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EDUCATIONAL OPPORTUNITIES OF E-LEARNING IN RENDERING DIDACTIC ACTIVITIES MORE EFFICIENT REFLECTED IN THE USE OF THE ADEPT COBRA E-VARIO ROBOT

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***Abstract**: The emergence of e-learning in the contemporary educational environment (as viable alternative to traditional education methods) is able to develop the inquiring-creative spirit to improve the quality of learning experiences, to ensure the conversion of scientific research results into e-contents. The authors of this paper intend to highlight the fact that the presence of the Adept Cobra E-Vario robot within the Research Centre for Management and Technology – The Advanced Logistic Technologies Laboratory of the "Nicolae Bălcescu" Land Forces Academy from Sibiu, as a result of research grant no.59/2010, is in a position to contribute to the harmonization of theoretical approaches to practical-applicative ones, to increase the level of performance, to exploit the creative potential and, last but not least, to emphasize the necessity and utility of transposing scientific research findings in the field of educational activities. In addition, the authors aim to bring to the attention a case study on the deformations that can occur in the modules composing the robot under study during its operation within a flexible work cell with a parallel organization. Based on the calculation of efforts, diagrams and emerging requests in the mechanical structure of the robot during its operation in dynamic mode, using finite element design software's, ways to improve and functionally optimize the robot during its activity will be determined. This paper is also a mouthpiece for the authors intention to designate a way in which contemporary technological realities can contribute to the shaping of a favourable environment for the educational endeavour, enrolling in the direction of promoting good practice examples in the realm of science and education, respectively.*

***Keywords:** efficiency, e-learning, robotics, optimization, creativity.*

I. ASPECTS ON THE IMPLEMENTATION OF THE *E-ROBMILCAP* EDUCATIONAL MODULE

One of the pillars underpinning a modern didactic approach is represented, among others, by the use of advanced logistics technologies implemented in flexible work cells within instructive educational activities. In a world of systems of systems, going from simple to complex or from part to whole, as existing relation, both theoretically and practically, between the robotic technology and the logistics system, we consider the following to be defining features for design in order to ensure the optimum robotic equipments capabilities: the appropriate sizing of the informational system and of the hierarchical computer control system, in order to achieve an optimal balance between the degree of centralization and that of decentralization, so as to minimize damage caused by some possible malfunctions; effectively matching the level of robotic equipments precision to performance indicators provided in regulations, rules, standards for the entire logistics system; using the mathematical tool (the graph theory, the queuing theory etc.) appropriate for the construction of models and the assay of the flexible work cells serviced by didactic robots profitability; the use of specialized sensors for dimensional control, the identification of components and the test of accuracy in terms of assembling and potential malfunctions diagnosis, investigation and adjustment to the targeted solution of all four main categories of the industrial robot's causes (geometric, kinematic and dynamic).

The flexible work cell serviced by the industrial robot, that highly technical automated system involved in handling, sorting and arranging components, represents an evolved manufacturing system not only because it is the latest concept developed in the production of material goods but especially because it lead to an important improvement in the economic efficiency of the manufacturing process.

The authors' concerns in areas such as: industrial robotics, mechanical engineering, design and pedagogy, have led to the design and implementation of a flexible work cell serviced by the Adept e-Vario robot, as well as to the creation of the *e-Robmilcap* application, which meet the requirements of *Management and Technology*, a master's degree programme, part of the military higher education, developed by the "Nicolae Bălcescu" Land Forces Academy from Sibiu, beneficiaries by means of: compliance with and fathoming of didactic principles (systematisation of knowledge, linking theory to practice, the principle of intuition, the accessibility principle and the principle of learning outcomes), the needs and interests of students, complete and correct formulation of objectives and the selection of active teaching methods appropriate in the case of e-learning (observation, practice, simulation, design, demonstration, discovery learning etc.).

Why all these? One possible answer could be that e-learning has established itself as modern and efficient means in our country, as well, where there are public and private initiatives aimed at introducing this teaching tool in the educational system, but also in the vocational training one. At this point, the only ones that can develop e-learning courses are those who have specific technical possibilities and knowledge, while novice users (beginner teachers, trainers, trainees etc.), do not benefit from the tool enabling the creation and dissemination of electronic content.

