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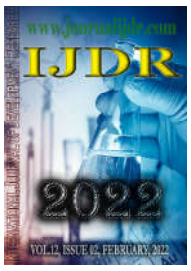

RESEARCH ARTICLE OPEN ACCESS

EMBEDDED SYSTEMS FOR ENERGY EFFICIENCY OF CLIMATE ENVIRONMENTS

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ABSTRACT

The consumption of electricity grows as technology advances, as this, almost entirely depends on the power of some energy source, the increase in this consumption causes positive impacts, but also negative one of them is due to the high cost of these resources , the reduction of resources destined to education in Brazil makes institutions look for strategies to reduce expenses and one is, to be able to use efficiency in the consumption of electric energy. This work aims to reduce electricity consumption, increase the duration of climate control devices and improve thermal comfort. To reduce the resources spent on air conditioning, a set of software and hardware was developed, aiming to control, in an automated way, environments with movement of people and with low management of resources, the use of sensors to measure the ambient temperature, control of people and, communication and control of the devices that make the environment climate control. After the implementation of this technology in the proposed environments, the system started to regulate the air conditioning device(s), seeking to compensate the temperature, when this is different from that projected by the user, from the ambient temperature measured by the set sensors and end the device activity when there are no people in theenvironment as well as start when a userentersthe site.

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INTRODUCTION

Energy efficiency envisions the improvement of techniques and technologies with the objective of improving the consumption of electric energy, this consumption being increasingly palpable in order to make the best use of this resource in the quest to do more with less from the efficiency of consumer appliances and the conscience of the people involved. "Brazil has a program called PROCEL (National Electric Energy Conservation Program) which is coordinated by the Ministry of Mines and Energy – MME and administered by Eletrobrás [1]." This program aims to combat the waste of electrical energy. With this program, Brazil seeks to follow the path of energy efficiency. Much of the energy produced in Brazil comes from the sources of hydroelectric plants, considered to be clean energy, yet it has impacts on the environment. Because the production process demands a large volume of water that are controlled in large reservoirs which are modified by engineering to hold such quantities and their flow is controlled. In Brazil, between 1990 and 2000, demand for energy grew by 49%, while installed capacity increased by 35%. In 1999, the plants' reservoirs were operating at 18% of their capacity. Due to periods of drought, the situation became dramatic: there was a major crisis in the energy matrix that caused energy rationing, causing inconvenience to society and economic damage to the country [2]. The paths adopted seek an improvement in consumption, but not necessarily in reducing the use of equipment, as the purpose of energy efficiency is to find ways to not have wasted consumption, since the costs and impacts caused by production affect society as a whole. Energy efficiency and renewable energies are "the two main pillars" of a sustainable energy policy. According to EPE, the PNEf is defined by the set of actions that reduce the amount of energy used to design products and services [3]. Not only Brazil, but many countries are looking for improvements in electricity consumption, as stated by CASTRO in his research. According to CASTRO, the 2018 International Energy Efficiency Scoreboard examines the energy efficiency policies and performance of 25 of the world's top energy consuming countries. Together, these countries represent 78% of all energy consumed on the planet and account for more than 80% of the world's gross domestic product (GDP) in 2014 [4]. This shows a concern with the consumption of electricity in countries that have the highest consumption, and that energy is directly linked to GDP.

Thermal Comfort: Thermal comfort, seen as a human sensation, depends directly on psychological, physical and physiological factors;

Psychological: they are factors that are related to differences in perception and response to sensory stimuli, referring to the individual's past experiences;

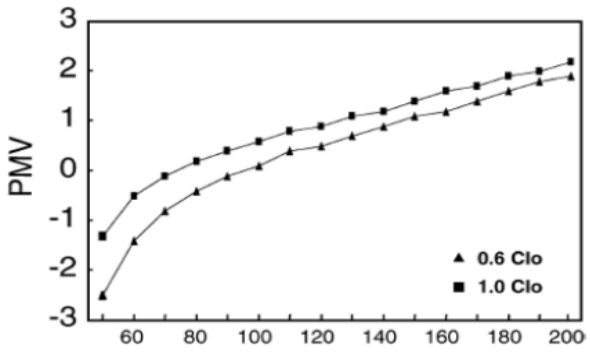
Physicists: they are factors that determine the exchange of heat between bodies and the environment;

Physiological factors: they refer to changes in the body's physiological responses, an action stimulated by the individual's exposure to the thermal conditions of the environment.

For [5] thermal comfort is mainly determined by 3 factors:

- The man's satisfaction or well-being in feeling thermally comfortable;
- Human performance, although the results of numerous investigations are not conclusive in this regard, and despite this inconclusiveness, studies show a clear tendency that discomfort caused by heat or cold reduces human performance. Intellectual, manual and perceptive activities generally have a better performance when performed in thermal comfort.
- Energy conservation, because due to the growing mechanization and industrialization of society, people spend a large part of their lives in artificially conditioned environments. By knowing the conditions and parameters related to the thermal comfort of the occupants in their environments, waste with heating and cooling, which is often unnecessary, is avoided.

Air-conditioned environments: Thermal comfort is a temperature that makes the individual feel comfortable in an environment, the same temperature can give sensation to different individuals, in a closed environment the conditions of thermal comfort can vary greatly. For this work, a comfortable average temperature among several individuals is sought. For [6], "the ISO 9241 standard establishes that an ideal temperature is between temperatures between 20 and 24 degrees in summer and 23 and 26 degrees in winter", this information will be used to assist in the functionalities proposed for the construction of a device which aims to optimize the operation of the air conditioning equipment in the place used as a case study in this work, the temperature conditions were determined based on the PMV index and the ISO 7730 standard, which proposes thermal satisfaction in closed environments. For [7], thermal comfort is “that mental condition in which satisfaction with the thermal environment is expressed”. As well as, which expresses the following thought, "thermal comfort is the mental state that expresses man's satisfaction with the thermal environment that surrounds him [7]. Figure 1 represents the inconsistencies of thermal comfort analyzed using the PMV technique.



Source: [9].

Figure 1. PMV Error Variation.

For [9] demonstrates through the figure above that an error around 15% in the metabolic rate this variation can lead to errors in PMV greater than 0.3 depending on other conditions. “the need for an accurate measurement of the metabolic rate for an accurate comfort analysis is highlighted” [10]. Some concepts with [11] say that heat resulting from the totality of chemical reactions that take place in the body. According to [12-16][[9], it is one of the least known parameters and most difficult to accurately estimate in field studies. To [10] they explain that part of the metabolic energy generated is transformed into work in the execution of a task, but the body's output is very low (rarely reaches 0.2) so that 80% of the energy generated by the body will be continuously transformed into heat as a combustion product [10]. Thus, the proposal aims to maintain an established and adjustable ambient temperature condition.

Embedded systems: An embedded system can be defined as a set of software and hardware that work closely together and that usually have a single function to perform, generally, it is part of a larger system and its functionality may depend on the decision-making of an application capable of managing a set of systems like that. After the application is embedded in the hardware, it is common not to make or change the system, that is, once programmed it will remain with the software until the hardware is removed or dispensed with, these devices must work without interaction with the user. The most common features in embedded systems are, reactive and protected or restricted operation. The action of embedded systems usually occurs through their interaction with other components of the systems such as processes and sensors that interact with the environment and after analyzing these data, there can be a decision making, where a call for the execution of a given task. Hence the need for the system to be reactive, responding in real time to process inputs to ensure the proposed system functionality. One of the first electronic devices to use a system considered “on-board” was the Apollo Guidance Computer (AGC). Developed at the MIT Instrumentation Laboratory by a group of designers led by Charles Stark Draper in the early 1960s, the AGC forms part of the guidance and navigation system used by NASA in the Apollo program for various spacecraft. In its early days, it was considered one of the highest risk items in the Apollo program due to its use ofpreviously-developed monolithicintegratedcircuits [17]. At the time AGC incorporated a user interface module that had CPU, RAM and ROM memories that functioned as a primary clock had four central 16-bit registers and executed eleven instructions.

