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Designing an ATmega328 microcontroller based gesture-controlled IoT UGV unit and creating a camera system using Linux distribution

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***Abstract*— The topic of the research is the design and building of a UGV (Unmanned Ground Vehicle), which we can control wirelessly with a glove designed for this purpose. The design and use of this gesture-controlled robot can be observed in this summary. A camera will be installed on the robot unit, whose image we can query through the local network. Furthermore, the hardware and software for this camera system will be described as well.**

Keywords—gesture-control; UGV; Arduino; Raspberry Pi; Linux; RF module; acceleration sensor; camera system

I. INTRODUCTION

The building mechatronics research center at the University of Debrecen gives home to internal research and development [27][28].

The goal of the current development is creating a wireless, flexible mobile device by using/modifying an existing RC car. The RC car has two DC motors, one of which drives the rear wheels, while the other one is responsible for moving the steered wheels [26]. At the time of the realization, a suitable motor controller had to be designed and created for this purpose, during which cost-effectiveness was an important aspect. This controller has been implemented using an ATmega328P [19] based Arduino Nano panel. Size was an important consideration while selecting due to the limited space. Before completing the project, it was important to understand the to-be modified vehicle, choose the components and parts required for the modifications and to plan the system. A thorough screening of the datasheets of the electronic components was imperative. Furthermore, using 3D technology, the design of a printable box plan also took place. Programming is also an important part of the creation, to allow the built system to be functional. Depending on the chosen components and complexity of the task an easy to understand program was made, with included comments and instructions, which, later on, can be configured easily depending on how the user wishes to use, or further develop it. After building and programming of the gesture-controlled system, it was also tested, then the various values were determined which allow the calibration of the controlled system.

Subsequently, the system's receiver section was built into the prepared RC car and the transmitter was placed on a glove. Finally, a Raspberry Pi [14] is along with the connected Pi Cam [12], which, along with the help of installed software, allows us to view the sight seen by the vehicle by connecting to the local network, and we can also record it to a micro SD card.

II. ATMEGA328P

Arduino is an open-source electronic platform based on easy to use hardware and software. The panels can read inputs, and based on those, turn outputs on and off. Due to its ease of use, cost-effectiveness and flexibility, numerous significant projects have been made using it [1] [20].

Arduino's product range is wide. Its smallest fully fitted panel is called the Nano, which, in terms of functionality, is the same as the larger Uno [2]. This hardware met the requirements of the task. The Nano has twenty two I/O, out of which four digital pins were used for controlling the motors, as well as the pins used for I^2C communication. Besides those the 3,3 V and 5V voltage outputs were used along with GND [2].

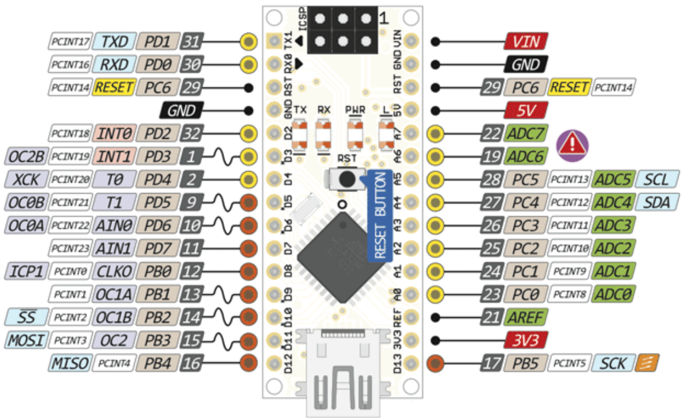

Figure 1: The Arduino Nano [2]

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The panel is based on ATmega328P microcontroller, and has 32 KB flash memory. Its operating voltage is 5V, but the input voltage can be varied in the 7 and 12V range. It can receive the supply voltage through the MiniUSB connector, or on the voltage input pin (Vin), since we can't speak of power supply via a DC jack in the case of this model [2]. The programming of the device can be done in the Arduino IDE integrated development environment, which also helps in connecting the panel to the computer and transferring data. The programming language is based on C++, the program is made up of functions. The setup() is only executed once while the program's running, which contains the declaration of the variables and constants, and the initial settings. In contrast, the loop() function is continuously executed during the operation of the device [3].