II. SOLUTION FOR THE MODERNIZATION OF THE DIDACTIC ACTIVITY THROUGH THE IMPLEMENTATION OF THE E-VARIO ADEPT ROBOT WITHIN A FLEXIBLE WORK CELLS

Figure 1 illustrates the 3D model of the Adept e-Vario robot possessing in its kinematic chain structure four degrees of freedom, consisting of the following modules: basic module 1 represented by the J_1 rotation joint with the role of arm movement along this axis; robotic arm 2 represented by the J_2 rotation joint with the role of orientation module movement along this axis; orientation module 3 with the translation joint formed by the screw-nut mechanism in its structure, which translates around the J_3 axis; prehension device 4 that is attached to the screw-nut mechanism by screws and has the role of gripping and manipulating various components, hence performing a rotation movement around the J_4 axis. Worth noticing is that the first two robotic modules (the basic module and the robotic arm) are driven by electrical DC motors, while both the screw-nut mechanism and the prehension (clamping) device are powered by pneumatic, linear or angular motors.

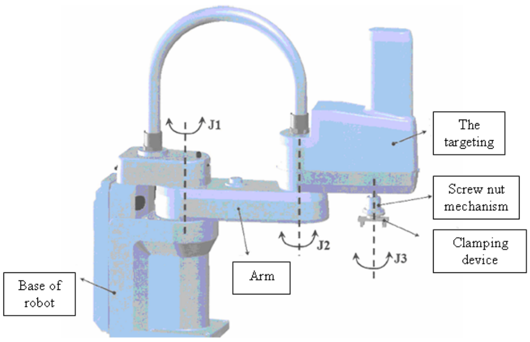
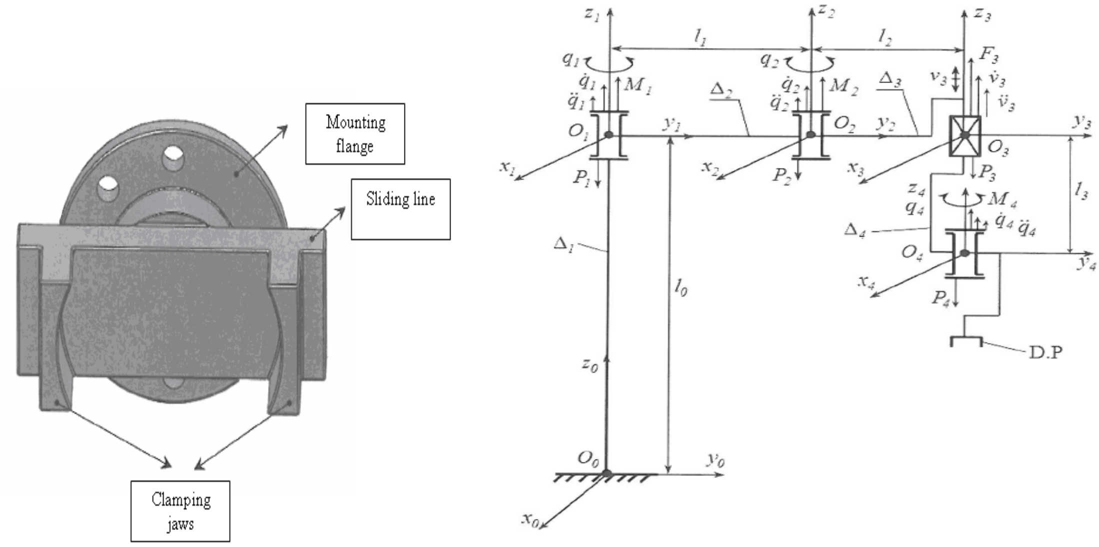


Figure 1. The Adept e-Vario Cobra robot 3 D model

Figure 2 illustrates the prehension device’s CAD model, whereby it can be seen that the grip-clamping movement of the piece can be achieved by means of wedge grips that slide along the sideway. The clamping device shown in the figure has a maximum sliding potential of 60 mm and a minimum one of 20 mm, which leads to the conclusion that the studied robot can grip cylindrical parts with diameters in the ranges listed above.



a) b)

Figure 2. a) The robot’s clamping device, b) The kinematic diagram of the RRTR-type industrial robot

Based on the CAD model presented in Figure 1 the studied robot's (type RRTR) kinematic diagram was also performed for implementation (Fig. 2 b), in which we noted by: $l_i, (i = 0 \div 3)$ - the robot’s constructive parameters, $q_k, (k = 1 \div 4)$ - the robot’s generalized coordinates, $\dot{q}_i, \ddot{q}_i, (k = 1 \div 4)$ - the robot’s operational coordinates (linear and angular velocities and accelerations), $k = 1 \div 4$ - the number of degrees of freedom, $\overline{P_i}, (i = 1 \div 4)$ - the forces of gravity corresponding to robotic modules and the prehension device while clamping the handled object, $\overline{F_i}, (i = 3)$ - the motility which includes module 3’s resistance force, $\overline{M_i}, (i = 1,2,4)$ - motor moments which include modules 1, 2, 4 resistance moments, $\Delta_i, (i = 1 \div 4)$ - RRTR type industrial modular robotic modules’ rotation axes.

