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DESIGN OF SOCIAL ROBOTS USING OPEN-SOURCE ROBOTIC PLATFORMS

Eleni VROCHIDOU[1,*], Michail MANIOS[2], Vassilis G. KABURLASOS[3], Fotis PANAGIOTOPOULOS[4], Charalabos AITSIDIS[4], Vasilis FERELIS[6],

[1)] PhD, Eng., Human-Machines Interaction (HUMAIN) Laboratory, Dept. of Computer and Informatics Engineering, Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Kavala, Greece
[2)] MSc, Assist., Eng., Human-Machines Interaction (HUMAIN) Laboratory, Dept. of Computer and Informatics Engineering, Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Kavala, Greece
[3)] Prof., PhD, Eng., Human-Machines Interaction (HUMAIN) Laboratory, Dept. of Computer and Informatics Engineering, Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Kavala, Greece
[4)] MSc, Assist., Eng., Dept. of Business Administration, Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Kavala, Greece
[5)] MSc, Assist., Eng., Dept. of Accounting and Finance, Eastern Macedonia and Thrace Institute of Technology (EMaTTech), Kavala, Greece

Abstract: *The use of social robots in child education has emerged as a promising human-robot interaction domain. Social robots were successfully implemented into educational institutions and revealed a great potential. The main obstacle against the wider design and use of robotics is that it is considered a task that only experienced roboticists can handle. Fostering robots in schools and every-day life, yells for tools and platforms able to reduce the costs of prototyping robots, in terms of time and money. The open-source paradigm offers the opportunity to overcome these obstacles. This article summarizes the most popular up-to-date open-source platforms, that can support the development of social robots. The aim of the paper is to provide the basic knowledge of the available platforms, so as to enlighten teachers, amateurs and researchers regarding the open-source paradigm. The most popular open-source robotic platforms, in term of software, hardware and simulator are presented. Open-source robotic platforms are numerous. Five of each category are selected and presented. The selection is based on the most recent educational and real-life applications that use these platforms according to the literature. Extensibility and applicability of the selected platforms are investigated, and comparison of features takes place. Future challenges are also discussed.*

Key words: *Open-source robotics, social robots, hardware, software, simulator, applications, education.*

1. INTRODUCTION

Robots have entered all fields of every-day life, including education [1]. In particular, social robots for education are becoming more available to the public and will likely play an essential role in educational settings in the near future [2]. Social robots that can interact with children have been suggested in education as affordable and efficient solutions, due to the dropping prices as well as their increased functionality [3]. In an educational setting, however, social robots need to be inexpensive. If social robots are becoming essential to schools, more tools and platforms are needed to reduce even more the costs in time and money of prototyping robots. The open-source paradigm seems to offer a potential solution to the problem.

This work aims to identify the most up-to-date open-source platforms and address the current difficulties of designing custom social robots, in terms of hardware, software and simulators. Additionally, an evaluation of the reported results regarding the use or the potential use of open-source social robots in education, typical and special, takes place.

The layout of the paper is as follows: Section 2 provides an overview on the most popular open-source platforms for the design of social robots. Section 3 presents recent applications of these robots in education. Discussion and future challenges are provided in Section 4. Conclusions are summarized in Section 5.

2. OPEN-SOURCE PLATFORMS FOR SOCIAL ROBOT DESIGN

Many open-source robotic platforms exist, yet five of each category (hardware, software, simulators) have been selected and are presented in this work. The selection is based on the most promising educational applications that utilize or suggest these specific platforms according to the bibliography.

2.1. Hardware

Open-source robotic hardware includes physical technological pieces designed and offered by the open

[*] Corresponding author: Agios Loukas, 65404, Kavala, Greece, Tel.: +30 2510 462 320
E-mail addresses: *evrochid@teiemt.gr* (E. Vrochidou), *m.manios@teiemt.gr* (M. Manios), *vgkabs@teiemt.gr* (V. G. Kaburlasos), *fpanag@teiemt.gr* (F. Panagiotopoulos), *aitsidis@teiemt.gr* (C. Aitsidis), *ferel@teiemt.gr* (V. Ferelis)

design community, distributed under free terms; mechanical drawings, blueprints, schematics, 3D model files, integrated circuit layouts, printed circuit board data etc.

