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STUDY AND DESIGN OF AN AUTOMATED PALLET SYSTEM

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ABSTRACT

The need to increase efficiency, reliability and work capacity becomes a priority in small and large companies. High-level automation entails minimizing human labor and the human factor itself, but it still needs monitoring, surveillance, and inspection through human action. An automated system is much more efficient, its degree of repeatability being definitely a much higher one. The palletizing process used before the development of the automated pallet system implied in a 90% percentage the human factor through a human-machine cooperation, and the only automated mechanisms used were the conveyor belts and a mechanism for fixing the lid of the products transported on the belt. Thus, the industrial handling robot used in the automated pallet process becomes an essential resource, much faster.

Keywords: robotic process automation**,** flexible manufacturing system**,** pallet systems.

INTRODUCTION

The present tendency of automating industrial processes is on the rise, due to the benefits brought by reduced costs, quality improvement, efficiency growth, as well as to production processes optimization.

Robotic Process Automation (RPA) [1] is a frecquently used notion regarding the impact of replacing the human factor by a robotic software resource; robots replace several workstations that imply recurrent tasks, but their role will remain limited to that, whereas human activity is indispensable. Nevertheless, the advantages of automation are obvious: automated systems are much more accurate, robots are more rapid and lasting. Another major advantage of industrial automation is the improvement of the employees safety, particularly for increased risk degree environments.

Between 1966-1972, Stanford Research Institute developed the first general-purpose mobile robot, Shakey, based on AI techniques (Fig. 1), that could recognise objects using an artificial optic system, found trajectories towards a specific target and performed simple activities. In 1970, General Motors becomes the first company that used „Consight”, a vision controlled robot system, in an industrial application, and in 1987 Unimation developed the first PUMA (Programmable Universal Machine for Assembly) robot (Fig. 2.). Nowadays, „cobots”- collaborative robots (Fig.3) - are designed to work along human operators; they can have multiple utilities as service robots for domestic and for professional use. ABI Research Institute stated that, by 2030, cobot market will exceed $11.8 billion [4].

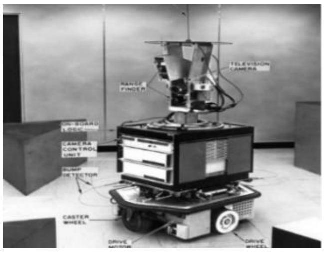

Figure 1. Shakey mobile robot [2]

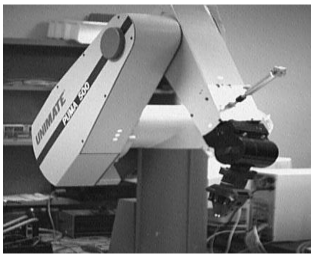

Figure 2. PUMA 500 [3]

Figure 3. Collaborative robot [4]

A flexible manufacturing system (FMS) uses an efficient technology based on the following components [5]: workstations, automated handling and storage system, computerized control system, and human resources. In order to implement FMS, one has to use industrial robots that perform handling, transport and displacement operations, by means of controlled speed, positioning, and forces. The related scientific literature [1-13] presents results of experimental researches related to applications of FMS, as well as to specific challenges and issues for their efficiency, reliability and working capabilities, that allow superior operational performances.

Considering the opportunity and modernity of this topic, the paper presents a case study regarding an automated pallet system for use with robot: the design of the system, the structure of the logic programming, and the development of the robotic software.

