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ROBOTICS AND ISA88 BATCH CONTROL STANDARD - OPPORTUNITIES AND CHALLENGES –

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ABSTRACT

Manufacturing processes can generally be classified as continuous, discrete or batch. An industrially well accepted way of structuring and controlling batch processes is presented in the ISA 88 standard (also known as IEC 61512). In exploring how this standard also could be used for discrete manufacturing processes, especially in robotic applications, different challenges and opportunities are found. The main opportunity is the advantage of having a stable and well tested and documented framework to be inspired by.

Keywords: Batch Control, ISA88, Robotics

INTRODUCTION

A manufacturing process is a process that generates products such as e.g., cars, paper, head-ache pills, plastics, yoghurt, cellular phones etc. Manufacturing processes can generally be classified as continuous, discrete or batch. Very briefly, processes which have a continuous outflow, e.g., production of energy, or paper, are classified as continuous processes. Discrete processes have a discrete output; one example could be the production of a car. The outcome of a batch process is neither continuous nor discrete, instead it consists of a “set of items”, i.e., a batch. An example of a batch process could be the production of cookies in which a set of cookies are produced from the same dough.

During the last decades, the level of automation has constantly increased in all types of manufacturing processes; discrete, continuous and batch. The challenges related to automation are however different. In continuous industries, most activities are performed in steady state, i.e., the challenge is to find good set point and to assure that the actual value is as close to the set points as possible even if disturbances enters. In discrete processes the challenge is to assure that the activities are performed in a correct sequential order. For batch processes, the challenge is a mixture of both discrete and continuous.

In order to carry out the manufacturing process, various assets are being used. The assets could be e.g., a human, a robot, a machine, a tools etc. The use of robots are most common in discrete manufacturing, where they are used in order to automate and perform manufacturing activities such as; grasping, moving, drilling, etc. In batch industries, assets such as tanks, reactors, fermentors, etc are used. Last decade a standard concerning the control of batch processes was developed. The standard, known under the name ISA88 (ISA, 1995) has been very well received in the batch industries.

The standard has also been adopted as an international standard under the name IEC 61512 (IEC, 1997). Lately it has also received attention from the discrete and continuous industries. This paper describes challenges and opportunities in using the ISA88 standard together with discrete manufacturing processes such as robotics.

SIARAS

One project that serves at looking at the usage of robots in various discrete manufacturing processes is SIARAS (Skill-based Inspection and Assembly for Reconfigurable Automation Systems). The main project objective of SIARAS is to facilitate simple but dynamic reconfiguration of the assets needed to carry out the manufacturing processes, (SIARAS, 2007).

Modern large-scale manufacturing facilities are characterized by a high degree of automation, accomplished by extensive engineering and limited by cost and complexity. That is, the actual production is executed by machines whereas the planning and the set-up of the production line is accomplished by humans. With increasing product variants and shorter product cycles, the dynamic reconfiguration of these complex production processes clearly is a key technology (Devendra et al., 2001).

SIARAS introduces the novel concept of skill-based manufacturing. This means that the assets have embedded knowledge about their skills and the automation system is able to reason about their skills and to find a solution of how the assets should interact in order to solve a given manufacturing task.

ISA88 BATCH CONTROL STANDARD

The ISA 88 standard entitled “Batch Control” was developed in the late 1990’ies and presents ideas of how to successfully control batch processes. Various models, such as the equipment model, and the procedural model are presented, and important concepts such as modularization and software reuse are discussed. The ISA 88 standard discusses how to structure the control system in order to make the work successfully, today it is impossible to imaging a conversation about batch process and batch control without mentioning the ISA 88 standard and its concepts.

The ISA S88 standard is a multi part standard that currently consists of four parts:

- ANSI/ISA-88.01-1995 Batch Control Part1: Models and Terminology
- ANSI/ISA-88.00.02-2001 Batch Control Part 2: Data Structures and Guidelines for Languages.
- ANSI/ISA-88.00.03-2003 Batch Control Part 3: General and Site Recipe Models and Representation
- ANSI/ISA-88.00.04-2006 Batch Control Part 4: Batch Production Records

Part 1 is the most known and applied part, it presents four basic concepts;

1. How to depict what you have in the plant (referred to as the physical model)
2. Implementation of what you can do in the plant (referred to as the equipment logic)
3. How to define what you would like to accomplish in the plant (referred to as the recipe)
4. How to put the three pieces mentioned above together in an intelligent, reusable and successful way.