III. SELECTION OF HARDWARE COMPONENTS

A. The sensor used

The gesture controlled system required a device which allows the transmitter can discern between different hand positions based on the measured values. For the task the type ADXL345 [6] accelerometer had been chosen. Its available functions along with its design made it suitable for the set task.

The ADXL345 is a small, low energy consuming, three axis accelerometer with high resolution (13 bit) +/-, while measuring up to 16 G. The output is available through SPI, and I^2C. The device measures the static acceleration of gravity, as well as the dynamic acceleration from movement and shaking. Additionally, it can sense activity and inactivity, and recognizes falls and taps [4].

The movements are measured via differential capacitors. The differential capacitor is such a plane capacitor, which has two static and, between those, a moving plate. The displacement of the moving plate is perpendicular to the surfaces. It displaces the differential capacitor from its state of equilibrium, thus creating such a sensor output that is proportional to the acceleration. The sensor uses phase-sensitive demodulation to determine the magnitude and direction of acceleration [5].

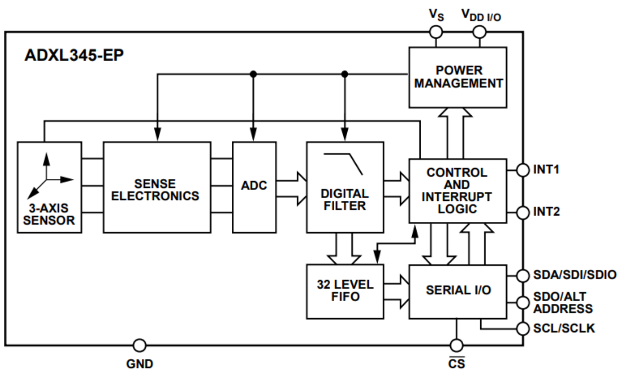

Figure 2: Function diagram of ADXL345 [6]

B. Wireless communication

For the wireless communication transceiver system with 433 MHz radio frequency had been used. The transmitter is type XD-FST, the operational voltage of which can be chosen in the range between 3,5-12V, while its operating range is between 20 and 200 meters, depending on voltage, and the possibly connected external antenna [7].

The receiving unit is type XD-RF-5V, which operates from a 5V supply voltage, and unlike the transmitter the input voltage cannot be changed [7].

The wireless control of the motors requires the use of an encoder (HT12E) and a decoder (HT12D) integrated circuit. The combination of the two is often used for remote controlled systems. The HT12E converts a 12 bit parallel input into a serial output, which can be transferred to the receiver via the radio frequency transmitter. The 12 bit can be divided into 8 address bits, (A0- A7) and 4 data bits (AD0-AD3) [8].

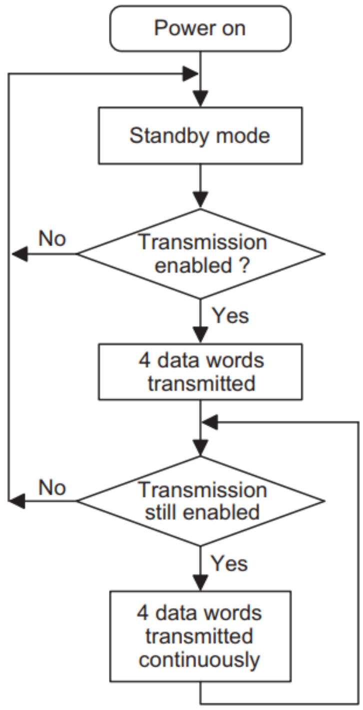

Figure 3: Block diagram of HT12E [8]

The pair of this IC, the HT12D converts the serial input into parallel output. It decodes the serial address and data received from the radio frequency receiver, then forward it converted into parallel data to the output data pins. The serial input data is compared with the local address, continuously three times. The input data is decoded, if there are no errors or different code found. the HT12D can decode 12 bits, which, like its pair, can be divided into 8 address bits and 4 data bits. The data appearing on pins remains unchanged until new data is received [9].

