STRUCTURATION ENVIRONMENT AND GUIDANCE OF A MOBILE ROBOT FOR CONSTRUCTION APPLICATIONS

Jean-Luc SALAGNAC,
Head of the Robotics and Construction Division
Sophie SIINO

Centre Scientifique et Technique du Bâtiment
BP 21
06561 VALBONNE Cedex FRANCE

ABSTRACT

The economical interest of robots for construction sites is not yet fully asserted. Existing experimental robots are still complex and costly machines. Most of these future robots are likely to be mobile robots. It is then essential to research simple technical solutions to ensure the mobility function. Attempts to use guiding devices developed for industrial purposes have given informations on the technical and economical limits of many systems. The use of the environment structuration of a building under construction to guide a mobile robot is probably a suitable way to develop simple navigation systems. This paper reviews some of the existing systems, presents an original experiment and draws out the lines of future research that will probably lead to propose modifications of the construction techniques in order to be able to use simple and cheap navigation systems.

0. Introduction

Since the early beginning of the research on Robotics in Construction, mobility has been confirmed as a key function to be developed for future construction robots.

Research has lead to experiment a great number of technical solutions for both navigation and environment perception.

It looks to the authors that there has been a lack of attention in the use of contruction techniques peculiarities. This point will be developed in this paper and an experimental work concerning a location and guidance system of a mobile robot using reinforcements will be presented. New experiments that will soon be undertaken in CSTB will finally be presented.

1. Mobile robot applications in construction

Mobility is obviously necessary on working sites. Mechanical structure with a large reach (tower cranes for instance) are usefull for handling loads outdoor but become inefficient indoor.

Most of existing working sites machines are mobile (dozer, excavators, cranes, ...). When needed these machines can be operated by remote control.

Some attempts have been made to transform these machines into robots by implementing sensors and control systems either preprogrammed (reinforcement bar placing by KAJIMA [1]) or using a learning capacity (hydraulic excavator by ORENSTEN and KOPPEL [6]).

The most spectacular machines are actual mobile robots which perform various indoor tasks in building construction such as :

- floor grinding
- concrete spraying
- floor cleaning
- ceiling painting (see picture 1)
- concrete slab finishing

or are mobile devices under development which will perform :

- gypsum board placing
- stud placing
- concrete block placing
- sand blasting

Information in table 1 refer to the geometry of the machines, the motorization, the sensors and the navigation techniques.

2. Construction techniques and space structuration :

It is interesting to look at the great variety of experimented guiding systems that goes from gyroscope to installed tracks on the floor.

The economy of such robots on actual working sites has not been fully asserted yet but we think it is necessary to develop simple systems to reach the economical goal.

A guiding system would be highly simplified if the environment is structured.

At the first glance, a working site (a building construction site for instance) does not seem to be very structured. In fact, the environment changes constantly but many parts of a building give a strong space structuration.

Obvious examples are beams, walls, floors, doors, windows, the position of which is preplanned with a sufficient precision regarding to the executed tasks.

Table 1 gives examples of location and guiding systems using this kind of structuration :

- SOFFITO (distance measurements to walls)
- SSR2 (distance measurement to the beam to be sprayed)

Space structuration can also be obtained from the placing of equipments :

- STUDBOT (follows a rail that has been installed by TRACKBOT)
- OSR1 (follows the hand rail of a balcony)

Another kind of structuration comes from some contruction techniques peculiarities. For instance, a reinforcement wire mesh placed in concrete slabs (figure 2) is theoretically a perfect coordinate system that is linked to the building all its life long and which can then be used both during the construction and when the building is finished (floor cleaning applications).

3. Guiding with a wire mesh

A feasibility study of such a guiding system has been lead by means of an experiment.

3.1. The basic principle

Typically, the mesh of the reinforcement is square shaped, 75x75 mm to 300x300 mm according to the slab resistance. The bars diameter is between 3 mm and 16 mm.

The regularity of the mesh allows to locate the mobile robot simply by counting the crossed bars.

Following a bar is a simple way to guide the robot on the desired distance in one of the two main directions.

3.2. The sensors

Inductive sensors have been used to detect the bars. In order to be able to follow a bar, two identical sensors have been implemented (TELEMECANIQUE sensors).

