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Specification of operations for a manipulator on a mobile robot using grafcet

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SUMMARY

This technical note deals with the way of organizing the work of a manipulator on a mobile robot. Every robotic mission is composed of several navigation and manipulation operations. In this research, the robot arm actions have been sequenced, once the mobile robot has stopped, with the help of the graphical specification tool Grafcet. The proposed method has been successfully implemented in the mobile manipulator RAM-2 for transporting videotapes.

KEYWORDS: Mobile robot; GRAFCET; Operations; Specification tools.

I. INTRODUCTION

Mobile manipulators have been introduced in order to extend the manipulation capabilities to large workspaces. Due to the fixed programming language characteristics from onboard robot arms and the complexity of some manipulation operations, it is necessary to employ specification tools in order to make the application easier to build, debug, document and maintain. Some research aims at extending the traditional use of graphical tools, e.g. Grafcet,[1,2] Petri nets[3] or Grafchart,[4] in areas such as control and software engineering. The strong similarity between the process of planning and the process of programming, and also between the concept of plan and the one of algorithms make these techniques well suited for the automation of the design of control programs, simply by using the final plans of action as control program skeletons.[5,6]

In this work, the mobile manipulator RAM-2 (see Figure 1) has the specific mission of transporting video tapes between positions of its environment using fibre optical sensors placed on the gripper (see Figure 2). A procedure has been established that organizes the way to carry out an operation by the manipulator once the vehicle has stopped. Firstly, the operation is divided into different stages and after that, every one is developed using specific algorithms written in the *ACL* language. This way of organizing an operation fits the Grafcet tool.

II. GRAPHICAL SPECIFICATION OF MANIPULATION OPERATIONS

Regarding the Grafcet steps representation, the single square has a single instruction associated with it, while the square with a circle inside means a program stored in the memory of the arm controller. The conditions associated with each transition are the result of the logical operations between:

i) The state of any of the seven optical sensors placed on the servo gripper where the active state is represented by S_i while the inactive state is represented by $\bar{S}_i$. The sensors are connected to the binary inputs of the MK2 controller.
ii) Some logical flags are given as arguments of some operations or as the result of previously executed manipulation operations. Every flag corresponds to the name of a logical variable stored in the memory of the arm controller and some of them are listed in Table I.

Each operation is commanded to the MK2 controller via RS232 by a high level program.[7] This controller returns a numeric code that describes the problems found during execution, if any.

As an example, the Grafcet of the FIND.TAPE(z_m) operation is described next (see Fig. 3), where z_m is the



Fig. 1. The mobile manipulator RAM-2: (a) The 180° laser scanner. (b) The lateral sonars. (c) The robot arm MK-2. (d) Baskets for video tapes. (e) The 360° laser scanner.

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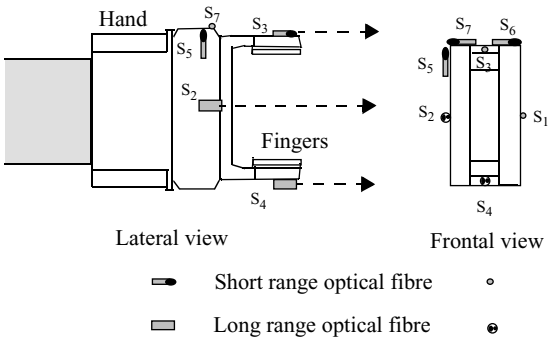


Fig. 2. Proximity detectors on the arm's gripper. Those pointing forward have been placed in pairs to discern distances (S_1-S_2, S_3-S_4). The rest of these sensors are used for collision avoidance (S_5, S_6, S_7).

Table I. The set of flags.

ACTIVE/$\overline{ACTIVE}$	The robot arm is working or not.
HEIGHT/$\overline{HEIGHT}$	The height of the table is in the available range or not.
ANGLE/$\overline{ANGLE}$	The angle of the video-case is known or not.
BASKET/$\overline{BASKET}$	The basket 1 is selected or the basket 2.
VCD/$\overline{VCD}$	The video-case position is known or not.
HPOINT/$\overline{HPOINT}$	The holding point of the video tape is available or not.

