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Enclosure maximum capacity control in pandemic time, using artificial vision

Control de aforo máximo de recintos en tiempos de pandemia, utilizando visión artificial

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Abstract

The article's objective is to show the results of the development of a prototype capable of counting people, using artificial vision tools, in order to maintain a maximum capacity allowed in any closed space and thus be able to maintain a healthy distance, taking into account to the health protocols established in our country by the competent health authorities. It is used an own methodology, taking aspects and combining the cascade and prototype model. The new normality requires maintaining a health protocol. According to the Undersecretary of Health, Dr. Hugo López Gatell declared in a virtual meeting with governors on June 17, 2021, that the capacity restriction in the tourist infrastructure, restaurant, bars, recreational centers and different public spaces would allow a rapid economic reactivation and a reduction in the risk of contagion (Health Secretary, 2021). By obtaining a functional prototype, it is helping to face the problems that have occurred with the current global COVID pandemic. The prototype was programmed in Python 3, using a Raspberry board with the *Raspberry Pi* operating system.

COVID, Venue Capacity, Artificial vision

Resumen

El presente artículo tiene como objetivo mostrar los resultados del desarrollo de un prototipo capaz de realizar un conteo de personas, utilizando herramientas de visión artificial, con la finalidad de mantener un aforo máximo permitido en cualquier espacio cerrado y así, poder mantener sana distancia, atendiendo a los protocolos de salud establecidos en nuestro país por las autoridades sanitarias competentes. La metodología utilizada es propia, tomando aspectos y combinando el modelo en cascada y de prototipo. La nueva normalidad requiere mantener un protocolo de sanidad, que, de acuerdo con el Subsecretario de Salud, Dr. Hugo López Gatell quien declaró en reunión virtual con gobernadores el 17 de junio de 2021, que la restricción de aforo en la infraestructura turística, restaurantera, bares, centros recreativos y distintos espacios públicos permitirá la rápida reactivación económica y la disminución del riesgo de contagios (Secretaria de Salud, 2021). Con la obtención de un prototipo funcional, se está contribuyendo a afrontar uno de los problemas que se han generado con la actual pandemia mundial de COVID. El prototipo se programó en Python 3 usando una placa Raspberry con sistema operativo *Raspberry Pi*.

COVID, Aforo en recintos, Visión artificial

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Introduction

All know the existence of a global pandemic due to the coronavirus COVID-19. In this context, the Government of Mexico points that the capacity restriction in the tourist infrastructure, restaurants, bars, centers recreational areas and different public spaces will allow for a rapid economic reactivation and a reduction in the contagion risk (Health Secretary, 2021).

From this approach at the federal level in Mexico, the idea arises of proposing a prototype that, based on an artificial vision technique, performs the counting of people who enter an enclosure or closed space in order to count such people and be able to know when the maximum capacity has been reached in real time.

To develop this research project, two types of software and hardware components have been required.

First, the hardware components are made up of a *Raspberry Pi* 3 B+ card, whose general characteristics are enunciated in Table 1. According to Clément (2018), the necessary connections for using Raspberry Pi are the following:

- An HDMI cable attached to an HD display.
- A USB keyboard.
- A USB mouse.
- A micro-USB power.

The of the Raspberry Pi card programming is made with the Python language since, according to Donat (2018), it is one of the easiest languages to learn, it is free to use, it is an interpreted language, which makes it easy to write the programs in any plane text editor.

The second important component is the camera that captures the images and video to be analyzed to perform the people count; its characteristics are shown in table 2.

