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COGNITIVE SERVICE MOBILE ROBOTS FOR HELP OF DISABLED PEOPLE

Roman ZAHARIEV[1], **Nina VALCHKOVA**[2,*], **Georgi ANGELOV**[3], **Yasen PAUNSKI**[4]
[1)] Prof., D-r, Eng. Institute of Robotics-Bulgarian Academy of Sciences, Sofia, Bulgaria
[2)] Assoc. Prof., D-r, Eng. Institute of Robotics-Bulgarian Academy of Sciences, Sofia, Bulgaria
[3)] Asist. Prof., D-r, Eng. Institute of Robotics-Bulgarian Academy of Sciences, Sofia, Bulgaria
[4)] Asist. Prof., D-r, Eng. Institute of Robotics-Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract: *This article describes a project that is aimed at the development and prototyping of Mobile Cognitive Robotic System designed for service and assistance to people with disabilities. In creating this Robot called "AnRI" (Anthropomorphic Robot Intelligent) used the experience from building the previous one and used in the project Conduct Research into the Adoption of Robotic Technologies in Special Education by Children, Young People and Pedagogical Specialists in the Implementation of the EC-funded program "Marie Curie" Project H2020-MSCA-RISE-2017, ID No 77720 "CybSPEED: "Cyber-Physical Systems for Pedagogical Rehabilitation in Special Education". Described is a device of the robot and realization of cognitive processes to integrate knowledge related information from sensors, actuators and multiple sources of information vital to the process of serving people with disabilities.*

Key words: *Robotics, Service Robot, Cognitive Robot, Mobile Robot.*

1. INTRODUCTION

As stated in Cybernetics, man is a purposeful system, to which behavior is determined by the set of tasks. The process of successful pursuit and achievement of the set goals, without prejudice to the pre-set restrictions, is determined to a large extent by the learner's desire and interest. The learner's interests are a powerful stimulus in the processes of education, learning the information on the path of pursuing the strategic task. At the modern stage of human society development, with the introduction of new ultramodern technologies, including robotics, it is possible to challenge the interest of the learners, thereby enlivening the perception of such important information in the process of education. It is possible to use the Service Robots like Assistant Teachers in the process of special education.

The first service applications of the mobile robots were very successful and soon the robotic community become aware of the great future of this new branch of robotics – service robotics, stating that their positions promises to be even stronger than those of the industrial ones in the near future. In the beginning, of service robotics they were developments mostly of single purpose (specialized) mobile robots able to be used only for specific tasks. Many designers and companies today are changing their design and production strategies in service robotics towards modularization in order to become more flexible and competitive in the market [3].

The present project aims to systematically examine the peculiarities of the adoption of robotic technologies in Special Education by young people and pedagogical specialists and in particular, in the following aspects:

- Socializing role of robotic technology - there is evidence that robots do not enhance isolation (as can be expected) but instead play a role as a social mediator - robot communication is easy, accessible and fun and helps to strengthen relevant skills.
- Three measured object as a service robot with a certain degree of autonomous behavior and skills for verbal or non-verbal communication with young people is, in principle, a new impetus whose perception compared to traditional objects deserves more careful and systematic research in a new theoretical framework.
- The theoretical framework of this project is the system of special school education in which specialists, teachers, youth and robots cooperate to overcome the main difficulties accompanying the learning process such as: distraction, functional illiteracy, lack of cognitive motivation, inadequate social motivation - both in the mainstream school and in the special education.

The degree of intelligence of the universal mobile robots, developed for R&D and scientific applications by the world leading universities and laboratories, is growing very fast [7]. This is possible with the development of modern microprocessor based control systems, and thanks to the use of sophisticated yet comparatively cheap sensors (like mono and stereo, color CCD video-systems, laser based sensors and a large variety of other type ones) and remarkable achievements in the software.

