Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnLine 51-30 (2018) 192–197

Cost Oriented Tele-Controlled Service Robot for Increasing the Quality of Life of Elderly and Disabled – ROBCO 18

Nayden Chivarov*, Denis Chikurtev, Emanuil Markov*, Stefan Chivarov*** and Peter Kopacek*****

**European Polytechnical University, Pernik, Bulgaria*
(E-mails: nshivarov@code.bg, emospy@gmail.com)
***Institute of Information and Communication Technologies, Bulgarian Academy of Sciences, Sofia, Bulgaria*
(e-mail: dchikurtev@gmail.com)
**** Intelligent Handling devices and Robotics – IHRT, TU WIEN*
(e-mails: chivarov@code.bg, kopacek@ihrt.tuwien.ac.at)

Abstract: This article presents the service robot ROBCO 18 and how it is designed to be cost-oriented. The purpose of ROBCO 18 is to support elderly and disabled, acting as a personal home assistant. The robot will be able effectively to assist people in their homes. The robot is designed to be cost-oriented, using low-cost devices and components. Robot control software has been developed to allow various interfaces and control methods to be used. The robot software system optimizes and distributes data from the robot's sensors and actuators. In this way, elderly and disabled people are safe in handling the robot and can choose their convenient method of robot control. Finally, we conducted experiments with elderly people to test how the robot is performing different tasks. As a conclusion usability review of the Cost Oriented Tele-Controlled Service Robot for Increasing the Quality of Life of Elderly and Disabled – ROBCO 18 is presented.

Keywords: tele robotics, distant control, service robot, multichannel control system, robot programming, user interface, elderly and disabled care

1. INTRODUCTION

Ageing of the population and respectively increasing the number of people with mobility difficulties can-not be served anymore only by social assistants and caregivers and society will be forced to apply automation and robotization for the support of elderly and disabled citizens. For example, labour shortages in hospitals and homes for aged people have led to a deterioration in the quality of life of elderly people. Robot technology is expected to play an important role in the development of a healthy and sustainable society (Yamazaki, 2012).

Service robots for elderly and disabled care offer a future assistance to caregivers and social assistance and (Feil-Seifer, 2005). A significant advantage in the use of such robots is that the elderly are able to give orders to the robots without worrying about the inconvenience of their human aides. It is therefore very important to develop user-friendly interfaces from which elderly and disabled can work with such robots (Gimenez, 2003).

Having as a base "ROBKO 17" robot (Chivarov, 2017), developed in 2017, we decided to redesign it using low-cost components and devices and to make it more functional and user-friendly. In addition, we upgraded its sensor system by adding a laser scanner for the autonomous navigation system. The manipulator "ROBKO 01" has been replaced with 5 Degree of Freedom articulated robot "Mover4." New software and new graphic-user interface have been developed for precise control and reliable communication. As a result, we have a new cost-oriented service robot "ROBKO 18" (fig. 1).

Fig. 1 ROBCO 18 Skeleton

Presented Tele-Controlled Service Robot – "ROBCO 18" is a cost-oriented personal assistant robotic system for elderly and disabled people care. It will improve the quality of their life by executing assistance tasks, such as:

- to motivate elderly and disabled people to perform independently more activities and tasks and by this it will contribute to their more active and healthy way of living

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2018.11.285

- to remind elderly and disabled people, when to take their medication
- to serve foods and drinks
- to switch on/off their electronic and electric equipment
- to alarm for eventual worsening of elderly and disabled people health parameters and to contact their GP, relatives, and friends or to contact the First-Aid.

For improving the quality of life of the elderly and disabled people served by Tele-controlled service robots, it has to be conducted fundamental research, which will contribute for the improvement and creation of new methods and approaches for the cost-oriented robot systems. Such systems are localization and navigation, technical vision, manipulation of the objects via articulated robotic arm, control system and user interface. The system for localization and navigation enables mobile service robots to be autonomous during their movements to the certain place and to avoid obstacles. Reaching autonomy and precision of the movements will enable the robots to move freely in a closed environment and to reach given goals. System for technical vision which can recognize people or objects is another important part of the service robots, helping them to find the objects wanted by the user (Yoonseok, 2015). Manipulation of the requested object is realized by the articulated robotic arm. Robot control system is based on a multi-channel system for data distribution from external devices – joystick, virtual joystick, microphone, Kinect and Leap Motion to provide efficient assistance to the elderly at their different needs. Depending on the necessity of the Elderly and Disabled person, ROBCO 18 can be controlled either by Joystick, Voice, Gestures or Web User Interface.

