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A PROPOSAL OF AN EXO-GLOVE ADAPTATION FOR INTERNET OF THINGS APPLICATIONS

ABSTRACT

We are building a prototype of an innovative wearable robotic glove (or exo-glove) for the applications in Internet of Things that will allow us to control remote device over unlimited distance using Internet. Our aim is to use this wireless exo-glove mostly in telemedicine and telemetry applications. This article is an initial presentation of our concept and the prototype.

KEYWORDS

robotic glove, exo-glove, IoT, remote control, telemedicine, Internet of Things, telemetry, wearables

1. Introduction

The number of areas of the economy where robots are not used nowadays is extremely limited. We can find them virtually everywhere around us, being used in every aspect of our lives [1][2]. Similarly, telemetry that allows remote control of devices, including robots, and remote data collection gains interest over past few years [3]. This is especially observed in telemedicine and in other biomedical applications of telemetry [4][5].

As a part of student's project for the engineering degree a wearable exo-glove for remote controlling of a robot was built. The project consists of an example robotic car and a controller in form of a wearable glove. Communication between both devices is maintained with HC 12 radio module which allows exchanging data wirelessly to up to one thousand meters distances. Signals received from the exo-glove's sensors are detected and processed by an Arduino Nano microcontroller, sent over the air thanks to HC 12 and received and processed by another Arduino Nano, installed on-board example robotic car. This setup allows a one-hand controlling and manipulation of a robotic car.

Our proposal and a prototype being constructed focuses on introducing an Internet communication between robotic glove and a controlled device (example robotic car in this case). Instead of sending data over radio we want it to be transmitted over Internet, through TCP/IP protocol, received and processed by a distant server and then received from this server (after signal processing) by any controlled device. In other words, we want to replicate the existing solution to allow wireless controlling of a robotic device with no distance limit.

Similar solutions were presented over passed years, especially in telemedicine, for remote-controller and distant-conducted surgery operations. Most, if not all of them assumed using expensive devices. Our proposed prototype is aimed to answer whether similar solution could be achieve using cheap hobbyist electronic elements available in every electronic store or on-line.

2. Theoretical basics
2.1. Microcontrollers

In both student's project and in a prototype being constructed a pair of Arduino microcontrollers are used. Then one responsible for processing signals from exo-glove is Arduino Nano Clone ATMega328P + CH340 [6] and the one that controls robotic car is Arduino UNO R3 Clone ATMega328P + Mega16U2 [7]. In addition, in our proposed proto-type we are using ENC28J60 Ethernet Shield for Arduino Nano [8] and W5100 Ethernet Shield for Arduino Uno [9].

In general, Arduino is a microcontroller board that, among other things, has digital and analog input-output lines, and a UART interface for communication with a computer, another Arduino, or other electronic device. Power to Ar-duino is supplied by connecting the GND (-) and VIN (+) inputs. Typical Arduino board can work on the voltage in 7-12 V range.

2.2. Exo-glove

The glove has five resistance sensors, each for a different finger. Arduino cannot detect the resistance changes di-rectly, but it can read the change of the voltage. That is why a voltage divider was used, which allows to "translate" changes of resistance detected on the sensors into changes of voltage. The input parameters of the glove control system are given in the below tables. Values were measured for 0 degrees flexion of the fingers (flat position) and 90 degrees flexion of the fingers (bent position). Both current and voltage were measured for this purpose.

