

**AN INTEGRAL HUMAN-MACHINE SYSTEM FRAMEWORK:
FROM AUTOMATION TO USABILITY ENGINEERING**

P. PONSÀ

*Department of Automatic Control. Technical University of Catalonia.
EPSEVG, Av. Victor Balaguer s/n, 08800 Vilanova i la Geltrú,
Barcelona, Spain. Phone number: 034938967231
Pedro.ponsa@upc.edu*

AND

R. VILANOVA

*Department of Telecommunications and Systems Engineering.
Universitat Autònoma of Barcelona. ETSE, Campus UAB, 08913
Bellaterra, Barcelona, Spain. Phone number: 034935812197
Ramon.vilanova@uab.cat*

Abstract. The aim of this paper is to show an additional advantage of the guide for start and stop modes, GEMMA guide, that should motivate its use as well as to introduce the consideration of the human operator as an integral part of the automation procedure. The inclusion of the human operator as well as his interplay with the automation device needs some ergonomic guidelines, that can be drawn from joining the GEMMA structured approach and some concepts borrowed from cognitive ergonomic theory and human-computer interaction. Finally, this paper shows some examples of human-machine interfaces and the users' experience.

1. Introduction

The design of increasingly complex production systems has called for new automation design tools. On the academic side different tools have been developed. Among them Petri Nets (PN) have proved to be a successful approach on a broad range of applications (Kontogiannis, 2005). There is however one point that is not clear how to deal with within the PN formalism: the introduction of the operator. In every automation problem the fully automated part is just one part of the solution. Other approaches like Sequential Flow Charts SFC or State-Transition Graph (GRAF CET) (AFCET-ADEPA, 1995) can be considered the primary automation design

tool found on industry. The important point with GRAFCET, even a simpler approach if compared with PN, is that it has a close and clear connection with the design guide for start and stop modes called GEMMA (ADEPA, 1981). Even the GEMMA guide started to be used twenty-five years ago and it is introduced to the engineering students in several places it is the authors opinion that has not widespread attention. This is the reason this communication would like to focus on other side advantages of using GEMMA: introduce the consideration of the human operator as an integral part of the automation procedure. This idea has a graphical representation. Different levels from top to bottom: human supervisory control, human computer interaction and automation (Figure 1). In industrial automation is necessary to study the human intervention (human in the loop) in critical situations (failure, emergency).

The operator can enter the loop in different ways, and such interaction needs to be considered as an integral part of the automation procedure as well as the communication of the automation with the operator. In the supervisory control level, inside a control room or near the machine, the human operator use a typical SCADA packages, - Supervisory Control and Data Acquisition software -, to develop the tasks: surveillance, decision making and planning. From the point of view of the usability engineering it is necessary to introduce usability evaluation to improve the performance of the human-machine system.

The paper is structured as follows. The second section of the paper presents the role of the human operator inside the GEMMA guide. The third section presents a set of guidelines in the design of a panel to facility human intervention with the use of GEMMA guide in industrial/academic domain. The fourth section presents an experimental study and the user's experience inside an educational manufacturing system. Finally the conclusions and future steps are presented.

2. The role of the human operator inside the GEMMA guide

We can identify the following three modules when dealing with the design of an automated system: Security module, Operation Modes module and Production module. Under the emergency situation or device failure, the Security module has higher priority over the other modules in order to take the appropriate decision. It is also worth to notice the introduction of the operator as an integral part of the system. The operator adds experience in the switch from automatic to manual operation modes. This way the global control of the process can be the result of intermittent actuation within the

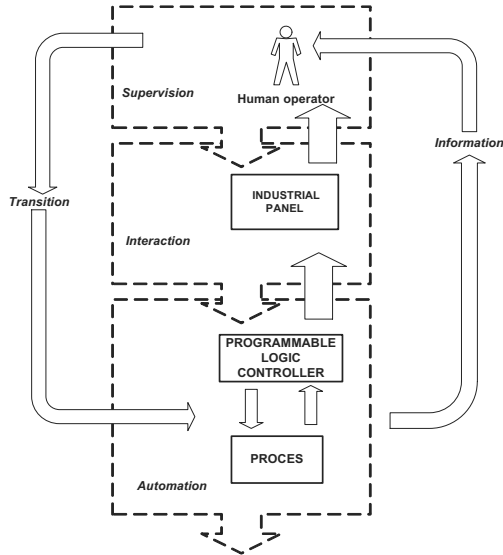


Figure 1. Human-machine system in automation domain.

