TECHNOLOGY TRANSFERS FOR CONSTRUCTION ROBOTICS

Jean-Luc SALAGNAC

CENTRE SCIENTIFIQUE et TECHNIQUE du BATIMENT (CSTB)
Etablissement de SOPHIA ANTIPOLIS
Boîte Postale 21 - 06561 VALBONNE CEDEX - FRANCE

0. INTRODUCTION

Studies on the theme "ROBOTICS and CONSTRUCTION" are recent. Significant projects have been worked out that perhaps prefigure the future construction working sites machines.

These developments illustrate the general trend of work productivity increase, quality enhancing and working conditions improvement.

These are not new stakes : the mechanization of construction work, started many decades ago, also illustrates this trend.

Builders have not been waiting for the advent of robotics to think of the ways to increase productivity and to decrease the number and the seriousness of industrial injuries !

So, what does robotics bring to construction industry ?

Are required technologies to be discovered ?

In the case these technologies already exist for other purposes how can they be transfered to construction industry ?

Are there obstacles to these transfers ?

This paper intends to provide material for an answer to these questions so as to contribute to the orientation of future studies.

to the orientation of future studies.

1. CONTRIBUTION OF ROBOTICS

This topic has already been developed in previous communications and publications so that we shall not particularly focus on this point. ([1] to [6]).

However, if nearly everyone agrees that robotics may potentially be used to increase productivity and to improve the working conditions, the ways to put this idea in practice are not yet clearly drawn.

Several attempts have been made to try to define criterions to select construction works to be robotized. These analyses are based, for instance, on a classification of construction works (figure 1). Laborious works are the most frequently quoted as tasks likely to be robotized.

The economic approach is not yet enough developed in spite of interesting attempts ([1], [7] [8]).

The most spectacular working sites robots, (most of them being japanese), illustrate both some technical abilities and a strong will of some building companies to have a resolutely modern look.

Robotization of construction works cannot be considered separately from other problems such as the consequences on construction techniques, on professional organization and on workers qualifications.

From a strictly technical point of view, robots tested up to now are either existing machines equipped with local antomatisms (engine control, assistance to driver, preprogrammed movements, ...) or newly designed machines that try to reproduce the motions of a skilled worker when performing a specialized task (spraying, painting, concrete finishing, ...).

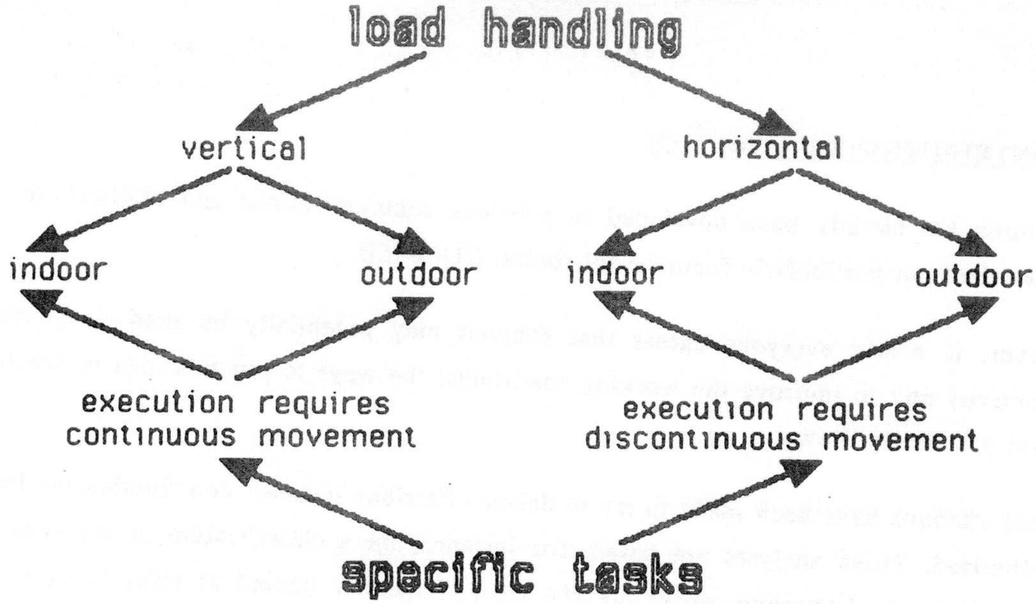

Figure 1 : Classification of construction tasks ([3])