2. INTERFACES FOR CONTROL OF THE “ROBCO 18”

Communication interfaces are a very important tool for integrating robots among people (Mast, 2015). Their role is to break the barrier between people and machines. At this stage, the basic idea is for people to be able to directly control the robots or to set commands for execution (Chivarov, 2018b).

There are four possible methods for controlling “Robco18” robot: joystick control, gesture recognition control, speech command control, and tele-control via Web user interface.

• Joystick control: this control is direct. The joystick is connected to the robot’s computer and the data does not go through web-sockets. The robot’s computer receives the data through the USB port. ROS system reads them and generates the corresponding control signals. This interface has been developed primarily to conduct robot experiments, tests on the mobile platform and manipulator motors and encoders.

• Gesture recognition control is divided into two types: hand recognition and wrist recognition.

- Control of the robot by recognition of hand gestures. This control method uses the Kinect sensor and human skeleton recognition. Depending on the position of the hand, control signals are sent to the robot. This type of control requires specific settings based on the user’s size and mobility capabilities.

- Wrist movement recognition control. Leap Motion sensor is used. Wrist Recognition Sensor recognizes gestures and position of the wrist. The control is based on both types of recognition. When the wrist is closed, the control is activated and control signals are transmitted according to the position. When the wrist is open, a stop command is sent. If there is no wrist within the sensor range, a stop is automatically sent.

• Speech command control. Speech recognition was implemented using the Google Speech API, and speech synthesizing was done by Espeak software. In this case, the robot must be connected to the Internet and the audio signals are transferred to Google servers.

• Web user interface. This interface starts on the robot’s computer and is connected to the ROS server. Developed Web UI includes different windows that provide different control options and methods. A great advantage of the UI is that it allows control of the robot from any device connected to the robot’s network. Thus, people can choose a smart-phone, a laptop, tablet or another device that is convenient for them. There are four main user interface menus: manual control mode, autonomous control mode, voice functions and settings.

- In manual mode, the user can control the robot by a virtual joystick. The virtual joystick provides the same control as a normal joystick. In addition, the user can watch the stream from the robot camera and data from the sensors. There are additional buttons for controlling both mobile platform and robotic arm manipulator according to the user preferences.

- In autonomous mode, the user can set the robot to the location where it moves independently. Using the ROS navigation stack, the robot can move autonomously in premises where a map is made. In this mode, the laser scanner, Kinect, and additional sensors are used to ensure path safety and reliability.

- Voice features of the robot include speech recognition and speech synthesis. In this menu is included the speech command control. To activate voice recognition the user has to push the microphone button. Recognized words are listed in the special field, this is a feedback to be sure what the system has been recognized.

- Settings Window. Here some basic parameters and settings for the robot control packages and sensors can be adjusted.

3. SOFTWARE AND PROGRAMMING

Robot Operating System (ROS) is used for Robco 18 control. ROS has some advantages: it is open source, it has maintenance, and it has a large set of ready-made packages (Munera, 2017). Under ROS was developed control system of the robot, which allows it to be controlled by various external devices simultaneously (Koubâa, 2016). For each device, priorities are set to ensure safety and no conflicts.

