THE FUNCTIONAL ANALYSIS: RESULTS AND APPLICATIONS TO THE ROBOTIZATION OF CONSTRUCTION OPERATIONS.

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ABSTRACT

Among the methods developed in different research centers and construction association to answer the questions: which construction tasks are to be robotized? How can these tasks be robotized? The functional analysis is an original and complementary answer to more traditional enquiries carried out in working groups.

The basic principle of this approach consists in a very detailed decomposition of construction tasks which allows to split any task over a set of few basic functions.
These functions are characterized by parameters which give reference indications about the technical feasability of their robotization.

It is then possible to study the robotization of some selected tasks which are necessary to achieve various operations on sites.

This methodology was applied to a set of operations which were selected from an economical analysis crossed with analysis of danger and tediousness of work conditions.

This paper presents the results of this study. It is pointed out some difficulties in the collection of parameters of the basic functions. These difficulties will need more specific work about experimental and economical task analysis.

The outline of these future actions are presented.

1. INTRODUCTION

The evolution of construction techniques is rather slow compared to other less traditionnal activities. There has been a growing concern for some years to modernize the execution methods of construction operations on sites.

The expected advantages of such a modernization have often been cited:
- improvement of work conditions;
- increase of productivity;
- improvement of quality.

The rise of robotics technologies gave a new interest to these problems, but basic questions are to be answered:

- which tasks are to be robotized?
- according to which criterions?
- which are the cost limits?
- when will the construction robotics be mature?

To try to answer these questions, we have developed a method named "functional analysis". Each construction task is analysed in details in order to give basic information in terms of required performances for robotics modules.

Constant discussions with professionnals are organized along this analysis process in order to avoid to stay at an academic level.

This method is presented below as well as the results and the future of this study.

The classification of construction operations, which is the early step of this method is first presented. The set of basic functions which is used during the ultimate step of the analysis is then presented.

An overwiew of the selective criterions and of the discussions with professionals is given as well as the results of an enquiry which was carried out to appreciate the interest of robot manufacturers for this new field of applications.

2. CLASSIFICATION AND FUNCTIONS.

A six level classification is used as a general frame of this method (figure 1). The main goal of this classification is to make sure that all the tasks and operations on (building) sites will be considered. We do not pretend to analyse all the tasks but we think that with such a frame we cannot miss any.

The basic functions defined at the lowest level modify 5 parameters which are the location, the mass, the shape, the surface quality and the degree of freedom. According to the variation of these parameters (+ or -) when an object comes from step 1 to step 2, 8 functions are defined (figure 2).

3. SELECTION OF OPERATIONS AND ANALYSIS.

3.1. Selection criterious.

By using directly this classification, it is clear that we face an exponential growth of the number of cases through the different levels.

In order to avoid such a situation, selective criterions have been defined:

- at level 1: information about the importance of the different classes have been used (number of employees, relative economical importance). This information appeared to be poorly selective.

- at level 2: information about danger and tediousness of tasks. This information is quite difficult to use because only bulk parameters are published. The analysis of particular accident situations is on the other hand too precise to be used as an efficient selective criterion.

- at level 3: information about operations costs (manpower, materials,...) are relatively easy to use and provide the basis for an efficient selection.

3.2. Selected operation.

The use of previously described criterions led us to list operations according to:

- the decreasing importance of manpower cost relatively to the total cost.

- the decreasing importance of danger and tediousness indicators (though, as mentioned above, this criterion is not very selective).

We then considered the top of the list down to a 50% rate of manpower cost/total cost.

This selection is given figure 3. This is of course not a definite selection. The quality of the selective criterions is not high enough to make such a conclusion.

This list was the basis for discussions with professionals. It was confirmed that the most promising cases were included in this list.

4. USE OF BASIC FUNCTIONS.

The discussions pointed out a small number of relevant operations to be considered. They are indexed on figure 3.

Figure 4 gives an example of the functional analysis, i.e. the way tasks are split over the set of functions.

The parameters of these functions are also given. We found relatively easy to make a description of operations in tasks and of tasks in functions but it is very difficult to give precise value to parameters. Such a detailed approach looks to be rather new for construction activities and data are not yet available.

Specific work will certainly be needed in this field.

5. OVERVIEW OF ROBOTICS PRODUCTS.

By means of an enquiry carried out aver a wide panel of robot manufacturers (components, sensors,...) in France, it was made possible to draw out an overview of the commercial offer both for manufacturing and for non manufacturing operations.

The main conclusions of this enquiry confirmed published information about the applications of robotics. Construction is mentionned for 13% of the total. This figure may look surprisingly high but it includes mainly components rather than robots.

6. RESULTS AND CONCLUSIONS.

The assumption when we began this study was that there was an common interest for both construction people and roboticians to create a reference frame in order to make easier the study of the robotisation of construction operations.

