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SOCIAL DISTANCING DETECTION BY DRONE EXPLORATION

A novel thermal images analysis model

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KEYWORDS

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ABSTRACT

Facing the criticality of the COVID 19 pandemic, we propose an artificial intelligence system with a modern approach detecting people and their social distancing in crowded places using thermal images obtained from the DJI Mavic 2 Enterprise Dual drone. We implement an algorithm that analyzes two types of images: color and thermal, to measure the distance between people. We used the Fast R-CNN neural network; the images with videos were extracted from the DJI Pilot application. The objective is to identify the distance between people. The results obtained show that the proposed algorithm is suitable for monitoring the city.

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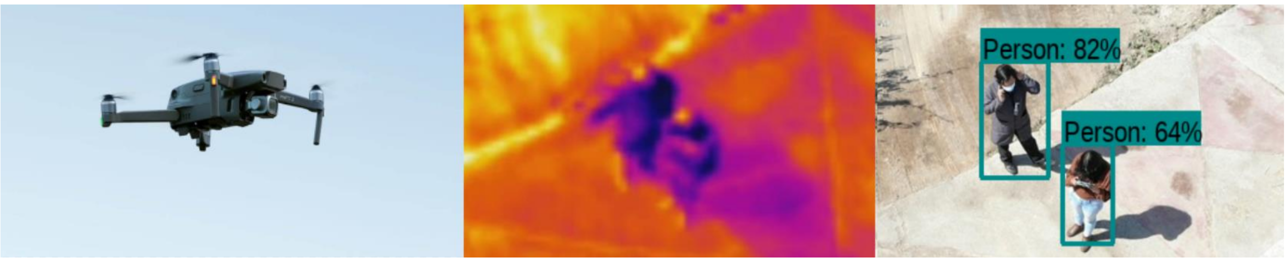
1. Introduction

Figure 1. Mavic 2 Enterprise Drone. Thermal and RGB image of two people



Source: own authorship

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the seventh human coronavirus, was discovered in Wuhan, Hubei province, China (Ciotti et al., 2020).

One of the most important particularities of COVID-19 is its easy level of transmissibility; due to its great resistance and extremely efficient fast transmission mechanisms. This highly infectious agent is usually spread by the respiratory route or by direct contact with secretions; therefore, human-human transmission has become the main route of dissemination to manage in this painful pandemic (Angulo et al., 2021).

The rapid spread of this serious disease caused the World Health Organization, on January 30, 2020, to declare it a health emergency of international importance and begin to place a great source of restrictions, based on the atrocious impact it could have the virus in the vast majority of underdeveloped countries with less infrastructure and a weak health service, for which it was recognized as a pandemic on March 11, 2020 (Strecht et al., 2015).

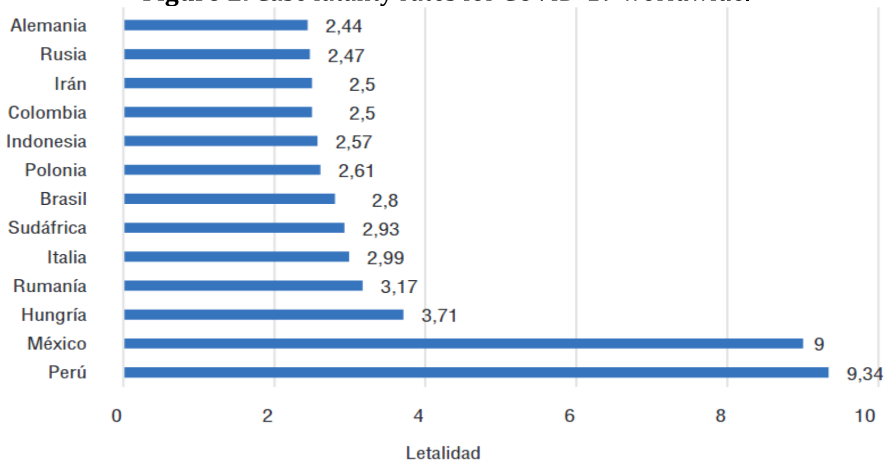
In America and the Caribbean, the first case was reported on February 25, 2020, in Brazil, and then, its presence was reported in different countries of the region (Rodriguez et al., 2020). In the case of Peru, the cases of COVID-19, caused by SARS-CoV-2, began on March 6, 2020, when the disease occurred in a traveler who had returned to the country. Days later, more cases of this virus began to appear.

On March 16, a quarantine was decreed throughout in Perú, along with other measures to mitigate the virus and contain what was already evident, that is, a pandemic (Gutiérrez, 2021).