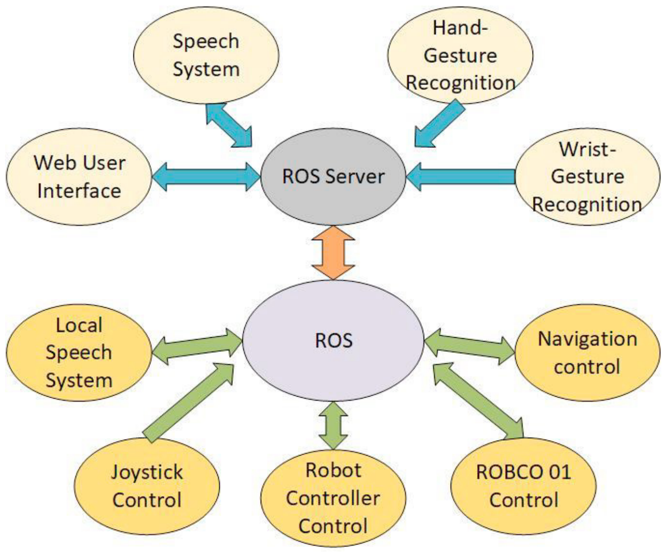

Fig. 2 Multi-channel control system based on web sockets

In order to achieve robot control by different devices, the principle of control over web sockets is used. On a local network, any device that subscribes to send and receive data to and from the robot address can control it. That allows the development of a multichannel control system that manages the control messages of all connected devices. In figure 2 is shown graphic of the connections.

In order to extend the control capabilities and implement the remote control of the robot, a Web-based user interface has been created. It is based on Python-Django and Nodejs languages for creating and managing web servers. They are free, have maintenance and documentation. The user interface consists of several menus, depending on the type of control.

A server has been created on the robot's computer. It connects ROS with the user interface and other external devices. A database has been added that stores information about personal settings and other data related to the robot and users.

4. IMPLEMENTATION OF THE ARTIFICIAL INTELLIGENCE METHODS FOR MANAGEMENT OF THE MULTI-CHANNEL CONTROL SYSTEM

Robot control is implemented as Moore's complex machine. After the action is performed in the current state of the graph, an assessment of the possible transitions is made, with the transition conditions being represented as a binary Boolean tree. Part of the table describing the binary Boolean tree is shown in Table 1. Figure 3 shows a graph of transitions between the different robot control channels.

