The 9th International Symposium on Automation and Robotics in Construction June 6-8, 1992 Tokyo, Japan

# Construction Robotics and Standardization

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## ABSTRACT

After a ten year period of development, construction robotics is now more mature than at the very early beginning. Many research have been carried out both in hardware (HW) (design and tests of experimental robots for instance) and in software (SW) (management of robotized construction processes for instance). These research works have clearly shown that interfaces between different modules ( HW and SW) have to be proposed and discussed. These interfaces are likely to become the basis of future standard. For instance, the efficient use of automatic grippers, replacing the hooks of crane, requires a standardized interface between the load packaging and the effector of the gripper. SW interfaces are also needed to ensure efficient and safe communication between design computers and robots. Many other examples can already be listed. The coming developments will give new opportunities. This paper analyses some of these first attempts to standardize both HW and SW interfaces in construction robotics. From this analysis, needs to foster the definition of future standards are drawn out, specially a need for a greater international cooperation.

## 1. INTRODUCTION

The previous ISARC meetings offered a presentation of many construction robotics developments concerning both :

- machines (remote controled, computer assisted, autonomous),
- and software (site organisation, machines control).

The most recent work carried out by th main Japanese contractors have lead to the design of (partly) automated construction processes in which the results of these hardware and software developments are intimately mixed.

These integrated construction processes, although they are still at an experimental level, outline the conceptual construction method of the future.

Communication plays a key role in these processes :

- communication between softwares (data exchange),
- communication between hardware pieces of equipment (compatibily of mechanical interfaces, adaptability of tools).

Obviously, the success of the development of such construction processes relies on the ability of the actors of the construction team to communicate efficiently. Due to the permanent change of partners for each new construction project, the development of a closed communication system is unlikely. Such a system would limit the widespread of the construction process to only a small market. This condition would not make the process economically viable.

The only possible development direction is to think of these construction processes as open communication systems. In this case, the interchangeability of partners having a given skill will be made possible. The construction team will consist of partners who are likely to join various construction projects without need of a deap adaptation of tools and methods.

Existing construction processes already offer such possibilities, but the low quality of the communication does hamper significant improvements. The information flows through chaotic channels (voice, paper, drawings,...) and the site machinery does not undergo important design change (the permanent use of hooks and slings to handle loads is a good example of this inertia). As long as this traditional situation will not be changed, there is no hope for any visible productivity improvement.

Computer related technologies offer a wide range of possibilities to reach these desired changes, but new construction processes will be effectively developed only if efforts are made to increase the utilisability of the techniques proposed by the research teams.

We think that this requires the development of standards for both software and hardware. Illustrations of these needs and description of the premises of standardisation procedures are given hereafter.

The two domains that will be considered are drawn on the general view of an integrated construction process given on figure 1. They are :

- A : sofware communication between design and components manufacturing,
- B : hardware communication for handling tasks.

