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INTELLIGENT SYSTEMS - SERVICE ROBOTS FOR MAINTENANCE OF PIPING SYSTEMS

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ABSTRACT
Development of information technology leads to constant change and development of new technologies that lead to new functional solutions and greater opportunities for the application of intelligent systems such as service robots. Day after day technological improvements in flexibility, accuracy, security, simplifying the monitoring and maintenance of the system in manufacturing processes are occurred. Varieties of intelligent systems are designed such as service robots for the specific type of tasks used in all industries. Such as service robots have found application in servicing, inspection and maintenance, which replaces the human work, mostly for substandard working conditions and health danger. Service robots have already found application in inspection and servicing underground installations such as pipelines for water, gas, oil and sewage. This paper will be based on concrete examples of the application of intelligent systems-service robots in processes of inspection and maintenance of the piping system.
Keywords: intelligent systems, service robots, inspection, maintenance, piping system.

1. INTRODUCTION
Service robots or automated structures, can have a wide range of applications in situations where conditions for operators are threatening, challenging or inaccessible [1,2,3,4]. For example, service robots have already found application in the inspection and maintenance, where it replaces the human and where the presence of the humans are disenabled or motions limited, in soil testing, installation and construction of underground tunnels, in the study of magmatic changes in volcanoes and so on. It is also widespread use of service robots in high temperature areas, areas where concentrations of substances hazardous to human health can be increased, such as manufacturing of metal products and metal casting, production of glass and ceramic products. Also in applications that involve high pressure painting, welding, grinding, polishing, etc. This paper will be based on concrete examples of the application of service robots in process operations, inspection and maintenance systems such as piping systems for water, gas, fuel and sewerage systems.

2. DISTRIBUTION OF SERVICE ROBOT SYSTEMS FOR INSPECTION AND MAINTAINING APPLICATION

International Federation of Robotics (IFR), United Nations Economic Commission for Europe (UNECE), and Organization for Economic Co-operation and Development (OECD) [1,2] have adopted introduction system for service robot classification for inspection and maintaining by categories and types of interaction, so that service robots in inspection and maintaining of systems have following classification presented in Table 1:

Table 1. Classification of professional service robots in inspection and maintaining of systems

II. Professional service robots	
29-31	Inspection and maintaining of systems
29	Building inspection
30	Inspection of piping and sewerage systems
31	Other inspection and maintaining systems

In following Table 2 statistical data of service robot application are presented. International Federation of Robotics (IFR), United Nations Economic Commission for Europe (UNECE), and Organization for Economic Co-operation and Development (OECD) have collected data from service robots manufacturers.

Table 2. Annual supply of service robots in inspection and maintaining of systems in period 2005 to 2010 [1,2]

Application/Year	Annual supply of service robots				
	2005	2007	2008	2009	2010
Inspection and maintaining of systems	41	190	170	168	186
Other	6.062	10.169	13.734	13.082	13.555
Total Σ	**6.103**	**10.395**	**13.904**	**13.249**	**13.741**

If table 2 is analyzed it can be concluded that in period 2005-2010 application of service robots for maintaining and inspection have been increased. In 2005 service robots for inspection and maintaining participated with 0,67 % of total number of units while in 2010 participated with 1,35 %. It can be seen that highest number of service robots for inspection and maintaining is supplied in year 2010.

3. APPLICATION OF SERVICE ROBOTS FOR INSPECTION AND MAINTAINING OF PIPING SYSTEMS

Inspection and maintenance of tanks, hoses and pipes are the tasks that are suitable for service robots. Typically, pipeline service robots are segmented robots which motion is achieved over wheels or caterpillars or some other motion elements that can move inside pipeline used for flow of oil, gas or sewage, industrial or air channels. In addition, advantages are the rapid detection of problems within the piping system, such as failures in the welds, corrosion, erosion, cracks, loose parts, defective internal coating etc. The tasks that need to be done by service robots are such that they require special tools to perform operations like grinding or milling. Sewer service robots can clean the pipe diameter 200-600 mm, which are unavailable to human operators. They are usually based on multi segment platform [5,6,7,8,9].

