ROBOTICS IN MEDICINE: A BRIEF SURVEY

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Abstract

A survey on different fields of application of robots and robot technology in medicine is presented. Robotics applications will be categorized according to the following areas: stationary laboratory robot systems, autonomous robot transport systems, robot systems for the severely handicapped, robot patient simulators, and robot applications in surgery. It is argued that robots and robot technology will be used in medicine at a more rapid pace than anticipated.

1. Introduction

Since the 1950s new technologies have effected major changes in the health field. Beside computerized axial tomography (CAT), scanners, diagnostic sonography, magnetic resonance imaging, thermography, and radioisotopes, we are experiencing today a second wave of development—spearheaded by the computer—in which robots play an ever greater role [25].

However, most industrial robots are designed for a specific purpose and unless subjected to extensive modifications do not lend themselves for use in the medical field. It was only in the last few years that systems with specialized, medically-oriented hard and software have come into more widespread use, sometimes equipped with gripper arms designed especially for various medical applications. Thus the robots can be "reprogrammed" to carry out highly specific tasks, in contrast to systems which cannot be reconfigured ("hard automation") [4,25].

2. Different fields of application of robots and robot technology in medicine

Today approximately 50% of the most common robot applications in hospitals are related to laboratory tasks; another 25% are related to medical care services. According to current estimates, the introduction of robots in hospitals could reduce personnel requirements to 10–15% in the future [1].

Table 1 gives an overview about different fields of application of robots or robot technology in medicine and provides several examples that fall into one of the established categories.

Stationary laboratory robot systems

The use of robots in laboratories is probably the least controversial area of application. The bulk of laboratory work consists of time-consuming steps in the preparation and testing of specimens; procedures that are tedious and often bring the staff into contact with toxic substances.

Procedures such as chromatography, spectral analysis, and infrared spectrography have greatly simplified the analysis of specimens and increased the precision in measuring specimen substances. Additionally improved test procedures such as radio-immunoassays and enzyme-immunoassays, now make it possible to detect a large number of biological substances [6,12,13,14,16, 23,27,34].

Table 1: Application fields of robot systems and robot technology in medicine.

Robot Systems in Medicine
Stationary Laboratory Robot Systems
General descriptions [5,11,34]
Robot system for chromatography tests [12,14,23,27]
Analysis of drugs in biological fluids [13]
Robot system for blood tests [34]
Immunochemical determination of cardiac isoenzymes [6]
Automating extraction methods for food samples [16]
Autonomous Robot Transport Systems
HELPMATE—mobile hospital robot [20]
LABMATE—mobile hospital robot [10]
ROBOTEK—robot assistant for pharmacy [25]
Robot Systems for the Severely Handicapped
Control of prostheses [2,19,24,26,29]
Assistance for quadriplegics in routine functions [7,8,17,33]
SICO—robot for mentally handicapped [25]
Robot Patient Simulators
General descriptions [36]
Mechanical simulation of human body joints [15,28,35,36]
Anaesthesiology and cardiology training [1]
Robot Application in Surgery
Stereotactic neurosurgery [18,21,25,37]
Automated biopsy devices [3]
Surgeon robot prostatectomy [9]
Removal of port wine stains and other angiodysplasias [32]
Robot assistant in microsurgery [25]

To be effective, however, all of these procedures require that the specimens are prepared and handled with the utmost precision. Typical tasks carried out by laboratory robots are: manipulation, liquid handling, separation, conditioning, pulverization, weighing, and measurement [34]. Today the use of robots has highly increased even in such routine clinical tests as determining blood glucose, urea nitrogen, or electrolytes. However, a significant number of other testing procedures have not been automated as yet. Among them are—on the one hand—several routine examinations which are carried out in every large hospital; still, those tests can usually be performed only by specialized laboratories (e.g., serologic tests for hepatitis) and their automation would be rather expensive. On the other hand, these are procedures which are difficult to automate and therefore will be conducted manually for some time until new advances of robotics technology are being made. At present, there are mainly three different robotic systems in practical use: The Minimover-5 (Microbot, Menlo Park, CA, USA), the Puma (Unimation, Inc., Danbury, CT, USA), and the Zymate Laboratory Automation System (Zymark Corp., Hopkins, MA, USA) [34]. The Zymate System is of particular interest because it is a unique system which was developed especially for highly-automated sample handling.