Tab. 1. Sensor resistance and measured voltage and current for a bent finger
Tab. 1. Rezystancja czujnika oraz mierzone napięcie i natężenie prądu dla palca zgiętego

Finger	Resistance [Ω]	Voltage [V]	Current [A]
1	470	1.598639	0.001598639
2	410	1.453901	0.001453901
3	145	0.633188	0.000633188
4	260	1.031746	0.001031746
5	300	1.153846	0.001153846

Source: Own work

Tab. 2. Sensor resistance and measured voltage and current for a straight finger
Tab. 2. Rezystancja czujnika oraz mierzone napięcie i natężenie prądu dla palca wyprostowanego

Finger	Resistance [Ω]	Voltage [V]	Current [A]
1	1400	2.916667	0.002917
2	11000	4.583333	0.004583
3	1000	2.5	0.0025
4	850	2.297297	0.002297
5	80000	4.938272	0.004938

Source: Own work

The summarized current consumption when all fingers are bent, rounded to two significant numbers, is 0.0059 A. And when all are straightened up — 0.017 A. According to the manufacturer's manual, Arduino Nano consumes 0.019 A during regular operation, and the radio module when sending data 0.1 A data. Therefore, the maximum current consumption is 0.136 A. In the original student's thesis, a 6F22 battery (9 V) was used. It has an approximate capacity of 0.4 Ah. This means that the glove can work for approximately three hours. This is by far not enough for any reasonable application, so replacing the 6F22 battery with a rechargeable battery.

2.3. Communication

Communication between the glove and the robot uses two HC 12 radio modules. The glove is based on the Ar-duino Nano and sends data wirelessly corresponding to the current hand movements. A robot is built based on the Ar-duino Uno, and it receives data and transforms it into motion or other kind of operations.

HC-12 wireless communication module is a new-generation multichannel embedded wireless data transmission module, acting as a serial port for data transmission. Its wireless working frequency band is 433.4-473.0 MHz. Multiple channels can be set, with the stepping of 400 kHz, and there are totally one hundred channels to be used, if needed. The maximum transmitting power of module is 100 mW (20 dBm), the receiving sensitivity is -117 dBm at 5,000 bps baud rate. Communication distance is up to one kilometer (1,000 m) in the open air and hundreds of meters in the closed area [10].

3. Construction
3.1. Exo-glove

The entire glove was designed in Fusion 360 application, split into two parts (finger rings and a control box). All the elements were printed using a 3D printer. Construction assumes three rings for each of the four long fingers and two rings for the thumb. Each ring has tapping at the top, to which velostat sensors are attached. For each fingers sensor tapping is the same (identical dimensions) while finger rings set are different per each finger. The radius of each finger ring is significantly larger than the radius of the corresponding finger, because when the finger is bent, the skin folds and the finger change its volume significantly.

3.2. Finger movement's sensors

The sensors are built using copper tape, velostat, plexiglass and electric wires. Velostat is a material with a thick-ness of 0.1 mm, made of a polymer foil impregnated with carbon. This makes the material conductive to an electric current and to change its resistance with pressure or bending.

Example set of finger rings is depicted in the following image.

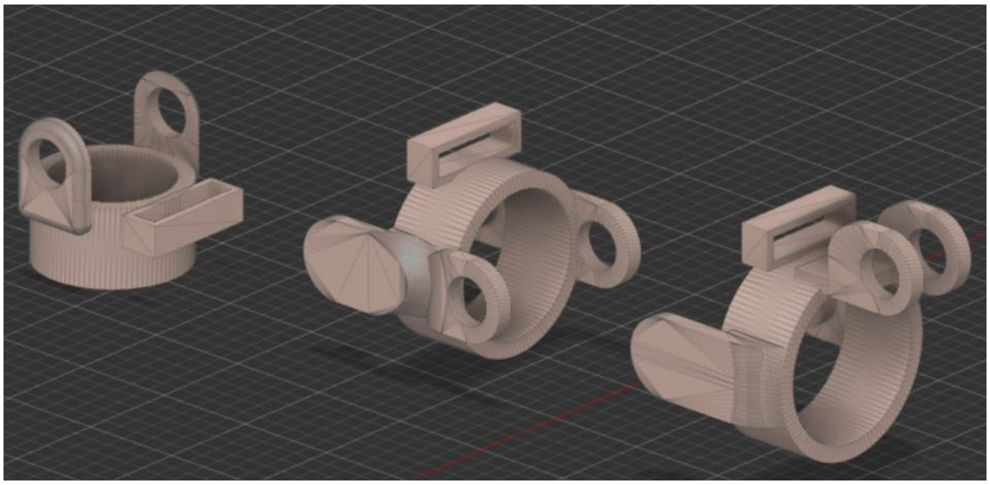

Fig. 1. Finger rings placed on the little finger
Rys. 1. Pierścienie zakładane na mały palec
Source: Own work

