforma mobila echipata cu manipulator s-a facut pe baza semnalelor provenite de la senzori si a unui system servoing visual, cu video camera fixa instalata pe statia de depozitare a sistemului de mecatronica. Conducerea plataformelor mobile pentru transportul pieselor care necesita reprelucrare s-a facut cu o metoda sliding-mode, bazata pe modelul cinematic.

Echilibrarea si conducerea liniei de mecatronica de asamblare /dezasamblare, Hera&Horstmann cu supervizorul implementat in in visual C++ face obiectul unui articol prezentat la 2015 19th International Conference on System Theory, Control and Computing (ICSTCC2015), Two Mobile Robotic Systems Synchronous Servicing an Assembly/Disassembly Production Line autori: Adriana Serbencu, Adrian Serbencu

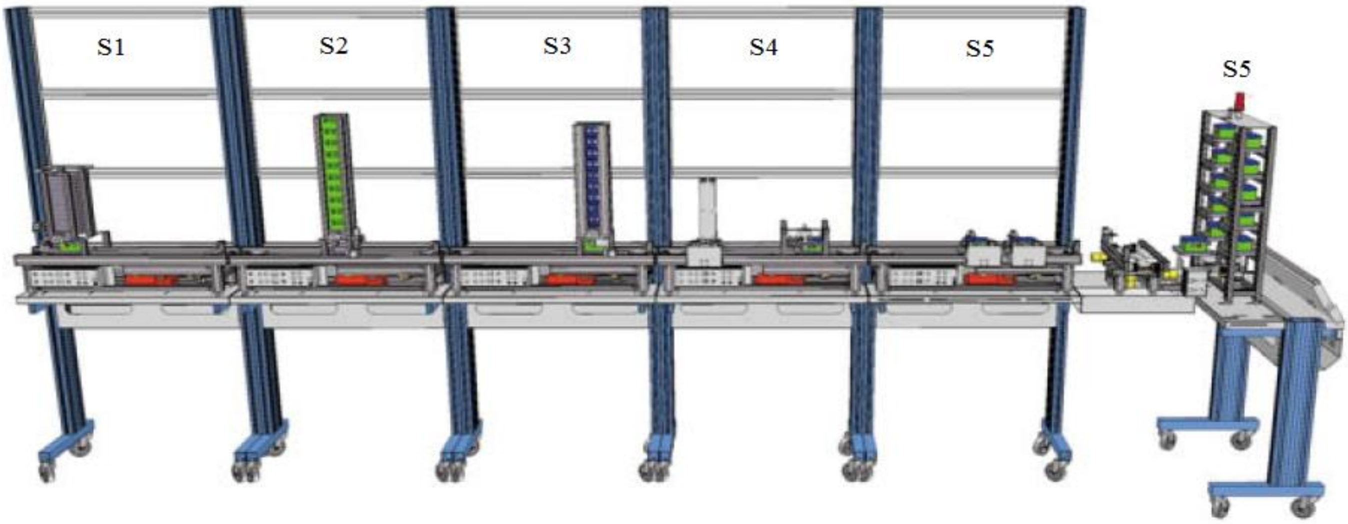

Fig. 10. Linia de mecatronica Hera&Horstmann, statiile de asamblare/dezasamblare, statia de depozitare

