An Experimental Platform for e-Manufacturing and Advanced Control^{*}

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Abstract

In this paper, we present an experimental platform for education and research purposes. The physical system of this platform is composed of a manufacturing workshop (physical plant) remotely controlled based upon Internet. The information system is composed of three Web applications allowing to order products (*e-COMMERCE*), plan production campaign (*e-PLAN*) and control the workshop in order to release production (*e-MES*). We first describe an education application for engineer students to learn them how to control several production units (eventually on different sites). This platform would also be used as a demo for research works in the field of industrial engineering.

Keywords:

Control education; Command & control systems; Remote and distributed control

1. INTRODUCTION

Remote control of one or more production units is a major issue within the globalisation of production [Panetto et al., 2006]. In a near future, we can imagine that a production manager will be able to remotely control in real-time several plants all over the world. Within this prospect, we developed an experimental platform. This platform comprises a real production line and an information system. The information system is composed of different applications accessible from the Internet. We intend to use this platform for education and research purposes.

In section 2, we present the architecture and functioning of the physical manufacturing system. In section 3, we describe the information system, with a highlight on the three applications used to process orders (ordering, planning and production management) from the Internet. We detail in section 4 the possible applications for education with this platform. The section 5 outlines some future research applications. Finally, section 6 gives an abstract of some problems we met.

2. OVERVIEW OF THE PHYSICAL SYSTEM

The system consists of a production line, composed of 4 workstations, one load station and one unload station linked by automatic conveyors. The aim of this production line is to fill boxes with different kind of components. The box is loaded on a pallet which contains a RFID chip to identify the product, operations to perform and data over passed operations. The pallets are automatically routed on each station thanks to the data written in the RFID chip.

Load station 1 and unload station 6 are the beginning and end of all manufacturing processes. A central loop supply each workstation with pallets. The bypass workstations 2 to 5 are dedicated to assembly tasks: inserting some components in the box automatically (workstation 2) or manually (workstation 3), closing the box (workstation 4), inserting some sub-assemblies in the box (workstation 5). The figure 1 shows an example of product and its route sheet and figure 2 details the functions of workstations.

Each station is placed in derivation of a circular conveyor belt. For each station, a Programmable Logic Controller (PLC) controls the behavior of the derivating conveyor belt, and manages priorities when products come back on the central conveyor belt (except for stations 1 and 6, which are controlled by the same PLC; see figure 3).

^{*} This work is based upon a project initiated by the École des Mines d'Albi-Carmaux and the "Plate-Forme Technologique" of the "Lycée Rascol", in Albi.

Figure 1. The box “H7-2” and its route sheet

Figure 2. Functions of the production line

The link between physical system (mainly: manufacturing line) and the information system we will focus on is provided by two servers. These servers are located on two different sites linked with Internet. The production line is located at RASCOL site with one server, and the other server in EMAC hosts the information system. The figure 4 shows the servers' disposition.

3. FOCUS ON THE INFORMATION SYSTEM

Based upon the physical system described above, we have an information system, consisting of mainly three applications:

Figure 3. The production line: conveyors, PLCs and operations

Figure 4. Location of servers

- *e-COMMERCE*, an application where customers may connect and order products;
- *e-PLAN*, connected with *e-COMMERCE*, it may verify the feasibility (in terms of date) of the commands, and it allows the production manager to plan the orders;
- *e-MES*, or *Manufacturing Execution System*, allowing the remote control of the production line.

The *e-COMMERCE* and *e-PLAN* applications are located on a server in EMAC site whereas *e-MES* is deployed on both machines (in EMAC and RASCOL; see figure 4). The *e-MES* services are all hosted in EMAC but the communication service hosted in RASCOL. This service is based upon the OPC¹ technology, which provides PLC data access. The OPC standard allows communication between PLCs and computers through local network (Ethernet). An hard point is access to OPC variables across the Internet (see section 6 and [Neumann, 2004, Banaszak and Zaremba, 2003, Dolgui et al., 2006]).

