Construction of a Rotation Acquisition System using Arduino and Scada Supervisory Software

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Abstract

This work presents the development and implementation of a System for Acquisition of Rotations composed of an open-source Arduino electronic prototyping platform and a Supervision and Data Acquisition System (SCADA). This system obtains instantaneous values for frequency, linear velocity, and angular velocity, and the graphical representation of said instantaneous values is in real-time. Thus, the proposed system is a mediator of learning for the teaching of Circular Movement Uniform, with theoretical/practical interaction essential in classes for understanding the content.

Keywords: Arduino, Data acquisition, Circular Movement Uniform, Supervisory system.

Introduction

The contents related to the Uniform Circular Movement (UCM) are usually studied in the discipline of Physics in the first year of high school and require, from the teacher, the use of different approaches, material resources, and methodologies with concrete examples, which sensitize students to seek to know the phenomena involved in this type of movement and consequently understand them.

A highlight made by Gaspar (2009) states that an experimental activity has real advantages over a theoretical one; however, the two need to walk together, both complement each other. The author says that practical training cannot be solitary or an individualized resource, as only the connection of theory with practice can lead to knowledge and learning.

The National Curriculum Parameters for High School (PCNEM in the Portuguese acronym, 2006) envisage a study of Physics aimed at social, cultural, and professional application, aiming that students have knowledge contextualized in the teaching-learning process with their reality.

Visualizing the phenomenon studied facilitates the understanding by students, according to Vygotsky (1987); for individuals, learning is built from communication, not only through speech but in the entire context of life.

Brazilian education and teaching have been re-discussed since the construction and publication of the Basic Education Guidelines Law No. 9394/1996. They are contexts, concepts, methodologies, and new ways of teaching that invade teaching institutions, from Basic Education to Teaching Higher.

The National Curriculum Parameters and the National Curriculum Guidelines for High School (DCNEM in the Portuguese acronym, 2011) were drawn from this Law, building new curricula and proposals.

Faced with these changes, teachers and students need didactics based on practical learning to attest competencies and abilities to make individuals suitable for the world in which they live.

The National Curriculum Parameters for High Schools show that Physics is often taught through confusingly configured concepts, laws, and formulas, far from the students' daily lives, leading to disconnected meanings from reality and making their understanding difficult. Given this statement, you realize that abstraction makes it difficult to perceive the phenomenon during content development; there is a motivating learning difficulty in dismantling theory and visualizing the physical concept. Therefore, emphasis on concrete examples is necessary for effective learning.

Re-discussing Physics is essential for the teacher to appropriate methodological knowledge and enrich their strategies. Teaching and learning can materialize in a greater understanding of the world and training for contextualized citizenship. It is essential to realize that there is no ready-made recipe for this to be accomplished; success will come when both teacher and student understand the limits, prior knowledge, gaps, and objectives; when this moment happens, success will be guaranteed (PCNEM, 2006).

Considering the importance of experimentation in the teaching of Physics, we present the development of a Rotation Acquisition System (RAS) composed of an Arduino open-source electronic prototyping platform and a SCADA (Supervisory and Data Acquisition System) supervisory software. The study of circular motion develops an understanding of related physical quantities, such as frequency, period, linear velocity, and angular velocity.

Method

The Arduino platform and the SCADA LAquis supervisory platform were chosen for the development of the system due to the non-mandatory use of licenses for the two tools, and because they are compatible with the Modbus Serial protocol, which also does not have mandatory licensing fees, and still is compatible with various physical means of transmission.

In this section, we present the methodology used to develop and elaborate the rotation acquisition system through the SCADA LAquis supervisory software and the Arduino free hardware platform.

For Arduino programming, the Arduino IDE (Integrated Development Environment) software was used, obtained from the address: https://www.arduino.cc/en/main/software.

The projected Arduino kit programming obtained the signals from the infrared reflective obstacle sensor module TCRT 5000, connected to the Arduino's digital input port. Data exchange between Arduino and LAquis via Modbus protocol is performed through the *SimpleModbusSlave.h library*.

The library has important functions in the elaboration of Arduino programming, among which *modbus.configure()* stands out, which allows you to define the communication settings, such as the serial port used, the transmission rate, the message format to be sent, the identity of the slave device, the data transmission enable pin in addition to the size along with the address of the block of registers used in the exchange of information.

Another essential function is *Modbus_update_comms()*, which updates the Modbus protocol communication settings, and has as parameters the baud rate, the message format, and the slave device's identity.