- Poppy: The Poppy project focuses on robot designs based on 3D printed components combined with Dynamixel-brand smart servos. The use of 3D printing enables quick and accurate reproduction of parts, but also allows the designs to be altered quickly. Poppy focuses mainly on locomotion and body gestures. Currently, Poppy project offers three designs: Ergo Jr which is a 6 Degrees-of-Freedom (DOF) arm, Poppy Torso which is a 13 DOF upper torso, and Poppy Humanoid which is a 25 degrees of freedom (DOF) humanoid robot. [4]. Indicatively, the overall materials needed to build a Poppy Humanoid robot costs around $10,250 (including motors, electronics and 3D printed parts).
- Opsoro: The Opsoro (Open Platform for Social Robotics) platform, allows non-experts to design, build and program new social robot embodiments. Opsoro targets face-to-face communication and emotions and it offers three packs: a starter kit, an expansion pack and the opsoro hat. The Opsoro robot does not have actuated limbs, so it allows the use of RC hobby servos. Additionally, the custom parts are made using laser-cutting supplemented with low-cost FDM 3D-printing. These features make it more affordable for beginners. The electronics of Opsoro robots are comprised of a Raspberry Pi single-board computer combined with a custom daughterboard to give the ability to interface with different sensors and actuators, bringing the robot to life. The board can drive 16 Radio Control (RC) hobby servos, one 5 W speaker, and a strip of addressable RGB LEDs. Sensing capabilities include 12 channels for capacitive touch sensors, as well as 4 generic analog inputs. The software offers four programming options; using built-in apps, using a visual programming environment based on Blockly, using Lua scripts, and using the Python API [5]. The starter kit costs $346, while the extension pack is an additional $218.
- iCub: Intelligent Cognitive Universal Body is a humanoid robot for research into human cognition and artificial intelligence. It has the size of a three and half year-old child, it is able to crawl on all fours and sit up to manipulate objects. Its hands have been designed to support sophisticate manipulation skills. The iCub is distributed as Open Source following the GPL/FDL licenses. 30 DOF have been allocated to the upper part of the body. The hands have 9 DOF each with three independent fingers and the fourth and fifth to be used for additional stability and support. The legs have 6 DOF each and are strong enough to allow bipedal locomotion. It is controlled by an an-board PC104 controller which communicates with the actuators and sensors and it is equipped with digital cameras, gyroscopes and accelerometers, microphones, and force/torque sensors. A distributed sensorized skin is under development using capacitive sensor technology. It is programmed in C++ and uses an open-source library, Yet Another Robotic Platform (YARP), for external communication via Gigabit Ethernet with off-board software [6]. iCub costs about $266,186.38, depending upon the version.
- Probo: Probo is a huggable animal-like robot, designed to act as a social interface. It is used as a platform to study human robot interaction (HRI) while employing human-like social cues and communication modalities. The robot has a fully actuated head, with 20 DOF, capable of showing facial expressions and making eye-contact [7]. The approximate cost of Probo is not defined.
- Ono: Ono is constructed from standardized components and readily available materials. The custom components of the robot can be produced using standard Computer Numerical Control (CNC) manufacturing techniques, mainly with laser cutting. Ono is a huggable, social robot for children. With 13 degrees of freedom, his face can express a wide range of emotions. The facial features of Ono are divided into modules. Each module is a group of related actuators, sensors and structural parts. The current prototype has 3 types of modules: 2 eye modules, 2 eyebrow modules, and 1 mouth module [8]. The cost to build Ono, is not defined.

2.2. Software

A robot needs intelligence in order to function. This intelligence can be applied by open-source robotic software, in terms of code, that anyone can inspect, redistribute, modify and enhance. A global network of programmers can improve the software by adding features to it or fixing parts that do not work correctly, thus, evolving it, increasing the reliability and decreased the cost.

