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Tesis

The Copper Babysitter Robot, a Childcare Monitoring System From the First Year of Age

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The COPPER babysitter robot, a child care monitoring system from the first year of age

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Abstract. This research work presents the design of a mobile robot that monitors the care and integrity of children from the first year of life. The monitoring is done with a surveillance system that uses artificial vision to identify the environment and with help of the SLAM system, the robot can move without any difficulty since the robot itself will be able to map and locate in the environment. The presence sensors also contribute to the robot's displacement, as they work together with the SLAM system to measure the robot's distance from objects to avoid collisions. The robot will have two drives, one manual and the other automatic; the choice will be made through an app interface with which the robot's movement can be controlled; this application can also display the webcam video in real time. In addition to this, there is an alert system in which when the robot detects risk or danger to the child, it emits an alarm and makes a call to the caregiver or parent. This design presents a stable and pleasant structure for the child, an intuitive mechanism for the user and all the suitable components for proper operation. The results of the project will be used to create more complex monitoring and alerting systems.

Keywords: Mobile Monitoring Robot, Artificial Vision, SLAM System.

1 Introduction

There are several accidents that children can suffer, so finding ways to ensure their safety has become a priority for parents. The most frequent accidents are falls, with 37.6%, and in 83.5% the place where the fall occurred was in home [1]. Many of these accidents are caused by poor child care or neglect due to lack of vigilance and supervision of the child; this lack of attention has consequences on cognitive, physical, mental and socioemotional development [2,3]. In Latin America, child abuse is a widespread problem [4,5,6] and in Peru, according to studies, the lack of training and resources for monitoring children is a common problem [7,8,9].

The use of surveillance cameras or Woki Toki radios has facilitated the monitoring of children's behavior. However, accidents are still present as there is no intelligent mechanism to alert the child's parents of the danger, since surveillance cameras only record the events, but do not identify them, so the parent has to be attentive to the images or sounds to realize the danger the child may be in. Babysitter robots are a new proposal that seeks to help in the care of children. The company AvatarMind created a robot called iPal, which interacts with children helping them with their tasks and keeping them company. It has a screen that shows drawings, makes use of applications and a learning engine to remember children's preferences and interests [10]. There is also another robot called BeanQ that, similarly, aims to accompany children as a babysitter by interacting with them through games or videos [11].

However, these robots do not focus on the care and prevention of risks and dangers for children. Artificial intelligence is very useful because it allows obtaining data and information to visualize situations. Cedano, in his research thesis, mentions that deep learning with the help of cameras contributes to the prediction and recognition of behaviors; specific actions can be recognized and measures can be defined for these actions, and finally classified [12]. According to Borja & et al. facial identification using neural networks is made possible by pattern recognition. In their research work, faces of people are captured and identified in real time to develop a neural network algorithm that allows capture and identification as required [13]. In addition, different intelligent mechanisms are presented to monitor baby care and issue danger alerts with different training techniques [14,15,16]. This work proposes the design of an intelligent mobile robot that not only serves to interact, but can monitor the behavior of the child and its environment, and issue an alarm alert to the parent or caregiver to warn of danger. It makes use of sensors, artificial vision and the SLAM system that will allow the robot to move by recognizing its position and location in the environment. The YOLOV7 object detection model will be used, which is a real-time object detection algorithm based on a convolutional neural network, the most advanced version of which uses the Darknet-53 architecture as a feature extractor.

This YOLO V7 algorithm improves information flow and training, using techniques such as spatial attention, multiple image scales and anchors of different sizes to improve object detection. The structure of YOLO v7 consists of an input layer, a backbone, a detection head and post-processing. These parts work together to efficiently detect objects in images [17, 18]. In the development of the article the methods used in the development and design, functionalities of the robot, technical analysis and evaluation of the robot will be visualized. Finally, it concludes with all the important aspects that have been taken into account for the development of the robot and the future improvements that can be added.

