Improving Human-System Digital Interaction for Industrial System Control: Some Systems Engineering Issues

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Abstract: In industrial system control, the human-system interaction represents one of the challenges, especially from the field operator's point of view. This interaction is usually guided by procedures. Nevertheless, the adage "error is human" is mainly confirmed in support phases such as maintenance, generally during shutdown and restarting phases. The solution proposed in this paper is to enhance the digital capabilities of the field operator in order to better balance the role distribution between the system and the human. Engineering this human-system interaction as a whole requires formal methodologies in order to define, develop and deploy digital solutions distributed over the technical system and the human operator, seen together as a unique socio-technical system. Ambient paradigm, infotronics technologies, as well as SysML modelling language are the key elements employed herein in order to improve the digital human-system interaction for industrial system control.

Keywords: Process Plant Operation, Human-System Interaction, SysML, Specification

1. INTRODUCTION

Galara emphasizes in his "roadmap to master the complexity of process operation" (Galara (2006)) the main issues concerning non-nominal operating phases like shutdown and restart in industrial systems operation, mainly power plants. These common causes of failures are particularly attributed to the difficulty encountered by the operators to cope with unfamiliar situations, and more precisely to an inadequate role distribution between the human operator and the technical system. For this reason Galara proposes to adjust the process control language semantics as it is the joint support for the control room operator and Field Operator (FO) in control situations.

In other words, the actuation and measurement systems must "disappear" from the FO's focus, as its attention must be centred on the process control and not on the instrumentation control. Conversely, the process must be "protected" with respect to control actions that may deteriorate or even cause dangerous situations. In this sense, the "LABIME" language (fr. LAngage d'expression des Besoins en Informations des Mtiers d'Exploitation) proposed by Galara et al. (2008) is based on process behaviour formalization using logical expressions to facilitate its understanding while banning forbidden actions.

This context highlights the need to enhance the digital interaction between human operators and the technical system, as expressed within the research community by Baptiste et al. (2007).

Herein, we propose a solution for the interaction between human and technical system. The problem is stated in section 2, as well as a reference model for requirement and specification of socio-technical systems. For engineering pur-poses, the "specification" concept is included in a SysML extension, as presented in section 3. Section 4 gives specifications for the human to technical system digital interaction: the digitalization of the technical system and the digitaliza-tion of the human system. Section 5 presents technological elements used to prototype such an improved interaction.

2. PROBLEM STATEMENT

Previous works have shown, in major european programs, the interest to distribute within the process a form of "technical intelligence" organized around a field bus: intelligent actuation and measurement systems (IAMS) and an integrated system of control, maintenance and technical management (CMMS) (Fig. 1) (Pétin et al. (1998)).

In a more general way, Zaremba and Morel (2003) addressed that the intelligence in manufacturing is generating a considerable amount of interest occasionally verging on controversy within both the research community and the industrial sector. This is particularly true when overlapping the engineering of technical systems to the engineering of mind, as addressed by Albus (1999), in order to propose a reference model architecture for intelligent systems.

Considering a production plant, such solutions only concern the instrumented components. However, an acknowledged issue within a power plant is the large number of non-instrumented components which are manipulated by the FO in supporting phases. Because these components

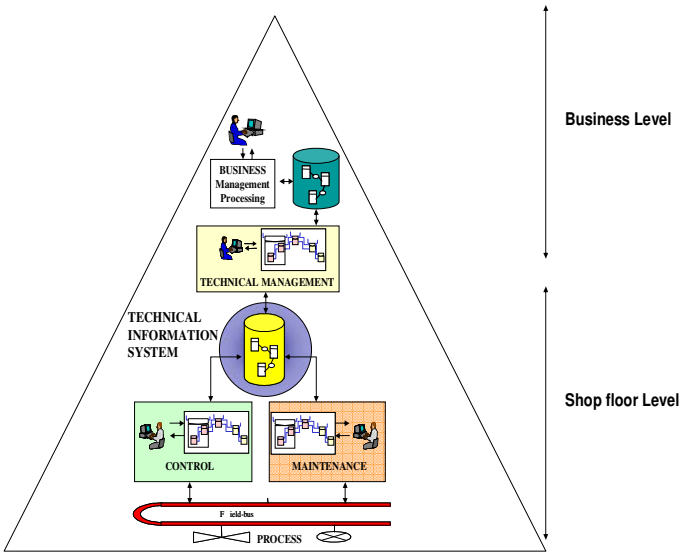

Fig. 1. Integrated Control, Maintenance, and Technical Management based on Intelligent Actuation and Measurement Systems