Problem: The IFAM has 432 students distributed in the morning, afternoon and night shifts, in addition to servers who are technicians, security staff, support staff and 56 teachers, totaling 488 people. The activities take place from Monday to Saturday when these are considered school days that have at least 200 each year, taking into account the d.Guidelines and Bases of National Education (LDB).There are sectors that work primarily during administrative hours such as the DAP sectors - finance department, CRA - academic registration control, the library operates during the day and even the night shift as well as the pedagogical sector, the institution works practically every day , but the service to the public and classes take place on weekdays and school days, which are from Monday to Friday. Some sectors have plenty of activities and large space, such as the library with about 120 square meters and is equipped with two Split air-conditioning units of 18,000 BTUscada, this environment does not have a person responsible for turning off the appliances at the end of the day, in addition to the works a laboratory for general use and a roomthatholdsteachingmaterials,

Solution: In order to reduce electricity consumption and increase the life of air conditioning equipment and thereby generate savings for the institution, a system is proposed that automates the control of air conditioning equipment, using interaction with the environment, thus being able to regulate the temperature, turn the appliances on and off. To develop the proposed system, software engineering, mathematics, hardware and electronics were used to build the control prototype. According to the Brazilian association of electric energy distribution[18] of the total paid in the electricity bill in Brazil, 44.5% refer to charges and taxes. Another 35.7% correspond to the price of energy, 16.9% is the cost of distribution and 2.9% of transmission.

The highest value of the residential energy tariff is in the Southeast Region, where the average price is US$ 88,72 per MWh and the lowest value is in the Northeast, where MWh costs US$ 79,45 [19].

Literature Revision: A recent study by the International Telecommunications Union [20], about 3.9 billion people have connected to electronic devices, making it a standard, especially in developed countries to coordinate programmed structures through wireless applications both at home and at home. organizations. These electronics depend directly on energy sources which have become a very valuable asset, make an effective management of this resource and allow especially the population with fewer resources to enjoy much more of the comforts provided by their electricity supply. Air conditioners are the villains in hot regions like the Amazon, the use of this equipment is directly linked to comfort and resource savings.

Thermal Comfort: Basic Concepts and Applications in the Built Environment: Comfort, according to the online dictionary, Dicio, is the act or effect of comforting (yourself). [21] and thermal also according to the same dictionary is an adjective related to thermal or heat in which the temperature is accentuated. to continue without feeling uncomfortable with the object(s) or place where you are and that the opposite is undesirable for the being, and that, howmany move awayfromthecomfort, the more uncomfortable and unbearable it willbe. For [8][22], thermal comfort is like "the condition of the mind that expresses satisfaction with the thermal environment". One of the most widespread methods for researching thermal comfort is the PredictedMean Vote (PMV) or Estimated Mean Vote (VME) method, developed and applied by the Danish professor Ole Fanger and published in [8]. For [22] he used a laboratory to implement his research where 1300 people participated in his experiments, with this he established an equation that allowed him, from the extracted data, to estimate the average thermal sensation of a group of people (VME) when they are exposed to a given combination of variables. VME is given on the following scale of thermal sensations. Table 1 below demonstrates the differences between the PMW and VWE methods.

Table 1. Temperature calculation per individual.

PMV or VME used by FANGER	
+	❖ 3
+	❖ 2
+	❖ 1
0	❖ 0
-	❖ 1
-	❖ 2
-	❖ 3

Source – Authors, from the technique used by [22].

To obtain the result, the number of people dissatisfied with the environment was related to the VME table with the estimated percentage of dissatisfied people (PEI). The standard [8] published on its website, in October 2017, a new version of the standard referring to thermal comfort, published in 2013. Among the main changes of the revision is the inclusion of calculations of direct solar radiation. According to the standard, she made adjustments to the older models that were published. The new standard – [8] Standard 55-2017, Thermal Environmental Conditions for HumanOccupancy – simplifies the previous language and clarifies three calculation approaches for thermal comfort: graphical method for simple situations; analytical method for the most common cases; method that uses air velocity to provide comfort. Furthermore, the big news is alsotheinclusionof a new requirementto include theimpactofdirect solar radiation [8]. [8] was founded in 1894 and has established itself as an organization in the heating, cooling, ventilation and air conditioning sector according to the institution itself. "Among its main contributions is the development ofnorms and standards, withthevoluntaryparticipationofrenowned experts in theinternational sector" [23]. Even in an earlier version, the norm [8] left the definition of comfort open to what is meant by condition of mind or satisfaction, but correctly emphasizes that comfort is a process that involves many cognitive inputs, influenced by physical processes, physiological, psychological and others. In his master's thesis [25] he makes a synthesis about body temperature based on Ruas' understanding. Man is a homothermic being whose body temperature is constantly within certain limits, regardless of the ambient temperature. To keep the internal temperature within these limits, there is a permanent need for a thermal balance between the body temperature (human) and the environment that influences the temperature. Therefore, Human beings understand that the thermal sensation is related to their body temperature and that this balance can provide a feeling of comfort. This balance is influenced by physical activity and clothing, as well as by environmental parameters. "When these factors are estimated or measured, the thermal sensation for the body as a whole can be predicted by calculating the estimated mean vote" (PMV) [22]. Man's scientific concern with thermal comfort comes from a long time ago. According to [25], he cites the researcher Walter Bernan who, in 1845, alreadypredicted a promising future withthetechnologicaladvancesdeveloped for thispurpose.

Energy savings: A reduction in the consumption of non-renewable energy and changes in production sources in addition to a conscious consumption of energies have been fierce debates between climate advocates and governments around the world, according to experts, environmental impacts and climate change directly depend in parts of the production and exploitation of resources such as energy. [26] states that buildings are responsible for 40% of global energy consumption and that most of this energy is used to promote thermal comfort via artificial air conditioning. Therefore, we realize that society is not limited to having only a comfortable environment, but there is a continuous demand for a thermal adaptation that matches the environment and temperature. Still for [26]. New advances in computer science allow the construction of new models for simulation and testing in climate-controlled environments for human beings such as the case of HVAC systems, as follows. First-generation construction simulation software is based on analytical formulations with many simplifying assumptions. The current generation simulates the non-linear performance of multiple aspects of buildings based on numerical methods of particle integrations, the building models are discontinuous with respect to some installation parameters for simulation software, such as Energy Plus and TRSYS, use adaptive algorithms and condition logic [26]. First-generation construction simulation software is based on analytical formulations with many simplifying assumptions. The current generation simulates the non-linear performance of multiple aspects of buildings based on numerical methods of particle integrations, the building models are discontinuous with respect to some installation parameters for simulation software, such as Energy Plus and TRSYS, use adaptive algorithms and condition logic [26]. First-generation construction simulation software is based on analytical formulations with many simplifying assumptions. The current generation simulates the non-linear performance of multiple aspects of buildings based on numerical methods of particle integrations, the building models are discontinuous with respect to some installation parameters for simulation software, such as Energy Plus and TRSYS, use adaptivealgorithms and conditionlogic [26].