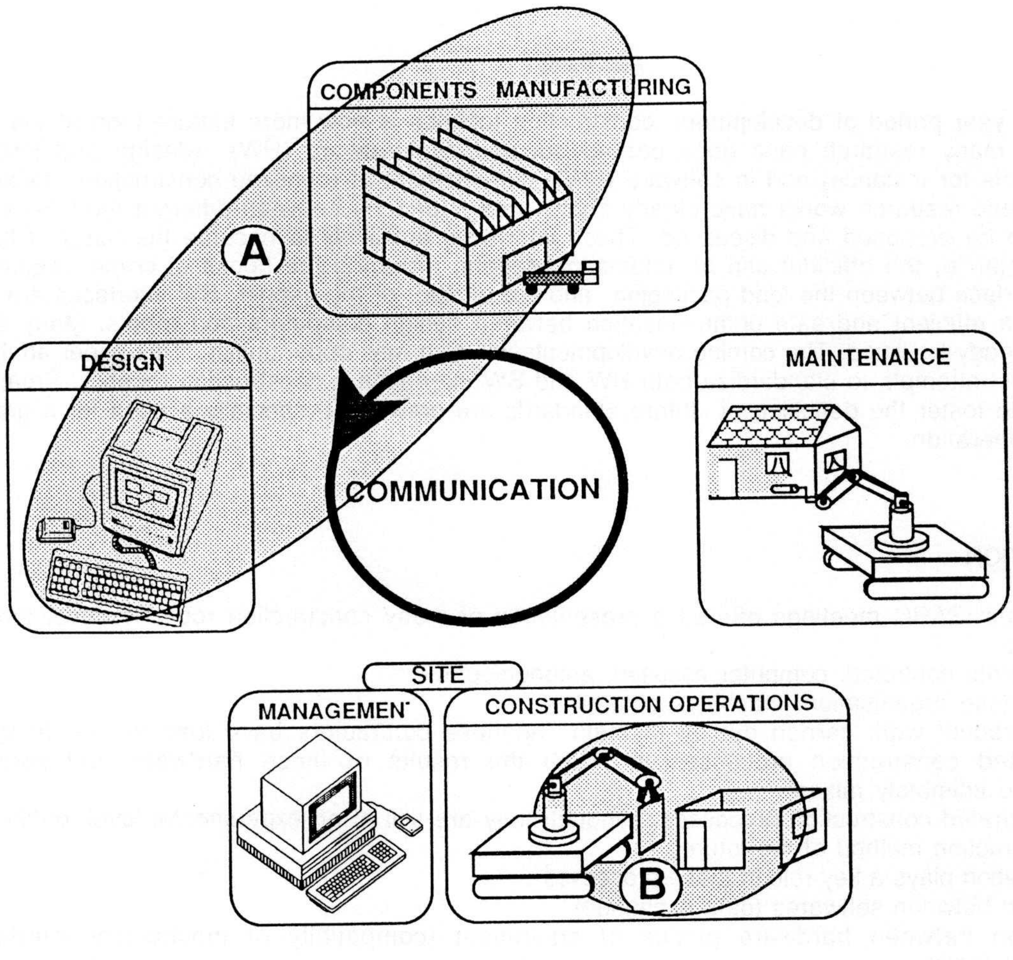


Figure 1 : A view of a computer integrated construction process

## 2. SOFTWARE STANDARDIZATION

During the past ten years, important efforts have been made by construction components manufacturers to enter the so called C.I.M. (Computer Integrated Manufacturing) world. These efforts have lead to significant improvements of the production processes. Most of the developments have been concentrated on the integration of software tools for inner purposes, i.e, product design, production planning, administration.

Though there are similarities between concrete panels and rebars productions for instance, the improvements have been carried out individually by the corresponding manufacturers without any cooperation. Their tasks has been made easier by the wide variety of production softwares which are now commonly offered on the market.

The most advanced production processes include production automation. The automation generally concerns a small part of the manufacturing process which is chosen because it is the most cost effective. This is also very often the most simple part of the process from a technical point of view. For instance, the full scale drawing on the surface of a production bench of the limits of prestressed concrete panel, the cutting to the required length of both electrical wires and of the sheaths, the spraying of glass reinforced concrete on the surface of a form, the shaping of a reinforcement bar to the desired dimension, the sawing of plywood panels in order to make architectural concrete forms.

Most of the time, the information needed for production are geometrical data. These data sometimes come to the manufacturer on a floppy disk, but very often paper documents arrive at the factory and it is necessary to enter manually the data in the production computer.

The data transfer to the production automatons is generally not very sophisticated. Data are prepared automatically from the "design" computer. A serial line transfers the geometrical data to either the drawing machine, or the cutting machine, or the shaping machine, or the sawing machine. In the case of the spraying machine, the movements are taught directly to the manipulator.

These examples show that the potential of robotics is presently underused, but the main reason is rather economical than technical. The situation will change in the future when a higher degree of automation is reached and when it is necessary to redesign the production process in order to fully benefit of the robotics potential.