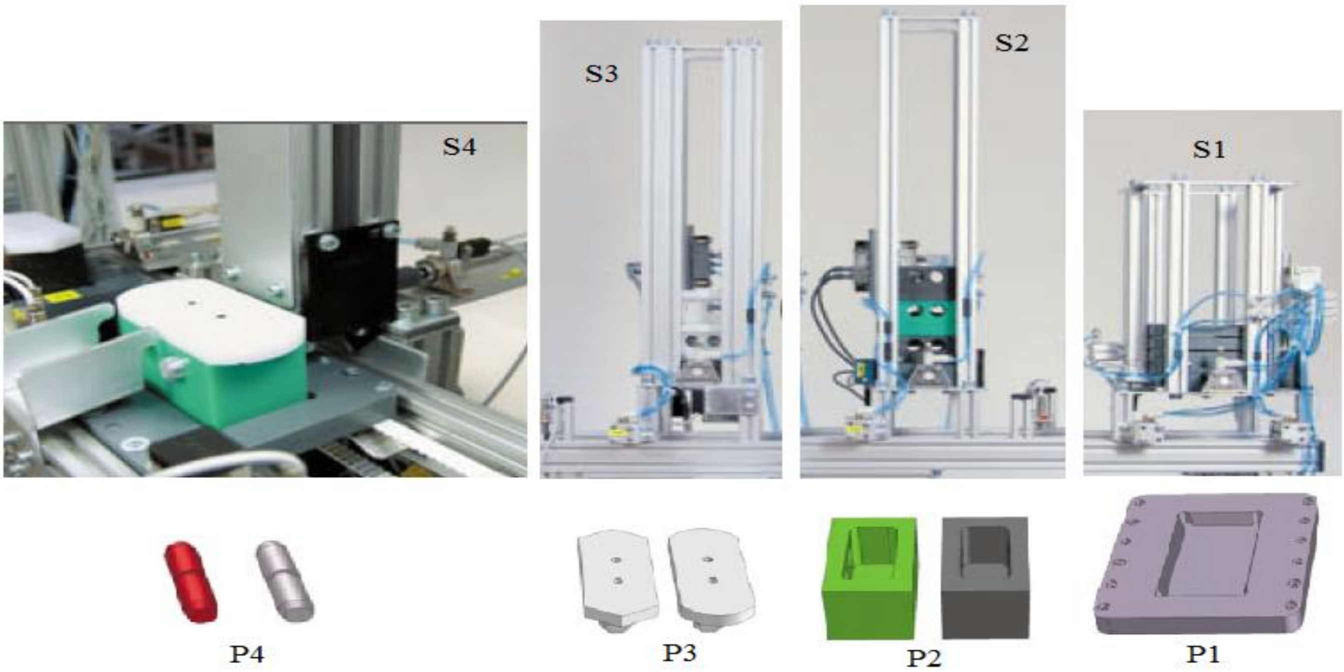

Fig.11. Linia de mcatronica Hera&Horstmann, magaziile de depozitare, componentele care se asambleaza

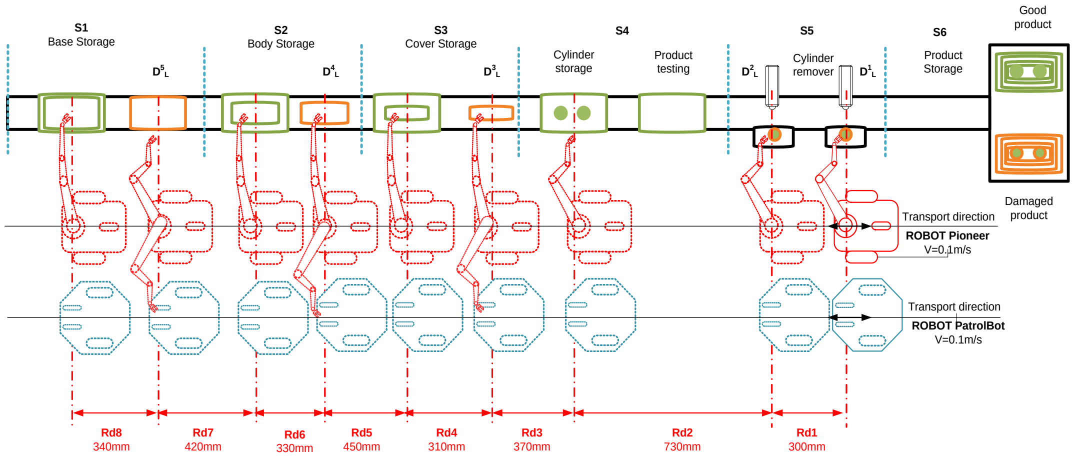

Figure 12. Two mobile robots servicing the disassembly operation on an ADML with five workstation

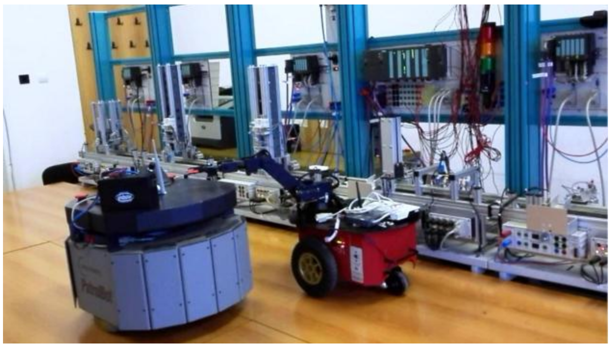

Figure13. The two mobile robots loading reusable components in corresponding warehouse.