Processor	Broadcom BCM2837BO, Cortex-A53 (ARMv8) 64-bit SoC
Clock frequency	1.4 GHz
Memory	1 GB LPDDR2 SDRAM
Wireless connectivity	2.4 GHz/5GHz IEEE 802.11.b/g/n/ac Bluetooth 4.2, BLE
Network connectivity	Gigabit Ethernet over USB 2.0 (300 Mbps de theoretical maximum)
Ports	GPIO 40 pin HDMI 4 x USB 2.0 CSI (Raspberry Pi Camera) DSI (Touch screen) Headphone jack / composite video Micro SD Micro USB (power) Power-over-Ethernet (PoE)

Table 1. Raspberry Pi B+ technical specifications
Source: Pastor, (2018)

Maximum resolution	720p/30 fps
Camera mega pixel	1.2
Focus type	Permanent
Lenses type	Plastic
Integrated microphone	Mono
Microphone radio	Until 2.74 m
Diagonal field of view (dFoV)	60°
Universal mounting clip ready for laptops, LCD or display	

Table 2 Logitech C505 camera technical specifications
Source: Logitech, (2022)

On the other hand, the software components that it was necessary to install in the Raspberry Pi, are briefly described in table 3, in which it can be seen the function of each program in the proposed prototype.

Software	Description
Raspberry PI Imager	Operating system to install on the Raspberry card, it was configured with the SSH protocol to be able to manage the Raspberry card (Raspberry Pi, 2022).
VNC Server	It is a free software program based on a client-server structure to access the Raspberry desktop remotely. (RealVNC, 2022).
OpenCV	It is an open source library that it includes computer vision algorithms. (OpenCV, 2022).
Numpy	It is a Python library that provides a multidimensional array object, various derived objects (such as masked arrays and matrices), and an assortment of routines for fast operations on arrays, including mathematical, logical, shape manipulation, sorting, selecting, I/O, discrete Fourier transforms, basic linear algebra, basic statistical operations, random simulation and much more. (Numpy, 2022)

Table 3 The software used description
Source: Various sources cited in each case.

The prototype is based on an artificial vision technique, in this area there are already previous works as cited by Flores & Sandoval (2021). In 2014, a study was carried out that focused on the design and implementation of a low-cost smart security camera with night vision capabilities using Raspberry Pi and OpenCV. The system was designed to be used inside a warehouse, having human and smoke detection capabilities that can provide prevention against potential crime and fire. Flores and Sandoval, also describe that in 2019, a Raspberry Pi and related camera modules were used for image acquisition. Here, special attention is paid to the recording of stereoscopic images and post-processing software that OpenCV applies. (Flores & Sandoval, 2021).

According to Pajankar (2020), the field of computer vision is a combination of different fields, including (but not limited to) computer science, mathematics, and electrical engineering. This field includes ways of capturing, processing, and analyzing real-world images and video to aid in decision-making.

Once a functional prototype was obtained, several tests and training sessions were carried out, for which a proprietary methodology was followed, based on a combination of waterfall and prototype development models. This development is presented later in this document.

Once the development of the research work has been explained, the results obtained are presented, which were the expected ones, but in addition to these, a series of observations were also obtained that allow proposing some improvements to the prototype in order to carry out the count in a correct way, more effective and reliable.

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Finally, the conclusions reached after carrying out this project are presented, as well as the sources consulted for the writing of the article. This article will allow the dissemination of the experiences that are being developed in higher education institutions as part of the human capital training, that is incorporated into the our country economic development and particularly of the state of Oaxaca.

Methodology

For the development of this capacity control prototype in an enclosure using artificial vision, a proprietary methodology was used based on the traditional cascade and prototype models. Well, as Somerville (2005) states, the waterfall model consists of five main stages, as illustrated in figure 1.

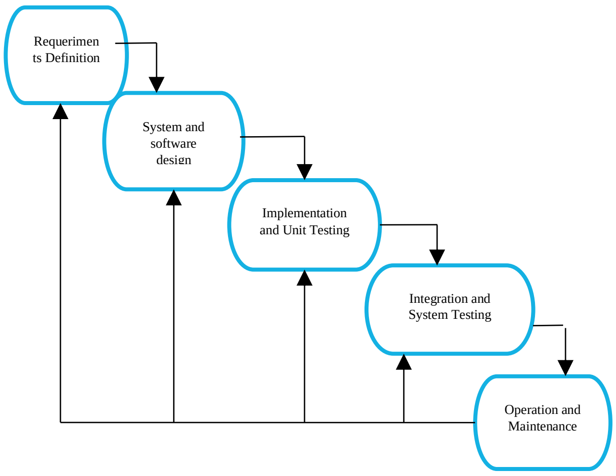

Figure 1 The waterfall model
Source: Somerville, (2005)

Alonso, Martínez & Segovia (2005), identify the following stages in the prototyping methodology:

1) Requirements gathering

2) Quick design

3) Prototype construction

4) Prototype evaluation

5) Prototype refinement

6) Product

Considering the above, six development phases are proposed for this project, which are:

Phase 1: Features definition of the used equipment.

