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Developing of KUKA youBot Software for Education Process

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Nowadays robotic manipulators are in almost all industrial processes, especially in the food area. The rate of development for the robot industry are growing every year and respectively grows the number of conferences and exhibitions. However, there is a task in providing personnel training for tuning, control and maintenance manipulators. The goal of the present work is to describe the structure of application, principles of user interaction and base of the first year students education with developed software. Main advantage of proposed software has client-server architecture that allows to carry out tasks not only in high school or university, but also in the industry worldwide. Students requires a PC or any mobile device to run the application. Popular conceptions of internet education and free education would be provided. In addition, there is a possibility to add own static and dynamic object to scene thanks to the open source Blender software. This allows to develop large class of different student tasks. Another benefit is using open source graphical engine Blend4Web due to the fact that it avoids to install any additional software.

1. Introduction

Nowadays on-line methods of education are growth rapidly. There are many education portals in World Wide Web, which make free of scientific journals, e-learning courses and University infrastructure elements. There are ways for getting feedback from lecturers, too.

On the one hand, all this sources provide theoretical and practical basis. On the other hand, sources are undeveloped, because they do not allow reinforcement of learning through the solutions of practical tasks. It tends to reduce of knowledge consolidation. These aspects are especially critical for technical specialists training. Described problem could be solved with including in education process work with real technical device. It is necessary to set up virtual remote laboratory with special software for extramural students, students from another Universities and secondary school students. The use of remote laboratories has been received with great interest in secondary schools since these resources are seen as a great chance to convert into practice theoretical contents, especially in areas such as electronics, robotics or control systems (Potkonjak et al., 2016).

Nowadays, robotics are widely used in food and chemical engineering and employers are looking for workers with knowledge and skills in this area. Academies are therefore moving towards the perspective to form these competences and, for instance, a Master of Science program for chemical and nuclear engineering (Goryunov et al., 2015) have been recently activated in Tomsk Polytechnic University including educational course in robotics.

The new approach of KUKA youBot remote programming is described in present work. It consists of a client/server architecture. Client interaction with developed software is organized with Web browser. It obviate the need for setup addition software, plugins. Therefore, the student could use PC, laptop, tablet or phone with java browser. Unique feature of developed software is ability of robot behavior strategy verification via program or with a real robot.

2. Robot programming software

Nowadays there are many integrated development environments (IDE) for robot motion planning. Formally, from one side it could be graded into GUI features: visual programming environments and text-based programming environments. Again, each group includes problem-solving environments and universal IDEs (that are support different models of robots). Neverthless, from other side, IDEs could be classified into functional features and implementation: educational and industrial IDEs.

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For instance, IDE NXT-G (Center for Engineering Education and Outreach, 2013) and Trik Studio (KiberTech LLC, 2016) could be referred into visual educational IDEs. NXT-G is a graphical IDE, developed for popular customizable, programmable robots Lego Mindstorms NXT. It uses for NXT Brick module programming. This software has intuitive interface. Program developing looks like a timed sequence block diagram. Program flow determinates by instructions sequence. Trik Studio is commercial software oriented for education Trik robot programming. It includes simulator, that allows to test program without real robot system.

In addition, there is a Microsoft Robotics Developer Studio (MRDS) (Microsoft, 2016). It could be referred into semi educational and industrial visual IDE. MRDS platform includes Visual Programming language (VPL) and visual simulated 3D environment. VPL recommended for newbies. It uses for programming strategies as block diagram. MRDS also support C# for professional developers.

Among the educational problem-solving text-based environments are the most popular IDEs RobotC (Robomatter Inc., 2014) and BricxCC (BricxCC, 2011). RobotC is a leader among programming languages for robot competitions. It is based on C programming language, has no freeware version. BricxCC is the most popular freeware supporting programming language NXC. There are many block for work with Lego Mindstorms. This software even can exchange standard Lego software, except drivers. There is multi-level access to device, realized with special libraries. For example, there are memory call (by physical address) and low-level input-output referencing.

In addition, there is a universal educational text-based IDE Arduino (Arduino, 2017). It got widespread use due to Arduino usage for education. Arduino GUI contains text console, tool and menu bars. Software allows transmitting data to controller.

Comparison study of educational IDEs is presented in Table 1.

There are five the most popular IDEs for industrial and science using: KUKA Sim Pro (KUKA AG, 2017), RobotStudio (ABB, 2017), MotoSim Touch (Yaskawa, 2017), V-REP (Coppelia Robotics GmbH, 2016), RoboDK (RoboDK, 2017).