The countries with the highest number of cases of people deceased by COVID-19 are established with a cut-off date of July 15, 2021, where it is detailed that among the first with the highest number of deceased people are: United States (608,269), followed from Brazil (537,394), India (411,989), Mexico (235,507), Peru (194,752) and Russia (143,657). And the countries with the highest fatality rates for COVID-19 are: Peru (9.34), Mexico (9.0), Hungary (3.71), Romania (3.17) and Italy (2.99). (Díaz, 2021)

Case fatality rates for COVID-19 worldwide (Figure 2), placing Peru in first place.

Figure 2. Case fatality rates for COVID-19 worldwide.

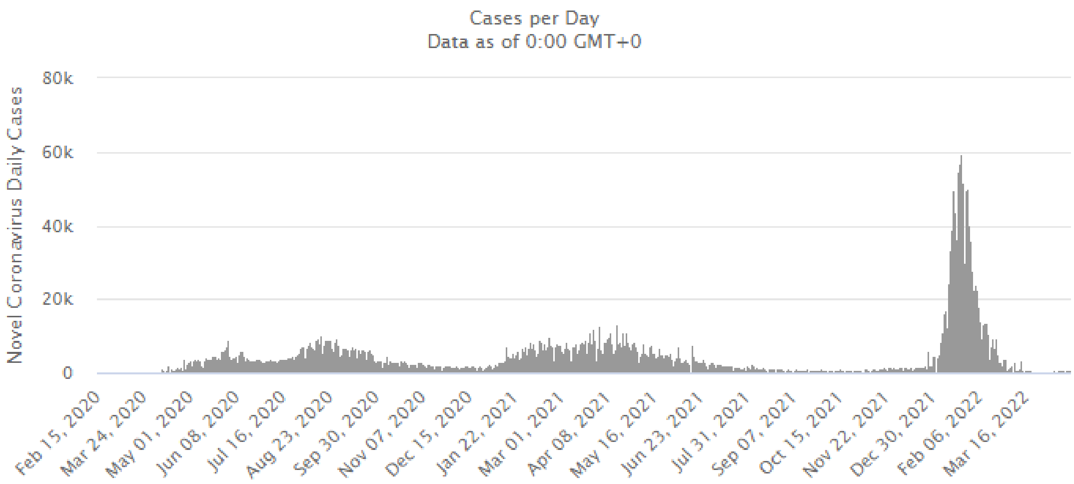


Source(s): Díaz, 2021.

According to the article by Ramírez & Ortega (2022), worldwide, Peru is the country with the highest number of deaths from COVID-19 per 100,000 inhabitants. In 2020, there is a figure of 93,851 deaths from COVID-19 in Peru, and as of December 26, 2021, a total of 202,524 deaths of people with the virus are recorded. These results only highlight the great limited capacity of the national health system that our country has, the collapse of health services throughout this period, in the first, second and third waves, shortage of beds in the intensive care unit (ICU), the lack of oxygen, leading to lack of care and the highest mortality rate from COVID-19, makes us highlight our reality and accept that the contagion of this virus is extremely lethal in Peru.

Figure 3 shows the evolution of daily covid cases in Peru as of March 16, 2022, showing a greater increase in the first quarter of this year, reaching almost 60,000 infected per day.

Figure 3. Evolution daily cases covid in Peru.



Source(s): Worldometer, 2022.

From that moment to the present in Peru, several restrictions have been decided to limit cases of contagion, the two main ones, and of greatest importance, being hand washing and social distancing. And although Peru was the first country in the Americas to implement such severe measures, the transmission of COVID throughout the country was inevitable and worrying. A rapid increase in reported deaths, in the first wave, reached a temporary plateau, so the restrictions were very strong. However, over time, a slow, albeit progressive, relaxation of the restrictions has been observed, associated with higher mortality.

In Peru and in the world, social distancing is the best way to reduce the spread, it is based on the fact that the person must maintain a distance of at least two meters with others, and there are non-contact instruments, which can help to monitor the agglomeration of people such as thermal cameras and infrared thermometer. These instruments recognize a person's surface based on their body temperature.

The purpose of this study is to identify, by means of a thermal camera located on a drone, the activity and agglomeration of people through Artificial Intelligence (AI), analyzing the effective fulfillment of social distancing. This type of technology will help us to better manage the monitoring of the practice of this restriction.

In this work, the main purpose is to propose a tool that can assist in the control of distancing measures and thus prevent the spread of COVID 19 in the person-to-person relationship, which is why a tool that identifies people is proposed, and the implementation of an algorithm for classification of social distancing in thermal images.

The present work is structured in six important sections: in Section I mentions a brief but concise introduction to the study carried out; section II refers to related works, studies focused on the subject and on which our research was based; for section III, it talks about the tool, proposed system, with its components and related information for the generation of the project; in section IV we will present the practical application and experimentation and the results obtained; for section V the final conclusions of the work will be presented, contrasting them with the related works and in section VI future studies will be proposed which will be based on this research.