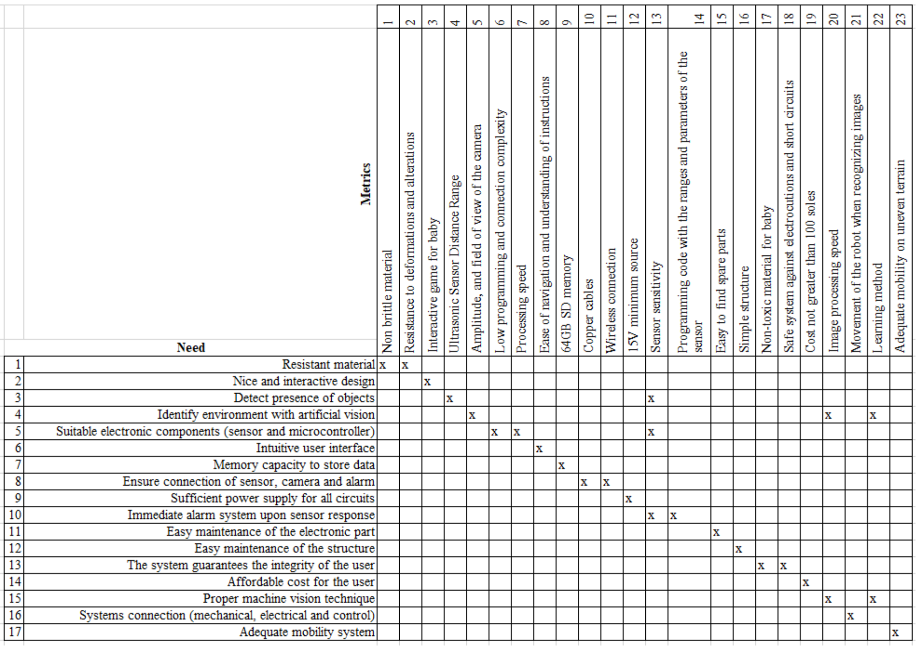
2 Methodology

2.1 Study of potential market for the product

According to a Stanford Medicine Children's Health study, children under 4 years of age are more likely to suffer injuries to the face and head, toddlers are prone to fall through windows, and injuries are more frequent in children under 5 years of age [19]. Interviews with mothers, fathers, and siblings revealed time-consuming childcare concerns. Many of the homes are not designed for child rearing, so a care establishment must be found. The vast majority are housewives and indicate that time is not enough to attend to household chores and child care, demonstrating the need to facilitate child care through a reliable instrument, for this reason the Cooper robot was created.

2.2 Specification plan

The list of requirements is presented based on the needs present in the development of the project (see Fig. 1):



	Metrics	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	Need	Non brittle material	Resistance to deformations and alterations	Interactive game for baby	Ultrasonic Sensor Distance Range	Amplitude, and field of view of the camera	Low programming and connection complexity	Processing speed	Ease of navigation and understanding of instructions	64GB SD memory	Copper cables	Wireless connection	15V minimum source	Sensor sensitivity	Programming code with the ranges and parameters of the sensor	Easy to find spare parts	Simple structure	Non-toxic material for baby	Safe system against electrocutions and short circuits	Cost not greater than 100 soles	Image processing speed	Movement of the robot when recognizing images	Learning method	Adequate mobility on uneven terrain
1	Resistant material	x	x																					
2	Nice and interactive design			x																				
3	Detect presence of objects				x									x										
4	Identify environment with artificial vision					x															x		x	
5	Suitable electronic components (sensor and microcontroller)						x	x						x										
6	Intuitive user interface								x															
7	Memory capacity to store data									x														
8	Ensure connection of sensor, camera and alarm										x	x												
9	Sufficient power supply for all circuits												x											
10	Immediate alarm system upon sensor response													x	x									
11	Easy maintenance of the electronic part															x								
12	Easy maintenance of the structure																x							
13	The system guarantees the integrity of the user																	x	x					
14	Affordable cost for the user																			x				
15	Proper machine vision technique																				x		x	
16	Systems connection (mechanical, electrical and control)																					x		
17	Adequate mobility system																							x

Fig. 1. Figure of list of requirements.

