Wireless Robust Robots for Application in Hostile Agricultural Environment

A.R. Hirakawa, A.M. Saraiva, C.E. Cugnasca
Agricultural Automation Laboratory, Computer Engineering Department
Polytechnic School, University of São Paulo
São Paulo - Brazil.

Abstract: -Robots for use in agriculture have been proposed for a number of operations, ranging from static applications under controlled environment to more challenging uses such as in field operations. Nonetheless the robots used in such applications are strictly industrial equipment which are not designed for hostile outdoor operations. As result, several problems often occur, such as system malfunction due to broken wires, difficulties in system placement and movement, poor adaptation and frequent maintenance.
This paper proposes a new wireless robust robot architecture, where all wires and cables in the robot joints are eliminated and a distributed control system is designed to allow the independent remote operation of the robot links. The functional independence of each link allows easy re-configuration of the robot to a specific application and increases the operation robustness of the system. The system proposed in this paper could be applied in most manipulator type robots due to its independence of operation, or application and low power consumption, making the new robot system better adapted to field application and robust for the hostile environment. *IMACS/IEEE CSCC'99 Proceedings,* Pages:4511-4515

Key-Words: - Robot System, Wireless Transmission, Distributed Control, Field Application, Robustness

1 Introduction

In some agricultural systems, robots have been used for operation in static applications under controlled environment, such as milking, shearing, harvesting, sorting, grading, micropropagation, and in some field operations. In the latter case, literature offers a fair number of robotic systems developed for performing operations such as harvesting fruits and vegetables (oranges, tomatoes, melons), pruning, etc. Some others have been mentioned which represent opportunities to be better explored including weed detection and control, and agrochemical application.
There seems to be no doubt that robots can play an important role in agriculture, whether in field operations or under controlled environment. By their very nature and the accuracy they are supposed to deal with, they will be very much suitable if the requirements of application and use would be solved.
Until now, however, a major problem is that presented by the hostile agricultural environment, specially in the field, and the relative fragility of the robots.
Nonetheless, the robot used in such application is strictly industrial equipment, which is not designed for outdoor operation. The industrial robot system usually has an electronic controller and a set of control and power wires, which makes the system very fragile for such application. Several problems often result from that structure, such as system malfunction due to broken wires, difficulties in system placement and movement, poor adaptation and frequent maintenance.
In this paper, a new wireless robust robot is proposed which tends to minimise the problems above mentioned. In the proposed system, all wires and cables in the robot are eliminated and a distributed control system is designed to allow the independent remote operation of each robot link. The functional independence of each link allows easy re-configuration of the robot to a specific application and increases the operation robustness of the system.
The original wireless power transmission was proposed by [1]. The wireless system was applied to transfer the power and information between rotational joints of an industrial machine in [2]. Kawamura [5] proposed a wireless system to transfer the power and information in the same physical channel of the robot manipulator.
The wireless robust system proposed in this paper was designed specially to accomplish the