2. Related works

In this section we will highlight some of the works related to our study from which we were able to guide ourselves for a clearer vision. The review of the state of the art mainly focuses on current research on object detection using machine learning and on the importance of thermal imaging.

To begin, we must highlight the great importance of drones at this time, since these unmanned aerial vehicles have various forms of application and management, whether for photography, photogrammetry, surveillance, agriculture, search, communication systems, etc. A clear example is the application given to operational and tactical drones in disaster management, since they can greatly help the rapid selection of ground locations. The drone can help administrators to keep an area under observation to a great extent. Another example is that it can also be used for fire detection, intervention monitoring and also for post-fire monitoring. These examples are given having a vision on the subject of disasters (Restas, 2015).

Although these drones, due to such extraordinary capabilities, represent a serious threat to the privacy of the general population. But you have to have in mind that in desperate situations privacy is seen surpassed by security in terms of priority (Kadam et al., 2021). That is why Kadam et al. in their article entitled "Autonomous drone for surveillance of social distancing", mention that walk the fine line between invasion of privacy and suspicion for the security, being convenient to sacrifice the first in the way of health security, since refers that it is important and a concern for all organizations in the world the prevention in the spread of the virus. That is why the main objective of your project is prevention using exploration with the application of drones in the field of surveillance.

While it is true that privacy is a right recognized by international conventions, it is equally true that there is a right to health and life that we believe should be prioritized in the framework of the health emergency caused by Covid-19, which has a high degree of lethality due to the saturation of health systems (Canals, 2020). In this way, the use of technology in situations like this is of public interest and of a humanitarian nature, and should be applied as long as there is legislation that frames the task of video surveillance in such a way that the rights of citizens are not violated. We insist that the use of unmanned aerial vehicles with a good strategy can be effective, although we are aware that it is invasive. However, the current context requires that we use various strategies to ensure biosecurity, especially when social distancing reduces the risk of SARS-CoV-2 infection (Garcia & Sanchez, 2022).

And regarding social distancing, it has been highlighted that the control of the COVID-19 pandemic in Peru may fail if actions that comply with the promotion and maintenance of low social interaction are not considered. This warning is focused on the need to pay attention to all the psychosocial variables that help us to better adopt protective behaviors (for example, washing hands every moment of the day, maintaining the mandatory social distance, wearing a double mask, etc.). The latest meta-analysis shows that physical distancing of at least one meter is too closely associated with protection and biosecurity against COVID-19; but that may indicate that distances of up to two meters can be much more effective for us. In the Peruvian context, there is evidence of non-compliance with the provisions on quarantine, community mobility and social distancing, limiting the effectiveness of actions to control the epidemic and generating an increase in virus infections (Cabanillas, 2020).

These signs of non-compliance are because the measures established led to the reduction of productive activities, generating losses in all sectors, mainly those most vulnerable. These restrictive measures have generated an impact at the macroeconomic level, specifically due to the fall in productive activities, which has led to the economic slowdown and has increased the levels of poverty, extreme poverty and social inequality in Peru (Fernández, 2021).

Despite this, the case of Peru is really striking, since being the first country to implement strong biosecurity restrictions, it was also the country most affected by COVID-19 in the world. (Huamani et al., 2020).

So technology began to be used to determine social distance, an example is the work presented by Rondón et al. (2020), its purpose is to determine compliance with the social distancing measure, through processing of video images captured in areas of public space, the people present in the video frame are detected, and, by estimating the distance between the centroids of the detections, it is determined whether or not they are in breach of the distance measure (two meters between people).

There are different ways to detect distance, one of which may be the use of the Matlab language as described by Meivel et al. (2022) in your project, for the implementation of this purpose, here they use the Matlab language to be able to process complex images of people, together with the Faster R-CNN convolutional neural network, and with it they use facial recognition packages. Its objective was to seek an improvement for face tracking, brightness and contrast colors, for better image processing and to be able to measure social distance.

Now, if we combine the vast majority of the techniques suggested for the recognition of social distancing and unite with the technology offered by drones, we have quite a few ways that can be implemented, one of which can be seen as a precursor to the group model of research Osiris and Bioaxis of the El Bosque University, which has been developing a technology of Autonomous Intelligent Drones, which make great use of Artificial Intelligence to implement Artificial Vision and Autonomous Navigation capabilities, with applications in different and multiple areas of the commercial sector, production and services. And through one of its lines of research, Engineering for health and biological development, the research group has thought about how the great technology of Autonomous Smart Drones can effectively and efficiently support strategies to make in the face of the SARS-CoV-2 pandemic, encountering multiple situations in which they are very useful to mitigate risks and effectively contribute to containing and mitigating the pandemic. An example provided in his article is that of the artificial vision and autonomous navigation capabilities that allow them to be used to generate help for the authorities in their environment with the control of social distancing and collect very valuable information in the field, useful for modeling and designing new measures for this pandemic (Beltrán & Álvarez, 2020).