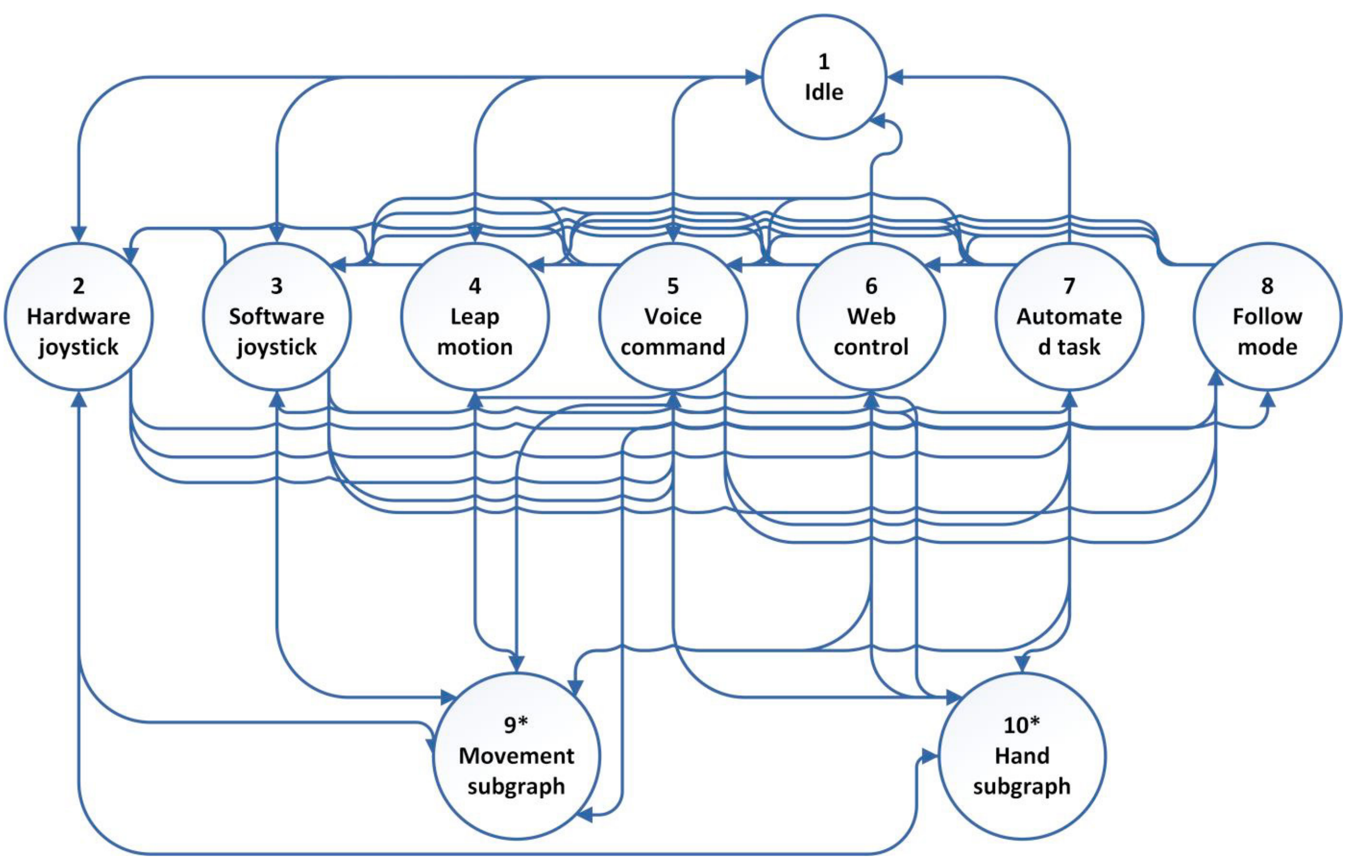

Fig. 3 The graph of transitions between the different robot control channels

To simplify the visualization, the graph is broken down by two subgraphs (states 9 * and 10 *), and the status of the column when moving to some of these subgraphs must necessarily return to the state from which the transition was made after the subgraph is executed. The parts of the column controlling the movement of the robot and the hand control are exported in separate columns, as their behaviour is similar regardless of the channel from which the commands arrive.

Table 1. Logics of the Binary Boolean tree

BDT №	**State**	**Condition**	**Transition on condition true**	**Terminal/ Non Terminal**	**Transition on condition false**	**Terminal/ Non Terminal**
1	1	Hardware Joystick active	6	T	2	N
2	1	Software Joystick active	10	T	3	N
3	1	Leap motion joystick active	15	T	4	N
4	1	Voice commands active	21	T	5	N
5	1	Web joystick active	27	T	1	T
6	2	Movement commands graph	M	T	7	N
7	2	Voice commands active	21	T	8	N
8	2	Follow mode	40	T	9	N
9	2	Preset hand movement graph	H	T	6	T
10	2	Preset hand	H	T	6	T

The robot can exit the idle state when a control channel (command source) is connected. The control channels are prioritized, i.e. entering a command from a higher priority channel will cause the current command to be stopped. The state priorities correspond to the state numbers (smaller number - higher priority). The remote control channels - hardware and software joystick - have the highest priority. Following are the channels of control by gestures and voice. With the lowest priority of the direct-control channels is the Web-based control, which involves remote access to the robot. The states in which the robot performs an automated pre-defined task - moving from one point to another or moving the hand are of the lowest priority. The management channel, as shown in the figure, can be changed to a higher priority channel at any time. The exception is the hand control state, where a guaranteed parking on the handler precedes the changeover of the control channel. Figures 4 and 5 show the graphs for the movement of the robot and the movement of the manipulator respectively.

During the robot movement, the collision avoidance has the highest priority. If the proximity sensors are activated the robot translation in the specified direction is stopped automatically. Rotating the robot in the place is still allowed to enable the robot to find an alternate way.