In addition to the four models, ISA 88 also offers standard terminology, with the objective of improving communication. In this way different people don’t use different terms for the same thing, or

the same term for different things. Difficulties in communication can cost time and money, or even worse, it can cause failures in control systems. This is true for batch industries, but equally true in the discrete manufacturing.

MODELLING THE PHYSICAL ENTITIES

ISA 88 and the Physical Model

In order to depict what you have available in the facility/plant in terms of assets, the Physical Model should be used. The physical model provides you with a terminology and a hierarchy than can be applied on the physical equipments in the plant, see Figure 1 (left branch).

In the physical model, the highest levels are the Enterprise, Site and Area. However, the levels of importance for batch control and ISA 88, start with the process cell. A process cell consists of one or many units that in turn consist of equipment modules and control modules. Within a process cell, a product is made. A unit might be a reactor or a mixer. Equipment Module might be the set of pumps and valves that is connected to the inflow of one unit, whereas a control module could be a simple PID-controller or a sensor or an actuator. In some cases, equipments within one level may be incorporated into another grouping at that same level.

The Physical Model has been extended to include physical assets found in the continuous and discrete industries as well as with physical assets used for storage. This extension was done as part of the development of the ISA 95 standard (Enterprise-Control system integration), see Figure 1.

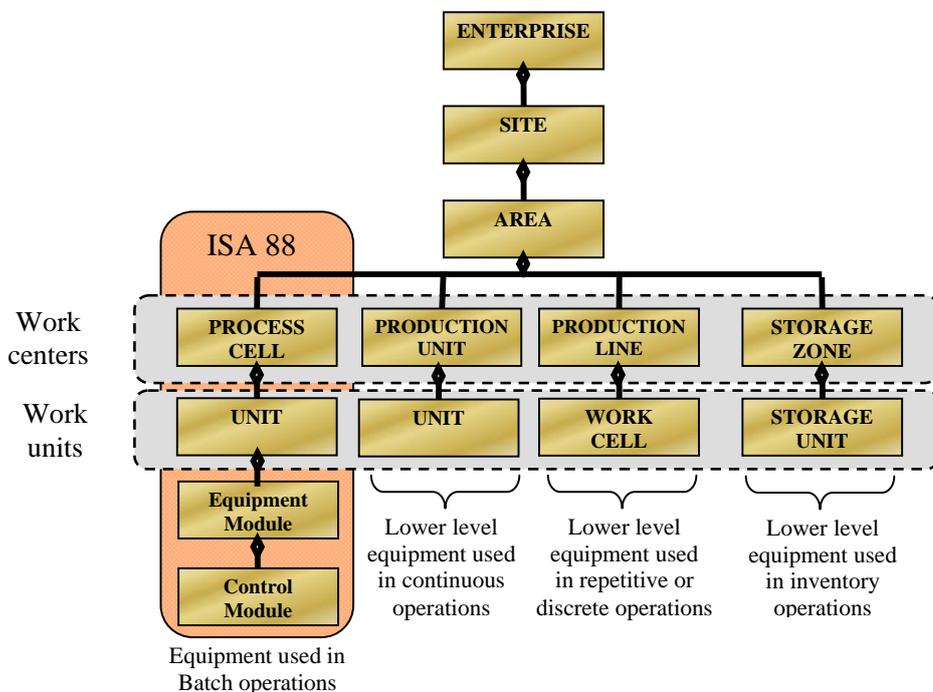


Figure 1 – The extended Physical Model of ISA 88.

An example of a process cell is shown in Figure 2. The process cell consists of 13 units, from top to bottom; three storage tanks, two mixers, three tanks, two reactors and three product tanks. One of the mixers is shown in detail, and its equipment modules and control modules can be seen (inlets, outlets, sensors etc).