OPC standard is a mean of access to a PLC variables. A computer hosts an OPC server, which

¹ Ole for Process Control, see [OPC Foundation]

is connected (in our case, through Ethernet) to the PLCs. An OPC client may be deployed on the same or another computer. The *e*-MES application provides an OPC client which may be delocalized on another computer (typically, the OPC server) to avoid every problems due to DCOM and firewall settings. This delocalized OPC client is called a “*daemon*” in our *e*-MES application [GlobalScreen Intra].

Figure 5. Servers and hosted applications

The RASCOL server hosts a *daemon*; this *daemon* is contacted by the *e*-MES server on the other host (this *daemon* is the communication service), and deploys an OPC client to communicate with the OPC servers, which gathers (and sends) data from (and to) the PLC (see figure 5).

Figure 6. Order processing

The figure 6 shows the whole process, from a customer ordering products to the manufacturing process. Using *e*-COMMERCE, all the orders of all customers are stored into a database. Then, the production manager may select different line items (from different orders and/or different customers) and sort them into a campaign, using *e*-PLAN. On

the figure 7, we can see the process of campaign making; currently, our applications do not provide any support to this process (see section 5 for future work). Finally, the *e*-MES users may release the production, integrating datas from campaign into the *e*-MES database. The *e*-MES sends to the load station the number of pallets to be done, and for each pallet the complete process data. These data are written in a RFID chip on the pallet.

Figure 7. Process of making a campaign: from line items to manufacturing orders

During the manufacturing process, the RFID chip is read by every workstation, and if an operation is performed, the PLC writes data over the operation (status, time,...) in the RFID chip. At every time of the manufacturing process, the *e*-MES has an access to a bunch of data from the PLCs, for example: number of pallets launched and finished, stock status for each station,...

The server in EMAC hosts the *e*-COMMERCE and *e*-MAC applications and their database. These applications allow customers to order products with a *Web* interface. Each order contains at least one line item (product, quantity and wished delivery date). *e*-PLAN may be called at this step for two reasons: (i) check that the wished date is in the future (ii) with a quick planning, ensure that the line item may be delivered within the wished date. At this stage of development, only the task (i) is integrated in *e*-PLAN. With *e*-PLAN, the production manager will make the definitive plan for production. When a campaign is ready (line items validated and integrated and some parameters set), it can be released.

The *e*-MES user (production line manager,...) has an interface to launch the line (switch conveyors on,...), and he can release the first campaign in the waiting line; The *e*-MES will load the data corresponding to the first line item and send them to the PLC # 1. Then, the production will start as soon as a pallet will be detected on the line before the first PLC (except if a campaign is already launched, or the line is stopped).

Now we described the way the system works, we will focus upon applications, with a special highlight upon education.

4. APPLICATIONS FOR EDUCATION

4.1 Goals of this experimental platform

We admit that globalisation of industrial production is to be taken into account for education of future engineers. To get on one side the best products and on the other side a better responsiveness, companies tend to organise into national or international-wide networks, including many production sites. To answer the customer needs, one of the major points is the flexibility responsiveness associated with the highest customer service ratio. However, the hard point of these networks (or companies which have several production sites) is (i) to get a better coordination of the set of plants/companies (ii) to globally optimize of the whole network, to get higher profits [Morel et al., 2007].

This experimental platform is intended to put the student in a “real-world” situation, as similar as the ones she could deal with as a production manager. First of all, her work consists in controlling a subplant, to satisfy orders by delivering finished goods. So, she must be able to mobilize her knowledges in production organisation, technical data, processes, performance measurement, planning, launching, reporting and flow analysis, quality, etc. It may be necessary to have more technical knowledges (*e.g.* PLC, robotics,...) if we want the student to be confronted with equipments problems and to be able to diagnose and solve them. Moreover, in order to anticipate the future technical and cultural evolutions in companies, we envisaged that the future production manager will not physically be present on the production site but may be on another site and will use tools to remotely control her production unit. To go further, we may imagine that the production lines will be located on different sites. Thanks to real-time remote control, the production manager would distribute orders on different sites, depending on the customers localization and the capacity and availability of each site.

