SITE ASSEMBLY IN CONSTRUCTION INDUSTRY BY MEANS OF A LARGE RANGE ADVANCED ROBOT

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ABSTRACT

This paper deals with the application of a large range robot for on site assembly operations in the construction industry. The wall erection task, using standard and special concrete blocks, is the main operation of the robot. The assembly process and the robot have been developed under the Computer Integrated Construction (CIC) concept. It means that the robot is easily integrated in the complete CIC system by adequated interfaces. Special attention has been paid to the man-machine interface (MMI) which permits to program and control the system in an automatic and friendly way, i.e., from the CAD building design the system commands and sequences are automatically generated. The hydraulically driven robot is a 6 DOF articulated manipulator with a working range of 8.5 m and it is able to carry payloads up to 500 kg. This work is part of the European ESPRIT III project nº 6450 ROCCO (Robot Assembly System for Computer Integrated Construction).

1. INTRODUCTION

Construction industry assembly automation demands completely integrated systems under CIC concept. In this systems the robots are considered key technologies. However, conventional available robots are able to carry only low payloads and they have short working range. The CIC systems required large range intelligent robots able to handle high loads. Several automatized cranes and mobile robots with different configurations have

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been developed during the last years.These systems can not be considered as real robots and it results very difficult to transport them [1]. An articulated robot placed over a mobile platform (a lorry, a towable platform or an autonomous mobile robot) results very appropriate for the assembly tasks on a construction site. The main obstacle for the good integration of the robot on the site is the nonadequation of the whole construction process to the automatization requirements under the CIC concept.

This papers presents some results obtained during the development of the ROCCO project. The main objective of the project is the automatization of the construction process which includes the following steps (Fig. 1):

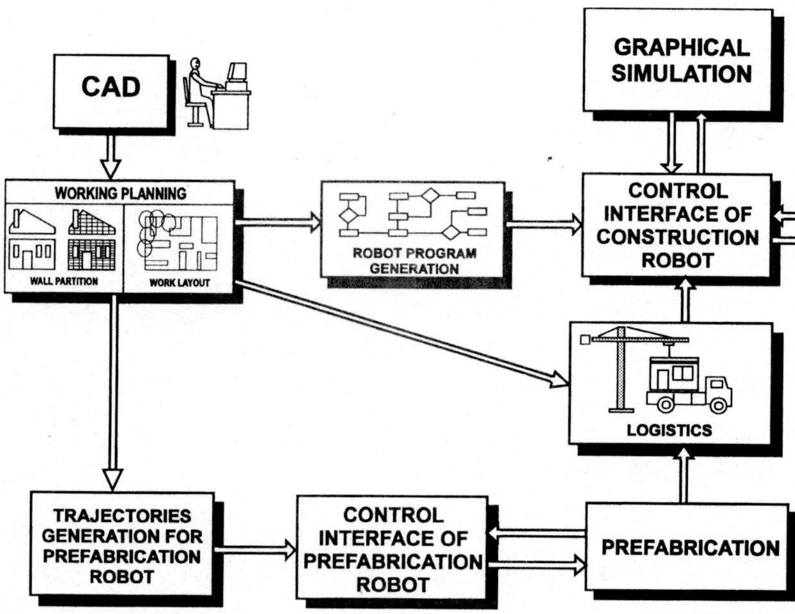

Fig. 1. ROCCO CIC concept.

1) Assisted drawing of the complete building using a conventional CAD system with specially developed tools and interfaces.

2) Working planning development which includes the facade partitioning in the elementary parts to be used through the expert knowledge rules, and on site work lay-out planning.

3) Generation of the manufacturing commands for the prefabrication of the elementary parts, like blocks, panels, etc. This commands include the control of the manufacturing robots and equipments [2], [3].

4) Development of the logistics of the on-site resources supply (parts, material, machines, operators, etc.). The elementary parts (prefabricated and precut blocks) are optimally situated in the on site pallets in order to improve the construction process. In the same way the optimal position and orientation of pallets, robot and other machines on the floor, are calculated [4].

