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Maintaining Social Distancing using Artificial Intelligence

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Abstract: ***A technological solution to help people stay six feet apart from each other and maintain social distancing in order to prevent the spread of the coronavirus. The software is installed in the hardware of CCTV cameras and can perform effective contact tracing. The application goes through the video footage and does the following process for every frame in the video. It uses Python libraries such as Keras-RetinaNet to detect which objects are human and where they are located in the frame. Then, it uses the law of similar triangles to find the distances between people, whose accuracy is improved by 30% using the law of cosines to find a more accurate distance. The application then uses Multi-task Cascaded Convolutional Neural Networks to grab people's faces from an image and then uses a face recognizer to recognize the names of people in the frame. The application then alerts every user that broke the social distancing rule through email and logs the instance into a database from that frame. For every frame, the application uses cv2 to create an edited image of the original that displays which people broke the social distancing rule, by writing names on top of their bounding boxes and drawing red lines between the people who broke it. In the end, the application outputs an edited video clip of the original, which in reality is a collection of all the edited frames. Already it has begun to show promise, with an 85 percent accuracy rate.***

1. Introduction

COVID-19 took the world by surprise in early 2020 and quickly became a global pandemic. Starting from Wuhan China, the new virus quickly exploded out of control as it spread across China and later hundreds of other countries. COVID-19 is caused by a coronavirus called SARS-CoV-2. Coronaviruses belong to a group of viruses that infects various animals such as peacocks and whales but have now transitioned to humans as well. Since the viruses' symptoms either never show or take a while to take effect, the viruses' reach has exponentially grown.

Similar to SARS and MERS, scientists suspect that Coronavirus was transmitted from animals. It was initially believed that eating bats–the most common carriers of the virus– were the cause of the virus in humans. However, scientists found that an intermediary animal was required for the virus to transition from bats to humans. The intermediary animal was discovered to be the pangolin that easily transmits the virus interspecies. Later, researchers in China found a market in the Wuhan province that sold pangolin illegally through a wild animal trafficking operation. Local authorities were unable to stop the spread of the virus in time and the situation quickly became much worse.

Many assume that the threat of the virus is similar to that of the common cold. However, while the coronavirus starts in the lungs like the common cold, it causes much more havoc in the immune system. In fact, some scientists say that the Coronavirus is almost 10 times deadlier than the common flu. The infection can be spread through the air and affect the upper respiratory system. Sometimes the virus attacks the lower respiratory tract –the bronchial tubes and lungs– and lead to pneumonia. Sometimes lifelong and extensive damage can be caused to the lungs when the body overreacts to the virus and creates a cytokine storm. Previous conditions, such as obesity and high blood pressure increase the risk of serious lung damage or death. In addition, no person is safe because the virus is brand new to humans and thus no immunity exists.

As of August 1, 2020, there have been over sixteen million cases around the world and more than 600,000 dead. In desperate times, countries such as America, Brazil, India, and others desperately require some sort of vaccine, cure, or a way to slow the spread of the virus. With vaccines and other possible cures remaining in the distant future, the only solution becomes wearing masks and social distancing at least six feet away. If the six feet rule is not closely obeyed, the virus has a chance of being transmitted to others through actions such as coughing, talking loudly, sneezing, etc.

Step 1: Confirming the Opportunity

In confined areas, such as corporate offices, schools, and malls the necessity to social distance becomes the biggest priority. An infected carrier can infect the whole population inside buildings if masks and the six feet rule are not strictly obeyed. In order to maximize productivity and worker safety, a system must be developed to track and alert personnel who break the social distancing rule.

Although many workplaces currently mandate social distancing, a large portion of the public does not strictly follow the six feet rule, which is leading to a surge in cases. Often many people do not realize when they break the rule because there is no effective method to manually measure the distances and even if there are, no method has been created to log all the instances where the rule has been broken in confined areas. In addition, some universities have developed a social distancing AI maintenance program. However, many of these programs are very inaccurate in-real time scenarios because they have not used cosine law to more accurately measure the distance between two people.

Maintaining social distancing to protect employee's health is important because safety is good for business. In order for a business to thrive in today's economy, certain health standards and precautions must be met. Ensuring the safety of workers can boost employee morale, reduce absenteeism and turnover, and increase worker productivity. A boost in productivity translates to more profit and output for

companies. Thus employee safety is key for businesses during the pandemic.

While at-home jobs may provide workers with more benefits than those who commute, the reality is that overall productivity has decreased for work-from-home employees during the pandemic. This drop can be attributed to little in-person collaboration and constant disturbances from roommates and family members. Keeping all this in mind, I have suggested an effective approach to overcome these barriers using a combination of artificial intelligence and image processing techniques. This program is a solution to the social distancing dilemma and can help save many lives in the future.