The structure must be resistant, it must have artificial vision to identify the environment and detect objects. It must have interactive design, adequate electronics, sufficient power supply, connection of sensors, cameras and alarms, memory capacity, intuitive interface, adequate mobility system, user integrity, affordable cost, easy maintenance and immediate alarm system. Sensor range, camera range and field of view, low programming complexity and processing speed should also be considered.

2.3 System architecture

The aim is to design and develop a baby surveillance system through a friendly mobile robot. Artificial vision, presence sensors, the SLAM system and an alarm system are used to warn of danger. This solution satisfies the need for comprehensive monitoring. To carry out the design, the following block diagram was made where the functional structure is shown (see Fig. 2):

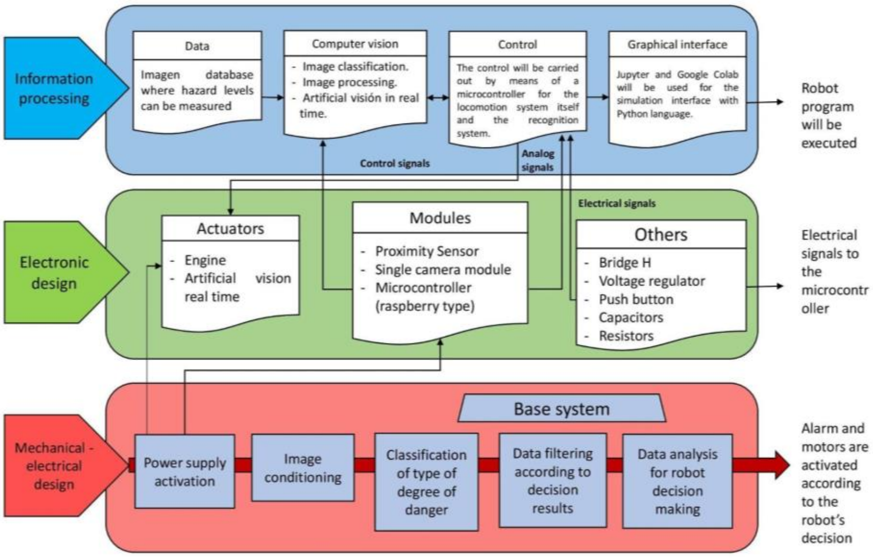


Fig. 2. Figure of function diagram.

The structure consists of three parts: information processing, robot locomotion, and mechanical-electrical design. In information processing, data is classified and processed in real time with the help of Jupyter. For locomotion a microcontroller, an H-bridge and sensors are used. The mechanical-electrical design from power activation to alarm activation, through hazard classification and data analysis. The realization of the system will be specified in the specialized design area.

2.4 Specialized design area

This specialized design area is divided into four distinct sections, as shown below:

Physical components and mechanical design. The design of the mobile baby monitoring robot is made of wood, which allows easy design, machining, and quick assembly. It is a safe and non-toxic material for contact with babies. The displacement system is by wheels with tapes since this mechanism is ideal for irregular surfaces.

The wheels are powered by a 6V geared motor to control the speed of the robot. They are powered by lithium batteries for easy battery replacement and charging. The measurements are 50cm high, 50cm long and 30cm wide. (See Fig. 3)

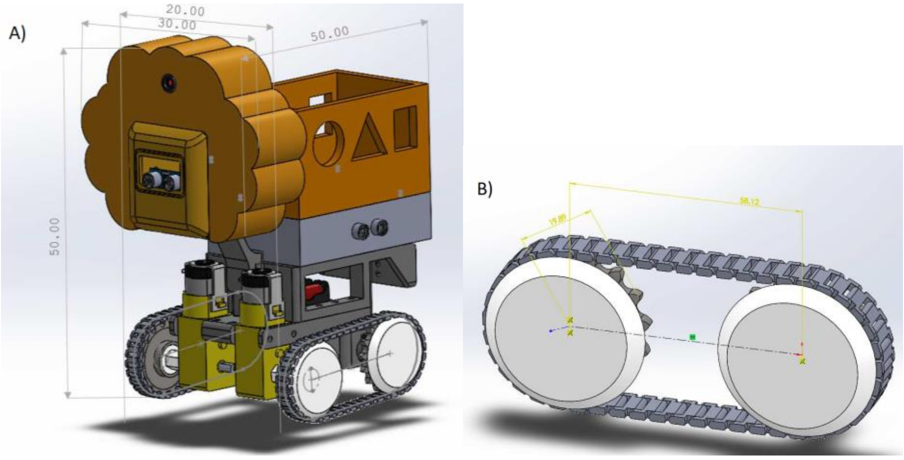


Fig. 3. In figure A) are the dimensions of the final prototype structure in Solidworks and in B) is the transmission system.