ASSEMBLING/DISASSEMBLING LINE BALANCING (A/DLB) MODEL

This section presents a model used to find an optimum solution for the A/DLB problem. Due to assumptions A.1 and A. 2, it may be considered that, in terms of the assembly process, the line is balanced. Consequently, the assembly line balancing (ALB) problem is solved implicitly. Because the disassembly process implies the use of the two WMR, the disassembly line balancing (DLB) problem must be solved.

Disassembly tasks

Let M be the total number of tasks required for the disassembly of a product, and M_c the number of tasks per cycle (period).

The tasks associated with a cycle, $TC_i, i = \overline{1, M_c}$ are:

TC_1 – Transport product on the line (using conveyor); TC_2 – Release disassembled component; TC_3 – MRM positioning at disassembly location; TC_4 – Grip disassembled component; TC_5 – Start line; TC_6 – MRM load component on WMRT displacement; TC_7 – MRM positioning for displacement; TC_8 – MRM displacement from disassembled location to storage warehouse; TC_9 – WMRT displacement from disassembled location to storage warehouse; TC_{10} – MRM unload component from WMRT displacement; TC_{11} – MRM positioning at storage warehouse location; TC_{12} – Store the component in warehouse; TC_{13} – RM positioning for WMR displacement TC_{14} – MRM displacement from storage warehouse to the next disassembled location; TC_{15} – WMRT displacement from storage warehouse to the next disassembled location;

Remark 2: It must be take into account that part of the task are executing in parallel.

	TC2	TC5	TC1…					
TC3	TC4	TC6	TC7	TC8	TC10	TC11	TC12	TC14
				TC9				TC15

DLB optimization problem criterion

Let CT be the maximum cycle time allowed for any cycle;

Let t_{ij}, $i=\overline{1,M}$, $j=\overline{1,M_c}$ be the processing time of task i from cycle j; hence t_{ij} is the processing time of task TC_{ij}.

Let d_j be the demand of the component released by task T_{ij} in cycle j;

Let NR_j be the net revenue of task TC_{ij}, i.e. the difference between the revenue obtained by releasing a component and the cost of the tasks associated with its releasing

$$NR_{ij} = R_j - \sum_{i=1}^{M} C_{ij} ,$$

where R_j is the revenue corresponding to component j and C_{ij} is the cost of task TC_{ij}. If task TC_{ij} does not release a reusable component then $R_j = 0$.

Let DV_{ijk}, $i=\overline{1,M}$, $j=\overline{1,N}$, $k=\overline{1,N}$ be the decision variables, which are assignments of tasks to work stations in each period. These assignments are explained by the following decision variables: if task i is assigned to work station j in cycle k, then $DV_{ijk}=1$. Otherwise, $DV_{ijk}=0$.

The following constraints hold:

C.1: The demand of the component releasing tasks should be satisfied

$$\sum_{j=1}^{N}\sum_{k=1}^{N} DV_{ijk} \geq d, i=\overline{1,M}, d=\sum_{i=1}^{M}\sum_{j=1}^{M_c} d_{ij} .$$

C. 2: The cycle time limit should not be exceeded considering also observation from Remark 2.

$$\sum_{i=1}^{M} t_{ij} DV_{ijk} \leq CT, \forall j, \forall k .$$

C.3: A task can be assigned to at most one station in each period

$$\sum_{j=1}^{N} DV_{ijk} \leq 1, i=\overline{1,M}, k=\overline{1,N} \quad (4)$$

C. 4: The decision variable should be non-negative since /it is binary, implying the assignment of each task to the work stations in each period

$$DV_{ijk} \geq 0, i=\overline{1,M}, j=\overline{1,N}, k=\overline{1,N} .$$

The target function of the DLB optimum problem, subject of constraints C. 1, C. 2, C. 3 and C.4, has to maximize the sum of net revenue obtained by each executed task

$$J_{DLB} = Max\sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{N} NR_{ij} DV_{ijk} .$$

