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# Mobile robotic laboratory - UNT Lab

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**Abstract:** The project envisages the creation of an experimental concept of a self-propelled laboratory - UNTLab. In crisis situations, it is necessary to examine the quality (contamination) and composition of the air (soil) in a room or on an open field. The UNTLab self-propelled platform, which was implemented at UNION Nikola Tesla University, Faculty of Information Technologies, will be used without risking human resources. In the current (first) phase of realization, UNTLab is equipped with ten sensors that provide information on temperature, pressure and air humidity, substrate temperature, gas concentration (carbon oxides, propane C3H8, butane C4H10, ammonia...), intensity of EM and UV radiation as and light intensity. In addition to the sensor group, a high-resolution Wi-Fi camera is also installed. All collected data from the sensor group is recorded on a micro SD card. The platform has an additional possibility related to mobility, it is equipped with mecanum wheels, which enables great maneuverability, which also includes holonomic movement. Control of the UNTLab platform is performed via mobile devices, Android application, bluetooth communication or wi-fi network.

**Keywords:** *robotic platform, mobile laboratory, mecanum wheels.*

## 1. INTRODUCTION

UNTLab is an independent robotic platform (Cvetković, & Stanković, 2010) equipped with a camera and a set of sensors. The platform is controlled via a serial communication channel with the Bluetooth system, which is paired with a mobile device. The Android application that controls the UNTLab platform simultaneously displays the data collected from the sensor array on the mobile device. The purpose of the robotic platform is multiple and can be used as:

- Educational tool,
- Mobile measuring module,
- Mobile security system

In addition to its core functionality, the UNTLab platform demonstrates the growing importance of robotics in addressing critical global challenges. By combining advanced sensor technology, robust mechanical design, and user-friendly control via mobile applications, UNTLab offers a versatile solution for real-time data collection and analysis. Its potential extends beyond crisis management, encompassing environmental monitoring, resource management, and educational purposes. The platform serves as a practical example of how modern technology can mitigate risks to human health and safety while fostering innovation in interdisciplinary research and education.

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## 2. ROBOTIZED PLATFORM

The realization of the self-propelled robotic laboratory began with the selection of the platform itself and its construction. We opted for a robust platform with independent suspension and four-wheel drive, Figure 1.

Figure 1: UNTLab platform

Electric motors via reducers drive wheels that can rotate at different speeds and in different directions, which enables the already mentioned holonomic movement (in all directions and directions). The mechanical assembly is elastic and allows the platform to move easily even on unstructured terrain. At the same time, there is enough space to integrate all the modules, sensor group, camera and power components on the platform, leaving enough space for further extensions.The mechanics of the chosen platform allow movement on unstructured terrain. The holonomic movement enabled by the mecanum (Campion et al., 2011; Salih, et al., 2006) wheels provides the great maneuverability UNTLab needs, Figure 2.

Figure 2: Mecanum wheel specific to the UNTLab platform

The specificity of mecanum wheels is the rollers on the wheel surface, placed at an angle of 45º. The wheels can be left and right, they differ in the direction of the rollers and are placed so that all the rollers are directed towards the point of intersection of the diagonals of the platform. A mechanical assembly designed in this way enables a specific holonomic movement. The presented mechanical assembly allows the UNTLab to overcome smaller obstacles and realize more complex maneuvers for the purpose of analyzing its environment.

The next step was defining the components that will be included in the UNTLab system. Key elements such as the sensor group require special attention when locating the sensors on the platform itself. The measurement system was the key component on the basis of which the positioning of the sensors and their fitting with other electronic components was carried out. Figure 3 shows the first working version of the UNTLab platform.