The International Federation of Robotics (IFR) preliminary definition of service robotics states: "Service robot – a robot which operates semi or fully autonomously to perform services useful to the well being of humans and equipment excluding manufacturing operations". Service robots may or may not be equipped with an arm structure as the industrial robots. Often but not always the service robots are mobile. Service robots usually consist of a mobile platform on which one or several arms are attached and controlled in the same mode as the arms of the

* *Corresponding author: Institute of Robotics-Bulgarian Academy of Sciences, "Acad. Georgi Bonchev" str., Bl.2, Sofia 1113, Bulgaria.*
Tel.: (+359 887) 557148; Fax: (359 2)405306
E-mail addresses: roman.zahariev@robotics.bg (R.Zahariev)

industrial robots. With this definition manipulating industrial robots could also be regarded as service robots provided they are installed for non manufacturing operations.

2. COLLABORATIVE FUNCTIONS

According to the international standard ISO 10218 "Robots and Robotic Devices - Safety Requirements for Industrial Robots", Part 1 Part 2, there are four types of Collaborative Functions [10]:

- Safe braking. This collaborative function is mainly used when the robot works mostly on its own, but it is possible for the user to enter its workspace. When the user enters the secure, virtually restricted work zone, the robot immediately stops, not shutting down, but stays in the standby mode.

- Direction of manual operations. This collaborative application is used to guide the hand when working with robotic tools or to train the robot on the desired trajectories in pick-and-place and other similar operations.

The technology allows the robot to engage in collaborative activities through additional force-sensing devices by means of force, compression, torque and torque sensors, and so on.

- Speed monitoring and redefined work area. In this type of collaborative applications, the robot's working environment is monitored by lasers or a machine vision system that track the user's position in space.

The robot operates only within the scope of the predefined work area. When the user enters this zone, the robot reacts with a significant decrease in its speed of operation, and when a person enters a predefined smaller perimeter around the robot, it stops completely. Typically, to resume work in Safe Shutdown and Safe Mode modes, the robot waits for a feedback (command or signal) from the operator.

Work areas and safety zones are classified so that the robot reproduces different responses to the human situation in space.

- Power and power limitation. Collectible robots with power and power limitation function are considered to be the safest as they can work side by side with no additional devices or restraint systems.

The robot is programmed to "recognise" unusual (too big) efforts and to stop instantaneously in the presence of such. This type of robot is designed to "distract" the force in the event of a collision with a person on a larger area, and therefore have rounded shapes. In addition, this type of robots have no display cables and other moving parts.

A large number of collaborative robots are certified by the relevant authorities in accordance with industrial safety standards for human and robot collaboration. In this respect, the technical specification ISO/TS 15066 "Robots and Robotic Devices - Collaborative Robots" defines the maximum force and energy that can be applied to a person without causing him physical harm. It is applicable to human-robot collaboration with both conventional industrial robots and collaborative robots with power constraints.

2.1. DEVELOPMENT OF SENSOR TECHNOLOGIES IN COLLABORATIVE ROBOTS

Sensor devices are key to integrating robots into industrial machinery and equipment. Mass presence sensors, including capacitive and inductive proximity sensors and distance sensors, ultrasonic and photoelectric sensors, are widely used.

Generally, all robots incorporate feedback devices - encoders, resolvers and electromechanical angular or revolution measuring devices. Additionally, depending on the particular purpose, the collaborative robots are equipped with three categories of sensor technology - Snap Sensors and other End-of-Arm Tooling devices (EOAT); preventive sensors (to prevent damage to the robots themselves) and safety sensors that take care of the security of people near robots on the move.

EOAT sensors are typically photoelectric sensors or proximity sensors that detect when an object is caught by the grippers or other robot tools associated with system logic. If the griper sensor is not active, the robot programming will instruct the robot to take another trajectory or to alert the operator that something is wrong.

This type of reporting has two distinct aspects - registering an object's presence in the gripper in order to safely continue the sequence of operations as well as qualitatively assessing an object when it enters the robot's workspace, verifying and deciding whether to be captured by tools and manipulation with it to continue.