It is possible to mention the investigation of Merizalde & Morillo (2020), in which it focuses on the COVID-19 pandemic and demonstrates the challenges that our society faces, for this reason they propose the development of a system to detect social distance but using algorithms and the use of an unmanned aerial vehicle. Once the breaking point is found in terms of distance, an alert is issued and thus it is possible to decide on the call for attention to the person. They also integrate video analysis in real time, for a better detection of people. Their stage metrics were 15, 30 and 50 meters respectively, which gave a result of 95% for the recognition of the distance from person to person.

Another example is the one given by Kumar et al. (2021), which proposes a UAV-based smart health system for better monitoring, indicating disinfection, and controlling social distancing, countering data analysis and generation of COVID-19 statistics. for the sector control room. When implementing it, it is observed that a great flight distance is covered in a short time of its execution and the exact identification of the people by the thermal camera included in the object, giving a positive control result for the proposed system.

And in the work presented by Saponara et al. (2021), they show us an investigation on a system that helps to monitor people through intelligent surveillance and indicates how the classification of social distancing between man-man using thermal images would look of people. Resulting in a high accuracy and precision of its learning model compared to other models, it is also possible to observe that it performed very well in real time as a detector and distance meter.

So by collecting all this information we can propose to unite the technology that presents a drone with a thermal camera and the Fast R-CNN neural network for a better detection technique for social distancing in different sectors.

3. AI System

In Peru, no works related to the health field have been found using AI with thermal images captured by drones, however, there are works related to other fields, such as Van et al. (2022) that uses drones to capture images thermal for the topography of archaeological sites, applied in the city of Pachacamac, Lima. Another related field is surveillance for citizen security, in the district of San Martin de Porres in the city of Lima, where Orihuela (2020) proposes the use of drones to reduce the level of insecurity in the population. There are also jobs in the agriculture sector, such as Jiménez & Medina (2022) where drones are used to detect pests in mango crops in the city of Piura.

In the following sections we explain our proposal.

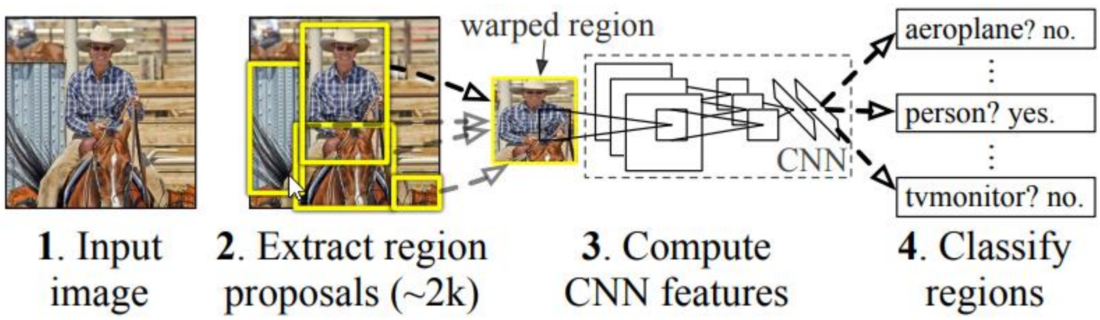
3.1. Neural network design

For object detection, a bounding box is placed around the object or objects, in this case people, and then the category that corresponds to the observed object must be associated. This type of detection that we see is thanks to deep learning, since it is the most accurate method that has been found.

Regarding the neural network, we must mention the work titled *Rich feature hierarchies for accurate object detection and semantic segmentation* Girshick et al. (2014) who is the one who explored and showed through his research the regional convolutional neural network detector (R-CNN). In the work it is shown that the found object detection system is mainly linked to three modules. The first module shows that proposals can be generated, which define the wide set of preliminary explorations available, for independent regions of the category. The proposals mentioned are for the best handling of the detector. The second module is explained as extracting the property vector that fixes the length of the regions by means of the large convolutional neural network. And finally, we have the third module, which is a set of class-specific linear SVMs.

According to figure 4 shows us the architecture of R-CNN, which enters the image obtained, then extracts regions that are proposed by the network, and begins to compress it and execute the detection sequences, in order to provide the information that is the object of the image, as explained with the three modules.

Figure 4. R-CNN Architecture.



