Organizational alternatives for flexible manufacturing systems

Moniz, António

UNINOVA, UNL-FCT, IET

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António Brandão Moniz

(Sociologist, CRI-UNINOVA and Faculty of Sciences and Technology-UNL)

Campus da FCT/UNL - Quinta da Torre • 2825 Monte de Caparica • PORTUGAL

E-Mail: abm@fct.unl.pt

Abstract

There is an increasing importance of different productive architectures related to worker involvement in the decision making, where is given due attention to the intuitive capabilities and the human knowledge in the optimization and flexibilization of manufacturing processes. Thus having reference point architecture of a flexible manufacturing and assembling system existent at UNINOVA-CRI, we will present some exploratory hypothesis about applicability of the concept of hybridization and its repercussions on the definition of jobs, in those organizations and in the formation of working teams.

Keywords: flexibility; robotics; work organization; manufacturing industry

Introduction

Some research projects aim the socio-technical evaluation of the appliance of human-centered systems to manufacturing industries with the objective of

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demonstrating and assessing the superiority of this method over the conventional approaches to automation. This evaluation should not be merely an economic one (cost analysis, accounting), but would include mostly social variables, such as: working conditions, development of indirect operations and it's effect in the tacit knowledge, skilled work in automated production systems, autonomous working groups, de-centralization of decision making.

The Engineering literature is not yet developed in this field, and there are some experiments in this scientific fields that use an intensifying collaboration with the Computer Sciences, Quality and Production Engineering, and Sociology approaches.

Some ESPRIT and BRITE projects can be used as reference frameworks to this collaboration, in particular those with special references to Social Sciences, i.e., the ESPRIT 1199/1217 “Human-Centered CIM Systems”, ESPRIT 5564 “Integrated Design and Evaluation of Assembly Lines within CIM”, or the BRITE projects 1381 (on interactive knowledge based shop floor control systems), 3302 (on Decision Support Systems) or 3345 (on flexible production groups), or even the ESPRIT exploratory action 5603 on “Joint Technical and Organizational Design of CIM systems for SME’s”.

At the same time has been recently recognized that the human-centered systems concepts, and the Human and Computer Integrated Manufacturing concepts, are more and more determinants for the correct efficiency and performance of flexible and automated production systems. It is necessary than to analyze, design and evaluate integrated socio-technical systems, specially the new systemic relation between the organization, the technical system and the social and economical environment. Some of those issues have been analyzed, and there is a trend to approach this new problems through some FAST projects, namely the ones related to APS-Anthropocentric Production Systems, and the FINE-The Future of Industry in Europe, that involved even colleagues from the United States and Japan.

Thus, there is a research program in Portugal where the development of an implemented output is taking place, using a real FMS as a demonstrator and producing several interfaces with IT criteria and architectures [2]. The goal is the development of methodologies for job design in complex environments/organizations. This aims the

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[2] This program is involving UNIVOVA-CRI, INESC-Porto and central trade union CGTP can join it in the near future.

analysis of social implications of use of IT platforms in advanced manufacturing systems, using a simulated situation that will be assessed.

In this sense the program will develop some new job design methodologies in reference to organizational networks (working groups, production cells) and with IT support tools. These methodologies will be implemented in a technical infrastructure that is also in a prototype stage. This means that alterations to the layout, or other technical re-configurations can be done after this global prototyping activity in a socio-technical framework of scientific and technological development.

Design of Complex Manufacturing Systems: sociological problems

In the analysis and design of Integrated Manufacturing Systems (IMS), simulation is a frequently used tool to evaluate and compare alternative scenarios for the organization of manufacturing activities and production management strategies. Simulation systems rely normally on computational models that describe the operational aspects of activity networks, enabling their quantitative and logical evaluation. The construction of these models depends on the simulation system. Maximum modeling flexibility is achieved with general-purpose simulation languages, but these offer very limited expressiveness for problem communication and understanding. On the contrary, “data-driven” simulation (based on pre-defined models, usually queuing networks), in conjunction with graphical interfaces, provides less flexibility but better communication for the system structure and the concepts under evaluation.