- ROS: ROS (Robot Operating System) is a collection of libraries, drivers and tools for effective development and building of robot systems. It provides a Linux-like command tool, interprocess communication system and various application-related packages. The ROS-based software is language and platform-independent and it is implemented in C++, Python, and LISP. It has experimental libraries in Java and Lua. The ROS packages include many sensor drivers, navigation tools, environment mapping, path planning, interprocess communication visualization tool, a 3D environment visualization tool etc., that allow effective development of new robotic systems [9].
- URBI: URBI (Universal Robotic Body Interface) is used as tool for handling various software modules. It integrates and delivers communications between the two lowest levels of the architecture; thus, it permits dynamic loading of modules and total control of their operation. It also delivers urbiscript, a script programming language used in robotics, oriented towards parallel and event-based programming. Urbiscript syntax is based on widely-used programming languages, and it is integrated with C++ and other languages such as Java, MATLAB or Python. The orchestration mechanism that is built into URBI, can handle scheduling and parallelization of tasks, so all activities of the robot can be synchronized with each other [10].

- YARP: YARP supports building a robot control system as a collection of programs communicating in a peer-to-peer way, with an extensible family of connection types (tcp, udp, multicast, etc.) that can be swapped in and out to match all needs. YARP is written in C++. The Adaptive Communication Environment (ACE) library is used for Windows builds, and to support extra protocols. On Linux and macOS, ACE can optionally be omitted, giving a very light footprint [11].
- Glue.AI: Glue.AI is an open source toolbox of software and specifications used to build social robotics systems. It can be used to make engaging robot characters, running inside both actual robot hardware, and computer simulations. Each character may use a broad combination of physical, verbal, and musical features [12].
- NAOqi: NAOqi, the embedded software on social robot NAO, includes a highly cross-platform, fast, secure, reliable and distributed robotics framework which provides a comprehensive foundation for developers to leverage and improve NAO's functionality. Since 2011 a significant part of its source code is shared with the research and developer community with the aim of contributing to the well-being of humans. NAO is used by the world's most prestigious universities and laboratories including Harvard and Tokyo University as both a research platform and an educational tool [13].

2.3. Simulators

The robot's functionality needs to be tested before starting to assemble the hardware. Simulators play an important role in robotic applications as tools for testing the efficiency, safety and robustness of new algorithms. This is important in realistic scenarios that require robots to interact closely with humans, e.g., in special and typical education or in medical/assistive robotics.

- OpenHRP3: Open Architecture Humanoid Robotics Platform Version 3 is an integrated software platform for robot simulations and software developments. It allows the users to inspect an original robot model and control program by dynamics simulation. In addition, OpenHRP3 provides various software components and calculation libraries that can be used for robotics related software developments. It is developed by the Advanced Institute of Science and Technology (AIST), the University of Tokyo, and the Manufacturing Science and Technology Center (MSTC). This simulator has become popular not only in Japan but also abroad, to promote research into humanoid robot control [14].
- Gazebo: An apache-licensed simulation solution, with advanced 3D graphics for indoor and outdoor robots, virtual sensors, extensive command line tool collection and the ability to run simulations on cloud. Gazebo has a standard Player interface and a native interface. The Gazebo clients can access its data through a shared memory. In the process of dynamic simulation Gazebo can access multiple high-performance physics engines including Open Dynamics Engine (ODE), Bullet, Simbody and Dynamic Animation and Robotics Toolkit (DART). It provides realistic rendering of environments and it can generate sensor data, from laser range finders, 2D/3D cameras, Kinect style sensors, contact sensors, force torque etc. It supports many plugins and many robot models [15].
- SIGVerse: Several multi-agent simulation systems have been proposed for modeling factors such as social interactions and language evolution, whereas robotics researchers often use dynamics and sensor simulators. However, there is no integrated system that uses both physical simulations and social communication simulations. SocioIntelliGenesis (SIG) simulator is a simulator that combines dynamics, perception, and communication simulations for synthetic approaches to research into the genesis of social intelligence [16].
- SimSpark-SPL: SimSpark simulator for Standard Platform Legaue is a generic simulator for various multiagent simulations. It supports developing physical simulations for artificial intelligence and robotics research with an open-source application framework. Agents communicate with the simulation server via User Datagram Protocol (UDP) or Transmission Control Protocol (TCP), and therefore can be implemented in any language that supports such sockets. Multiple software agents can participate in one simulation. Simulations are created within the server using the Ruby language and text-based RSG files. SimSpark uses the Open Dynamics Engine (ODE) for detecting collisions and for simulating rigid body dynamics. ODE allows accurate simulation of the physical properties of objects such as velocity, inertia and friction [17].
- V-REP: V-REP (Virtual Robot Experimentation Platform) is a robot simulator with integrated development environment, based on a distributed control architecture. Each model can be controlled via an embedded script, a plugin, a ROS or BlueZero node, a remote API client, or a custom solution. This makes it versatile and ideal for multi-robot applications. Controllers can be programmed in C/C++, Python, Java, Lua, Matlab or Octave. It is used for fast algorithm development, factory automation simulations, fast prototyping and verification, robotics related education etc. [18].

