CVCER: Robot to Learn Basics of Computer Vision and Cryptography

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Abstract. This paper describes the design of CVCER (Computer Vision and Cryptography Educational Robot) - the working model of the mobile robot used as a training stand for students. We describe the hardware and software of the robot. Hardware part of the robot can be used to teach the basics of robot architecture and software part can be used to teach the basics of computer vision and cryptography. The main goal of the project was to create a low cost, re-configurable and re-programmable robotic platform that could be used to teach the basics of the subjects described above and to test the algorithms written by students having internships in our institute and partner university.

1. Introduction

Research and development in the area of robotics during past decades brought new subjects into an educational program of schools and universities. Highly motivated scientists and hobbyists are creating and developing new platforms, educational programs, and methods of teaching STEM subjects like physics, mathematics, engineering, etc [1-3]. However, most of robots are vendor-dependent, without source code and expensive. Aim of this paper is to describe the process of continual development of a robotic platform, which can be used in teaching STEM subjects and basics of Robotics, Control Theory, Machine Vision, Information Security, and building blocks of which can be bought or 3D printed and used to test robotics projects or in competitions. To reach this aims we developed CVCER - cheap, flexible and multi-functional robotic platform that makes use of mecanum wheels. CVCER's hardware part is built using Arduino platform, which is most popular hardware-platform that gives open architecture and lot of compatible sensor sets. Moreover, article describes successive to previously described project [4] steps in creating easy to use libraries on the basics of tracking objects and data encryption using the CVCER robot.

CVCER is an educational robotic platform (Fig. 1) that was firstly developed as a platform for practical realization of Machine Vision algorithms, now the system evolved and we wanted to be able to teach Information Security basics with the help of the system. From this field we wanted to teach the basics of information retrieval between the operator and robotics system, that is why to ensure the privacy of sent commands we developed a system with an information security using and NPNs algorithm described in [5]. The advantage of this platform, compared to other similar platforms, is that it is built from affordable parts, on open architecture (all parts, except wheels and driving mechanisms, can be printed out using 3D printing technology), and meets university-level functionality. In our work the main aim is not to teach the basics of constructing physical robot by joining different 3D printed objects but to foster the teaching of development of control, pattern recognition, and information security algorithms and immediate testing of result on the platform because the real-life tests drive more attention in training process than simulation or theoretical results [6,7,8]. To make the process easier, OpenCV library was used for the purpose of implementation of computer vision teaching software. First part of the article describes the platform architecture. In second paragraph, we describe the developed software architecture. Third paragraph is about use cases and scenarios.

2. Platform

CVCER body is made from 3D printed chassis [4] with modification: two middle wheels have been refused to make the system more flexible and all wheels were replaced by omni-wheels that also adds flexibility. Body frame is made from perforated aluminum that makes platform flexible to any modification and attachment of additional equipment. For now, two NiMH batteries with 7.2 Volts and 2000mAH connected in parallel (7.2V and 4000mAH in total) gives the system 50-60 minutes of life to power the platform. Parts can be replaced and new parts can be easily adjusted to the base that has drilled holes. Movement of the platform is done using four motors: two motors on each side of the platform. Each motor can be programmed to move on its own, which gives more flexibility in motion planning, because you can control almost any behavior of the platform by using the torque from each of them. Micro-controller board in combination with two motor shields are used to control motors - each motor shield is responsible for two motors making you able to control speed and direction of each motor.

Figure 1. CVCER robotic platform

Raspberry Pi 3 Model B and Arduino Mega 2560 are selected as the brain and motion control unit of the robot. Raspberry Pi includes 802.11n Wi-Fi, Bluetooth 4, and Quad Core 1.2GHz Broadcom BCM2837 64bit CPU with 1 Gb RAM [9,10]. Such characteristics and capability of using Linux-type operating system makes it one of the most commonly used single-board computers for robotics projects. Moreover, it makes possible the usage of OpenCV, Python and programmable GPIO's - functions that perfectly suit the aim of our project. Because we have to run object recognition and data decryption programs, as well as sending control commands to Arduino to perform motion.

Arduino is very popular platform for robotics. Its flexibility and availability makes it ideal for fast prototyping and experiments. Arduino Mega 2560 is used as main controller. This board is based on the ATmega2560 chip and has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog pins [11].

Description of mechanical and electronic parts you can read from our previous work [4]. Usage of the Arduino makes the hardware part of the system easy to assemble and program.

Platform makes use of mecanum wheels to add the flexibility and fast side-to-side movements [12,13].

