THE FUNCTIONAL ANALYSIS : AN ORIGINAL APPROACH TO THE ROBOTIZATION OF CONTRUCTION TASKS

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ABSTRACT

Robotics techniques in operation in the industry or under development in laboratories supply basic functions to carry out many different operations. Some of these techniques are compatible with construction sites operations under reasonable economic constraints, some other are not (too fragile, too costly, ...). Obviously, construction site operations are executed by means of a set of basic functions (handling, pouring, spraying, ...). It is then interesting to detail the parameters of these functions in order to compare the needs with the potential capacities of robotics techniques.From such a comparison, we expect to point out the needs and demands of professionals for robotizing construction operations. We also expect to draw out the main lines of the evolutions of construction techniques that will be necessary to fit with the capacities of robotics techniques. The backbone of this study is a classification of construction operations that helps to split operations in tasks and tasks in basic functions. The parameters of each function are defined with professionals. This information is then processed in order to reach the assigned goals. This paper presents the main lines of this study and states the major results and difficulties in carrying out this work.

1. INTRODUCTION

Which construction operations are worth to be robotized ?

How to robotize the selected operations ?

Many attempts have already been made to answer these fundamental questions.Global feasibility studies have pointed out the most relevant operations to be robotized regarding to criterions such as economics, safety of workers, productivity and quality improvement for instance.

Within the framework of the japanese programmes (Advanced Construction Technology : ACT and WASCOR), the results of such an investigation have been published. More recently, american studies concerning either building construction or heavy works have been presented ([1],[2]). A great number of bulk parameters are first considered in these studies such as labor or cost distribution.

A first set of potential areas is given including piping or earth removal, but the point is that this first approach must be completed by a technological analysis so as to get a global overview of the technical and economical feasibility of robotization. The conclusions of these studies will probably be soon presented but, as TUCKER [1] already mentioned, these results are dependent on the dominant construction technology. These technologies are not the same in the U.S and in the european countries.

Concerning the european countries, some national programme have been recently launched which are preceded by global feasibility studies.
For instance, the dutch programme PKMB [3] concerning building construction is firstly interested in the task of concrete form maker. The english programme prepared by the CIRIA [4] intends to consider first the survey, maintenance, repair works for existing constructions.

This matter is difficult and ideas are far from being stabilized.The second question has mainly got experimental answers. The first attemps have consisted in imitating the human skill.A typical example is the KAJIMA MARK I concrete clab finishing mobile robot (see figure 1).

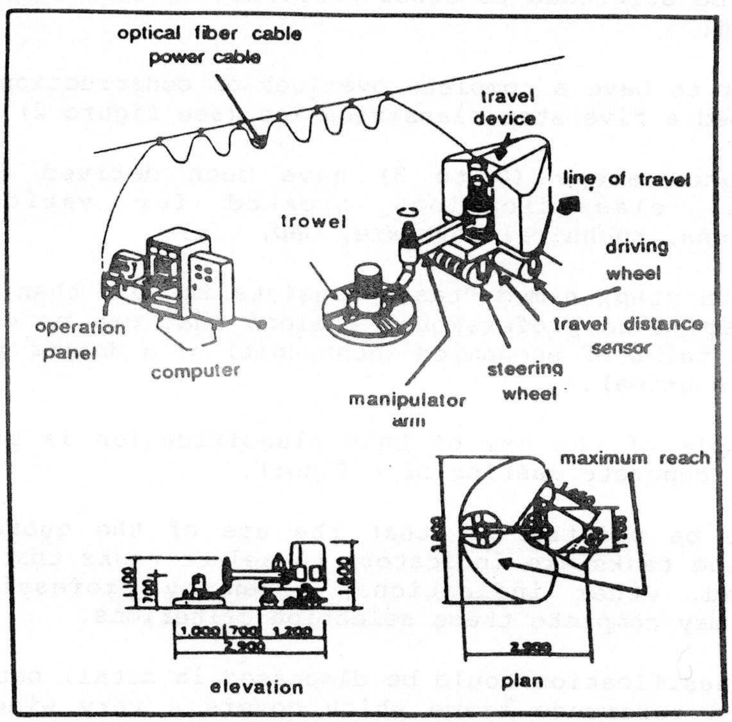


Figure 1 : Concrete finishing robot MARK I

The walking human operator has been replaced by a mobile platform (handling function). The oscillating movements of the trowel are given by an articulated arm instead of the arms and trunk of the operator (handling function). The finishing work results in a change of the concrete surface (shaping function). The path of the mobile robot is programmed so as to cover the concrete slab (covering function).

This early design has quickly been abandoned.

