Mechatronics and Robotics for Service Applications

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Led by the Japanese, industrial robots have been in use for some 20 years. While the level of development in industrial production is already well advanced, the service area is just now emerging as the future field of application. The number of service robots currently in operation is small, but the number of people working in the service field shows a constant growth rate. Consequently, there is an enormous potential for the expansion of this sector.

Almost all branches of the service industry already use highly modern information and communication technologies to carry out administrative tasks efficiently and in a customer-friendly manner [1, 2, 3]. However, the full range of possibilities of (semi-) automated implementation of services through robot systems is still barely apparent to the supplier and manufacturer, and to the user/customer alike even though the use of robot systems in the field of service offers, in principle, advantages to all those involved.

Due to often strict requirements with respect to safety (personal and functional) associated with robot autonomy or navigation in partially or entirely unknown environments, the use of robots for carrying out service tasks has been very limited. These criteria are responsible for the uncertainty of the service supplier in the evaluation of innovative attempts at the (semi-) automation of services. In many cases, this automation would have already been advisable, considering its kinder-to-man workform, and, as currently existing series devices or prototypes show, technological feasibility.

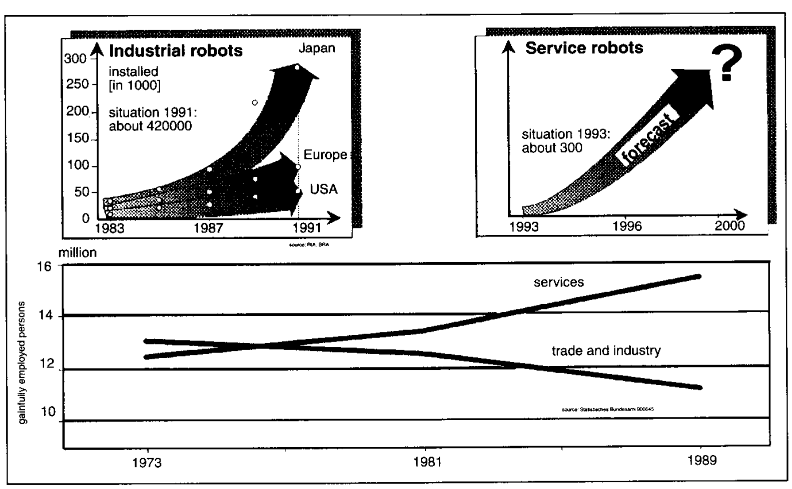
Articles in the Research Forum present the observations and opinions of individual leaders in the field. We look forward to your comments.

WHAT IS A SERVICE ROBOT?

For the first time, developments in the areas of sensor, control, transmission and material technology render possible the exploitation of so-called service robots in areas outside the industrial manufacturing environment, [4]

In this context a possible definition of a service robot has been suggested by IPA:

A service robot is a freely programmable kinematic device which performs services semi- or fully automatically. Services are tasks which do not contribute to the industrial manufacturing of goods but are the execution of useful work for humans and equipment.



Forecast of industrial and service robots.

PRESENT SITUATION OF APPLICABILITY OF SERVICE ROBOTS (SOURCE: IPA).

subsector \ application area	transportation	health care	hotel & gastronomy	household	public services	safeguarding persons/buildings	construction	agriculture	disaster & emergency relief	natural resource exploitation	underwater
maintenance							◒		◒		◒
repair							◒		◒		◒
transport		●	○	○			●		◒		
cleaning	◒		○	○	●		●		●		◒
safeguarding & rescuing									●		○
data acquisition		◒				●					○
others	●							◒		○	

Concept: ○ Test: ◒ Application: ●

The actual execution of tasks by the service robot can be a series of complex movements, which can also be carried out when influenced by unforeseeable occurrences or environmental conditions. A service robot must therefore be able to act, within certain limits, independently.

GENERAL CHARACTERISTICS OF SERVICE ROBOTS

It is widely recognized that the automated execution of handling and manufacturing tasks in the service sector is technologically feasible. Still, uncertainty prevails with respect to the appropriate degree of automation and the required safety precautions when working envelopes of the robot and operator/user overlap.

Robots in the service sector will differ from industrial robots because they will be individually designed for the execution of a given task taking place in a specific environment following a predefined organizational scheme

A successful design of future service robots will be based upon detailed knowlege of available technologies and methodologies to design handling devices or mobile platforms, peripheral devices, and organizational schemes which account for a flexible, fault-tolerant and user friendly human-machine interaction.