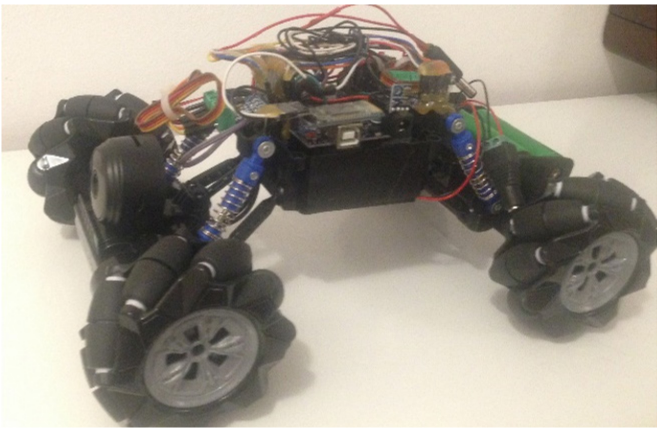


Figure 3: UNTLab platform V10.7

In Figure 4, the system of movement of the platform is shown schematically, i.e. the direction of rotation of each individual wheel. Depending on the direction of rotation of the wheels, we also get the resulting motion of the platform.

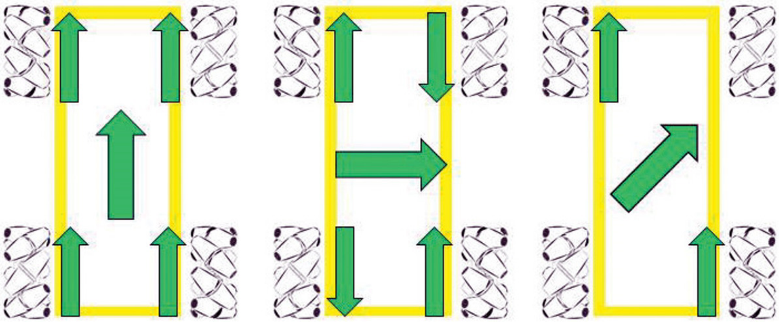
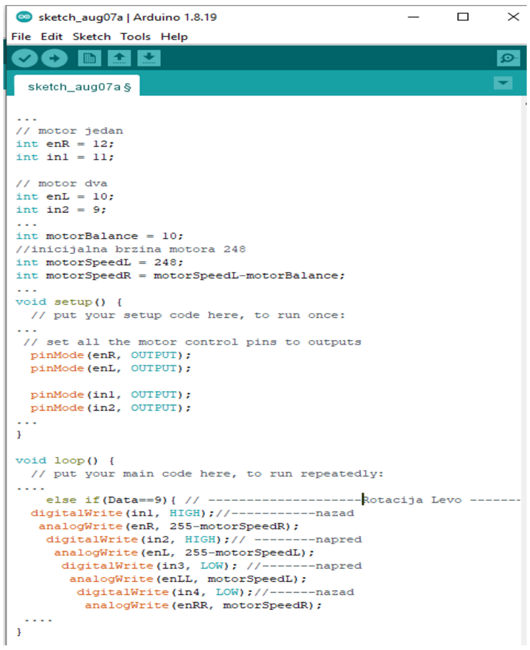


Figure 4: Holonomic motion of the UNTLab 3327 platform





```
...
// motor jedan
int enR = 12;
int in1 = 11;

// motor dva
int enL = 10;
int in2 = 9;
...
int motorBalance = 10;
//inicijalna brzina motora 248
int motorSpeedL = 248;
int motorSpeedR = motorSpeedL-motorBalance;
...
void setup() {
  // put your setup code here, to run once:
...
 // set all the motor control pins to outputs
  pinMode(enR, OUTPUT);
  pinMode(enL, OUTPUT);

  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);
...
}

void loop() {
  // put your main code here, to run repeatedly:
....
    else if(Data==9){ // --------------------Rotacija Levo -------
  digitalWrite(in1, HIGH);//-----------nazad
   analogWrite(enR, 255-motorSpeedR);
    digitalWrite(in2, HIGH);// --------napred
     analogWrite(enL, 255-motorSpeedL);
      digitalWrite(in3, LOW); //-------napred
       analogWrite(enLL, motorSpeedL);
        digitalWrite(in4, LOW);//------nazad
         analogWrite(enRR, motorSpeedR);
 ....
}
```

Figure 5: Part of the code - control of the operation of individual motors

## 3. ELECTRONIC COMPONENTS OF THE PLATFORM

All functions of the UNTLab are unified in the pro MEGA microcontroller, shown in Figure 6. The controller allows parallel programming so that we solved all measurement operations with code. We were able to use a large number of sensors because there was no problem in separately monitoring all measurement parameters of each sensor.