RobotStudio based on ABB VirtualController. It allows simulating with high level of reality, using real-time program and configuring models as well as the real manipulators. For this software developed special plugins (PowerPacs) for different industrial processes: ArcWelding PowerPac, Cutting PowerPac, Painting PowerPac, Palletizing PowerPac, Picking PowerPac and so on. Each PowerPac has own specific interface.

MotoSim Touch is an effective, autonomous IDE. It developed special for Universities and research centers. This IDE contains programming system MotoSim Touch and virtual robotic controller MotoSim EG-VRC. MotoSim Touch can switch between two modes: software (virtual) and hardware. Each of modes uses MotoSim-EG-VRC for offline programming education and virtual modeling.

KUKA Sim Pro is a software for 3D modelling with KUKA Robotics. It is a specific software for research centers and system integrators. It is an official software of German company KUKA AG. There are many components in standard library of KUKA Sim Pro. Intelligent components have grasp points that are allowed to connect their between themselves. Connections also possible with analog and digital signals KUKA.OfficeLite. There is an open script language Python 2.6 for user's process programming. KUKA Sim Pro supports API and COM for developing user's plugins.

RoboDK is a powerful tool for autonomous programming and modeling complex processes. Software developer is Canadian company École de Technologie Supérieure (ETS). This software allows developing and simulating robot's behavior strategy of different manufacturers with Python language. In addition, there is a possibility of developing programs with special languages for different models: for instance, RAPID – for ABB robotics, KRL – for KUKA robotics and so on. RoboDK software supports more than 200 robot models of different manufacturers. It is cross platform free software (Windows, Mac, Linux). There are API and C/C++, Python, Java, Lua, Matlab, Octave, Urbi support.

The last of studied software is V-REP. It has free version for education. Software developer is Sweden company Coppelia Robotics. Software developed for quick process modelling, verification, remote monitoring of robotic systems. It has distributed control architecture: each object/model can be controlled individually with own scenario (script), plugin, robot operating system (ROS) node, remote client's API. V-REP is a perfect solution for developing multi-robot control systems.

Table 1: Comparison study of educational IDEs

Educational IDE	Advantages	Disadvantages	Application area
NXT-G	Easy of use; interface clearness	Definition of variables is not quick and easy; crockhood	Developing simple program. Good for school children
Microsoft Robotics Developer Studio	High-level programming; include simulator, that allows to check the program without real robot system; supports widespread of robot systems	Definition of variables is not quick and easy; crockhood; cannot upload program to robot (communication only with Bluetooth)	Software could be used for academic and commercial purposes
Trik Studio	Include simulator, that allows to check the program without real robot system	Crockhood; oriented only for one robot; do not support Lego	Using for programming Trik robots
RobotC	Based on C programming language; there is no age limit; there are many free lessons	commercial software	For robot competitions
BricxCC	User-friendly interface; Combination high-level and low-level commands; Accuracy of control	Has no visualization; bags	Using for Lego programming
Arduino	NXC support; Accuracy of control	Do not support Lego; oriented only to Arduino platform; necessary to know microelectronics	Arduino robot programming

Table 2: Comparison study of industrial IDEs

Software feature / IDE	V-REP	RoboDK	Kuka Sim Pro	RobotStudio	MotoSim Touch
Free version	+	+	-	+	+
Big product scope	+	+	+	+	+
Support of different manufacturers	+	+	-	-	-
Cross platform software	+	+	+	+	+
Support 3D animation in the PDF	-	-	+	-	-
API and addition libraries	+	+	+	+	+
Client-Server version	-	-	-	-	-
Basic programming language	Lua	Python	Python	Rapid	Arduino

As seen from Table 1, there is no software for online robot programming. It is necessary for organization educational online laboratory. Therefore, authors decide to develop own software for online access to the robot platform. There is the Robot Manufacturing Laboratory in Tomsk Polytechnic University. It opened together with KUKA Russian division. So, KUKA youBot platform with robotic-arm was chosen for testing.

3. Software description

KUKA youBot is a mobile manipulator with omnidirectional holonomic platform (Bischoff et al., 2011). It allows studying fundamentals of robotics, programming techniques and robot control. Robot programming accomplishes with internal KUKA youBot API. There is a source code with manual. General characteristics of

KUKA youBot arm and platform presented in work (Bischoff et al., 2011). Into platform, a mini ITX PC was integrated. Recommended operation system is Linux.