are unobservable and uncontrollable, the human-system interaction supposes to study first the problem of the balance between the technical intelligence of components and the human intelligence of operator, and then the engineering of this interaction.

This paper proposes to improve this interaction with non-instrumented components by digitalizing it.

Digitalizing the human-system relationships is another challenge of intelligence in manufacturing by considering the human as a component of a socio-technical system. The requirements analysis model (Fig. 2) proposed by Hall and Rapanotti (2005) extends the original model proposed by Gunter et al. (2000) in order to add the human area (H) to the previous area related to the relevant environment (W) and the target machine (M).

A basic principle in this framework for systems engineering issues is that the specification S mediates between

- the *problem space* W of the contracting authority eliciting the statement of requirements R and
- the *solution space* M of the prime contractor prescribing the program P that implements the specification S.

This is recursive to the operational solution.

Another important distinction is that the machine has to guarantee a restricted optative form S of requirements R while the environment has to guarantee a complementary indicative form W of requirements R. The consideration of the human H in this framework introduces two new specifications, one UI which determines the Human-Machine interface and the other I which determines the knowledge K and behaviour that is expected of the human as a component of the socio-technical system.

Our work restricts the formal predicate $W \wedge S \wedge I \wedge UI \Rightarrow R$ of this reference framework to $W \wedge S \wedge UI \Rightarrow R$ in order to specify both the technical intelligence to be embedded into

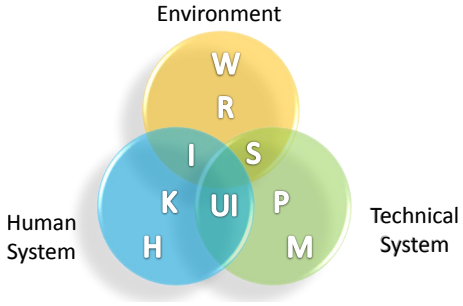

Fig. 2. Requirements analysis model for socio-technical systems (Hall and Rapanotti (2005))

the machine and the digital capabilities to be provided to the human for interacting with the machine (Fig. 3).

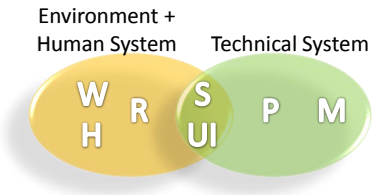

Fig. 3. Specifying the digitalization of the human to technical system interaction

Specified requirements are considered as specification S and are considered as the central structure of the system's requirements repository. Indeed, this requirement repository of our socio-technical system is built by successive refinements and derivations of the original requirements taking into ac-count the domain knowledge. Thus, compared to the realized task, in each work domain a portion of the repository is kept, and allows to achieve traceability between specified requirements.

3. SPECIFICATION METAMODELING

Our Systems Engineering (SE) proposal is built on the pillars of SysML modelling language: the machine M is modelled using the *structure* pillar, the program P is modelled using the *behaviour* pillar and the requirements and specifications are built using the *requirement* pillar.

As the SysML standard does not consider methodological aspects, in order to guide the designer in considering all factors (W, R, S, P, M) in system modelling, we propose to support this modelling approach by extending SysML meta-model (Fig. 4). Some constraints are also defined like: "the SpecifiedRequirement must be satisfied by a Structure that has at least one Behaviour", and "the SpecifiedRequirement must be verified by one TestCase", etc., and expressed using OCL formal language.

As SysML is a semi-formal language, it can not be used to formally verify or validate specified requirements. Thus, in conjunction with SysML one must take into account the use of formal languages and tools for specification verification, and simulation languages to validate this specification.