A/DML served by cooperative robots

Hardware description

The general approach is exemplified on a laboratory mechatronic A/DML with five workstation produced by Hera&Horstmann (see Fig. 10). This laboratory line is controlled with a Siemens PLC and is assembling products using 5 components shown in Fig 11 si 13. During disassembly process the line is served by two WMR: a mobile robotic manipulator (MR) fixed on a Pionee3-DX and a wheeled mobile robot transporter (WMRT) represented by a PatrolBot, both produced by MobileRobots. The two robots have odometric systems, and their moving is based on two driving wheels and one respectively two free rear wheels. Each robot has an on-board embedded system able to rapport current position, to move to a target position and to fallow a trajectory transmitted by a supervisor. The Pionee3-DX is equipped with a RM with three articulations and one gripper paddle.

Software description

The supervisor application is implemented on a desktop computer and is responsible to plan the disassembling operation at optimum moment. In our laboratory application, the supervisor communicates with mobile robots through TCP/IP protocol and with A/DML through a data acquisition board connected to desktop paired with few digital IO on PLC. On an industrial application the communication with A/DML should take place also over TCP/IP and using an OPC server. In the case that more WMRs are available the supervisor application should select a pair. The supervisor application will allocate tasks to them with position to be achieved and operation to be completed. After that, the supervisor will mediate the synchronization signals and will monitories the disassembly evolution. The communication between software entities is presented in Fig. 14. A capture of the graphical interface is shown in Fig.15. HPN model of A/DML served by cooperative robots is shown in Fig. 16.

The HPN model is used to model the evolution of the considered hybrid system. This model permits the design and the analysis of the synchronization protocol that should be implemented for real-time control of the A/DML and of the two WMRs. The HPN model corresponding to an elementary disassembly cycle is presented in Fig. 16. In this HPN, the WMRT is modeled by place and transition grouped in the left. The WMR equipped with RM is modeled by the place grouped in center and the A/DML by the discrete place and transition grouped in the right. There are arcs which pass from one group to other. These arcs model synchronization messages that are transmitted between A/DML and WMRs. In order to develop control algorithms from presented HPN, this must be converted in a model in form of an automata. For PN, TPN and SPN there are algorithms that can support this conversion. For special cases of HPN[8], there are also developed methodologies to transform HPN in hybrid automata. One assumption required in [8] is not met by HPNs corresponding to the WMRs such that we must base on the particular simple structure of our HPN to transform it in an automata model to support the real-time control.