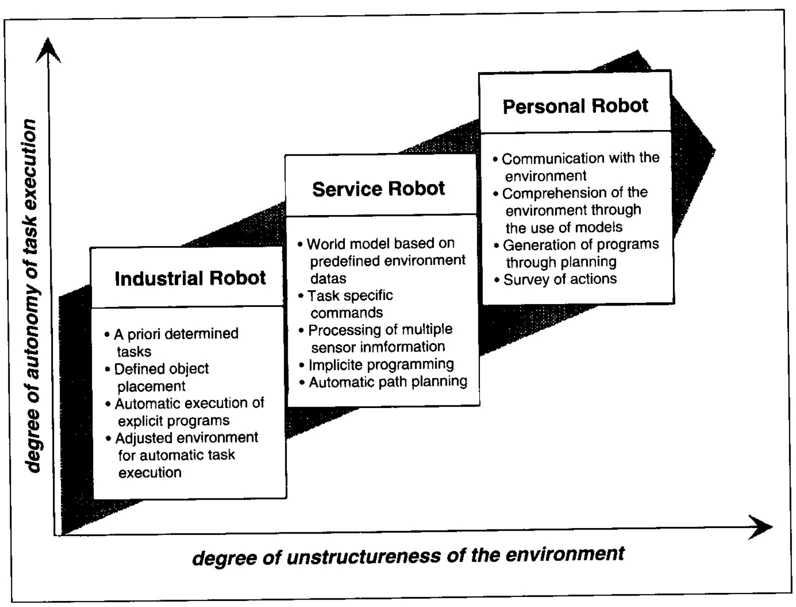
DESIGNING SERVICE ROBOT APPLICATIONS

Automated services tend to be performed in environments of traditionally little mechanization. Task execution therefore may be initiated and supervised by unspecialized personal. Only a fraction of existing services which incorporate handling, transportation and working can be automated.

Service robot technology constitutes the further development of semi-systems, as developed in industrial robot technology. The design of a mechanized service demands the specification of the degrees of automation, autonomy and structuring of the environment. These greatly influence the dexterity and movability of end-effectors, the kinematic structure of the robot or the mobile platform, intelligence of the computer control with its ability to automatic planning, execution and monitoring sequences of actions or whole tasks, and man-machine-interfaces for interaction with operators or users.

Unlike in the case of the industrial area, a well-structured or known environment can not always be expected in the (semi-) automated implementation of service tasks. Handling tasks or driving operations are therefore to be carried out in an environment about which information can be ambiguous, incomplete or inaccurate, and subject to time changes.

In the past, considerable efforts have been invested in developing systems which support autonomous task execution, navigation of robots in unstructured environments and comfortable man-machine interfaces. Many key components, however, are still in the prototype state and, therefore, are not available for practical solutions in the short term at acceptable cost. Some sub-



Characteristics of industrial service and personal robots.

Intelligent Mobility		Intelligent Handling	
Component	**Task**	**Component**	**Task**
Mobile Platform	free movements	**Kinematics**	multiple arm kinematics
	climbing of stairs		flexible arms
Sensors	collision avoidance	**Endeffectors**	sensor integration
	navigation		dextrous hands multi-function tools
	object and scene recognition	**Transmission**	sensor controlled drives
	modelling, mapping of the environment		high capacity power supply
	docking	**Sensors**	collision avoidance
			sensor based motion control
Computer Control	explicitly programmed movements		
	model-based trajectory generation		
	event-driven trajectory generation		

Components supporting intelligent handling and intelligent mobility.

Hobbies & spare time	Ball collecting machine		
Household	Vacuum cleaner	Autonomous shopping boy	Personal robot
Elderly & Disabled Care	Personal Carrier System	Systems to increase individual autonomy	Autonomous Buggy
Office & Logistics	Autonomous office transport system		
Medicine & Rehabilitation	Semi-autonomous driven wheelechairs	Operation Assistance	
Municipality, Infrastructure & Environment	Sewer cleaning robot		
Hotel & Restaurants	Automatic Transport of Luggage, Meals		
Building Trade	Redevelopment robots for steel structural engineering		
Disaster Control & Rescue Services	Rescue Platforms	Active Lifebelts Robots	Autonomous Rescue
Availability	Short term	Mid term	Long term

Development of Industrial Leading Applications.

The plane washing robot "Skywash."

systems orcomponents, which have been identified as key components, need to be improved for higher functionality and wider exploitation of robots in the service sector.