The three applications constituting the information system (*e-COMMERCE*, *e-PLAN*, *e-MES*) are available from Internet. This wide availability allows students to access every functions, specially the production line control, even they're not on the site. An IP cam, installed on production line, allows the overseeing of the process and workshop.

From now, we will present some education and research applications and we will limit these applications to one production site.

4.2 Education for production management

In this subsection, we propose an education application for engineer students, working on a remote site (not the production site).

Assumptions We suppose that they have been presented the global platform and that they are able to use it: (i) create and parameter production campaign with *e-COMMERCE* and *e-PLAN*; (ii) release and follow the status of the production with *e-MES*. With these applications, they have a discrete events flow simulator with a model of the production system. We assume the model is valid, *i.e.* its dynamic behavior is really similar to the one of real production system, specially for production flows. Thanks to this model, the students can release simulations to test their campaign before releasing them on the real production line.

The work to be done From a list of line items coming from different customers (with different reference, quantity and delays), the students have to prepare the production campaigns before release. The making criteria of the campaign are numerous but the main goal is to respect each order's delay. The student's work may be decomposed into two steps: (i) a preparation and planning step: for that, the students have a simulation model of the production line flows, and the production data filed by the *e-MES* from the passed campaigns. The simulation allows to familiarize with the line and identify the parameters influencing the objective, therefore determine an optimal solution, which may satisfy each customer's needs, in terms of delay. This step may eventually be done on its own, without calling the real production line. (ii) A release step on the real line, and the students may remotely release and follow the production status, taking different events into account (breakdowns, interruptions, order modification, new order,...)

Following of the work A technician is physically present on the production site to deal with the tasks needing to be present, but cannot interact with the choices made by the students on organisation and control, except in case of emergency. The *e-MES* allows to real-time follow the execution of every line items thanks to the RFID chips on the pallets. The students, thanks to the *e-MES*, may assign and fix every parameter of the campaigns (priority, upstream and downstream queues management on each workstation, release sequence,...). The *e-MES* informs them of the disturbances that may occur on the line and the students may react by modifying some control parameters to keep the delay objective. When a campaign is finished, they may compare their real results with the simulated results they get within the preparation step. The production data filed by the *e-MES* allow them to analyze the real functioning of a production campaign.

4.3 Other education applications

Such a system integrates many physical and information subsystems; these subsystems may be disconnected to get more traditional education applications. For example, we may ask the students to work on a robot's programming (one of the robots installed on the line), on a PLC's programming, on the development of a monitoring application, etc. For the remote control, many applications may be conceivable: configuration, interconnection and performance measure of different networks (PLCs and Ethernet), configuration of OPC server and development of an OPC client to access PLCs' variables, etc.

5. RESEARCH APPLICATIONS

With this system, the research labs have an access to an experimental platform, complete, open and near to reality. The interests are (i) to have a demonstration platform to show the lab's works to industrials with an original and innovating application and (ii) to mutualise funds and resources with a system many labs can remotely use. Thanks to this system, researchers may valid their works on structure, organisation and control of one or more real and remote production sites. Indeed, to take into account the recent production technologies (machines, transportation, ERP, MES, RFID, etc.), this platform offers to researchers an access to means of production like those used (or will be) in the industry. This is a way of support research more realistic, easier to communicate and to show, and quicker to transfer on industrial sites.

Possibilities offered by this system Production data filed by the *e*-MES may be useful as real experimental data to make or validate models. A progressive extension to higher levels of an information system (ERP, APS) may be done, letting different labs the opportunity to connect their own applications, in particular in the fields of decision aid. On another way, we may consider an extension to other production units in other labs/universities to get a multi-site production system.