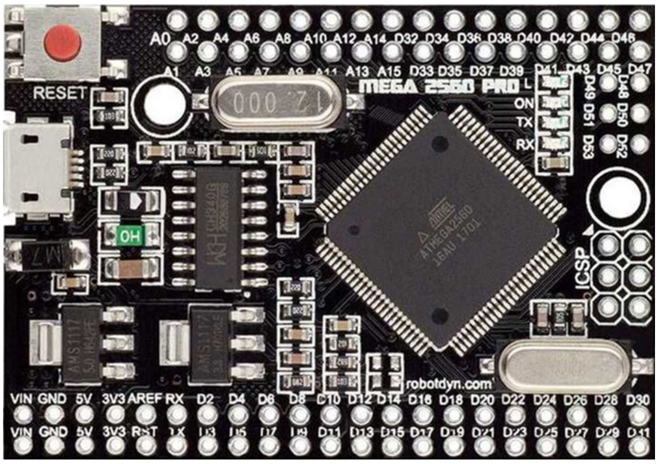



Figure 6: Microcontroller Mega Pro

The set of electronic components used on the platform are divided into several groups:
a) control and operation of DC electric motors,
b) communication module,
c) sensor group,
d) sensor shield,
e) video subsystem,
f) energy group.

**a) Control and operation of the DC electric motor -** is carried out via two modules, (eng. driver) HG7881 which can support the operation of the DC electric motor in load mode up to 2A. That is more than the motors “pull” at the start (single peak is 0.6A). Figure 7 schematically shows the connection of the Uno R3 microcontroller with a system of two HG 7881 modules and DC electric motors (the drive group of the platform).

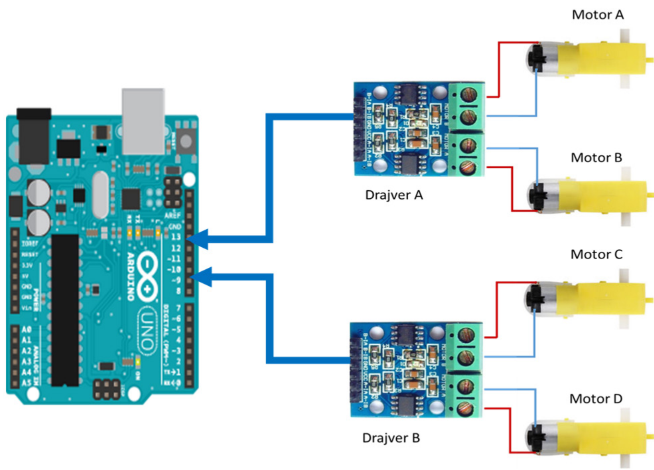



Figure 7: UNTLab platform powertrain connection

**b) Wireless communication** with the platform takes place via the new (eng. Bluetooth) module HC06, which has a range of up to 25m, Figure 8.

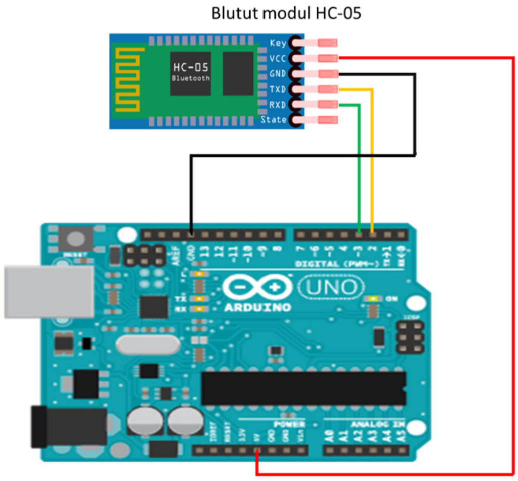



Figure 8: Connecting the Uno R3 microcontroller to the Bluetooth module HC05

For laboratory experiments it is quite enough. All mobile devices (phones, tablets...) have an integrated Bluetooth module and by installing the UNTLab android application, it is possible to control the platform with a mobile phone and at the same time receive data from the sensor group.