Phase 2: Preliminary design of the prototype.

Phase 3: Identification of operating environments.

Phase 4: Color and contour recognition tests with the prototype.

Phase 5: People recognition tests.

Phase 6: Prototype tests.

Phase 7: Prototype improvement proposal.

Developing

Phase 1. Features definition of the used equipment

In this phase, the characteristics of the components are defined. First, as mentioned in previous paragraphs, Table 1 shows the characteristics of the processor used, which is *Raspberry Pi*.

Likewise, table 2 lists Logitech C505 camera features, which is used to capture the images and video. They are processed to first identify people, then image processing is performed based on techniques of artificial vision. Finally, carry out a count when people have been identified entering an enclosure, in which it is required to keep a control to know when it has reached the maximum number of people allowed.

The hardware requires the software to be able to operate together, for this, the necessary programs, libraries and tools are installed to achieve the coupling between the hardware and the software, the list is presented in table 3, as well as a brief description of the role that each of them plays in the proposal.

Phase 2. Preliminary design of the prototype.

The proposed design is a simple design, in which there is a Raspberry Pi card, a Logitech C505 camera, a display, which allow observing what the camera captures, and, a VGA to HDMI converter to be able to process the images in the Raspberry. Figure 2 shows the block diagram of the design, and figures 3 and 4 are images of the real components.

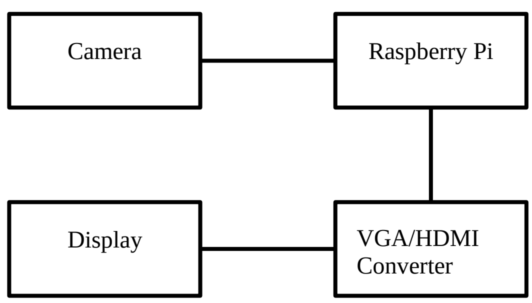

Figure 2 Block diagram of the proposed design
Source: Own elaboration

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Figure 3 *Raspberry Pi* and converter VGA/HDMI
Source: Own elaboration

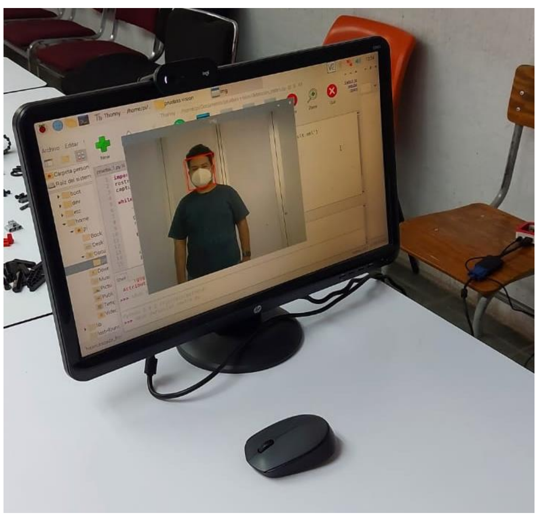

Figure 4 Display and camera of prototype proposed
Source: Own elaboration

Phase 3: Identification of operating environments

In this phase of the investigation, we worked on the identification of the possible scenarios in which the prototype could be used, identifying two possible scenarios:

1. On the outside of the enclosures where people counting is necessary to determine the capacity in real time.
2. In the interior part of the enclosures where the people count must be carried out.