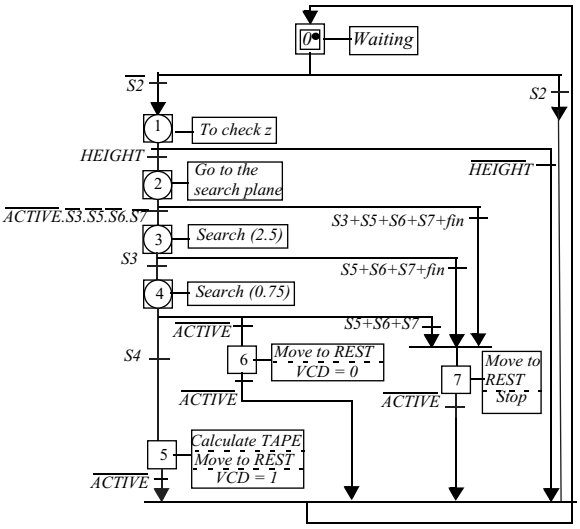


Fig. 3. Grafcet of the *FIND.TAPE* operation.

height of the table where the tape is placed. Nevertheless, the movement of the manipulator must be cautious because this information can be erroneous and should be confirmed through sensorial readings (see Fig. 4). As can be observed in Fig. 5, it is necessary for every height of the table to adjust the x coordinate that the gripper can reach when it moves in the articular space.

A sweeping procedure is carried out in the articular space, firstly by S_3 with a radial increment of 2.5 cm and, secondly, by S_4 with radial increments of 0.75 cm in order to detect more precisely the border of the tape (see Fig. 6).

It is assumed that the video tape never crosses the border of the table and that the gripper is empty.



Fig. 4. Position of the gripper for operations of looking for tables or cases with a pitching angle of -90°. The plane where the gripper has to move is given by the expression: $z = z_m + z_t - z_o + \Delta$ where z_o is the manipulator fix distance regarding the floor, z_t the height of the tape and Δ a security distance.

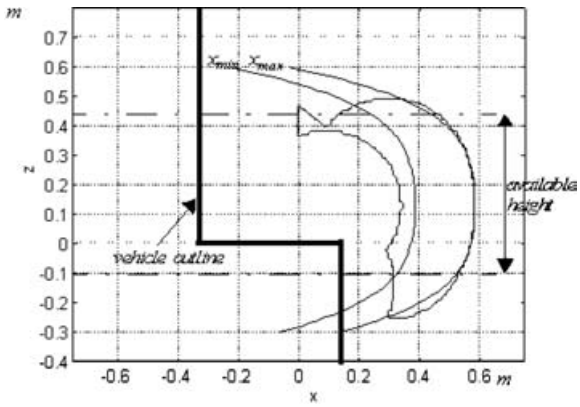


Fig. 5. Available height for a -90° pitch angle; *xmin* and *xmax* curves are approximated by the expressions $xmin \approx xmax - 0.20$, $xmax \approx -1000 \cdot (z - 0.13)^4 - 58.5 \cdot (z - 0.13)^2 + 0.5892$.

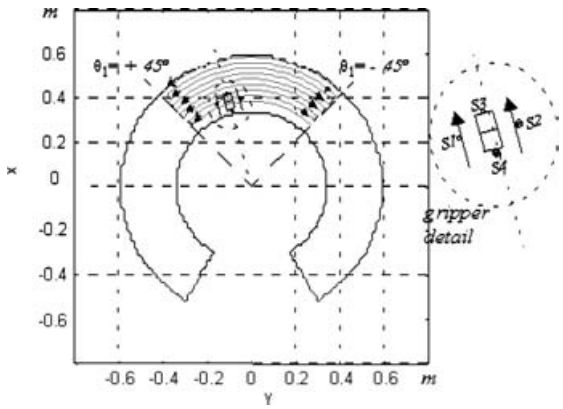


Fig. 6. Sweeping Procedure for searching for tapes.

The results of the experiments carried out with different positions of the video case over the table show a maximum of 56 seconds when the program finishes without detection, and 25 seconds when the tape is found in the first path before any radial increment.

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III. CONCLUSIONS

From the intuitive ideas of dealing with an onboard manipulation operation, the Grafcet tool has been successfully employed to organize each one appropriately. Grafcet is capable of easily integrating the sensorial information with relevant flags in order to sequence logical actions and to take into account possible occurrences and causes of errors.

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