Although simulation is a well-established field in the analysis and evaluation of FMS at the physical operations level, there are few contributions to the simulation of organizational structures and even fewer when we add the modeling and simulation of software applications supporting manufacturing activities. Organization structure simulation has been addressed from an exclusively operational viewpoint and focusing on evaluation criteria similar to those used in the physical operations level: lead-time, WIP level, system loading and delivery dependability (Zülch, 1993). Also work on shop floor control software and physical operations joint simulations have been reported in (FERREIRA, 1994). Here the modeling purpose is the shop-floor software behavior and their interaction with the physical operations, the goal being to support the technical system development.

At the same time, some problems can occur during the application of each possible hypothesis for the development of such systems, namely the following ones:

a) Total automation with centralized human control;

b) Non-automated process of shop floor work with a “one job, one machine” system;

c) Hybrid system of automated cells with “elastic” jobs.

Simulation-based approaches, although important as a design step, are not sufficient to understand and evaluate all behavior of a planned system (cf. MONIZ and SOARES: 1996). The realization of a physical demonstration system is therefore a very important tool to help in the discussion of the solution and also a catalyzer for gathering precise definitions of requirements and to refine solutions (cf. BARATA, J.; MATOS, L.C.: 1993).

It is possible to develop arguments of psychosocial and ergonomic types, as well as is possible to build up alternatives that consider the inclusion human jobs integrated in such complex manufacturing environment (NICOLAISEN, P., 1986, pp. 265). These jobs should be richer in terms of content, because they would demand a more advanced qualitative intervention from individuals. So, although hybridization was not a prime objective, it became a variable of the integrated manufacturing system.

System Architecture

This unit can therefore support the development of demonstrating solutions jointly developed by researchers and enterprises. It is expected to involve in a later stage, research people from trade unions, and operators that can perform some demonstration tasks.

The demonstration unit has an architecture in which it can be operated either as an integrated FMS/FAS system or as a set of isolated subsystems (machining, assembly, transportation and storage, etc.). This last aspect has particular consequences on the design of the control architecture.

The CRI's pilot unit has 5 subsystems, designed to install in two adjacent rooms, with a total area of approximately 60 m2:

(1) FMS subsystem,

(2) Multi-Robot FAS subsystem,

(3) Automatic Warehouse subsystem,

(4) Transportation subsystem and

(5) Sensorial subsystem.

Each subsystem can be operated autonomously or as part of an integrated system. Subsystems 4 and 5 are mainly complementary to the first 3 modules. The transportation subsystem itself can work in separate sectors, to support the isolated operation of any of the other subsystems.

The transportation medium is a pallet-based conveyor belt. Each pallet can be adapted to transport different kinds of parts and products. In order to define the computational architecture to be used in this system for the demonstration proposes it is necessary to consider the diversity and heterogeneity of existing controllers.

In this system, several local controllers must coexist: ABB robot controllers, BOSCH robot controller, Transportation subsystem controller (BOSCH PLC CL 300), warehouse controller, platform controller, CNC Milling and Turning machines controller.

Each controller has own facilities. It is, therefore, necessary to define architecture able to integrate all these controllers, assuring a coherent and effective interoperability between them. This will no be developed within this project, but some requirements are to be presented for the design of a distributed control architecture based on autonomous agents. An infrastructure to support negotiation and other forms of cooperation between agents will be investigated, especially in Tasks 2, 5, 6 and 7.

The client-server paradigm in a network of UNIX machines, resorting to Remote Procedure Calls, can be used, and another area that can benefit from the existence of this unit is the field of Systems Modeling. Experiments with OOP languages, generalized Petri Nets and EXPRESS/STEP are being developed.