Step 2: Characterize the Problem

The problem of maintaining social distancing must have some system for immediately detecting when both users who break the social distancing rule and then alerting those users. There must be some database that holds every instance of when the rule is broken so that managers can track which employees may be at risk, based on whether they came near to the COVID confirmed employee. Therefore, the solution must effectively perform contact tracing.

The problem is of high importance as thousands die every day because of a lack of proper social distancing. With business remaining closed, some form of safety measures must be employed to conveniently help protect employees' lives. Every day that business remain closed, the economy, as well as business, suffer from lack of productivity and communication.

Confirmed coronavirus cases displayed around the world. Updated: August 8th, 2020

Step 3: Architect and Deploy the Solution

The project is divided into six parts: video collection, human detection using Keras-Retinanet, calculating distances between people, identifying who broke social distancing, creating a database with all the employees that broke the rule, and finally sending emails to alert all those that broke the rule.

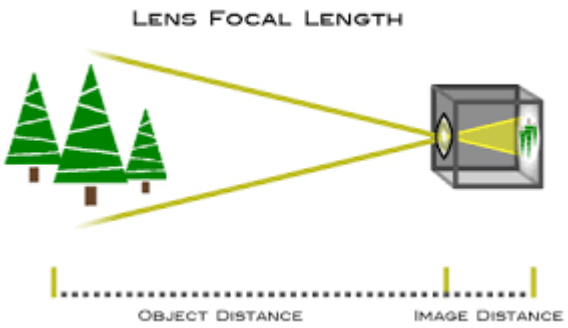
Human Detection

Video Collection: I collected tons of online stock videos of people moving in a video camera frame. I gathered high dimensional video clips that were less than twenty seconds in length. I used the open-cv library to go through the stock videos.

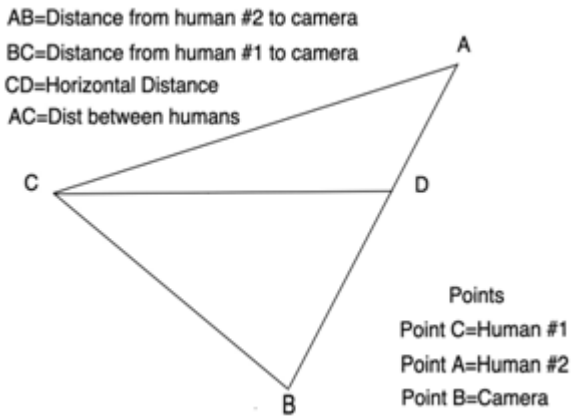
Human Detection Using Keras-RetinaNet: Keras-RetinaNet by Facebook AI Research (FAIR), is a one-stage detector with ResNet+FPN as a backbone for feature extraction, plus two task-specific subnetworks for classification and bounding box regression, which achieves state-of-the-art performance, and outperforms Faster R-CNN, the well-known two-stage detector. We have used a pre-trained model with ResNet50 backbone on the COCO dataset. The model already has perfected weights and biases that can confidently detect up to sixty-eight items at a very high accuracy rate. One of the many objects it can detect is humans, which is why I used the RetinaNet model for human detection. The RetinaNet returns the bounding box, along with the confidence percentage and label of the object it detects. I put a condition to make sure that the model only displayed green boxes around humans that had high confidence percentages.

Calculating Distance Between People:

Finding distance from the camera: In order to find the distance from the camera to the people, I used the similar triangles equation for lenses and optics. For the equation, in terms of distance, I needed to get the focal length of the camera, the objects' height, and the pixel length of the object. The diagram depicts the variables that govern the object's distance and size in the frame.



The focal length of an optical system is a measure of how strongly the system converges or diverges light. For many CCTV cameras, the average focal constant tends to be around 2200 pixels per centimeter. Similarly, the average height of humans tends to be around five feet and five inches. Thus, we applied both 2200 and five feet 6 inches as constants in our equation. The only missing variable was pixel height. In order to get pixel height, I subtracted the maximum y coordinate by the minimum y coordinate of the person's bounding box. Plugging in all the above variables into the equation led to finding the distances of the people from the CCTV cameras.