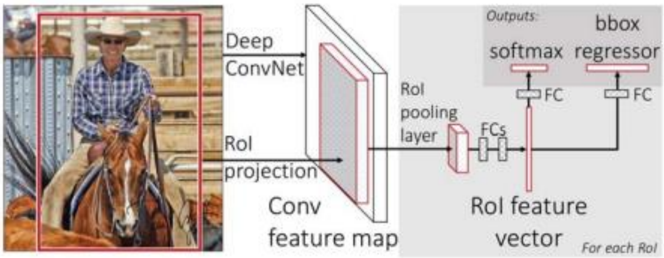
Source(s): Girshick et al., 2014.

Already established as is the process that the R-CNN neural network has in tracking objects in real time, we recognize that it has a correct detection but its implementation is complicated and slow. And another point in which it is difficult for the investigation is that R-CNN can only train each part separately, it cannot train at the same time.

Another version of the neural network is known, it is the Fast R-CNN, which is a regional algorithm proposal, it should be noted that it was demonstrated by the same author of the R-CNN Model In the work titled *Fast R-CNN*, (Girshick, 2015) in it indicates that Fast R-CNN is a cleaner and faster update of R-CNN. Since it introduces many improvements on problems seen by the previous R-CNN model, one of which was object detection being too expensive (in processing time) to investigate. In the past, and by implementing Fast R-CNN, your processing time decreases, making it less costly in comparison and much more practical.

And as in the previous image, Figure 5 shows us the composite architecture of Fast R-CNN, it changes in the sense that it does not separate the image and compresses it, with this model it integrates the entire image for analysis and converts to a feature map.

Figure 5. Fast R-CNN Architecture.



Source(s): Girshick, 2015.

Analyzing the two algorithms (R-CNN and Fast R-CNN) it is shown that both use selective image search and extract a region recognized by their algorithm for object detection. For our project we will use Fast R-CNN, since we will be placing the main frames and according to them the bounding frames must be formed for processing in the different objects displayed in the images provided. We must say that the tables that will be our main ones are defined to obtain the scale and dimension of some classes that will be observed in the figures and according to this, they will be selected in focus on the sizes of the objects in the entire image, information delivered through the images.

3.2. Camera Thermal

To talk about the thermal camera it is necessary to understand that it has a good basic principle in terms of its provided images, as indicated in the work entitled *Estudio del diseño de un sistema electrónico para detectar a personas con fiebre mediante el uso de una cámara térmica*, Atoche (2020), mentions that this principle is the use of infrared thermography, which recognizes the human body in its entirety and its environment, indicating its temperature in the scale of degrees centigrade, for this work, or it can also be indicated that it handles the range above absolute zero (0 K or -273 °C) and if we want to process the images, we will begin by recognizing the type of thermal energy that bodies present by incorporating the radiation presented according to the infrared spectrum.

Now, if we focus on thermal cameras, we must understand that their main function is to detect and capture the infrared energy that is shown in all objects and once this energy is focused, to be able to convert the data presented in the image in scales of color, as required in the processing, since each color spectrum will represent a certain level of temperature, it can also be taken into account that there is a gray color and can help on certain occasions to better visualize and manage data with respect to the input image. Knowing the concepts, it is recognized that, in the thermally proportioned image displayed with a wide color palette, a temperature will be displayed for each of the pixels as a function of the radiation focus of the object with its total area. We observe that each value provided can be very different, because the temperatures begin to vary and according to the object and therefore this will map an image with different colors according to the scale provided by the researcher, for a better representation of the temperature radiated by the object and its environment, so it can be seen visually for the human. If we talk about the different colors that can be represented with the variation of temperatures, let's start first with the colors for the sensation of heat or a warmer radiation, these are usually represented by a reddish, orange or yellow tone, or show colors between these mentioned scale, to denote that infrared heat emission radiation is extremely strong and bright. On the other hand, for a more subtle temperature or also called cold, darker colors are shown, this is the case of the main blue color, it can also follow a medium purple color or even green, simply with these colors it is indicated that they do not exert a heat emission and strong radiation, that's why they are only for cooler temperatures.

3.3. The Mavic 2 Enterprise Drone

For our research, the drone used will be the DJI Mavic 2 Enterprise series, according to DJI (2020) that has a wide omnidirectional vision system, which allows us to use it in all directions, and has an infrared detection system, according to your thermal chamber. If we look at the best exclusive technologies provided by the DJI brand, such as obstacle detection and the advanced pilot assistance system, we will have the best option for capturing complex and effortless shots that we require in this project.