THE AUTOMATED PALLET SYSTEM

An automated pallet handling system is an FMS software-controlled system that replaces manual storage and retrieval processes with automated ones. These systems are used in a wide range of industrial applications, such as:

- Packing bottles in cardboard boxes, with up to 7000-8000 bottles/h (Fig. 4a), with custom configuration for higher rates;
- Palletizing 5kg – 10kg pasta bags (400-600 bags/h), as seen in Fig. 4b;
- Palletizing semi-finished wood products (Fig. 4c) that serves an assembly line with a dedicated robot equiped with a vacuumatic gripper.

a *b* *c*

Figure 4. Automated pallet systems for semi-finished wood products [14]
a. packing bottles in boxes; b. palletizing pasta bags; c. palletizing semi-finished wood products

The pallet handling lines are groups of devices including interconnected conveyors used to transport both empty and loaded pallets. The automated pallet handling system optimizes the processes of moving, accumulation, and distribution of products transported on various types of pallets. Industrial robots used in these systems have 2 - 6 degrees of freedom used in order to perform complex operations, and are relatively autonomous, being endowed with a programmable memory able of data storage. The architecture of a robot system is presented in Fig. 5.

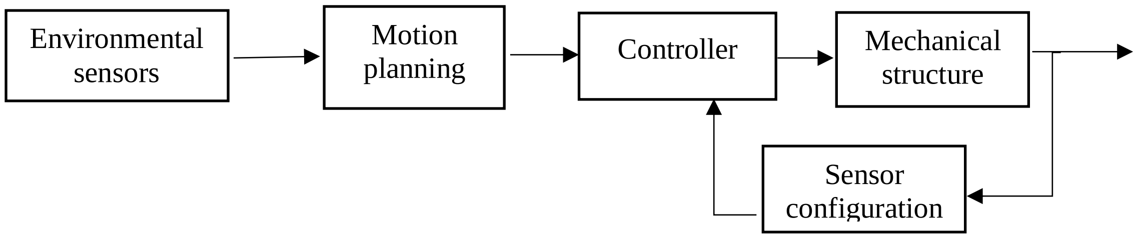

Figure 5. Architectural structure of a robot system

Considering these, the components of the proposed automated pallet handling system are:

1. A PLC (programmable logic controller) - digital electronic system for industrial environments that uses a programmable memory for internal storage of the instructions that implement functions controlling different types of machines and processes;
2. A handling robotic arm type ABB IRB 660, with 4 degrees of freedom, a 3,15 meters beat, a 250 kg task, ideal for palleting. The robot is equipped with an IRC5 controller and a RobotWare software package, that ensures motion control, development and actuation of application programs, and communication;
3. A supervizing safety system that implements safety applications reffering to machines performing elementary functions and interconnected devices allowing control for both automated functions and for safety functions. A PAS4000 software platform is used for programming and setting the PSSuniversal PLC and the PSSuniversal multi controllers. The protection devices include electrosensitive protection equipments (ESPE) with optic sensors, security laser scanners, and camera-based protection systems.

IMPLEMENTATION OF THE PROPOSED SOLUTION FOR THE AUTOMATED PALLET SYSTEM

Implementing PLC operational logic

The “brain” of the entire system is a S7-300 (SIEMENS) programmable automaton, with 3 digital input modules (DI) and 3 digital output modules (DO). The communication of analog data is performed using PROFIBUS communication protocol, and the programmable logic used is GRAFCET (**Gra**phe **F**onctionnel de **C**ommande des **É**tapes et **T**ransitions) [13], that allows operational description of any sequential process by means of a sequence of stages that generate actions (commands).

The programming requirement presumes palletizing buckets of different sizes, based on predetermined frames, named as follows: JET 44; JET 56; JET 70; JET 86; JET 110; JET 150; JET 180; JET 210. JET 44 - JET 86 products are transported on the A Line, JET 150 - JET 210 products, of bigger size, on B Line, and JET 110 product will be transported on both lines, as required. For all these products there are palletizing „scripts": EUROPALET form of 1200 X 800 X 150mm dimensions, and EUROPALET form of 1200 X 1000 X 150mm dimensions (Fig.6).

