TRANSPARENT FACTORY, « INFORMATION EVERYWHERE »: BENEFITS TO USERS IMPACTS PLC DESIGN

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Abstract: « Information everywhere » is the ability for factory managers to reach from their computers, the right facts, at the right place and the right moment to take the successful decision; it is also to improve efficiency of maintenance and production operators minimizing machine downtime...
Communication from field equipment (PLCs,...) and IT computers is one key element but other fields need to be addressed to provide enhanced users services, cooperation of different vendors software is an example.
As the deployment of Internet access, client-server architectures as well as object/component technologies are taking such a big momentum, the requirement for « Information everywhere » becomes a strong market value for users and push for a next generation architecture.
Automation technology is impacted by this optimization and Automation products have to change to bring users to a new « Transparent Factory » era.

Keywords: Automation, Manufacturing information systems, Programmable logic controllers, Three tier architecture, Distributed object framework, Request object broker

1. « INFORMATION EVERYWHERE »: BUSINESS NEEDS, ACTIVITIES, AUTOMATION SUPPLIER ROLE

Transparent access to information is one success factor for Next Generation Manufacturing systems. The **business requirements** have been covered by research and commercial activities for more than 2 decades now: enhance **productivity,** structure **manufacturing knowledge**, reduce **time to market** and provide a **global competitive edge** to the enterprise.

The key factor is flexibility for enhanced efficiency. To take decisions faster in different phases of the enterprise life cycle, humans need enhanced and transparent information access and processing tools (system & application) relevant to the manufacturing field to:

1. bring better product concept faster to market
2. design enhanced products and process/equipment and manufacture faster,
3. plan and execute better quality products faster integrating unexpected disturbing events
4. save raw material, components, energy, time,...
5. minimize machine or process down-time,
6. re-organize production lines and retrofit equipment faster
7. manage the 'extended enterprise' to get better components faster, with enhanced flexibility
8. learn faster accessing an enhanced recorded and structured enterprise knowledge

Automation device manufacturer need now to seed their products with the appropriate technology to play a significant role in items 2, 3, 4, 5, 6 and 8: those devices must be capable of dealing with information representing real-life objects and concepts significant in a manufacturing environment and integrate seamlessly with the other information processors of the enterprise.

1.1 Research teams have emphasized the role of information management to get to the right level of enterprise integration

At **ICEIMT'97 in October 97**, the US/EC initiative to come to a common Enterprise Integration (EI) model (ICEIMT, JG Nell, 1997), one workshop identified the information integration needs as follow:

- Identify the right information : this is really a model of knowledge
- Provide the right information at the right place : interoperability and migration are key
- Up-date the information in real-time to reflect the actual state of the enterprise operation
- Coordinate business process : beyond information exchange, it is the capability to support real time decision making : it is business intelligence
- Organize and adapt the enterprise : this is evolution of the knowledge...

The **4th Annual National Manufacturing Technology conference in April 97** focused on actions definitions and priorities for the Next Generation Manufacturing project (NGM), a collaborative effort involving more than 500 industry, university and US government representatives (NGM, 1997). Among the Priority Implementation Actions one can find :

- Establish unified semantics and an integrating framework for global manufacturing information networks
- Establish standards and tools to ensure interoperability of networks and manufacturing systems
- Intelligent process and equipment : develop hardware and software to implement optimized process configuration on the shop floor, using modular machine tools and modern computer control and sensor equipment
- Process Design Environment : Development of an environment to be used by process engineering team to gather knowledge about manufacturing process and optimize process plan
- Manufacturing Collaborative Environment : Develop information services needed to operate in a collaborative extended enterprise
- Provide product data to manufacturing workstation

Back in 94, the TEAM (Technologies Enabling Agile Manufacturing) project (Kim Cobb, 1996), gathering needs from a diverse group of American firms representing many industrial sectors encompassing aerospace/defense, automotive, machine tools, robotics, consumer electronics and software defined some TEAM thrust areas among them:

- Manufacturing Planning and Control -Integrated manufacturing planning and control systems including macro and micro planners and agile shop floor control system to optimize the design and execution of manufacturing operations for best use of resources, materials, supplies and manpower ; and government
- Intelligent Closed-Loop Processing - Advanced, intelligent closed-loop processing capabilities including validation of open-architecture capabilities for high-value manufacturing processes

1.2 Industrial organizations are funding R&D projects to design the appropriate components to get to the right level of enterprise integration

- In October 97, AMD, the well known semiconductor company and a small Texan company (A.Weber, et all, 1997) got an ATP funding from the NIST (3M$) to Design and validate a distributed computer infrastructure for defining and deploying software agents to improve the productivity of semiconductor factories by 5 to 10 %, an impact worth an estimated $300 million to $400 million a year per factory.