The most essential element of the exo-glove is the Arduino Nano microcontroller connected to the HC 12 module and sensors. The radio module is connected to PIN A10 of the Arduino Nano. The sensors are connected to the analog input pins A1, A2, A3, A4, A5. Source code written for the microcontroller causes sequential read of movement data from each sensor. Power is supplied by a 6F22 (9 V) battery through the GND and VIN pin. Figure 17 shows the glove connection diagram.

All the connections (Arduino Nano, HC 12 module and finger sensors) are further explained below.

Tab. 3. Connection of the HC 12 radio module with the Arduino Nano microcontroller
Tab. 3. Połączenie modułu radiowego HC 12 z mikrokontrolerem Arduino Nano

Arduino Nano	HC 12 radio module
5 V	VCC
GND	GND
10	TX

Source: Own work

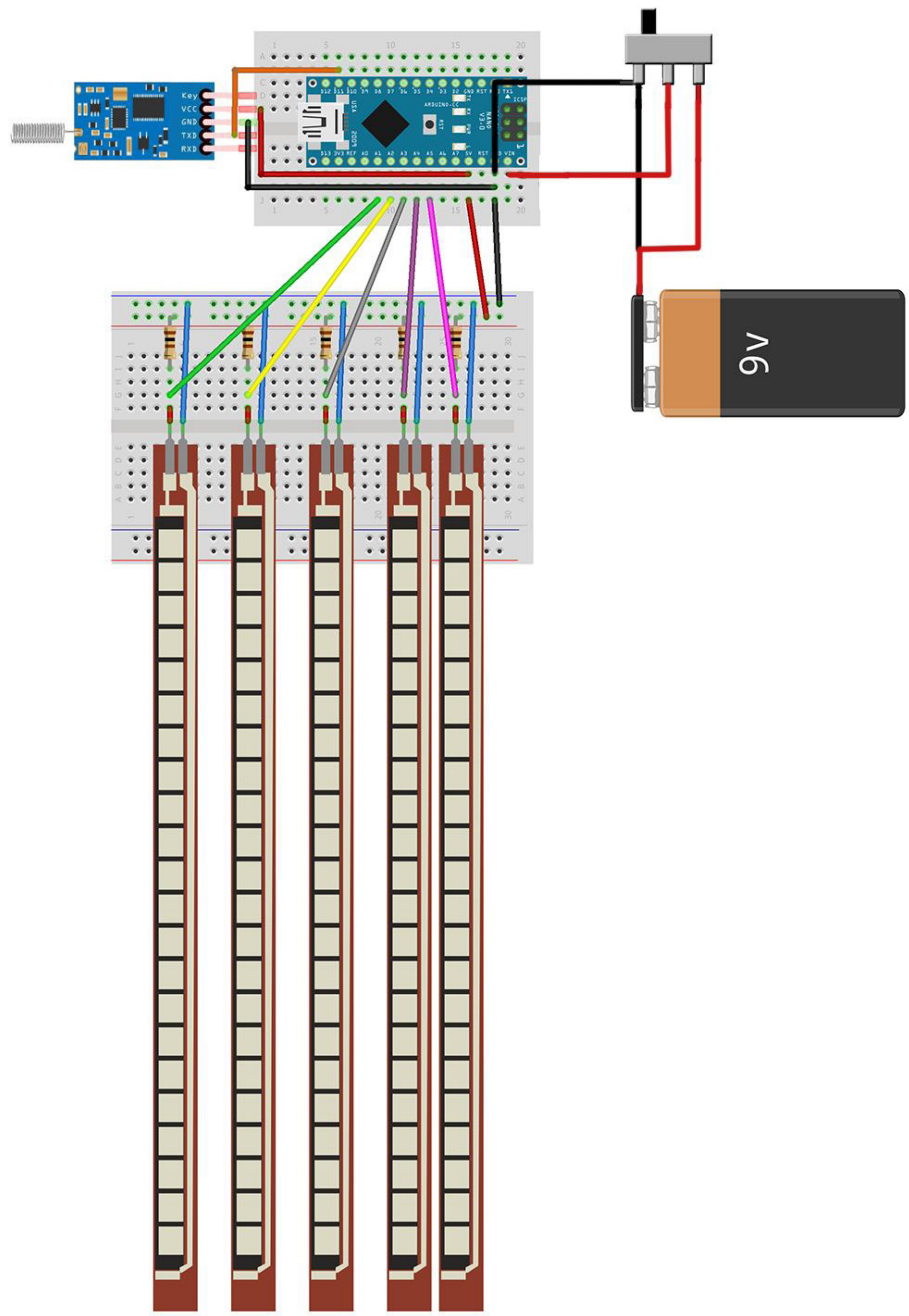

Fig. 2 HC 12 radio module connection with Arduino Nano microcontroller, battery, and sensors
Rys. 2. Połączenie modułu radiowego HC 12 z mikrokontrolerem Arduino Nano, baterią i czujnikami
Source: Own work

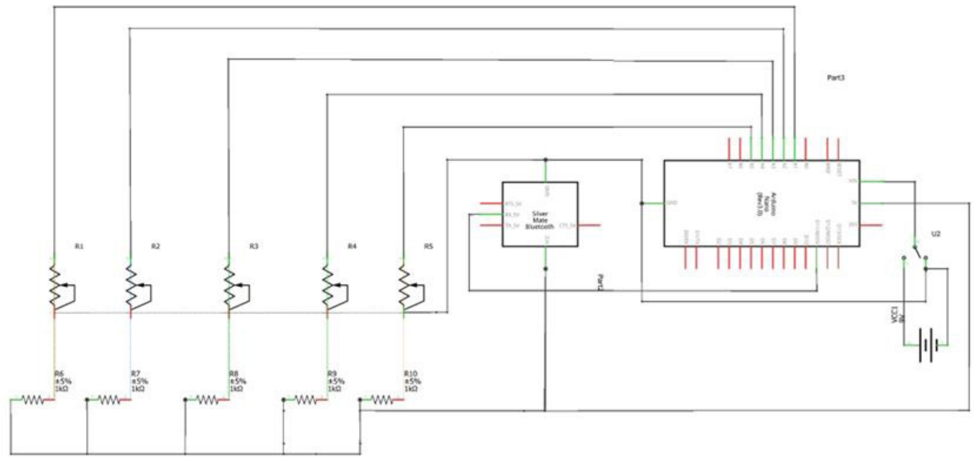

Fig. 3. Electric diagram of Arduino Nano microcontroller, HC 12 radio module, batteries, and sensors
Rys. 3. Schemat elektryczny połączeń mikrokontrolera Arduino Nano, modułu radiowego HC 12, baterii i czujników
Source: Own work

Entire controlling unit (radio module, Arduino board, battery, and sensor connections) are put into a box placed above the palms, as depicted below.