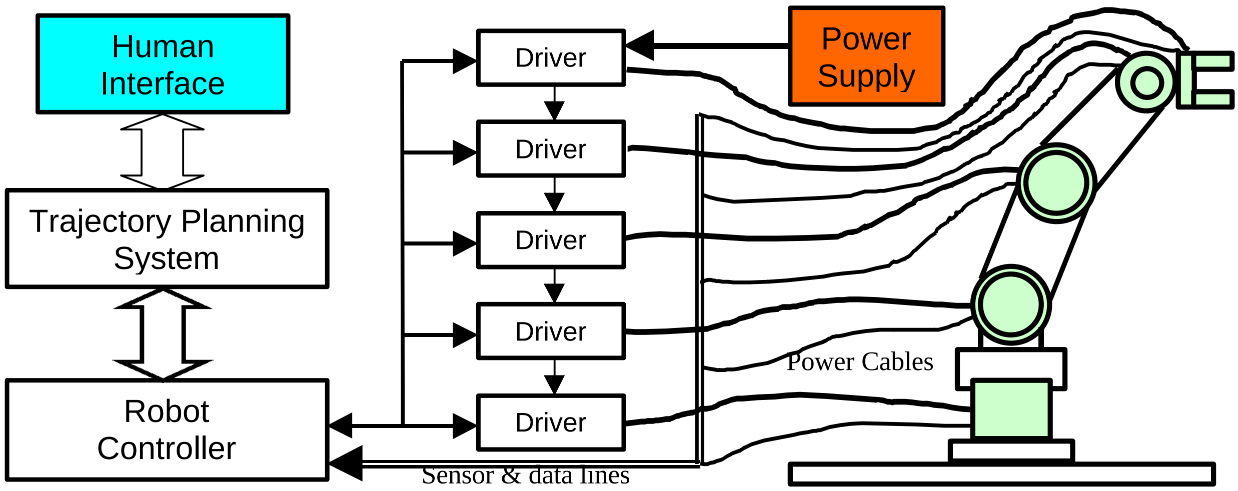


Fig. 1 - Present Robot System (Showing the many cables for power and information)

agricultural task performed in hostile field environment. The limitation of information transfer rate of Kawamura [5] was eliminated using 2 separate channels for transmission. The control structure, composed by a main system and the distributed control system, allow re-configuration of tasks in case any link could not be achieved. Thus, an overall robust robot system for hostile environment is obtained.

2 Present robot system

Robots used in any field of application, even in industrial, military, spatial or agricultural applications are driven by electrical motor or by pneumatic actuators. In all cases, it is necessary to supply power to each actuator and take the information from sensors attached to links and end-effector of the robot. Thus, many cables and wires are required to provide that communication with the robot manipulator. Fig. 1 shows the typical robot system with its electrical and mechanical parts.

As a problem, these wires limit the movability of robot arm in order to avoid the risk of breaking wires. Usually, a joint cannot rotate more than 360^o due to the wire limits. Also, connection of the electrical contact points reduces the reliability of the system because robot manipulators repeat the motion and subsequently the contact points move back and forth.

Another problem is the reduced adaptability of the present robot system. Any change in the robot configuration implies a complete new system design. At last, using a centralised control system, any fail in one of the robot links will disable the system operation.

To avoid these problems, a new wireless robot system is proposed. The overall system is described

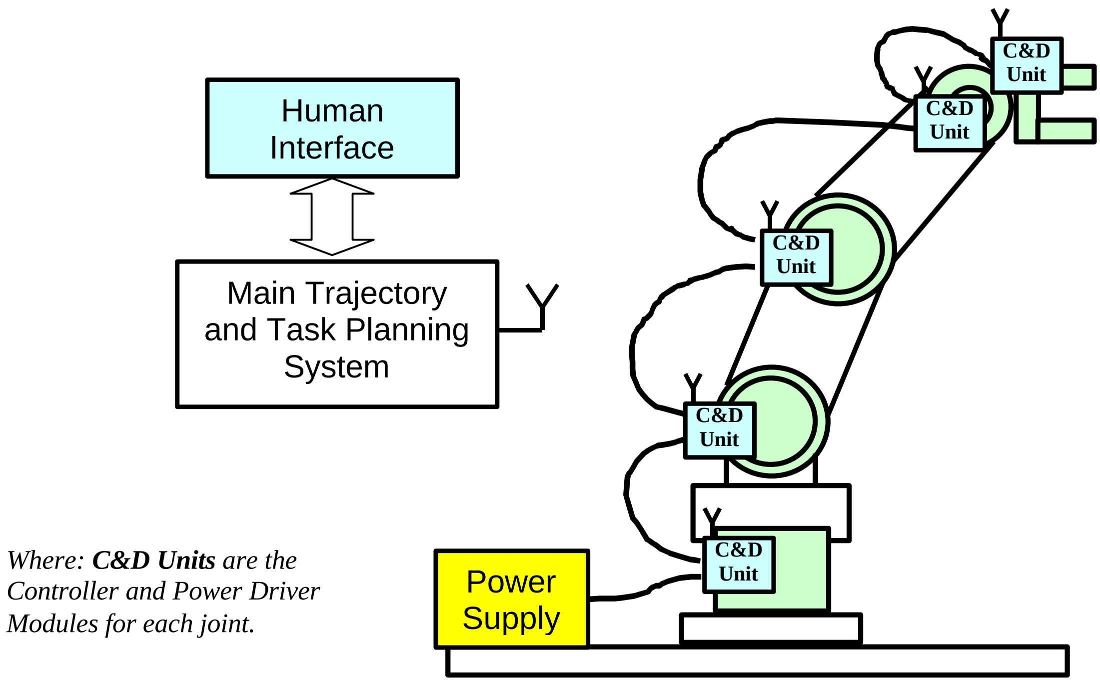


Fig. 2 - Proposed Distributed control Robot System

in the following chapters.