For the Adept e-Vario robot’s prehension device to follow a given trajectory within the flexible work cell intended for didactics, coordination is necessary to control all the degrees of freedom in terms of position, velocity and acceleration on each motor joint. To this end, a direct and inverse geometric study was performed, using the 3*3 rotation matrix method, in order to determine the $\overline{X}^0$ column vector of operational coordinates (relation 1) which expresses the prehension device’s position in one of its p_{x5}, p_{y5}, p_{z5} coordinates point and in the $\alpha_z, \beta_x, \gamma_z$ elements of the orientation matrix. At the same time, considering the robot’s limiting couplings and the following geometric-constructive dimensions to be known: $0, \pi$ for q_1, $\frac{\pi}{4}, \frac{3\pi}{4}$ for q_2, $[0,1]$ for q_3, $\frac{-\pi}{2}, \frac{\pi}{2}$ for q_4, $l_0 = 0{,}387[m], l_1 = 0{,}20[m], l_2 = 0{,}15[m], l_3 = 0{,}2[m], l_4 = 0{,}22[m]$ and given that the prehension device’s characteristic point movement follows a curve, we can highlight the studied robot's workspace (fig. 3). Given these data we can conceive and design a flexible work cell for teaching and scientific research purposes, represented by the *e-Robmilcap* educational module, useful in conducting classes with students attending the *Management and Technology* master’s degree program within our academy.

After the calculations made, the following resulted:

$$[R]_5^0 = [R]_4^0 \bullet [R]_5^4 = \begin{bmatrix} cq_1cq_2cq_4 - sq_1sq_2cq_4 - cq_1sq_2sq_4 - sq_1cq_2sq_4 & -sq_4cq_1cq_2 + sq_4sq_1sq_2 - cq_1sq_2cq_4 - sq_1cq_2cq_4 & 0 \\ sq_1cq_2cq_4 + cq_1sq_2cq_4 - sq_1sq_2sq_4 + cq_1cq_2sq_4 & -sq_4sq_1cq_2 - sq_4cq_1sq_2 - sq_1sq_2cq_4 + cq_1cq_2cq_4 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[\alpha_z \quad \beta_x \quad \gamma_z] = \begin{bmatrix} \frac{\pi}{2} + q_1 & q_2 & -\frac{\pi}{2} + q_4 \end{bmatrix}^T, \quad \overline{X}^0 = \begin{bmatrix} p_{x5} \\ p_{y5} \\ p_{z5} \\ \ldots \\ \alpha_z \\ \beta_x \\ \gamma_z \end{bmatrix}^T = \begin{bmatrix} 0 \\ 0 \\ l_0 + l_1 + l_2 + l_3 + l_4 + q_3 \\ \ldots \\ \pi/2 + q_1 \\ q_2 \\ -\pi/2 + q_4 \end{bmatrix}^T,$$

$$q_3 = p_z - (l_0 + l_1 + l_2 + l_3 + l_4). \tag{1}$$

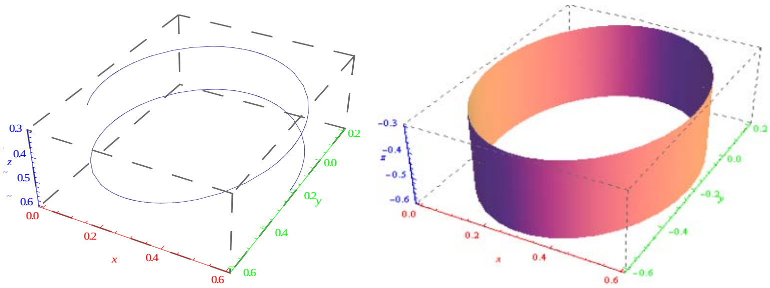


Figure 3. The prehension device's characteristic point trajectory

Given the overall dimensions of the RRTR type robot and knowing the law of motion of the prehension device's characteristic point trajectory, the *e-Robmilcap* didactic work cell was designed and is presented in 3D in Figure 4. The main constituent elements of the flexible work cell serviced by the robot under study can be observed, a robot that will be destined for manipulating and arranging cylindrical parts of three different colours (yellow, violet, blue).