Prevention sensors are usually analog sensors. They are used to detect small deviations in the robot's work by analogue measurements, which he is not able to account for as errors. Such are, for example, attempts to assemble two parts that do not fit in assembly operations.

In such cases, the sensor sensing system detects more effort than is typically required by the load sensors and instructs the robot to stop trying to perform the processes. This type of reading prevents breakage or other damage to the clamps and other robot tools and systems.

Safety sensors: The sensor systems for industrial robots have undergone significant development over the years. Among the most advanced technology to provide staff safety today are 3D scanners. Usually, they are positioned next to the robot perimeter of the operating area and programmed to register the entry of a person into predefined range of the system. This technology is suitable for ensuring robot safety, which is triggered automatically.

Proximity sensors have the main function to register the presence or absence of an object (device, product, component, tool) at a certain stage of the robotic processes necessary for the safe performance of the desired subsequent operations. Installed mainly of buckles or the relevant enforcement tools (end effectors) on top of the robotic arm/hand, this type of sensors take into account whether they were engaged with the right object, and whether it was engaged in a correct way. For this purpose different solutions exist - from simple discrete sensors that only turn on and off to more sophisticated sensors that send information to the controller about the constant spatial position and size of the object via analog or serial digital outputs.

3. PROJECT OF MOBILE SERVICE ROBOTS FOR HELP OF DISABLED PEOPLE

The project for creation of Cognitive Mobile Service Robots for help of disabled people aims explicitly at fostering the scientific, innovation and patenting excellence of a leading Bulgarian institute – the Institute of Robotics of the Bulgarian Academy of Sciences (IR-BAS) in its striving for European and World Recognition in the area of research, being unique for the Region and acting as a Center of Innovation in: Innovative solutions of advanced system engineering and robotics for supporting independent living. There is an emerging need worldwide for „Personal Robots", following the development of personal computers and personal devices like tablets, iPad, touch screen GSMs, etc. It is widely accepted that Service Robots can significantly contribute to better human working conditions, improved quality, profitability and availability of services. Some visions depict these robots as companions for household tasks like fetch-and-carry-services, maintenance, cleaning, entertainment, elderly care and even care for disabled persons, which on its own right – is no longer a matter of fiction in view of the recent advances in robotics of Honda, Sony, European robotics and many others.

Present day systems engineering and robotics research aims at implementing cost oriented innovative approaches to build smart, robust, reliable and understandable robotic devices and technological systems serving better the needs of people and creating conditions for a better quality of life for the future generations. These systems have to be projective – not replicating the existing solutions - implementing excellence and innovation based scientific thinking in the socio-economical context of the current world crisis. This is crucially important for countries like Bulgaria and the region of South East Europe – where short-cut technologies have to be newly designed and made cost-oriented in order to converge faster to the standards of the European Union and be competitive on the international market.

4. DESCRIPTION OF THE ROBOTS "AnRI-0" & "AnRI-1".

The Robots from series ANRI (Anthropomorphic Robot Intelligent) was developed based on the Robots from family "ROBCO", in the Institute of Robotics – Bulgarian Academy of Sciences. The Robots "AnRI-1" and "AnRI-0" (Fig. 1 and Fig. 2) are on the base of mobile platforms with four wheels, of which two are driven and two are independent "free" wells. In the Robot "AnRI-1" the wells are located in the form of cross. The driven wheels are at two sides of the platform and the "free" wills are at the rear side and in front side.

With the help of this location of the wheels it is possible to realize the Robots movements around the vertical axis at geometrical center of construction in the left and right sides [3]. At the hub of the driven wheels are built electric motors, DC powered by a rechargeable battery. The robot is equipped with a manipulator of anthropomorphic type, situated on the platform with three regional and three local degrees of mobility and gripper with separate drive and with three fingers. The same construction has the Robot "AnRI -0" with the difference is of situation of the wells, which are in the form of "triangle". At the two tops of the triangle located driven wheels and at the third top is "free" well.