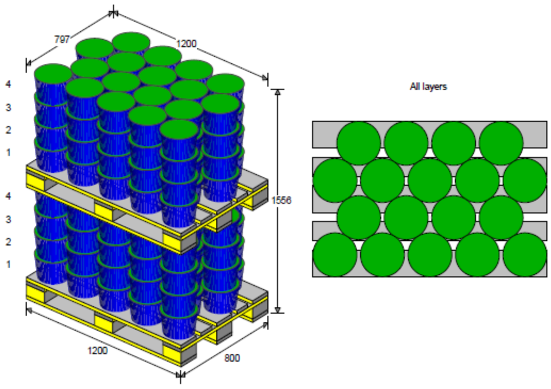

Figure 6. Palletizing JET 44 product on EUROPALET frame 1200 X 800 X 150mm

Between the PLC and the robot controller has been implemented a continuous bidirectional data communication logic: PLC sends data to the robot controller (Fig.7) and waits for an acknowledge message, and reciprocal, thus being performed a program structure specific to the palletizing script.

PLC TO ROBOT

Q85.0		REQUEST AUTO ABB	DI10_8
Q85.1		REQUEST MAN ABB	DI10_9
Q85.2		EMERGENCY STOP PLC	DI10_10
Q85.3		STATIE PALETIZARE IN AUTOMAT	DI10_11
Q85.4		START ABB PROCES LINIA "A"	DI10_12
Q85.5		START ABB PROCES LINIA "B"	DI10_13
Q85.6		CONFIRMARE POZITIE GRIPPER	DI10_14
Q85.7		SAFETY GRIPPER	DI10_15
QW86		NUMAR CURENT CICLU LINIA "A"	NR_CICLU_L1
QW88		NUMAR CURENT STRAT LINIA "A"	NR_STRAT_L1
FUNCTIE ROBOT QW90	0...10	0=INACTIV 1=HOME POZITION 2=MAINTENANCE POZITION 3=ASEZARE PALET L1 4=ASEZARE PACHET L1 5=ASEZARE FOLIE L1 6=ASEZARE PALET L2 7=ASEZARE PACHET L2 8=ASEZARE FOLIE L2	FUNCTIE _ROBOT
GO TO POSITION QW92	1...4	1=HOME POZITION 2=MAINTENANCE 3=EXECUTA FUNCTIE LA L1 4=EXECUTA FUNCTIE LA L2	GO_TO_POSITION
COD RETETA L1 QW94	1..20	NUMAR IDENTIFICARE RETETA LINIA "A"	COD_RETETA_L1
COD RETETA L2 QW96	1...20	NUMAR IDENTIFICARE RETETA LINIA "B"	COD_RETETA_L2
QW98		NUMAR CURENT CICLU LINIA "B"	NR_CICLU_L2
QW100		NUMAR CURENT STRAT LINIA "B"	NR_STRAT_L2
QW102		NUMAR PALETI DIN MAGAZIE	NR_PALETI
QW104		NUMAR ETAPA PROCES LINIA "A"	NR_PROC_L1
QW106		NUMAR ETAPA PROCES LINIA "B"	NR_PROC_L2
Q108.0		LINIA "A" IN AUTO	DI10_192
Q108.1		LINIA "B" IN AUTO	DI10_193
Q108.2		SENZOR ULTRASONIC	DI10_194
Q108.3		SENZOR DETECTIE OBIECT	DI10_195
QB110		NUMAR TOTAL DE STRATURI DIN RETETA LINIA "A"	
QB111		NUMAR TOTAL DE STRATURI DIN RETETA LINIA "B"	
QB112		NUMAR TOTAL DE CICLURI / STRATURI DIN RETETA LINIA "A"	
QB113		NUMAR TOTAL DE CICLURI / STRATURI DIN RETETA LINIA "B"	

Figure 7. PLC – robot controller data transmission

An example of a GRAFCET program section is presented in Fig. 8., regarding the palletizing process on A Line, structured as a function (FC) with adress number 25 in the PLC memory.

