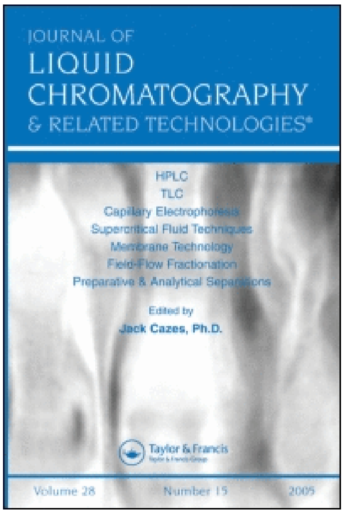

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Laboratory Robots: Partners in Productivity

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LABORATORY ROBOTS: PARTNERS IN PRODUCTIVITY

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The widening acceptance of the robot in industrial and clinical laboratories leads to the expectation that the robot will soon be viewed as a standard item in the laboratory environment. To become such a generally accepted product, the robot manufacturer must provide a system which will suit the needs of a wide variety of users, and the specific application of the device may not always be well defined. In addition, the robot must be designed such that almost anyone can use it with a minimum of training and with which they can become familiar and comfortable. I would like to describe the characteristics of a robotic system which has these attributes and which will augment the laboratory staff and provide great gains in operational productivity.

In the laboratory, the robot of choice should be relatively straightforward in its design and operation. For the largest proportion of laboratory tasks, complete replication of human capabilities is not appropriate. Pattern recognition, vision, etc. are capabilities which are not generally required, although reference (1) speculates on some clever means of adding sensory capabilities in future designs. What is required, however, is a motion

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flexibility which makes it possible to orient the end effector or tool in almost any direction. Figure 1 shows such a robot, the Fisher MAXX-5. Table 1 provides specifications for the robot.

Figure 1. The MAXX-5 Robot

The robot is capable of 5-axis motion, including base-unit, shoulder, elbow, wrist-roll, and wrist-pitch rotations. Gripper operations are in addition to the rotational capabilities. This wide motion range provides the capability to interface with a large variety of existing accessories necessary to the assembly of a total robotic system. For example, the extraction of a centrifuge tube from a 45-degree angle rotor requires a rather complex coordinated move by the robot, which the multi-axis arm performs readily. The design of the robot has

TABLE 1

MAXX-5 PERFORMANCE SPECIFICATIONS

System Description	Five axis robotics arm w/cable operated mechanical gripper, and power supply/control interface
Power Requirements	115 VAC @ 1.5A; 220 VAC @ .75A; 110 VAC @ 1.7A; 47-400 Hz.
Operating Environment	Ambient temperature limit 32°F - 104°F (0°C-40°C).
Payload	3.0 lbs. (1.326 Kg)
Reach	18.4 inches (467 mm)
Speed	0-51 ips (0-1295 mm/sec) max. selectable, with acceleration and decelaration
Resolution	.010 inch (.25 mm) each axis
Repeatability	±.015 inch (.38 mm)
Operating Envelope	Base 345°, Shoulder 145°, Elbow 135°, Wrist Roll 540° Wrist Pitch 180°
Gripper	Force programmable 0 to 8 lbs. Maximum jaw opening 3 inches (76.2 mm). Optional grippers available
Accessories	Linear slide; Lab.appliances; Analytical instruments

thus preserved the most important facets of human motion, without encumbering it with unnecessary complexity.

The design of the robot arm will also be a determining factor in the speed of performance of the robotic system. If the arm can be structurally strong and, at the same time, light weight, the inertia can be minimized and the operating speed increased without excessive drive power required. The MAXX-5 robot achieves this design rationalization through use of a refined system of aircraft-type cable drives for each rotation joint, which relieves the need for a drive motor at the joint. The arm structure can thus be significantly lighter, without sacrificing essential strength and lifting capacity. It should be noted that the MAXX-5 robot can be varied in speed over a wide range in any part of a task sequence.

For a laboratory robot, localizing accuracy is an important characteristic, especially if operations with critical tolerances must be performed. Positioning a syringe needle consistently in a small septum demands a high level of repeatability. MAXX-5 achieves a repeatability within .015 inch, which will satisfy demanding requirements.

For a robot to be fully productive and complement the activities of the operator, it must be capable of effectively utilizing the envelope of space assigned to a particular task. Effective utilization of space an be readily achieved, if the robot can move its inherent spherical or cylindrical envelope by linear translation. Additionally, if the robot has the capability of working from above, a higher density of accessories can be accommodated on the standard workbench. Figure 2 illustrates the use of the MAXX-5 robot in an inverted mode, with the base able to move linearly on a translation slide for a distance of four feet.

Figure 2. MAXX-5 Robot on slide in inverted mode.

As shown, the majority of the workbench area is utilized by typical accessory stations, including pH electrode and washer, the pH meter, a bar code reader, a balance, a hot plate, a vortexer, a solids dispenser, a two-place liquids dispenser and a 28-place beaker tray. All of these devices can be positioned on a standard 3' by 7' laboratory bench top. In the clinical and industrial laboratory environments, where the conservation of space is also critical, the ability of the robot to adapt spatially is a vital characteristic.