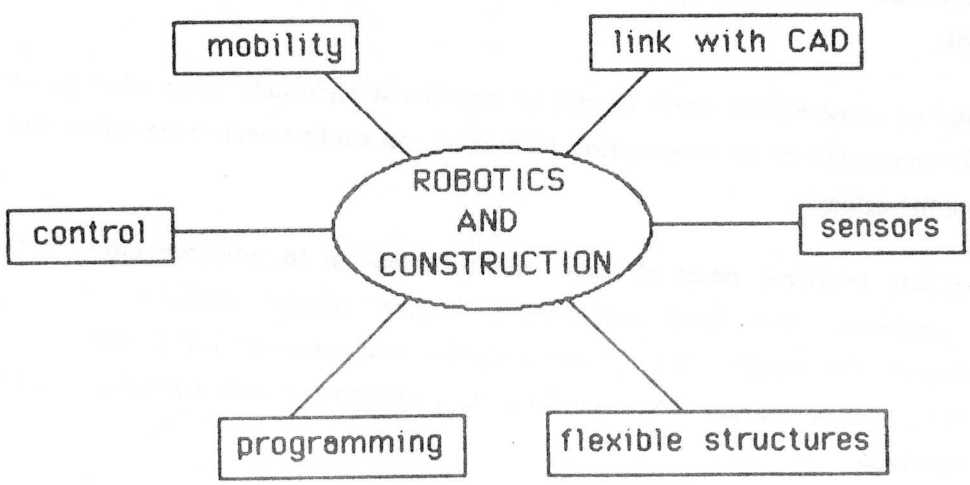

Figure 2 : Robotics techniques in connection with the topic "ROBOTICS and CONSTRUCTION"

2. <u>REQUIRED ROBOTICS TECHNIQUES</u>

A synthesis of experiments and technical developments following one of the two previously mentionned approaches drives to distinguish a limited number of "robotics" techniques (figure 2).

This list, which does not pretend to be exhaustive, needs some comments :

- the rigid mechanical structures of industrial robots have often been used, for cost and availability reasons, to experiment some models of construction robots (SSR1 and SSR2 by SHIMIZU [9], mobile robot for finishing works SOFFITO (figure 3)). These structures have revealed to be unfit for excessive weight, excessive precision, excessive bulkiness of control systems for instance ;

- flexible structures have been used for a long time on working sites (tower cranes for example) but the automation, the control of the movements of such a structure give rise to difficult problems that must be properly posed in particular when trying to locate precisely a tool at the end of such a flexible structure (telescopic boom for instance) ;

- mobility appears as an obligatory function for working sites robots ; this function has been mainly developed for indoor construction robots, knowing that most of the traditional working sites machines performing outdoor tasks have been facing mobility problems for decades (under human control) ;

- programming is also an essential aspect of robotics for construction. The use of direct learning is limited because of the few repeating tasks. More sophisticated means, joining a priori data of the project (by way of CAD) and a sensor knowledge of the actual working site are to be developed ;

- sensors are of course absolutely necessary to ensure the carrying out of the environment perception as well as all the measures (distances, pressures, temperatures, ...) needed for robots functionning ;

The separation of these topics has been done to make things clear but it is obvious that there are links between these themes.

The main interest of this overview is to point out study fields that can be examined from the technology transfer point of view.

3. TECHNOLOGY TRANSFERS

Technology transfers are defined as any means to adapt a technology developed either for laboratory purposes or for industrial activities to another kind of activities : construction in our case.