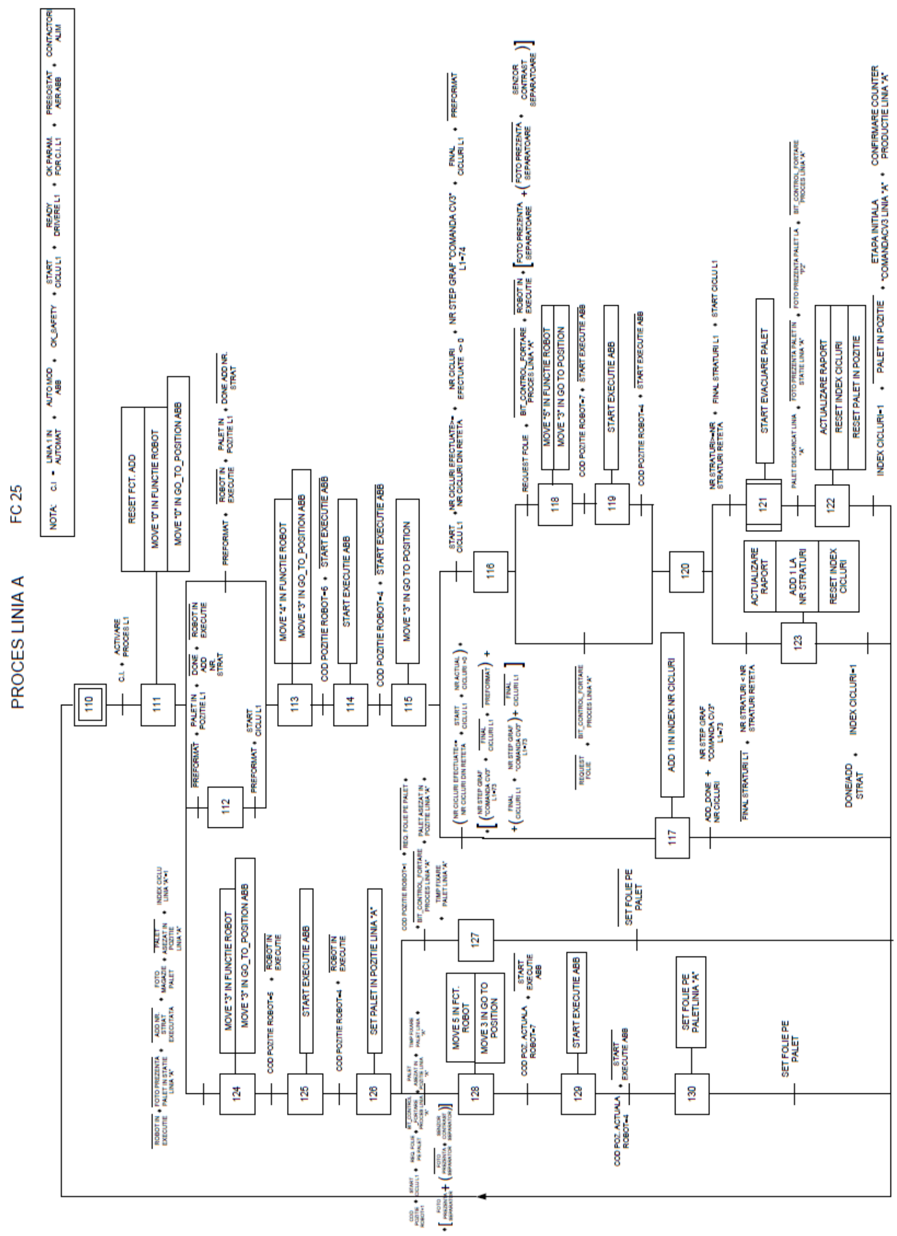

Figure 8. GRAFCET structure for the palletizing process program on A Line

Implementing robot manipulator operational logic

The development and implementation of the robot manipulator operation is performed using the RobotStudio software package. A 3D model of the entire automated pallet system for a first cycle simulation is presented in Fig. 9.