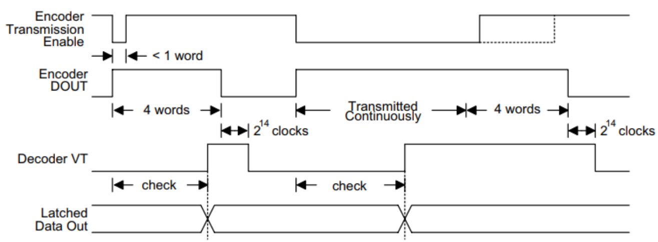

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Figure 4: The HT12D's decoding time[9]

C. Driving the motors

Since the microcontrollers can only output 5V and 200mA, they cannot be used to drive the motors, so other circuits have to be included, called drivers, between the controller and the motor.

The L293D is one of the most widespread drive circuit on the market. Among its advantages is the reasonable price, the shape and size, ease of use, and the indispensability of protective circuits and heat sinks. The IC can drive motors with voltages between 5 and 36V up to 600mA current, but it can also bear 1200mA for the duration of 100 microseconds [10].

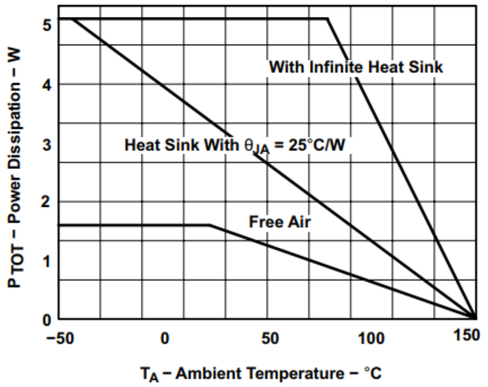

Figure 5: Maximum Power Dissipation vs Ambient Temperature [17]

The L293D contains two built in H-bridge drive circuits. The two motors connected to the drive are controlled by input logic on 2 and 7, as well as 10 and 15 pins. The 00 or 11 input logic stops the given motor. The 01 and 10 logic input causes the motors to rotate clockwise or counterclockwise [11].

This direction changing was also tested and simulated with the TinkerCAD online circuit simulation software [21].

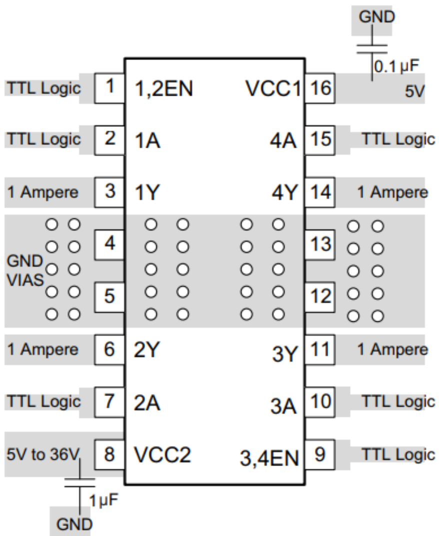

Figure 6: The pinout of L293D motor driver IC [17]

D. Camera system using Raspberry Pi

A Raspberry Pi 3 Model B was selected to monitor the vehicle's image, along with a Pi camera module that can be connected via its CSI port.

The Raspberry Pi has been the cheapest and most popular mini computer ever since its release. With its size, reasonable price, and developing unique, open source hardware and software it created a brand new category. It can be used for countless tasks that could only be solved with expensive solutions, via costly development systems. In addition to being used as a full-fledged computer, it is widely used in various project, such as data logging systems, home automation, remote monitoring, home servers, etc. The Raspberry is also important from an educational point of view, since it makes the discovery of technology and mastering of programming languages such as Scratch and Python available to all ages [12] [22].

