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SOFFITO : A MOBILE ROBOT FOR FINISHING WORKS IN BUILDINGS

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ABSTRACT

Most of future construction robots are likely to be mobile robots. They will also manipulate tools to perform various tasks. The coordination of the mobile robot movements, of the handling of tools and products, of the task control will be executed by informatic systems that will probably be on-board systems.

So as to get a clear idea of some of the problems related to the introduction of such robots on construction sites, the french institutional research center in the building field (CSTB) and roboticians (IIRIAM and AID) have managed together a research project that lead to the experiment of a mobile robot named SOFFITO.

SOFFITO is the first mobile robot for construction operations in Europe. For experimental purposes, the painting of ceilings was the first task performed by SOFFITO.

This project was sponsored by the french Ministry of Research and Ministry of Construction.

0. Introduction

Since the early eighties many experimental construction robots have been designed and tested either under laboratory conditions or under working sites conditions. Most of these robots are japanese and have been presented at various international meetings or when visiting japanese construction companies ([1] to [7]).

Other industrialized countries have proposed research programs in order to evaluate by their own the interest of robotics for construction purposes.

SOFFITO is the most recent product of these research in France. This paper gives a detailed presentation of this robot and a synthesis of the experimental results.

1. The aim of SOFFITO

Considering the robotization of construction points out some characteristics of future construction robots. In particular, they must be able :

- to reach distant working places,
- to manipulate tools and/or products,
- to control the execution of a task,

under working sites conditions.

The first function is nowaday ensured either manually or by man-controlled machines such as cranes or mobile machines (excavators, dozers, ...).

The robotization of some of these traditional machines is now in progress by manufacturers.

Another axis of research is to develop mobile machines that will perform manual tasks (handling, punctual or surface works) either automatically or under human control.

SOFFITO intends to be one of these machines and is designed to perform automatically movements. The autonomy of SOFFITO is limited to the execution of a preplanned trajectory. Attempts to develop an automatic planification module have been made in parallel to the SOFFITO project but have not been tested under final experimental conditions*.

The second function can be achieved either by designing specially a manipulator or by using an industrial robot arm. For SOFFITO, it was choosen to use a UNIMATE PUMA 560 which is a six axis spherical electrical robot arm. Despite of the total weight of this device (arm 56 kg, control unit 160 kg), we have choosen to use a standard equipment. A consequence of this choice is that SOFFITO is not autonomous in energy : it must be connected to the mains.

Due to the geometric characteristics of the robot arm, we have considered working on the ceiling surface. In order not to control both position and efforts of a tool in contact with a surface, we have choosen a spraying tool.

These are the reasons why the first experimental task of SOFFITO is the painting of a ceiling.

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* Refer to the communication of this symposium "Software design of a mobile robot for finishing works in buildings" by G. GALLAIS and al.

As the two basic functions of SOFFITO (mobility and manipulation) are never activated at the same time, the control of the execution of the spraying task is mainly achieved through the control of the location of the robot in the room. The manipulator works in open loop on the environment.

SOFFITO is then the assembly of basic functions that we have tried to ensure by existing modules in order to limit the cost of the project and to get quick answers to the numerous questions that appears when thinking of robotizing construction operations.

2. Description of SOFFITO

Figure 1 presents the different modules of SOFFITO and Figure 2 is a picture of the robot.

2.1 Mobile platform

This platform has two independent back wheels and two loose wheels. It contains the DC motors power control unit, a pair of batteries for movements under wire remote control and the tank of painting. Six compressed air stabilizers are fixed to the platform.

2.2 Ultra-sonic sensors belt

In order to locate the mobile robot in the testing cell, twenty four ultra-sonic telemeters are arranged in belt around the platform. These sensors are controled by a CPU Motorola 68 000 and this system gives twenty four measurements to the supervisor that treats these informations.

2.3 Manipulator

The movements of the manipulator are programmed in order to spray painting on a rectangle (0.9 x 1.6 m^2).Due to the geometry of the robot arm, this surface is divided in six elementary surfaces (see Figure 3).

The stabilizers and the trigger of the spray gun are controlled through the control unit of the manipulator.

2.4 Painting tool

It is a traditional spraying tool. The energy used for the pump is compressed air which is supplied to SOFFITO by a tube connected to a fixed point in the environment.

2.5 Supervisor/navigator

The general architecture of the on-board informatic system is shown on Figure 4. A master/slave architecture has been choosen. The supervision/navigation software is implemented on a CPU Motorola 68010 and two other cards with Motorola CPU 68XXX are used for ultra-sonic sensors (see 2.2) and for wheel motors controls.

This architecture results from the use of ready-to-use control cards for both sensors (ROBOSOFT product) and axis control (THOMSON product).

3. SOFFITO at work

3.1 Path planning

As mentioned previously, the trajectory of SOFFITO in the testing cell is planned manually taking into account a first set of experiments under manual control and the constraints resulting from the energy supply (AC and compressed air).