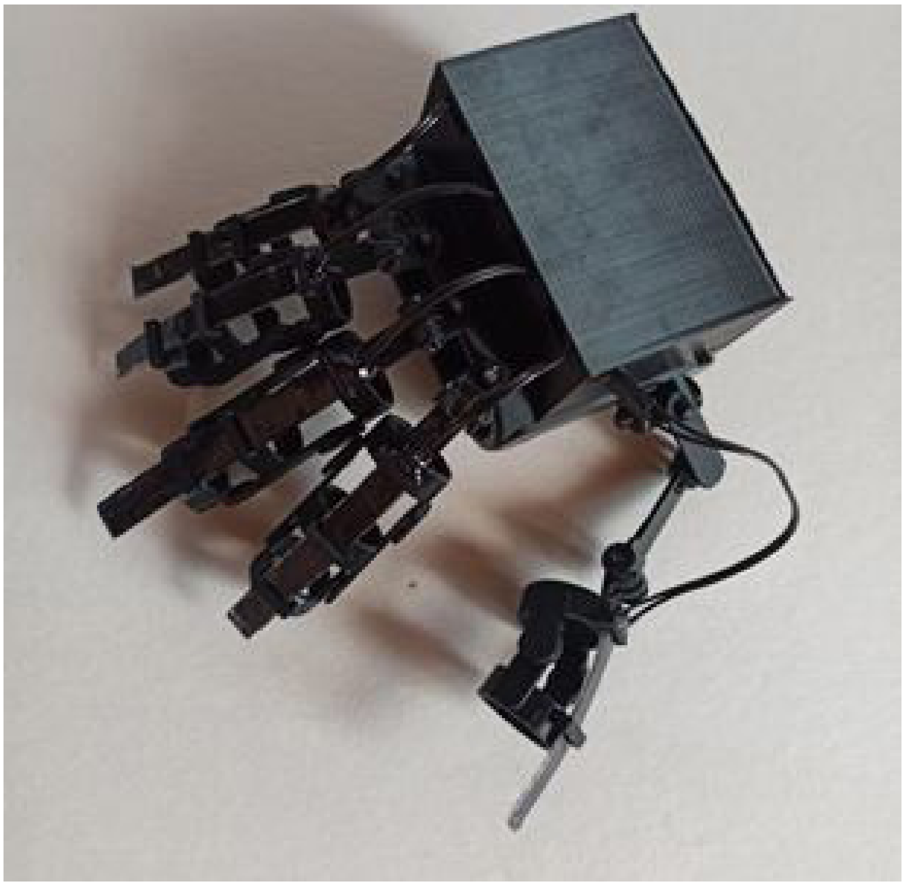

Fig. 4. Complete exo-glove
Rys. 4. Gotowa rękawica
Source: Own work

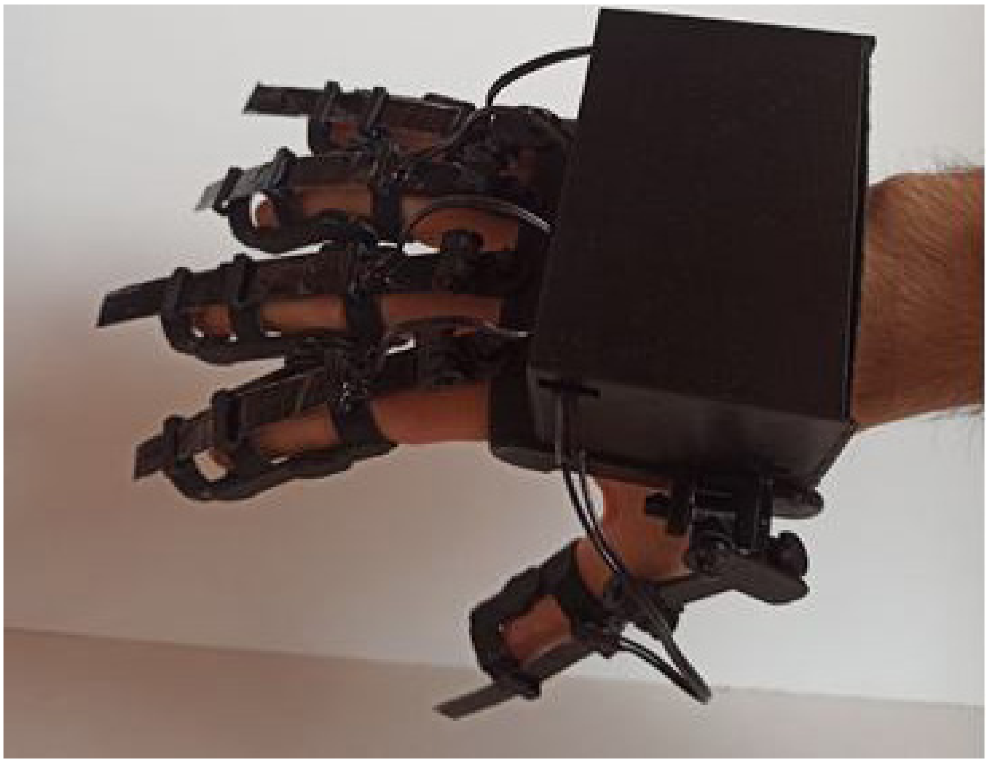

Fig. 5. Exo-glove on the hand
Rys. 5. Rękawica założona na dłoń
Source: Own work

For each finger sensor following elements were used:
- Two pieces of plexiglass
- One piece of velostat and
- Two pieces of copper tape

Each piece of velostat was smaller a bit in length and width than plexiglass. Each two pieces of copper tape were smaller than velostat. To each piece of copper tape, a one wire was soldered. Each piece of copper tape was then glued to the plexiglass. Finally, it was arranged that a piece of velostat was surrounded with two pieces of plexiglass (acting as an insulator), which was surrounded with two pieces of copper tape.

The construction of each finger sensor is depicted below.

Fig. 6. Finger sensor
Rys. 6. Czujnik
Source: Own work

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3.3. Robotic car

The controlled device, a robotic car, was also designed in the 3D design application and each of its part were printed using 3D printer. But since it stands as an example (the proposed prototype aims to control of any device using an exo-glove) we will not give any construction details in here and focus on electronic design only.