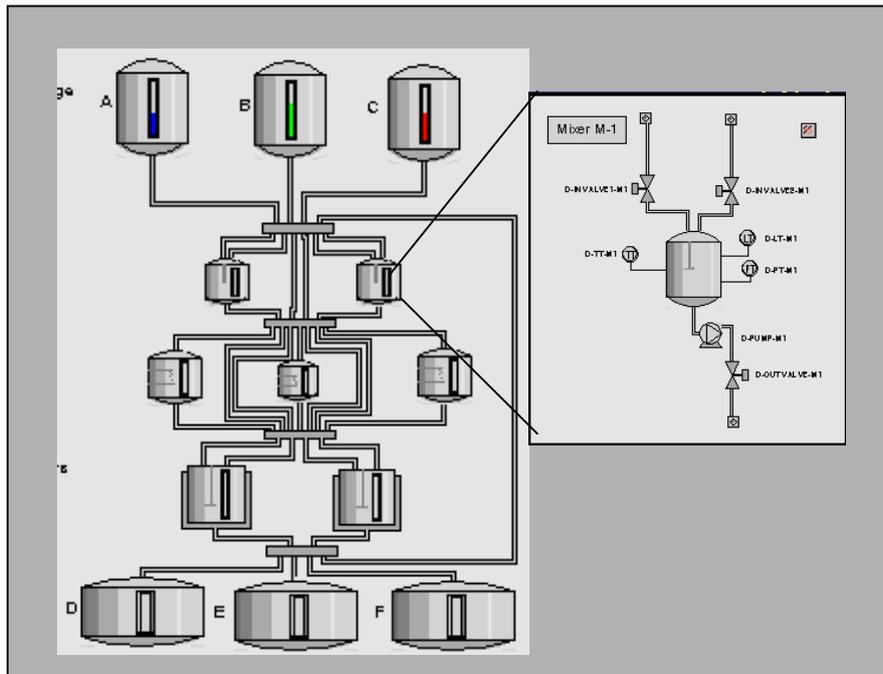


Figure 2 – A process cell.

SIARAS and ISA88’s Physical Model

The main project objective of SIARAS is to facilitate simple but dynamic reconfiguration of the assets needed to carry out the manufacturing processes, (SIARAS, 2007). Manufacturing processes focused on in the SIARAS project are carried out in a Work cell. Figure 3 shows an example of three different Work Cells. Together the three work cells constitute one Production Line.

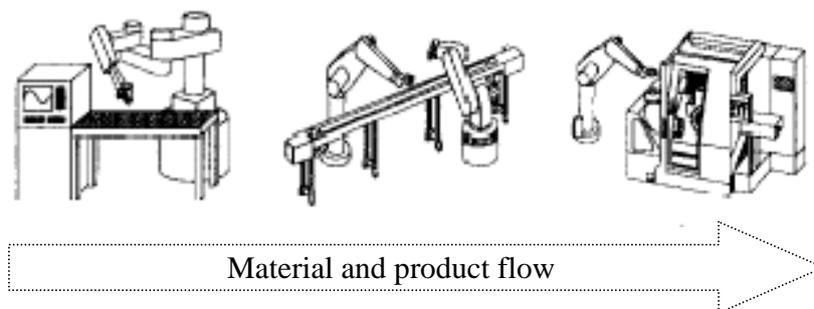


Figure 3 - One production line consisting of three work cells.

The physical equipments below the Work Cell level are not presented in the extended Physical Model of ISA 88 (Figure 1). However, work cells typically integrate robots, a wide variety of machine tools, material handling equipment, packaging devices, sensors, actuators, controllers, and similar other hardware, (Devendra et al, 2001). The common term used in discrete industries for the equipments below the Work Cell level is Devices and Control Modules. A device could be recursive i.e., a robot could be a device that contains other devices such as tools, material handling equipments, packaging devices etc, and a control module could be sensors, actuators, controllers etc.

Figure 4 shows the Physical Model used in the SIARAS project.