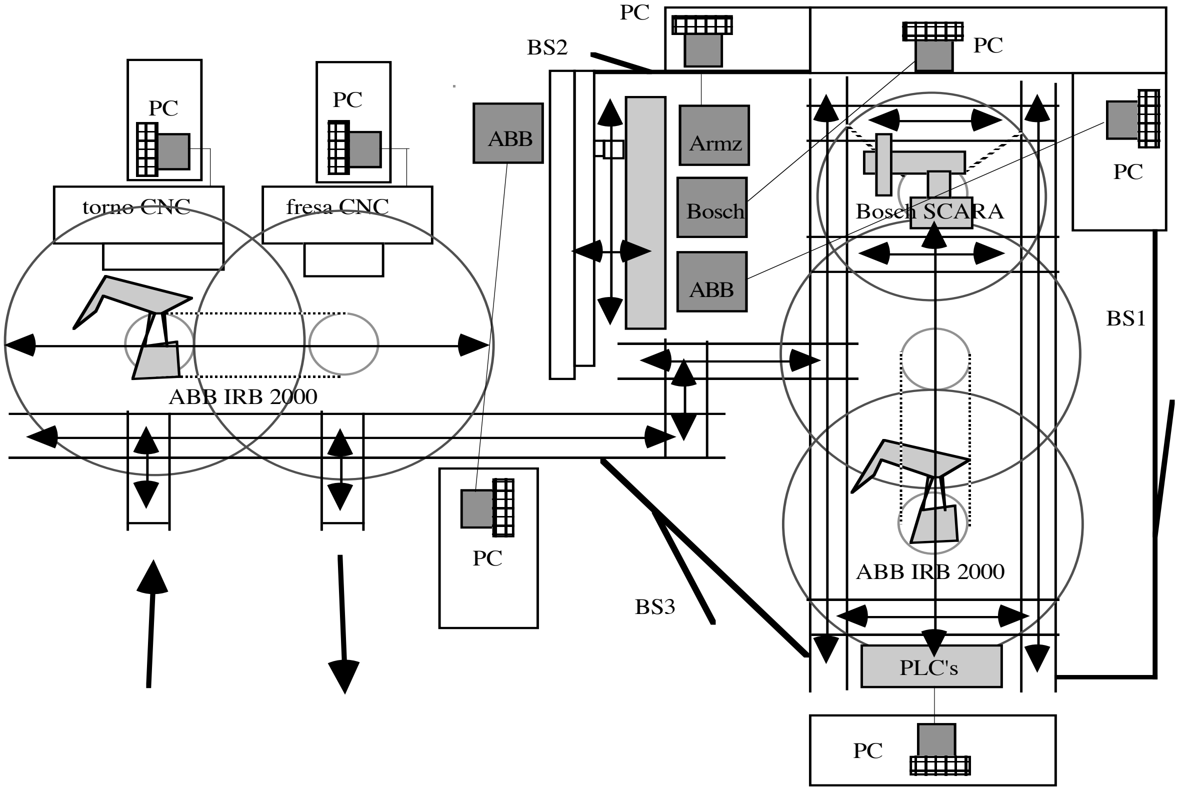

Fig. 1 - The Flexible Manufacturing and Assembly System of UNINOVA-CRI

Considering those few units and sub-systems we can speak about the implementation of three *cells* (cf. MONIZ, OLIVEIRA, BENTO, 1995):

C1 - machining cell

C2 - assembly cell

C3 - warehouse and transportation cell

Table 1 - Production Cells

Cell	Machines	
C1	MF1	CNC turning Machine tool
	MF2	CNC milling Machine tool
	R1	IRB 2000 Manipulation robot
	PC/MF1	Controller of MF1 Machine
	PC/MF2	Controller of MF2 Machine
	I/O Buffers	Input and output Buffers
	PC/R1	Controller of R1 Robot
C2	R2	IRB 2000 Manipulation robot
	R3	SR 800 Scara Robot
	PC/R2	Controller of R2Robot

	PC/R3	Controller of R3 Robot
	BS1	Security barrier of R2 Robot
C3	Arm-Flex	Flexible warehouse (units)
	R4	Arm-Flex Manipulation robot
	PLC	Conveyor PLC
	PC/PLC	Transport System Controller
	PC/Arm-Flex	Warehouse and R4Controler
	BS2	Security barrier of Arm-Flex
	BS3	Security barrier of Conveyor

Based in a flexible manufacturing and assembly system like the one presented in the pilot-unit UNINOVA-CRI, job design task of the work organization system and the eventual establishment of working groups, is a task that can be preformed by social scientists, or similar technicians, that would intervene in this type of system (cf. MONIZ, A.B., 1992). In this moment this task is not yet finished. In this paper are presented some suggestions that allow the design of some possible trends, and the definition of some presuppositions and limits to the implementation of those jobs.