3. OPEN-SOURCE SOCIAL ROBOTS IN EDUCATION

Social robots for education are becoming more available to the public and will play an essential role in the future in educational settings. Thus, it is important to study child-robot interaction and the effect of robots on children especially over a long term. Studies have shown that social robots can enhance playing, learning, self-confidence, social and cognitive skills [19]. In this section, the selected open-source platforms are evaluated according to the most recent results in educational settings. Tables 1, 2 and 3 summarize the applications of the bibliography where the selected open-source platforms for social robots' design have been used, the year of the application and the study details, for hardware, software and simulators, respectively.

Table 1

Application of the selected open-source robotic hardware in education

Open-source hardware (Study Year): Study details [Ref.]
Poppy (2014): A hackathon was organized in a Science Museum, for the general public around the assembly of a Poppy robot. It involved 15 robotic enthusiasts, from children to adults. In two days, this group of new users, self-trained using online documentation have been able to build from scratch the whole robot and make it move using the Pypot library. This experiment showed that the platform was easily usable in an educational context with users of all ages and it also revealed high educational value as testified by users and educators [20].
Opsoro (2017): Two educational initiatives that focused on teaching non-engineering students about robotics using Opsoro platform. In one initiative, a group of younger students, including those with autism spectrum disorder, received hands-on experience with robotics in a context that was not overly technical, while in the other initiative, college students in the social sciences and humanities developed robotics applications. Themes common to both initiatives were to reach non-technical students who are not traditional targets for robotics education and to focus their learning on creating interactive sequences for robots. Both initiatives were successful in terms of producing desired learning outcomes and fostering participant enjoyment [21].
iCub (2016): To investigate the functional and social acceptance of a humanoid robot, an experimental study with 56 adult participants and the iCub robot took place. Trust in the robot has been considered as a main indicator of acceptance in decision-making tasks characterized by perceptual uncertainty and socio-cognitive uncertainty and measured by the participants' conformation to the iCub's answers to specific questions. Participants conformed more to the iCub's answers when their decisions were about functional issues than when they were about social issues. Moreover, the few participants conforming to the iCub's answers for social issues also conformed less for functional issues. Trust in the robot's functional savvy did not thus seem to be a pre-requisite for trust in its social savvy. Finally, desire for control, attitude towards social influence of robots and type of interaction scenario did not influence the trust in iCub [22].
Probo (2014): This study investigates whether the social robot Probo could help children with autism spectrum disorders to enhance their performance in identifying situation-based emotions. Three participants, of age between 5 and 6, diagnosed with autism spectrum disorders were included in a single case experimental design, with inter-subject replications. The results showed that children's performance improved in identifying both sadness and happiness [23].
Ono (2016): A series of studies were conducted to understand therapists' attitudes towards robotic support and to discover what is most needed in such devices. An experimental study of the feasibility of robots playing one of those roles took place. Through observational studies and a series of ten meetings, with a group of seven therapists of autism, a list of possible roles was created. In a Wizard-of-Oz type experimental study, a robot was used to play a role of “emotional mirror” with seven therapist-child pairs. Study participants stated that a robot was acceptable and was not disturbing, although most did not find it particularly useful [24].