Electrical design - electronic. The electronic scheme has a 7.4V LiPo battery that will power the circuit, it also has a voltage regulator that will send 5 V as electronic output. Four HC-SR04 ultrasonic sensors will be used to have better accuracy when measuring distances and detecting the presence of objects by the 4 faces of the robot, this sensor will serve as part of the SLAM system localization and mapping of the robot within the baby's environment. The signals from the sensors are sent to start the movement of the motors with the L293D, an H-bridge, which allows better precision and control.On the other hand a high resolution webcam, Argom Tech Cam 40 full hd 1080p FHD, whose images obtained will be processed in the Raspberry pi 4, and when it recognizes a dangerous situation it will activate the alarm buzzer to alert the family member or caregiver. (See Fig.4)

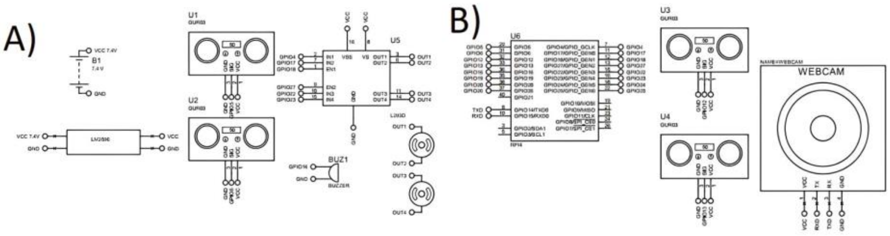


Fig. 4. In figure A) is the first part of the electrical schematic of the system and in B) is the second part of the schematic.

Image recognition. Image recognition is essential in a mobile robot with machine vision, using an FHD webcam to obtain high quality images. Training the recognition system is crucial to achieve maximum accuracy of the algorithm.

Data and systems analysis. Data were classified into 21 categories and approximately 8,479 images were collected. The Google Image Downloader extension was used to extract the images from the Internet. The YOLOV7 system requires the items in Table 1 to function.

Table 1. Table of system requirements.

Requirements	Details
Operating System	Windows
GPU	NVIDIA - NVIDIA GeForce RTX
RAM Memory	8 GB RAM
Storage space	100 MB - 10.5 GB
Software and libraries	Python and libraries such as OpenCV, NumPy and PyTorch.
Interface	Google Colab - Jupyter - Thonny

Storage requires at least 100 MB of space, which includes source code, configuration files, and files needed to run YOLOv7. For the interface, classification tests were carried out with Google Colab, while Jupyter was used for real-time detection. Thony will be used for the physical implementation of the prototype.

Application of the YOLO V7 algorithm. The application of the YOLO V7 algorithm is summarized by a flowchart as follows (see Fig. 5):

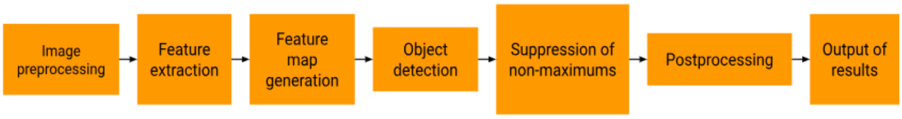
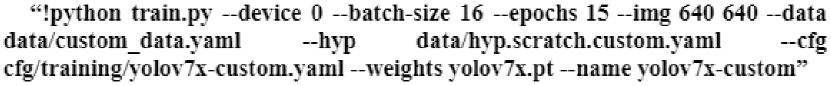


Fig. 5. Flowchart of the Yolo V7 technique.