Finding Distance between Using Cosine Law:
Once I found the distance of every person in the frame from the camera, I use the cosine law to determine the distance between people. I take subsets of two people at a time in the frame. I already had the distance of the people from the camera but I also needed to find the horizontal distance between the two people. I averaged the x value's in the midpoints using the coordinates from the bounding boxes to get the pixel distance. Using similar triangles, I was able to calculate the real-life horizontal distance. We also know that the line BC approximately equals BD because the humans are parallel in the frame since it is 2 dimensional. To get line BD I subtract the distance from object 2 to the camera and BD.

$$\text{Cos A} = \frac{b^2+c^2-a^2}{2bc}$$

$$\text{Cos B} = \frac{c^2+a^2-b^2}{2ca}$$

$$\text{Cos C} = \frac{a^2+b^2-c^2}{2ab}$$

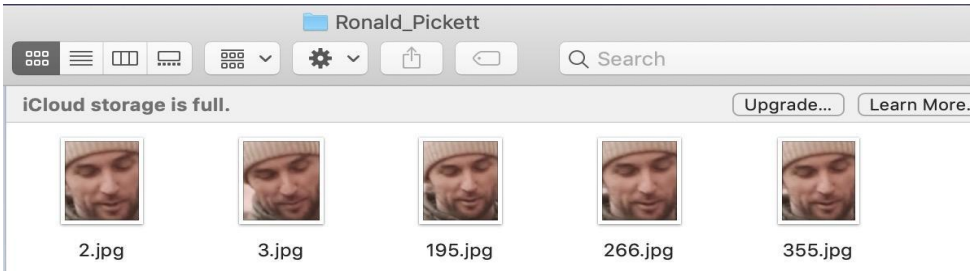
Since we now know all the side values in the CDB triangle, the formula above can be used to get the inverse cosine of (b^2 +c^2-d^2)/2bc, which will yield the angle CDB.

<CDA = 180 - <CDB

We already have the values of line CD, AD, and now angle CDA. Once again we can plug these values into the cosine law, to get the line AC. This line represents the distance between the two people.

Using open-cv, I drew lines from the center of people's bounding boxes to represent the distance. The green lines show that a person is maintaining social distancing, while red shows a breach in the rule. As shown above, lines are drawn from every person to the other in every frame.

Facial Detection
I needed to use face detection in order to programmatically log the names of people who have breached the six feet rule in the video. In a corporate scenario, I would require many real-time photos of all the employees in order to create an accurate model. In the case of using stock videos, I detected all the faces in the first few frames, saved them in a file, and trained the model using that file.

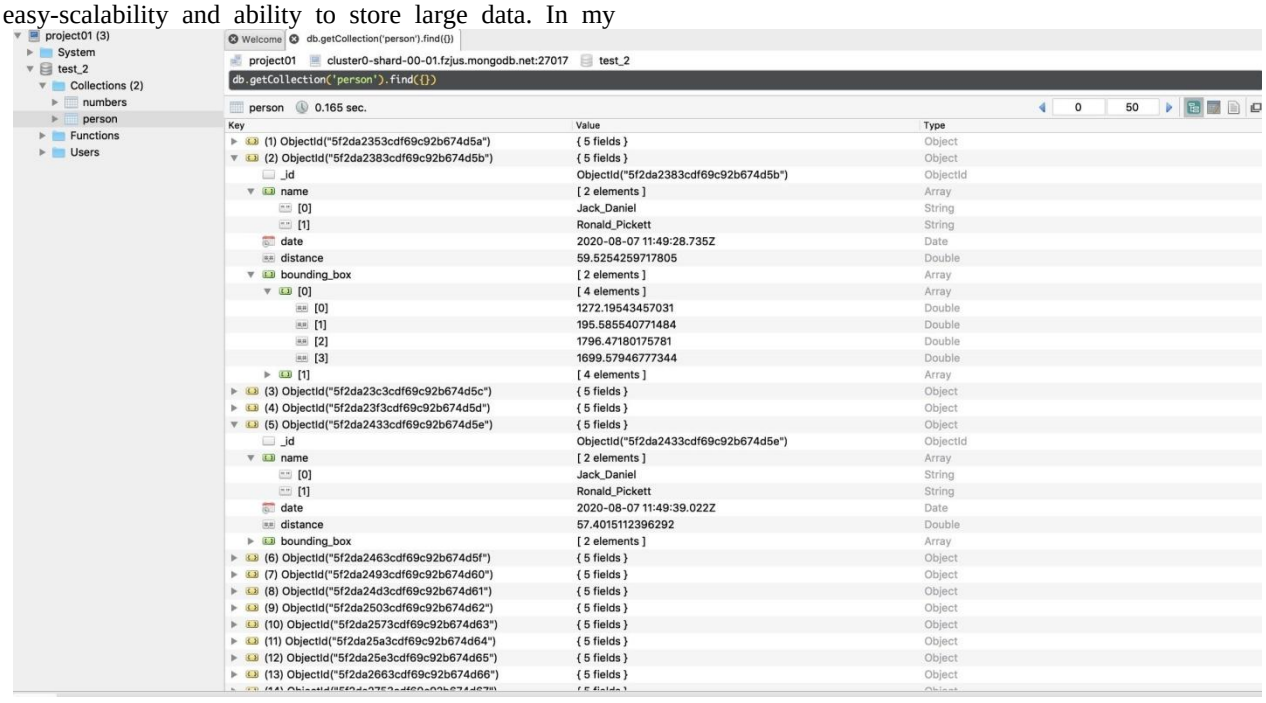


The face detection was done using Multi-task Cascaded Convolutional Neural Networks. Next, I used the LBPH Face Recognizer object in the open-cv library to recognize the names of the people who broke social distancing.

