Competency-Based Education in Automation Teaching

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ABSTRACT

This paper shows how the concepts associated at Competence-Based Education are applied in Automation Teaching at the Mechanical Engineering Department of University of Minho, in Portugal.

The principal actor in the learning process should be, in fact, the student not the teacher. Cognitive theory states that knowledge learned and applied in a realistic problem solving context is expected to be remembered and used properly when needed later. In fact, these problem-based learning/teaching strategies, case methods and simulations, are useful tools for an effective teaching since students must become active participants rather than passive observers. Students must make decisions, solve problems and analyze the results achieved.

For this, it was developed a methodology that must be apprehended by the industrial automation students that consists on applying some theoretical concepts, using some powerful advanced computational tools. A case study is presented and treated in this context.

I. INTRODUCTION

Competence-based education (CBE) is a concept that exists already for several decades. In the 1960’s it originated in performance-based teacher education in America [16] Competence-based education has been introduced and used throughout the United Kingdom, Europe, Asia, United States and New Zealand, although models differ between countries as well as the degree to which competence-based education is used [4]. According to Velde [4] the concept of competence-based education can facilitate learning in a society of rapid change and complexity.

Competence-based education, in vocational education and training system (VET) is a leading development for innovation on different levels of the school organization. Biemans, Poell, Nieuwenhuis and Mulder [8] made an overview of the aspects contributing to the popularity of competence-based education nowadays. The first reason is the emphasis that the concept puts on the positive side of education and learning. The main goal is to make individuals more competent instead of emphasizing their knowledge deficits. But the second and also the main reason for the popularity of competence-based education is the expected reduction of the gap between the labour market and the school system. Wesselink, Lans, Mulder, Biemans [12] also postulate this argument as one of the main reasons for the popularity of the concept of competence-based education.

Since the society and the world, in general, continues to become more sophisticated in terms of technological and engineering applications, it is imperative that Engineering students should be prepared to enter into the workforce with the skills and levels of knowledge capable of sustaining such progress. In the last decade, a trend can be observed in the field of higher education from knowledge-oriented to competency-based education [6, 17]. CBE is aimed at providing students with the knowledge, skills, and attitudes to enable them to recognize and solve complex problems in their domain of study or future work. The successful realization of CBE heavily relies on the teachers, who are expected to give up their role as ‘knowledge transmitter’ and adopt the new roles of “coach”. It is in this context, that the use of powerful simulation software tools helps the teachers to implement this kind of methods.

Competence-based education is creating opportunities for students and workers, close to their world of experience in a meaningful learning environment wherein the learner can develop integrated performance-oriented capabilities to handle the problems in practice.

Trying to adopt the CBE in teaching automation in the Mechanical Engineering Department of University of Minho, the Automation Group uses some powerful computation tools to achieve this goal.

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Technically, in order to implement a safety automated system controller program it is necessary to develop it in a systematic way and it is necessary that its conception and development obey into a set of rules that will allow easiness of perception and implementation of the controller system.

Currently, there exist some suitable formalism for the development and creation of the structure of an automated production system controller. Between these formalisms, are distinguished the GEMMA [1, 14] (Guide d’Étude des Modes de Marche et d’Arrêt) and the Sequential Function Chart (SFC) [9], both developed in France. The GEMMA is adapted to define the controller structure and SFC is adapted to the complete controller specification.

For this, it was developed a methodology that must be apprehended by the industrial automation students and this methodology is applied since the definition of the specifications set for the behavior of the automated production system into the complete specification of the system controller that is intended to implement. For this, it is used the GEMMA for the controller structure, the Grafcet for the controller specification and Automation Studio software for the controller simulation [3, 5, 7, 18]. The simulated controller is developed using the formalisms and tools related before.

The application of the related methodology is shown in a case study based on an Automated Production Line.

In the chapters II, III and IV there are presented the formalisms SFC, GEMMA and the powerful Automation Studio simulation software, respectively. Next, in chapter IV, it is presented the application of the CBE methodology. Further, in the chapter V, there are presented some conclusions and evolution perspectives.

II. SFC

The implementation of the automated system requires, in particular, a description relating cause and effect. To do this, the logical aspect of the desired behavior of the system will be described. Fig. 1 shows a graphical representation of a typical sequential automated system.

The sequential part of the system, which is accessed via Boolean input and output variables, is the logical aspect of this physical system. The behavior indicates the way in which the output variables depend on the input. The object of the SFC is to specify the behavior of the sequential part of the systems.

The specification language SFC enables a Grafcet to be created showing the expected behavior of a given sequential system. This tool is characterized mainly by its graphic elements, which, associated with an alphanumerical expression of variables, provides a synthetic representation of the behaviour, based on an indirect description of the situation of the system [2, 10, 11].

The behavior description on states is the following: the states, "monomarked", correspond to the SFC situations, which implies that only one situation can be active at a given instant. The states are connected from one to another by ways of an evolution condition, which allows the passage from one situation to another one to be described [13, 15].