The YOLO V7 algorithm follows a defined workflow. The input image is preprocessed, relevant features are extracted using convolutional layers and object detections are performed with bounding boxes and confidence scores. Redundant detections are removed and post-processing is performed to assign labels and calculate final confidence. Results include coordinates, labels, and confidence scores. The labeling process used more than 53 convolutional layers.

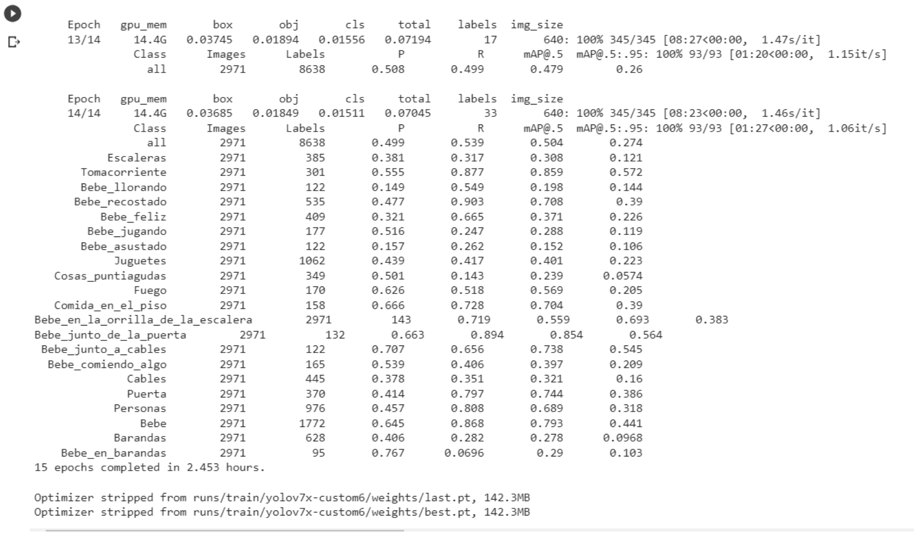
Explanation of the training code. Python and Google Colab are used to train an accurate neural network. A folder is created in Google Drive called "TheCodingBug" and the YOLO V7 architecture is cloned. The optimized YOLO v7x version is downloaded and training is started using a custom data file with specific parameters. The code is shown below (see Fig. 6).



```
“!python train.py --device 0 --batch-size 16 --epochs 15 --img 640 640 --data
data/custom_data.yaml --hyp data/hyp.scratch.custom.yaml --cfg
cfg/training/yolov7x-custom.yaml --weights yolov7x.pt --name yolov7x-custom”
```

Fig. 6. Training code.