The importance of the work was probably underestimated and results were difficult to obtain. Up to now the main results we got are:

- a general methodology to analyse task down to descriptive level.

- a list of operations which must be considered in priority as regard to a set of criterions.

In spite of our objectives, this remains still a bit academic but we can hardly go beyond if interested people do not spend any energy to help us to solve some problems.

Among these problems:

- the lack of information to value the parameters of the functions.

- the difficulty to choose robotics solution likely to ensure these basic functions.

The common modules of future construction robots did not yet come from our analysis as we expected. To do so, we should consider a higger number of cases.

The work has been carried out in such a way that it is open to any researcher who wishes to continue.

We would like to take opportunity of this presentation to make a call for partners who would like to join us.

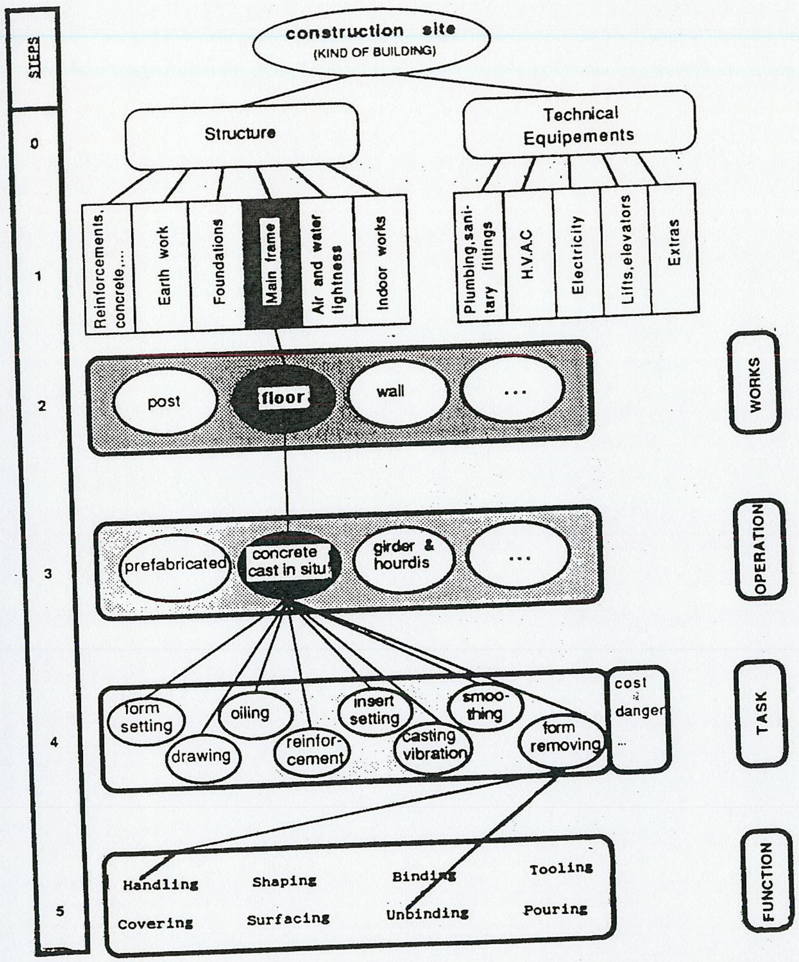

fig. 1: Frame of classification.

NAME FUNCTION	A 1 -> 2	m 1 -> 2	F 1 -> 2	S 1 -> 2	DLR 1 -> 2
HANDLING	#				
TOOLING POURING		- # +			
SHAPING			#		
SURFACING COVERING				- # +	
UNBINDING BINDING					- # +

A location
M mass
F shape
S surface quality
D degree of freedom
1 step before execution
2 step after execution

fig. 2: Functions.

RENFORCED CONCRETE SHELL WITH FORM.

TASKS	FUNCTIONS
1 Marking, tracing	
2 Form setting and shoring	HANDLING-BINDING
3 Oiling	
4 Insert setting	HANDLING-BINDING
5 Placement of reinforcement	HANDLING
6 Fastening and locking of reinforcement	BINDING
7 Closing of form	HANDLING-BINDING
8 Placement of concrete	POURING
9 Concrete vibration	SHAPING
10 Removal of form	UNBINDING-HANDLING
11 Cleaning of form	SURFACING
12 Fill in concrete	POURING
13 Smothing	SURFACING-COVERING

FUNCTIONALS PARAMETERS.

HANDLING	2	4	5	7
direction(degree)	0	0	0 et 90	0
distance (m)	5 à 10	5 à 10	5 à 10	<à1
mass (kg)	3500	50 à 100	18	1700
packaging	plate	frame	plate	plate
size (m)	2.5x7.5	medium	medium	2.5x7.5
speed				
accuracy (mm)	5	5	10	3

fig. 4: Example of functional analysis.

