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Research article

BICYCLE PARKING STAND

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ABSTRACT

This paper presents the design and construction of a bicycle parking stand that protects a standing bicycle from theft. The design includes the construction principles, a 3D model made in SolidEdge software, the electronic components used in the construction of the stand and an electronic schematic with control software. The stand consists of mechanical (stand, handle), electronic (microcontroller, display, RFID system) and software (C++ language) parts. The stand was made and tested under real conditions, which confirmed the effectiveness of the system. The bicycle stand can be used in all public areas where bicycle parking should be safe.

KEYWORDS: bicycle parking stand, RFID system, 3D model

1. Introduction

With the ever-increasing number of motorised vehicles and the increase in traffic jams, people are increasingly using bicycles. More and more bicycle lanes are also being built, which also contributes to the increase in the number of users of single-track bicycles, and the number of places where one can safely leave a bicycle is not increasing. In order to secure the bicycle in the designated places, the user usually needs a special lock, which allows the vehicle to be left safely. However, not every bicycle user has such a lock or has not brought it with them. These locks usually use a multi-digit cipher or key, where the code can be forgotten and the key lost or damaged. A bicycle parking rack can prevent the above-mentioned situations and adequately secure the bicycle against theft, as well as making it easier to use with a proximity grid with a stored ID or a smartphone app, which everyone has nowadays. The bike stand would, through such solutions, eliminate the problem of needing different types of bike fasteners and the problems caused by transporting them. The device would adequately secure the bicycle against theft and provide versatility of use for most types of unicycles.

2. Design assumptions

The design of the bicycle parking rack is intended to protect the bicycle from theft and to provide versatility of use for most types of bicycles. It would also eliminate the problem of needing to carry and transport different types of fasteners, and to use the device all that would be needed would be a proximity card equipped with a memory stick with the ability to write and read data or a smartphone with access to NFC communication, which could very easily fit in a pocket.

Using an RFID reader that generates an electromagnetic field by means of a coil, it is possible to read the data stored on such devices. By approaching a card with a suitably stored identifier, the bicycle parking stand informs the user by means of an acoustic signal and messages displayed on the screen that access has been granted, followed by the opening of the grippers. This is the time it takes to place the bicycle between the jaws of the grippers in order to secure it. Pressing the bicycle frame against the button in the middle will initiate the automatic closing of the grippers and a message will appear on the display, indicating that the vehicle is secured. If the specified time for placing the unicycle has elapsed, the clamp jaws will automatically clamp. The same identifier must be entered to unlock the bike. In the case of cards with a different identifier stored on them, appropriate messages will be displayed, indicating that access is not possible to the device.

The structure of the bicycle parking stand is mostly made of steel. The exceptions are the tubes superimposed on the bars and the housing for the display, LEDs and RFID reader, these elements are made of plastic. Thanks to holes in the plate, which is the base of the device, it is possible to fix it to the ground. The extendable profile makes it possible to adjust the height of the arm from 65 cm to 112 cm, and the gripper plate attached to its end has the possibility to rotate and adjust the appropriate angle to the bicycle frame. The wide opening angle of the grippers makes it possible to secure unicycles with different frame thicknesses and geometries, while the two support points increase safety and improve stability. The grippers are controlled by servo motors and the whole is controlled by an Adruino Uno microcontroller. The unit is mains-powered and will be equipped with an additional battery in case of power failure.

3. Design

The design of the parking bicycle stand includes a 3D model made in Solid Edge [1], electronic components, including an electronic schematic, and software.