The Raspberry Pi 3 Model B contains a quadcore 1,2 GHz, 64-bit BCM2837 processor along with 1 GB SDRAM. It also supports the WiFi and Bluetooth standard, which played an important role in the selection for my project. Among other things, the 40 GPIO also makes the user's job easier [13].

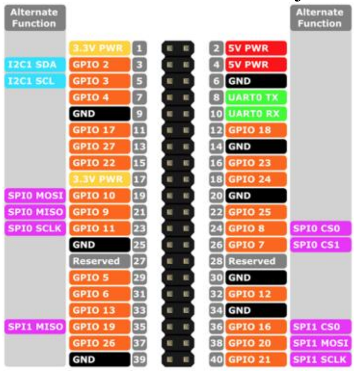

Figure 7: The pinout of the L293D motor driver IC [18]

The Raspberry-compatible Pi Cam v1.3 used for the camera system has a 5 megapixel sensor, which supports also 1080p and 720p video recording [14].

IV. PCB & 3D PLANNING

A. Creation of a schematic diagram and printable PCB design

Following the selection of the devices needed to complete the task, the next step was to design the connections of system built from them. The wiring diagrams were created using the software called Eagle [23].

After the wiring diagrams the creation of a physical connection schematic was necessary, on which the 2D drawings of given components and the connections between them are shown. The physical connection was created using the software called Fritzing [24]. The components found here connect via a breadboard.

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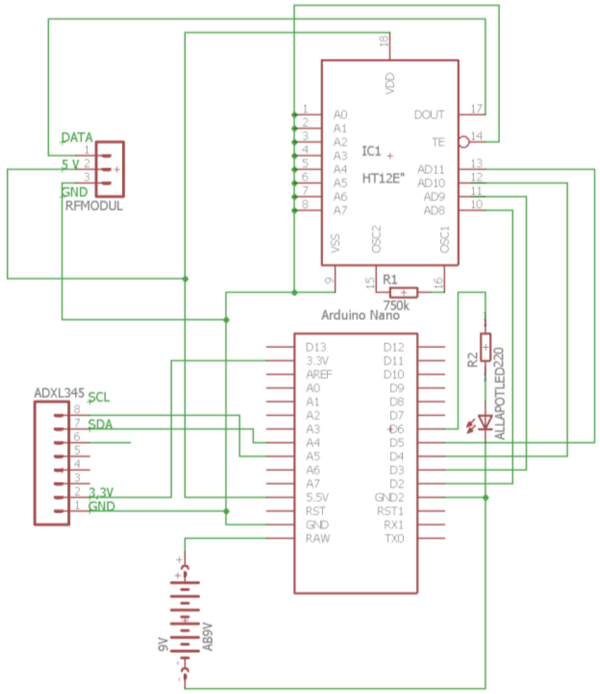

Figure 8: The physical connection schematic of the transmitting unit [15]

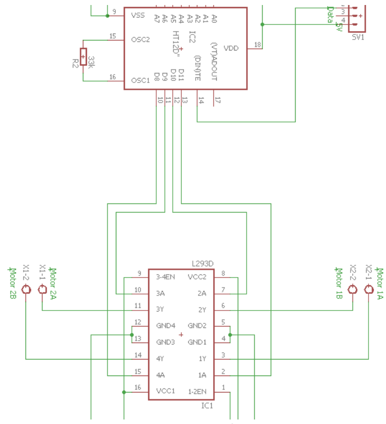

Figure 9: The physical connection schematic of the receiving unit[15]

After the wiring diagrams and physical connection schematics were made, the design of the printed circuit board was next, which was also made using the Eagle software. Based on the wiring diagram the program prepared the connections, linkages, then by designing the conducting strips the circuit plans were created. Due to the complexity of the schematics a double-sided printed circuit had to be created. Since the transmitter will be installed on a glove, the small size was very important too. The receiving unit must also meet size requirements as mobility and ease of placement is an important consideration when installing on an UGV. Inside the Eagle software we can design our own PCB by adding the components on the printed circuit board designing interface. After the arrangement of the components, the conducting strips were added. Since mountability is an important aspect during the production of PCBs, holes were added to our circuit, which can serve as mounting points in the future [15].