Research perspectives Planning optimization and campaign making/ordering is the priority perspective. Indeed, the *e*-PLAN application does not contain any decision aid support, such that the campaign are made empirically. As mentioned above, a simulation model of the physical system's flow allows to test the campaign releases but it is not used with any optimization algorithm. So the research works may relate to the coupling of the simulator and some metaheuristics to optimize the campaigns. The objective function could be composed of many criteria as the respect of the date for each manufacturing order, minimization of the number of pallets used, load-balancing of workstations, etc. [Valckenaers et al., 2005, Fowler and Rose, 2004].

Another perspective is actually being prospected within a PhD. The aim is to use the flow simulation for control aid, being connected with a real process. The idea is to simulate in the short run the process functioning and to measure the consequences of hazardous events (stockouts, breakouts, urgent orders,...) to compare with aimed objectives. We can imagine that some simulations launched at each event on the real process would allow to compare the objective at the beginning of a production with the already reached objective to check if nothing has changed. Practically, the simulation tools are not able to interact with tools such as *e*-MES. So the initialization of the simulation model in a state equivalent to the real process status and the response time of the simulation are the first gaps to fill. On their side, unlike the other tools of information system such as ERP, the *e*-MES tools allow to real-time follow the evolution of indicators reflecting the process state. However, *e*-MES tools do not provide any help in the decision to correct the control variables. For this work, a proposal has to be made to integrate simulation with a *e*-MES use for decision aid in control [Mirdamadi et al., 2007, van der Zee, 2006].

The integration of the customer in the planning and execution system is another perspective. Indeed, the current information system (specially *e*-COMMERCE) runs without feedback: when a customer orders a product, there is no check for the workshop capacity to satisfy this order for the due date. The production line is therefore considered as unlimited capacity; that may cause late delivery. Here, the idea consists in integrate the workload calculations induced by an order to the planned workload to check the feasibility of deadlines. In case of non-feasibility, the client must be given other possible delivery dates. So the client would become an interactive agent in the planning process.

6. PROBLEMS ENCOUNTERED

The first kind of problems we met are due to the tentative of remote control. Indeed, Internet connections and remote control of computers over the Net (with VNC, for example) suffer from the lack of reliability of Internet. Although the network is resistant, some breakouts may occur, specially at our final nodes.

Another kind of problem is due to OPC. This standard is based upon Microsoft DCOM, and the settings to get things working are quite complex and not really fault-tolerant. For example, some Windows updates may be the cause of a weird dysfunction. In fact, for the use with *e*-COMMERCE, *e*-PLAN and *e*-MES, we do not need special settings for DCOM. These special settings are useful to connect a simulation tool, which is generally hosted on another computer, and needs to access DCOM variables through different kind of clients, for example VBA for Excel with an OPC library.

This is one of the issue for the connection between simulation tools and e-MES to work.

Finally, we get some classical problems in this kind of project, as the installation (and sometimes development) of a wide information system is a hard task.

7. CONCLUSION

In this paper, we presented an experimental production platform, which may be remotely controlled and would be used for education and research purposes. The education applications are almost designed to train students with real-world situations and allow them to remotely control one or more production sites. This platform is a very interesting teaching support for students as it allows them to train with real industrial equipments, playing the role of a production manager (in the near future). Currently, the remote control of a production line is not quite used, specially for security reasons, reliability and remote links robustness, almost with Internet. We may also call cultural reasons. However, we may imagine that technology progress and globalisation would relax these constraints. We also present other applications for this platform for research to show some works results or prospect for new perspectives.

ACKNOWLEDGEMENTS

This project was led by the Industrial Engineering lab of the École des Mines d'Albi-Carmaux and the "Plate-Forme Technologique" of the *Lycée Rascol*, in Albi, France.

Special thanks to Jean-Claude Grisenti, teacher at the *Lycée Rascol*, who programmed the PLCs.

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