For [27] he simulated a conventional heating, ventilation and air conditioning (HVAC) system for several US cities. The operating temperature of such systems is commonly set to guarantee ambient temperatures of 21.5◦C and 24◦C. Their simulations indicated that the increase in this temperature by 1 C resulted in a 7%-15% reduction in energy costs. Therefore, one suitable [27] states that there is a great deal of room for temperature adjustment that in his research "In the RP-1515 study zone, the zone temperature remains close to the heating setpoint of 21.1oC (70 oF) for most periods observed in both high and low minimum cases" there is a zone that overlaps with the ideal temperature which is 21.1 degree Celsius as follows [27]. In the case of simulated high minimum, the zone spends almost 70% of the hours at the heating setpoint, which suggests that supercooling occurs in the simulation with great frequency, in the case of high minimum this occurs despite the fact that the rate of terminal airflow is always at its minimum. This suggests that all cooling in this zone is

performed by the minimum airflow rate, and effectively cooling the space when the cooling load is not large and the terminal heating coil is not active, in the case of low minimum, a phenomenon similar occurs to a lesser degree. There is some high airflow in the 0.24 m3/s (500 cfm) range which is a zone thatrequires a higherairflow rate tomeet a highercoolingload. Monitoring to control environments allows a more efficient management of energy consumption [28]. It states that "factors such as CO_2 and temperature we can control the HVAC system from the workspace to Abstract to obtain the right environment for work and save energy with the help of the energy management policy" the comfort and well-being in an environment goes beyond of an ideal temperature, but components such as dust particles, CO2 and other gases can be monitored through sensor technologies to better suit the environment. As per the standards of [8] 1000ppm was recommended as the upper limit for indoor CO. Therefore, it is necessary to monitor the CO2 concentration inside the room for user comfort and to solve health problems due to poor air quality. In this work, the MHZ14-A CO2 sensor is used, which works on the principle of non-dispersive infrared (NDIR) to detect the existence of CO2 in the air. To maintain temperature and increase user comfort, the LM35 is installed to detect ambient temperature. Infrared sensors are used to detect the movement and heat of objects to automate electrical appliances within the corridor and current sensors are used to measure the energy consumption of each appliance. The detected values from the built-in sensors are sent to Google Firebase using the ESP32 microcontroller, which has a built-in Wi-Fi module. Some of the detected data can be viewed using the Blynk applicationprogramming interface and some outputs canbeuseddirectlytoautomatelights and fans [28].

Free software: Free software are sets of programs that have open cores, allowing the user to change their algorithms, creating new functionalities for interaction with the system or even with users. The difference between free or open source software and closed source software is that only the right developers, ie their creators, have the source code, while the other users only have access to the closed code known as executable code. The use of free software by the user, according to [29], is free to run the program for any purpose. A big step forward in the advancement of open source technologies came when the American lawyer Lawrence Lessig created the Creative Commonslicense, with the intention of allowing authors to create works that could beshared, Creative Commons licenses were designed to give permission and restriction to the distribution of cultural content in general (texts, music, images, movies and others), so that they can be made available to all users according to the attribution of their author. The non-governmental organization Creative Commons [...] created six licenses for regular use that guarantee the rights of execution, reproduction and distribution of works according to the selection of four conditions: credits to the author of the work, non-commercial use, no permission of derivative works and sharing under the samelicense.

Industry 4.0: According to the Brazilian Agency for Industrial Development (ABDI) Industry 4.0 cansaveUS$ 13,27billion a year for Brazil [31][32]. Of these amounts, it is estimated that sevenbillion can be saved with electricity and US$ 6,36 billion with repairs. This proposed experiment is not part of a manufacturing environment, but it is not limited to government organizations, to glimpse a contest of how much can still be improved in use. energy resources in Brazil, in addition to other indirect benefits, with pollution and environmental impacts related to energy production. For [31], the improvement in processes that bring a significant improvement in the economy of resources is linked to technological advances inserted to accompany what is called the fourth revolution or industry 4.0 The fourth industrial revolution or industry 4.0 involves increasing computerization in the manufacturing industry, with machines and equipment fully integrated into internet networks. As a result, everything can be managed in real time, even from different locations. "Artificial intelligence, robotics, data analysis and the internet of things work in an integrated way [28]. The terms of industry 4.0 have become widely discussed in various media for some years now, mainly in industry and business sectors, these concepts also permeate congresses and universities presented by consultants and experts in innovation and modernization of high-level processes where they attract interested in continuing with the learning in order to apply it in their businesses or even entrepreneurs who envision the evolutionary characteristics of construction processes with highly complex technological support, but which bring an encouraging perspective of the new sources of knowledge employed in this area, as businesses more efficient with a focus ranging from the capture of material for the production or understanding of the service to the final destination or end of the life cycle of the product or service,always looking for business models and operational efficiency. Para [33] says that many companies mainly in Germany are aware of the evolving needs of the industry and that many have already started some concrete initiatives. But there is still a long way to go and for some industries the subject is still unknown [33]. The industry began to develop, leaving aside the artisanal process or at least part of it from 1784 onwards, since until then this production was made at home and completely artisanal, from then onwards, the creation of mano invoiced productsbegantoappear.One of the first technologies to boost these productions was the entry of steam machines to the manual loom, with that, the first industrial revolutionbegan.Many significant improvements have been added, but it still takes more than eight decades to emerge fromthe new revolution.The commercial use of electric energy began in 1882, but it was already being implemented in some factories in the lighting process, which started in the second revolution in 1870, where electric energy started to be used to drive production lines, a revolution that even had its expansion marked by the use of the Ford T assemblyproductionlineconcepts.At the end of the 1960s, with advances in personal computers and electronic controllers such as the PLC (programmable logic controller), they left the machines more modern and moving towards communication between them, as well as the creation of robots, mainly in a factory environment, transforming these advances to be called the third revolution. In 2010 therewere advances and a growing demand for customized products and the immersion of enabling technologies such as traceability, data mining, artificial vision, cloud technologies, Cybersecurity, additivemanufacturing, collaborative robot, IoT and others.

Internet of Things: Internet of Things was a term first used in 1999 by the executive Kevin Ashton, speaking at Procter & Gamble (P&G) in 1999, at the time Kevin was talking about the future communication between things, today it has become a reality but there is still a lot to be done, but the technological segments such as the internet, sensors and the processing capacity of electronic equipment allow for a great increase each year. progress along this path, we can cite some more popular ones, such as a card reader in a factory that saves and makes this information available, such as a pressure cooker capable of sending a signal to the stove to turn it off. So the internet of things is the communication between objects connected to each other through the internet.

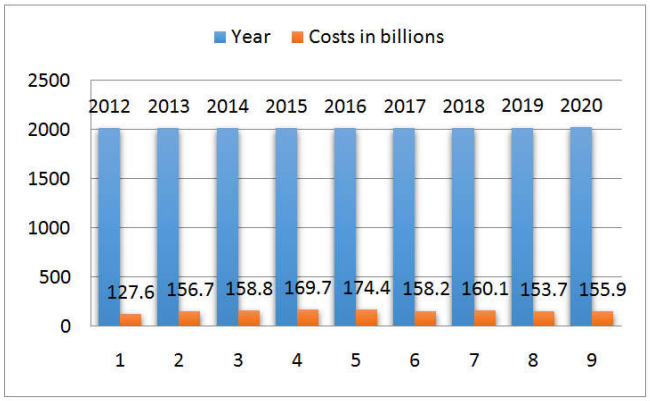
On the Internet of Things Kevin Astho says: We are currently on the verge of witnessing the emergence of a "megamarket", where markets such as home and building automation, electricity generation and distribution, logistics, automotive, as well as telecommunications and information technology will continually converge . For now, we don't know the consequences of connecting all these smart objects (smart meter, electronic vehicle, cargo container, fridge, etc.) tothe Internet [34].

