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1 Human-Machine Cooperation in Manufacturing System: Support to diagnose command error

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1.1 Introduction

The objective of this paper is to present theoretical aspects and first results of a study on diagnosing command error in a discrete parts manufacturing system. The study took place within the framework of the GIS 3SGS project (French acronym for Scientific Interest Group – Systems Monitoring, Dependability and Security). The project was realized with partners from the University of Reims (CReSTIC) and Nancy (CRAN UMR 7039). The goal of this study, called ADEXEC (Approach to Detect and EXplain Errors of Command), is to support human operator decision making facing process breakdown.

In manufacturing systems, “model-checking” refers to the checking of the command before it is implemented in a programmable logic controller (PLC) [1]. However, model checking does not take into account potential process modifications (e.g., product specifications or manufacturing system changes) made by operating and maintenance staff.

One way to limit serious consequences of an unsuitable command is to stop the process. The detection of dangerous forbidden states of the process is performed by a robust filter placed inside the PLC [2] [3]. This approach provides, on the one hand, process safety by avoiding damage to products and manufacturing system. On the other hand, the filter’s decision to stop the process may suppress important information that human operators can use to diagnose and correct the command. Therefore, the implementation of a filter must be complemented with some functionality that can assist human operators to diagnose command errors. Such an assistance system is studied here according to the Human-Machine Cooperation approach.

1.2 Human-Machine Cooperation principles

The principles of Human-Machine Cooperation (HMC) have been laid down by Millot et al. [4] with a focus on Dynamic Task Allocation. HMC has been applied in several domains, including car driving [5], air traffic control [6] [7] [8], and robotics [9]. Two main abilities have been defined in order to design HMC: the Know-How (KH) and the Know-How-to-Cooperate (KHC) of an agent. The word agent is used for the human operator as well as for the technical entity, that is, the assistance system. The KH is the agent’s ability to control the process, whereas the KHC is the agent’s ability to interact with other agents [10].

The KH is based on the competencies of an agent to control the process. Knowledge, rules, and skills of agents [11] are competencies that are used to define plans, reach goals, and complete tasks [12]. Agents, human as well as artificial, acquire and analyse

information, select decision, and implement actions [13]. The volume of competencies that can be used at each time is restrained by the agent's capacities, that is, the number of tasks that can be performed during a time span. The KH allows agents to build a model or a representation of the process.

The KHC is based on agents' abilities to cooperate with other agents, that is, to communicate with them and to build a model of other agents' KH and KHC. Owing to these abilities, agents strive towards goals. Furthermore, by interfering with the goals of the other, they try to improve the activities of the other [6].

Agents' KH and KHC can be used to represent the process according to the agents' point of view by means of a so-called Common Work Space [10] [14]. The above definitions mainly stem from continuous process modelling. However, theoretical models previously used in continuous process industry, also appear to be useful in discrete parts manufacturing [15]. The next section presents the design and analysis of a manufacturing problem according to the HMC principles.

1.2.1 Application to manufactory problematic

At first, the filter was seen only as a technological innovation that has to prevent the process and products from damage. However, the necessity to improve its implementation in order to avoid human misunderstandings quickly appeared. The assistance system composed of the filter and assistance system is now presented according to its KH and KHC.

The assistance system is designed by an expert and its KH consists of several logical constraints defined by PLC inputs (sensors), PLC outputs (actuators) and observers (linked to products or system states). Logical constraints take into account the physical and functional layout of the process. Using their knowledge, expert process designers define the control program according to the process configuration. The assistance system's KHC comprises the ability to communicate and explain its decision making, but also its ability to adapt its explanation according to the human operator who has to understand the process state. This paper deals with the presentation and evaluation of the first ability, that is, how the assistance system is able to support the maintenance staff to understand why the process stopped and what could be the command error.

The KH of the human operator is linked to her/his job. In this paper, it is assumed that the human operator concerned with the process stop is a maintenance agent. She/he is repairing or modifying a part of the process when another part stops. An alarm is triggered and the agent goes to the stopped part of the process in order to understand the problem.

The agent is not a process engineer. She/he does not know the control program but she/he has the ability to understand it and to trace the error in order to correct the command, or to transmit the error to process designers. The KHC of the maintenance agent is not well identified for the moment. For the present process situation, a KHC has been defined in order to be learned by agents. The KHC is mainly composed of the ability to communicate because the maintenance agent has no training to be able to have a

model of the assistance system. In other words, she/he does not know the filter's logical constraints.