The question is : Is-it necessary to develop new technologies to solve specific technical problems of construction robotics, or are there already operational techniques that can be transfered from the original activities to construction ?

The realization of experimental construction robots is the beginning of an answer to such a question but the problem must be further examined to try to find more suited solutions.

To illustrate our purpose, we choose two examples :

- the mobility function ;
- sensors as measurements tools.

3.1. The mobility function

The execution of this function requires the use of a mechanical structure coupled to a control system (figure 4).

The mechanical structure is designed to support a load and is connected to the ground by a fitted system : traditionaly wheels or cartepillars but also legs, air-cushion or any other lifting process.

The control system ensures several functions :

- navigation (definition of the trajectory to be followed) ;
- pilotage (follow the defined trajectory) ;
- perception of the environment (necessary for navigation and pilotage but also for safety).

For mobiles machines performing outdoor tasks on working sites, mechanical problems are fully mastered and the control functions are ensured by the driver by the driver who is altogether the navigator, the pilote and the host of the system of perception of the environment.

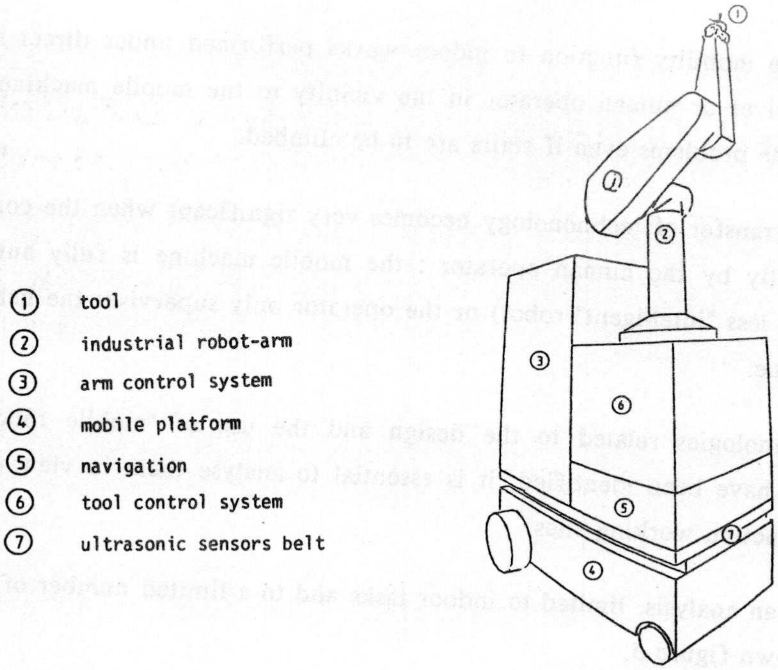

Figure 3 : SOFFITO mobile robot for finishing works developed by AID, CSTB and IIRIAM