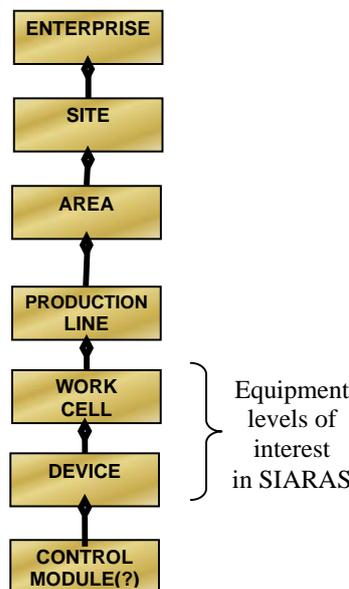


Figure 4 - Physical hierarchy used in SIARAS.

Additional information related to the Physical Hierarchy

The ISA 88 as well as the ISA 95 standard presents detailed object models for how to structure the equipment. The models are given in UML (Unified Modeling Language) which is a software independent modeling language. The two models are very similar.

EQUIPMENT LOGIC

ISA 88 and Equipment logic

The equipment can carry out certain functions, e.g., a mixer could charge, discharge and mix and a reactor could charge, discharge, heat, and cool, whereas a process cell could make-product-A. The functions are referred to as equipment phases. The implementation of the equipment phases is done in the Process Control System (PCS) and generally referred to as the equipment logic.

Figure 6 shows the process cell with Mixer-M1 and its three equipment phases. The implementation of the equipment phases is contained in the PLCs in the process control system. The implementation of the equipment logic is often done following the IEC 61131-1 standard, e.g., by the use of SFC (Sequential Function Charts) which is a graphical programming language.

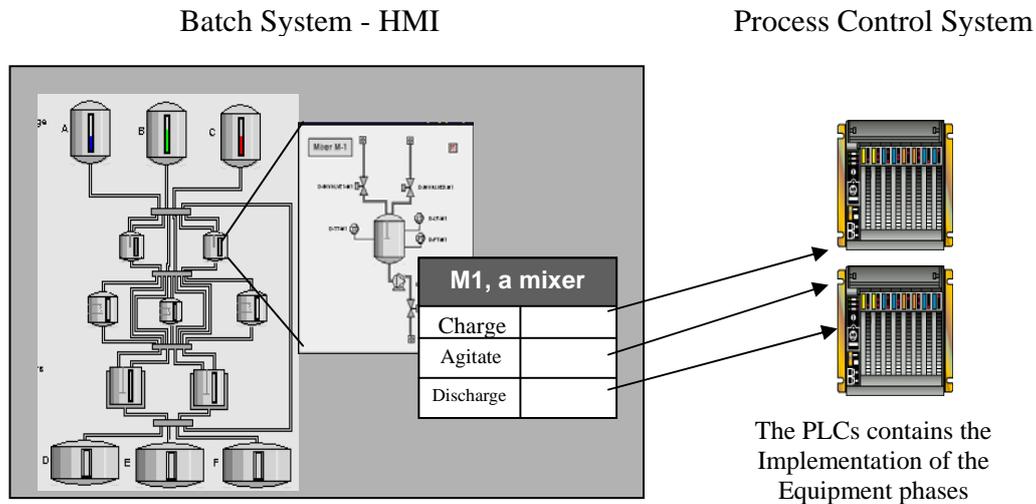


Figure 6 - Mixer M1 with its three equipment phases.

SIARAS and ISA 88 equipment logic

The devices in the SIARAS project, e.g., the robots, can carry out certain functions. These functions are referred to as the skills (Malec et al, 2007). The implementation of the skills is contained in a Process Control System. The implementations might look very different, and rely on different programming languages depending on the robot type, i.e., ABB, KUKA, etc.

MODELLING THE PRODUCT DEFINITION

ISA 88 and the Recipe

In order to describe the production of the batch that should be carried out in the process cell, the concept of recipes should be used. The most important part of the recipe is the procedure, defining what you would like to do, e.g., first you would like to fill the mixer with a certain substance, then agitate and finally empty what you have in the mixer. The procedure complies with the procedural model, i.e., a procedure can be broken down into unit-procedures, a unit-procedure into operations and an operation into phases. Each level describes the batch process at a more detailed level and not all levels need to be used. The phases used in the recipe must refer to an equipment phase implemented in the process control system. In order to stress the fact that a phase resides in a recipe, the term recipe phase is often used; this also helps indicating that there is an important difference between a recipe phase and an equipment phase.