First of all, this job definition is biased by strategies of development of work organization in the system that supports the pilot-unit. It can support only one job that supervises and manages all the system, as a complex system that affects one job to each machine or element, i.e., about 18 jobs with segmented tasks and quite pre-determined functions, adopting a Tayloristic production model.

We consider a scenario that includes only 8 jobs that require some specialization, but are basically polyvalent. Its distribution could be the one presented in figure 2.

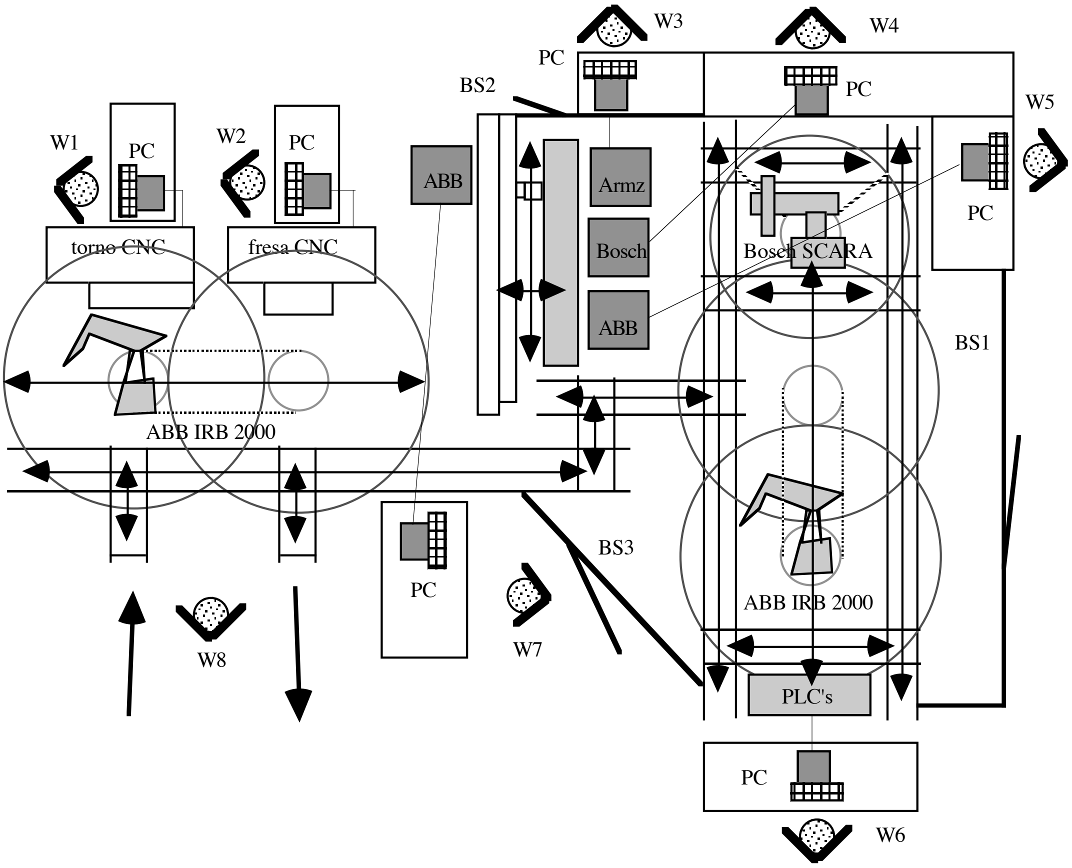

Fig.2 - Flexible manufacturing and assembly system of UNINOVA-CRI integrating eight Job