Among the different implements that come in the Mavic drone kit, there is its gimbal camera that contemplates its 3 axes, which provides better stabilization for image capture, where the infrared thermal camera and a visual camera are included, both are for capturing color images and thermal images, which means that the emission of images of visible and infrared light at the same time is facilitated. The infrared thermal camera records 640x480 video and the visual camera captures 4K video and 12MP photos. (DJI, 2020)

The highlight of the Mavic 2 Enterprise Dual is its large THERMAL CAMERA that will help us detect different temperatures, capturing different levels of infrared light, from people in crowds.

In Figure 6 it can be seen that obtaining images is through a cell phone incorporated into the remote control included in the Drone kit, then when capturing images two photos are obtained, one thermal and one colored, and then sent to the computer for processing.

Figure 6. Obtaining photos using Drone.

Source: own authorship

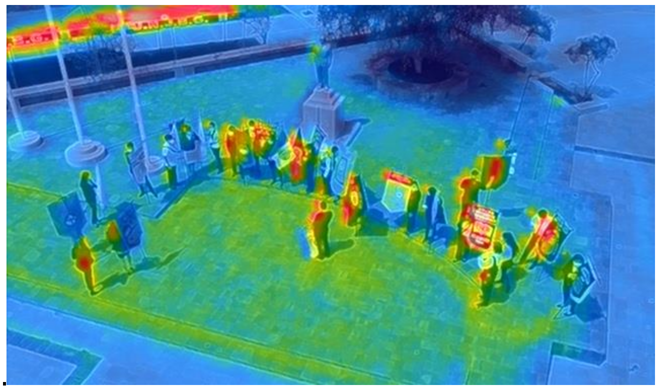
There are different ways of looking at thermal images, but the ones we used the most in this research were:

- HotSpotlso, which focuses on people and animals with shades in reddish color scales, and in the background, you can see colors close to grayish.
- Rainbowlso, which gives a panorama with yellow, green, blue, red and black colors. Red is the strongest temperature color or also called heat temperature.

As for the handling of the drone, for capturing images and videos it was very practical, it is enough to follow the recommendations of the ignition and the calibration obtained through its application.

Figure 7 is one of the thermal images taken for the project, where the color scale provided by the thermal camera is shown, the points where people are observed are marked reddish, which indicates that their temperature is higher than that presented by the environment.

Figure 7. Raw thermal image captured by the drone



Source: own authorship

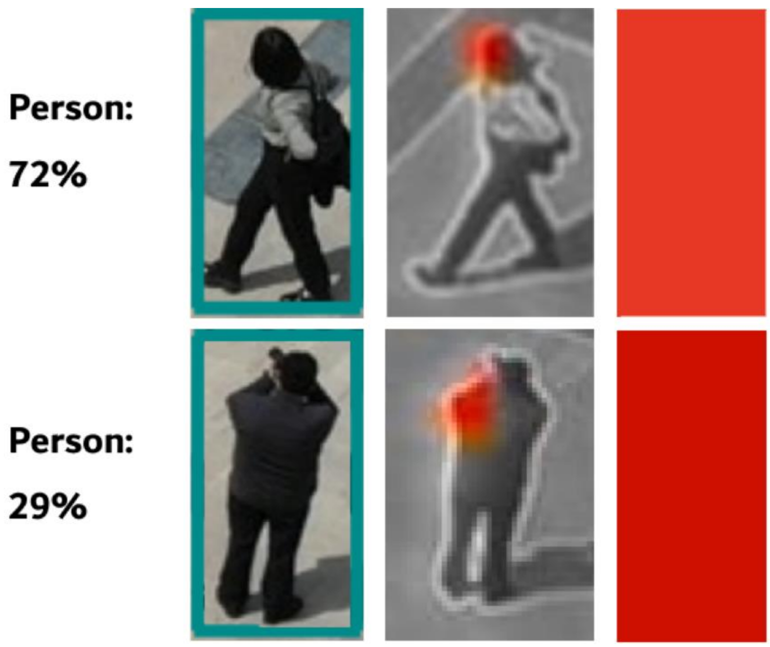
3.4. People detection and Bounding Box

To determine whether or not there is crowding, we must first detect all the people in the different images captured by the Mavic drone. To carry out this task, we have used, as indicated above, a fast training neural network: Fast-RCNN. That, once the object is detected, it proceeds to obtain the four coordinates of the bounding box and its classification as a person.

3.5. Using thermal information

In Figure 8 we visualize two people, but for the neural network the first object has a 72% probability of being a person (high probability) while the other only has a 29% (low probability), in order to confirm whether it is or it isn't a person. That is why we use the thermal information provided by the drone, in which we detect the presence of heat by quantifying orange pixels. If the presence of these pixels is large in proportion to the image, we assume that it is indeed a person and consider this in the following steps.