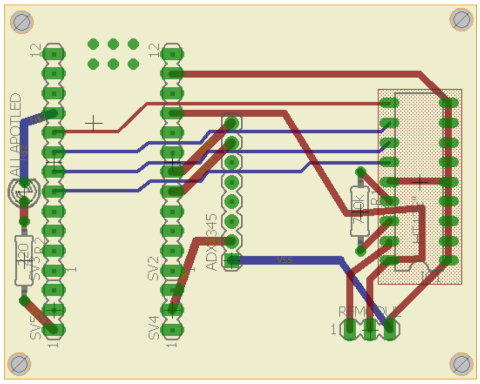

Figure 10: The printed circuit schematics of the transmitting unit [15]

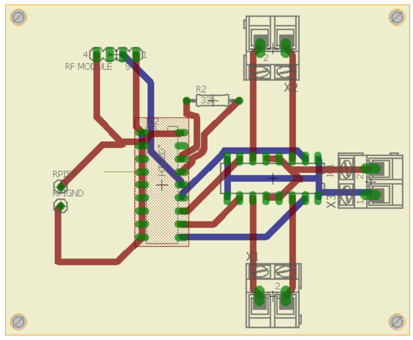

Figure 11: The printed circuit schematics of the receiving unit [15]

B. Creating a 3D printable box design

The completed PCB plan was exported using a pre-installed plugin (eagleUp export) as a file that is then imported into Google SketchUp to provide an editable 3D model of our printed circuit board [25]. During the export the PCB, the conducting strips' color, and the level of detail of our object can be selected [15].

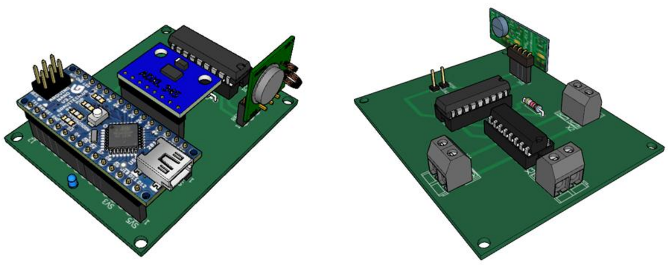

Figure 12: 3D model – Transmitter & Receiver [15]

Once this is done, the next step is done with the use of Google Sketchup software. Like before, the use of an installed add-on called eagleUp import is required, with which we get the three-dimensional model of our circuit when opening the exported PCB plan. After creating the receiving unit's model the creation of a 3d printable box design was required, which makes the finished device easy to transport and protects it against physical impacts.

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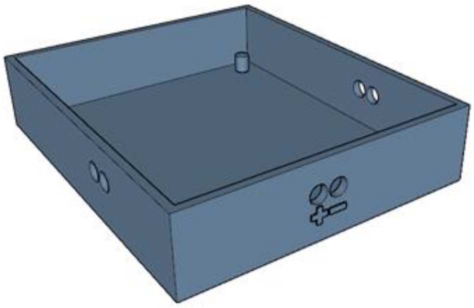

Figure 13: 3D printable box design[15]

V. Creation and programming of the gesture-controlled system

In accordance with the printed circuit board designs the components included in the circuit were installed into a 5x7 cm, double sided, metalized universal PCB. The Arduino and radio frequency units were installed with pin row sockets, and the integrated circuits with DIL-sockets, with the goal of creating a flexible, modular system. In the event of a malfunction or expansion of this panel the installed components can be removed and replaced easily. Afterwards the transmitter unit was mounted on the glove, while the receiver unit was placed on the RC car.