APPLICATIONS

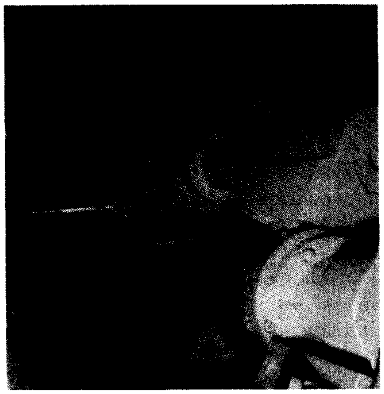
IPA's considerable know-how in demonstrating automation potential and realization reserves to help make companies more competitive with innovative technologies and unconventional solution approaches has been successfully introduced into the field of service. Extensive work involving the planning, development and realization of service robots in (semi-) automated task implementation has been carried out in application- oriented research projects. The figure below shows the main operation with the conceptual application.

A distinction must be made between the short-, middle- and long-term releasable application possibilities of service robots. Before fully autonomous robots can be realized, considerable development work is necessary in the field of computer technology. Some examples of already produced service robots will be explained in more detail in the following:

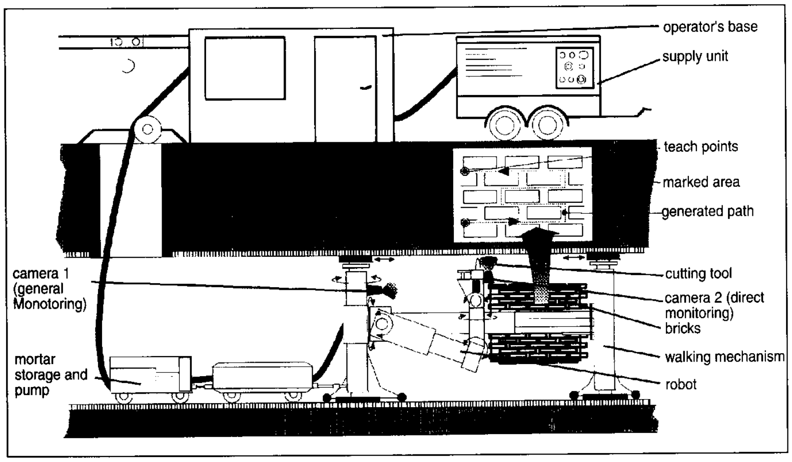
Aircraft Cleaning Robot

Regular cleaning of aircraft bodies enables damage detection and helps to create an attractive carrier image. To increase up-time, to improve cleaning results and to save labor costs, a special manipulator has been developed. It incorporates nine hydraulically powered axes, a maximum load capacity of 1500 kg (positioning accuracy of some 15 mm), a reach of 22 m and a maximum tool-center-point-velocity of 1.5 m/s. Various end-effectors such as brushing tools or working platform are available. The system architecture is based on a hybrid concept where the task execution includes initiation of action sequences and monitoring by an operator:

- pre-positioning of the robot relative to aircraft
- initiation of the referencing of the station frame (robot) to the goal frame (aircraft) and trajectory generation
- initiation of the folding and unfolding of robot arm,
- monitoring the washing of the aircraft.



The telemanipulator for sewer repair.



Schematic depiction of the entire telemanipulator system for sewer maintenance and repair.

Manipulator for Sewer Repair

Many older sewers in Germany are made of bricks. Due to ageing, sewers tend to leak and therefore must be resealed. Manual repair is extremely hazardous and must be performed under difficult working conditions. A 5-axis manipulator, which includes a walking mechanism, for the repair of leaks in brick sewers has been developed. Repair tasks include cutting of old mortar, gap cleaning and refilling with special epoxy resin mortar. The system architecture is based on a telemanipulation concept where the task execution is controlled manually by an operator [5]:

- detection of weathered mortar with cameras
- marking of the area of repair
- overriding of generated trajectories with a spaceball
- control of walking movements along the sewer
- assembly/disassembly and maintenance of the robot.

Automated sequences comprise:

- referencing base frame (robot) to station frame (sewer)
- trajectory generation along bricks (horizontally and vertically) within the marked area
- graphically supported pre-simulation of movements
- control of cutting depth.

Cleaning Robot for Sewers

The development of a service robot to clean sewers essentially serves the humanization of work. The worker is released from this hard and dirty job and takes over the handling function of the service robot. Through suitable positioning of the vehicle, the robot independently removes the drain cover with a claw arm. Then the dirt that has been collected is vacuumed with a corresponding suction pipe. In the case of heavy soiling, water is used for softening up purposes. On completion of cleaning the service robot replaces the drain cover in its original position. This application will be of increasing interest to urban and municipal cleaning services.