5) Robot programs generation which includes an off-line program for planning of complex assembly tasks and for generating robot actions. The wall assembly system is organized on the base of the successive generation of the different type of actions [5].

6) Development of the robotized on-site assembly. The robot system is supervised by means of a friendly MMI which permits the graphical simulation of the robot tasks before the real execution. For this simulation the TOROS (Toolbox for Robot Simulation) developed at DISAM is used [6].

2. ROBOT DESCRIPTION

The main objective of the ROCCO robot system is to assembly blocks (maximum dimensions of 100 cm x 50 cm x 50 cm) in industrial buildings with typical height of up to 8 m and standardized layout. The robot (Fig. 2) has a working range of 8.5 m and it is able to carry payloads up to 500 kg. This working range allows the robotized masonry in the 90% of the industrial buildings. The cycle time has been calculated between 30 and 45 sec. for the smaller blocks (less than 100 kg) and between 100 and 150 sec. for the bigger ones (up to 300 kg).

The robot has 6 DOF (all of them rotational joints) driven by hydraulic motors and hydraulic cylinders, and the oil flow is controlled by means of servo valves. The robot repetitivity is about ±5 cm. Nevertheless, this accuracy is not enough for the required block assembly. This is way the required final position accuracy (±2 mm) is achieved by means of a compliance device installed on the special developed gripper [7]. The robot is designed to be fixed on a lorry or a mobile platform. This permits the mobility of the robot on the construction site.

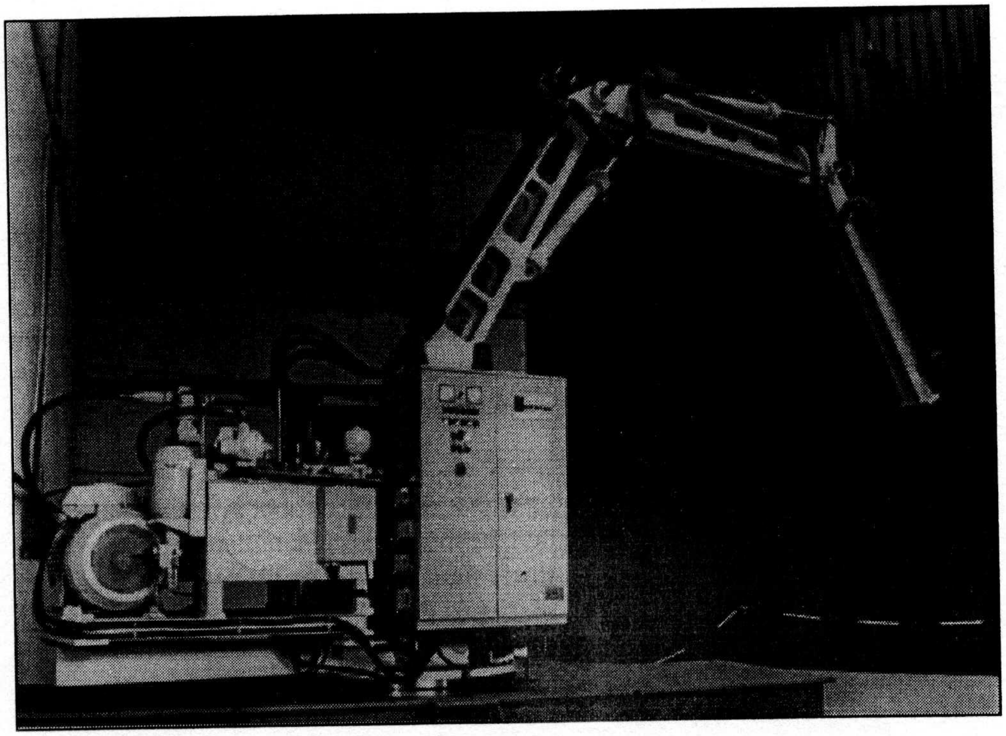

Fig. 2. ROCCO robot view.