The batch size is determined by the number of images and the processing speed. In the code, the location of the images, training data, labels, pre-trained model and hyperparameters are specified. The results of the trained model are available, and are stored in the "weights" folder in the file named "best.pt", as illustrated in the following figure (see Fig. 7):



```
     Epoch   gpu_mem       box       obj       cls     total    labels  img_size
     13/14     14.4G   0.03745   0.01894   0.01556   0.07194        17       640: 100% 345/345 [08:27<00:00,  1.47s/it]
               Class      Images      Labels           P           R      mAP@.5  mAP@.5:.95: 100% 93/93 [01:20<00:00,  1.15it/s]
                 all        2971        8638       0.508       0.499       0.479        0.26

     Epoch   gpu_mem       box       obj       cls     total    labels  img_size
     14/14     14.4G   0.03685   0.01849   0.01511   0.07045        33       640: 100% 345/345 [08:23<00:00,  1.46s/it]
               Class      Images      Labels           P           R      mAP@.5  mAP@.5:.95: 100% 93/93 [01:27<00:00,  1.06it/s]
                 all        2971        8638       0.499       0.539       0.504       0.274
           Escaleras        2971         385       0.381       0.317       0.308       0.121
       Tomacorriente        2971         301       0.555       0.877       0.859       0.572
       Bebe_llorando        2971         122       0.149       0.549       0.198       0.144
      Bebe_recostado        2971         535       0.477       0.903       0.708        0.39
          Bebe_feliz        2971         409       0.321       0.665       0.371       0.226
        Bebe_jugando        2971         177       0.516       0.247       0.288       0.119
       Bebe_asustado        2971         122       0.157       0.262       0.152       0.106
           Juguetes        2971        1062       0.439       0.417       0.401       0.223
   Cosas_puntiagudas        2971         349       0.501       0.143       0.239      0.0574
               Fuego        2971         170       0.626       0.518       0.569       0.205
   Comida_en_el_piso        2971         158       0.666       0.728       0.704        0.39
Bebe_en_la_orrilla_de_la_escalera        2971         143       0.719       0.559       0.693       0.383
Bebe_junto_de_la_puerta        2971         132       0.663       0.894       0.854       0.564
 Bebe_junto_a_cables        2971         122       0.707       0.656       0.738       0.545
  Bebe_comiendo_algo        2971         165       0.539       0.406       0.397       0.209
              Cables        2971         445       0.378       0.351       0.321        0.16
              Puerta        2971         370       0.414       0.797       0.744       0.386
            Personas        2971         976       0.457       0.808       0.689       0.318
                Bebe        2971        1772       0.645       0.868       0.793       0.441
            Barandas        2971         628       0.406       0.282       0.278      0.0968
    Bebe_en_barandas        2971          95       0.767      0.0696        0.29       0.103
15 epochs completed in 2.453 hours.

Optimizer stripped from runs/train/yolov7x-custom6/weights/last.pt, 142.3MB
Optimizer stripped from runs/train/yolov7x-custom6/weights/best.pt, 142.3MB
```

Fig. 7. Trained model.

A performance test of the best training is performed using the code shown. The "detect.py" script is used with a trained model and specific weights. A confidence threshold of 0.3 is set and the size of the input images is defined. You can perform detections on images as shown, for video you would change it by --source video.mp4 and for detect on camera you would change it by this command source 0 --no-trace (see Fig. 8).

```
"!python detect.py --weights runs/train/yolov7x-custom6/weights/best.pt
--conf 0.3 --img-size 640 --source fig2.jpg --no-trace"
```

Fig. 8. Code to test the training.

Detection information, such as coordinates and classes, is obtained using the "pred" command.

Control design. The control system unifies the other systems: mechanical, electrical-electronic design and image recognition. This section explains the operation of the entire system, as well as the coding used for it.

Manual and automatic actuation. Manual drive is proposed in which the user can control the robot through an interface and automatic drive. The selection interface is shown in Figure 9 (see Fig. 9).

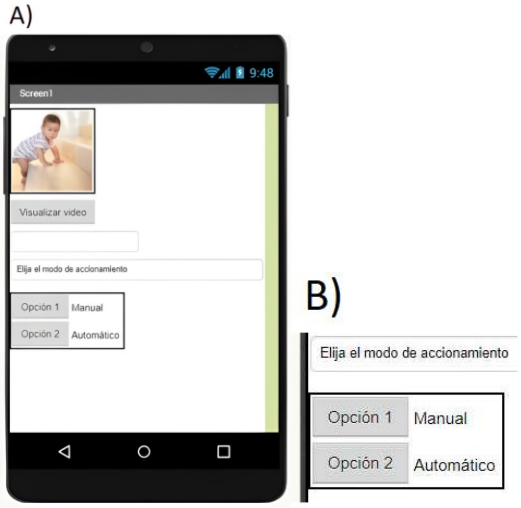


Fig. 9. Figure A) shows the general drive selection interface and B) shows the options more closely.

Manual. For manual operation, the robot was programmed to move following the baby and be controlled from a mobile application. The interface is shown in Figure 10, for this the sensor and motor pins are configured, and the motor initialization. In addition, the distance sensor and the control function of the geared motor are configured for the direction of rotation of the motors (see Fig. 10).

Fig. 10. Robot control interface.

Automatic. For automatic drive, the machine vision system of YOLO V7 is used, and the integration of sensors and the SLAM system. The automatic drive flowchart is shown in Figure 11 (see Fig. 11).