3.1. 3D model

The first component of the bicycle parking stand is a steel profile measuring 40 mm x 40 mm x 2 mm. The profile has been welded to a metal plate, which, thanks to holes, can be fixed to the ground. The top of the section has been slightly bent in order to prevent the smaller profile from pulling out, which will be placed inside it. The welded M10 nut is designed for a screw with a handle, which will make it possible to adjust the height of the unit. A 30 mm x 30 mm x 2 mm section, bent at 90°, is the part of the device responsible for adjusting its height. A small steel plate has been welded to its base which locks against the top of the larger profile when an attempt is made to pull it out. At the end of the arm, a piece of flat bar is welded with a hole intended for the bolt holding the steel plate. The steel plate (Fig. 1a) is the executive element of the whole device, which is attached to the adjustable profile with the arm through a hole in the top. Four 8 mm diameter rods are welded to the plate, over which plastic tubes are placed. Eight M5 screws, welded to the plate, are intended for fixing electronic devices. The servos are tightened with flat plates through nuts and the Arduino Uno microcontroller is screwed to the wooden plate. The orbs of the servos are connected to the angles by flat connectors, which in turn are attached to these components via bolted rivets and allow them to rotate freely during operation. Through the notches, flat angles, which act as grippers, pass through the notches and are mounted on cylindrical rods welded to the plate, which pass through their holes to allow rotation. Two square-shaped flat bars welded to the edges of the plate with a hole in them are the elements used to fix the housing of the unit.

A 3D model of the fully assembled bicycle parking stand is shown in Figure 1b. The section with the arm is placed inside a profile with a welded base, and a screw with a handle allows it to be locked at a chosen height. The sheet metal housing is fixed with screws and covers all the equipment and components on the inside of the plate. A bolt is passed through the hole of the flat bar and the plate and the end of the bolt has been welded to the surface of the steel plate so that it can be rotated. On the profile arm, there is a housing for the display, LEDs and RFID reader, along with holes for the wires.