Figure 14: The receiver unit fitted on the vehicle [15]

Figure 15: The transmitter unit fitted on the glove [15]

In order to put the system into operation, the program run by the microcontroller needs to be written as well, which was done in the Arduino IDE environment, with the help of the software called AtmelStudio.

As a first step the software for the ADXL345 was implemented. The manufacturer of the sensor, Sparkfun, provides a premade, free-to-use test and calibration program for its product [15].

The gesture controlled system’s software was implemented using this program, during the creation of which “modularity” was also an important aspect, and so the parameters of the program are easily modified, the user can configure it for his own application.

In addition to the program segments necessary for the control and movement of the UGV unit, a “tap” recognition section has also been created, which causes the device to start the main part of the program in case of a single tap, processes the values from the sensor outputs, and then moves the vehicle based on them. This status is indicated by an LED light. In case a double-tap was performed on the surface of the sensor then the program jumps to such a section where it stops all the sensors, the measured values are not processed, thus replacing a physical switch.

During the tests, the values at which the UGV unit executes the selected movements were determined. Those values can be found in Table I. Those values were read through the serial port.

I. Táblázat [15]

Hand position	Thresholds	Instructions to be executed
Horizontal	-5 <x <5 & -5 <y <5	Stop
Inclined forward	-5 <x <5 & -25 <y <-15	Forward
Inclined backward	-5<x<5 & 10<y<25	Back
Inclined left-forward	0<x<10	Forward, turning left

	& -30<y<-20	
Inclined right-forward	-20<x<-10 & -30<y<-15	Forward, turning right
Inclined left-backward	0<x<10 & 10<y<25	Backward, turning left
Inclined right-backward	-10<x<0 & 5<y<20	Backward, turning right

VI. Software for the Camera System

The camera system, through which the picture seen by the drone can be monitored, was implemented with the help of a Raspberry Pi 3 Model B and a Pi Cam, and by using the RPi Cam Web Interface

The RPi Cam Web Interface is an internet based interface for the Raspberry Pi camera module. It has a wide variety of uses, including security systems and DVR recording applications. It is easy to configure and expand with the use of macro scripts. It can be opened from any browser including browsers used on smartphones[16].

Using this interface, it is easy to monitor the live image seen by the device, configure various settings like brightness and contrast, as well as creating image and video recordings which can be saved to the Raspberry Pi's SD card.

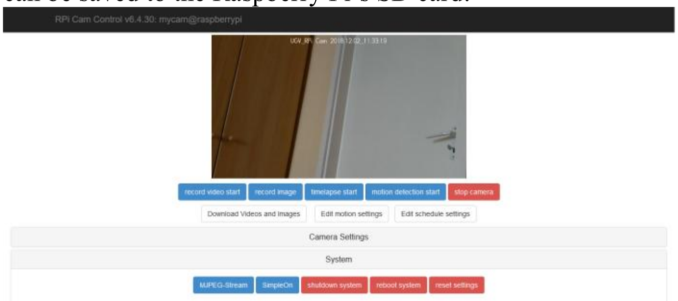

Figure 16: RPi Cam Web Interface

It is also worth noting that among the numerous functions is the ability to restart or stop the device remotely.

To use the interface, the Raspbian system needs to be installed on the Raspberry device. After installing and enabling the camera and downloading and installing updates, the program can be installed with the use of ./install.sh command. There are six different scripts available for the user to make or maintain the settings. After successfully installing the program the camera can be started with the /start.sh command. After those, by typing in the IP address of the Raspberry Pi, the live image captured by the drone's camera becomes visible [15].

VII. Summary

The goals set at the beginning of the project were met, and the planned system has been fully implemented. The finished vehicle can be controlled by the control glove, and the image it sees can be monitored via a local network.

The system has multiple aspects that can be developed further, including the implementation of variable addressing, and the use of additional sensors which allow the UGV unit a more effective operation in the given space.

Figure 17: The finished UGV unit [15]

VIII. Acknowledgements

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