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SOME CONCEPTS FOR INDUSTRIAL CONTROL PROCESS MODELLING

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ABSTRACT

After an introduction concerning today Firm evolution and the state of the art of industrial control and making decision, this paper first presents a classification of decision depending on production span, reactivity, application field and number of actors. Then, it introduces the methods (a priori, reactive, a posteriori) and the dimensions (hierarchy, space, time) of control. And last, it proposes some concepts for generic modelling of its process using “control centre”, “local” and “global” structures.

INTRODUCTION

In Companies, it is important to examine the methods of anticipating and resolving problems, deciding and controlling physical, informational and decisional flows. To study an integrated industrial control process, we must distinguish between the information acquisition and evaluation, the making-decision process, the act of deciding and the implementation of actions. Some authors [5] [9] [11] proposed models to formalise the making-decision process. But, this process changes with Companies evolution and management according to new concepts of Just-In-Time, Total Productive Management, Total Quality Management, continuous improvement, etc. Then, the process of control also must be adapted to this change and the industrial flows organised and synchronised with time. The control process must take into account external factors of environment and internal factors of organisation and technology. In the classical Taylor’s model the action is based on a clear definition of roles and highly simplified tasks. Individual thinking and decision are minimised. The interpretation of problems and the decision about actions concern an actor endowed with a control capacity on the social system. A local interpretation and a local decision can not be practised. The process of decision based on the model of Simon [12] is simple, linear and without interactions (problem analysis, elaboration of solutions, choice). This model supposes that the problem is perfectly defined, a complete information exists, all actors have the ability to manage this information and the consequence of alternatives may be known. Unfortunately, this model is utopian because the ability of actors is limited and leads to substitute satisfaction against maximisation. In present day Companies, skills and autonomy of actors increase giving them more responsibility. An action will result from a local interpretation and actors will be further

requested to interpret their work. We pass from a centralised model to an integrated control model able to react to the internal and external evolution of systems. The works of Burns and Stalker [4] underline the fact that the performance of a structure depends on its capacity to anticipate the variation of its environment. In the next sections of this paper mainly we analyse the industrial control and present some concepts and formalisms for its process modelling.

INDUSTRIAL CONTROL

It is classic to decompose the Firm system into physical, informational and decisional sub-systems. The object of the decisional sub-system is to control the evolution of the physical sub-system via the informational sub-system considered as the nervous one [13]. Prior to present the approach developed in this paper, we give next an analysis on decision classification and control methods.

Classification of Decision in Industrial Control

The literature situates the first important developments on decision theory during the Second World War, when some researches endeavoured to elaborate methods called by “operational research”, to rationalise military and economic choices. According to this literature [2] [3] [7] [10] [11] [15] [16], we present the following typology of decision:

- According to the *production span*, decision could be *strategic, tactical* or *operational*.
- According to the *reactivity*, decision is *event driving* or *periodic*.
- Decision depends on the *application field* and is *economic, technological* or *human*.
- Decision depends on the *number of actors* and is *individual* or *collective*.

Approaches of Industrial Control

Whatever the organisation of Companies, the industrial control could be based on one or more of the following three different approaches:

- The «*a priori control*» is a theoretical upstream approach based on objectives, models and tools of planning, scheduling, simulation... It poses fundamental problems if models are founded on assumptions non-coherent with the actual system.

- The «*anticipated reactive control*» is a preventive event driven approach applied in actual time to prevent risks and problems. It needs the use of tools as process performance indicators, control charts, preventive maintenance... to correct permanently controlled process trend or deviation.
- The «*a posteriori control*» is a downstream corrective approach applied to correct residual risks and problems. It is more adapted to periodic control and could be used by the help of result performance indicators, corrective maintenance...

Dimensions of Industrial Control Process

The term of «Industry control» introduces voluntarily a comparison with some complex, rapid and heavy vehicles such as aircraft, missiles or ships. Controlling a vehicle corresponds to choosing an objective and defining the best trajectory according to it. Once the vehicle is launched, one must permanently correct its deviation against this trajectory. Then, eventually it must be envisaged to modify during functioning, the trajectory or even the objective, whether the information about the environment and about the behaviour of the vehicle shows that the original plan can not be maintained [1]. Then, the control is a dynamic process built on the basis of several actions decided by different actors, at different times and points of the system. This implies that a system to be controlled it must have an organised structure and in movement. Consequently, the control process depends on the dimensions of *hierarchy*, *depth* and *time*:

- The «*hierarchical dimension*» concerns decisions relevant to the hierarchical structure of the system. At a given time and according to this dimension, actors situated at different levels examine decisions. The decision and control level is a function depending on the objective and the complexity of problem. The *co-ordination* principle constitutes the basis of decision coherence between successive levels of the hierarchical structure [6] [8].
- The «*depth or spatial dimension*» concerns decisions relevant to the lateral structure of the vertical levels. At a given time and according to this dimension, actors situated at the same level examine decisions. The results of a decision act directly on lateral actors and horizontal propagation of the decision. The *co-operation* principle constitutes the basis of decision coherence between successive actors of the lateral structure.
- The «*temporal dimension*» concerns decisions relevant to the behavioural dynamic evolution of the state of the system. At a given point of the system and at a given time a decision is different from a decision at another time. An applied decision becomes irreversible with time. According to this dimension, decisions are dependent and some triggering events, some actions are susceptible to definitively call into question the strategic objectives of an organisation.