Table 2

Application of the selected open-source software in education

Open-source software (Study Year): Study details [Ref.]
ROS (2016): An embedded robotic platform was used for professional training in Electrical Engineering. ROS was used as communication and control software, to prove a better appropriation of theoretical concepts, increased students' enthusiasm, improved ease of communication and teamwork and greater interest in participation in research activities [25].
URBI (2015): The OSR platform URBI was used to control a robotic companion. Experiments demonstrated that both children and adults felt comfortable interacting with the robot and could easily recognize the emotions he expressed [26].
YARP (2012): Robots must be capable of interacting in a cooperative and adaptive manner with humans in open-ended tasks that can change in real-time. An important aspect of the robot behavior is the ability to acquire new knowledge of the cooperative tasks by observing and interacting with humans. This research presents results from a cooperative human–robot interaction system that has been specifically developed for portability between different humanoid platforms. The proposed system provides the ability to link actions into shared plans, that form the basis of human–robot cooperation, applying principles from human cognitive development to the domain of robot cognitive systems [27].
Glue.AI (2014): This research presents a novel, cost effective and indigenously developed educational framework for grasping hands-on concepts of Robotics and Mechatronics. The novelty of the platform lies in its ability to transform its shape from a humanoid to a wheeled mobile robot thus increasing the range of experiments that can be conducted using the proposed platform. Preliminary experiments demonstrate efficacy of the platform potentially useful for robotics community academicians, educationalists and hobbyists [28].
NAOqi (2018): This work presents a module to encourage children with autism to improve their social and communication skills, through a specially designed game-based approach. The humanoid robot NAO is utilized to autonomously engage with a child. The proposed module suggests a multiple role for the robot which can act as a teacher, as a toy and as a peer, through a successive set of joint activities. Overall observation encourages the utilization of NAO in the rehabilitation of children with autism [19].

4. DISCUSSION

Despite their potential as educational tools, robots are still not as widespread in schools as they could be. Among the possible reasons, the following might play a crucial role: 1) a versatile robot performing behaviors is a complex piece of technology and therefore expensive, thus, prevents most schools, which have a limited budget for equipment, from acquiring educational robots, 2) introducing robotic tools into teaching activities requires investment in time and training for the teachers. Therefore, to be accepted by teachers, robots must be both accessible with minimal effort and accompanied by well-prepared educational material shared among colleagues, 3) robot construction, use and programming is often perceived as a boyish activity. This also limits the potential of robots as general-purpose educational tools and 4) finally, many teachers are reluctant to follow new trends, especially if these are based on commercial arguments. Teachers prefer to invest in stable tools, in contrast to trends in current consumer technology [34].

Table 3

Application of the selected open-source simulators in education

Open-source simulator (Study Year): Study details [Ref.]
OpenHRP3 (2011): A virtual representation of a human-robot interface has severe advantages and attractive detailed visualizations of the results, auto collision checking visual representation of concepts from robotics teaching, etc. In order to interact with a Bioloid humanoid robot, a user interface in software is developed, for pedagogical representation of this robot [29].
Gazebo (2016): A graduate course project on humanoid robotics. The target was for the students to map human limbs into robotic joints, guarantee the stability of the robot and teleoperate the robot to perform the correct movement [30].
SIGVerse (2012): The aim of this work is to propose a cloud computing architecture simulation platform for social human-robot interaction. Three current applications are discussed for the validation of the cloud computing architecture in social human-robot interaction simulations [31].
SimSpark-SPL (2008): This paper presents the architecture and concepts of SimSpark, and its application in the RoboCup 3D Soccer Simulation League. Moreover, it presents ongoing and future development plans [32].
V-REP (2016): Students of a Master program used an OSR platform for hands-on laboratory sessions with mobile robots, to contribute to engineering studies [33].

Researchers in the field of robotics that investigate human-robot interaction, face the option between using an existing robotic platform or developing their own custom social robot. Both approaches have their challenges. Building a custom robot is time-consuming but it offers a large scale of flexibility. Using the commercial robots is more feasible, yet more expensive and inserts limits to the experimentation since the embodiment of the robot is usually hard to change [35]. The open-source approach is promising in robotics research, though this approach is not without its challenges. The main bottlenecks are: the lack of time for activities related to open-source, the difficulty of building communities around niche research topics and the challenge of consolidating open hardware approaches with traditional business models [8].