After implementing the 3D automated pallet system model, the coordinates of each position of the robot trajectory are chosen by selecting the so-called endpoints of the robot manipulator gripper, namely the “targets”. The displacement between two points is a “path” on a strict linear or joints trajectory, performed using the degrees of freedom of the robot.

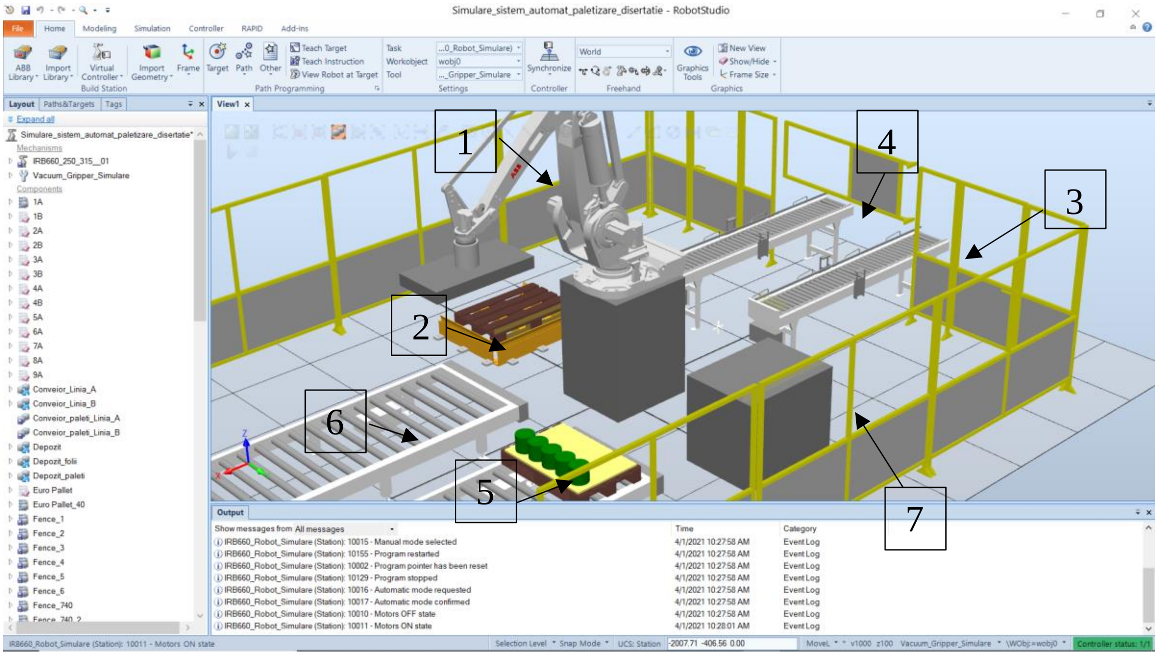

Figure 9. 3D model of the automated pallet system:
1. IRB 660 handling robot; 2. Pallet stockpile; 3. Flexible line feeding conveyor for Line A; 4. Flexible line feeding conveyor for Line B; 5. Transportation conveyor for loaded pallets A Line; 6. Transportation conveyor for loaded pallets B Line; 7. Protection foil stockpile.

Using “Synchronize to RAPID” option, all the selected memorized points are transferred to the robot manipulator programming language, thus being developed all the specific functions (Fig.10).