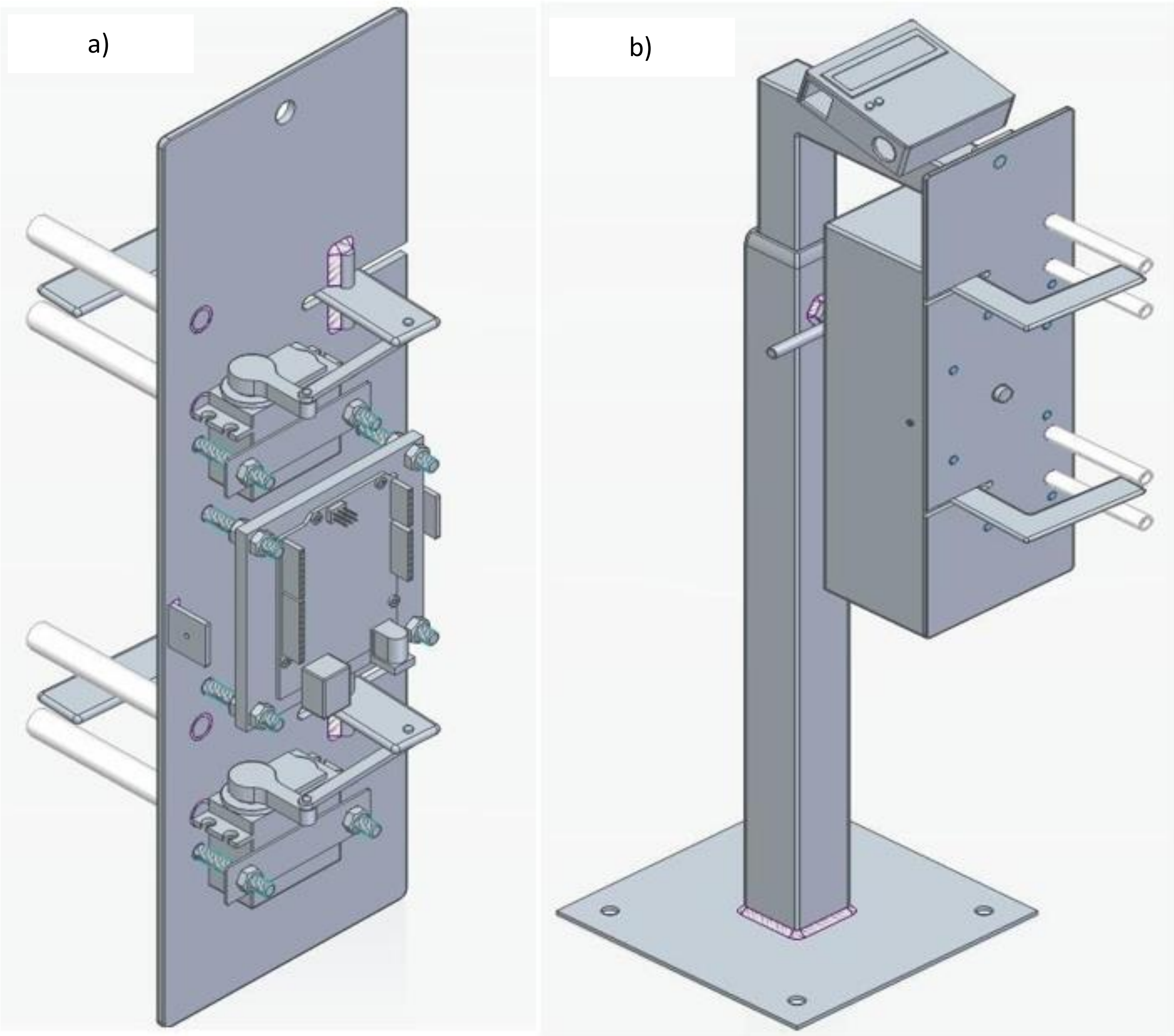

Figure 1. a) Steel plate with grippers and electronics b) 3D model of bicycle parking stand

3.2. Electronics

The electronics diagram of the bicycle parking stand is shown in Figure 4. The Arduino Uno microcontroller is the main control circuit for the bicycle parking stand (Figure 2). The board contains an 8-bit ATmega328 microcontroller clocked at 16 MHz, which has 32 kB of Flash memory and 2 kB of SRAM. The board is equipped with 14 digital outputs and inputs, where 6 of them can be used as PWM outputs, and 6 analogue outputs for, among other things, sensor operation. The board can be powered via the power connector with a 7 V to 12 V DC source or via a USB port [2, 3, 4].

The bicycle parking stand uses two Tower Pro MG-996R servos, controlled by the PWM outputs of the Arduino microcontroller, which are responsible for opening and closing the grippers. The alphanumeric LCD display is powered by 5 V from the Arduino microcontroller. It is capable of displaying 32 characters in two lines of 16 columns and has a blue backlight with white characters. The display can operate in 8-bit or 4-bit mode. The screen displays messages to indicate to the user whether a given ID has been accepted or rejected, and informs about the opening and closing of grippers, additionally showing the elapsed time until closing.