Figure 8. Thermal image analysis



Source: own authorship

3.6. Changing perspective to bird's eye

The image captured by the drone is a perspective image, the camera angle was set with an inclination of approximately 45°. To optimize the measurement of distances, we opted for a change towards a superior view like that of a bird's eye.

3.7. Measuring Social distance

To detect the agglomeration of people, the distance between them must first be determined.

To determine the distance in pixels between two detected people, the Euclidean distance (1) and the Manhattan distance (2) were tested, choosing the first option due to its precision and leaving the second option for when the computational calculation should be prioritized (future works).

Determining the distance in meters was a complex task because the drone captured images using different heights and positions. For this, the mean of the bottom side of all the bounding boxes present in the images was used and we assigned the value of 0.6 meters to the result obtained in pixels, which represents 30% of the minimum value of social distancing (two meters between people). Using this relationship, it was possible to estimate each of the distances in meters and verify if social distancing was being complied with.

1. ***Euclidean distance***

   $d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$

2. ***Manhattan distance***

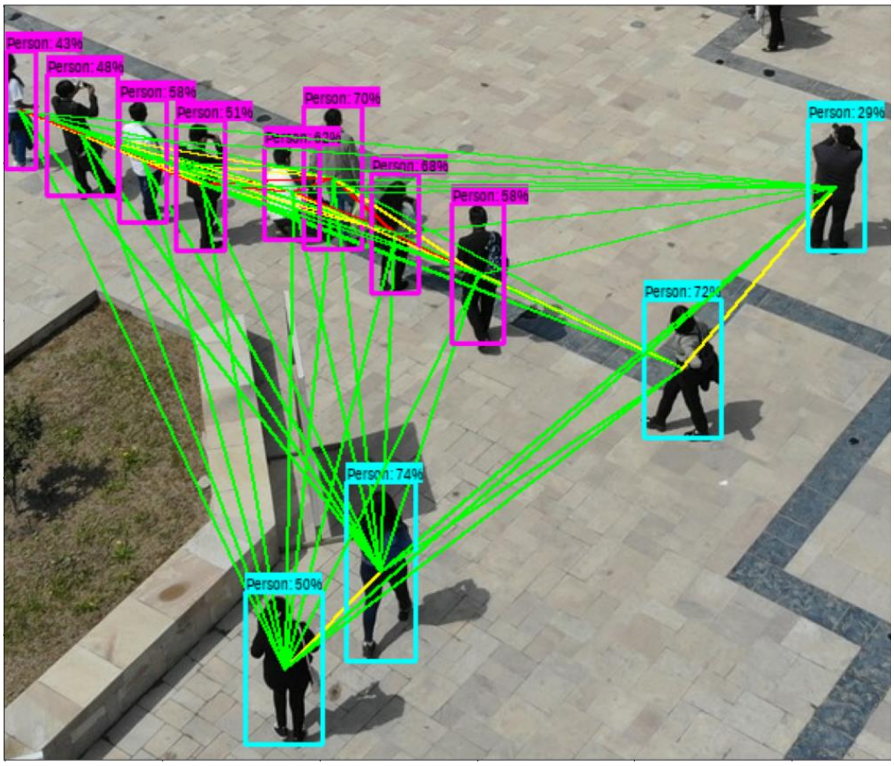
   $d = |x_1 - x_2| + |y_1 - y_2|$

   As:
   d = distance
   (X1, X2) = position of a point p
   (Y1, Y2) = position of a point q

3.8. Visualizing and Reporting Metrics

Finally, we have placed the analyzed elements in the RGB image for a better understanding. We draw the bounding boxes in Cyan for people who meet the distance margin and in Purple for people crowded and next to others. We then draw the distances as lines, in Red if the distance is less than 2 meters, in Yellow if it is less than 4 meters, and in Green if it is greater than 4 meters (Figure 9). Subsequently, we have obtained excellent metrics reflected in Table 1, which shows the percentage of people recognition, the percentage of this group that does not comply with social distancing and the time it takes for the images to be processed by the neural network.

Figure 9. Final prototype



Source: own authorship

4. Experimentation and Results

For the proposed prototype, we used the Mavic 2 Enterprise Dual Drone and was configured with HotSpotlso and Rainbowlso modes for the best recognition of people in open and closed environments. Through its management, our data sets (RGB images and thermal images) were obtained, which we selected to evaluate the ability to detect and measure people's distance.