In addition to the procedure, a recipe also contains the formula, the equipment requirements, the header and other information. Figure 7 shows a recipe with the following information:

- Header: who created the recipe and when
- Procedure: a description of the batch process, e.g., “make product-A”
- Formula: a collection of parameters and their values, e.g., 3 eggs, 300 gr sugar and 300 g flour
- Equipment information: mixer with agitator, reactor.
- Other info: anything that might be of interest for the recipe

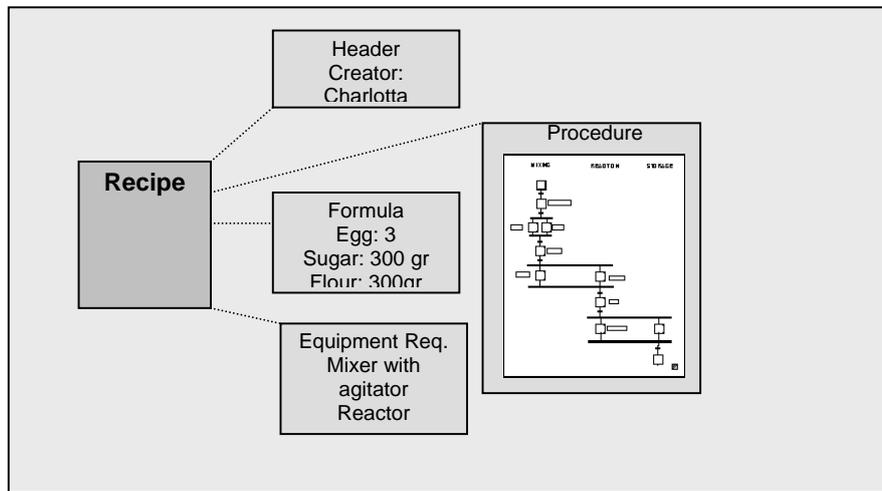


Figure 7 - A recipe.

SIARAS and ISA88's Recipe

The description of the discrete process that should be carried out in the work cell is referred to as the task description. There are still a lot of work to be done in defining how the structure and what the content of the task description should be.

Additional information about the Recipe

Object models and XML schemas have been worked out for the Recipe, in the same way as was done for the Physical Model. In the ISA 95 standard, the term Recipe is not used since this is specific for batch processes, instead the more generic term "Product Definition" is used. Object models (UML) for Product Definition exists.

ADVANTAGES USING THE CONCEPTS OF ISA88

The smart thing is that the recipe can be written without knowing anything about how the equipment logic is implemented. It is enough to know their interfaces. Vice versa is also true, the equipment logic can be implemented without knowing anything about how they will be used in different recipes. The two activities can be completely separated. The equipment logic focuses on implementing a certain function in a good and efficient way, whereas the recipe focuses upon combining the equipment logic in such a way that the desired end product is produced. Modifications can be done in the recipe without affecting the equipment logic.

Figure 8 contains an example of how the recipe and equipment logic is linked. The figure contains a process cell with several units. One unit is the mixer-M1 with its three phases; discharge, charge and agitate. A recipe is created for the process cell, indicating that the first activity, i.e., the first recipe phase, should be to execute the charge phase of mixer-M1, followed by other activities associated to the tanks and reactors. When the recipe is executed, the recipe phase becomes active (point 1), a check is done to verify that possible equipment requirements are fulfilled (point 2), the charge phase of mixer M1 is called (point 3) and the corresponding equipment phase starts to execute (point 4).