In the first case, making an analysis of the proposed prototype, security aspects of the devices should be considered, since, being electronic parts, they can suffer deterioration when found outdoors, so some casing would have to be developed to its protection, in this research project this option is not considered as a scope of it. In the second case, the prototype may be protected by being installed inside the enclosure, but in a strategic way that allows people to be counted without obstacles. An important aspect to consider is that the camera must remain fixed, since if it has any movement or vibrations, its operation will not be adequate and it causes failures when capturing images and counting people.

Phase 4: Color and contour recognition tests with the prototype

In this phase, color detection tests were carried out in order to identify the image recognition functions, as well as extract only the images of interest through the background subtraction function. With these tests the recognition of people is finally achieved. As an example of these tests, Figure 5 shows an image in which the red object is detected. To achieve the detection of the red object, it is necessary to import the Numpy and CV2 libraries, the RGB (Red, Green, Blue) image is also converted to HSV (Hue, Saturation, Value), thus obtaining the binary image shown in Fig. figure 6. With the binary image of the object, it is converted back to RGB and activating the background subtraction, the result is the recognition of the red object, which can be seen in figure 7.

Figure 5 Original image of the red object
Source: Own elaboration

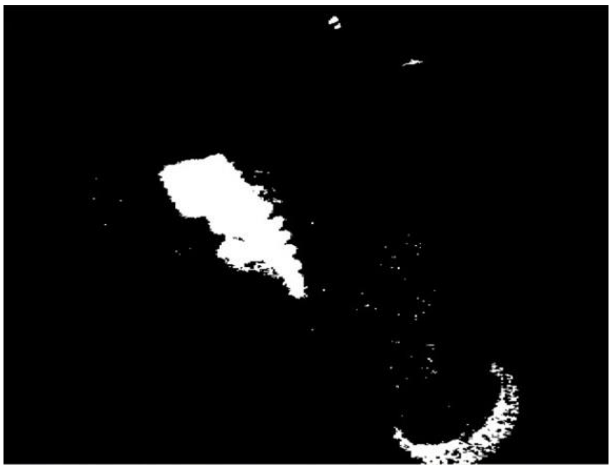

Figure 6 Binary image of the red object
Source: Own elaboration

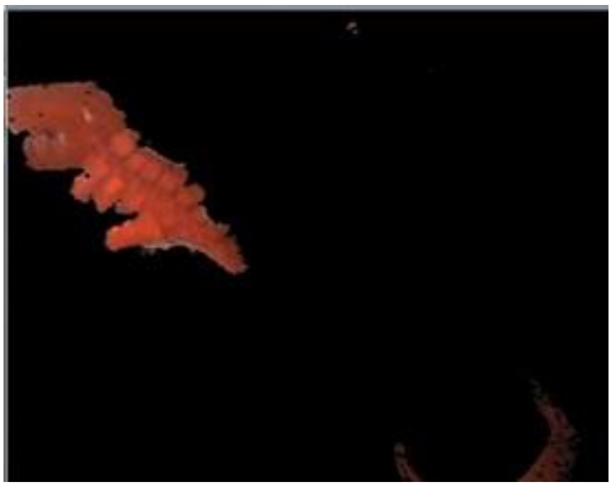

Figure 7 Isolated image of red object
Source: Own elaboration

This process was repeated with blue and yellow objects, changing the adjustment parameters to be able to detect the binary image and the color in question (blue or yellow).

For contour detection it is a similar process, but in this case the original RGB image is converted to grayscale, once this is done, edge detection is applied with the cv2.canny function which detects that the lines pass by an established threshold, providing a maximum and minimum value, with these values the contours can be identified.

Figure 8 shows the original RGB image, figure 9 shows the grayscale image, and figure 10 shows the detection of the contours from the binary image.