**c) Sensor group** - it is composed of seven modules. The BMP180 module is a digital sensor and is used to measure air temperature and pressure, Figure 9. The BMP180 sensor can measure pressure in the range of 300 to 1100 hPa (500m-9000m above sea level) and temperature in the range of -40° to 85° with with an accuracy of 1°.

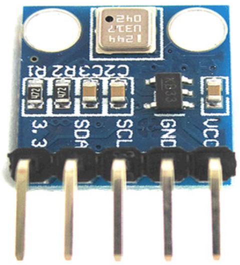



Figure 9: BMP180 module

The second element of the sensor group is the MQ135 module, Figure 10. The sensor is used for the detection of gases harmful to human health such as carbon dioxide, ammonia, sulfur, as well as for the detection of smoke.

Figure 10: Module MQ135

The MQ135 has both analog and digital outputs, with the analog output giving more accurate results and was used in the UNTLab project, Figure 11.

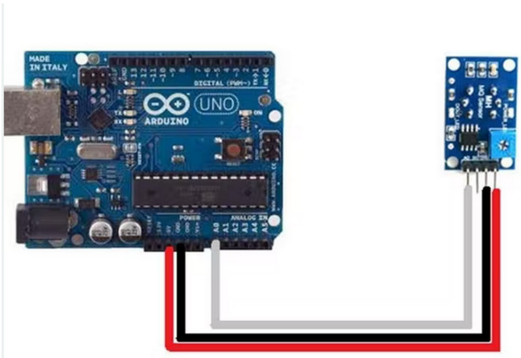


Figure 11: MQ135 connected to the analog input of the microcontroller

It is necessary to calibrate the sensor in order for the results to be accurate. The calibration of the CO2 gas sensor was done in the laboratory premises and the value obtained was a program constant.

The third module is the DHT 11 air humidity sensor, Figure 11a.

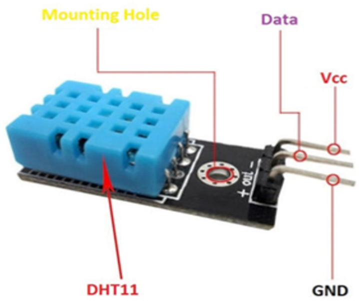



Figure 11a: Humidity sensor

The fourth sensor is the UV module S12SD, which is shown in Figure 11b.

Figure 11b: UV sensor S12SD

The fifth module is an IR temperature sensor. In the project, the role of the IR sensor is to measure the temperature of the substrate on which the ROBOLab is placed, figure 11c.

Figure 11c: IR module

The last in the series is the BH1750 light module, figure 11d.

Figure 11d: BH1750 light module

**d) Energy group** - battery power supply of the UNTLab platform is divided into two segments. The first segment is a 9V battery power supply that ensures reliable operation of the microcontroller, communication module and all sensor modules. The second segment is the battery power supply intended for the motor group and the NANO controller. Two 18650 batteries with a nominal voltage of 3.7V are connected in series (total voltage is 7.4V). With its capacity, the battery block enables continuous movement of RoboLab in a time interval of more than 20 minutes.

## 4. MEASUREMENT AND READING OF SENSOR VALUES

The program for the microcontroller (programming language C# is used) is divided into four segments:

- Communication part that opens and maintains a two-way Bluetooth channel (module HC06),
- Control elements (drivers) that control the operation of the electric motor,
- Acquisition of data from the protective sensor group,
- Acquisition of data from ambient sensors BMP180 and MQ135, DHT11, BH1750, EMZ and SD125.