The maximum reach of these industrial sensors is 60 mm.

3.3. The experimental cart

An experimental cart has been built (see figures 3 and 4). It was equiped with a fixed back wheel (DC motor and reducer) and a steering wheel (stepping motor and reducer).

The control system and the energy are on board.

A table computer (EPSON HX20) and interface cards have been used to get informations from the sensors (distance to the bar) and to give orders to the step motor.

3.4. The simulation and the experimental results

We mainly focused on the following of a bar.

The behavior of the cart using different control laws was simulated and a PID control law was implemented on the computer.

The cart was experimented on a test track and the coefficients of the control law were determined in order to follow the bar when the maximum initial distance between the bar and the cart main axis was half of the distance between the centers of the two sensors and at a speed of 0.4 ms^{-1}.

Due to the limited reach of the sensors, the depth of the bar during the experiment was much less than the actual depth of a reinforcement wire mesh (8 cm to 20 cm typically).

4. Further developments

This must not appear as a limitation of the system. There are two ways to solve this problem :

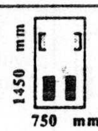
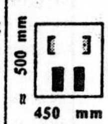
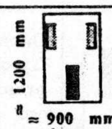
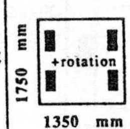
- designing of inductive sensors with a higher reach ;
- implementing a surface wire mesh (as used to improve the electrical floor conductivity in computer centers or in hospitals).

The first way leads to huge sensors and will probably not be followed. The second way leads to the development of suited floor coatings.

A closely related way that is now beeing developed in CSTB is the use of floor tiles (with optical sensors) as a linked coordinate system to the building.

This first experiment was encouraging to go on the research of simple location and guiding systems using typical building technique peculiarities.

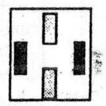
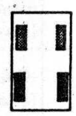
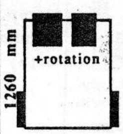
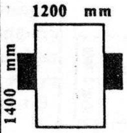
This was a first attempt to approach the problem of modifying construction techniques due to the future use of mobile robot in construction operations.

IDENTIFICATION				TASK	MOBILE PLATFORM		MANIPULATOR		TOOL
name	coun-try	partners	ref.		mechanical part	location/ navigation	mechanical part	program-ming	
SOFFITO	FRA	CSTB. IIRIAM,AID	2 *	finishing works (painting of ceilings as a first task)	 m= 430 kg	-24 ultra-sonic sensors -Odometry with wheel coders -Matching between ultra-sonic images and memory kept images	-Industrial robot arm -6 axes spherical structure -Electrical actuators	language	spray gun
OSR 1	JPN	SHIMIZU	3	painting of facades	 m ≈ 200 kg	-Guiding by following the hand rail of a balcony -Odometry	-Prototype -1 axe cartesian structure -Pneumatic actuators	prepro-grammed process?	spray gun
SSR1	JPN	SHIMIZU	7	metallic beam fire-proofing	 + robot arm trailer m=575 kg	-Wire guiding (temporarily installed wire)	-Industrial robot arm -6 axes spherical structure -Hydraulic actuators	learning process	spray gun
SSR2	JPN	SHIMIZU	7	metallic beam fire-proofing	 m=470 kg	-Location by distance measurements to the beam -Odometry	-Industrial robot arm -6 axes spherical structure -Hydraulic actuators	learning process	spray gun

back wheel   free wheel

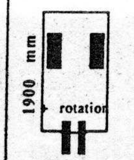
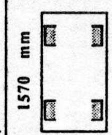
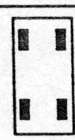
* : refer to the communication of this symposium :
"SOFFITO ,a mobile robot for finishing works in buildings"