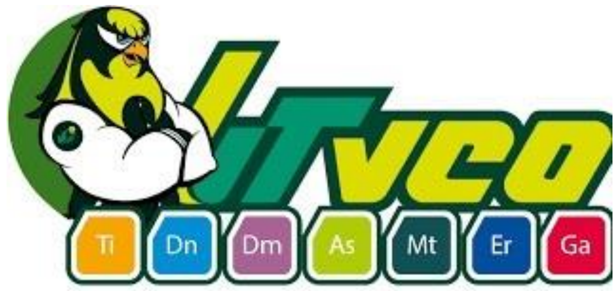

Figure 8 Original RGB image
Source: UTVCO, (2022)

Figure 9 Grayscale image
Source: Own elaboration

Figure 10 The image on the left is the binary and the one on the right is with the detected edges
Source: Own elaboration

Phase 5: People recognition tests

For the recognition of people in real time, the first thing that must be taken into account is that the camera must be totally static, otherwise the algorithm will have failures by not being able to adjust the detection. Next, the cv2 and imutils libraries (phyton tool for image processing such as rotation, size, etc.) are imported, the background subtractor mog tool (also known as Foreground detection) is also used to subtract the background of the video. It is important to note that this tool is a computer vision algorithm that attempts to distinguish foreground objects from background objects.

To avoid performance problems, the video is resized with imutils. Subsequently, the binary image of the regions with white points is obtained, since these white points imply that there is movement.

The cv2.findcontours function is used to mark the person within a box, likewise, the detection threshold is configured, this particular step is of vital importance for the operation of the prototype because if this value is not correctly configured, there will be false positives or some people are not counted. The value is adjusted according to the needs of the environment in which it is to be used, since it mainly has to do with the distance from the camera to the ground. Figure 11 illustrates the detection of a person moving through the counting area.

Figure 11 Detection of a person moving through the counting area
Source: Own elaboration

For counting people, the coordinates of the box generated with the binary image are taken into account and a line is drawn in the middle of the screen as a reference. When people pass through that line, the counter is increased by one.

Phase 6: Prototype tests.

The prototype tests start with the detection of the binary images, and then they are passed through filters. In these tests, it is important to obtain the correct detection of people, since the count would not be reliable.

In the Python programming, the count is made as soon as the people pass through the auxiliary line drawn in the middle of the image, and to show when a person is added, the centerline becomes thicker, indicating with this, that one person passed through the counting area. Figure 12 shows when the prototype detects a person and counts it as a person entering the room or space to be controlled.

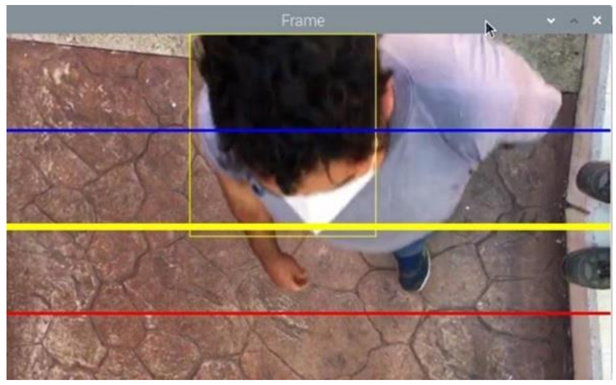

Figure 12 Moment when the prototype detects a person and counts her/him
Source: Own elaboration

The prototype only counts people because the reading threshold is configured so as not to detect smaller objects, that is to say that, for example, if a dog were to move through the detection threshold, it would not recognize it because it is smaller than the established size.

Phase 7: Prototype improvement proposal.

The improvements proposed for the prototype are based on the results obtained from the tests applied to it, a possible improvement is the expansion of the RAM memory of the Raspberry to at least 4 Gb. The foregoing, in order to make code execution more efficient, since the memory used in the analyzed prototype was limited to 1 Gb of RAM, due to the fact that there was no more budget to expand the memory.

Another important aspect is the processing speed, which has to do directly with the Raspberry model, this parameter can slow down the execution process of the artificial vision algorithm, causing some counting failures, among which it is identified that for some cases does not count people or double counts for the same person.

On the other hand, in order to optimize the code and consume fewer resources, a cascade detector can be implemented, in this way the heads or bodies of people would be specifically identified, without having to consider the rest of the objects in the input image. , and thus, optimize the reading process.

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Finally, the prototype can be improved by adding a second camera to be able to detect when people leave the premises. Since, the current prototype makes the count for the entrance to an enclosure or closed space. However, there would be a lack of a counterpart to do the output counting, and with this the prototype would be more complete and would perform better for the purpose for which it was intended.