According to developers recommendations (Bischoff et al., 2011) user need to know C++, knowledge of architecture of KUKA youBot API, kinematic properties of platform and arm, interpolation methods. Requirement of solutions in different scientific and engineering missions simultaneously can be a source of problems with developing robot program. For this reason, special software was developed. Its structure is sketched in Figure 1.

Developed software is a web application. Server part written in Python and based on a flask framework, which follows the model-view-template (MVT) architectural pattern. Template consist of html-page and 3D scene with KUKA youBot model. Scene loading and interaction user with scene organized with Blend4Web library. Blend4Web is a web-oriented 3D engine – a software framework for authoring and inter-active rendering of three-dimensional graphics and audio in browsers. The Blend4Web framework is integrated tightly with Blender (Lesage et al., 2007) - a 3D modelling and animation tool. The content is rendered by means of WebGL and other browser technologies, without the use of plugins. Technically, Blend4Web is a library for web pages, a Blender add-on and some tools for debugging and optimization.

Web application uses 3D scenes in json format, developed in Blender. Scene contains KUKA youBot model and ambient objects. User interaction organized with JavaScript program. It uses Blend4Web for animation and sends the post request to server for saving scenario of robot behavior. Python script that includes into server part has functions: saving user scenarios, loading scenarios, launch binary program that is translates scenario to KUKA youBot API, importing data form KUKA youBot console. After processing the request, on the user's screen will shown interface, presented in Figure 2.

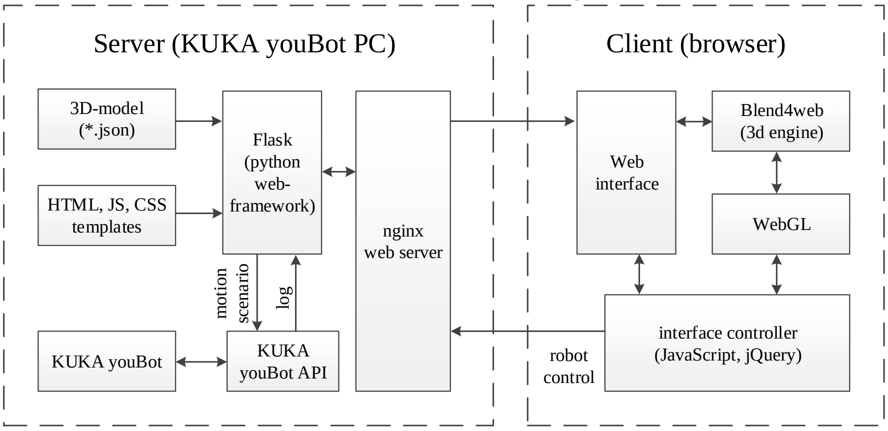

Figure 1: Structure of "youBot manager"