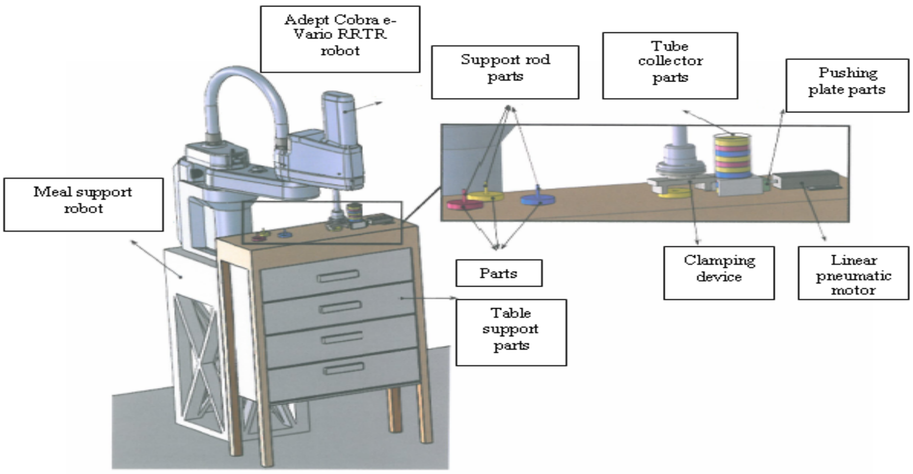


Figure 4. The didactic work cell for manipulation of parts serviced by the Adept Cobra e-Vario (RRTR type) industrial robot

As far as the working cycle of the robot is concerned (Fig. 5) within the didactic flexible cell four major stages are specified:

- Stage I: in this stage parts are randomly stored (by colour) in the tube collector;
- Stage II: after parts storing, by means of the rod (which is provided with a pushing element) of the linear pneumatic motor, parts are pushed, one at a time, in the gripping position of the robot's prehension device;
- Stage III: at this stage of the operation, the grip-clamping movement of parts (one by one) and their displacement are performed by the robot's gripper;
- Stage IV: After the parts are displaced by the gripper, they are stacked neatly, one by one, according to colour, on the three rods mounted on the working bench.

Thus, at the end of the working cycle, all the pieces are stacked neatly by colour, on the three rods mounted on the working bench. We mention the fact that another possible functioning cycle of the robot could be to randomly place parts in the tube collector (the reverse operation).

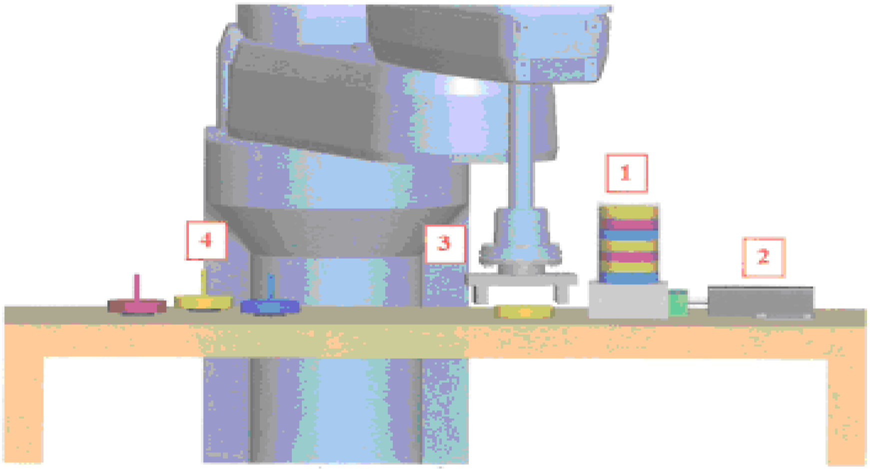


Figure 5. The working cycle within the Adept Cobra e-Vario industrial robot (RRTR type) C.F.F.