The *modbus_update()* function is the function responsible for sending and updating data between devices. It is where the sequential updating of the registers takes place in each loop within the code execution. The complete code with all the functions used is shown in Figure 3.

```
//CODIGO PARA CONTAGEM DE RPM
//Autor: [redacted]
#include <SimpleModbusSlave.h>
int rpm;
enum
{
 RPM_SCADA,
 HOLDING_REGS_SIZE // leave this one
 // total number of registers for function 3 and 16 share the same register array
 // i.e. the same address space
};
unsigned int holdingRegs[HOLDING_REGS_SIZE]; // function 3 and 16 register array
volatile byte pulsos;
unsigned long timeold;
// Quantidade de pulsos por volta no sensor
unsigned int pulsos_por_volta = 1;
// interrupção
void contador()
{
 //Incrementa contador
 pulsos++;
}
void setup()
{
// configuração da porta serial
 modbus_configure(&Serial, 9600, SERIAL_8N1, 1, 2, HOLDING_REGS_SIZE,
holdingRegs);
 modbus_update_comms(9600,SERIAL_8N1, 1);
// pino para conexão dos pulsos advindos do sensor
 pinMode(2, INPUT);
//Interrupcao 0 - pino digital 2
 //Aciona o contador a cada pulso
 attachInterrupt(0, contador, RISING);
 pulsos  = 0;
 rpm     = 0;
 timeold = 0;
}
void loop()
{
 modbus_update();
 //Atualiza contador a cada segundo
 if (millis() - timeold >= 1000)
 {
  //Desabilita interrupcao durante o calculo
  detachInterrupt(0);
  rpm = (60 * 1000 / pulsos_por_volta ) / (millis() - timeold) * pulsos;
  timeold = millis();
  pulsos = 0;
  holdingRegs[RPM_SCADA] = rpm;
  //Habilita interrupcao
  attachInterrupt(0, contador, RISING);
 }
}
```

Figure 3 - Code recorded in Arduino.

The structure of the code used in Arduino is composed by the addition of the libraries used, then comes the definition of the number of data records that will be used within an *enum* type structure. We have the configurations of the communication and pins parameters, and lastly, the repetition structure where inside it we have the constant sending of data between the devices (Oliveira Junior, 2019).

The rotation acquisition system (RAS) was developed on a wooden board MDF (Medium Density Fiberboard), widely used in joinery, with the following dimensions: 200 mm wide, 300 mm long, and 15 mm thick.

For the SAR implementation, an Arduino UNO R3 Platform was used, which is composed of an “Open-Source-Hardware” electronic board, a CPU cooler measuring 9 cm x 9 cm, an operating voltage of 12 volts, a 400-point protoboard (contact array), a green light-emitting diode (LED), a 220-ohm resistor, a TCRT 5000 infrared-reflective obstacle sensor module, a 1.0k ohm linear potentiometer, a battery 9.0 volts, battery connector, an AM/BM USB cable, protoboard jumper wires, and a notebook (Figure 4).

Arduino UNO R3 Platform

CPU cooler

Protoboard (Contact Matrix)

Light emitting diode

Resistor 220 Ω

Infrared reflective obstacle sensor

Potentiometer 1 kΩ

Battery 9 V and Battery Clip

Jumper and cable USBAM/BM

Figure 4 - Components used for RAS implementation

Figure 5 shows the schematic diagram of the RAS, while Figure 6 shows, in a pictorial way, the interconnections of the components.