A typical trajectory is shown on Figure 3. This trajectory is entered in the navigation system as a set of points (coordinates + angle of the platform).

3.2 Execution of a task

The software has been developed in "C" language with a Motorola development system. It comprises different modules that will not be detailed in this paper but that concern in particular :

- the location of the robot (by matching segments obtained from ultra-sonic measurements and the images of the walls),
- the determination of a set of three basic movements (turn, move, turn) to go from the evaluated position to the next planned location,
- the coordination of all the sequences between one working place and the next one (or an intermediate point when the distance between two working places is rather long : S4 and S5 for instance).

An executable software is generated by the development system and loaded in the on-board memory attached to the master CPU.

After initializing some parameters, the task begins. The operator can choose to stay connected to a Macintosh to have informations (text and graphics) about the different operations (location, movements, possible problems) or can decide to disconnect the robot from the environment. The robot is then autonomous from a decision point of view.

The only link with the environment is energy.

4. Teachings and further works

Considered as a research tool, SOFFITO has fulfilled the assigned objectives.

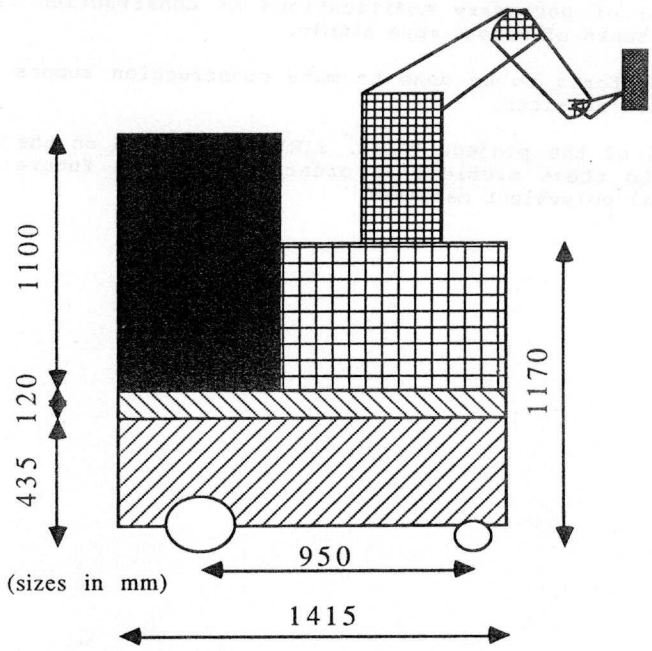
It allowed to :

- test some techniques to ensure basic functions of future construction robots,
- draw out axises of research to study simple solutions suited to nowaday construction techniques,

- start thinking of necessary modifications of construction techniques in order to make tasks of robots more simple,

- evaluate the efforts to be done to make construction robots ready-to-use machines on working sites.

The three partners of the project (CSTB, IIRIAM, AID) are on the way to study suited solutions to these problems in order to make the future construction mobile robots actual polyvalent machines.



width :750 mm ; weight : 425 kg

spraying gun
control unit of the robot arm
robot arm (PUMA 560)
supervisor/navigator control unit
ultra sonic sensors belt
mobile platform

SOFFITO (C.S.T.B. ,I.I.R.I.A.M. ,A.I.D.) :