Newly designed concrete floor finishing robots have been experimented ([5] to [8]). They all ensure the same quoted basic functions as the MARK I but with a more simple structure (no more arm). It might then be expected cheaper, more reliable and more flexible future robots.

This example clearly illustrates the interest in considering these basic functions.

Our study aims to generalize such an approach. To reach such a goal, we must first be able to split any construction operation in basic functions. We must then characterize these functions by a set of parameters in order to be in position to compare these needs to the offer of robotics techniques.

2. A CLASSIFICATION OF CONSTRUCTION OPERATIONS

At present, we have restricted the scope of our study to buildings construction operations. The conceptual sketch presented below could be stretched to other construction activities without any major problem.

In order to have a complete overlook of construction operation we have developed a five step classification (see figure 2).

The higher steps (0 to 3) have been derived from existing professional classifications created for various purposes (specifications, technical software, CAD, ...).

The fifth step, named "task" consists in more than hundred tasks which correspond to professional actions that can be described, for instance, in terms of economics (cost/unit) or a danger (statistics of industrial injuries).

An example of the use of this classification is given figure 2 (operation : concrete casting of a floor).

It must be pointed out that the use of the quoted parameters describing the tasks are indicators to select tasks that are worth to be robotized. Other indications, given by professionals during interviews, may complete these selection criterions.

This classification could be discussed in detail but its main use is to give a reference frame which covers a very wide spectrum of construction operations and which allows to describe any of these operations in terms of professional tasks.