3 Proposed Robot System

3.1 Distributed control system

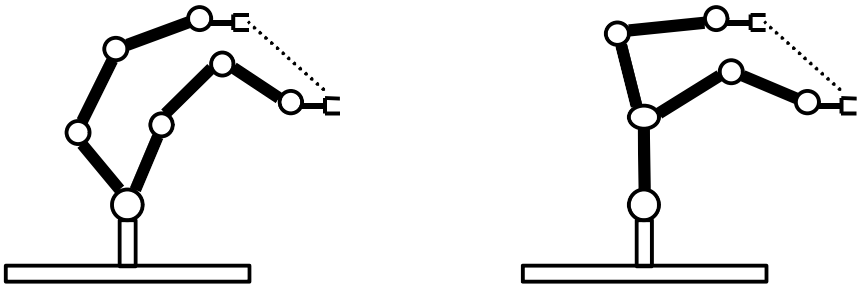
As mentioned previously, one problem of the present robot system was due to the centralised control system. In this chapter, a distributed control system for robot manipulator is proposed. Fig. 2 shows the block diagram of the proposed robot system.

For interfacing the robot system with the human operator or to any other high-level task planning system, the distributed system has a master task distributor. In this sub-system, the overall task for the robot manipulator is optimally distributed for each one of the local link controllers. The status and availability of each local link controller is verified to define the optimal distribution way.

commercial robot manipulator is usual, because it gives more flexibility in the movements and avoids obstacles through the task path of the robot manipulator. Then, robots with six or more links for working in three-degree workspace are usual commercially.

For these robots, as there is redundancy in the number of links, if one or more links (up to number of redundancy) are not available or cannot be achieved, the task assigned for those links could be redistributed to the other achieved links [4]. Thus, in spite of problem in some links, the overall robot system can accomplish its job. Fig. 3 shows the task re-distribution effect in the robot manipulator.

But another problem in the present robot system, the presence of wires and cables, remains. To solve this problem, a wireless information and power transmission system for robot manipulator is proposed.



a) Usual robot movement. **b) The same movement with joint 0 fixed.**

Fig. 3 - Task re-distribution in Redundant Robot

Each link controller receives its own task reference by radio-frequency transmission and, according to its control programming, accomplishes the given task. The control parameter of each local controller could be initialised before the movements or changed during the task by a sequence of commands from the main controller. It can also check the status of each joint for its availability during the task in real time by requesting information to each local controller by a radio-frequency link.

The advantages of this system are its adaptability and robustness. Change in robot configuration or its job could be done by changing only the high-level task planner and without any change in the local link controllers. Thus, the same robot can be used for several tasks by changing only the main task program, which is less expensive than changing the robot hardware.

The robustness in the distributed control system is reached if there is redundancy in degree of freedom (DOF) in the robot manipulator. The redundancy in

3.2 Wireless transmission system

The main problem regarding wires in the robot manipulator is the joint movement between links that may cut the wires and also, limit the joint movement. Wires in the links do not take matter as shown in Fig. 4. Therefore, to avoid system malfunction by communication failure and to eliminate the joint movement limit, a non-contact wireless transmission system is implemented between robot links.