Appropriate platform by Company RedZone Robotics in the United States of America performs inspection and repair tasks in pipes whose diameter 900-1250 mm or more. Technology Laboratory (DOE / NETL) Carnegie Mellon University (CMU), with the help of the gas company (NGA), has designed a service robotic system of the next generation Explorer II (X-II) capable of working under pressure, has good visibility and control of gas pipelines. Electronic architecture allows using GPS locating pipelines during the control deficiencies and take prompt intervention to troubleshooting.

Camera module has been designed so that integrates computer, lighting, camera recording and wireless communication. Drive module is used to move a service robot and gives possibility for motion in the piping system with 90° corners. The robot can move vertically along a pipe, down the

pipe or at any angle. The battery module is used to power the whole system of robots Explorer – II. Articulated robot module in Explorer - II has been designed and equipped with servomotor that robot can execute the desired position.

Pipeline inspection is performed by a service robot Explorer - II in a way that robot is positioned in the pipeline, and this positioning can be done in several ways, as shown in Figure 1. Tracking Robot Explorer - II in the pipeline, pipeline inspection and control is done through the monitor and control unit (Figure 1).

Figure 1. Inspections of pipeline by monitor and control unit [10]

Another robot for testing pipelines is MACRO plus robot. This service robots have remarkable mobility and it moves like a snake through the pipes with its flexible body. Segments of the body contain two batteries for power supply, computer, two heads and two symmetrically placed ports for operational elements. Computer allows the robot to move autonomously. Ball joint has three degrees of freedom and is located between the drive unit. Highly integrated electronics uses a digital signal processor that controls the motor and gives accurate calculations of angles Service robot MARKO is shown on Figure 2.

Figure 2. Robot MARKO plus for pipline inspection [10]

Both robotic platforms and operating module have separate CAN - bus. Images from the camera are transmitted to the PC computer by FireWire communication. During the Macro plus is on entrance to the pipe, the connection with robot is realized by WLAN. When robot enters the tube and moves a few meters, wireless connection is interrupted and the robot operates autonomously.
Service robot Jetty is a service robot that is designed to be used for cleaning and inspection of pipes, ducts of air conditioning, channels of kitchens and industrial air holes or spaces that are inconvenient for human to clean. Service robot is constructed so that a six-foot provides stability when cleaning and moving through pipes and canals during cleaning. Jetty service robot is shown in Figure 3. Jetty service robot can go and clean channels, circular, rectangular and square shaped with maximum efficiency because the rotation velocity of the cleaning and the rotor speed can be set to clean depending on the degree of contamination.

Figure 3. Service robot Jetty [10]

Figure 3 shows service robot in the open position. The robot can clean not only horizontal channels, but vertical and angled channels, as well as in the form of the letter S. The robot is equipped with a camera. Monitoring the inspection process and cleaning is done by using a computer display. Control of the robot is done by Jetty joystick.

4. CONCLUSION

Service robotics in contemporary life takes an important place. At beginning of the 21st century practical applications of service robotics and intelligent machines in general will have significant expansion. Technology is developed rapidly, and it is not known the end of its further development and new ideas, which are influence to the service robotics that also, evolve to infinite possibilities. Today, the development and achievements in the field of service robotics have reached such a stage of development that a large part of humanity is not aware of haw advantage that have. Usually are presented in the sci-fi films as enemies of man and mankind. But on the contrary, scientists of various scientific disciplines improve, facilitate, or embellish life of mankind thought service robots. Generally speaking, continuous improvement of the robot is expected, so that they will become systems that are easy to put into operation, program, optimize and use. This will naturally lead to increase in their applications, which is already evident from the annual statistics presented in Table 2.
Advantages of service robot application for cleaning and inspection are: operation in inaccessible areas, contaminated areas and areas dangerous for humans. In this paper yearly application of service robots is presented from where can be concluded that application of service robots for inspection and maintenance year after year have been increasing. As example service robot Explorer II (X-II), Marko plus and Jetty that are used for inspection, maintaining and cleaning of piping systems are shown. Mentioned robots are used for water piping systems, gas, fuel and sewage systems. They are very effective in diagnostic of piping systems, repairing and after that using again.

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