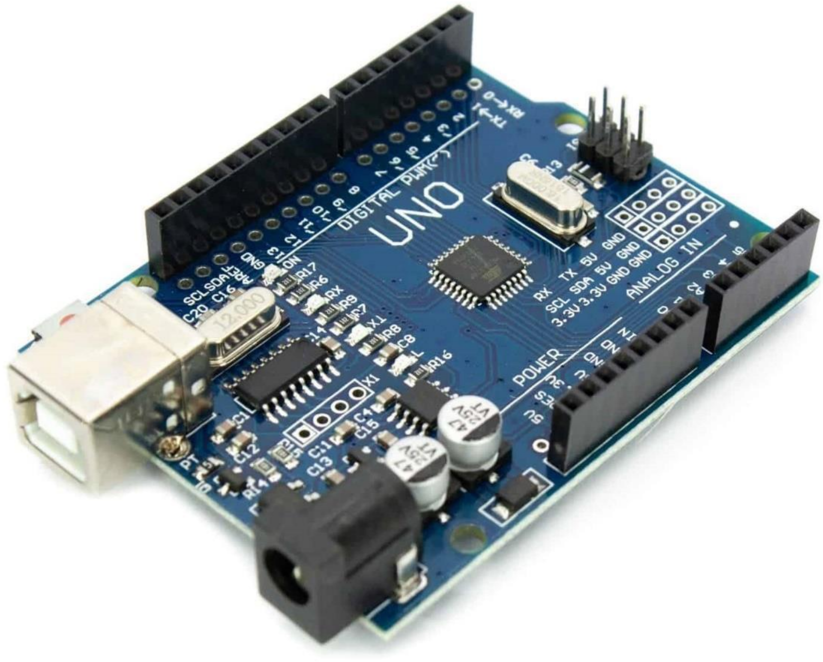

Figure 2. Arduino Uno R3 z mikrokontrolerem AVR ATmega328 [5]

The I2C converter, powered by 5 V, allows the LCD display to be controlled via the I2C bus. Thanks to the use of this module, operation of the display is possible - using only two lines: SDA and SCL. Additionally, the converter is equipped with a potentiometer for contrast adjustment and a jumper - pulling it out will disable the backlight. The RC522 RFID module (Fig. 3), supplied with 3.3 V, enables reading data from RFID devices operating at 13.56 MHz, compliant with ISO/IEC 14443 A/MIFARE standard, MF1xxS20, MF1xxS70, MF1xxS50. It is equipped with an antenna that allows communication within a range of up to a few centimetres, even through the small size of the enclosure.

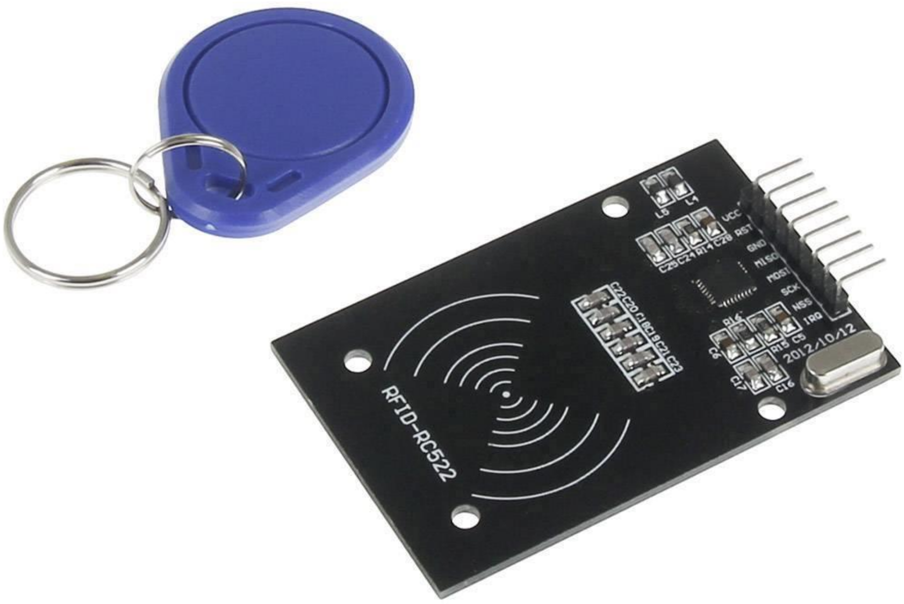

Figure 3. RC522 RFID module with key fob [6]