The purpose of this didactic flexible cell conceived, designed and developed within the *Advanced Technologies Logistics Laboratory*, is to produce the movement of manipulation, sorting and arrangement of cylindrical parts of different colours on corresponding rods and / or the tube collector, thus highlighting the high positioning accuracy of the Adept Cobra e-Vario robot, that exists in the laboratory. At the same time, research team members were able to perform a numerical analysis, based on the observation of the step by step movements performed by the studied robot, on the dynamic strains and stresses. The purpose of the dynamic analysis using the finite element method (FEM) was to determine stress displacements for the resistance structure and that of the $J_1 \div J_4$ rotation and translation joints of in the composition of the RRTR type industrial robot while performing a simple manipulation task. The dynamic *FEM* analysis was performed in the virtual environment of the *Visual Nastran* software, software dedicated to structural and dynamic analyses of the various mechanical ensembles.

Given the complexity of the studied robot's mechanical structure, for the dynamic study the following simplifying hypotheses were considered: the rotation joints (*RR*T*R*) and the translation joint (RR*T*R) were represented by means of equivalent modules, thus the rolling movement of the balls in the mechanical structure was transformed into a simple rotation or translation movement between two cylindrical parts; reductors were not analyzed as, their function is only to convey movement; the RRTR robot kinematic chain composing modules together with the caps and screws for fixing them on the structure, were considered to be a single body, simplifying in this manner, the mathematical model underpinning the *Visual Nastran* software. The first stage performed in view of the numerical analysis in dynamic conditions consisted of modelling equivalent robotic joints and assembling them within the resistance structure. Then, in the working environment of the *Visual Nastran* software, through the *e-Robmilcap* application, constraints were initiated between *rigid joint* elements (joint/fixed element), having the function of fixing elements one to the other being considered within the *FE* analysis as a single body, and *motor joint* elements, having the function of generating the movement of rotation and translation joints. In order to program joints and simulate a *pick and place* elementary unit charge, laws of motion were imposed for each rotation and translation joint in the robotic structure, each joint performing movement along its own coordinates system (Fig. 1, 2), automatically attached by the software. If this is the case, joints move along the z axis.

The numerical study of the robot's resistance structure displacements and stresses was performed by analysing one robotic component at a time, digitization being obtained by using finite elements with dimensions ranging from 8 [mm] to 38 [mm], depending on the component's size and section. The following restraints were assumed for the study:

- The robot is fixed on the bed plate by means of screws. In developed numerical analysis the basic module is considered to be secured by fastening its lugs onto the bed plate (Fig. 6);
- For the simulation of the RRTR-type robot loading with a unit charge (F= 0.5 [kg]) a force permanently oriented along the z axis with F= 5 [N] was considered;
- Determining stresses and strains was performed for a *pick and place* elementary unit charge. Figure 7 presents the laws of motion for the rotation joints and for the translation joint during a single working cycle in graphical form, considering the duration of a working cycle of the robot in the cell to be of 12.6 [s].

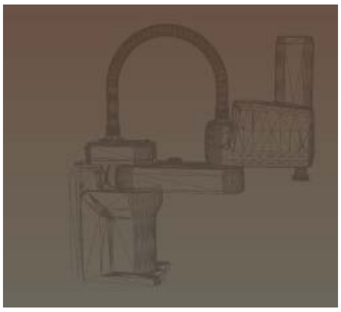


Figure 6. Digitizing the Adept e-Vario (RRTR type) robot resistance structure

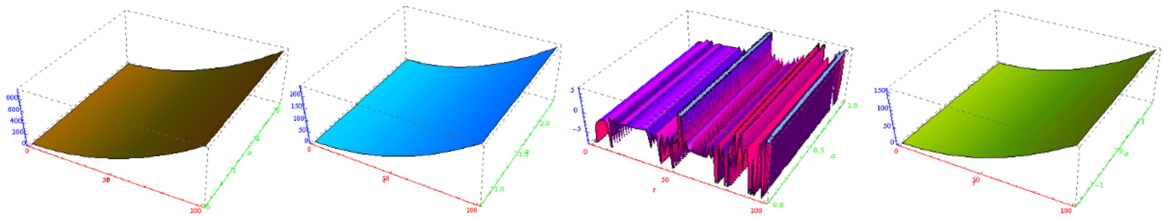


Figure 7. The RRTR type industrial robotic joints' laws of motion

III. CONCLUSIONS

Evidently, e-learning solutions in industrial robotics and mechatronics can be spectacular in terms of design, but very difficult to implement. Promotion of the educational module, called *e-Robmilcap*, will have the effect of creating a community of content developers to ensure progress in e-learning, on the one hand, and on the other hand, it will provide master's degree programme students with a new training and education module suitable to the new educational paradigms.

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