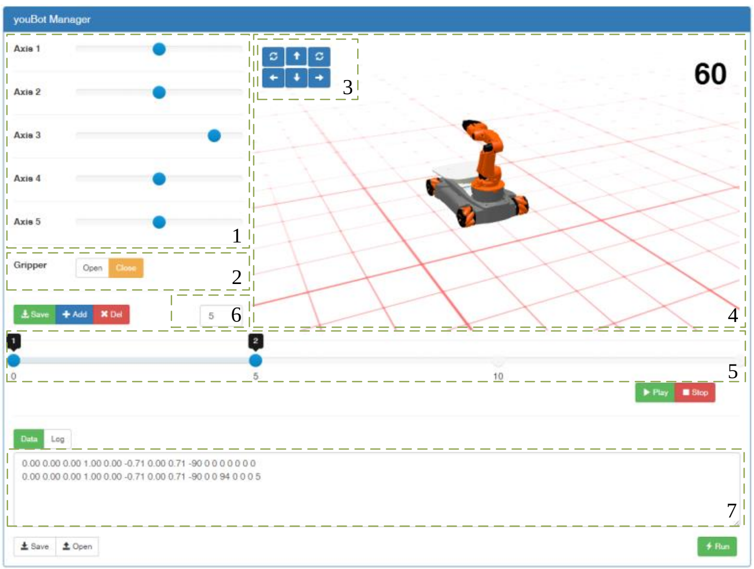

Figure 2: "youBot Manager" interface

Position control operation of an arm is carried out with sliders, placed in area 1. Gripper status fixes in area 2. Platform spatial motion and rotation run over buttons, placed in area 3.
Scene with KUKA youBot model are shown in area 4. Grid size equals 25 cm. User can control camera with mouse, as in computer game.
Button “Save” start save spatial motion of platform and arm in memory. Coordinates of platform and arm also save in slider-2 position from area 5. User can set the time of operation in area 6. After pressing of button “Play”, simulation starts. It can be terminated after completing all motions or with “Stop” button.
Buttons “Data” and “Log” switches the mode of area 7. If “Data” mode is chosen, coordinates of platform and arm will shown. in area 7. In “Log” mode supporting information, input and robot errors show in area 7. “Run” button starts the simulation of KUKA youBot.

4. Usability and performance testing

Developed software tested with Windows 7, 10 in Google Chrome, Microsoft Explorer, Microsoft Edge, Opera, Mozilla Firefox browsers. It includes 32 and 64-bit architecture. In all the tests, CPU load does not exceed 20 %, utilized R/W memory does not exceed 250 Mb. In Mozilla Firefox browser for 32-version leak was observable because of Blend4Web engine. It confirms by engine developers. In addition, software tested in Google Chrome, Opera and Firefox browsers for Android. Minimal comfortable screen resolution on mobile device is 640x480 in landscape mode. Fps does not exceed 15 on the mobile device without hardware acceleration WebGL. Initial program load with KUKA youBot, connected with Wi-Fi, does not exceed 7 seconds. Reloading process requires less than 2 seconds.
Theoretically, maximum number of users does not limited, but empirical test confirmed capability of software deal with 50 inquiries per second.
Take the usability testing was among 22 students, studying in Master of Science program for chemical and nuclear engineering of Tomsk Polytechnic University (Goryunov et al., 2015). Observation evaluation method (Carvalho, 2002) of “youBot Manager” was checked in the case of the platform motion between walls (maze performance) laboratory work. Aim of this task is platform motion through the labyrinth. Platform will not contact with the walls. In the test, authors registered actual activity completion time, task success, error rate. Test results are presented in Table 3.

Table 3: Results of usability testing

no	Phase of a programme	scheduled time	actual activity completion time	task success	error rate
1	youBot characteristics familiarization	30	20.0	99,95	1.1
2	«youBot Manager” software familiarization	20	12.9	99,95	0.4
3	youBot clockwise rotation on 90˚	10	6.1	100	0.3
4	youBot platform motion from point 1 to point 2	5	3.7	100	0.1
5	youBot platform motion from point 2 to point 3 (“strafe motion”)	5	2.1	100	0.1
6	youBot platform counterclockwise rotation on 180˚	5	1.9	100	0.0
7	youBot platform motion from point 3 to point 4	5	1.6	100	0.0
8	youBot platform diagonally motion from point 4 to point 5	10	3.9	100	0.0
9	youBot clockwise rotation on 90˚	5	1.1	100	0.0
10	youBot platform motion from point 5 to point 6	5	2.1	100	0.0
11	Scenario simulation	15	8.0	100	0.0
12	Test on the actual unit	20	13.8	100	0.0

Data from Table 3 confirms that everybody from the test group successfully fulfill the tasks. Two persons had troubles with the first and second tasks, but then they successfully complete it.

5. Conclusions

Modern education is impossible without Internet. Access to text and media educational content erases territorial limitation and allows checking and analyzing experience of different high schools. However, existing software cannot be used for remote training organization in robotic area. In addition, whizzbang technician in robotic area training is under way offline. In this case, student develops program step-by-step and verifies code from time to time.

It serious limits to train several students with one device simultaneously. Support actual laboratory facilities in multiple copies is economically unwise.
Result of the proposed paper is “youBot Manager” software. It is web application for visual programming and simulation strategy of KUKA youBot behavior. There is no need for additional plugins setup through the use of Blend4Web library and WebGL technology.
Using of free software Blender for scene preparation allows teacher to determine necessary scenario of laboratory work. It can be walls, angled surface and special objects for gripping and so on. Change initial conditions (environment) around the KUKA youBot model does not influence to the work of program, because motion visualization realized in Blender with bone system. It allows to determinate position of each arm axis with high accuracy. So, developed software can be used for education secondary and high school students.
Then authors will include feedback from internal and external KUKA youBot sensors. It will allow to develop modern decision-making algorithm.

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