Fig. 1. *View of the Mobile Service Robot "ANRI-1"*

Drive the robots is realized, based on "servo" controllers with feedback from incremental sensors, located in each degree of mobility of the manipulator. Regional levels are equipped with electromagnetic brakes and drive wheels of the platform are equipped with worm gearboxes that do not allow movement back using their braking effect.

The Control System of the robot is hierarchical, distributed, microprocessor type and includes different levels, different devices and systems and corresponding software modules. The connection between all devices on the management takes place via the serial interface RS 232. The total control module is based on 32 bit microprocessor embedded in the CPU module.

In recent years, 32-bit microcontrollers are widely used in robot control applications. Cortex-M processor family is most popular and wide spread architecture [8]. The number of microcontroller variants is now well over 3000.

This is a range of scalable, energy efficient and easy-to-use processors and currently comes in six variants: Cortex-M0, Cortex-M0+, Cortex-M1, Cortex-M3, Cortex-M4 and Cortex-M7. The Cortex-M4 family is well suited for robot control applications. It's integrates Digital Signal Processing (DSP) unit with floating point support for fast and a power-efficient algorithm processing. Therefore, Cortex-M4 can be used in digital control application such as sensor fusion, motor control and power management [1].

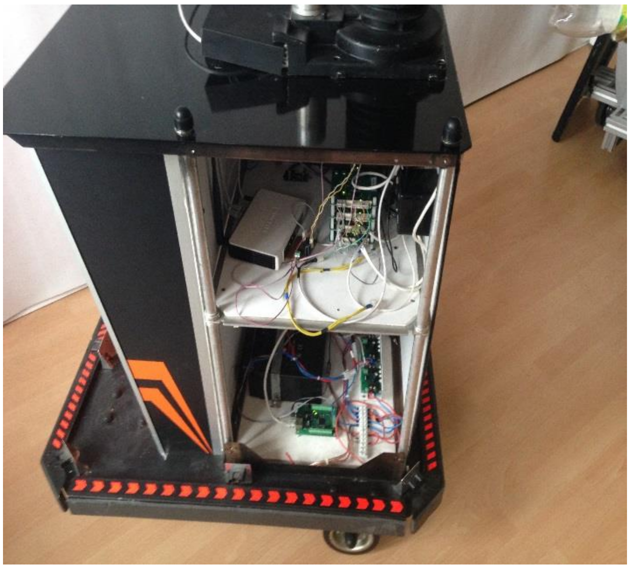

Fig. 2. Different Degrees of Mobility of Robot "AnRI -0".

In this paper we propose a practical realization of Cortex-M4 based universal I/O board for service robots which provides a set of digital and analog inputs, 10/100 Ethernet interface, PWM controls and CAN, SPI and I2C buses. This configuration enables flexible solution for attaching various sensors and actuators to the robot. Using the modern Cortex-M4 architecture simplify the design and reduces amount of external components. This greatly improves the whole system reliability [2] .

Using a standard control TCP/IP [9] network for communication with the board allows platform independent control. Also various standard libraries and diagnostic tools can be used for rapid implementation.

In the same time is presented another serial interface module, GPS module for navigation and GPRS for Internet communication. This is intended to be used for vision module and the module of the laser interferometer, along with integration module, reading and loading data from sensor systems. Used operating system is ROS (Robots Operating System).

5. REALIZATION OF TCP/IP COMMUNICATION WITH USER INTERFACE FOR SERVICE ROBOT IN ROS ENVIRONMENT

Objectives: Maximum flexibility and future multiplatform portability of the design concept. Bandwidth optimization is to be fast enough for near real time operation or most common available Internet connections. Build on ROS concept and optimal reuse of existing framework. User friendly, intuitive user interaction with the "**AnRI"** system [6].

Assisted Detection Node.

The "**AnRI"** robot assisted detection feature enables the user to initiate the detection process on selected region and choose the right object in the UI_PRI, when multiple detections are available. This node operates as an ROS service / **"AnRI"** assisted detector, called from the UI_PRI via the ROS Bridge [6].