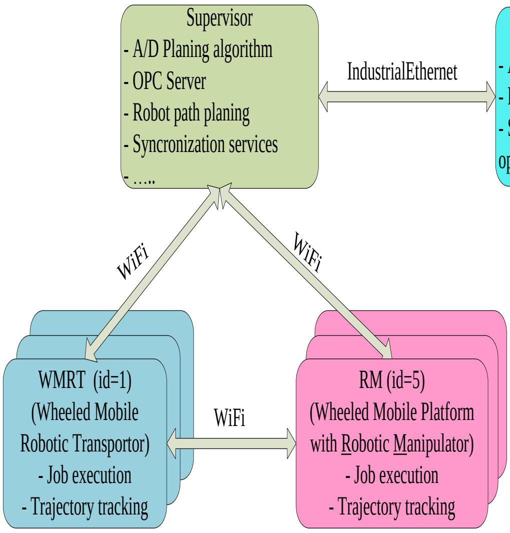

Figure 14. Software configuration of the real time controller for Hera A/DML

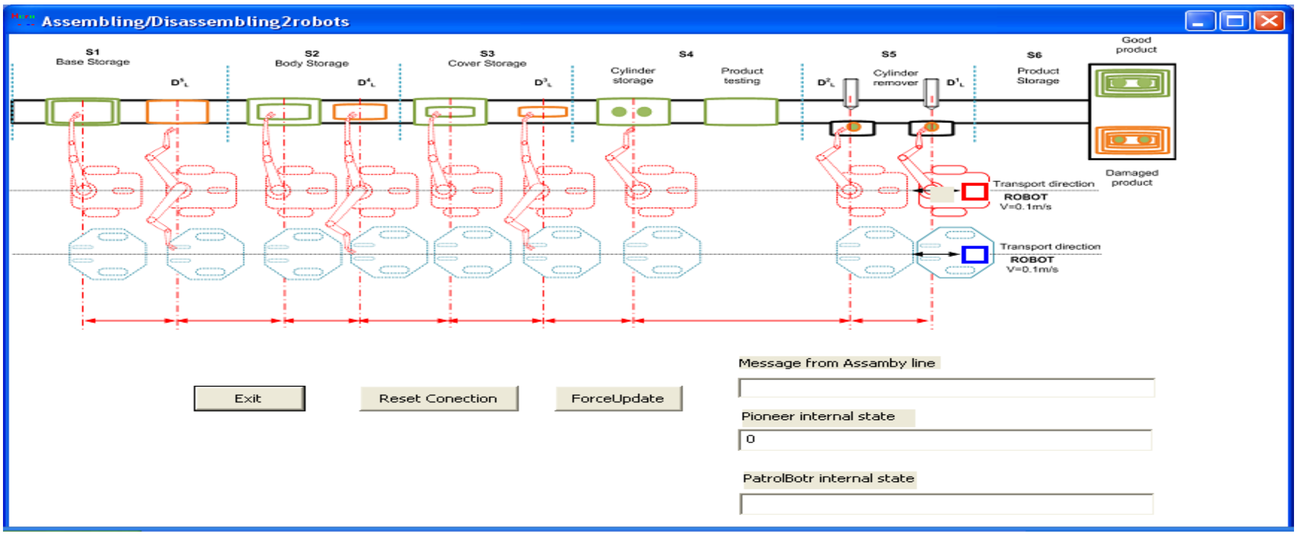

Figure 15. Graphical user interface of Visual C++ application.