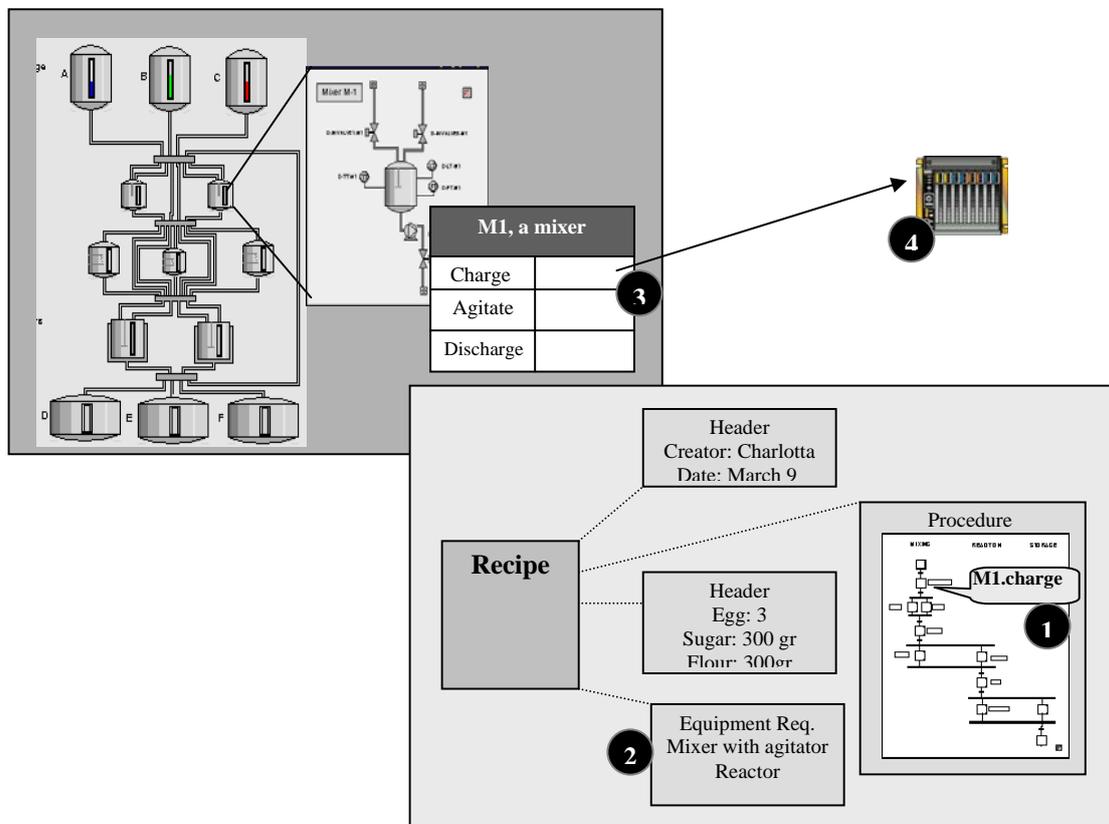


Figure 8 - Recipe-Equipment Logic linking

It is possible to include parameterization to the recipe. Instead of specifically indicating that the first recipe phase should be the charge phase of M1, it could indicate that it should be a charge phase of any mixer fulfilling the equipment requirement (has an agitator). The reasoning system behind should then search through all mixers and concluding which mixer should be the best one to use.

ADVANTAGES USING THE CONCEPTS OF ISA 88 IN SIARAS

The main project objective of SIARAS is to facilitate simple but dynamic reconfiguration of the assets needed to carry out the manufacturing processes, or in other terms: If the task description (recipe) is changed in what way will the assets/devices (units) be affected?

An initial example is shown in Figure 9. A work cell containing one robot is shown, there are three possible robots that could be used in the work cell, one from Kuka, one from ABB, etc. The task description only specifies that the first activity to be executed in the manufacturing process is that a drilling function (point 1) should be carried out.

The system should now conclude that out of the three available robots, only two are capable of performing the activity (point 2), and suggest one of them (point 3).