The ready acceptance of the robot as a partner for laboratory personnel will depend on, more than any other aspect, the ease with which the robot can be programmed and the total robotic system configured by the operator. Routine setup of the system, its operation and the accumulation of experimental data is the initial concern of the potential user. As the laboratory requirements change, reconfiguration of the system, reprogramming of the robot and control of new accessories will become important. All of these activities dictate a control system architecture which can be easily understood and operated. The control system design philosophy of the MAXX-5 robot employes the flexibility of the personal computer as the overall robotic system controller. The MAXX-5 robot arm is controlled by a dedicated microprocessor-based unit under the direction of the PC. with this philosophy, the system can be structured as shown in Figure 3.

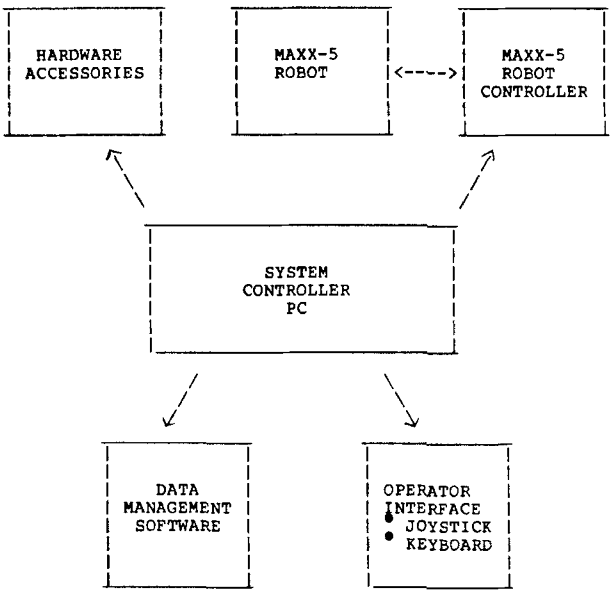

Figure 3. Robot system architecture.

This configuration allows the PC to be an extremely effective executive for the operation of the total system. Not only can it conduct routine sample preparation and analytical tasks, manage the data base and generate reports, but it can also make judgements as to how well the tasks are proceeding, based on the data being generated. A good discussion of the effectiveness of an integrated analysis system of this type for HPLC is presented in reference (2).

With MAXX-5 the operator is able to interact with the robot system at various levels, depending on his or her needs and skill level. For example, if the system is constant in configuration and only the experimental or analytical parameters are to be varied, then the interaction is totally menu driven and essentially a "fill-in-the-blanks" mode. However, if the system is to have new accessories added or other major changes made, then the robot and the total system must be reprogrammed. The operator will again interact through a menu driven mode, but it is much more comprehensive. This requires either the use of a "joy-stick" controller or the entry of exact spatial coordinates defining start and end travel points at the PC keyboard to train the robot in its new movement pattern. For the very highly skilled user, the motion algorithms can be utilized to develop any specialized motion patterns which might be desired. The tiered structure of the control software gives the MAXX-5 system-user the maximum flexibility to define the system and reconfigure it as needed.

The data management capabilities of the robotic system must also be easily understood and used by the operator. In order to take the greatest advantage of the large body of data management software available, the robot system controller should be programmed to communicate analytical data to standard management software. The operator should have the option of either manipulating the data and generating reports on the system control PC or collecting data and saving it for later manipulation on the control PC or some other computer. Because MAXX-5 robotic systems can be controlled by the IBM PC or XT, many data management software systems exist which can interface directly with the analytical results, making it an operator choice of the preferred scheme. In order for potential users to view the robot with the same level of confidence as an appliance, the reliability of the system must be excellent and the failure modes must be benign. The design of the robot and all of the accessories will establish the system reliability. It is, therefore, generally out of the hands of the operator. It does, however, have a good deal of influence on the nature of the failure modes, principally by determining what action the system should take, if operating parameters go out of set limits. In the case of the MAXX-5 robot, the system designer is aided by the fact that the robot is able to detect whether or not it has gripped an object at any point in the program sequence. In combination with various other hardware and software checks, this feature can be utilized to minimize the impact of a system failure. Since the system cost and complexity will be affected by the selected degree of fail-safe capability, the designer and the user must make tradeoffs in this area, with consideration for the requirements of totally unattended operation or the handling of dangerous substances. Only when the operator is convinced of the safety and reliability of the system will there be the confidence level which can be associated with an appliance product. The state of the art in laboratory robotics can provide this confidence with good system design and execution.

With the perspective of a long-time supplier and manufacturer of products to the industrial and clinical laboratory, Fisher Scientific is expanding its product lines to be compatible with its robotics systems. This expansion comes in response to the needs of our customers to whom productivity improvement has become mandatory. As product competition in robotics increases, the customer will recognize a coincident increase in product value. At the same time, the robot itself will become more nearly a commodity appliance, much as IBM compatible PC's have become a commodity product. The added value will then come from a supplier's capability to render support services, including application programming, training, installation assistance, repair services and accessory development. With the MAXX-5 product, Fisher Scientific Company is entering the laboratory robotics market, already well positioned to offer these necessary support services.

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