In this scheme is possible to deduct some needed tasks to be performed in each job. Those tasks, described in a generic way, and being associated to specific jobs presupposes a need for enriched contents. In other words, the several previewed jobs (W1...Wn) will be always object of tasks enrichment (vertical enlargement of aggregated tasks), once one operator at job W2, for example, would not only execute the associated functions to the operations of machine tool MF2, but also should perform its programming, quality control (cf. ZACHARY, W.; WEILAND, M.1994), maintenance, preparation of work and planning/scheduling of different operations. Table 2 illustrates other examples that can be verified.

Table 2 - Task Definition

Job	Tasks	Job	Tasks
W1	MF1 Programming	W5	R2Programming
	Quality control		Quality control
	Maintenance		Maintenance
	Preparation and scheduling		Preparation and scheduling

W2	MF2 Programming	W6	PLC’s Programming
	Quality control		Movements Control
	Maintenance		Maintenance
	Preparation and scheduling		Preparation and scheduling
W3	Arm-Flex Programming	W7	R1 Programming
	Maintenance		Quality control
	Preparation and scheduling		Maintenance
W4	R3 Programming		Preparation and scheduling
	Quality control	W8	Support to the material input
	Maintenance		Support to product expedition
	Preparation and scheduling		Buffers and stock management

Having this description some alternatives can be raised if, and only if, there exists the possibility for the development of *new forms of work organization* besides the tasks enrichment already referred. In particular, we are mentioning a form that can promote tasks rotation or the constitution of working groups.

Based on the technical presuppositions for the definition of manufacturing and assembly cells we can preview a grouping of jobs according to those principles, presented in table 3. In this framework one can consider that job W1, W2, W7 and W8 can be allocated in the machining cell C1, W4 and W5 jobs in the assembly cell C2, and W3 and W6 jobs in the warehouse and transport cell C3. Even so, other multiple hypotheses can be considered based on other criteria [3].

Table 3 - Task grouping by manufacturing cell

Cell	Machines	Jobs
C1	MF1	W1
	MF2	W2
	R1	W7
	PC/MF1	W1
	PC/MF2	W2
	PC/R1	W7
	Buffers de I/O	W8
C2	R2	W5
	R3	W4
	PC/R2	W5
	PC/R3	W4
	BS1	W5
C3	Arm-Flex	W3
	R4	W3
	PLC	W6
	PC/PLC	W6

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[3] An ergonomic analysis was already done for W5 job: cf. OLIVEIRA, P.; BORGES, P.; FERREIRA, R., 1994.

	PC/Arm-Flex	W3
	BS2	W3
	BS3	W6

Work organization based on nets and working teams

The network organization (vertical and horizontal task enlargement, and operators frequent inter-acting) and the constitution of working teams, seems to be good strategies for situations with high levels of working qualification and technological complexity.

In this sense, the automation of the own programming process, via automatic plan generation, monitoring of the plan execution and the eventual error recovery (cf. STEIGER-GARÇÃO, A.; MATOS, L.C., 1988), should take into consideration organizational aspects and the ones derived of the men-machine relation. This process can be able to reconfigure and re-distribute the workload in multi-machine cells and multi-cell systems (as is the case of the pilot unit UNINOVA-CRI). In the case of problem or error existence, the more important is the possibility of inclusion of social variables in this system that demands an intensive capacity of intervention and of autonomy of competent decision-making.

In this way, information in circulation can not only be processed automatically, but also can be changed and added by individuals (operators W), or even it can circulates only among individuals aggregating new data that allow a major quality in decision.

The “production cell” concept in these flexible systems, gains a new sense as element of the new manufacturing models. Is not only a problem of coherent integration of a multi-machine system, but a advanced technological system that permits that integration allied to the possibility of operators to intervene, correct, program, forecast in a co-operative way the performance of a complex system. But that demands a basic technological development strategy oriented for those organizational principles. At this moment, the referred pilot-unit allows this intervention, which is a challenge for the sociological practice in the industrial activity.

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