« **Advanced Micro Devices** (AMD) and **ObjectSpace Inc**. (Austin, TX) will address these challenges by researching and developing an agent based computing infrastructure for defining, configuring, and deploying autonomous and mobile "software agents" that mimic and improve the functioning of "real world" agents The technical challenges to be overcome include the application of agent software technology to complex manufacturing problems, the simulation of static and dynamic factory conditions. This technology will be used in AMD's state-of-the-art microprocessor wafer fabrication facility in Austin, TX. This approach is expected to extend the capability and lifetime of legacy manufacturing systems, resulting in a much more "active" control system that supports the real needs of the factory ».

1.3 Conclusion

A lot of research activities attempt to define models in the area of Enterprise Integration. Many products and industrial experiments or R&D projects have addressed this field in the past two decades.

Even if a common model will eventually emerge over time, given the complexity of this field, not one vendor will cover the needed spectrum of products and services.

Competition also bring overlapping solutions to common technical problems.
The risk is market fragmentation that prevent any progress in this field.
Moreover, the need for transparent access to information is strong but users have to manage changes in other area (mechanical flexibility is even a greater challenge) in order to fully benefit from this technology.
However, every body agrees about the following « fundamental needs »:

- updated information in « real time » : i.e., information must flow in the enterprise as soon as it is available (with scope relevant update cycles).
- information must represent objects or concept relevant to the manufacturing field and must encompass knowledge : information is not a computer thing, it must be relevant for human beings in the manufacturing environment.
- As time is a critical resource, turning hardware and software together to work in a manufacturing environment should make information integration easier than in the early days of automation and IT.

From the bottom-up perspective, a minimal set of key technical concepts and components can improve today situation and bring transparency to the **application level** for industrial devices, hence going one step further than communication standardization i.e. **system level transparency**, TCP/IP and gateways to legacy networks : Automation suppliers have to seed their products to support that, it is the goal of this paper to investigate the technical implication to be able to implement products.

2. TECHNICAL NEEDS FOR TRANSPARENT INFORMATION ACCESS AT THE APPLICATION LEVEL

Application to application communication will become truly transparent if the next generation manufacturing framework fulfill users needs. Let's now browse the main technical users requirements.

2.1 Interoperability

Different vendors equipment on the network participate in product manufacturing
Different vendors software on the network need to be integrated
Different software platforms are 'de-facto' standard : Microsoft Windows platform, Sun Java platform, OMG Corba,...
PLC controllers are valuable assets for machine control and need to better cooperate with Manufacturing Information System (MIS) or Manufacturing execution system (MES).

2.2 Migration, equipment retrofit

reconfiguration of manufacturing needs new software or equipment to work among old ones.

2.3 Machine/process stations networked information management

The unit that is under an operator control, the machine/process station, has a key role in the manufacturing environment. In the discrete industry, a shop is composed of a set of stations. Starting a shop is an incremental job of testing stations and linking them together. Re-configuring a shop is to introduce a new station and/or suppress or modify some others. The station concept must be re-engineered with the network in perspective, but in such a manner that only as few as basic services should be part of the system and as many as possible services should be composed by the 'application' to be relevant:

a machine/process station should be considered in the client/server perspective

- as a service provider for a network application i.e. : servicing objects relevant to the manufacturing scope and user defined
- as a client of a set of general services (e-mail,...) or of other stations

machine/process stations needs to have an ad-hoc repository to

- auto-load the programmable or configurable devices of the station at boot or at demand : devices are thin-client of the station repository
- repair it on a device exchange basis : shut-down the hardware, unplug the repository, put a new hardware, plug back the repository and start the station again
- migrate to another shop/factory : if information capabilities comes with the station, they will plug and play faster in their new environment. This is the case when the machine station comes first from the machine builder facility to the end user shop floor.

this repository should provide services to all the station devices needing support, hence encompass a multiple vendors scope.
this repository should be exposed to the network and accessible via a browser.

machine/process stations should provide a common access for network applications

- a network browser should be able to navigate/search the services provided by the station
- a network application should be able to subscribe to a service provided by the station
- station services should be expandable : i.e., from a set of permitted basic services, a user should be able to make a compound service that could be resident or downloaded in the station repository and become a new service : this feature enable to

keep the basic services at a minimal level in order for the applications to custom services relevant for there scope. This was not necessarily the case of previous attempts like MAP or MMS.

- One of the basic services is to provide a set of tags (real-time variables) which make sense for station operation or diagnostic. Those tags are variables that enable real-time control of machine operation and are managed by the different programmable or configurable devices.

machine/process station operator-panel human interface should expose its remote-services

- should be served by the station repository as the other devices
- should define services that can be accessed by remote network applications and share with them a set of services provided by the station as 'remote human interface services'
- some services must be only executed by a given operator panel device for machine safety reasons (you can only move a machine bit if you comply to a given set of rules : you must physically see it for example, even if remote-controlled operation is still possible), they should not be accessible from other clients.