According to [16], the maintenance activity to detect component failures is split into three steps: the first is the preparation of the intervention, that is, the organization of the intervention on the system according to a pre-diagnosis. The second is the intervention and includes diagnosis and carrying out of the work. Finally, the last phase occurs after intervention. According to the authors, the second phase consists of several stages: the acquisition of clues and their categorization, the refinement of this categorization and gradual reduction of assumptions, locating the faulty component, and finally a validation step. According to [17], the cognitive processes of maintenance workers are directed by the normal and abnormal functioning of the system, and searches can be functional (functions performed by a component or subsystem) or topographical.

In our study, the filter stops the operating part as soon as a dangerous forbidden state is detected. The maintenance agent has no clues to direct her/his search in order to detect the error in the command. Figure 2.1 represents such a situation, simulated with ITS-PLC software. The KHC of the assistance system provides information to help the maintenance agent to build clues through the use of the common work space.



Figure 1-1: Sorting process of cases simulated with ITS-PLC

Four levels of explanation have been defined. Explanations provide information inferred from the logical constraints and process state. The higher the level of explanation, the more the information is “intelligent”, but the less easy the explanation is to extract and to understand.

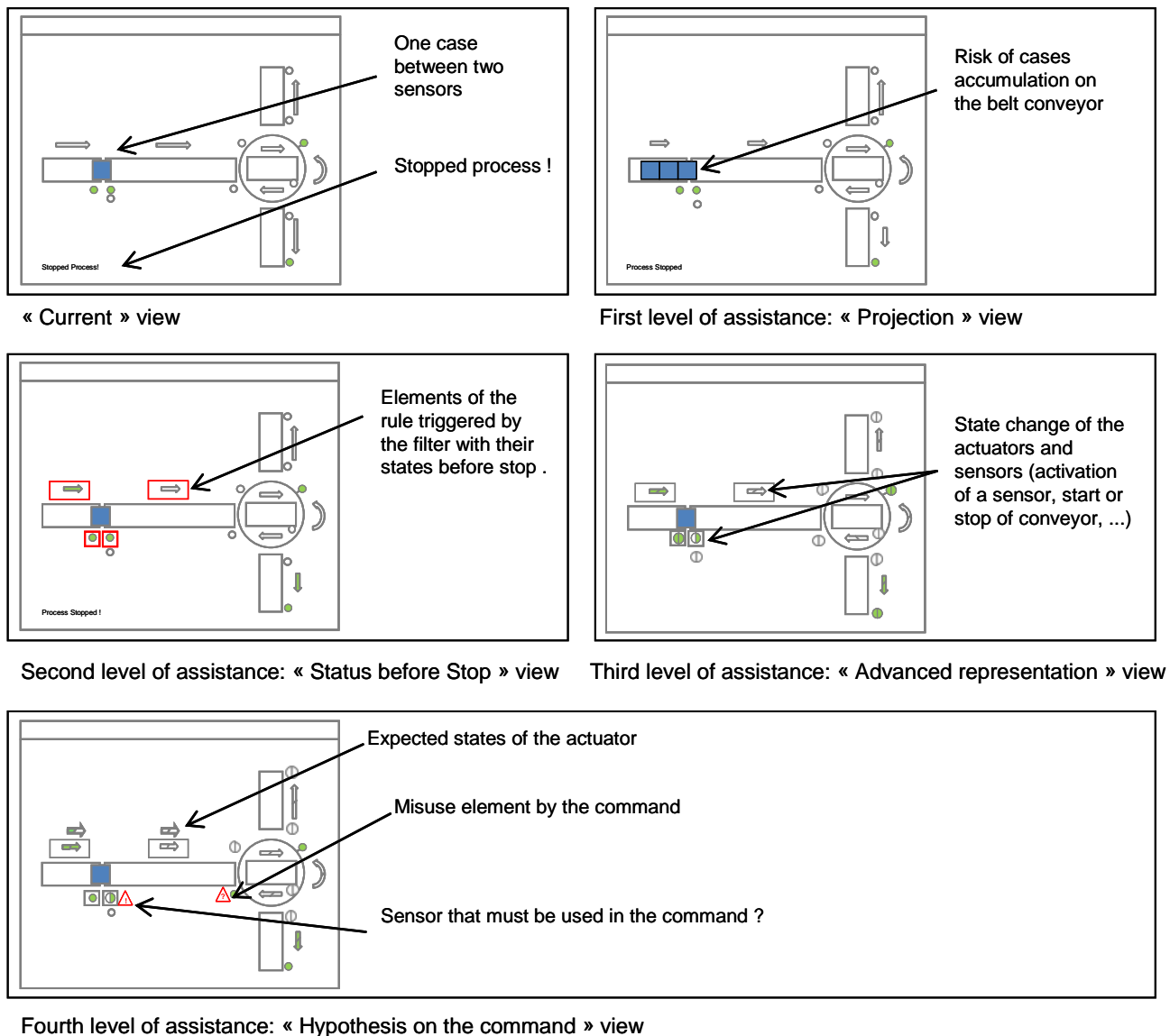


Figure 1-2: Explanations provided by assistance systems on a sorting process of cases

Four levels of explanation have been represented on a top view of the process, which represents sensors and actuators, and information according to the levels of explanation (Figure 2.2). This kind of representation supports topographic searches of clues. The same top view is also used to present the “current view”, displaying sensors and actuators states at the stopped time.

First level of explanation is proposed by the “projection view”, that is, what would have been the state of the process if the process had not been stopped by the assistance system. This is in fact the representation of the bad consequences due to command error; it is a functional representation of the problem. The second level of explanation (“status before stop”) is the presentation of the state of the process just before the stop. This representation focuses on the process elements that had triggered the filter and presents the result of the erroneous command. The third level of explanation (“advanced representation”) is the presentation of the events (rising and falling edge) which had reached a forbidden process state. Here, the display presents two process states, before the forbidden state and after, and explains the bad behaviour of the command. The fourth level of explanation is the presentation of hypotheses concerning the command errors.

This representation explains the behaviour that the command should have, and presents information concerning the non-use of information to reach an output, or the explanation of an unwanted output.

1.2.2 Experimentations