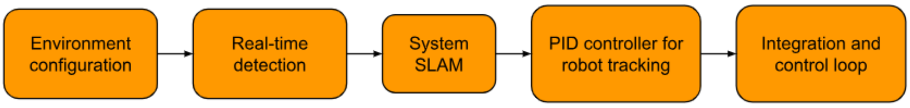


Fig. 11. Automatic drive flow diagram.

To configure the environment, libraries are installed, sensors and motors are connected, and component availability is checked. YOLO V7 is used for real-time detection, an alarm is triggered and a text message is sent if there is danger. For the SLAM system, the extended Kalman filter and a PID controller are used. Everything is integrated into one main control circuit.

Configuration of automatic code execution with "autorun". The "autorun" on Raspberry Pi is achieved by following these steps:

1. Create a script file (autorun.sh) with the text editor: nano autorun.sh.
2. Add the command line to execute the main code, for example: python main_code.py.
3. Grant execution permissions to the script: chmod +x autorun.sh.
4. Open the rc.local file: sudo nano /etc/rc.local.
5. Add the following line before "exit 0": /complete_path_of_your_script/autorun.sh & (replace the path with the actual location of the script).

With this, the autorun.sh script will run automatically at startup of the Raspberry Pi 4B, automating the execution of the main code efficiently.

2.5 Unification of systems

The integration of the project system is presented below (see Fig. 12):

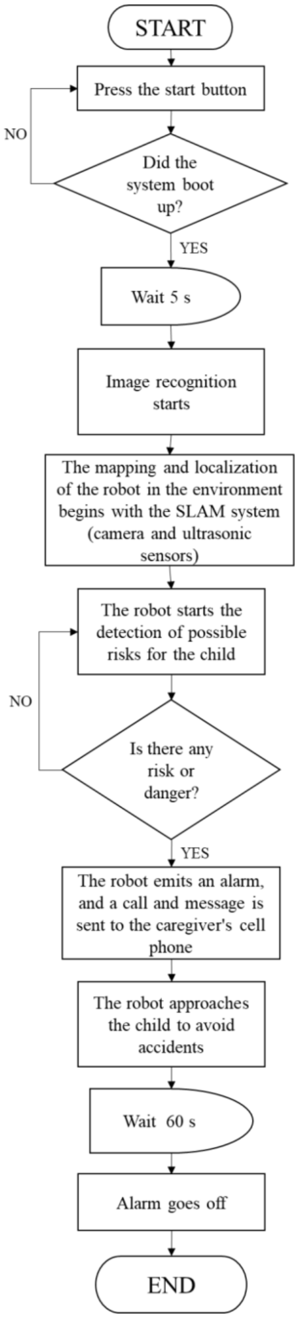


Fig. 12. Unification of systems

3 Results

The results obtained in the research are shown.

3.1 Mechanical design

The figure below shows the simulation of the load stresses of the structure that was performed in the SolidWorks program with a force of 19.6N, which complements the mathematical calculations previously performed. A static analysis of the box made of MDF material is carried out (see Fig. 13).

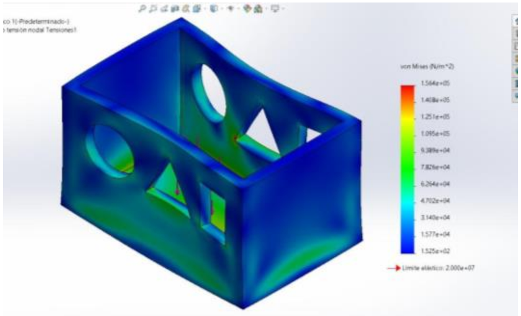


Fig. 13. Simulation of efforts in box

It also shows the static analysis of the configuration and the upper part of the base, which includes the electrical components, with a load of 19.6 N. The material used is wood. (See Fig.14)

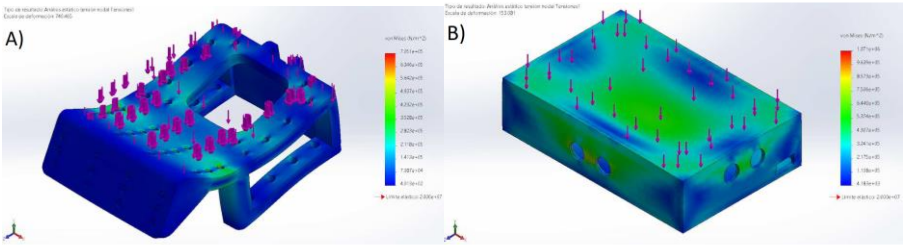


Fig. 14. Figure A) shows the simulation of stresses in the frame and in B) the stresses in the base.