MANUAL EARTHWORK
-> excavation-embankmant

INTERNAL REVETMENT
wall lining
floor surfacing
-> tile
plaster floor

MIDDLE WORK
form

HORIZONTAL FRAMEWORK
-> block

PUGGING
-> concrete block

ROOFING
tiles, zinc works, slate, arris tile, ridge tile

EXTERNAL REVETMENT
-> external painting work, cement paint

INTERNAL REVETMENT
-> internal painting work

CEILING

ROOF FRAMING
principal beam

STAIRCASE
concrete staircase

VERTICAL FRAMEWORK
reinforced concrete post
-> shell, window pier

OPENING
-> reinforced concrete beam

EXTERNAL ISOLEMENT
fibreboard
coat

fig. 3: Selected operation.

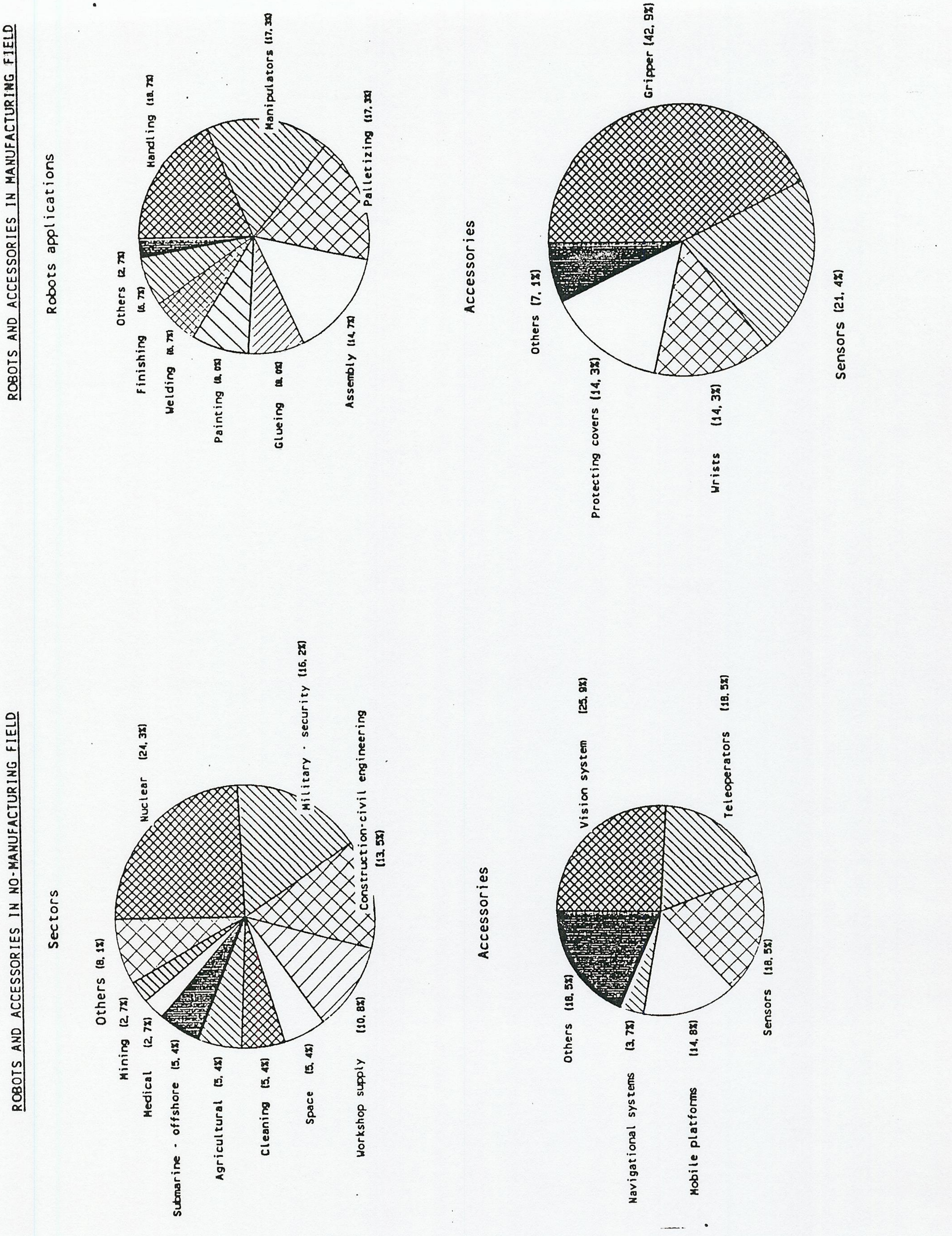

fig. 5: Overview of robotics products.