TABLE 1

IDENTIFICATION				TASK	MOBILE PLATFORM		MANIPULATOR		TOOL
name	coun-try	partners	ref.		mechanical part	location/ navigation	mechanical part	program-ming	
SSR3	JPN	SHIMIZU KOBESTEEL	8	metallic beam fire-proofing		-Off line pro-gramming -Odometry	-Prototype -spherical structure + Z axis -DC actuators	off line	spray gun
MTV1	JPN	SHIMIZU	8	floor grinding and cleaning	 ≈ 700 mm	-Ultra-sonic sensors -Odometry -Gyrometry -learning of the room geometry and path planning	no arm	aimless	-vaccum cleaner -grinder
MARK 1	JPN	KAJIMA	1	concrete surface finishing	 1260 mm +rotation 1270 mm m=470 kg	-Odometry -Gyrometry -preprogram-med trajec-tory -Ultra-sonic sensors for safety	-Prototype -2 axes cylindrical structure -Electrical motors	-Periodical movements	rotating trowels
MARK 2	JPN	KAJIMA	8	concrete surface finishing	1200 mm  1400 mm +supporting point (tool) m=200 kg	-Gyroscope -Fixed link with operator	no arm	aimless	rotating trowels

back wheel   free wheel

TABLE 1 (cont.)

IDENTIFICATION				TASK	MOBILE PLATFORM		MANIPULATOR		TOOL
name	coun-try	partners	ref.		mechanical part	location/ navigation	mechanical part	program-ming	
	JPN	SHIMIZU	4	placing of gypsum boards under ceiling	 750 mm m ≈ 300 kg	remote controled machine	-cylindrical structure	aimless	suckers
	JPN	TAISEI	5	placing of boards both indoor and outdoor	 700 mm	remote controled machine	vertical telescopic axis	aimless	suckers
TRACK-BOT	USA	MIT	9	placing of floor and ceiling rails for indoor walls	 ≈ 500 mm	-laser guiding	translation axis	prepro-grammed	percussion hammer
STUD-BOT	USA	MIT	9	placing of vertical rails for in-door walls	 ≈ 500 mm	-Guiding by rails installed by TRACKBOT	rotation axis	prepro-grammed	
BLOCK-BOT (project)	USA	MIT	9	masonry			6 axes structure		

back wheel free wheel

TABLE 1 (cont.)

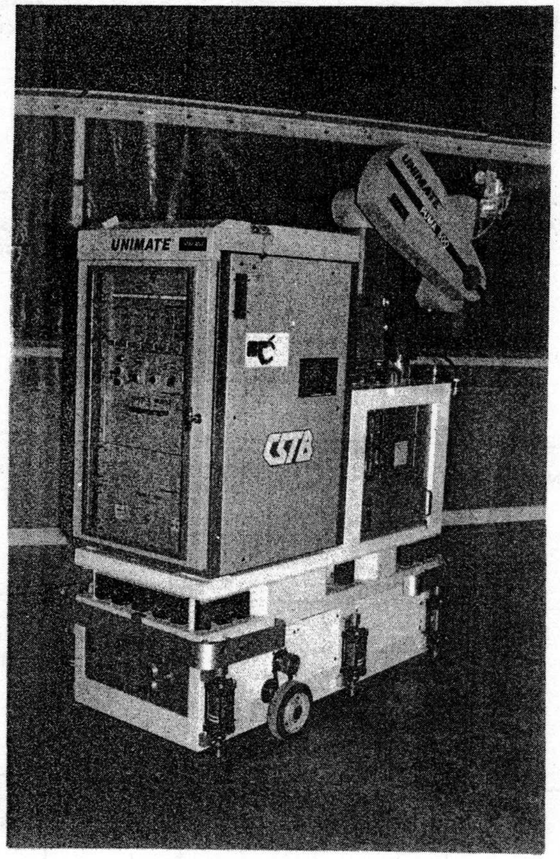


Figure 1 : SOFFITO (CSTB, IIRIAM, AID)
Mobile robot for finishing works in buildings