Figure 1 : Modules of SOFFITO

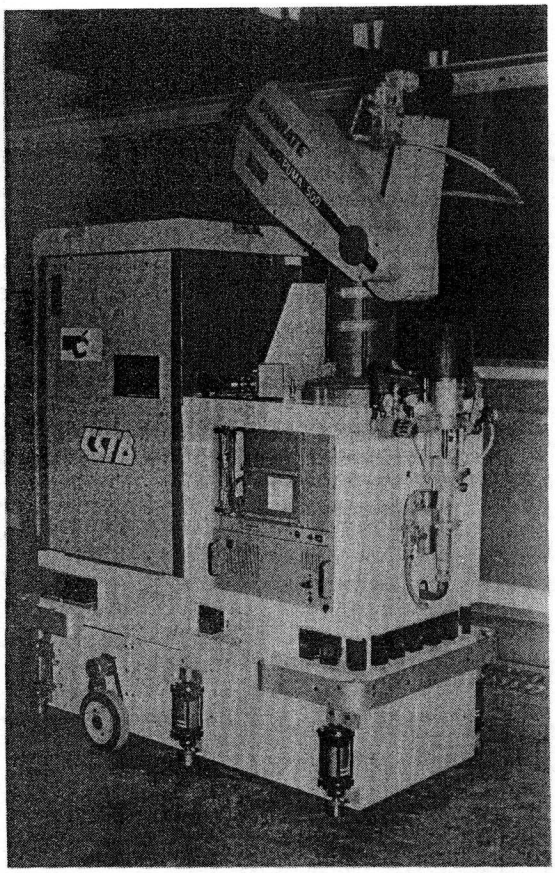
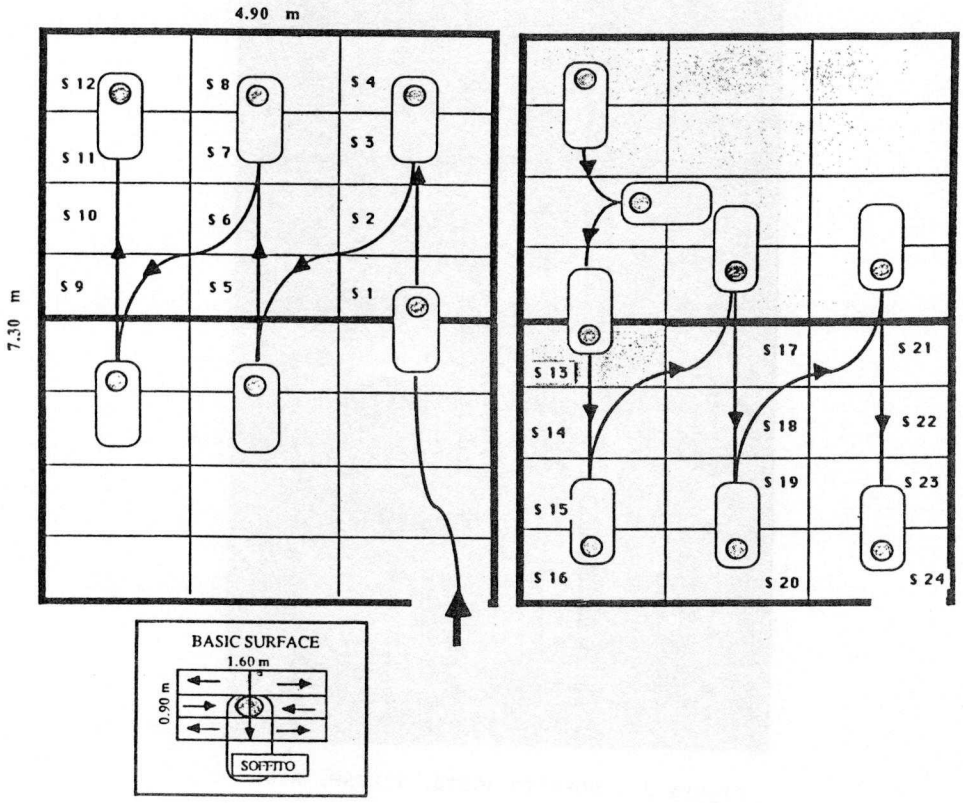


Figure 2 : SOFFITO (CSTB, IIRIAM, AID)



SOFFITO : MOVEMENT OF THE MOBILE ROBOT IN THE TESTING CELL

Figure 3 : Typical trajectory of SOFFITO

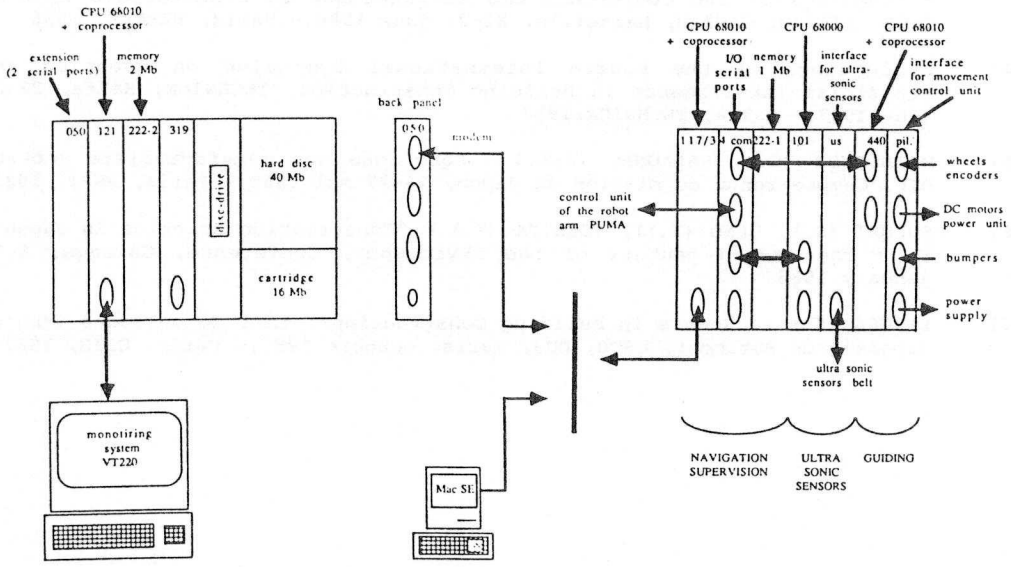


Figure 4 : Informatic system of SOFFITO

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