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For reasons of convenience, the behavior description based on states is better replaced by a description based on steps called SFC. In the SFC several steps may be active simultaneously, the active situation being then characterized by the set of active steps at the considered moment. The evolution conditions of a set of steps to another one are translated, by one or several transitions, each characterized by:
- its preceding steps;
- its succeeding steps;
- its associated transition condition.

The SFC is used for the design of Grafcet charts to provide a graphical and synthetic representation of the sequential systems behavior. The representation distinguishes:
- the structure, which allows possible evolutions between the situations to be described;
- the interpretation, which enables the relationship between input, output variables and the structure (evolution, assignment and allocation rules are necessary to achieve this interpretation).

The structure comprises the following basic items:
- Step: A step is either active or inactive, the set of the active steps of a Grafcet chart at any given instant represents the situation of this Grafcet at this instant;
- Transition: A transition indicates that an evolution of the activity between several steps may envolve. This evolution is realized by the clearing of the transition;
- Directed link. A directed link connects one or several steps to a transition, or a transition to one or several steps.

The following elements are used for the interpretation:
- Transition-condition. Associated with each transition, the transition-condition is a logical expression which is true or false and which is composed of input variables and/or internal variables;
- Action. The action indicates, in a rectangle, what must be done on the output variable, either by assignation or allocation.

III. GEMMA

The GEMMA (Guide d’Etude des Modes de Marches et d’Arrêts) [1], developed in France by ADEPA (Agence Nationale pour le Developpement de la Production Automatisée) is a method that, on the basis of a very precise vocabulary proposes a simple structured guide, to the designer, based on a graphical chart, presented in Fig.º2, that contains all the run and stop modes, or states, that a machine or an automated system can assume. It is a tool for helping the system analysis, being used for its supervision, maintenance and evolution definition.

The GEMMA method is based in three basic concepts:
A. The Ways of Run are seen by the command module in the Way of Run. All the systems are composed by a command module and an operative module. In the application of GEMMA, it is assumed that the command module is always on power.
B. The Production Criteria. Two states are considered for the production systems: ON production and OUT of production. That states are shown on the graphical chart of the method.

C. The three groups of run and stop ways or states of the Plant.
1) States "A": Stop states
2) States "D": Failure ways
3) States "F": Running ways

The graphical chart of GEMMA is composed by three parts corresponding each one to each group of run and stop described ways or states. Each one is represented by a rectangle. All the rectangles are connected by oriented arcs and two consecutive rectangles must always have a transition condition between them. In each rectangle the specific way or state must be identified as well as the corresponding operation developed by the operative module.

This method is directly devoted to the structure of the automation system controller. It is useful for the designers that intend to develop a controller for a complex system.

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IV. AUTOMATION STUDIO

Automation Studio is a design, animation and simulation software tool. It was created for the automation industry, specifically to fulfill engineering, training, and testing requirements. The workshops associated with the software reflect the prevailing usage in the industry as closely as is possible. The simulation utility makes Automation Studio an efficient tool for the certification of automated processes and programs.

In the Automation Studio environment, all the design tools are readily accessible. The core system contains three utilities: a Diagram Editor, a Project Explorer, and a Library Explorer.

The Diagram Editor allows you to generate and simulate diagrams and create reports, while the Project Explorer handles file management and the classification of all documents associated with a simulation project. The Library Explorer supplies the symbols libraries necessary for the creation of the diagrams that make up your projects [5].

Finally, this software allows you to document your project. You can print and export your diagrams along with the various associated lists and reports to assemble a complete work file.

V. CASE STUDY

The automated line production which was used in this study is a machine for the automatic assembly of car wheels. It is a system that puts in the wheel in the cube of the car.

The machine is composed by three modules:
- Module 1: It receives and rotates the wheel for a known position (alignment of axes of the holes);
- Module 2: It distributes and it transports the screws for the wheel;
- Module 3: It puts the wheel in the cube and it tightens the screws.

Fig. 2 shows the plant of the case study, which it can be seen in detail the three modules with the respective switches, sensors and actuators used.

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All the command structure was developed based on the direct application of the GEMMA method. In order to facilitate the understanding of the GEMMA application, a short description of the system presented in figure 3 is given:

Being detected a car by the sensor CAR, in the main platform, the operation of the machine starts. The wheel positioned in the feeding runner is pushed by the cylinder AR to the alignment platform. The cylinder PIN moves forward and it beats in the wheel being half advanced. The motor R moves the cylinder PIN along the circumference where are made the holes of the wheel. As soon as, the cylinder PIN is aligned with the hole moves forward and the motor R stops. The cylinder ROT moves forward to allow the rotation of the wheel. The motor R is again turned on until the position of sensor FCM1 to be reached. Following, the cylinders PIN and ROT move back.

However, the screws were already loaded in the gripper in agreement with the following steps:
- The motor P gives a whole rotation, so that the four screws are positioned;
- The cylinder CV moves back allowed the individual gripper to be on the screws;
- The cylinder CG moves forward doing with that the gripper catch the screws.
- The cylinder CV goes up;
- The cylinder CH moves forward, being the gripper on the wheel;
- The cylinder CV goes down;
- The cylinder CG opens the gripper and the screws fall in the holes of the wheel;
- The cylinder CV goes up;
- The cylinder CH moves back.