ARSE cleaning robot.

Vacuum Cleaner

Robots which will carry out typical household tasks are eagerly awaited by the housework-hating public. Realistically, the demands here are especially high, both from an economic and technical viewpoint. However, the first steps to conquer this market here have already been taken. Automatically driven robots for domestic floor cleaning are about to be released on the market. The autonomously moving vehicle ensures an optimal surface cleaning of floors. Without colliding, you can move around the room and regulate vacuuming according to the floor covering and degree of dirt.

Public buildings such as concert halls, hotels, banks etc. could also make use of this service robot.

Robot for Assisting the Disabled (MANUS-Arm)

An assisting manipulator brings significant benefits to disabled people. It has been shown that manipulators could be successfully placed into integrated systems

ARSE claw arm and suction pipe for removing and cleaning drain covers.

for disabled users [6]. Probable tasks are: pouring drinks, picking up and drinking from a glass, opening doors and general picking and retrieving operations. Therefore, a crucial factor is the right choice of appropriate user interfaces which take advantage of existing abilities [7]:

- joystick, keyboard, voice, tongue switch, 6D-spaceball as command interfaces
- task level control (implicit and explicit programming)
- voice, graphics or text as output signals.

The MANUS manipulator (which possesses 8 degrees of freedom) has been a joint development of TNO and the Institute for Rehabilitation Research, NL and is undergoing rapid enhancements in terms of functionality, safety and integration of user interfaces. A dedicated M3S-Bus and protocol for communication between manipulator has been designed for general input and output devices. Passive safety measures, which include uncritical speeds and mass properties as well as torque limits and compliance, make the MANUS manipulator suitable for unknown environments.

MANUS-arm assisting the handicapped in task execution (source: Exact Dynamics b.v.).

A next step would be a further integration of sensors for better coping with partially structured or unstructured environments, so that objects can instantly be grasped or manipulated either automatically or after pre-positioning without laborious programming. It was discovered in these applications that referencing the base frame relative to the goal or station frame is of crucial importance. Dedicated solutions had to be developed to ensure proper task execution.

CONCLUSION

The first robots are now being introduced into the service sector. Further considerations regarding profitability, conservation of resources and human working conditions will spawn a further mechanization of services. It can be assumed that only a fraction of services are suitable for automation. In order to develop systems which are both innovative and of significant benefit to the user or customer, planning and conceptual work takes on a crucial role. Adopting the robot to new tasks by just changing or modifying its peripheral components as is common practice with industrial robots will be possible for only a few applications of service robots. Rather, new structural and technical approaches for service robots will be necessary. Efforts have to be undertaken to further develop key components of these robots towards efficiency, performance, miniaturization and cost. Here the collaboration of research institutions, service industry and robot and component manufacturers has the potential to create valuable synergies.

REFERENCES

[1] J. F. Engelberger, Robotics in Service, First MIT Press edition, 1983.

[2] I Kato, Y. Ono, K. Yonemoto, "Feasibility Study of Personal Robots in Japan," in Proceedings of the 1st Workshop on Domestic Robots, Newcastle-upon-Tyne, United Kingdom, 5 - 7 September 1 989, pp. 1 -10.

[3] R. D. Schraft., M. Hägele, "Serviceroboter - Perspektiven der Automatisierung des Dienstleistungsbereichs," in wt, Produktion und Management, vol 83, pp. 18 - 20, January 1993.

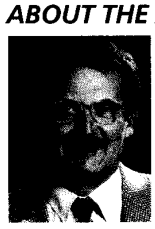
[4] R. D. Schraft, "Serviceroboter - von der Vision zur Realisierung," Technika 7, pp. 27 - 31 .

[5] K. A. Schließmann, Rechnergestütztes Bedienssystem für einen Telemanipulator zur Sanierung von gemauerten Abwasserkanälen, Springer Verlag, 1993.

[6] H. F. van der Loos: "Rehabilitation Robotics at the Palo Alto Veterans Affairs Medical Center," in RESNA International '92, pp. 605 - 607, June 6 -11, 1992.

[7] R. D. Jackson, R. G. Gosine, W. S. Harwin, "An Interactive Workstation in a Vocational Setting," in Robotics in Medicine, IMechE, June 1990.

ABOUT THE AUTHOR



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