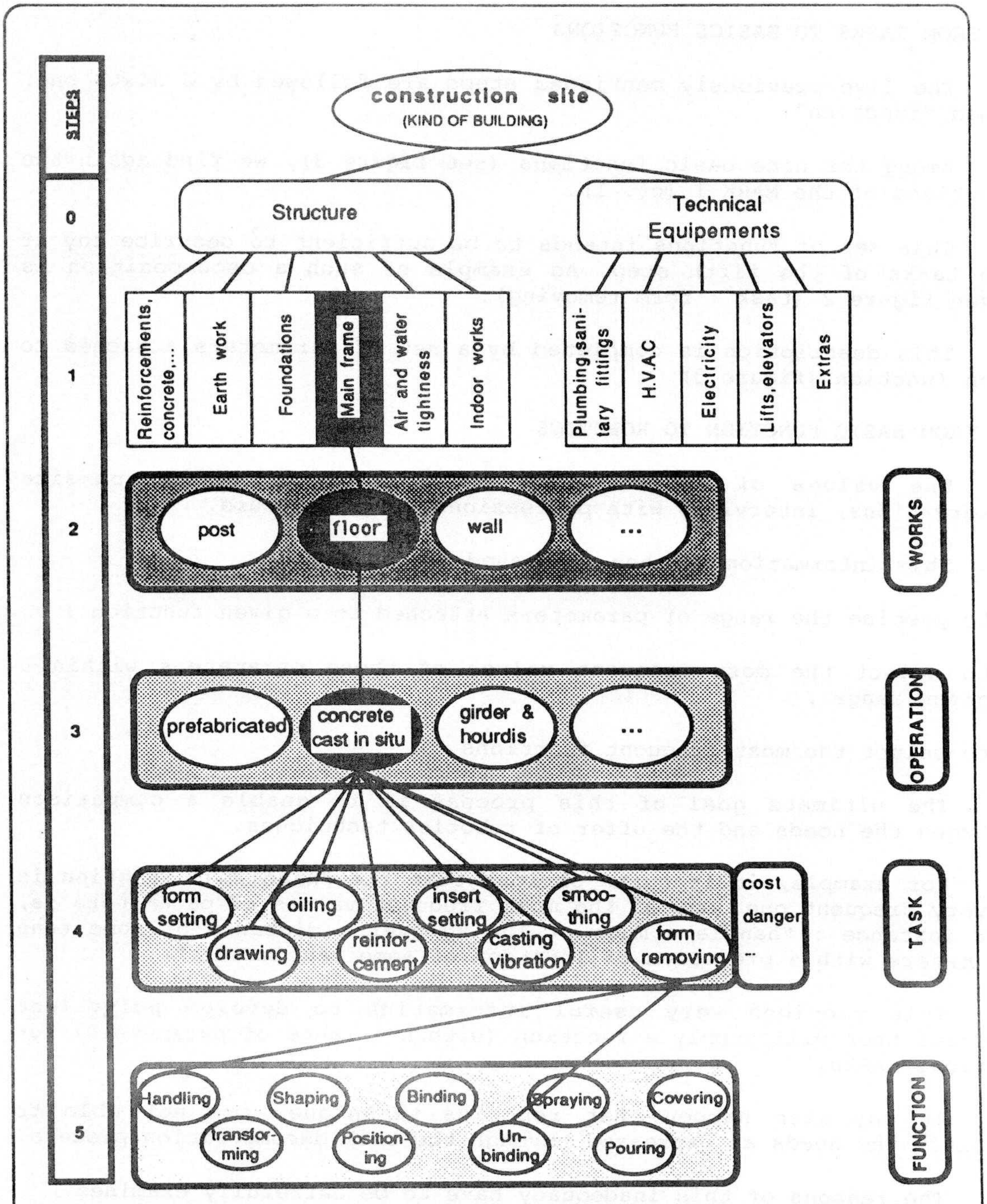


Figure 2 : Classification of construction operations

3. FROM TASKS TO BASICS FUNCTIONS

The five previously mentioned steps are followed by a sixth one, named "function".

Among the nine basic functions (see figure 3), we find again the functions of the MARK I (cf. 1).

This set of functions intends to be sufficient to describe any of the tasks of the fifth step. An example of such a decomposition is given figure 2 (task : form removing).

This description is completed by a set of parameters attached to each function (figure 3)

4. FROM BASIC FUNCTION TO ROBOTICS

The values of these parameters are given through on-site observations, interviews with professionals, litterature.

This information is then processed in order :

- to precise the range of parameters attached to a given function ;

- to select the most frequent values of these parameters within a given range ;

- to select the most frequent functions.

The ultimate goal of this process is to enable a comparison between the needs and the offer of robotics techniques.

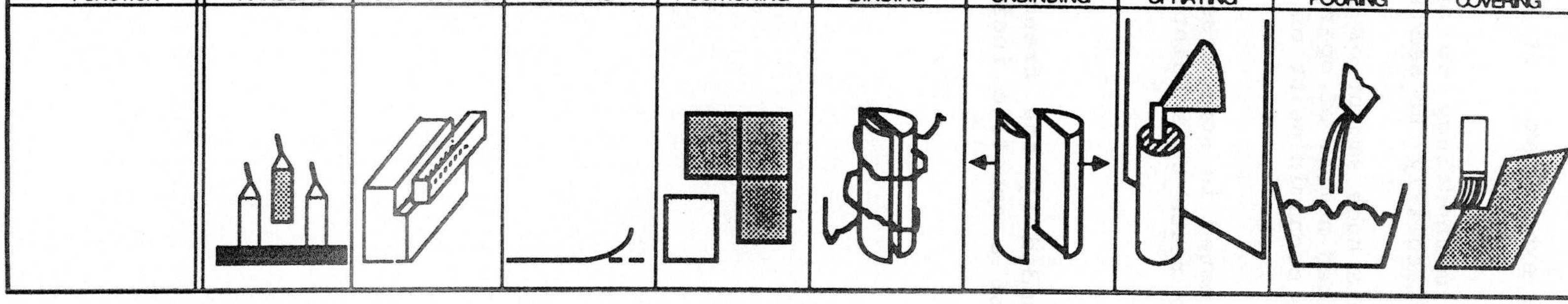
For example, it is quite obvious that the "handling" function is a very frequent one. One of the most frequent values of parameters is, for instance : "handle a mass of 100 kg over a distance of some tens of meters with a precision of location of some centimeters".

This provides very useful information to develop polyvalent modules that will supply a function (within a range of parameters) for various tasks.

It may also happen that robotics techniques are not able to satisfy the needs as expressed through the task decomposition process.

The reasons of this inadequacy have to be carrefully examined.

The basic process (the task itself) must be analysed and alternative solution may be proposed to facilitate the robotization of the considered operation (for instance, replace the nailing process by a gluing process in the function "bind").



FUNCTION	HANDLING	TRANSFORMING	SHAPING	POSITIONING	BINDING	UNBINDING	SPRAYING	POURING	COVERING
CHARACTERISTICS OF MATERIALS	- weight - dimension - state	- nature - hardness - abrasion	- nature - plasticity - fragility	- nature - weight - dimension	- nature - weight - dimension	- nature - weight - dimension	- density - state - viscosity	- density - viscosity	- density - viscosity
EXECUTION PARAMETERS	- distance - trajectory - precision - accelera-tion	- dimension - precision	- final geometry	- precision	-binding process -precision	-binding process -précision	- flowrate - thickness	- volume - process	- thickness

Figure 3 : Description of the basic functions

5. CONCLUSIONS

This study does not intend to be exhaustive : it would be a life long work.

It only intends to perfect a methodology to answer the two questions set in introduction and particularly the second one.

The main difficulty is to manage a huge amount of information. At present time, we have selected a limited number of operations known as being the most representative from an economic point of view (concrete casting, block laying, roof covering, ...).

This methodology will then be tested in some cases and proposed as a design tool. It is expected to reach this point by the end of 1989.

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