For the vertical block assembly only 5 DOF are necessary. However, the ROCCO robot kinematics has been developed with 6 DOF which increase its movement capability. It also allows good robot positioning in order to transport it inside the dimensional limits of the transportation by road.

The first robot axis (the interface between the manipulator and the base) is a gear slewing track ring driven by a radial piston hydraulic motor coupled to a speed reductor. It has been designed in order to support higher speed to make the robot able to move fast while keeping fixed the other joints (typical robot movement between the pallet and the wall).

The second, third and fourth axis are driven by the differential hydraulic cylinders. Axis four has dragshovel kinematic in order to avoid free work space losses and good position in transportation. The two last axis are accomplished by directly driving planetary-type motors, that guarantee high positioning accuracy and sufficient torque with small dimensions.

The main idea in the robot kinematic design has been to get the maximum work space for wall assembly, avoiding waste of time due to vehicle movement during its operation. Fig. 3 shows the reachable wall segments at different distances from the first robot axis to the wall. As an example it has been chosen a typical 5 m. wall height (dashed zone). The number of blocks (80 cm x 50 cm x 40 cm) that the robot is able to place is indicated in the figure. In this example the distance of 2-3 m is the best robot position.

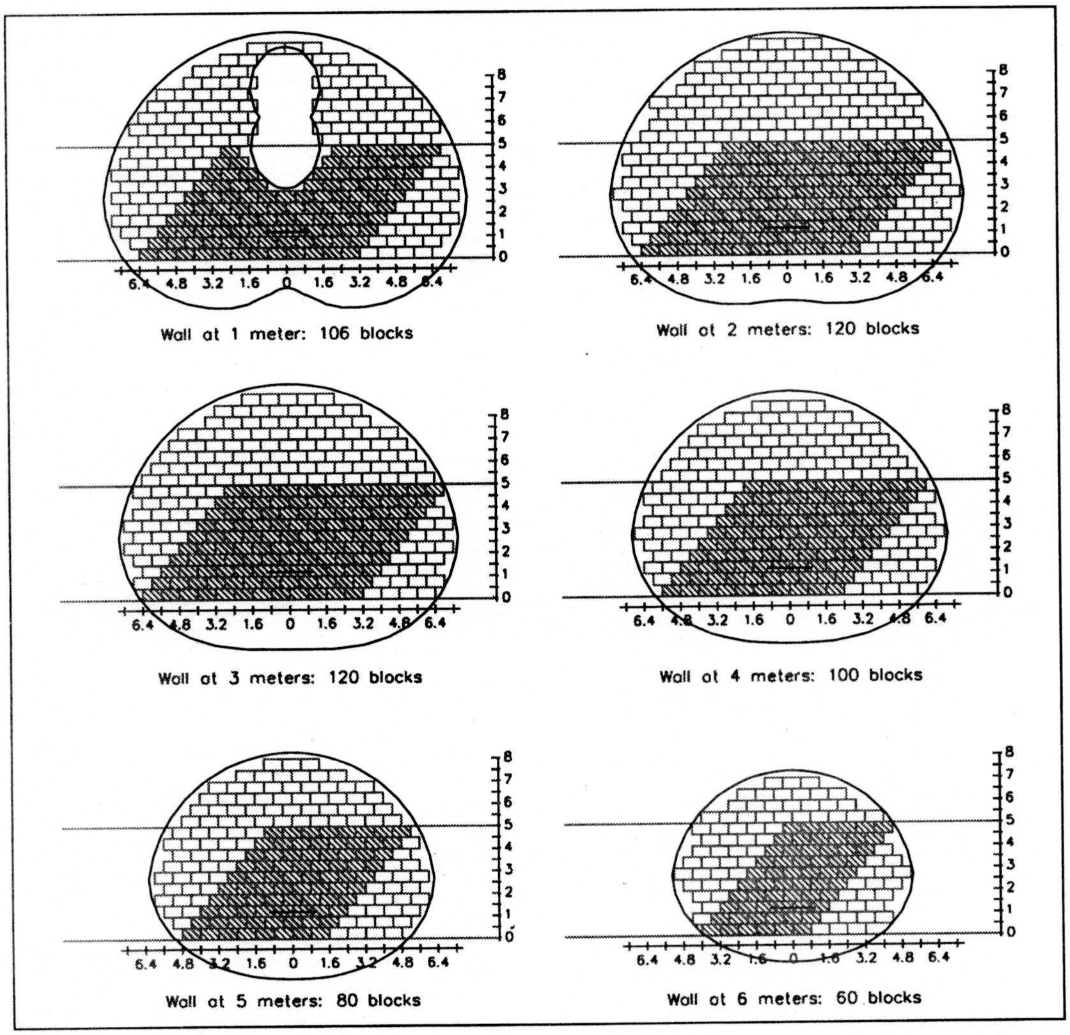

Fig. 3. Reachable wall segments.

3. CONTROL SYSTEM

The control strategy of large range hydraulical driven robots is one of the central point of nowadays robotics research [8],[9]. The high non-linealities of the system (specially of the actuators) and the mechanical flexibility of the robot links and joints leads to sophisticated control strategies. For the ROCCO control system a powerful hierarchical architecture has been selected (Fig. 4). It is formed by two levels:

0) It is based on a programmable motion multiaxis controller board and the servo valves electronics.

1) The workstation (as a host) that allows to control, to supervise and to monitor the complete system by means of a friendly graphical user interface. An external position sensor and the off-line programming systems which generates the robot tasks are also in this level.