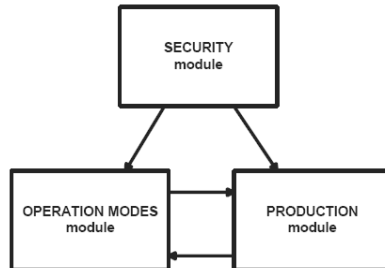


Figure 2. GEMMA modular approach of automation design.

Manual mode and the Automated mode. The Production module appears hierarchically under the previous ones. This module is the responsible for the sequential operation of the production process and operates on the basis of the state of the other modules.

The representation used within GEMMA takes into account these modules as well as the internal relations among them. The hierarchy shown in Fig. 2 tries to stress the security aspects of automated production systems. It is worth to notice the introduction of the human operator as an integral part of the system. The operator adds experience in the switch from automatic to manual operation modes. This way the global control of the process can be the result of intermittent actuation within the Manual mode and the Automated mode. The Production module appears hierarchically under the previous ones. This module is the responsible for the sequential operation of the production process and operates on the basis of the state of the other modules.

With this modular approach this means we will have different partial GRAFCET that will be needed to interconnect. Each module of the GEMMA guide structure is associated with a partial GRAFCET. Within the Operation Modes module the human operator takes decisions over the Production GRAFCET and can decide to enter into the control loop (by changing the operation mode to manual; or to leave the loop if the problem is solved by turning back to Automatic mode).

The Security module has associated the Security GRAFCET. When the human operator makes an action over the emergency stop, the Production and the Operation Modes GRAFCET are stopped. The human operator makes a sequence of actions to reduce the failures and finally activates the reset switch to redrive the normal functioning of the system.

All this aspects make clear the close connection of the inherited operations modes between the human-machine interface and the way the automated system is designed.

3. Human-machine interface design

In industrial automation there is a wide range of devices called human-machine interfaces) (Kee et. al., 1999). In this paper we will focus on industrial panel design applying the prescriptions from GEMMA guide. The human operator awareness of interaction processes is crucial in order to classify system states and events, to process information and to plan consistent interventions.

It is important that the design of context interfaces could be based on identifying the classes of situations that human operators have to deal with.

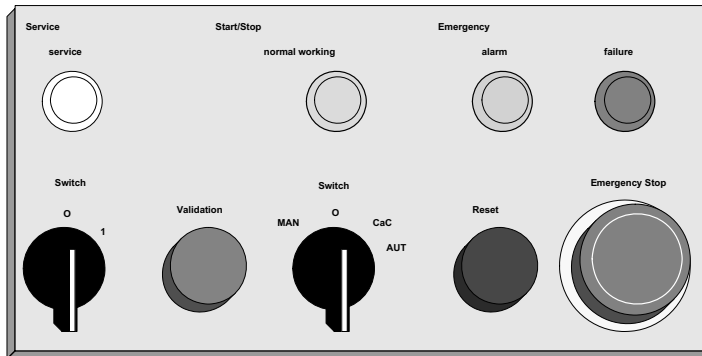


Figure 3. Ergonomic industrial panel.

We are working with an industrial enterprise panel and we are designing new prototypes. The industrial panel shown in Fig. 3 is organized with a top level with visual information devices (lights) and a down level with control switches (Ponsa and Díaz, 2007), (Shneiderman, 1998), (Rasmussen, 1986).

The visual information devices are:

- White led: machine with energy
- Green led: normal functioning
- Yellow led: precaution
- Red led: abnormal functioning

The control switches are:

- Mode selector: machine with energy or not
- Validation switch to validate an operator's action
- Mode selector: automatic mode AUT, manual mode MAN, a stop request at the end of the automation cycle CaC

And finally, from left to right the panel shows clearly the diverse operation modes:

- Service mode: machine with energy or not
- Manual/automatic mode: the control is manual (human operator actions) or automatic (controller actions)
- Security mode: an emergency stop and a reset switch

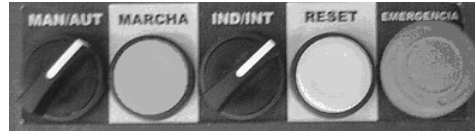


Figure 4. Industrial enterprise panel.