The final video displays the names on top of the bounding boxes.

Logging Data in MongoDB Database

I used a MongoDB database to log all the instances where the distance between two people was less than six feet. I decided to implement MongoDB in my program because of its easy-scalability and ability to store large data. In my database, I insert every record of when the social distancing rule is broken from every frame in the video. The record contains information on the date broken, who the person broke the rule with, the proximity between the two people, and finally the bounding boxes of the people who broke the rule.



Sending Emails

In the case that the social distancing rule is broken, in addition to logging the instance in the database, the people who broke it will also immediately be alerted. I used the Simple Mail Transfer Protocol server in order to communicate with mail servers to send emails. The mail contains details of the breach and is sent to every user that broke the rule. Users can prioritize the programs emails because I put the subject as SOCIAL DISTANCE BREACH.

The mail is sent from a third party gmail account. An email is sent to all users for every frame where the rule is broken. The message will help perform contact tracing so that management and users know when they are at risk and may have the virus.

Step 4: Evaluate for Business Value

Ensuring worker safety will enable employees to become much more productive through in person collaboration and work. Workers will feel much safer and comfortable working in an environment where they know that their safety is guaranteed by the company. Increased productivity means more profits and output by the company in the long run.

In addition, companies are often liable for workers' health. If a worker were to get Coronavirus at the workplace, companies may be forced to pay for insurance, cover the hospital fees, or allow sick leave. Economically, the company will enter a loss if many employees enter the workplace and contract the virus. Thus, some system of mandating social distancing must be applied.

The most obvious non-technological solutions may be to hire extra personnel to watch over employees and manually ensure workers' safety. However, extra personnel can be costly, error prone, and can not detect a breach as accurately. With the program that I set in place, no extra personnel are required to watch over employees and create their restrictions. The program will constantly send messages and alert the proper users when the time comes. The error of the program is lower than that of human error.

Furthermore, with no vaccine in sight and increasing costs, businesses are being forced to open up during the pandemic. In places such as India, America, and Brazil, many companies are attempting to manually and often failing at protecting their employees. Therefore, a technological solution such as mine is key to protecting employees and maximing profits. The database and email can enable those in charge of faculty to take control of contact tracing. Management can then make their own decisions about which employees to send home and when.

Step 5: Scale-Up the POC

1) **Retraining Keras-RetinaNet model:** I currently use a pre-trained model with ResNet50 as the backbone. While this model works efficiently, sometimes it does not predict a human in one frame, while it does in the next. Therefore, retraining the model with thousands of more human objects could improve the accuracy of the model. The improved model could lead to more consistent and accurate results.
2) **Using Deep Learning for Facial Recognition:** I currently use the LBPHFaceRecognizer object from the open-cv package. However, the feature-based recognition that the LBPH recognizer uses is not state-of-the-art anymore. The recognizer is sensitive to changes in the image conditions. For that reason, research in face recognition has turned to deep learning and CNN's. Implementing deep learning can greatly improve accuracy and improving the most important part of the program: correctly identifying those that breached social distancing.
3) **Checking if Person is Wearing Mask:** Masks can stand as another barrier for contracting the Coronavirus. According to UCSD, wearing a mask can decrease the risk of transmission by sixty-five percent. If both people are wearing masks the transmission probability decreases to two percent. To augment the applicability of the project, I would use open-cv to add the ability to detect whether a person is wearing a mask. If that condition was true, then I would make changes to the six feet rule and ease the restrictions in place in order to be alerted.

4) **Detecting the spread of the Virus:** To improve the program in the future, I could optimize the model by adding the ability to alert all users again when someone with a confirmed COVID-19 case has come within four feet of them in the past two weeks. All of these users will get messages to work from home for the next few weeks.

Step 6: Other Applications

Some of the other potential applications of artificial intelligence during the Coronavirus pandemic are as follows:

1) Early detection and diagnosis of the virus
2) Predicting the effect of Coronavirus on the economy
3) Predicting surges in Coronavirus cases in the months to come
4) Development of drugs and vaccines
5) Analysis of data for future confinement measures or the death toll

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