Part of the code for communication with Bluetooth module HC06 is shown in Figure 12.

```
SoftwareSerial Bluetooth(2, 3); // TX, RX

 if    (Bluetooth.available()){    //prijem
podataka

   Data=Bluetooth.read();
```

Figure 12: Opening the communication channel

The electric motor is controlled via a module (driver). The signals from the controller are sent to the drivers that control the complete operation of the motor (starting, stopping or changing the direction of rotation). Figure 13 shows the code that activates all four motors. The wheels rotate in the same direction ensuring that the platform moves forward.

```
//------- to move FORWARD ----------------------------
digitalWrite(in1, HIGH); analogWrite(enPD, 248-motorSpeedR);
digitalWrite(in2, LOW); analogWrite(enPL, motorSpeedL);
digitalWrite(in3, HIGH); analogWrite(enZD, motorSpeedL);
digitalWrite(in4, LOW); analogWrite(enZL, 248-motorSpeedR);
```

Figure 13: Part of the code to control the electric motor - forward movement

The BMP180 module is a digital temperature and air pressure meter. The algorithm we used during programming is shown in Figure 14.

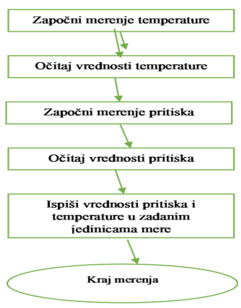



Figure 14: Algorithm for the BMP135 sensor

A part of the code that was developed for the purposes of the UNTLab project is shown in Figure 15.

```
//---------------------------------CO2
char status;
  double temp,P,p0,a;

   status = pressure.startTemperature();
  //--------------------------------------

if (status != 0)
  {
    // Cekamo da se merenje zavrsi:
    delay(status);

    status = pressure.getTemperature(temp);
    if (status != 0)
    {
      // Prikazi merenje:
      Serial.print("temperature: ");

      Serial.print(temp);
      Serial.print(" stepeni C, ");
```

Figure 15: Code for temperature measurement

The MQ135 module is a digital gas detection measuring element that was already described in the previous chapter. The code defined for UNTLab is shown in Figure 16. In Figure 17 we have a control listing generated during program testing. The modules must programmatically coordinate with downloading, sending data and controlling the powertrain. Otherwise, the response of the motion control system has a noticeable delay, which is not an acceptable option.

```
    co2now[x]=analogRead(A0);
     delay(20);
  }

  for (int x = 0;x<10;x++)   //
  {
    zzz=zzz + co2now[x];
  }

  co2raw = zzz/10;
   co2ppm = co2raw - co2Zero;

  Serial.print("Vazduh=");
   Serial.print(co2ppm);  //
    Serial.println(" PPM");

//----------------------------------CO2
```

Figure 16: Code MQ135 gas detection measuring element

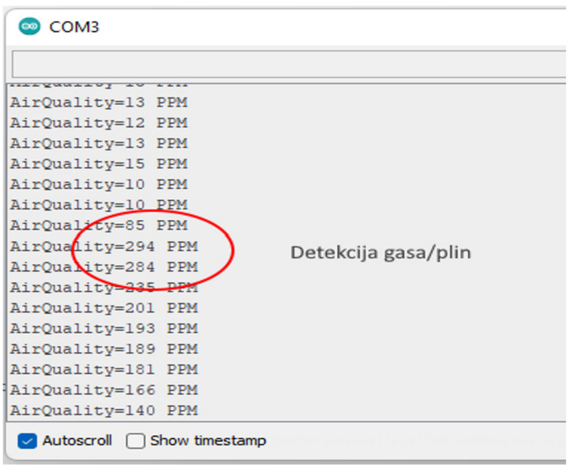



Figure 17: Listing for gas detection measuring element

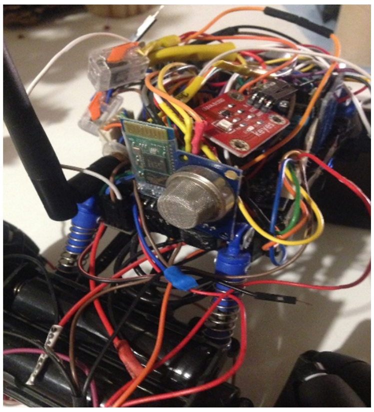


Figure 18: Gas detection sensor (taken on development environment V15.9)

## 5. RECORDING THE ENVIRONMENT

In addition to the sensors whose functions have already been described, the UNTLab is equipped to record all collectign data. The recording set is sent to the mobile device and stored on the micro TF card. One more, RoboLab has a high resolution camera - 1280HD and a coverage angle of 130º. The above characteristics meet the minimum requirements of the UNTLab.