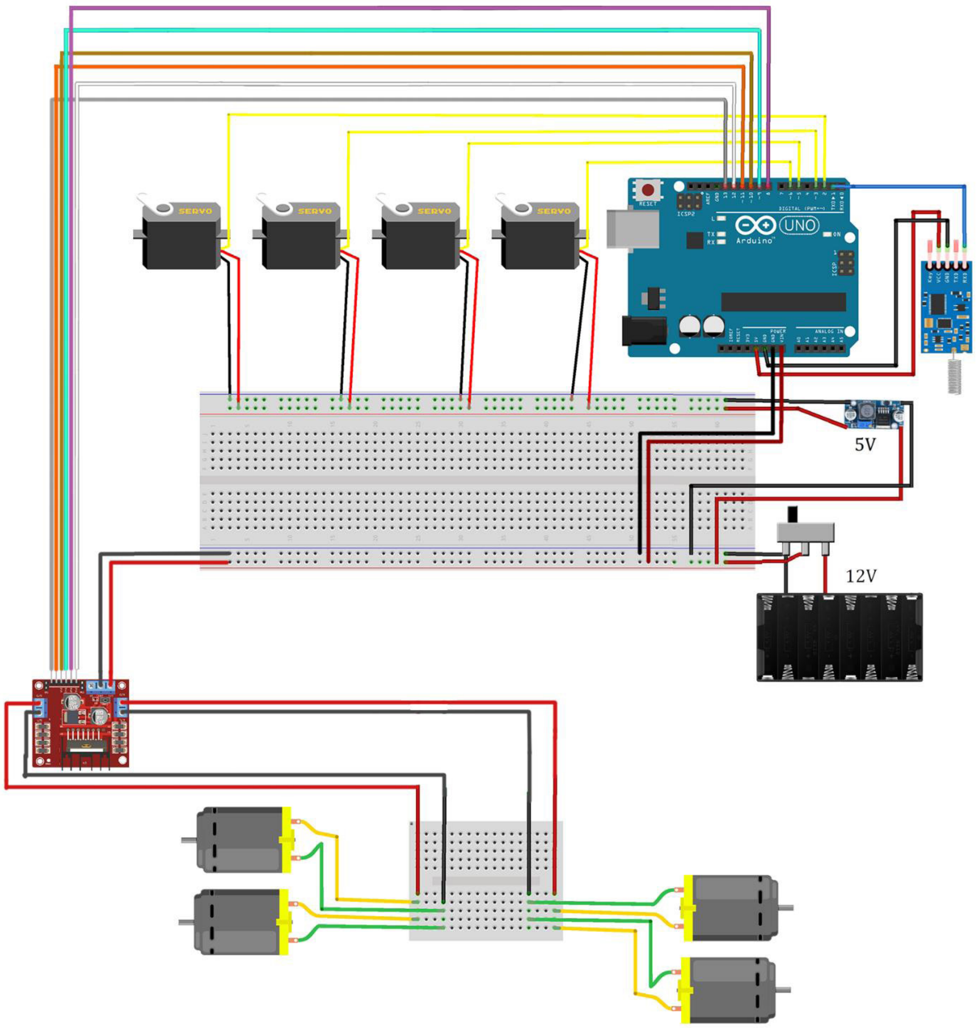

Fig. 7. Connection diagram of the Arduino Uno with the robot controls
Rys. 7. Schemat połączeń Arduino Uno z elementami sterującymi robota
Source: Own work

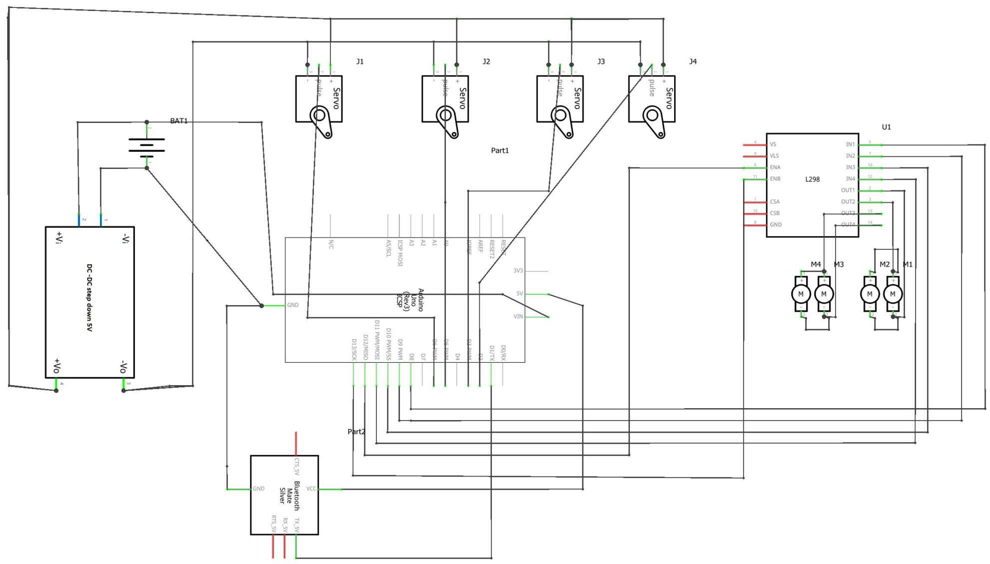

Fig. 8. Robot wiring diagram
Rys. 8. Schemat elektryczny robota
Source: Own work

Fig. 9. Completed robot with a closed gripper jaw
Rys. 9. Gotowy robot z zamkniętymi szczękami chwytaka
Source: Own work

4. Proposed modifications
4.1. Communication medium

The presented prototype uses a wireless radio communication based on Arduino Uno / Arduino Nano microcon-trollers and HC 12 radio communication module. It therefore uses radio waves as a communication medium. The pro-posed change covers switching into TCP/IP-based communication, using Internet network (or optionally intranet networks). This can be achieved in two separate ways.