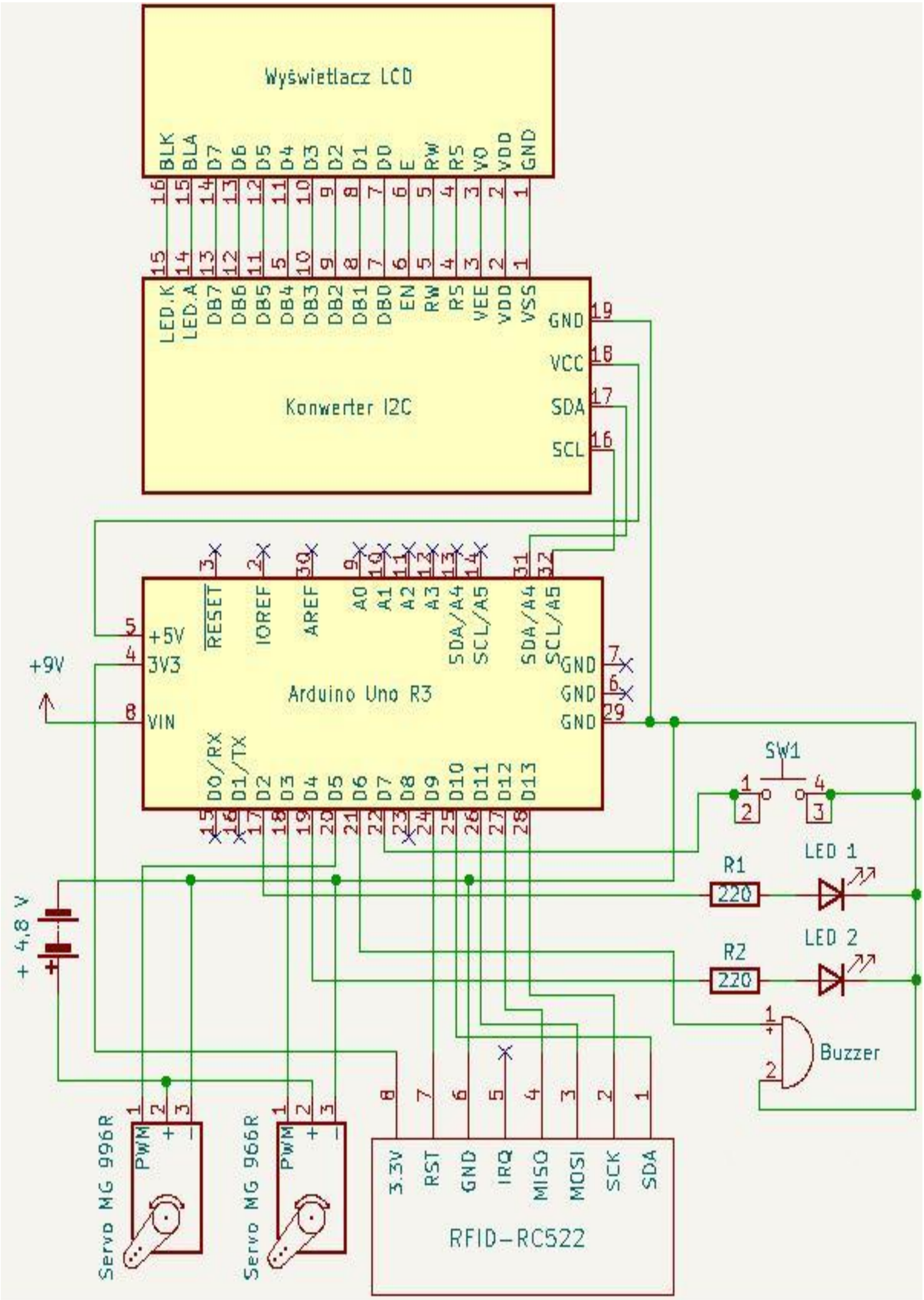

Figure 4. Diagram of the electronics of a bicycle parking stand

3.3. Software

The software for the bicycle parking stand is written in C++ [7, 8], using the Arduino IDE (Fig. 5). The *setup* function declares the input and output circuits and assigns the individual components to the corresponding pins of the microcontroller. The instructions in this function are executed only once during start-up and set the position of the servos so that the grippers remain closed.

```
tag.toUpperCase();
if (tag.substring(1) == "B2 07 F1 1B" )
{
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Chwytak");
  lcd.setCursor(7, 1);
  lcd.print("otwarty");
  digitalWrite(LED_G, HIGH);
  tone(BUZZER, 600);
  Serwo_1.write(20);
  Serwo_2.write(50);
  delay(300);
  digitalWrite(LED_G, LOW);
  noTone(BUZZER);
  delay(1000);
  for( int k = 0 ; k<15 ; k++)
  {
  czas = licznik -1;
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Wcisnij przycisk");
  lcd.setCursor(0, 1);
  lcd.print("Zamkniecie za:");
  lcd.print(czas);
  delay(1000);
  licznik--;
  while (digitalRead(7) == LOW)
  {
     goto zamkniecie;
  }
     }
  {
     zamkniecie:
     Serwo_1.write(130);
     Serwo_2.write(110);
     lcd.clear();
     lcd.setCursor(0, 0);
     lcd.print("chwytak");
     lcd.setCursor(7, 1);
     lcd.print("zamkniety");
     delay(1000);
```