Description of assisted detection operation modes:

Operation mode 1 – UI Detect. The user starts the detection process in the UI_PRI via clicking on the Detect button. The service **"AnRI"** assisted detector is called. It triggers the call to UI Detect service and converting the received array of detected objects from 3d bounding boxes to camera pixel coordinates via the BB Estimator Alt service. The output of the detected objects with the corresponding pixel coordinates is then passed back to the UI_PRI. After that an 2d rectangle around the object is displayed in the UI video. The user can select particular object and its id is passed via the UI Answer service.

Operation mode 2 – if the detection is not successful the user can select an region of interest and the robot will be repositioned to allow better detection. The "**AnRI"** _assisted_detector service is called with operation value 2 and p1, p2 coordinates of the selected points. The assisted detector calls BB Estimator to transform the coordinates from 2d to 3d bounding box and then calls the BB Move service. The response of the BB Move service is then passed to the UI. And if it possible the BB Move service repositions the robot to enable better detection.

Operation mode 3 – This mode is for test purpose only. It allows to test if the assisted detector node is running, the communication path and the video overlay augmentation in the UI_PRI. In this mode the service **"AnRI"** _assisted detector returns coordinates and name of a test object - Milk box.

Results:

The realized communication solution is used in 3 different "**AnRI"** user interfaces – UI_PRI running on iOS iPad, UI_LOC running on Android Smartphone and a robot test interface running through Chrome browser on a PC.
It enables the operator to execute common tasks such as:

- ✓ Direct robot control (manual movements).
- ✓ Navigation aided move to desired map position.
- ✓ Grasp objects.
- ✓ Detect or learn new objects.
- ✓ Execute more complex tasks – for example: bring an object on the table.
- ✓ Define new tasks based on available basic actions as: move, grasp, detect object and etc.

6. SENSORS SYSTEM FOR SERVICE ROBOTS "AnRI".

The robots are equipped with infrared and ultrasonic sensors that determine the distance to obstacles. Around the platform are elastically mounted micro switches that are activated at the touch of the robot with other objects and block its operation when it necessary. In total complex of devices is enabled and a video camera type "KINECT" capable of monitoring and responding to the changing dynamic stochastic environment.

On the robot is mounted too sensor, representing a **Scanner Laser Interferometer**, of company Hokuyo Automatic Co. LTD, Japan (Fig. 4) by which is possible to observe changes in the environment. With his help to obtain the details of the perceived obstacles and on this basis a decision was taken by the robot for planning a safe path of Travel with the ability to avoid collisions [7].

At the screen of control computer is possible to observed the information from the scanner laser interferometer in which are visible the coordinates of the points in the environment, which represent obstacles. By integrity procedure of specialized software module, data is read and loaded into another such module that is process leads to the recognition of the resulting "pseudo" image of the environment and this information is updated interactively every 60 milliseconds.

Fig. 4. *Scanner Laser Interferometer (Hokuyo Automatic Co. LTD, Japan)*

All information is in CPU module, where planning and safe trajectory of movement of the robot [4]. The resulting picture of the environment is verified using data from ultrasonic and infrared sensors, which is built and confirm or deny the existence of certain obstacles

The used algorithm provides that in case of unclear picture information received from the scanning laser interferometer, is possible to use TV system type KINECT, while is realized monitoring an object from the environment and define its geometry characteristics. Failing to plan a safe path of travel in the mode "real time", having to stop the movement of the robot to take a decision and then started again, his movement is already under way on a new, corrected safe trajectory [3].

Fig. 5 shows experimental use of Robots "AnRI" of the disabled people, which is consistent with the experience of the partners in the project.