One of the possibilities is to enrich both Arduino Nano ATMega328P and Arduino UNO R3 ATMega328P mi-crocontrollers with the ENC28J60 Ethernet Shield, connect it to a wired network and use wired RJ45 cable as a commu-nication medium [8].

The other option assumes the replacement of Arduino Nano ATMega328P and Arduino UNO R3 ATMega328P microcontrollers with the ESP8266 or ESP32 microcontrollers which has the same functionality as Arduino microchips, but also incorporates Wi-Fi antennae and Wi-Fi encryption module. And thus, connect both exo-glove and the controlled device to a wireless Wi-Fi network [11][12].

4.2. Exchange server

The original concept implements a direct connection between the glove and the controlled device. In our proposed modification such direct communication is possible, but not advised. Mostly due to security concerns. A classic client-server paradigm is proposed instead [13].

In both above mentioned solutions the TCP/IP transport protocol will be used. The server software is planned to be developed using PHP language and a powerful and fast Yii 2 Framework. This framework exposes developers with an extensible support for building RESTful applications meaning that such server will bring up the exo-glove to controlled device scheme to the new levels. In which single glove will be able to control multiple devices, placed even thousands of kilometers one from another, where it will be possible to control devices using i.e., mobile devices [14].

4.3. Other changes and plans

If the proposed solution will require an extra level of protection and security then a blockchain can be used instead of a typical server-based backend, as discussed in another article, titled “Protection of personal data using blockchain”, by Maciej Madejczyk, Tomasz Trejderowski and Beata Trejderowska. One of the proposed changes is an already mentioned replacement of single 6F22 battery with a rechargeable battery set that will allow an exo-glove to operate hours between each charge.

One of our next steps, after the entire prototype is completed, is to assess communication speed and quality, be-tween an exo-glove and controlled device, over TCP/IP network, when middle backend (server or a blockchain) is hosted in a various geographic locations among the entire world. For example, we want check details between bending fingers and controller device reacting to such change, if both exo-glove and the device are placed thousands of kilometers from each other. We plan to author another article on summarizing these tests.

5. Conclusions

The following article is our initial report on the prototype on which we are currently working. It consists of an exo-glove that uses Internet as the solely communication channel and TCP/IP as a communication protocol's proposed replacement for the HC 12 radio module and a wireless communication. We are aiming into producing a cheap exo-glove for the application in Internet of Things in general, especially in telemedicine and telemetry applications.

Affiliation

Lucjan Kozielski is the author of the original idea (a robotic car controlled wirelessly using exo-glove).
Grzegorz Ociepka was responsible for the design and development of the exo-glove and robotic car as well as for writing source codes for the original concept (radio controlling).
Tomasz Trejderowski is responsible for the general idea of the proposal and a prototype being constructed (Internet-based communication and IoT application) as well as the author of the source codes for a proposed prototype. Łukasz Sowa is responsible for the design and the development of the discussed prototype.

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PROPOZYCJA ADAPTACJI RĘKAWICY DO STEROWANIA ROBOTEM NA POTRZEBY APLIKACJI W ROZWIĄZANIACH Z ZAKRESU INTERNET OF THINGS

STRESZCZENIE

Niniejszy artykuł stanowi wstępną prezentację koncepcji oraz budowanego prototypu rękawicy sterującej zdalnymi urządzeniami. Planowany prototyp pozwoli na sterowanie nimi na praktycznie nieograniczone odległości, przy pomocy sieci Internet. Naszym celem jest wykorzystanie bezprzewodowej egzo-rękawicy w zastosowaniach z zakresu telemedycyny oraz w rozwiązaniach telemetrycznych.

SŁOWA KLUCZOWE

rękawica do sterowania robotem, zdalne sterowanie, Internet of Things, IoT, telemetria, telemedycyna