Figure 5. Extract from the source code controlling the operation of the bicycle parking stand

The *loop* function carries out the main part of the programme, which executes continuously. At this point, the microcontroller waits for an identifier to be entered, and the *if* function checks whether the identifier entered matches the one assigned to the device. If the identifier is accepted, the instructions indicating that access has been granted are executed. The green LED then changes its state to high, the buzzer emits a short beep and the servos change their position and open the grippers.

A for *loop* counts down the time until the grippers automatically close. The while *loop* inside the for *loop*, when the state of the button changes from high to low, will stop the countdown and the programme will proceed to execute the instructions responsible for closing the grippers. In the case of an invalid identifier, the instructions indicating no access are executed. After all instructions have been executed return to the beginning of the *loop* function.

4. Actual design of the bicycle parking stand

Based on the 3D documentation, a bicycle parking stand was made (Fig. 6). Thanks to an extendable profile with an arm, the unit is height-adjustable. The maximum height at which the arm can be positioned is 112 cm. On the upper surface of the arm is a small plastic housing, under which the display, LEDs and RFID card reader are located. The entire structure has been varnished black.

Figure 6. Manufactured bicycle parking rack with open grab racks

5. Check tests

The first bike on which the bicycle parking rack was tested was a mountain bike. Bringing a card with a suitably assigned ID close to the RFID reader, the device emitted a short beep and a green LED lit up to indicate that access had been granted. The display showed that the grippers had been opened and a countdown to their automatic closure took place. Thanks to the height adjustment and the possibility to rotate the gripper plate, it was possible to fit the device very well to the horizontal tube of the bike frame. By pressing the frame against the button, the jaws of the grippers automatically tightened and the bike was secured (Fig. 7).

Unlocking the bike was possible by re-entering the same badge that opens the grippers, and any incorrect card was rejected by the device and prevented the vehicle from being unlocked. The bicycle parking rack also allows other types of bicycles to be secured. The device was tested on a city bike with a women's frame type. When trying to fit the device to the upright tube, there was a problem as the steel plate blocked against the chain guard and prevented this part of the bike from being grasped. However, this type of bike was successfully secured by gripping the lower curved frame tube.

Figure 7. Mountain bike secured on a bicycle parking rack

6. Comments and conclusions

A bicycle parking stand can effectively protect a unicycle from theft, but the low torque of the servos responsible for closing the grippers makes it easy to open the grippers using forceful methods. To eliminate this problem, it would be necessary to equip the device with more powerful servos or self-locking worm gears.

Noteworthy is the height-adjustable profile combined with the rotating plate. These elements work well and, for security purposes, allow the bicycle parking stand to be adapted to most structural elements of the unicycle.

The housing of the electronic components should be fixed so that it cannot be removed. The push button for automatic locking of the grippers could be replaced by a proximity sensor, for example, or placed at another point, as it is not always possible to press on the frame so that it can be pushed in.

The whole structure would need to be made of damage-resistant material where the grippers and the bolt holding the plate to the profile with the arm are most vulnerable.

It is also important to power the bicycle parking stand - the battery power used is not the best solution to guarantee the safety of the bicycle. The Ni-Cd battery used in the tests discharges quickly under the load of the servos. A way of eliminating this problem would be to power the device from the mains. Battery power would be an additional safety feature in the event of a power failure.

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