Middleware for the Internet ofThings: Middleware are tools that hide technological functionalities and, fundamental in the security of a system, it hides details of the system from people who do not have the need to access information that is not relevant to its function. IoT. has many benefits with middleware systems, which bring the implementation of new services and facilitate the interaction of objects, in addition to improving existing services. To [35] "andThis is a software layer interposed between the technology and application sub-levels. Several solutions are understudy". The implementation of methodologies such as SOA (Service Oriented Architecture) supports a higher level of scalability in systems that are interactive and

undergo frequent changes, needing to adapt with as little effort as possible, in an organization that has maturity of external integration processes and internal, it finds in the middleware, favorable conditions for editing, adjustments and changes in the functionalities of the services. Service definition can be a computational entity that has an open and mappable specification of its expected behavior. As for the definition of entity for computation, it is characteristics and behaviors of objects or their components, while the extension ofanentitycanownoraccess software componentsthatencapsulate sensor and actuatorfunctionality.For thesetechnologiesto work, it is necessary to integrate these devices and systems so that communication is in harmony between all business layers and ready to receive or remove new devices, software and people who also interact directly or indirectly in the services being able to change the services or results themselves, hence the need to establish both one-way interaction patterns as well as response notification, providing these invocation requirements, SOA implementation solutions. One of these available services is a solution presented by the middleware SAI (Service Application Integration) presented by [36] "is um grid and scalable service-oriented middleware for distributedheterogeneous data and integratedinto systems in context-awaredomains." SAI is also based on adopting the SOA approach to facilitate the integration of heterogeneous resources for developing context-aware applications across enterprise domains. The SOA approach interprets distributed systems primarily as a serviceissue.As well as SAI, Inter Data Net has aninfrastructurescalable middle wares for intelligent data integration": InterDataNet based on SOA principles, it allows you to allow networks of heterogeneous objects to integratetheir data in themostint elligent way possible. AboutSOAVinoskiSafirmthat: While the core idea behind SOA is valuable, it hardly shakes the Earth: abstracting your business services and separating them from your application cations can produce an overall system that's easier to build, maintain, and extend. This may sound like basic software engineering, but real-world IT systems have countless business rules and permissions inadequately buried within countless monolithic applications. The goal of SOA is to avoid such monoliths by separating business rules and policies into distributed services that applications can share as needed [37]. Inter Data Net has a core with object information models with the service architecture inherent to its functionality in ordertoprovidescalable and open support that supports the consistent reuse ofobjects, being a global reference in addressing mechanismtolocate and retrieveobjects via the internet, having a set of transparent application services functions, thatis, data management from historical information. Accordingto [38] "InterDataNet (IDN) is an open source framework that offers resources to represent and manage information units and their structural and semantic relationships on the Web, in a RESTfulway."

MATERIALS AND METHODS

Research Problem Specifications: The costs with fixed consumptions in the institution where this case study was carried out, permeates the essential needs that allow the maintenance of activities inherent to its function, among these expenses is computed the expenditure on maintenance, of electronic devices, as well as their replacement, among them computer materials and air conditioning equipment stand out, these assets are also large consumers of electricity, and in addition to these, other equipment that are indispensable, are lighting, totaling a monthly cost around eight thousand reais. The institution also has two high-cost contracts, one for cleaning services, which are called outsourced support, and another for the provision of security services costing over 400,000 four hundred thousand reais annually, they are legal services that were contracted based on the bidding laws, and management without a legal focus cannot achieve any reduction in values. The institution also has resources from the PNAE (National School Feeding Program) to contribute with part of the costs of feeding students who take integrated education, complementing resources from other sources. Thus, based on data from the MEC (Ministry of Education), there has been a reduction in the budget in recent years for national public education institutions, leading to a search for resource optimization in order to adjust expenses. Figure 2 shows a graph of investments in education from 2012 to 2020, based on information taken from federal government websites.



Source: Authors Adapted from [39].

Figure 2. Education costs.

Research Characterization and Design: The IFAM object of this research is located on the Manoel Urbano road, Nova manacá, city in Manacapuru-AM. The road on which the building borders has a large flow of vehicles (also known as AM 070), less than half a km away there is a bath known as one of the tourist attractions of the city, the city is located on the banks of the Manacapuru river which flows into in the Solimões river forming a meeting of the waters because they have different colors, this occurs in front of the city and, as it is bathed by these rivers it is also known as the Little Princess of Solimões, the building is surrounded by trees that run to the shore of the lake. Miriti. The space used to carry out the experiments were; the course coordination room, where the following course coordinators are:

- Integrated Technician in Informatics;
- Integrated technician in fisheries resources;
- Integrated technician in digital game development;
- Integrated technician in administration;
- Subsequent internet computertechnician;
- Subsequenttechnician in secretariat;
- Subsequenttechnician in game development;
- Extension coordination and research coordination.
- And also the library area which, in addition to the books area, has a studyarea, a mini-laboratory and a smallcoordinationroom.
- The room in questionhas 30m2 and isheatedby 22,000 BTUS Split-typeairconditioning.

Data Collection and Data Analysis: Requirements Engineering is a phase of the project aimed at understanding the activities to be developed, they are and not only the elicitation, analysis, specification, validation and management of requirements. Elicitation is the abstraction of information about the proposed system tobedeveloped. The analysis is part of a qualitative process on the collected data that will be part of the system components to be developed. The specification encompasses writing the user and system requirements in a requirements specification document [as detailed descriptions of the software's functionality/services and operational constraints. Validation consists of verifying that the collected, analyzed and documented requirements meet the client's needs regarding the software. Management, in turn, is an ongoing activity of analysis, understanding and tracking of requirements to control their changes.

MATERIALS

Arduino Espe32g
Ultrasonic sensor;

Temperature sensor;
IDEArduino.
III.1.1 Temperature sensor
A DS18B20 digital temperature sensor used to report temperature in degrees C with 9 to 12 bit accuracy, -55C to 125C (+/- 0.5C). Each sensor has a unique 64-bit serial number engraved on it - allowing you to identify it individually from others so it is possible to use a large number and manage them individually.

Characteristics

- The interface only requires one port pin for communication
- Each device has a unique 64-bit serial code stored in an on-board ROM
- Multidropcapabilitysimplifiesdistributedtemperaturesensing applications
- No external components required
- Can be powered by data line. The power supply range is 3.0V to 5.5V
- Measures temperatures from -55°C to +125°C (-67°F to +257°F)
- Accuracy ± 0.5 ° C from –10 ° C to + 85 ° C
- The thermometer's resolution is user selectable from 9 to 12 bits
- Converts temperature to 12-bit digital word in 750 ms (max.)
- User-defined non-volatile (NV) alarm settings
- The alarm search command identifies and addresses devices whose temperature is outside programmed limits (temperature alarm condition)
- Applications include thermostaticcontrols, industrial systems, consumer products, ther mometers or any the rmally sensitive system.

Source: Authors, (2021).

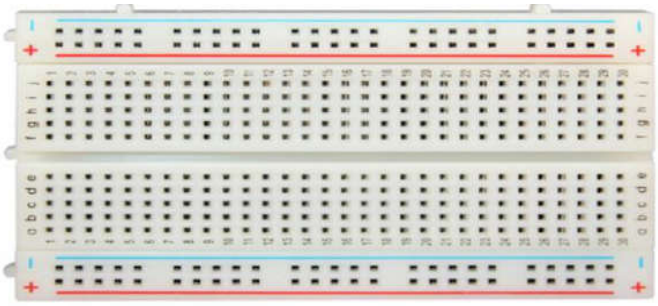
Figure 3. DS18B20 temperature sensor.