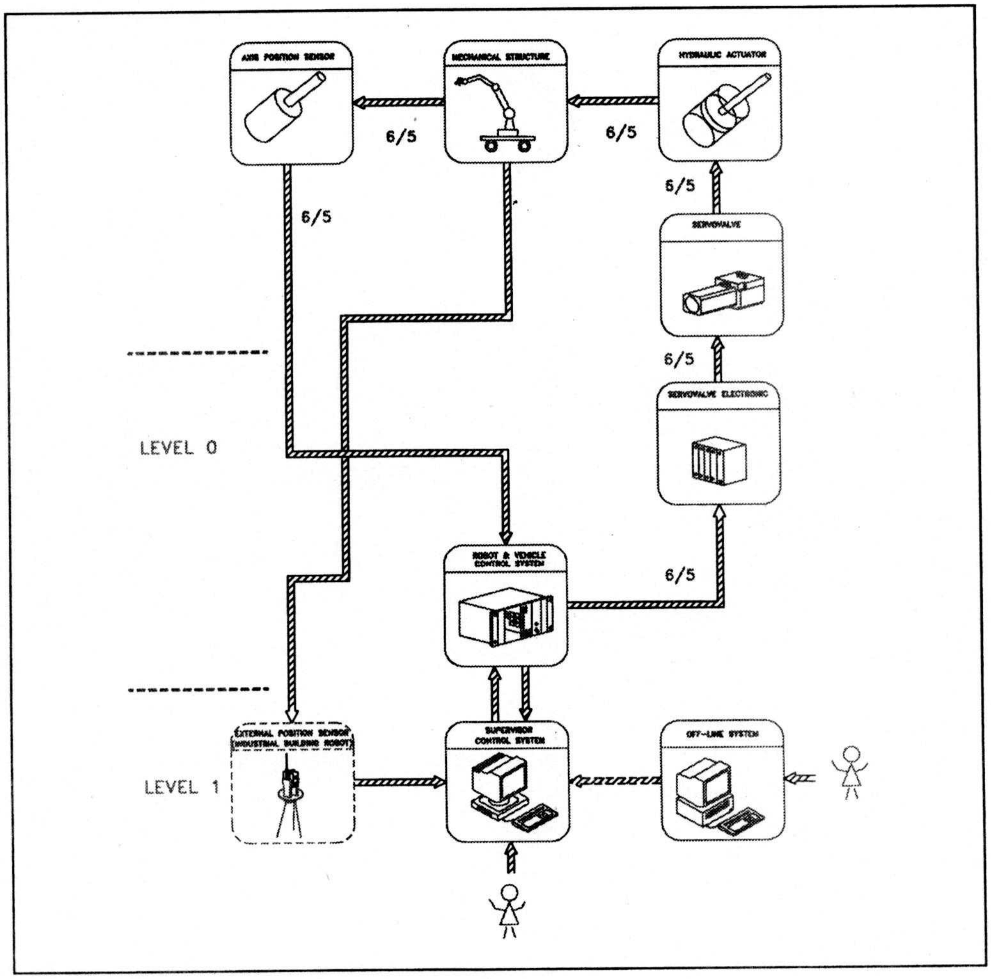

Fig. 4. Architecture of the control system

A supervised control strategy has been selected to cope with the high non-linearities and poor damping characteristics of the mechanical and hydraulical system while a specific system has been developed to compensate the static deviations of the structure. For this purpose an external sensor is used.This sensor is a laser-based telemeter with autotracking capability which supplies in real-time data about the actual position of the robot TCP. This measure is compared with the expected TCP position. From this position error the control system generates correction trajectories for the robot. The external sensor is also used for the calibration procedures: the robot position with respect to the wall and pallet are measured to calibrate the systems.

The user interface (MMI) allows the communication with the user by means of a window based system. It also allows to introduce commands and to control the system. Due the fact that the robot is programmed in RRL (ROCCO Robot Language), the MMI permits to simulate the RRL programs