The results of the mechanical design show that the correct choice of material allows to improve the child-robot interaction. The chosen material is hard enough for the purpose of the robot and resistant to the stresses submitted.

3.2 Electric design

The connections of all electrical-electronic components are shown. The motors allow the movement of the locomotion system with belts, the L293D module is used to control the motors. The engine rotation simulation was made. On the other hand, the UART communication of the sensor with the microcontroller is observed, which allows the exchange of serial data. The Raspberry Pi 4 controls the distance values of the HC-SR04 ultrasonic sensors and the displacement of the locomotion system by controlling the direction of rotation of the geared motors located on the side of the robot, and also controls the webcam for image recognition. (See Fig. 15)

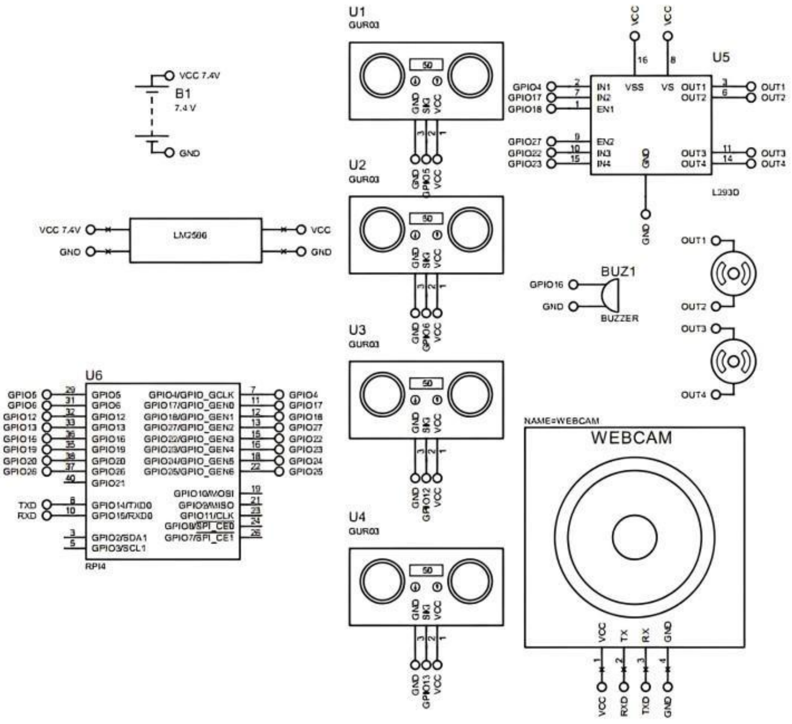


Fig. 15. Electrical-electronic connection of the system

3.3 Image recognition

The results obtained from the classifications were saved in the "runs" results folder. In this folder, the specific results are found in folders named "exp_". These folders are used to verify the correct operation of the system. Figure 16 shows what was obtained from the neural training through a video, with the recognized labels Bebe_acostado, Bebe and person. (See Fig. 16)

Fig. 16. Recognition of the label Bebe_acostado

3.4 Control design

The programming for the sensor, the displacement system and the neural training of image recognition were carried out. The integration of all the systems was shown, using the SLAM system it was possible to map and locate the robot in the baby's environment and to unify the data obtained from the camera and the sensors.

4 Conclusion

A mobile robot with a monitoring system for child care was designed from the year on to reduce and avoid accidents or dangerous situations. This is thanks to the artificial vision system trained with Yolo V7, the ultrasonic sensor and the SLAM System. In this way, the robot can move to monitor the behavior of the child automatically or manually managed by the user or parent.

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