Presence and motion sensor (PIR): The output of the PIR motion detection sensor can be connected directly to one of the Arduino's digital pins. The PIR modules have a passive infrared sensor that detects the occupation and movement of the infraredradiated from the human body.

Source: Authors, (2021).

Figure 4. PIR motion sensor.

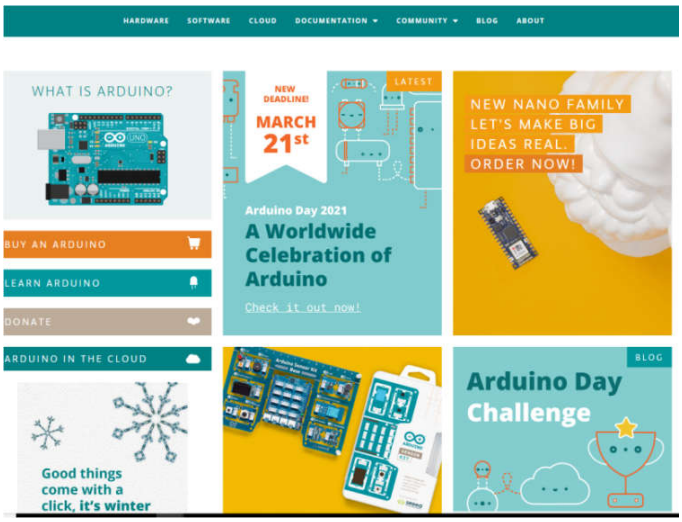
Protoboard: The breadboard board is an equipment used in projects with embedded systems technologies such as the Arduino, raspberry, Esp families, among others, of electronics projects. Its purpose is to connect electronic circuits, a practice known as prototyping, its mechanism forms a rectangular base with lines of holes where the pins of the components or even a wire fit directly, and has a connection logic between the holes that facilitates understanding the logic used in communication between project components.



Source: Authors, (2021).

Figure 5. Protoboard.

Arduino IDE: An IDE is sets of programs that form an Integrated Development Environment where new programs are built because it has a scheme that reads, interprets, debugs and executes a program and even displays the outputs from a monitor or terminal , In this type of application are all the functions necessary for the development of computer programs, smartphone applications, as well as some features that reduce the occurrence of errors in thelinesofcode. IDEArduino works with the C++ programming language and canbedividedintothreemainparts: structures, values (variables and constants) and functions.



Source: [40].

Figure 6. Arduinoweb-site interface.

The IDE used in the project had some updates from the Arduino IDE version 1.8.9 to 1.8.14, version for Windows operating system. Its interface has two versions, one called Arduino IDE and one Arduino IDE.

The desktop is a standard environment for most tools.To be able to program with Arduino it is necessary notions of programming languages and programming logic this can make it very easy to develop programs, this understanding is essential for you to make your own projects in the future. structurecontainingtwofunctions setup() and loop().

The libraries used for this work were:
Adafruit_Circuit_Playground;

Arduino-IRremote-master;
DallasTemperature;
DHT12_sensor_library;
IRLib2;
IRLib2-master;
IRLibRecv;
Remote IR;
MAX31850_DallasTemp;
OneWire.

METHODS

A prototype will be assembled from the technologies presented, in order to carry out communication between the prototype equipment and the computer program for arduino will be developed, allowing each sensor to meet the proposed communication, returning the requested data and performing the necessary functions totherealization and functioning in ordertomeetthedesiredneeds for thisproject.

Source: [40].

Figure 7. Arduino IDE version.

Source: [40].

Figure 8. Arduino Idea

Use ofArduino Technologies: Aiming to popularize the interaction with microcontrollers, the Arduino platform is part of a project that aims to include a set of tools with a friendly interface, accessiblelibraries.

IDE Installation: After downloading the IDE [40] simple as long as it meets the minimum system requirements, after installation, the software is ready to boot.From then on, the "sketch" name given to the set of lines of code written in the program must be compiled and then sent to the microcontroller board, the compiler's function is to locate possible sitting errors made by the developer, if the user is found receives information of possible errors and lines where they were made so that the necessary repairs can be provided.

Serial port: The configuration of the serial ports are directly connected with the input and output of data from the motherboard where the Arduino is installed to communicate with the board that can also be Arduino, in the case of this study both the Arduino uno board and the Esp32 board were used which, uses the same IDE as a programming medium. After locating the serial port, the user uses the option download sketch to send it to the intended board. One of the advantages of Arduino technology as a platform for prototyping and experimenting with microcontrollers is that for each block of microcontroller code it is embedded in both hardware and software. The microcontroller is capable of being booted along with the code, allowing a binary file containing a compiledprogramtobeloadedfrom a USB connection.

With the IDE installed: One of the goals of the Arduino project is to maintain its graphical development platform. This platform facilitates the editing of source code files, the compilation and loading of the program on the microcontroller, and the monitoring of any serial communication established with the device. With the development environment prepared, the coding starts to be built, in the case of our study, which, it was necessary to test the sensors mentioned in the articles, the first codes contained logic to update these sensors, however before downloading the program totheArduino/Esp32 board it isnecessarytocarry out communication betweenthecomponents.

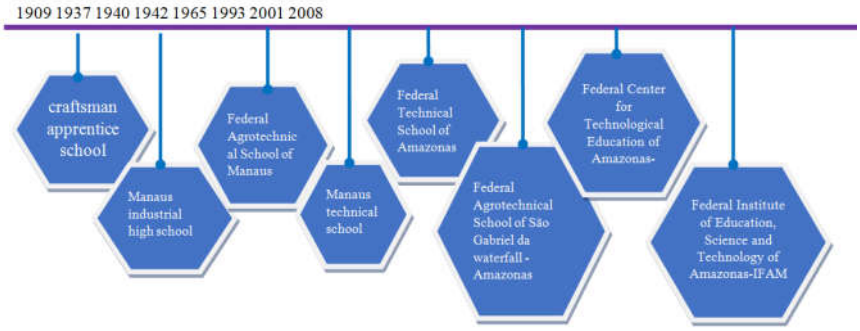
Communication between Arduino peripherals: Microcontroller squares have a combination of ports that are analog and digital, connections with these ports are made from direct contact with the equipment, in the case of our study, sensors or through wires called jumpers, and , still withanexpansiveequipmentcalled a protoboardque, wasalsoused in thisproject.

Communication with sensors: The program that we are going to call "code1" here will interact with an infrared light receiver sensor that has the function and logic that seeks to capture information emitted by the air conditioning control transmitter sensor, as with this data it is possible to know the combination for its functionality.Program titled "codigo2" enjoys an infrared light emitting sensor with the purpose of sending data to the air conditioning receiver, so the code1 and code2 programs with their duly connected sensors, assume the airconditioningcontrolfunction.The “code3” program, on the other hand, has the function of acting on the temperature sensor that, for this experiment, two types were arranged, the LM35 and the ds18b20. Thus, after the program is successful, it is possible to monitor the temperature captured by the sensor from a communication terminal that can be a computer with IDEArduino and, connected by a USB cableoran LCD type display configured for such output.For the “code4” program, the distance sensors were made, which, in this case, used the Ultrasonic sensor and also the motion sensor called PIR. With the success of these sensors and the software logic, it becomes possible to control the passage of objects in front of these components. Program "code5" integratesall the codes developed and adds code components to allow the temperature of the air conditioning unit to be adjusted using code2 and using the parameters obtained by code3 and, finally, when monitoring code4, code5 will be used, codes: code4 to obtain input data from objects (people) in the environment, and code2 to start or stop theactivityoftheairconditioner.