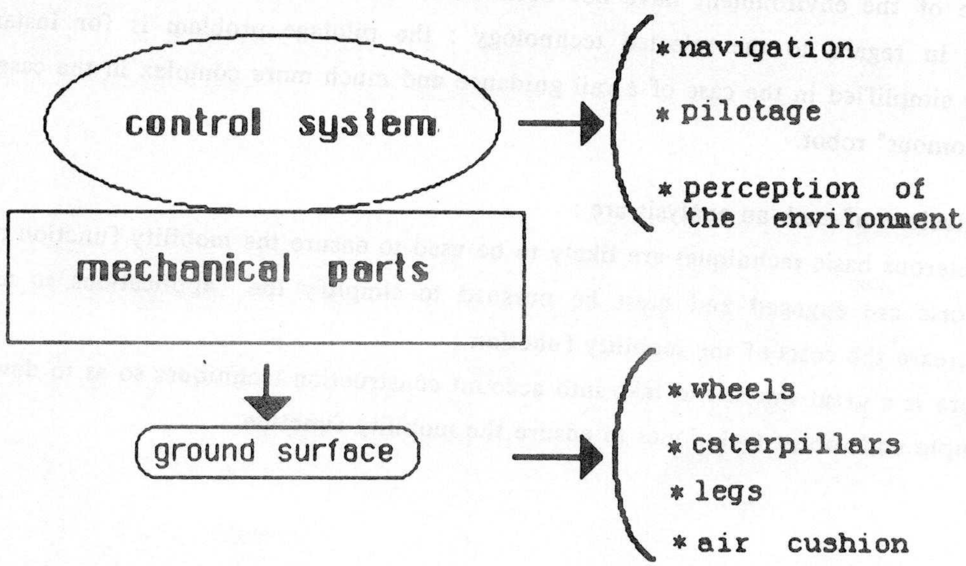

Figure 4 : The mobility function

The adaptation of the mobility function to indoor works performed under direct human control (supported driver or human operator in the vicinity to the mobile machine) does not lead to insuperable problems even if stairs are to be climbed.

The question of the transfer of technonology becomes very significant when the control is not performed directly by the human operator : the mobile machine is fully automatic (case of the more or less "intelligent" robot) or the operator only supervises the behaviour of the mobile machine.

When "mother" technologies related to the design and the use of "mobile robots" for various applications have been identified, it is essential to analyse them in view of their utilization on construction working sites.

The results of such an analysis, limited to indoor tasks and to a limited number of mother technologies are shown figure 5.

Some of these technologies have already been tested by means of experimental construction mobile robots.

Some of the derived technology are actually being developed, particularly at CSTB.

So as to simplify this presentation, distinctions between navigation, pilotage and the perception of the environment have not been made. Such a distinction is more or less important in regard to the selected technology : the pilotage problem is for instance extremely simplified in the case of a rail guidance and much more complex in the case of an "autonomous" robot.

The conclusions of such an analysis are :

- numerous basic techniques are likely to be used to ensure the mobility function ;
- efforts are engaged and must be pursued to simplify the applications so as to decrease the costs of the mobility function ;
- there is a great interest to take into account construction techniques so as to develop simple and robust techniques to ensure the mobility function.

mother techniques	rail guidance	wires guidance	optical guidance	teleoperation	autonomous robot
typical application	transport, manufac. industry	manufac. industry	manufac. industry	nuclear, space, under-sea	research, non-manuf. industry
technology transfer to construction	Y	Y	?	remote-control?	Y
exemple (reference)	O S R1 (10)	SSR1 (11)			SOFFITO (12)
adaptation to construction	use of quard rail	placing a wire	placing of optical guide		no specific equip-ment
remarks	temporary installation or equipment bound to the construction				
further developments	rails on external walls	use of reinfor-cements	use of floor tiling		

Figure 5 : Analysis of mobility function

3.2. Sensors for distances and locations measurements

Distances measurement is an omnipresent activity when erecting a building : from the land-marking to the final control going through the measurements necessary to place concrete moulds.

Theodolites and distance-meters are currently used on working sites and the most recent devices are equipped with local sensors and computers so as to perform calculations and to memorize data.

For short distances measurements (some meters), commercialy available infra-red or ultra-sonic devices are available which may be connected to local computers to ensure surfaces or volumes calculations.

The likely development of construction robots means the mastering of these measurements techniques which may also be applied to :

- the marking of the location of the hook of a crane with respect to the erecting construction ;
- the determination of safety gaps to avoid for instance collisions ;
- the guidance for the automatic placement of components ;
- the measurement of "as-built" distances on an existing building (to prepare for instance the outdoord insulation works).

The field of activity of measurements techniques is then very wide and it is not as simple as in the case of the mobility function to present a synthesis of these problems in terms of technology transfers.

Anyhow, figure 6 shows the results of such an attempt.

The association of several techniques increases the number of applications as it is shown figure 7 where vision techniques (pursuit of an infra-red belt) and ultrasonic techniques (distance measurements) is used to measure the space location (one distance, two angles) of a moving point.

There are then virtually numerous possibilities, the use of which should not strongly interfere with construction techniques.