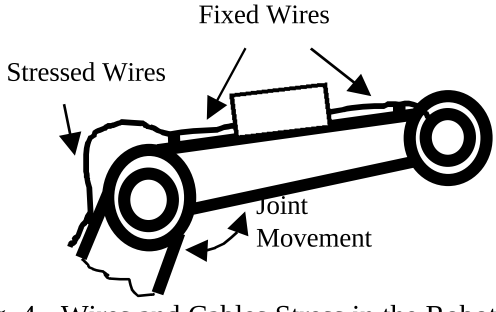


Fig. 4 - Wires and Cables Stress in the Robot

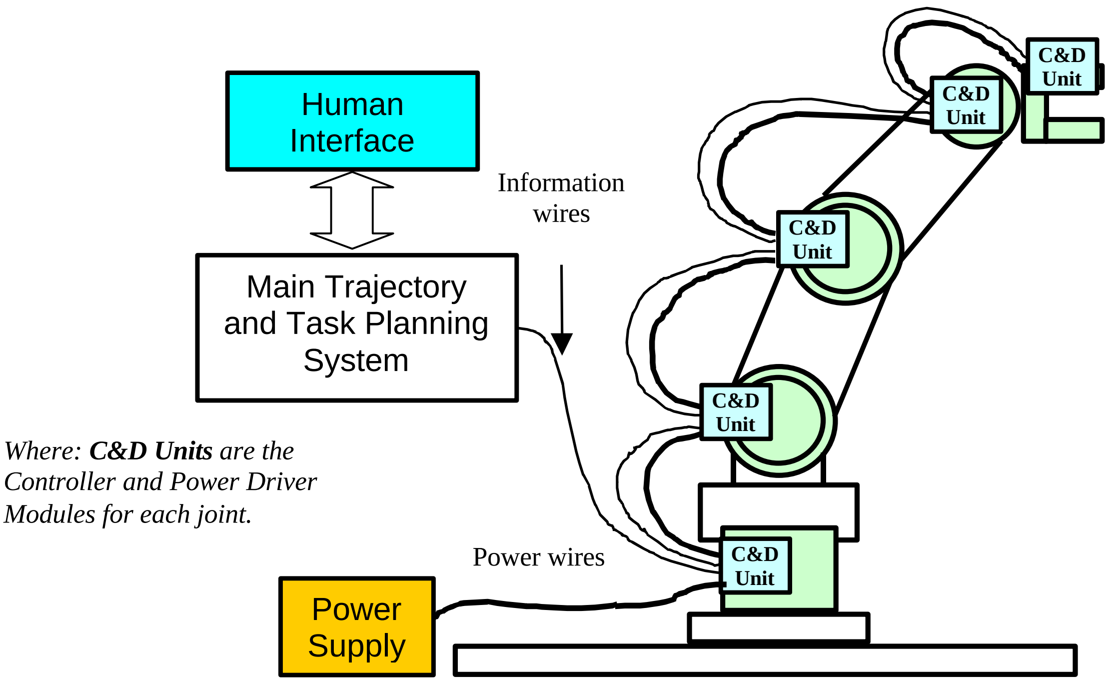


Fig. 5 - Proposed Robot System

Obviously it is necessary to transfer the power energy to the robot motors drivers, which would require a pair of cables. In the proposed system this is done by designing a wire decoupling among links, using axial transformers which allow complete disconnection of the robot links and the elimination of wire breaking at robot joints.

Kawamura [5] proposed a wireless transmission using the same physical way, but there was a problem in the maximum information transfer rate. In this paper, a separate and independent way is used for transferring power and information among robot links. The overall wireless robot system is shown in Fig. 5.

The separate axial transformer (TR) used for power and information transmission is shown in detail in Fig. 6. The transformer was designed with ferrite core for high-frequency operation, small dimension, and with high efficiency in the power transference.

3.3 Experimental wireless robust system

To conduct analysis of and study the proposed system, an experimental implementation was done using YASKAWA Motion Link distributed control system and a specially designed axial transformer coupled to an experimental robot. A personal computer (PC) is used as main task controller and to distribute the tasks for each local controller. The control program was written in C language and could be linked to other path planning systems or receive task directives from other machines. Fig. 7 shows the block diagram of the experimental robot controller.