In general, the application of stationary laboratory robot systems makes it possible to increase the number of tests conducted per unit of time, while at the same time the intervals between subsequent tests are reduced [5,11].

Autonomous robot transport systems

Today materials handling systems [22,30,31] are being developed more and more as mobile and autonomous robot systems. For example, HELPMATE [19] is a mobile robot handling meal distribution in hospitals. It is especially suited for tasks where a high quantity (nearly 90% in a certain hospital) of the demanded meals are special orders due to various dietary requirements of patients. HELPMATE is equipped with a vision system, sonar and infrared sensors, enabling it to navigate successfully along the corridors of the hospital. LABMATE [10] is a robot vehicle especially designed for hospital use, consisting of a chassis unit and drive controls as well as extensive sensor equipment. The basic system can be modified by means of interface routines for application programming to suit a wide range of tasks. ROBOTEK [25] is a robot assistant used in pharmacies and hospitals, where it selects automatically (from up to five hundred drugs) and delivers the daily medications for each patient, predesignated by the physician for verification by the personnel. Further applications are, for example, sweeping of hospital corridors, handling and sorting of dirty sheets in the laundry where the staff might be exposed to contamination, or control and inspection of important areas of the hospital, such as the pharmacy [4].

Robot systems for the severely handicapped

There are two basic areas of application:

a) After amputation, arms or legs may be replaced by a prosthesis. These applications are already quite advanced [24]. The aim is to control as many functions of the prosthesis as possible with the few muscles that are still functioning [2]. In this way, some important body functions may be regained [19,26,29].
b) Assistance in necessary routine functions difficult or impossible to perform by the handicapped person. For example, the only way a quadriplegic can eat or drink without help by another person is with the assistance of voice-controlled robot systems [7,8,33]. Some of these systems can also be modified to carry out other tasks [15,17].

SICO [25] is a mobile robot which moves around the room, speaks several languages, and is used to assist in the treatment of the mentally handicapped. Even autistic children are made aware of the world around them by the robot's simple movements and its use of language.

Robot patient simulators

The sequence patterns of human movement must be thoroughly understood [36] to develop the kind of systems for handicapped persons as described above. Systems of this type attempting to simulate certain parts of the human body [28,35] are also often used to train medical students in areas such as anaesthesiology and cardiology. Above all, the cooperation of experts in biomechanics, neurophysiology, biology, and many other fields is necessary to gain more knowledge in this area. For example, the human hand cannot be simulated realistically by a computer unless there is a thorough understanding of its function and its motional sequences, perhaps even an understanding of the human dexterity or skill related to certain kinetic mechanisms [15,35].

Robot application in surgery

The main reason for the slowness in introducing robots in the field of surgery is the safety consideration. At present, it is primarily auxiliary functions that robots perform in this area. However, the development of computer tomography makes it possible to establish more precise facts than ever before for example regarding the localization of tumors. In particular for stereotactic operations in neurosurgery, robot systems are being used with increasing frequency [18,21,37]. Here, the stereotactic device is attached to the skull in accordance to its external bone structure. A robot analyzes the CAT data, then drills a hole precisely at the desired spot. Subsequent to this procedure, the system can place a probe inside the skull for a biopsy [3] at exactly the correct angle to the actual targeted point.

Another application which is presently tested is a surgeon robot for prostatectomies [9]. A prostatectomy involves removal of some or all of the prostate gland tissue which has grown to block the urinary tract. This requires the surgeon to continuously view the operation through an endoscope attached to the end of the cutting instrument. This together with the wide angle variations of the instruments can cause the surgeons to develop chronic neck and back pains in their later lives. With the robot system, the surgeon now only inserts the endoscope at the beginning of the operation, the robot makes all necessary movements for surgery. The surgeon has the opportunity to interrupt the operation by pressing a key at any point in the process.

There is also a system currently in use which is able to remove port wine stains and other forms of angiodysplasia [32]. In microsurgery, attempts are now being made to transfer the surgeon's hand movements directly to a robot arm to achieve even finer and more precise movements [25].

3. Discussion

Robotic technology is being used in health care at a more rapid pace than many believed before. Perhaps within the next 10 years, robots and robot technology will be utilized at a greater rate not only in laboratories but also as supplementary systems in clinical medicine and health care. Robotic technology cannot replace human care but it can aid in increasing the quality of care provided by health care professionals to patients [4,25].

Acknowledgement. The authors are indebted to F. Alesch, M.D., for various help.

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