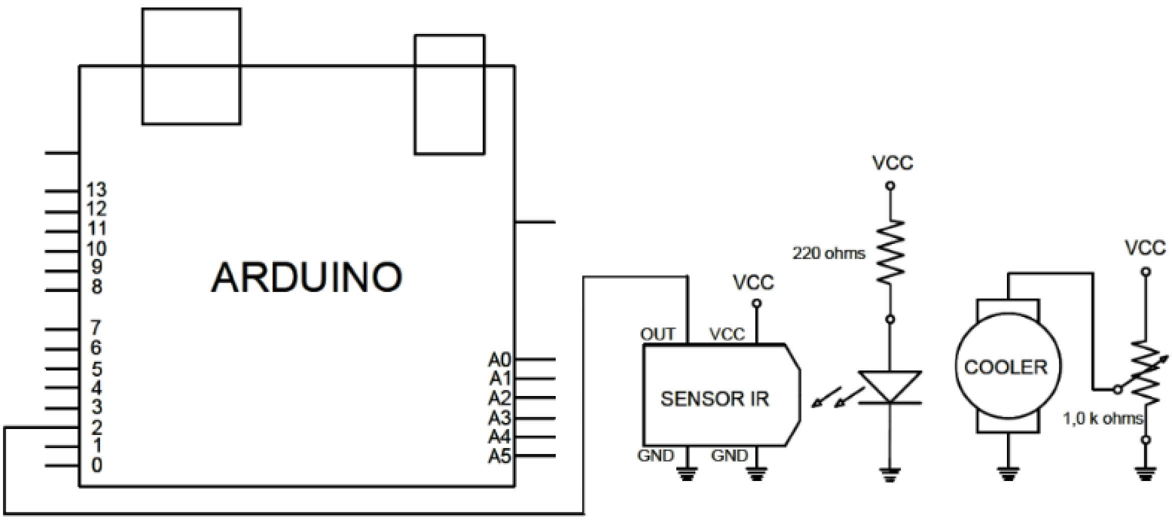


Figure 5 - RAS schematic diagram

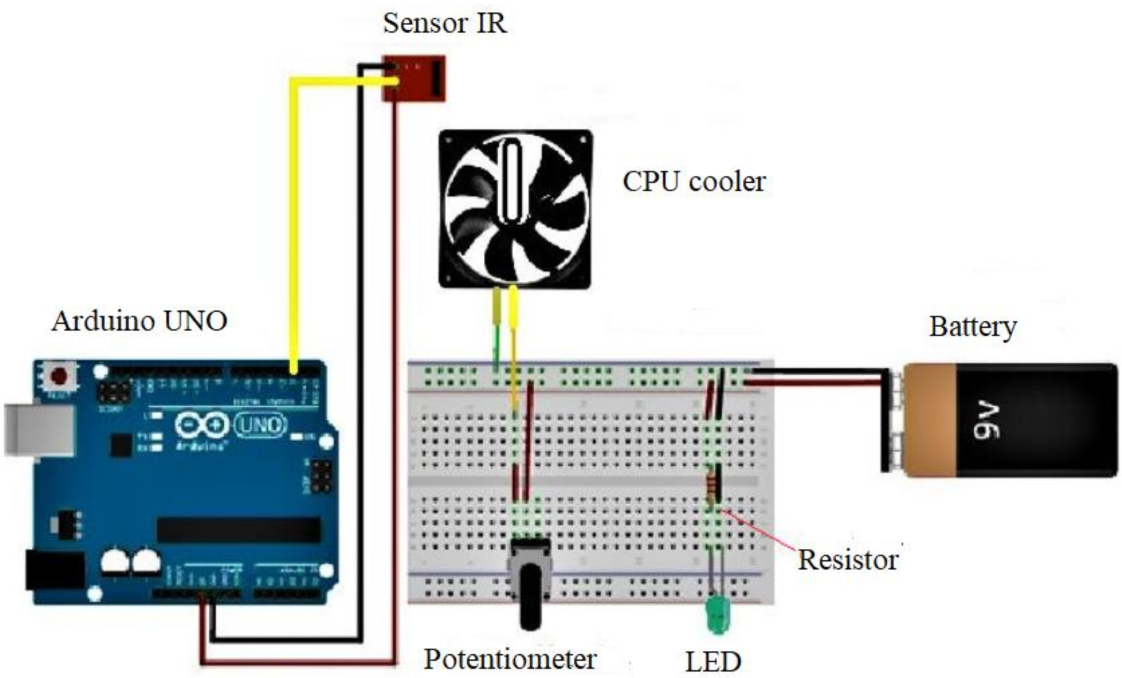


Figure 6 – Interconnections of the components of the Rotation Acquisition System (RAS).

The communication between Arduino and SCADA Laquis was carried out via USB-Serial. Figure 7 is the actual hardware used to implement RAS.