7. PLANNING TRAJECTORY OF THE ROBOT USING THE FUSION OF THE SENSORS INFORMATION.

The Sensors Informational System of the robot converts various values (most often physical) into an information signal (most commonly electrical) that gives an idea of the quantity and quality of the measured quantity. The mobile service robot is subject to specific requirements for the sensor information system, dictated, in particular, by the following features of the robot:

- ✓ Heterogeneity of the system: it must combine elements that function in different ways, communicate on different protocols and fulfill different purposes.
- ✓ Heteroarchism, heterogeneity of the organization of the system: some of the elements are centralized and hierarchically organized, while others are distributed with a high degree of autonomy:
- ✓ Work in conditions of uncertainty: since dynamics of change leads to reaching the limits of knowledge, it is often necessary for the system to use probabilistic or fuzzy methods.

Fig. 5. *Experimental use of robot "AnRI - 0" from the disabled people.*

- ✓ Working in real-time mode: all changes to the structure and functions of the system must be embedded within real-time mode.

The coherence between the sensors and the mechanical units for which they are to provide information is not unambiguous. For example, one sensor is connected to a mechanical link (robot encoder), in other cases several sensors measure the same magnitude (radar, optical sensor, infrared sensor), in the third case the same sensor gives information about several mechanical components (Video sensor and multiple point tracking in space), and so on. It is important to note the dynamics of the configuration, which requires a rapid change in the overall functioning of the Sensor System under the influence of the mobile robot coordination unit. This ambiguity and dynamics of the sensor flow implies the need to integrate information, merging, sorting, filtering and completing the data needed to meet the current goal. The dynamics of changing the environment requires the integration of information from new sensors connected in a new way to new mechanical units, new algorithms and approaches [4]. In practice, there is a large arsenal of approaches and methods for integrating information into the mobile service robot. The question of strategy and tactics of the particular implementation is what combination of such methods will be applied. The sensor subsystem merges the signals from all the sensors and, after processing, outputs information about the situation in which the robot is at all times.

8. CONCLUSION

The main challenge of the Project is to make personal robots affordable to people – which is to be achieved by implementing innovations in all aspects of functioning of the robotic device – materials, sensors, cognitive, communication, actuators, energy consumption, etc.

In the extremely complicated process of education, an essential point is the definition of clear street work and tactical goals.

With a certain clarity, the teacher should be aware of the goals set and be able to create an interest and desire in learners to absorb information based on key elements. These elements are also keywords that make it easier for learners to perceive the matter and create the prerequisite for higher learning efficiency.

According to M. Minsky's Theory of frames, the information can be organized by the robot in separate frames, each subsequent frame inserted in the previous one clarifying and specifying it and thus progressing to a deep penetration of the problem. The information displayed in this way by a robot will cause a certain interest in learners, which will be a powerful stimulus in the role of absorbing matter on the way to reaching the goals.

The innovations in their concerted design will bring cost efficiency in order to make the product complying with the market demand. That is why the main purpose of the project of conduct research into the adoption of Robotic Technologies in Special Education by children, young people and pedagogical specialists in the Implementation of the EC-funded program "Marie Curie" Project H2020-MSCA-RISE-2017, ID No 77720 "CybSPEED: "Cyber-Physical Systems for Pedagogical Rehabilitation in Special Education", was to examine what extent the developed robots contribute to ensuring a dignified and independent life (with a focus on young) people with disabilities.

On the basis of the studied necessary robots behavioral models, the hardware part should be further developed, which can provide the necessary basis for further development of the program platform in order to better meet the service needs of the same users. In this respect, advances in modern technologies are developing and increasing the capabilities of the used equipment for robots control in "real time" mode. Here, not only the rapid development of digital technology has led to an unprecedented rise in communication tools in society.

There is already a new technical revolution with the possibilities for developing analog technology. In this way, extremely fast processes for collection of analogue information from the environment are obtained, without having to transfer it in digital form in order to process it properly and then to decide on the implementation of a given task.

That is why these two processes of development of the hardware and the software part of the robot should go in parallel and iteratively with the development of one part implying a jump in the development of the other part, which in turn puts its own possibilities and requirements that catalyze the development of the other part.

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