An experimental protocol has been designed in order to evaluate these levels of explanation. Each participant is tested individually during two hours at most. On arrival, participants are briefed on the project objectives and experimental protocol. They read and sign an informed consent document and fill in a brief demographic questionnaire in order to be informed about their KH regarding the automation domain (knowledge-based). Next, they have a short training with the experimental platform to improve their KH regarding process type (rule or skill-based). They learn to control a sorting process. The operative process is simulated on a computer connected to a PLC. Participants are also trained with the assistance system; they learn to use explanations provided by the common work space in order to acquire a KHC. Thanks to their own level of KH and common level of KHC, their cooperation with the assistance system can be assessed during the correction of an erroneous command.

Participants will perform three tests. They receive a photo of the stopped process (cf. Figure 2.1) and the “current view” of the process for each test (cf. Figure 2.2). The first test is the reference condition, and participants receive no explanation and no product information. The second test deals with the first level of explanation provided by the “projection view”. The last test is one of three more advanced levels of explanation provided by the view corresponding to the level. Participants only test one advanced level of explanation in order to avoid learning effects of using the assistance. For the same reason, the command and the type of command error are different for each test. Scenarios and levels of explanation will be crossed in order to avoid carryover effects.

Three types of measurements are realized. Participants will fill in questionnaires regarding their perception of the assistance system. They have to choose an answer between 1 and 7 to assess readability, understability, and relevance of the explanations provided by the assistance system. Second, we will assess participants’ situation awareness regarding the operative part of the process and the information provided by the assistance system. Third, error detection and error correction performance will be assessed.

For the moment, only three participants (License 3 students) have been tested, with the aim to evaluate the experimental protocol. These first measurements underline the necessity to adapt the experimental protocol in order to define the time span for each step of the experiment, and to improve the slides and documents for process and assistance system training. The goal is to have as few questions as possible to avoid affecting the participants’ KH or KHC. Three participants is a too small number to extract results, but a main trend can be distinguished. This trend is that the more the assistance system provides explanations about its analysis of the process (i.e., if participants have more explanations than just the current and projection views), the more they detect and correct the error in the command. They report that the more advanced views are visible, clear, and

understandable, and that explanations help them to detect and correct the control program.

1.3 Conclusion and Perspective

Human-Machine Cooperation principles are a useful means to study how to assist a human operator using a technical entity that has particular abilities. These principles, complemented by a specific method [18], may lead to the definition of abilities in term of KH and KHC.