CONCEPTS FOR INDUSTRIAL CONTROL PROCESS MODELLING

In literature, the control process is limited to the lowest level of the industrial system and called “Production Activity Control” or “Shop Floor Control” [14]. On the other hand, decision is linked to the highest levels, it is a matter of strategic or tactic decisions for managers and a question of shop floor control for production actors. It is important to note that we are not faced to two-tier concepts. Decision is a part of the control process, which must be expanded to the whole corporate system. Very often, the system is analysed according to decisional levels, and a global analysis of physical, decisional and informational flows is not clear enough. The systemic approach is not adapted for an analysis considering the time factor. Then, we think that it is judicious to model the control according to a process approach, in which we consider the major role of time factor, hierarchy, space and internal and external risks.

To design and model the control process, we propose the following three concepts: *global*, *local* and *control centre* concepts. The global concept (fig. 1) situates the control process in its environment and proposes a structure based on its dimensions, the local concept (fig. 2) organises control process around its methods whereas the control centre represents the brain of control process. The complementarity between these concepts creates an integrated vision to build the whole control process.

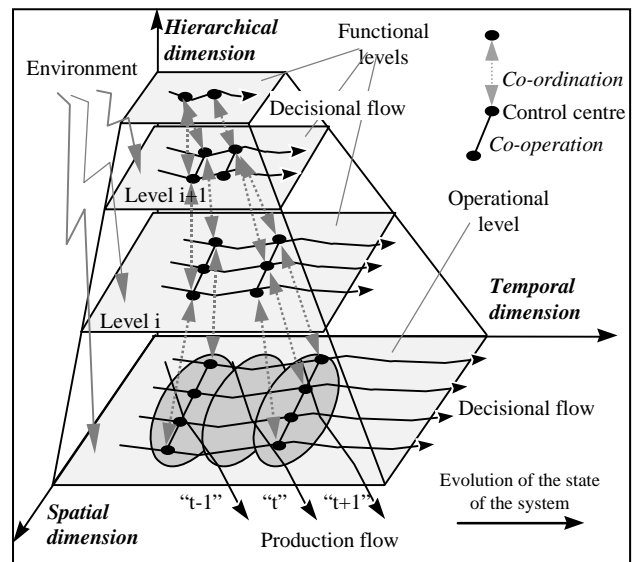


Fig. 1 - Global structure of industrial control process

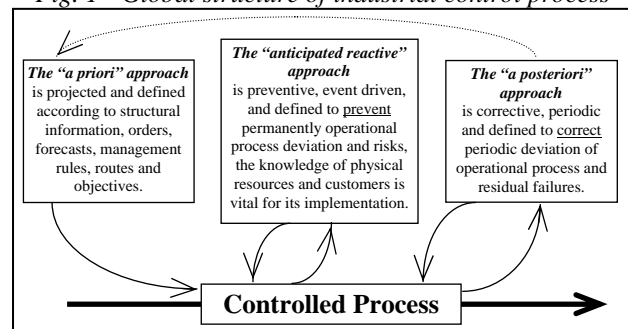


Fig. 2 - Local structure of the industrial control process

The control centre is composed of the following components: actors (a), referents (R), objectives (O), rules (ρ), actions (A), measures (m), resources (r).

We use the following notations to formalise the industrial control process:

- Control centre

$$C = C_{i,j}(a_{i,j}; R_{i,j}; O_{i,j}; \rho_{i,j}; A_{i,j}; m_{i,j}; r_{i,j}) \quad (1)$$

Where i = hierarchical level,

j = number of control centre at the same level

- Objective of a control centre

$$O = O_{i,j}(R_{i,j}) \quad (2)$$

- Co-operation relation (at the same level i)

$$R_{cop} = R_{cop,i,j}(C_{i,j-1}; \mathbf{C}_{i,j}; C_{i,j+1}) \quad (3)$$

- Co-ordination relation (between levels $i-1$, i and $i+1$)

$$R_{cor} = R_{cor,i,j}(C_{i-1,j}; \mathbf{C}_{i,j}; C_{i+1,j}) \quad (4)$$

- Action decided by the control centre C_{ij}

$$A = A_{i,j,t}(m_{i,j,t}; O_{i,j,t}; \rho_{i,j}; (R_{cop,i,j}); (R_{cor,i,j})) \quad (5)$$

CONCLUSION

This study shows how the process of industrial control is deeply linked to the change and mutation of systems. The design of industrial control process must be founded on significant analysis of this system, its evolution and its environment. The modelling of control process becomes more complex with the consideration of environment, time, risk factors and new management approaches. Then, we must have necessary experience and skills about the considered field and about situations needing frequent decisions. In order to consider industrial preoccupation, our research takes into account the numerous interconnections between actors and flows according to the dimensions we have fixed: hierarchical, temporal, and spatial. Considering time is a necessary condition for dynamic modelling and design of control process. With time advance the effects of an action could change. According to the proposed concepts, we focus our research on risk factors (breakdowns, scraps, lateness, uncertainty...) needing corrective or preventive decisions, whatever the level of the structure: operational, tactic or strategic. The existing researches on decision and the consideration of irreversibility allow us to consider the increasing complexity of the organisation on the proposed concepts. Modelling the system by a non-

linear model calls into question traditional linear models. However, the proposed concepts must be refined and a generic model integrating the decision making process will be proposed to model the concept of control centre. Aggregation of results and decomposition of decisions and structural information must be considered to formalise both co-operation and co-ordination relations.

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