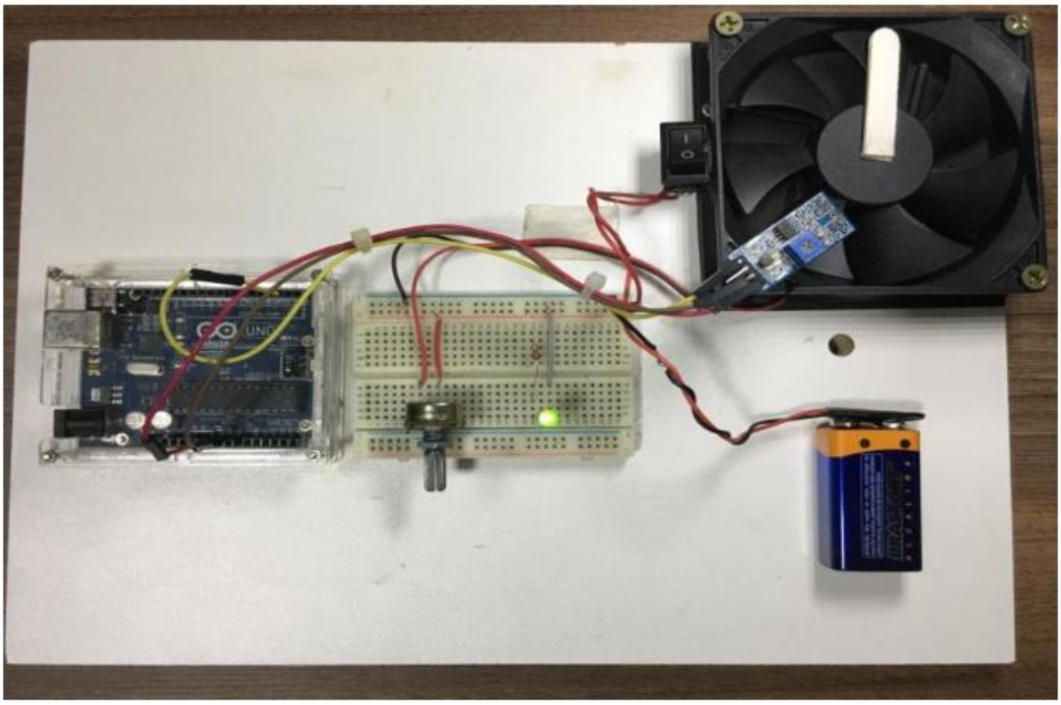


Figure 7 - Photo of the Rotation Acquisition System - RAS

The acquisition of the signals and presentation of the instantaneous values referring to frequency, linear velocity, and angular velocity, as well as the graphical representation of said instantaneous values, in real-time, used a notebook, with the graphic interface developed in the supervisory program SCADA LAquis 4.1 (Laboratory of Acquisition).

The SAR graphical interface, developed in SCADA LAquis 4.1 Supervision (Acquisition Laboratory), was obtained from the developer's website: https://www.lcds.com.br/scada.asp, as shown in Figure 8.

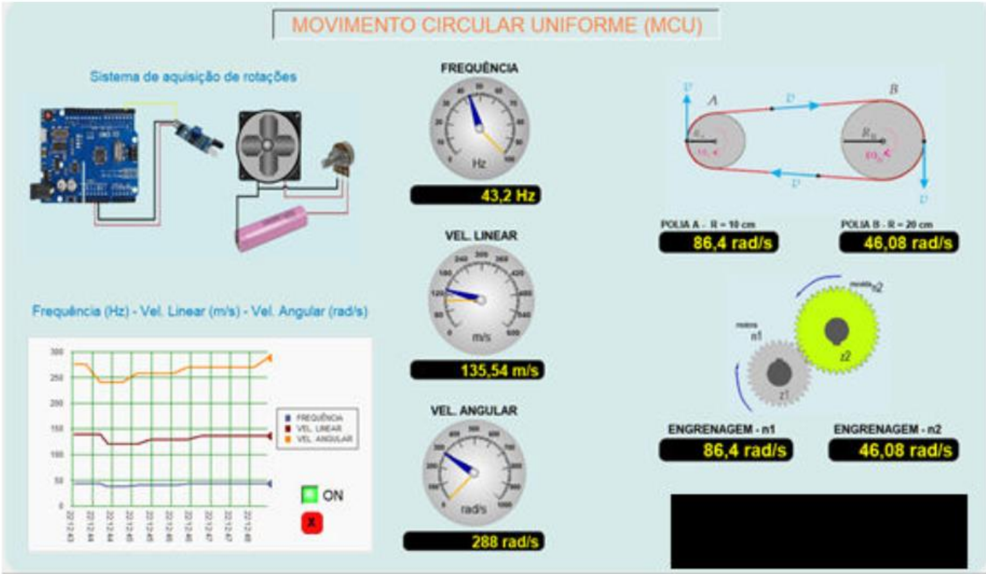


Figure 8 - SCADA LAquis Supervisory Screen in operation.

The tags required for the construction and operation of the RAS supervisory system, shown in Figure 9, are as follows:

tag – C001 - Frequency (f) *in Hz*

$$f = (rpm) \cdot 1/60 \rightarrow f = (rpm).0{,}016$$

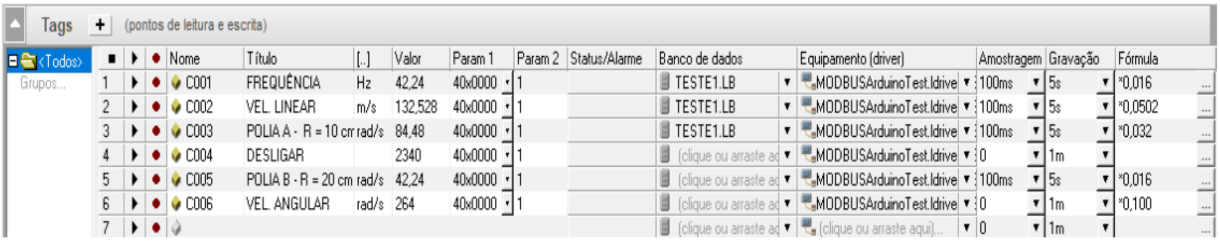
tag – C002 - Linear velocity (v) in m/s

$$v = 2\pi.f.r \rightarrow v = 2\pi(rpm).0{,}016.0{,}5 \rightarrow v = (rpm).0{,}0502$$

tag – C006 - Angular velocity (ω) in rad/s

$$\omega = 2\pi.f \rightarrow \omega = 2\pi\,(rpm).0{,}016 \rightarrow \omega(rpm).0{,}100$$

The graphical interface will be operational after entering the values in the “tags” spreadsheet, as illustrated in Figure 9.


Tags + (pontos de leitura e escrita)

<Todos>
Grupos...

	Nome	Título	[..]	Valor	Param 1	Param 2	Status/Alarme	Banco de dados	Equipamento (driver)	Amostragem	Gravação	Fórmula
1	C001	FREQUÊNCIA	Hz	42,24	40x0000	1		TESTE1.LB	MODBUSArduinoTest.ldrive	100ms	5s	*0,016
2	C002	VEL. LINEAR	m/s	132,528	40x0000	1		TESTE1.LB	MODBUSArduinoTest.ldrive	100ms	5s	*0,0502
3	C003	POLIA A - R = 10 cm	rad/s	84,48	40x0000	1		TESTE1.LB	MODBUSArduinoTest.ldrive	100ms	5s	*0,032
4	C004	DESLIGAR		2340	40x0000	1		(clique ou arraste aq	MODBUSArduinoTest.ldrive	0	1m	
5	C005	POLIA B - R = 20 cm	rad/s	42,24	40x0000	1		(clique ou arraste aq	MODBUSArduinoTest.ldrive	100ms	5s	*0,016
6	C006	VEL. ANGULAR	rad/s	264	40x0000	1		(clique ou arraste aq	MODBUSArduinoTest.ldrive	0	1m	*0,100
7								(clique ou arraste aq	(clique ou arraste aqui)...	0	1m	

Figure 9 - SCADA Laquis 4.1 program screen with tags.

Results

To use the RAS as a teaching resource, the teacher must plan, according to the class profile, predicting the execution time, strategies, pedagogical resources, and methodology. The teacher can choose to work with this device in lectures when explaining the UCM concepts or can do it after the theoretical content, working the experimental part.

Conducting an initial "diagnosis" with the class to verify knowledge and difficulties can help in the development of guiding questions for the use of RAS, which can be carried out with an available script or a more traditional script where students can based on the values found in the proposed system, it determines physical quantities such as angular velocity, frequency and period. Later, students will be able to check the values calculated by them with those informed by RAS.

RAS allows the teacher to explore various concepts by performing multiple tests and experiments; it is possible, after establishing the radius in the UCM, to determine the period and frequency from the rotations per minute (RPM) of the fan.

In addition to these concepts mentioned, the teacher can work unit transformations with the students so that they understand the measurement units, which are widely used in the characterization of various types of engines, where the rotations are expressed in RPM, as well as the unit in the International System of Units (SI), which is used scientifically, in this case, the angular (or rotational) frequency, expressed in hertz.

When studying the UCM, a difficulty for students is to identify the difference between linear velocity and angular velocity. With this system by varying the radius, the student perceives the change in linear velocity and can conclude when thinking about solving a problem that on a bicycle, for example, the linear speed of rotation of the wheels will be lower for a point located closer to the center of the revolution than for a point located farther from the center of the wheel.

Conclusion

Experimental activities for teaching the Physics curriculum component contribute to concrete learning, in which the student can visually perceive the phenomenon. The strengthening of this learning occurs when the student is put in contact with the experiment.

Bringing this theory/practice interaction into the classroom is often not a very simple task for the high school teacher due to many factors we won't address at the moment.

We brought the RAS proposal to assist the teacher in an interactive experiment where the student can work with the variables, controlling them as needed. Here, this system is already developed so that the teacher can follow the steps described in this work and set up his rotation acquisition system.

If the teacher knows the Arduino platform, he can modify and improve the system, however even not mastering the programming principle, it is possible to follow the steps described in this work and build a rotation acquisition system such as experimental measurement equipment for physics classes.

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