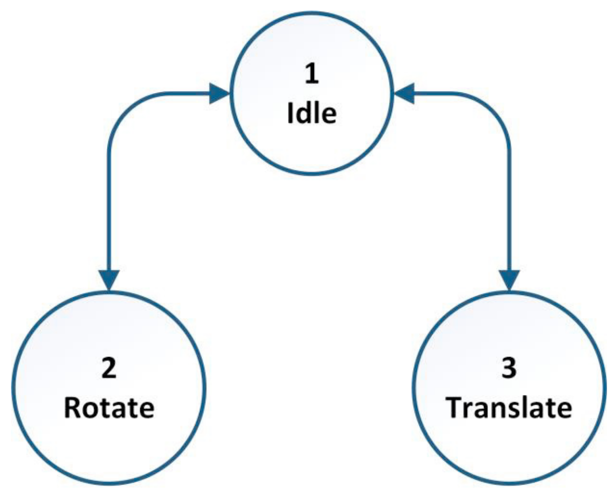

Fig. 4 The graph for movement of the robot

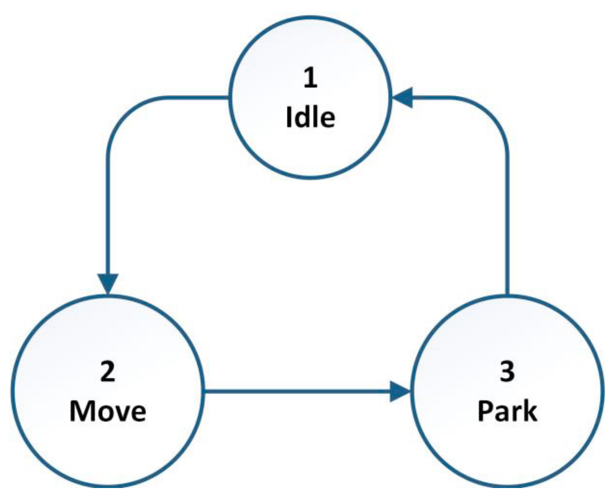

Fig. 5 The graph for moving the manipulator

The conditions for making a transition between the different graph states are structured in a Binary Decision Tree (BDT).

The automated state transition graph is executed by performing the actions specified in the particular state in which it is located, then evaluating the BDT and calculating what the next state will be. The BDT is built in such a way that the graph is allowed to remain in a certain condition indefinitely until conditions occur to cause a transition. For example, the robot will remain in a follow-up mode until it receives a command to go to another mode.

The BDT described in the tables lists the conditions for making a transition from one state to another. The columns in the table are as follows:

- BDT № - tree node number
- State – state number
- Condition – a condition that is checked for true or false
- Transition on condition true – if the verified condition is true, a transition to another BDT node is made if the transition is non-terminal or a transition to another state if the transition is terminal.
- Terminal/ Non-Terminal (N/T) – a type of transition in BDT
- Transition on condition false - if the verified condition is false, a transition to another BDT node is made if the transition is non-terminal or a transition
to another state if the transition is terminal.
- Terminal/ Non-Terminal (N/T) - a type of transition in BDT

Evaluation of BDT continues until a terminal condition is reached. If the transition is a terminal, the tree execution finishes and the control graph goes into the state indicated by the terminal condition.

5. TEST AND RESULTS

They have been performed tests with 15 elderly men and women. They have used a multi-channel control system for controlling ROBCO 18 via virtual joystick, voice commands, mimic gestures and head movement. For executing certain tasks, such as Remembering when to take medicine; Serving of food and drinks; Switching on of electronic devices; Alarms to the treating physician, social worker, relatives, or emergency in an emergency ambulance in case of a deterioration in health indicators.

The results present that the elderly people are positive about using service robot ROBCO 18 for their personal assistant (Chivarov, 2018a). We gained useful information about how the elderly perceive our robot. In terms of functionality, they expect the robot to be able to monitor their health, bring heavy or hard-to-reach items, and carry food, water, and medicine. For the design, they prefer the robot to look like a human. For the voice of the robot, they prefer the female voice. For controling mode, elderly prefer voice and joystick control. They also prefer to be the ones to do the remote control of the robot.

6. CONCLUSIONS

Cost-oriented robot ROBCO 18 is used to help elderly or disabled people. Its interfaces provide different approaches for communication between the elderly and robot.