4. User's experience in an educational manufacturing system

From the educational point of view, the educational frame of the automation and human operator activities, at the author's own Universities is conformed through diverse subjects from the Technical Engineering degree programs: Industrial Automation, Robotics Modelling and Simulating Systems and Integrated Production Systems. These subjects make a special emphasis on technical topics of controllers (programmable logic controllers PLCs) and industrial handler robots by working on a educational manufacturing system composed by different stations. Each station has a particular controller and a particular industrial panel (Figure 4) initially installed on it. From left to right the enterprise panel of the Fig. 4 shows clearly the diverse operation modes:

- MAN/AUT Manual/Automatic mode: the control is manual (human operator actions) or automatic (Programmable Logic Controller actions)
- MARCHA: manual switch
- IND/INT: machine is autonomous mode or integrated mode inside a flexible manufacturing system
- RESET: reset switch
- EMERGENCIA: an emergency stop

A team of technical engineers are asked to apply the GEMMA guide to each station of the manufacturing system with the purpose of automating the corresponding task. In example, they are asked to perform the test of the use of the industrial panel manufactured by the commercial distributor, and test the use of the GEMMA guide.

The disadvantages verified by the technical engineers and gathered in a final project along 6 months are: difficulty of implementation of all the situations contemplated in the GEMMA guide, and absence of visual information displays. The industrial enterprise panel shows ambiguity. It is necessary to organize the panel, add visual information devices, and distinguish between visual information devices and switches. It is necessary to apply ergonomic guidelines to interface improvement.

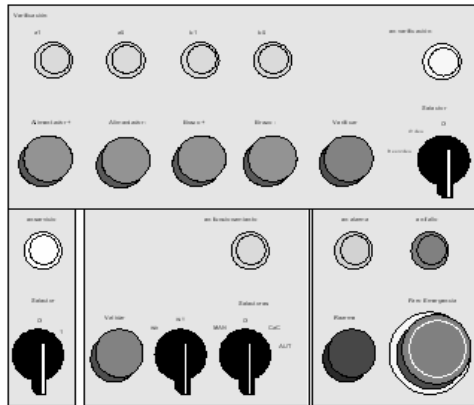


Figure 5. Authors' panel with ergonomic specifications and a new function (verification) at the top of the panel (to act over pneumatic actuators).

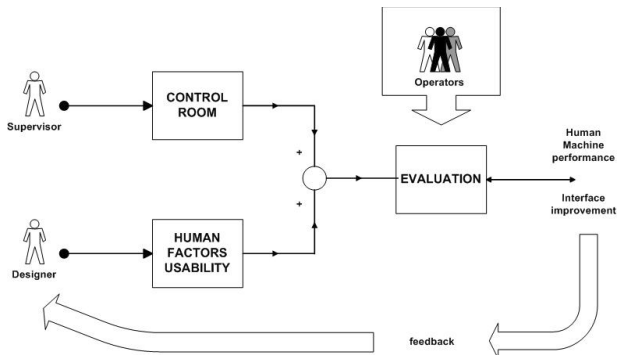


Figure 6. A human factors and usability framework in industrial control room.

In collaboration with the technical engineers, the authors show a new prototype of industrial panel with ergonomic specifications and user's satisfaction (see Figure 5).

As a final result of the new proposal for the industrial panel and the verification of the advantages of linking its design with the operational modes that arise from the application of the GEMMA guide, a physical

prototype has been developed and is being now subject of usability tests and experiences (see Figure 6) (Nielsen, 1994).

5. Conclusions

The GEMMA guide approach is a recommended taxonomy approach for the introduction of the human operator into the automation cycle in complex academical/industrial domain. It provides a natural relationship between the design of the automation system and the operational modes that are to be considered from the industrial panel point of view.

It is necessary to improve the relationship between the interface design in automation systems with the guidelines in human-computer interaction.

It is necessary to apply usability engineering techniques as cognitive walkthrough in order to improve the reliability of the human-machine system.

The next step in this work is to perform experiments on a usability laboratory in order to compare the use of the initial and proposed interfaces (mental workload, performance, user's satisfaction).

Acknowledgements

The work of the second author is partially supported by the Spanish program CICYT DPI2007-63356.

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