This "weak" link between measurement techniques and construction techniques is perhaps a sign of a good penetration of the automatization of measurements on working sites.

mother techniques	contact	ultra-sound	infra-red	laser	vision (any wavelength, active stereo, passive stereo)
typical application	research, industry			land marking	research, industry
measurement range (m)	10^{-2}	10^{0}		10^{2} →	scene analysis, 3D marking
technology transfer to construction	Y	Y			
exemple (reference)	SSR1 (11)	SOFFITO (12)			
adaptation to construction	no specific				
remarks				importance of computing	
further developments			working sites measurements, marking		as-built measurements

Figure 6 : Analysis of distance measurements

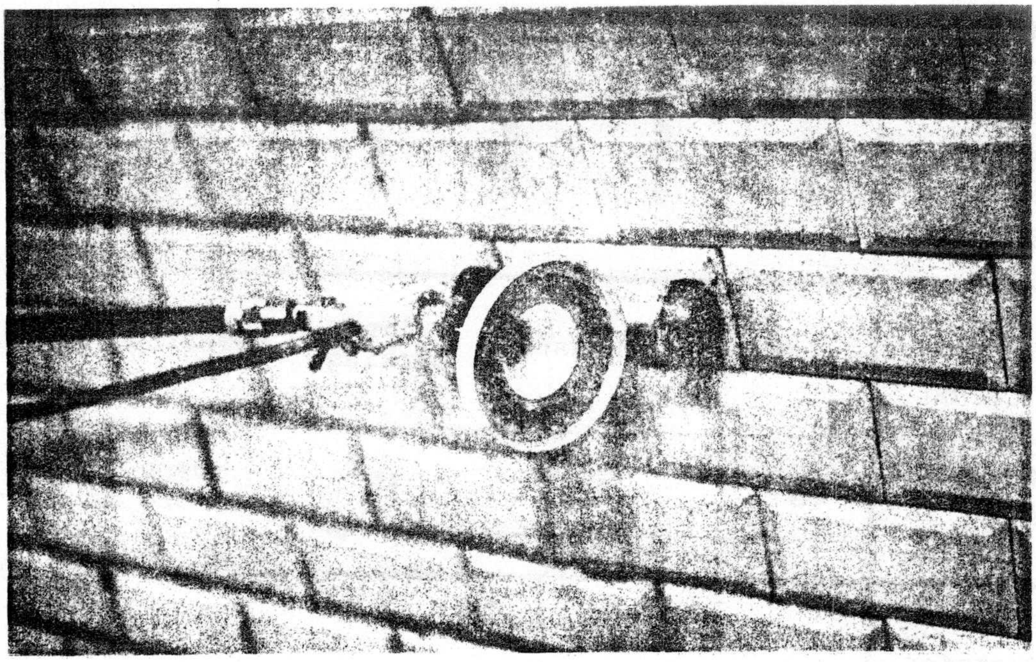

Figure 7 : Detail of a location measurement system using vision and ultra sounds (document MICROMAINE)

4. ENLARGING THE METHODS

We have previously sketched out a working method that consists in :

- identifying technical topics, the study of which is necessary to develop robotics for construction ;
- looking for similar technical points that have been treated for other applications ;
- analysing the collected data so as to discriminate between possibilities the fittest solution in terms of cost and robustness.

Such a method is not very original in itself but is likely to drive to fitted solutions when applied rigorously.

Construction industry is not nuclear, space or undersea industry. On the opposite, construction industry is close to traditional activities both manufacturing (components making for instance) and non-manufacturing (agriculture as an example).

There is a lot to gain in thinking in terms of construction method so as to avoid the developement of too sophisticated machines that would unlikely work on construction working sites.

Construction professionals need useful "robots".