## 6. PROGRAM FOR REMOTE CONTROL OF UNTLab

In the MIT APP Inventor development environment, the Android code used by the mobile device was written, Figure 19. The development environment allows students to quickly and easily create code using all the advantages of modern technologies.

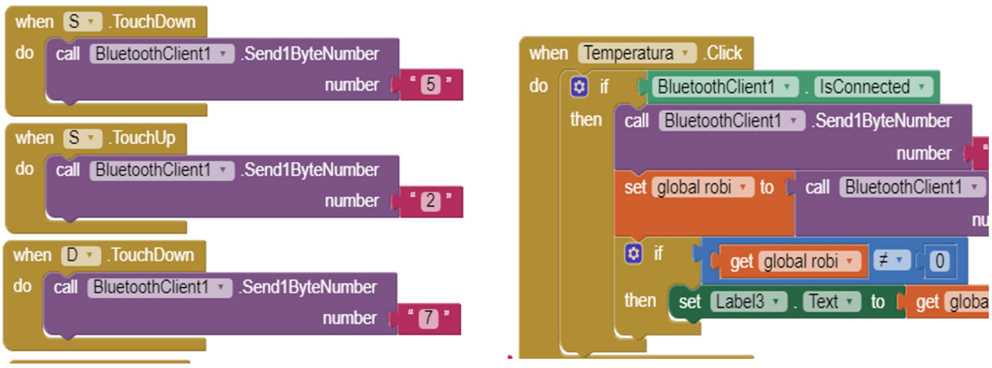



Figure 19: MIT Invetor, graphical representation of part of the code for a mobile device.

The interface of the UNTLab program, which we use for mobile devices, can be seen in Figure 20.


Figure 20: Android application for managing the robotic platform

## 7. CONCLUSION

UNTLab can be used in several fields. The first aspect of application that we observe are crisis situations, which are becoming more and more common. The need for a robotic platform of this type is getting bigger and bigger. Encapsulated information collected by UNTLab in a dangerous (contaminated) environment can be of importance in critical situations, without human resources being exposed to danger.

Another aspect of the development of the mentioned platform is in the educational process, as a modern teaching tool. UNTLab represents an excellent ram for further platform development. Through practical examples like this, students are introduced to the world of robotics, mechanics, electronics, and programming the fastest. The projects noticeably increase the students' interest in the mentioned fields, which, through the further development of UNTLab, enables them to become familiar with concepts that are ubiquitous and represent the general trend of implementing new technologies in the syllabi of modern faculties.

The third aspect of the development and application of the platform is of a security nature. The platform can be used as an active security element. According to user requirements and the nature of the purpose of the platform, a suitable set of sensors is also selected. UNTLab, which we have already mentioned, is also equipped with a camera, which further increases the utility value of the platform.

## REFERENCE

Campion, G., Bastin, G. and D'AndréA-Novel, B. (2011) Structural Properties and Classification on Kinematic and Dynamic Models of Wheeled Mobile Robots. Russian Journal of Nonlinear Dynamics, 7, 733-769. https://doi.org/10.20537/nd1104002

Cvetković D., Stanković Ž, (2010) Modern programmable educational tools", Conference ITeO 2010, Banja Luka, Republika Srpska, ISBN 978-99955-49-48-0, pp. 181-186

Salih, J.E.M., Rizon, M., Yaacob, S., et al. (2006) Designing Omnidirectional Mobile Robot with Mecanum Wheel. American Journal of Applied Sciences, 3, 1831-1835

https://www.youtube.com/watch?v=Xrc0l4TDnyw