The open-source community promises to bring research-level robots into the undergraduate and high school classroom. Amateurs in robotics and non-specialists usually face some challenges. These challenges are 1) to building their first working robot system, 2) to obtaining relevant information about the open problems and existing solutions and 3) to find a community to demonstrate and compare their developments. Open-source robotic platforms allow participants with different levels and types of expertise to share their capabilities and introduce them to a wider audience. There are many potentials for the design and control of robots; many robotic competitions for students, to motivate and provide the tools with which student, could make novel contributions. Moreover, open-source robots can be used in large scale studies, by users that previously did not have access to social robots, such as students, hobbyists and social scientists [8].

5. CONCLUSIONS

This article summarizes the most popular up-to-date open-source platforms, that can support the development of social robots. Its scope is to analyze and evaluate the effectiveness of the open-source paradigm in real-life applications. Advantages and drawbacks of open-source robotic platforms are also discussed. The aim of the paper is to provide comprehensive knowledge of the available open-source robotic platforms, to enlighten amateurs and researchers regarding their usability and the possibilities they promise.

It should be acknowledged that the platforms presented in this work are selected by the authors based on the most recent reports in applications, according to the bibliography. Different criteria would have yield different platforms and reference articles.

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REFERENCES

[1] M. J. Timms, *Letting artificial intelligence in education out of the box: educational cobots and smart classrooms*, International Journal of Artificial Intelligence in Education, Vol. 26, 2016, pp. 701-712.

[2] F. Kirstein, R. V. Risager, *Social Robots in Educational Institutions: They came to stay: Introducing, Evaluating, and Securing Social Robots in Daily Education*, *Eleventh ACM/IEEE International Conference on Human Robot Interaction*, IEEE Press, March 2016, pp. 453-454.

[3] T. Pachidis, E. Vrochidou, V. G. Kaburlasos, S. Kostova, M. Bonković, V. Papić, *Social Robotics in Education: State-of-the-Art and Directions*, 27th International Conference on Robotics in Alpe-Adria-Danube Region, RAAD 2018, Patra, Greece, June 2018, 017, v3, pp. 1-11.

[4] Poppy, available at: `https://www.poppy-project.org/en/`, accessed: 02-07-2018.

[5] Opsoro, available at: `http://www.opsoro.com/`,accessed: 02-07-2018.

[6] iCub, available at: `http://www.icub.org/`, accessed: 02-07-2018.

[7] K. Goris, J. Saldien, D. Lefeber, *Probo: a testbed for human robot interaction*, 4th ACM/IEEE international conference on Human robot interaction, ACM, March 2009, pp. 253-254.

[8] C. Vandevelde, F.Wyffels, B. Vanderborght, J. Saldien, *An Open-Source Hardware Platform to Encourage Innovation*, IEEE Robotics & Automation Magazine, 2017, 1070(9932/17), 2.

[9] ROS, available at: `http://www.ros.org/`, accessed: 02-07-2018.

[10] URBI, available at: `https://urbi-project.soft112.com/`, accessed: 02-07-2018.

[11] YARP, available at: `http://www.yarp.it/`, accessed: 02-07-2018.

[12] Glue.AI, available at: `http://www.glue.ai/`, accessed: 02-07-2018.

[13] NAOqi, available at: `http://doc.aldebaran.com/2-4/naoqi/motion/index.html`, accessed: 02-07-2018.

[14] OpenHRP3, available at: `https://fkanehiro.github.io/openhrp3-doc/en/`,accessed: 02-07-2018.