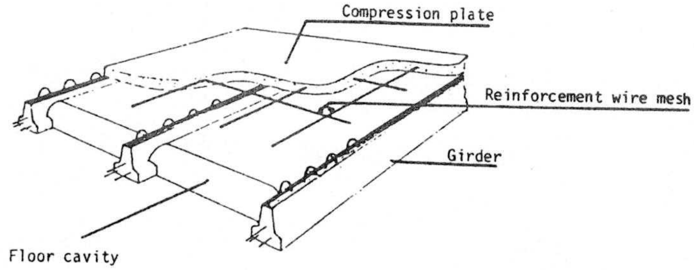


Figure 2 : Floor construction technique

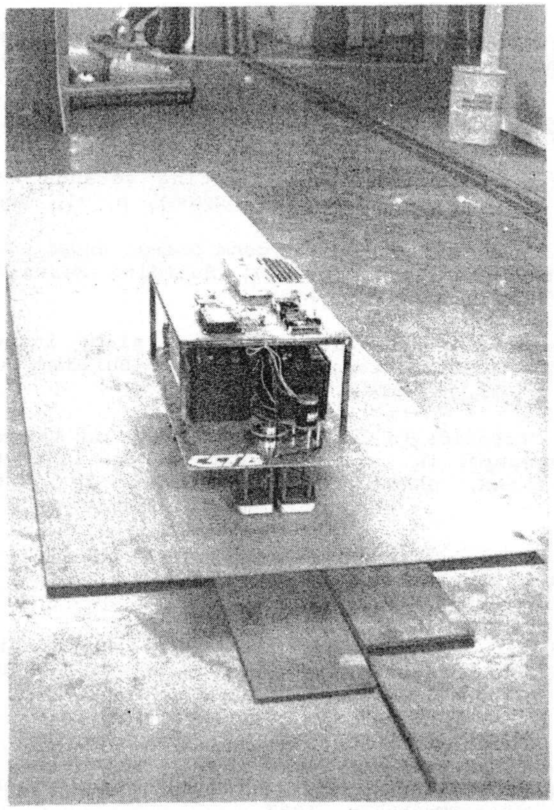


Figure 3 : General view of the experimental cart on the test track

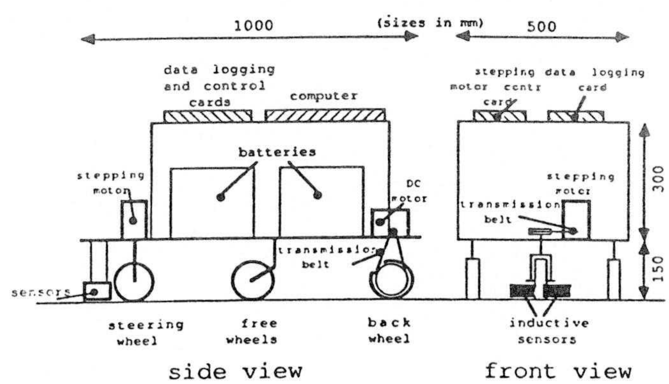


Figure 4 : The experimental cart

Bibliography

[1] MATHONNET (S.), SALAGNAC (J-L.).- Robotique non manufacturière secteur BTP, Compte rendu de mission au Japon, 16-27 mai 1985.- Paris, AFRI, 1985

[2] SALAGNAC (J-L.), SIINO (S.).- "Le projet SOFFITO", Plan Construction Actualités, Paris, février 1988

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

[4] "Development of a robot to place gypsum boards under ceilings", KENCHIKU GIJUTSU (Construction Technologies), Building Research Institute (in japanese), p. 54, december 1987

[5] "Use of a manipulator to place finishing slabs indoor and outdoor", KENCHIKU GIJUTSU (Construction Technologies), Building Research Institute (in japanese), p. 53, december 1987

[6] WANNER (M.C.), "Robotics in Construction : state of the art in the Federal Republic of Germany", in : Colloque CAO et Robotique en Architecture et BTP, CSTB, IIRIAM, GAMSAU, Marseilles, 25-27 june 1986.- Paris, HERMES, 1986

[7] YOSHIDA (T.) and al., "Development of a spray robot for fireproof cover work", in : Workshop on Robotics in Construction, CMU, Pittsburgh, june 1984.- Pittsburgh, CMU, 1984

[8] UENO (T.) and al., "Construction robots for site automatisation", in Colloque CAO et Robotique en Architecture et BTP, CSTB, IIRIAM, GAMSAU, Marseilles, 25-27 june 1986.- Paris, HERMES, 1986

[9] SLOCUM (A.H.) and al., "Construction automation research at the Massachussets Institute of Technology", in : Fourth International Symposium on Robotics and Artificial Intelligence, Technion, Haïfa, 22-25 june 1987.- Haïfa, Technion, 1987