RESULTS AND DISCUSSIONS

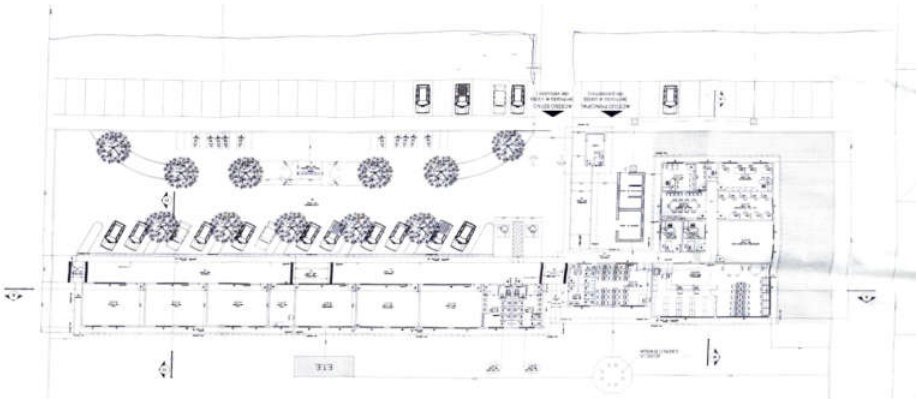
History: The IFAM- advanced campus Manacapuru was inaugurated on 05/17/2017, located in the city of Manacapuru, according to IBGE (2016) has about 92,000 inhabitants and is the fourth largest municipality in the state of Amazonas. 78 km away from Manaus, being considered a satellite city of the capital, the institution aims to provide education at secondary and technical levels. However, the Federal Institute of Education, Science and Technology of Amazonas (IFAM) is much older. The IFAM, which according to Ordinance No. 373, of August 31, 2009, of the Ministry of Education, published in the DOU of 09/01/2009 (No. 167, Section 1, page 29), the institute was created by Law No. 11892, of December 29, 2008 with headquarters initially located at Avenida Sete de Setembro, nº 1975, Bairro Centro, CEP: 69,020-120, in the city of Manaus Capital do Amazonas, todaylocatedat Av.Started in 2008, in the then government

of the President of the Republic, Luís Inácio Lula da Silva, who sanctioned Decree Law No. 11892, creating thirty-eight Federal Institutes of Education, Science and Technology, including IFAM. However, the Institution's trajectory in Amazonas dates back to the beginning of the 20th century, as we will see below in the timeline. Figure 9. Sketches a timeline and the institution's changes



Source: [41].

Figure 9. History of IFAM.



Source: Authors, (2021).

Figure 10. IFAM Manacapuru's ground plan.

In a process that is constantly changing, IFAM already has 15 campuses, three in Manaus (Manaus Centro, Manaus Distrito Industrial and Manaus East Zone), Coari, Lábrea, Maués, Manacapuru, Parintins, Presidente Figueiredo, São Gabriel da Cachoeira, Tabatinga, Humaitá, Eirunepé, Itacoatiara and Tefé providing quality professional education to all regions of Amazonas. It is the IFAM providingquality Professional Educationwith courses from Basic Education to Higher Education, Graduate and Post-Graduate Lato and Stricto Sensu, servingtheAmazonian and Braziliansociety (Mello, 2009). According to the institution's website, the IFAM is currently established in 23 municipalities, three of which are Distance Education poles in Roraima. In the first half of 2018, the Institution already has 25,768 enrollments, according to Nilo Peçanha Platform, distributed in 162 technical courses in person, 68 courses in EaD, 15 technologists, seven Bachelors, five Bachelors, two Lata Sensu specializations and three Professional Masters. In addition, wehave 1,967 servers acrossthestate.Todaylocatedat Estrada Manuel Urbano, km 77, new manacá, the IFAM-Manacapuru already had its provisional headquarters at 57 Rio de Janeiro, COHABAN, Manacapuru, until the Magnificent Rector of IFAM, Antonio Venâncio Castelo Branco, and the Director -General pro tempore of the Advanced Campus Manacapuru, Ana Maria Alves Pereira, in a ceremony inaugurated the headquarters of the Advanced Campus Manacapuru, on June 8, 2017 at 2:30 pm, with the presence of the Minister of Education, Rossieli Soares da Silva.

Current status of physical facilities: The physical facilities on the campus are distributed as follows: classrooms, coordination room, teachers' room, pedagogical sector room, computer labs, fisheries resources labs, auditorium, library, information technology management and director's office in addition to the parking lot, there is also a cafeteria under construction. Figure 10 shows the layout of the building's internal blocks, where the location of this study is located, in addition to highlighting the parking lot. The present case study has as a place of observation the spaces of the coordination room and the library. This study is opportune given the fact that the institution's costs have risen while the investments do not follow the same route. Table 2 below shows the monthly expenses during the period 2017 and the first half of 2020, which are part of the amounts charged by the electricity concessionaire.

Table 2. IFAM - Electrical Energy Consumption

Electric Power consumption: IFAM-Manacapuru				
Month	Year			
	2017	2018	2019	2020
January	US$ 4.806,06	US$ 7.100,39	US$ 5.086,06	US$3.782,92
February	US$ 6.050,20	US$ 7.365,03	US$ 6.131,75	
March	US$ 7.568,28	US$ 8.374,43	US$ 7.762,16	
April	US$ 8.153,85	US$ 7.445,03	US$ 8.433,76	
May	US$ 8.032,08	US$ 7.963,56	US$ 2.812,71	
June	US$ 7.986,17	US$ 6.285,56	US$7.850,39	
July	US$ 6.984,68	US$ 5.537,92	US$ 4.423,64	
August	US$ 8.535,72	US$ 8.535,72	US$7.912,64	
September	US$ 7.789,47	US$7.108,39	US$ 6.977,95	
October	US$ 7.662,74	US$ 6.638,20	US$7.353,00	
November	US$ 9.621,99	US$8.142,82	US$ 8.039,15	
December	US$ 7.541,36	US$ 5.805,73	US$ 6.423,86	

Source: Authors, adaptedbased on the website (https://website.amazonasenergia.com/), (2021).

In 2019, EPE presented, through the Electric Energy Statistical Yearbook, data on electricity consumption in Brazil by consumption class. In the specific case of Brazilian buildings, the data indicated that, in 2018, around 242TWh of electricity were consumed. Of this amount, public power buildings were responsible for consumption of approximately 6.3% in the same year analysed. In national commercial and public buildings, electricity has its highest consumption for air conditioning.

Table 3. Electricity consumption (GWh) by consumption class.

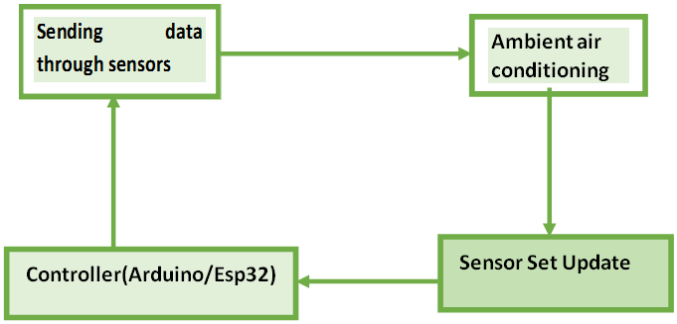
Consumption class	year				
	2017	2018	2019	2020	Δ% (2017-2020)
Residential	131190	132872	134368	137615	4.70%
Industrial	169289	165314	167398	169625	0.02%
Commercial	90768	87873	88292	88631	-2.40%
Rural	25899	27266	28136	29168	11.20%
Public Power	15196	15096	15052	15076	-0.80%
street lighting	15333	15035	15443	15690	2.30%
Public service	14730	14969	15196	15778	6.60%
Own consumption	3304	3355	3277	3238	-2.00%
Brazil	465709	461780	467162	474821	1.90%

Source: Authors, adaptedfrom [3].