The multi-channel control system of the robot enables elderly people to choose a method for controlling the robot according to their preference for control by executing various support activities. The prioritization of control methods contributes to increasing the safety and reduces control errors.

The cost of service robots to assist elderly and disabled people can be greatly reduced if low-cost devices and components are used.

The future work on the robot is to achieve autonomy when moving the mobile platform and performing manipulations with the robotized hand. We plan to apply autonomous navigation control of the mobile platform and trajectory planning for the robotic arm. This will allow to be improved semi-autonomous robot control mode.

ACKNOWLEDGEMENT

This research was carried out as part of the project “Tele - controlled Service Robots for Increasing the Quality of Life of Elderly and Disabled, № DN 07/23 – 15.12.2016”, financed by the Bulgarian National Science Fund.

REFERENCES

A. Gimenez, C. Balaguer, A. M. Sabatini and V. Genovese, "The MATS robotic system to assist disabled people in their home environments," *Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003) (Cat. No.03CH37453)*, 2003, pp. 2612-2617 vol.3.

D. Chikurtev, I. Rangelov, N. Chivarov, N. Shivarov, A. Gigov, Control of service robot via voice commands, *Problems of Engineering Cybernetics and Robotics*, Vol 69, Sofia, 2017, p. 62-67

D. Feil-Seifer and M. J. Mataric, "Defining socially assistive robotics," *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005*, pp. 465-468.

Eduardo Munera, Jose-Luis Poza-Lujan, Juan-Luis Posadas-Yague, Jose Simo, J. Francisco Blanes Noguera, Distributed Real-time Control Architecture for ROS-based Modular Robots, *IFAC-PapersOnLine*, Volume 50, Issue 1, 2017, Pages 11233-11238.

K. Yamazaki *et al*., "Home-Assistant Robot for an Aging Society," in *Proceedings of the IEEE*, vol. 100, no. 8, pp. 2429-2441, Aug. 2012.

Koubâa *et al*., "Turtlebot at Office: A Service-Oriented Software Architecture for Personal Assistant Robots Using ROS," *2016 International Conference on Autonomous Robot Systems and Competitions (ICARSC)*, Braganca, 2016, pp. 270-276.

Mast, M., Burmester, M., Graf, B., Weisshardt, F., Arbeiter, G., Španěl, M., et al. (2015). "Design of the human-robot interaction for a semi-autonomous service robot to assist elderly people," in Ambient Assisted Living, eds R. Wichert and H. Klausing (Berlin, Heidelberg: Springer), 15–29

M. Pleva, J. Juhar, A. Cizmar, C. Hudson, D. W. Carruth and C. L. Bethel, "Implementing English speech interface to Jaguar robot for SWAT training," *2017 IEEE 15th International Symposium on Applied Machine Intelligence and Informatics (SAMI)*, Herl'any, 2017, pp. 105-110.

N. Chivarov, *et al.,* Telecontrolled Service Robot for Increasing the Quality of Life of Elderly and Disabled, ADP 2017, June, Sozopol, Bulgaria; p. 171-175

N. Chivarov, *et al*., Usability study of Tele-Controlled Service robot for increasing the quality of life of elderly and disabled – "ROBCO 17", *27th International Conference on Robotics in Alpe-Adria Danube Region (RAAD)*, Patras 2018.

N. Chivarov, D. Chikurtev, M. Pleva, S. Ondas, Exploring Human-Robot Interfaces for Service Mobile Robots, *World Symposium on Digital Intelligence for Systems and Machines 2018 (DISA)*, Kosice 2018.

Waldherr, S., Romero, R. & Thrun, A Gesture-Based Interface for Human-Robot Interaction, *Autonomous Robots (2000),* Volume 9, pp 151-173

Yoonseok Pyo, Kouhei Nakashima, Shunya Kuwahata, Ryo Kurazume, Tokuo Tsuji, Ken'ichi Morooka, Tsutomu Hasegawa, (2015), Service robot system with an informationally structured environment, *Robotics and Autonomous Systems*, Volume 74, Part A, Pages 148-165.