in the TOROS simulator and to debug theese programs. The direct manual control of the robot using a joystick mode is possible. This mode includes several security levels in order to protect the robot and the environment. Fig. 5 shows several windows of the MMI: main, robot pendant, program execution and robot status.

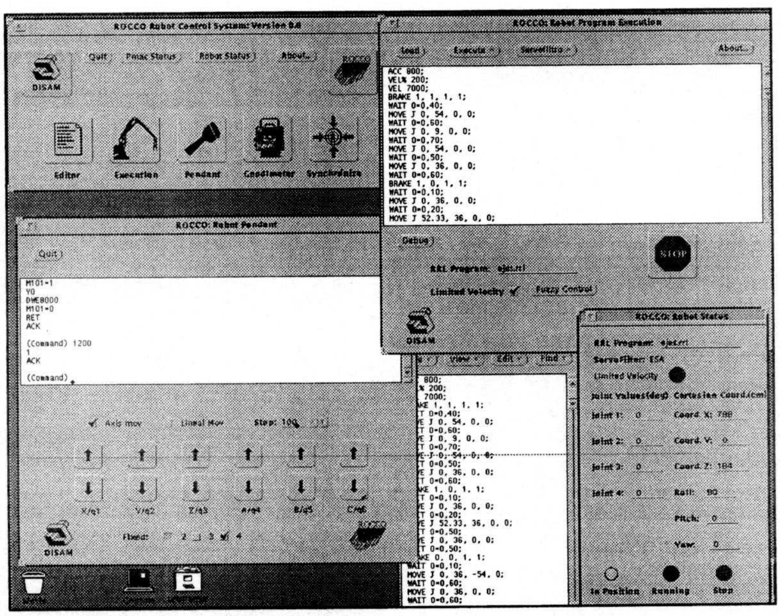

Fig.5. Man-machine interface

4. CONCLUSIONS

The development of the large range robot for the on site assembly of blocks for construction industry is presented in this paper. The CIC concept developed under the

ROCCO project and its implementation are briefly discussed. The main ideas of the kinematic design of the robot, its control system architecture, specially for the hydraulic-based actuators, and man-machine interface are also presented. The common interfaces permit the complete integration of the robot in the total CIC system. In the present moment the first on site experiments is being prepared to check and validate the robots ability to erect the block-based walls.

5. ACKNOWLEGMENTS

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