Before this development stage is reached, industrials will have to solve new problems that will arise from the coming of new softwares used by construction designers. The trend by designers is to think of integrated sofwares that will allow a multiple actors design procedure using a shared digital construction model.

The expected result of the use of such softwares is a better communication between actors together with a selected access to relevant data for given technical activities (structural design, thermal performances,...).

The sofware products allowing such integrated design procedures are still under development. The CSTB recently launched the ATLAS (Architecture, methodology and Tools for computer integrated LArge Scale engineering) project together with european partners (contractors, software houses, research) within the frame of the European Community ESPRIT programme. An important work has to be carried out to propose a consistent reference data model of a construction project. Research output of the ongoing programmes should contribute to the definition of a standard description of the construction project. Working-groups already act in this field in the ISO/STEP environment.

In spite of these efforts, the widespread use of such standards will still need a lot of time. Besides such official procedures, there are some attempts to define "standards" from the de facto dominant market place of some CAD softwares. As an example, the DXF file structure of the AUTOCAD software is used as the kernel of the French SUC "standard" for graphical and semantic communication proposed by a group of major French contractors.

From these developments, the communication between construction components manufacturers and other actors (architects, structural engineer, ...) will be made easier and more reliable than now. In order this specification work to be carried out efficiently, it is wished that a significant presence of these industrials can be met in the working groups. Some of these groups have in charge at the national and international levels the definition of the relevant communication messages (technical EDI(electronic data intercjhange)).

## 3. EQUIPMENT INTERFACES STANDARDIZATION

The up to date technical equipment used to handle a load (panel, pallet, concrete bucket,...) is directly derived from the millenial technique : the hook and the slings!

Even if this example may be considered as exaggerated, it is a very pedagogic way to illustrate that our traditional construction techniques are not likely to be interfaced with computers.

The cost effectiveness of automated cranes or cable-less manipulators will remain low as far as the slinging and unslinging operations will be manual. This manual operation will hamper the full benefit of the movements automation and of the programming capacities. Moreover, this operation may be very dangerous. Previously developed remote controlled unslinging devices designed by SHIMIZU offer a partial solution to this problem.

Attempts have been made to propose automatic hooking equipments. For instance, the system developed by the crane manufacturer POTAIN mainly consists of a beam fitted with one lock at each end. These locks are mechanically and automatically oriented in order to be connected to lugs attached to the load.

An experimental system has proved the feasibility of such an automatic system, but the main problem is that of the standardization of the interface between the system and the loads (or load containers).

The variety of loads on a construction site is very important. The corresponding products (panels, partition walls, palster boards, baths, water heaters,...) are made by a great variety of manufacturers from different countries. Moreover, these parcels have to be transported by rail and by trucks. We then see the difficulty of finding a compromise between all these actors, some of them not being directly in charge of operations on the construction site.

In spite of the difficulty of such a procedure, the automation (and robotisation) of construction operations absolutely needs an agreement on many such technical points. The standard interface between mobile platforms and tools, the standard interface between "small" components (to be handled and assembled automatically) and the handling device are other examples.

Once again, the success of such a procedure relies on the close cooperation between actors.

## 4. CONCLUSION

On the contrary of other economical markets, the construction market has not the capacity to quickly absorb innovations. The tradition, the specificities of these long term investments are not favourable to a quick change in products or methods.

The current software developments leading to integrated design processes are not likely to stay at the fence of the construction sites. So, automation and robotisation of construction operations will come at least as a follow up of these developments.

Nevertheless, both software and automated construction equipments need to be standardized in order not to be restricted to single use.

After the first ten years, the situation in the construction automation and robotics community is mature enough to take interest in these subjects as we will still remain on a precompetitive level for some years.

Working groups within the frame of the IAARC could be the meeting points where topics like :

-interface between construction project knowledge base and component manufacturing;
-interface between construction project knowledge base and site machine control;
-interface between handling equipment and material packaging;
could be efficiently studied as required competences are present.