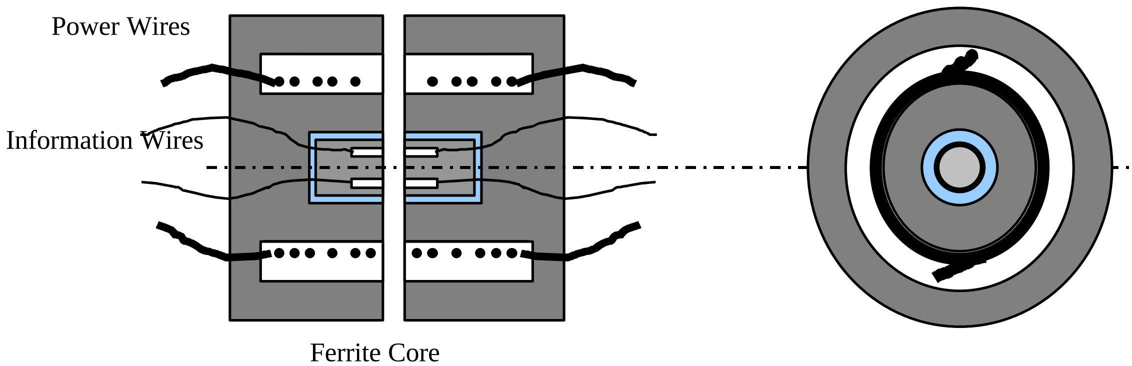


Fig. 6 - Detail of the Isolated Axial Transformer (TR)

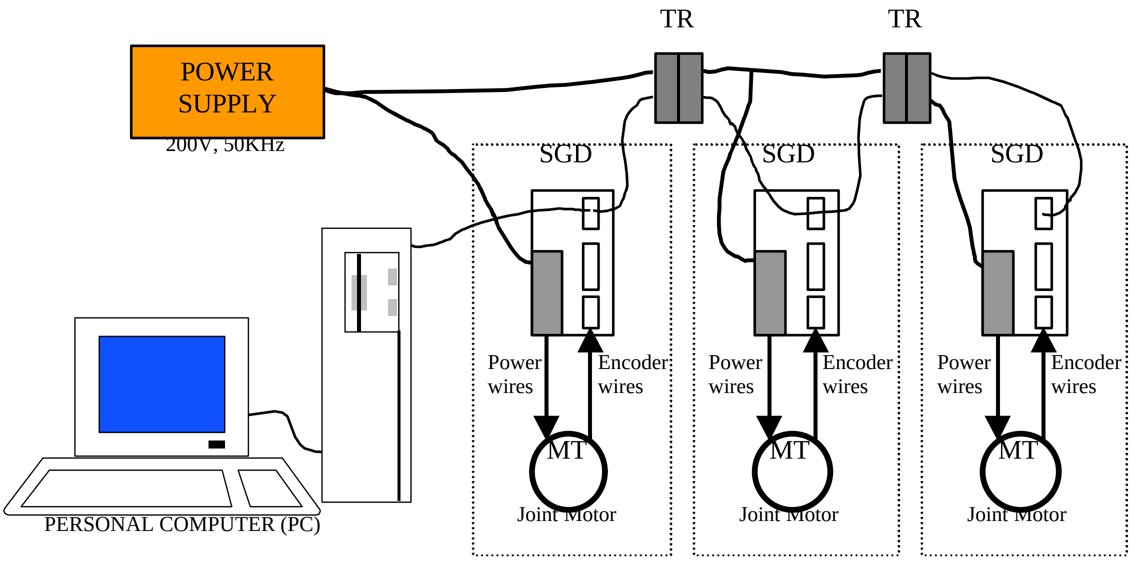


Fig. 7 - Experimental Robot Controller System.

Each local controller was composed by an SGD-02ANP controller (PID controller for AC inductive motors with encoder input, power module and network interfaces - YASKAWA). Control parameters of each local controller can be set or changed by a command from a PC running a parameter setting program.
Each and every sub-system is connected to its own network designed to allow 4Mbps of data transfer rate and uses the poling method to avoid control timing uncertainty. Each joint of the robot manipulator is driven by an AC inductive motor. At present, the control system is being checked in task distribution to guarantee the proposed robustness and the wireless system is being submitted to field tests in hostile conditions.

4 Conclusions

A new wireless robust manipulator type robot was proposed. The distributed control system and the wireless transmission system can be applied in most manipulator type robots due to their independence of operation, application, system dimension and power consumption.
The new robot system is better adapted to field application and hence shows a good potential to agriculture in general. A prototype system is being tested and upon approval on these tests, a specific application to agriculture will be conducted.

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