In the given system, four wheels are placed like standard wheels of four-wheeled car, it gives the system stability and simplifies control approach [14]. Moreover, this makes the object tracking task easier by enabling the platform to follow the object without turning the whole chassis.
Motion control is written using IICTv3.h library used in previous version of the system. Additional functionality was added including the motion control of the 2DOF camera mount. Camera mount is a pan and tilt system driven by two Hitec HS-785HB servos and able to work with maximum payload of 2.5 kgs. Power is supplied using 11.1V 5000 mAh Li-Po battery by placing the voltage regulator which reduces the voltage to 5V.
Combination of two MegaVideo cameras with optical zoom lenses by Arecont vision was used as the vision system.

3. Software

One of the main goals of the robot is to use the most advanced programming tools in robotics. Different architecture of the robot allows for it. As mentioned earlier, the robot is composed of several parts. Therefore, the latest complete software consists of a combination of several components (Fig. 2 software architecture). We believe that last year students are familiar with basics of programming languages.
The advantage of the project is that the user has no restrictions on hardware and software. That is, a student can use the programming language based on his choice, programming environment and methods, different algorithms, and, if necessary, additional devices (motors, sensors, etc.). This can lead to robotic manipulation or autonomous control.
Depending on the purpose of the user, each piece of the robot can be programmed individually.

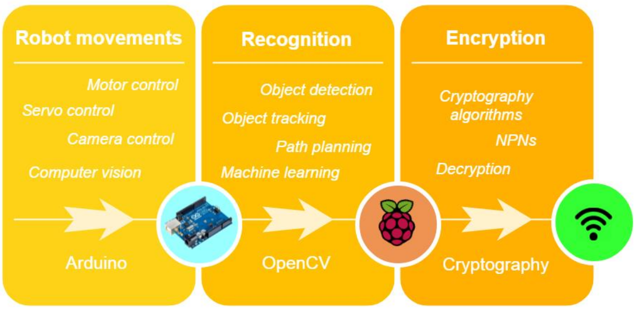

Figure 2. Architecture of the software

3.1. Programming basic behaviours of the robot

At this stage, user needs to move devices connected to the Arduino platform (originally 4 motors and 2 servomotors). Code should be written in C/C++ language in the Arduino IDE environment. For this purpose, user can program on his own or perform programming using our IICTv3.h library by just using key functions for motion programming (like forward(seconds), backwards(seconds), left(seconds), right(seconds), etc). The main purpose of this stage is to carry out all possible movements of the robot.

3.2. Object recognition algorithms and the robot movement based on machine vision

Since the platform is designed to be used at different levels of learning, the connection of robot motion and computer vision parts should be made to meet this differentiation (it should be made to make everyone familiar with the connection of these two parts). A combination of two cameras makes it possible to use stereo vision approaches and camera mount with 2 DOF allows user to learn basics of trajectory generation, motion planning and perform object tracking and mecanum wheels makes the object following simpler by making it possible not to turn the whole platform. OpenCV's basic template matching methods (square difference matching, correlation matching, correlation coefficient matching, normalized square difference matching, normalized correlation matching, and normalized correlation coefficient matching) were used to perform the task of recognition of the object, the corresponding functions were written to be able to test each method by using just single line of code. Object tracking and following tasks were made to give simple two variable outputs that denotes the distance and angle to object from the optical center of the cameras. This part was written as the C++ console application on Raspberry platform that sends the necessary commands to the Arduino board.

3.3. Application of the encryption algorithm for robot control

There is a need to encrypt the security of data exchange between the robot and the other device. To that end, the user can use the encryption algorithm based on non-positional polynomial notations developed by our colleagues [5]. Keys of different lengths are required for encryption and decryption between the operator and the robot. It is generated in a special program on the computer where the control point is located and is sent to the computer on a mobile robot through WiFi.

4. Conclusions

The article gives brief description of the motion control, computer vision strategies and encryption algorithm used in the development of mobile educational robot. It describes the achieved results, ideas used and in future report will be described the ready-to-use software package with friendly GUI, rebrained and finished backend and polished body. As the platform has the ability to hold different sensors and additional hardware, by adding them and including additional functions in combination with our library users can modify and enhance the capabilities of the system. Presented library includes commands for setting up pins, driving motors, turning the platform, pre-written commands for combination of joystick buttons (if user is going to use them), basic computer vision algorithms and encryption algorithm. The mobile platform was developed to help beginners – enthusiasts, school and university students – to become familiar with the basics of development of robot systems, which involves different fields of study. We picked up trending areas of robotics and computer science fields and tried to make the robotics software development and motion programming easier, more understandable by providing live examples of how things made and what processes robot developers are undergoing during the development cycle. We also used most popular computer vision library, encryption algorithm and motion control library developed in our institution to make it easy to get the documentation (in case of OpenCV) and help from community as well as to describe the technologies from first person view (as we have the direct connections with each of the developers of the given system). Future report will also be about the development of the described system, but more detailed insights will be given to each part.

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