3. WHAT ARE THE POTENTIAL TECHNOLOGIES TO ADDRESS THOSE NEEDS

3.1 Key technologies and architecture

3-Tier: This architecture has been implemented to introduce client/server technology inside main-frame installed base (Aberdeen Group, 1996).

- Everyone who has utilized once MIS software in the past, can recognize that the human interface was not so handy. In another side, million of lines of code where underneath and a lot of money was invested on mainframe.
- When windows showed-up and the PC entered inside the enterprise, a lot of people where looking to the nice human interface and wondering why this could not apply to their mainframe software.

To bridge the gap between both world, people brought the idea of 3-Tier architecture:

1st tier is the *presentation layer*: the client, Windows based human interface, enable access, via the services layer, to the data in a convenient format and with a good ergonomics

2nd tier, the *function layer*, screen the access to and arrange information from the data layer : functions range from users management (security,...) to application management (SQL server,....)

3rd tier is the *data layer* : those computer are the data repository of the company (database applications and engines)

Thin-Client : In a standard client-server environment, the client station needs to be configured with the appropriate software application to access the server side.

The thin-client architecture suppose that the client station is configured with a standard browser that is able to access any application on the server. In fact, all the client application reside in the server and is loaded on demand on the client and the user has not to worry about installation, update and so on.

In order to have interoperability under different platform, Sun & Netscape introduced a browser and an interpreted object language -JAVA, able to run under different operating systems : Windows, MAC-OS, Unix, ...

This was a key technology to be able to have client side program application –Applets, on the Internet and had an instantaneous success over the planet:

Not only you can browse hypertext documents, but most computers, with different operating systems, are now able to execute small programs embedded inside those pages.

Object/component technology, distributed object framework

- Object programming is the capacity to program a system dealing with information processing representing entities (machine subsystems, products parts, controlling devices) or concepts (planning, schedule, material quantities) in such a way that it is directly relevant to the application scope. With this definition, somehow, we can say that automation control is dealing with objects since a while...
- Object technology is now mature and get a bigger momentum in the IT field. De facto standards are emerging -JAVA for example, which are thrust by the Internet event.
- Object technology is also distributed over the network : object broker (ORB), with the unifying CORBA initiative from the OMG enable application distributed over the network to inter-operate.
- One of the service of ORB is name space : any object accessible over the network has a unique name and one can browse and introspect system capability from its content, users will be able to do contents based object query:

I want to have the list of all objects on the network which are motor starters having an overload protection of less than 5Amp.

As we are aiming toward interoperability of automation device and IT system, it is time to use the IT system object framework to achieve it while respecting automation usage. Object distribution technology is embeddable (GSM telephones are using such a technology today) : we can make that happen for automation device now.

3.2 Expected spill-out for automation

The combination of those technologies can help automation architecture migration and service enhancement: wrapping control real-time data (3rd tier) and managing the application (access, presentation,...) a new tier 2 server can provide seamless integration of the automation world inside the enterprise.

The tier 2 server can be distributed and embedded inside automation devices (PLCs, CNCs, Robot controllers, vision controllers, specialized automation devices (nut-runners, welders)...).

The tier 2 server can be the repository of the 'station application' :

- Object representing the process and/or machine components
- Objects representing the inter-action of equipment with the upper-level planning and execution system
- HMI application for machine operation
- HMI application for machine diagnostic
- HMI application for automation device diagnostic
- Any programming or data file, with the relevant user objects able to fit the different machine operating mode and behavior.

Thin-client can browse the tier 2 repository to access automation information. They are also able to browse MIS applications.

Machine operator panel can be based on thin-client technology . i.e. : operators can now access from the machine operation terminal the information system of the factory.

Manufacturing Execution System Applications can browse automation devices from the network, as an Object-Space, to learn about their capability and retrieve information in a seamless manner.

3.3 Next generation control potential architecture for « Transparent Factory »

A typical shop example is represented in figure 1: It is composed of a set of machines under control of a

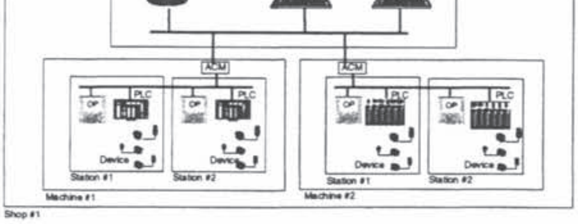

Fig. 1 Typical shop example

a manufacturing execution system (not describe in this document).