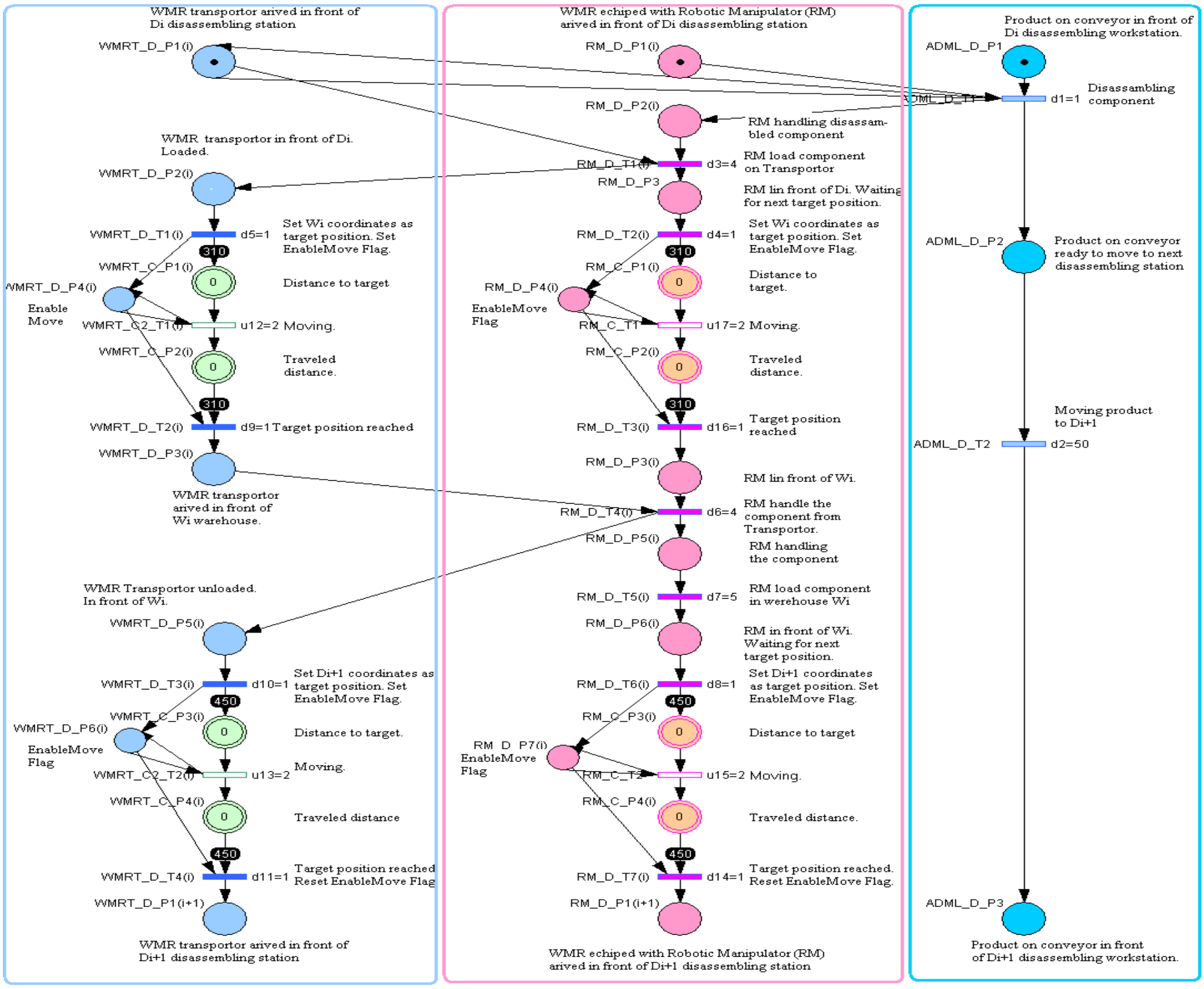

Figure 16. The HPN model for the *i*th elementary disassembly operation

OB 3) Conducerea în timp real si echilibrarea liniei de prelucrare/reprelucrare FESTO-MPS. Conducerea sliding-mode a doua sisteme robotice autonome care deservesc linia pentru procesul de reprelucrare: Pioneer 3-DX (2DW/1FW) echipat cu manipulatorul Pioneer 5-DOF Arm, utilizat pentru transport şi PatrolBot (2DW/2FW) echipat cu manipulatorul 5-DOF Cyton Premium, utilizat pentru transport. Implementarea in timp real a sistemului servoing vizual pentru manipulatoarele Pioneer si/sau Cyton.

Activitatea 3.1: Realizarea compatibilităţii hardware şi a sincronizării între linia de prelucrare/reprelucrare şi sistemele robotice.

Activitatea 3.2: Realizarea interfeţei pentru monitorizarea evenimentelor şi a conducerii. Testarea in timp real a sistemelor servoing vizual.

Activitatea 3.3: Diseminare rezultate

S-a proiectat supervizorul in Labview pentru linia de mecatronica de prelucrare/reprelucare FESTO MPS-200 deservita doua paltforme, Pioneer 3-DX si PatrolBot sau Peoplebot.

Platforma mobila Pioneer 3-DX este echipata cu manipulatorul Pioneer 5-DOF Arm, este utilizata la preluarea de pe statia de depozitare a pieselor care necesita reprelucrare sau rebutare si depozitarea pe platforma robotului mobil PatrolBot sau PeopleBot pentru a fi trasportate la inceputul liniei, la statia de manipulare (handling)(Fig.18). Platforma PeopleBot are montat manipulatorul Cyton.6-DOF Cyton 2 Premium P-Series Robot Arm. Sincronizarea dintre linia de mecatronica si robotul mobil Pioneer 3-DX se face cu ajutorul unui sistem servoing vizual cu camera fixa. Pozitionarea platformei mobile si a manipulatorului pentru a prelua piesa este facuta pe baza prelucrarii de imagine, imagine furnizata de o camera postata la sfarsitul liniei de mecatronica, pe statia de depozitare si sortare. Transportul la inceputul liniei al piesei care este supusa la reprelucare se face cu robotul mobil PeopleBot cu ajutorul unui algoritm de conducere sliding-mode. Depozitarea piesei pe statia de manipulare este facuta cu manipulatorul robotic Cyton.6-DOF Cyton 2 Premium P-Series Robot Arm (Fig. 17).