The use of air conditioners accounts for approximately 48% of electricity consumption in this sector. While The use of artificial lighting encompasses a 23% share, followed by 15% of office equipment and 14% of other loads [5]. For the government sector, between 2017 and 2018, there was a growth of around 0.2%, as shown in Table 3. Aiming to reduce energy consumption on campus, which has an impact of 16% on the institution's budget, an experimental case study of climate control in one of the observation environments was proposed, seeking to optimize the consumption and efficiency of electricity.

RESULTS AND DISCUSSIONS

This section presents the results of the experiments carried out with the assembly of programmable hardware resources and the interaction between the developed software and the various sensors, both those connected to the new device and those belonging to the room cooling equipment. The results achieved so far corroborate to reach the proposed objectives for this study, are in accordance with the steps planned for the research, where many experiments were carried out in order to validate the proposal, the tests indicate progress and glimpse the possibility of the work's success , which aims to implement the system. Figure 11 below represents the direction of actions in operation in the case study.



Source: Authors, (2021).

Figure 11. System flow.

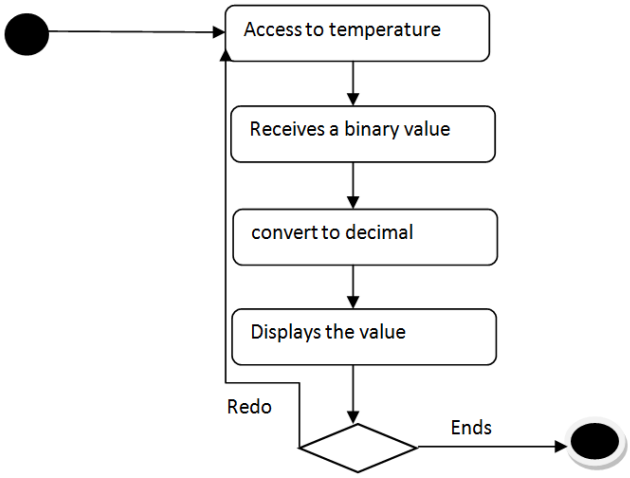
To seek the proposed results, theprojectwasdividedinto four stages with Arduino/Esp32 technology, which are the following prototypes:

- ✓ Temperature sensor;
- ✓ Infrared light emitter;
- ✓ Infrared light receiver;
- ✓ Ultrasonic sensor;

As shown in Figure 12 below, this algorithm aims to capture the code of the air conditioner control that will be used between the infrared light emitter and the air conditioner later.

Partial results of step 1: Arduino code runs in Arduino IDE software and the image is shown in figure 13. Arduino IDE software must be downloaded and include all necessary libraries before running the code, all necessary libraries are mentioned in methodology. Then, open the serial monitor terminal to view the measured temperatures.

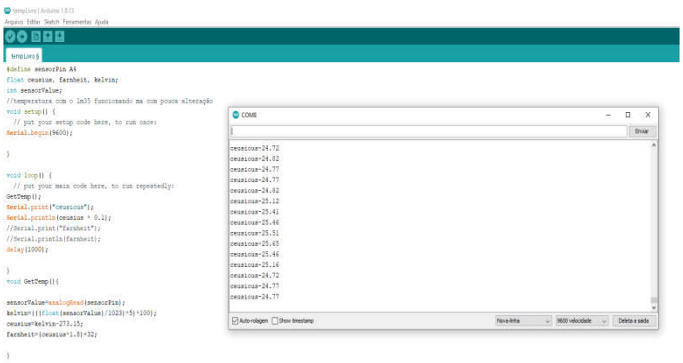
The following figure shows the computer program that communicates between the Arduino system and the DS18B20 temperature sensor, which measures the ambient temperature and displays the corresponding values in real time.



Source: Authors, (2021).

Figure 12. Flowchart of the temperature control algorithm.

Figure 11 shows the Arduino terminal printing the values onscreen.



Source: Authors, (2021).

Figure 13. Temperature code compilation.

As a result, the system receives a variation in the ambient temperature that, in the case of the DS18B20 sensor which can vary from -55C° to +125C°, the arduino receives these values in binary numbers, then uses a formula that converts them to numbers decimals, like the code section below:

void GetTemp(){sensorValue=analogRead(sensorPin);
kelvin=(((float(sensorValue)/1023)*5)*100);
ceusius=*kelvin*-273.15;
farnheit=(ceusius*1.8)+32;
}"

Partial results of step 2: The next figure shows a program that, when compiled, performs the interaction between the infrared light emitting

sensor which sends data totheairconditioner'sinfrared light receiving sensor, performing the functions of a remotecontrol.

Partial results of step 3: Prototype with arduino and infrared light receiver, the algorithm shown in Figure 14 below interprets the data received from the air conditioning by the infrared receiver. These data represent information accepted by the air conditioning system as, for example, the value of a temperature.

```
receptor-arcondicionadoOK | Arduino 1.8.13
Arquivo Editar Sketch Ferramentas Ajuda
receptor-arcondicionadoOK §

// receptor dos codigos do arcondicionado da corrdenação hilton
#include <IRLibRecvPCI.h>

IRrecvPCI myReceiver(2);//pino de dados para o sketch

void setup() {
  Serial.begin(9600);
  delay(2000); while (!Serial);
  myReceiver.enableIRIn(); // inicializa o receptor
  Serial.println(F("pronto para receber o sinal"));
  myReceiver.setFrameTimeout(100000);
}

void loop() {
  //o loop executa até que receba o sinal do controle
  if (myReceiver.getResults()) {

    Serial.println(recvGlobal.recvLength,DEC);
    Serial.print(F("uint16_t rawData[RAW_DATA_LEN]={\n\t"));
    for(bufIndex_t i=1;i<recvGlobal.recvLength;i++) {
      Serial.print(recvGlobal.recvBuffer[i],DEC);
      Serial.print(F(", "));
      if( (i % 8)==0) Serial.print(F("\n\t"));
    }
    Serial.println(F("1000;"));//Adicionar espaço final arbitrário
    myReceiver.enableIRIn();      //Reiniciar o receptor
  }
}
```

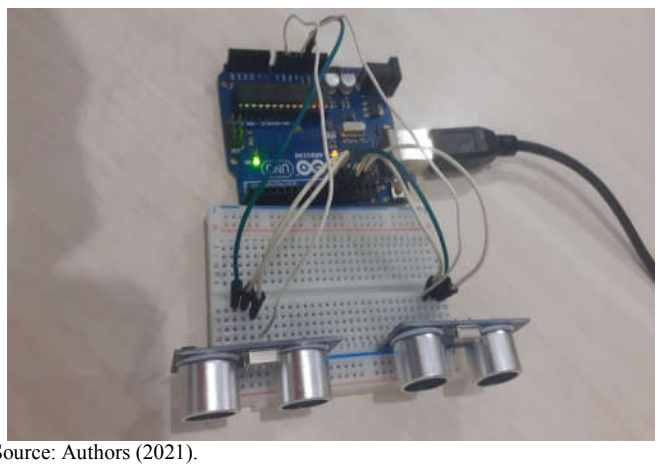
Source: Authors, (2021).