Results

The results obtained were satisfactory, the algorithm can successfully count the people who enter a room and store the data. However, if there were some limitations when programming the code, because the Raspberry card with which the project was developed, it is limited since it only has 1 gigabyte of RAM, which complicates fluid work in real time. Several versions of the code had to be made, until a version was found in which the execution was efficient and thus, avoiding reading errors that led to obtaining false positives or omitting to count people. In this last scenario, by omitting the counting of a considerable number of people, the capacity may be exceeded and generate a potential risk of contagion within the closed space in which the entry control is being carried out.

The camera can be used vertically or horizontally as if it were a security camera, although as mentioned above it is essential that the camera is static so as not to contribute to counting errors. Although the camera has some versatility to be positioned, the ideal position would be vertically with a sufficiently wide angle of vision to be able to observe people from full length.

Figures 13 and 14 show the detection of people with two different positions of the camera used, figure 13 shows the detection of a person when the camera is placed facing the entrance area of the enclosure. Figure 14 shows the detection of the person in front of the entrance with a slight forward tilt.

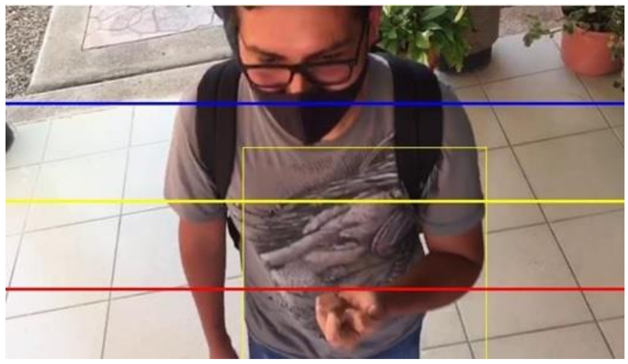

Figure 13 Detection of person with the camera placed in front of the entrance area of the enclosure
Source: Own elaboration

Figure 14 Person detection with the camera placed in front of the entrance area of the enclosure with a slight inclination
Source: Own elaboration

Originally, it was proposed that the prototype be installed at the entrance of classrooms; however, the option is not viable, since the entrance to the classrooms is a very limited area to count people, the suggestion that is issued is to install the prototype in an area with a greater influx of people where support is required to control capacity. It is worth noting that the current prototype has hardware limitations such as heat dissipation, it requires being in an area where air circulates so that it does not overheat and it is not recommended to use it with a capacity greater than 100 people to not compromise the integrity of the Raspberry Pi card. This problem could be improved in the future by using a cooling system in the prototype that includes a fan and heat sink, which allows maintaining the temperature of the components in a range no greater than 65° so that they do not suffer damage or alterations in its operation, mainly the Raspberry Pi.

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Conclusions

Currently, because of the pandemic, it is essential to protect yourself from contagion; face-to-face activities cannot be suspended indefinitely since it strongly affects the economy of societies. However, the return to face-to-face activities has had to be carried out under protocols that have been established globally by the World Health Organization and in each country by their own governments. A relevant point in this new world normality is to maintain a healthy distance where the gathering of people is necessary, mainly in closed rooms.

The objective of this project is to provide a tool that helps to control the capacity of people in those closed spaces that require housing people, controlling the maximum capacity allowed. Which is achieved by establishing a count that is done automatically using a Machine Learning technique, using artificial vision techniques.

During the testing process of the proposed device, several opportunities for improvement were found, and within them, it is considered to keep most of the components in order not to raise the price of the prototype.

In this first stage, the cost of the prototype is $4,000.00 Mexican pesos, which is a high cost for certain sectors. Therefore, in the future, components that can reduce the production cost by some percentage would be analyzed. But, despite the limitations, during the tests the prototype performed adequately for the established purposes, concluding that it was functional.

Once the prototype is more stable and affordable, the application can be transferred to different types of closed spaces such as offices, restaurants, stadiums, among others.

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