Platforma mobila Pioneer 3-DX este echipata cu manipulatorul Pioneer 5-DOF Arm, fiind utilizata la preluarea de pe statia de depozitare a pieselor care necesita reprelucrare sau rebutare si depozitarea pe platforma superioara a robotului mobil PeopleBot pentru a fi trasportata la inceputul liniei, la statia de manipulare (handling).Manipulatorul robotic 6-DOF Cyton 2 Premium P-Series Robot Arm este montat in pozitie fixa la inceputul liniei de mecatronica si este utilizat pentru preluarea pieselor de pe paltforma superioara a platformei mobile PeopleBot si a le pozitiona pe statia de manipulare pentru a fi reintroduse in procesul de prelucrare sau a fi rebutate (Fig.18).

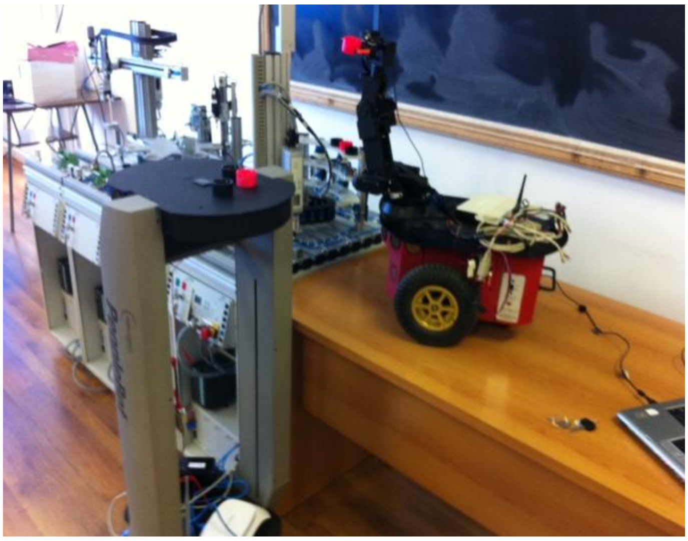

Fig. 17. Linia de mecatronica Festo MPS-200 deservita de doua platforme mobile

Conducerea platformelor mobile cu algoritm de evitare de obstacole a fost diseminata prin lucrarea :

Filipescu, A., Minca E., Voda A., Dumitrascu B., Filipescu A., Jr., Ciubucciu G., Sliding-Mode Control and Sonnar Based Bubble Rebound Obstacle Avoidance for a WMR, Proceedings of the 19th IEEE, International Conference on System Theory, Control and Computing, ICSTCC 2015 14-16, Oct. Cheile Gradistei, Romania, 2015, pp.105-110, ISBN: 978-1-4799-8481-7©2015 IEEE.

Fig. 18. Linia de mecatronica FESTO MPS-200 deservita de platformele mobile: Pioneer 3-DX (echipata cu manipulatorul Pioneer) si PeopleBot utilizata pentru transport

In 2015 rezultatele au fost disseminate prin urmatoarele articole publicate, indexate IEEE Xplore si in curs de indexare ISI Thomson:

Razvan Solea, **Adrian Filipescu**, Adriana Filipescu Jr. Eugenia Minca, Silviu Filipescu, Wheelchair Control and Navigation Based on Kinematic Model and Iris Movement, Proceedings of the 2015 7th IEEE International Conference on Robotics,Automation and Mechatronics (CIS&RAM), 15 – 17 July 2015, Angkor Wat, Cambodia, IEEE Catalog Number: CFP15835-CDR, ISBN: 978-1-4673-7336-4, pp:78-83.

Minca E., Filipescu, A., Dragomir O., Coanda, H., G., Dragomir F., Cycle Time Optimization of a Reversible A/DML Served by a Mobile Robotic System, Proceedings of the 19th IEEE, International Conference on System Theory, Control and Computing, ICSTCC 2015 14-16, Oct. Cheile Gradistei, Romania, 2015, pp.99-104, ISBN: 978-1-4799-8481-7©2015 IEEE.

Filipescu, A., Minca E., Voda A., Dumitrascu B., Filipescu A., Jr., Ciubucciu G., Sliding-Mode Control and Sonnar Based Bubble Rebound Obstacle Avoidance for a WMR, Proceedings of the 19th IEEE, International Conference on System Theory, Control and Computing, ICSTCC 2015 14-16, Oct. Cheile Gradistei, Romania, 2015, pp.105-110, ISBN: 978-1-4799-8481-7©2015 IEEE.

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Conf. Dr. Ing. Alina Vodă

A Voda