BIBLIOGRAPHY

[1] WARSZAWSKI (A.).- Application of robotics to building constructions.- Pittsburgh, Carnegie Mellon University, 1984

[2] RUBINSTEIN (M.).-" Mécanisation dans le Bâtiment : l'apport de la robotique", in : Mécanisation dans le Bâtiment : Evolutions et Perspectives, les rendez-vous du CSTB, Paris, 22 avril 1986

[3] SALAGNAC (J-L.) .- Applications des techniques robotiques au secteur de la construction, Valbonne Sophia Antipolis, CSTB, juin 1987

[4] WHITTAKER (W.L.).- "Construction Robotics : a perspective", in : Colloque CAO et Robotique en Architecture et BTP, CSTB, GAMSAU, IIRIAM, Marseille, 25 au 27 juin 1986.- Paris, HERMES, 1986

[5] Robotics, Special issue : Automation in Construction, , vol. 2, nº2, juin 1986

[6] HASEGAWA (Y.).- "Robotization of reinforced concrete Building Construction in Japan", in : Colloque CAO et Robotique en Architecture et BTP, CSTB, GAMSAU, IIRIAM, Marseille, 25 au 27 juin 1986.- Paris, HERMES, 1986

[7] SKIBNIEWSKY (M.J.).- Engineering and Economic analysis of robotics application Potential in selected construction operations.- Pittsburgh , Carnegie Mellon University, mars 1986

[8] KANGARI (R.).- "Major Factors in Robotization of Construction Operations", in : Colloque CAO et Robotique en Architecture et BTP, CSTB, GAMSAU, IIRIAM, Marseille, 25-27 juin 1986.- Paris, HERMES, 1986

[9] SUZUKI (S.), YOSHIDA (T.), UENO (T.).- "Construction Robotics in Japan", in The Second Century of the skyscraper, conference, Chicago, 6-10 january 1986

[10] "Self travelling robot for spray painting veranda walls", The Japan Industrial and Technological Bulletin (JETRO), p. 31, mai 1986

[11] YOSHIDA (T.), UENO (T.), NONAKA (M.), YAMAZAKI (S.).- "Development of spray robot for fireproof cover work", in : Workshop Conference on Robotics in Construction, Carnegie-Mellon University, June 17-20, 1984

[12] SALAGNAC (J-L.) et al..- "SOFFITO : une maquette de robot mobile pour l'exécution de tâches de second-oeuvre de Bâtiment", in : Colloque CAO et Robotique en Architecture et BTP, CSTB, GAMSAU, IIRIAM, Marseille, 25 au 27 juin 1986.- Paris, HERMES, 1986

HUMAN KNOWLEDGE: AI & CAD

Aart Bijl
EdCAAD, University of Edinburgh, Department of Architecture
20 Chambers Street, Edinburgh EH1 1JZ
Scotland

Perceptions of design and CAD are discussed, leading to a distinction between human knowledge and machine representations of knowledge. A strategy for "mechanistic" symbol processors is presented, employing "mechanisms" of formal logic to manipulate written and drawn expressions of designers' knowledge.

Keywords: knowledge, notions, representations, formalisms, symbols, drawings, design.

INTRODUCTION

We have now experienced two decades of CAD. In that period, the promise of CAD has met with obstacles presented by: firstly, the essentially idiosyncratic nature of design practices, particularly in loosely constrained fields; secondly, the prescriptive nature of conventional computer technology; and, more recently, the assumptions underlying machine intelligence.

It is time to return to two fundamental questions:

1. What can we know about design that will inform our efforts in CAD?

2. What can we know about human intelligence that will inform our efforts to link AI and CAD?

The field of CAD requires theories of design that embrace human designers. By designing CAD systems - focusing on machine systems - we are in effect designing designers. All CAD systems have in-built anticipations of the behaviour of designers who will be invited to use them. The orthodox argument is that these systems relieve designers from the routine and uninteresting tasks involved in designing. The assumption underlying this position is that we know what is tedious to designers. To test this assumption, consider each of us as designers and then ask whether we would be happy to let other system designers decide what each of us finds interesting when we design CAD systems?

A theory of design does not need to explain all that goes on within individual