Each machine is composed of

- an Access Control Manager (ACM)
- stations representing a process step or operation.

Each station is composed of

- an operator panel (OP)
- a controller (PLC)
- bus(es) and devices

The communication infrastructure is made with an homogeneous network, linking the MES and the different machines.

Flavors of Ethernet are good candidate for this network infrastructure.

The role of the ACM device is to make sure that real-time interlocks signals between stations are not disturbed by any traffic coming from outside the machine.

Device buses may be connected with a different technology than the above network. Gateways, routers and the protocols used on the networks enable a global access to every addressable devices.

The controller (PLC) of each station support an *embedded application server*. Ideally, each device in the scope of the station is a 'thin-client' of this server i.e.: they will download the code they need for a given task at demand or at boot time. Eventually, a 'proxy' application can do that job for devices not supporting this thin-client feature as most of the legacy device will.

All the embedded application servers support a naming service and an Object Broker that enable to browse the factory Object Space from any thin-client attached to the network.

This object Space can be search by contents and any object introspected to learn about the capacity and the state of the different machine resources of the shop.

For example, on fig. 2, the Station1 of Machine1 Application Object Container is open. It holds many different objects

Control programs of the station (for the different production runs of the station)

- Smart tags objects, which wrap the real-time data to introspect them from the object Space
- MES objects which represents information relevant to the production planning and that are supposed to be accessed by MES applications

Machine operation container

- Services container which holds the objects that are relevant for the different operation screens on the server side
- Screens container which holds the different screens relevant for machine operation

The valve V5 of this screen has a unique object name in the name space :

//Shop/Machine1/Station1/Application/Machine Operation/Screens/V5

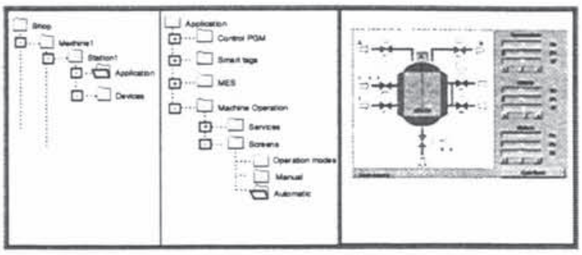

fig. 2 Browsing the seamless Factory ObjectSpace

Any program having the access right to deal with this object can then subscribe to this object events or forward it any message.

The architecture comply with 3tier and thin-client principles (see figure 3). Any operator panel can operate their attached station and also access MES information. Maintenance files can also be accessed : for example, a maintenance operator could use the station operator panel to look to the drawings of cabinet wiring based on a central server complying with the thin-client architecture.

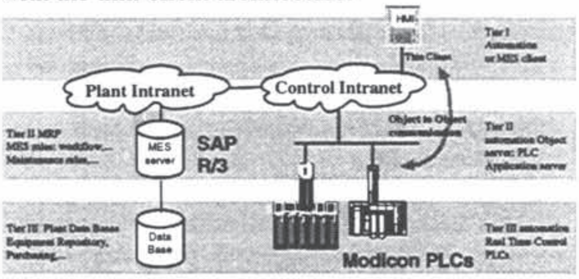

fig. 3 The Machine Operator Panel is also an MES console

4. CONCLUSION, FUTURE RESEARCHES AND DEVELOPMENTS

This paper first summarize the wide interest for Factory Information Integration and stated the underlying technological impact:

Bring transparent « Application to Application » communication to keep up-to-date the information « web » among the different factory information layers (business repository and production equipment)

Analyzing the associated « technical user requirements », it then refine the impact on the « control equipment ».

The third part, In order to implement products, analyze the existing technology mostly thrust by the Internet and propose a next generation technical architecture for control equipment derived from the previous technical user requirements.

There is now at least two different fields of investigation that needs to be addressed for a successful implementation of this next generation architecture into products and systems:

- **A marketing strategy**. As the border between IT and automation seems blurring with this next generation architecture, analyze the impact and propose implementation plans for the deployment of such a technology among the different actors of the industrial chain :
  Automation suppliers, MIS suppliers, IT software house and automation system integrators or machine builders and finally, the different teams of the end user (IT teams and Automation teams, production engineering and shop floor operators). What use to be « two different world » are now highly interacting.
- **Ergonomic and sociological impact study**. This new set of tools improve drastically the awareness of the different actors of the Enterprise activities and resources. Lets give some examples :
  - A manager is able to monitor actual work, with a « minute resolution », of shop floor workers.
  - A worker can have the capability to browse the internet from a machine operator panel.
  - A maintenance worker can check the status of the process from its home.

Different « use case » of the system and products must be designed and investigated to enhance or limit some capabilities of this next generation architecture in order to protect people and equipment against malicious use and make it a commercial success.

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