Experiments will be conducted with much more participants, and with participants with different levels of KH, different expertise (students, teachers, designers) and experience (novice vs. professional). The experiments so far have been conducted with paper forms of the assistance system, in order to be sure to repeat the same conditions (same control program, same error) for all participants. One objective is to conduct the same experiment with all views and documents on a computer. This situation would be similar to a real situation. Another possibility is to use the assistance system during actual practical work.

1.4 References

- [1] Berard B., Bidoit M., Finkel A., Laroussinie F., Petit A., Petrucci L., Schnoebelen P., (1999), Systems and software verification: Model-checking techniques and tools, Heidelberg, Springer-Verlag Edition, 1999.
- [2] Marangé P., Benlorhfar R., Gellot F., Riera B. (2010) "Prevention of human control errors by robust filter for manufacturing system", 11th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, Valenciennes, France, August, 2010.
- [3] Marangé P., Gellot F., Riera B. (2009) "Industrial risk prevention by robust filter for manufacturing control system", 7th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes (SAFEPROCESS'09), Barcelona, Spain, June 2009.
- [4] Kamoun A., Debernard S., Millot P. (1988). Implicit Dynamic Allocation of Tasks between Man and Computer based on Optimal Control. 7th European Annual Conference on 3human Decision Making on Manual Control", Paris, France, january.
- [5] Pacaux-Lemoine M-P., Ordioni J., Popieul J-C., Debernard S., Millot P. (2005) Cooperating with an assistance tool for safe driving. Proceedings of 16th IFAC World Congress, Prague, Czech Republic, july
- [6] Hoc, J-M., Pacaux-Lemoine, M.-P. (1998). Cognitive evaluation of human-human and human-machine cooperation modes in air traffic control. International Journal of Aviation Psychology, 8, 1-32.

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- [7] Vanderhaegen F., Crévits I., Debernard S., Millot P. (1994). Human-machine cooperation: Toward activity regulation assistance for different air traffic control levels. *International Journal on Human-Computer Interaction*, 6 (1), pp. 65-104.
- [8] Pacaux-Lemoine M-P., Debernard S., Crévits I., Millot P. (1996). Cooperation between humans and machines: first results of an experimentation of a multi-level cooperative organisation in air traffic control. *Computer Supported Cooperative Work*, 5 (2), pp. 299-321.
- [9] Pacaux-Lemoine MP., Debernard S., Godin A., Rajaonah B., Anceaux F., Vanderhaegen F. (2011). Levels of automation and human-machine cooperation: Application to human-robot interaction, *Proceedings of the 18th IFAC World Conference, Milano Italy, September*.
- [10] Pacaux-Lemoine M-P., Debernard S. (2002). A Common Work Space to support the Air Traffic Control. *Control Engineering Practice, A Journal of IFAC*, 10, pp. 571-576.
- [11] Rasmussen J. (1983) Skills, rules and knowledge; signals, signs, and symbols, and other distinctions in human performance models, *IEEE Transactions on systems, man and cybernetics, SMC13, n°3, May-June*.
- [12] Hoc J.M., Amalberti R. (1995) Diagnostic : some theoretical questions raised by applied research, *Current psychology of cognition*, 14, pp.73-100
- [13] Parasuraman, R., Sheridan, T., Wickens, C. (2000). A model for types and levels of human interaction with automation. *IEEE Transactions on Systems, Man, and Cybernetics-Part A*, may, 30(3), 286-297.
- [14] Riera B., Debernard S. (2003). Basic Cognitive Principles Applied to the Design of Advanced Supervisory Systems for Process Control. In Erik Hollnagel (ed.) (Ed.), *Handbook of Cognitive Task Design*, Lawrence Erlbaum Associates, Publishers, London, pp. 255-281.
- [15] Stahre J. (1995) Evaluating human/machine interaction problems in advanced manufacturing, *Computer Integrated Manufacturing Systems*, Vol. 8, N°2, PP. 143-150.
- [16] Ribert-Van De Weerd C., Brangier E. (2000). L'usage et l'efficacité des aides à la maintenace en télédiffusion. *Le travail Humain*, ISSN 0041-1868, Vol. 63, N° 4, pp 331-352, *Presse Universitaire de France*.
- [17] Rasmussen J. (1986). *Information processing and human-machine interaction*. Amsterdam: Elsevier Science.
- [18] Pacaux-Lemoine M-P., Crevits I. (2010). Methodological approach and road safety system evaluation, *11th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design and Evaluation of Human-Machine Systems, Valenciennes, France, 31 August-3 Sept*.