[15] Gazebo, available at: `http://gazebosim.org/`, accessed: 02-07-2018.
[16] SIGVerse, available at: `http://www.sigverse.org/wiki/en/`, accessed: 02-07-2018.
[17] SimSpark-SPL, available at: `http://simspark.sourceforge.net/`, accessed: 02-07-2018.
[18] V-REP, available at: `http://www.coppeliarobotics.com/`, accessed: 02-07-2018.
[19] C. Lytridis, E. Vrochidou, S. Xatzistamatis, V. G. Kaburlasos, *Social Engagement Interaction Games between Children and Humanoid Robot NAO*, The 13th International Conference on Soft Computing Models in Industrial and Environmental Applications ICEUTE'18, Springer, Cham., San Sebastian, Spain., June 2018, pp. 562-570,
[20] M. Lapeyre, P. Rouanet, J. Grizou, S. Nguyen, F. Depraetre, A. Le Falher, P. Y. Oudeyer, *Poppy project: open-source fabrication of 3D printed humanoid robot for science, education and art*, In Digital Intelligence, 2014, pp. 6.
[21] J. D. Zenk, C. R. Crowell, M. Villano, J. Kaboski, K. Tang, J. Diehl, *Unconventional students in robotics and HRI education: a review of two initiatives*, Journal of Human-Robot Interaction, Vol. 6, No. 2, 2017, pp. 92-110.
[22] I. Gaudiello, E. Zibetti, S. Lefort, M.Chetouani, S. Ivaldi, *Trust as indicator of robot functional and social acceptance. An experimental study on user conformation to iCub answers*, Computers in Human Behavior, Vol. 61, 2016, pp. 633-655.
[23] C. A. Pop, R. Simut, S. Pintea, J. Saldien, A. Rusu, D. David, B. Vanderborght, *Can the social robot Probo help children with autism to identify situation-based emotions? A series of single case experiments*, International Journal of Humanoid Robotics, Vol. 10, No. 03, 2013, pp. 1350025.
[24] I. Zubrycki, G. Granosik, *Understanding therapists' needs and attitudes towards robotic support. the roboterapia project*, International Journal of Social Robotics, Vol. 8, No. 4, 2016, pp. 553-563.
[25] F. Martínez, H.Montiel, H. Valderrama, *Using embedded robotic platform and problem-based learning for engineering education*, Smart Education and e-Learning, Springer, Cham., 2016, pp. 435-445, 2016.
[26] J. Kędzierski, P. Kaczmarek, M. Dziergwa. K. Tchoń, *Design for a robotic companion*, International Journal of Humanoid Robotics, Vol. 12, 2015, pp. 1550007.
[27] S. Lallée, U. Pattacini, S. Lemaignan, A. Lenz, C. Melhuish, L. Natale, G. Metta, *Towards a platform-independent cooperative human robot interaction system: III an architecture for learning and executing actions and shared plans*, IEEE Transactions on Autonomous Mental Development, Vol. 4, No. 3, 2012, pp. 239.
[28] A. H. Arif, M. Waqas, U. ur Rahman, S. Anwar, A. Malik, J. Iqbal, *A hybrid humanoid-wheeled mobile robotic educational platform–design and prototyping*, Indian Journal of Science and Technology, Vol. 7, no. 12, 2015, pp. 2140-2148.
[29] V. Nunez, U. Zaldivar, D. Rodriguez, V. Rodriguez, P. Espino, A. Sapiens, U*ser Interface for Interaction with a Virtual and Real Humanoid Robot*, XIII Congreso Mexicano de Robótica, Matehuala, Mexico, 2011.
[30] S. Michieletto, E. Tosello, E. Pagello E. Menegatti, *Teaching humanoid robotics by means of human teleoperation through RGB-D sensors*, Robotics and Autonomous Systems, Vol. 75, 2016, pp. 671-678.
[31] J. T. C. Tan, T. Inamura, S*igverse-a cloud computing architecture simulation platform for social human-robot interaction*, 2012 IEEE International Conference on Robotics and Automation (ICRA), IEEE, May 2012, pp. 1310-1315.
[32] J. Boedecker, M. Asada, *Simspark–concepts and application in the robocup 3d soccer simulation league*, Autonomous Robots, Vol. 174, 2008, pp. 181.
[33] E. Fabregas, G. Farias, S. Dormido-Canto, M. Guinaldo, J. Sánchez, S. D. Bencomo, *Platform for teaching mobile robotics*, Journal of Intelligent & Robotic Systems, Vol. 81, 2016, pp. 131-143.
[34] F. Mondada, M. Bonani, F. Riedo, M. Briod, L. Pereyre, P. Rétornaz, S. Magnenat, *The Thymio Open-Source Hardware Robot*, IEEE Robotics & Automation Magazine, 20017, 1070(9932/17), 2.
[35] C. Vandevelde, J. Saldien, M. C. Ciocci, B. Vanderborght, *Ono, a DIY open source platform for social robotics*, International conference on tangible, embedded and embodied interaction, 2014.