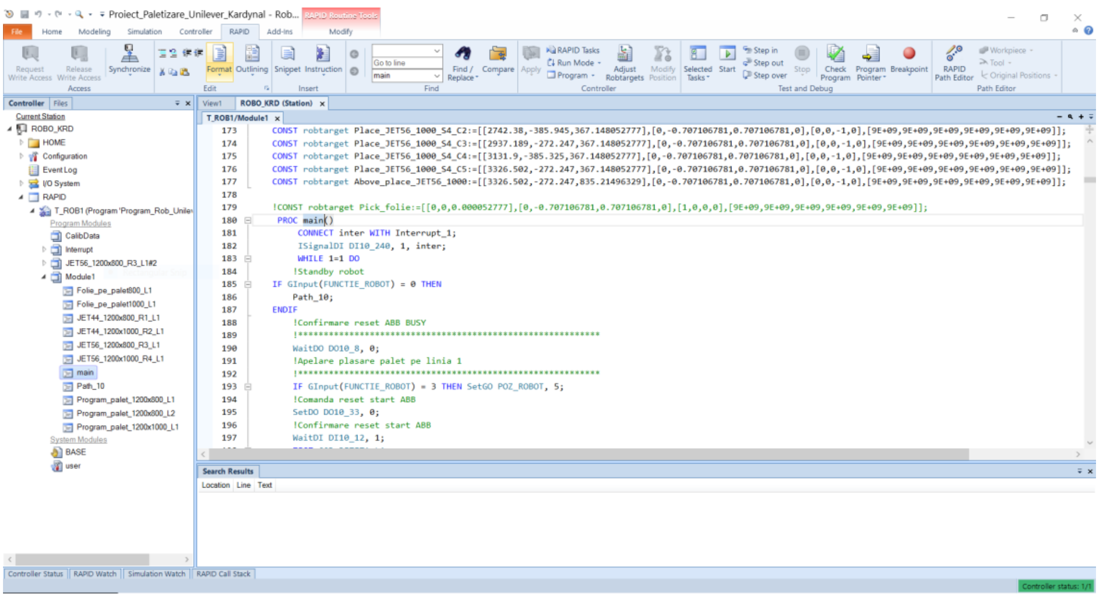

Figure 10. RAPID section (implementation of the manipulator robot program)

Specific codes are assigned to different program modules; RobotStudio uses a selectivity function based on these codes, as presented in the following example.

TEST CODE_SCRIPT_L1

CASE 1, 3, 5, 7, 8, 9:

Program_pallet_1200x800_L1;

CASE 2, 4, 6, 10, 11:

Program_pallet_1200x1000_L1;

ENDTEST

Each program module that represents a pallet script has a code, transmitted by PLC and identified in the robot memory. Thus, when *CODE_SCRIPT_L1* has the values 1, 3, 5, 7, 8 or 9, it will be selected the program module specific for take over and positioning the EUROPALET 1200X800X150mm; for the other values, another program module will be selected, specific to EUROPALET 1200X1000X150mm.

In order to take over the objects, a search function is used, based on establishing a set point for the search operation following a linear trajectory until the gripper's proximity sensor detects the presence of an object, as follows:

Search_Palet_800 := Offs (Pick_palet800_1, 0, 0, -1310);

WaitTime 1;

SearchL \PStop, DI10_194, searchP, Search_Palet_800, v100, Vacuum_Gripper_Unilever\WObj:=Palet_1200x800_L1

After on line performing the program and testing the coherence in operation by simulation using RobotStudio, the program is downloaded in the robot controller in order to obtain the validation of the equipments performances in compliance with the simulation.

CONCLUSION

The topic of the presented paper can be considered an example of the transformation that is taking place in industrial processes, the staging transit from a pallet system initially performed with predominant human effort to an automated centralized system having a high degree of efficiency.

The initial palletizing process involved in a high degree the human factor through a human-machine cooperation, as the only automated mechanisms were the conveyor belts and a mechanism for fixing the lid of the products transported on the belt. Otherwise, the palletizing mechanism of the products was strictly human conducted, the employees being the ones who took over product by product, and placed each product separately on the pallet. The industrial handling robot used in the proposed automated pallet system thus becomes an essential resource, much faster and safer.

An important factor remains the cost of automating such a process; for the automated pallet system presented in this paper one has mostly used the already existing equipment, while the system program was almost completely changed. Even so, the automated pallet system can not ensure a maximum degree of efficiency, because of the very nature of the product to be palletized, its shape entailing an extremely low probability of repeatability of the position per palletizing cycle.

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