After that, the wheel is in a known position with the respective screws. At this time, the module 3 begins its operation. The wheel is fit in the cube of the car by the motion of the cylinders CVA, TEA and CRA (this

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allows the rotation of 90º of the wheel). The screws are tight for the actuation of the motor A. The gripper release the wheel and it moves back and finally rotate 90º, being the machine ready for a new production cycle.

A. Application of the GEMMA Method

In the graphical chart presented in Fig.4, based on the general graphical chart of GEMMA, it is possible to identify the run and stop ways or states that can be considered for the system. In this case, were considered the following run and stop ways or states:

1) A1 - In this state all the cylinder are retreated less those that can be advanced for the action of the gravity force. There is therefore needed to go through a preparation operation mode;
2) A2 – After running the system in production in any way, it is previewed a state of stop in the end-of-cycle;
3) A5 – After any failure of the system, it will be necessary to perform a checking/cleaning to the system before being restarted to the normal production mode;
4) A6 – After A5, is defined a state in which the machine returns to the initial state;
5) F1 – After A1, when it occurs the actuation of the button start_auto, it happens the execution of the main program corresponding to the automatic assembly of car wheels, whose short description was presented previously;
6) F2 – In the preparation mode it is verified if the vertical cylinders of the transport of screws (cylinder CV) and the vertical cylinder of transport of the wheel (cylinder CVA) are advanced. In case they are not, it will be given an order to validate this condition. It is also verified the existence of screws and wheels in the respective feeders, if it doesn’t verify, an error message of the respective component it appears in the display of the machine control panel;
7) F4 -In the unordered verification mode the machine is supplied with electricity and compressed air, but commands of the controller for the plant don’t exist, allowing to the operator the manual actuation of cylinders and motors of the plant;
8) F5 – In ordered verification mode, being the system in the state of normal production is possible to perform an individual verification of the modules 1, 2 and 3 with the actuation of the button semi-auto conjugated with an selector button that define which module will be checked;
9) D1 – When the operator detects any problem in the line, he must press the Emergency switch to immediately stop the system.

Fig. 4. Graphical Chart GEMMA applied to the Plant – Operative Part; Controller. – Command Part.

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B. Application of the Grafcet Method

The Fig. 5 shows, as example, the Grafcet of the state F1 of GEMMA, corresponding to the normal production mode of the automatic assembly of car wheels. The Grafcet presented depicts the expected behavior of the sequential system illustrated in this paper. The behavior description on the states, correspond to SFC situations, implies that only one situation can be active at a given instant. The states are connected from one to another by ways of an evolution condition, which allows the passage from one situation to another one to be described. It can also be seen in this Grafcet parallelism and alternative runs for the controller program. Furthermore, they were used timers in same evolution condition to describe properly the sequential system.

Fig. 5. Grafcet of the normal production mode of GEMMA.
C. Automation Studio

Fig. 6 shows, the implementation of the system in the Automation Studio Software that it was performed to simulate and validate the controller developed in Grafcet. In this figure, it can be seen various programming windows with the Grafcet corresponding to each state of GEMMA considerer in this example (see Fig. 4), which correspond to the system controller. To carry out the synchronization of these Grafcet’s, that operates like subroutines, exists an additional programming window called “gemma” that is a Grafcet corresponding to the graphical chart of GEMMA. Finally, on the other hand, it can be also observed a window related with the plant of the system. This manner, using these programming windows together will be possible to simulate the behavior of the system.

VI. OBTAINED RESULTS

The following figures show results of the system simulation performed with the Software Automation Studio. They are presented in the Fig. 7, 8, 9 and 10, as example, pictures of the simulation for the mode F1 of GEMMA, respectively, of its initial state and of the operation endings of the modules 1, 2 and 3.

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Fig. 8. Simulation picture of the system (Plant + Controller) at the production ending of the module 1.

Fig. 9. Simulation picture of the system (Plant + Controller) at the production ending of the module 2.

Fig. 10. Simulation picture of the system (Plant + Controller) at the production ending of the module 3.

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According with the obtained simulation results, it can be concluded, that the system controller developed in Grafcet, based on the direct application of the GEMMA method, allows to system the obtaining of the required operation behavior. Additionally, it can be concluded that use of simulation in the analysis of the system control program it is very desirable because with that it was possible to debug a set of errors in the program of the controller.

VII. CONCLUSIONS

The Integration of knowledge, skills and performance relating to Competency-Based Education in the Automation Teaching at the Mechanical Engineering Department of University of Minho, was implemented based on case studies. The role of the teachers in this learning process was just to be coaches to support students in practice. The students were free to choose between several ways of gathering information and decide which the best way to accomplish the case study proposed.

The results of the implementation of these learning methodologies were very interesting seen that the successful approbation in the final examinations was very high. This good result was gotten due to the considerable increase of the students’ motivation for the approached matters.

Another important characteristic of these projects is the opportunity of increasing the promotion and motivation of new researchers in the fields of science and technology among the youth, sometimes difficult to achieve.

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