Figure 14. Infrared receiver

The excerpt from the asser code is an example of the device's control by raising the temperature. Temperature test from 16 to seventeen degrees:

uint16_t rawData[RAW_DATA_LEN]={
8930, 4550, 490, 1754, 490, 1754, 490, 614, 490, 618, 490, 618, 490, 618, 490, 618, 490, 1762,482, 1754, 490, 1750, 490, 1754, 490, 1754, 490, 1750, 490, 618, 490, 618, 490, 1754, 490, 618, 490, 618, 490, 618, 490, 618, 490, 614, 494, 618, 490, 1750, 490, 1754, 490, 1750, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 614, 494, 1750, 490, 618, 490, 1754, 490, 618, 490, 618, 490, 618, 490, 614, 494, 614, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 1750, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 614, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 1754, 490, 618, 490, 618, 486, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 614, 494, 614, 494, 614, 494, 614, 490, 618, 490, 618, 490, 618, 490, 618, 490, 618, 490, 1750, 490, 618, 490, 618, 490, 618, 490, 1754, 490, 1750, 490, 1000};

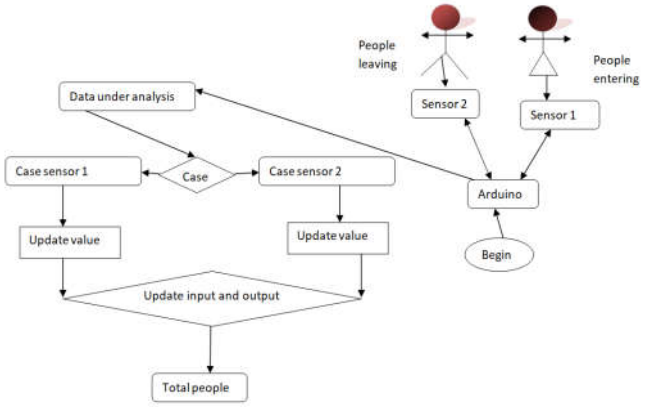
Partial results of step 4: Figure 15 is an image of the prototype with Arduino and ultrasonic sensor.



Source: Authors (2021).

Figure 15. People counting module.

The Figure 16 shows the arrangement of elements in the experiment environment and the willingness to carry out interactions.



Source: Authors, (2021).

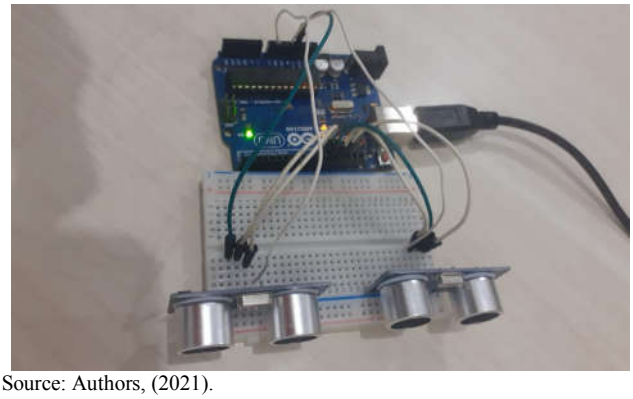
Figure 16. Person counting diagram

Figure 17 represents the algorithm that performs the interaction to perform the counting of moving objects.

```
Arquivo Editar Sketch Ferramentas Ajuda
testeUltrasonic0504 §

#define trigPin 13
#define echoPin 12

float duration, distance;

void setup() {
  Serial.begin (9600);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
}

void loop() {


  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  // Measure the response from the HC-SR04 Echo Pin
  duration = pulseIn(echoPin, HIGH);

  distance = (duration / 2) * 0.0343;

  Serial.print("Distance = ");
  if (distance >= 400 || distance <= 2) {
    Serial.println("Out of range");
  }
  else {
    Serial.print(distance);
    Serial.println(" cm");
    delay(500);
  }
 delay(500);
}
```

Source: Authors, (2021).

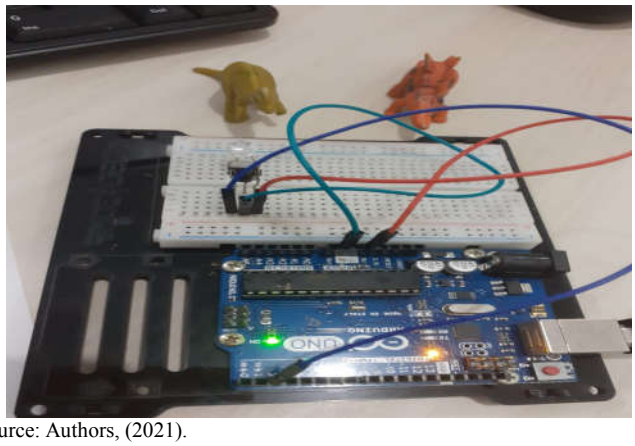
Figure 17. counting of people with anultrasonic sensor



Source: Authors, (2021).

Figure 18. Prototype with ultrasonic sensor

Figure 18 below shows an Arduino board and a breadboard board communicating with the ultrasonic sensors, which aim to detect the presence of objects, providing data for the galgorithm to identify the passage of objects in a certain direction. Figure 19 shows the communication between the arduino board, the protoboard and the infrared emitter and receiver, which has as oneof its functionstosend a signal to the air conditioner.



Source: Authors, (2021).

Figure 19. Prototype with infrared sensor and receiver

Thus, the proposal that aims to increase thermal comfort using Arduino technology works as follows, when identifying the first user who enters the experiment environment (IFAM-Manacapuru coordination room) the system activates the air conditioning unit at a temperature of 22°C, from then on, the system monitors the number of people in the room and regulates the air conditioning to maintain the temperature as close as proposed until the last user leaves the place, by identifying the zero number of people , the system communicatestheairconditionertoturn off untilthenext loop happens.

CONCLUSIONS

When creating a device as a model to optimize the institution's resources with objects centered on the automation of air conditioners and thermal comfort, the prototypes were divided to carry out the development of Hardware and software separately as follows:

- Part one, a prototype was assembled for monitoring the ambient temperature using sensors, Arduino board and programming, after carrying out theconstruction and testingstepstheresultsachievedweresatisfactory;
- Part two, the assembly, programming and testing process were made to receive and send communication information between the developed system and the air conditioning system, the results achieved were reasonable and should still improve, but they remain within the expected;
- Part three is the communication of a prototype capable of monitoring the environment and responding to the entry and exit of individuals from the site;
- Finally, the last part is to carry out an evaluation of the data received and make the decision, which stage obtained satisfactory results.

Thus facilitating the construction and testing, in the end, the integrations of both hardware and software parts were carried out in order to carry out all the proposed activities, so the main expected contributions are:

- Provide the turning on and off of air conditioning equipment when necessary;
- Adjust the room temperature, correcting it with an intervention on the device responsible for the climate of the environment;
- Monitor the entry and exit of people from the environment.

Therefore, according to the classification suggested by the National Council for Scientific and Technological Development (CNPq), this research contributes to the areas of programming language, software engineering, computer system, hardware, electrical engineering, health sciences and human sciences. Computing.

ACKNOWLEDGMENTS

To the Graduate Program in Engineering, Process Management, Systems and Environment of the Galileo Institute of Technology and Education in the Amazon (PPG.EGPSA/ITEGAM) and the Federal Institute of Education, Science and Technology of Amazonas (IFAM) for their support of this research

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