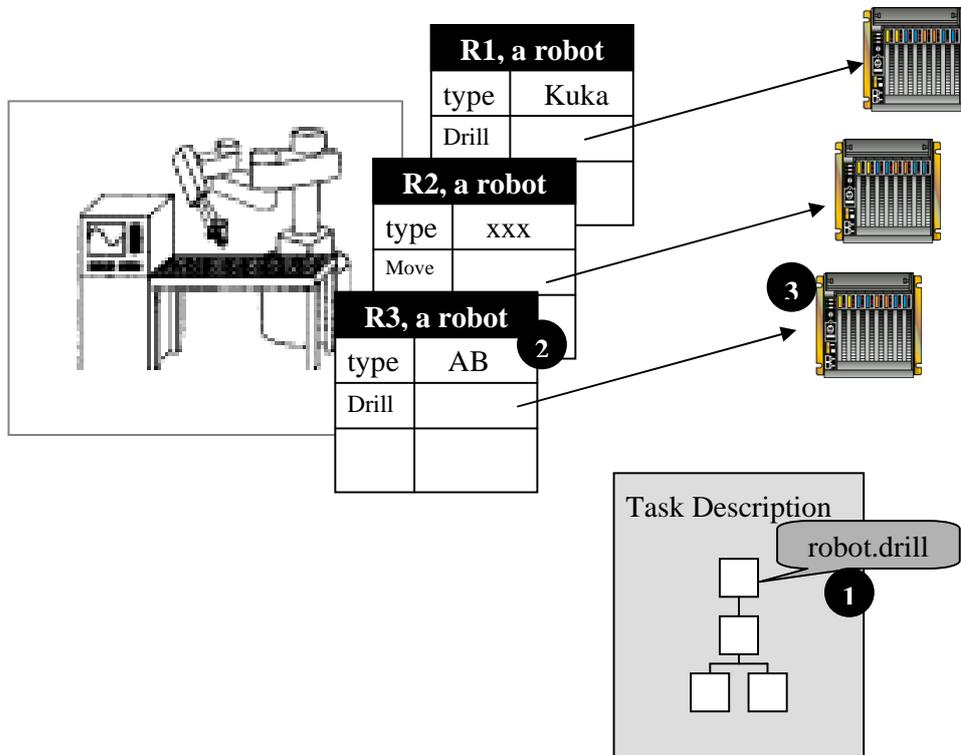


Figure 9 - A work cell with three possible robots, and one task description.

Extensions that can be done;

- 1) By extending the task description with additional information about e.g., equipment requirements etc, the system could also suggest what tools the robot should be equipped with.
- 2) By extending the properties listed for the robots, so that they include, not only the skills but also set up information, the system could also indicate how the system should be set up for best performance.

SUMMARY OF THE SIMILARITIES BETWEEN ISA 88 AND SIARAS

The table below summaries the similarities between the concepts of the ISA88 batch control standard and the project objectives of SIARAS.

ISA 88	SIARAS
Physical hierarchy <ul style="list-style-type: none"> • Process Cell • Unit • Equipment Module • Control Module 	Physical hierarchy <ul style="list-style-type: none"> • Production Line • Work Cell • Device • Control Module
Equipment logic <ul style="list-style-type: none"> • Equipment Phase <i>More levels exist</i>	Equipment logic <ul style="list-style-type: none"> • Skills

Recipe	Task
<ul style="list-style-type: none"> • Header • Equipment Requirement • Formula • Procedure <ul style="list-style-type: none"> ○ Recipe phases • Other info 	<ul style="list-style-type: none"> • ? • ? • ? • ? <ul style="list-style-type: none"> ○ ? • ? <p><i>The task description is currently subject for research</i></p>

Table 1 - A list showing the similarities between the concepts of ISA 88 batch control standard and project objectives of SIARAS.

CONCLUSIONS

Manufacturing processes can generally be classified as continuous, discrete or batch. An industrially well accepted way of structuring and controlling batch processes is presented in the ISA 88 standard (also known as IEC 61512). In exploring how this standard could be used also for discrete manufacturing processes, e.g., robotics such as the SIARAS (Skill-based Inspection and Assembly for Reconfigurable Automation Systems) project, various challenges and opportunities are found.

The main opportunity is the fact that the ISA 88 standard is an industrially well accepted standard that helps structuring the control of batch processes, and this framework could be applied also to discrete processes such as the SIARAS robotic project. This is underlined by the fact that the hierarchical structure of the physical entities, as well as the separation of the equipment logic, apply to discrete robotic processes as well as to batch processes.

The main challenge, however, is the structure for the product definition, i.e., the batch recipe and the SIARAS task description. This is due to the fact that the exact definition of the task description is not yet set.

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