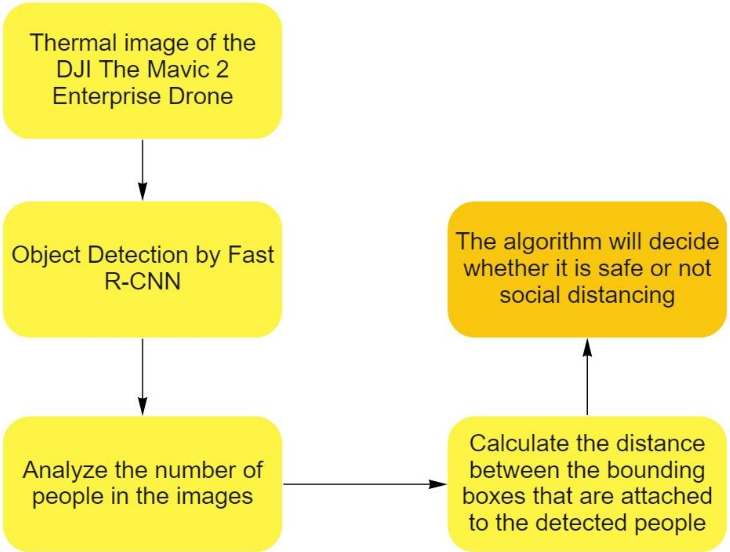
Table 1. Metrics Obtained

	Metrics		
Image	**Recognition of people**	**Distance non-compliance**	**Time**
1	90%	50%	33.19
2	100%	90%	33.61
3	90%	90%	32.64
4	100%	60%	32.85
5	100%	50%	32.28
6	95%	65%	32.50
7	95%	100%	32.73
8	90%	60%	32.27
9	90%	90%	32.60
10	100%	100%	32.83
11	100%	90%	32.52
12	80%	90%	32.79
13	80%	95%	32.29
14	100%	100%	31.92
15	75%	80%	32.21
16	90%	95%	32.96
17	100%	90%	32.42
18	100%	100%	33.15
19	80%	85%	32.21
20	100%	90%	33.36

Source: own authorship

For our experiment, we used the data sets and with the “Fast-RCNN” neural network we detected all people and we draw the Bounding Boxes. Then, using an algorithm, we proceed to the processing of thermal images. After, we move on to the implementation of the function that modifies the perspective of the images towards top view like bird's eye and the Euclidean Distance is used to implement the distance measurement function with the Bounding Box's center.

Figure 10. Pipeline for social distancing detention



Source: own authorship

To measure the efficiency of the proposed approach, the metrics evaluated are: the precision (percentage of recognition of people), identification of the distance (percentage of non-compliance of the established space) and the actual processing time. We randomly selected 20 images, obtaining the result in Table 1.

Our approach gives us a person recognition accuracy of 92.75%, in which we saw that 83.5% fail to comply with mandatory social distancing. The images being processed in an average time of 32.66 seconds.

5. Conclusions

This article shows an innovative and safe method of intelligent surveillance by means of an unmanned aerial vehicle, which captures images that allow the identification and detection of crowds from thermal images. This new proposed detection system has shown very good and effective performance results for the detection of people through the metrics of precision and identification of social distance, by processing the data in the Fast-RCNN neural network and by using the Euclidean distance function refined the points observed and collected from the previous works.

And like the related works, such as Beltrán & Álvarez (2020), where the design and construction of an Intelligent Drone is presented, which although initially they did not develop it for the control of Covid 19, at the time of its execution they managed to be able to observe better results for the alert contribution in these critical moments of the pandemic.

Similarly, in Kumar et al. (2021), they propose a UAV-based smart health system for COVID-19 monitoring, where they build a drone-based monitoring suite and note that it is an effective way to control mandatory social distancing. They indicate with alerts through some electronic device when people break that distance.

Another clear example is the work presented by Merizalde & Morillo (2020) where he presented a system in the same way of detection of social distancing only that implements real time. In this project they have as a result a percentage close to 90% in recognition of people and they also detected 3% with regard to distance measurement errors, which is a clear example that there is always a margin of error, having a large detection rate and minimum error it is indicated that the proposed system is useful for the emission of letters that would be infringing the social distance in order to avoid possible new COVID-19 infections.

And finally Saponara et al. (2021), it presented an incredible intelligent surveillance system for people tracking, and thermal images are already being used, together with videos that achieved promising results for people detection in terms of accuracy evaluation and precision.

The proposed project is a solution to help assess the problem related to mandatory social distancing from the pandemic state that the world is currently experiencing.

6. Future Works

In the present work, the use of a DJI Mavic drone is proposed to capture thermal images in crowded places and then process them using an algorithm to monitor compliance with social distance. In future work, we will use this methodology using real-time images and streaming video transmission in such a way that any case of non-compliance with biosafety protocols can be reported instantly to the health authorities. Our research can also be extended to generate our own dataset and design an unpublished algorithm with its respective training. In addition to that, the research may also be expanded to deal with satellite images obtained from PeruSat-1 or from other providers of high-resolution satellite images. selected to evaluate the ability to detect and measure people's distance.

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