Protecting the Public: Using Image Classification to Mitigate Gun Violence

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Alamo Regional Science and Engineering Fair
February 11-13

Abstract

In the past 24 hours, 32 people have been shot and gravely injured or killed in the U.S. Gun violence is a major issue and is continuing to get worse. The number of school shootings per decade has exploded, with 400 more mass shootings occurring in the past decade than 30 years ago; with the current political climate, it has been impossible to make progress towards gun restriction, making effective gun detection methods for high-risk areas such as schools and churches essential. The researchers propose an effective, real-time, high accuracy AI based system for detecting guns that works with almost any existing surveillance system and on commodity hardware. The system offers detection of weapons using state-of-the-art AI based image classification models InceptionV3, Xception, ResNet50, MobileNet, and RetinaNet, as well as the real-time object detection model YOLOv5 trained on custom data compiled from various sources. The researchers found that models using depthwise-separable convolutions produced an average validation accuracy of 95%, and tended to produce strongly positive Cohen Kappa scores, suggesting that reducing the number of parameters tends to facilitate effective learning, increase model prediction speed, and alleviate overfitting as was seen with the larger models such as MobileNetV3 Large. To the researchers' knowledge, this is the only fully-fledged gun detection system designed to work on top of existing surveillance cameras.

The researchers are providing this as open source in the hope that this helps further development on gun violence mitigation strategies and makes a difference in the world.

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Rationale

Gun violence is a major problem within the US. When such incidents occur, it’s often found that, to a certain extent, there were signs, signs that we were incapable of seeing not simply because we weren’t listening but also due to simple human error. These incidents never truly feel real, as if they would never happen to our community until *they happen*. We have already created semi-autonomous systems to remove human error, to find illness within x-rays or cardiograms, to enable detection of small traces of illegal substances or other chemicals. With the sharp increase in instances of preventable mass shootings over the past decade, it is necessary to apply these state of the art technologies to protect our community and what should be safe public areas such as schools or churches. We can prevent human error, scanning and flagging social media posts and users indicating a threat to a particular area. We can prevent immediate casualties by using existing security frameworks, scraping camera footage to detect the presence of a firearm to alert authorities. It is necessary to take human error and emotion out of inherently inflammatory situations such as gun violence using preexisting social and security systems we already have in place, significantly reducing the cost of these systems. Within this project, we will target surveillance footage, using a machine learning model to detect the presence of a firearm. The system will be semi-autonomous, meaning it will immediately take action without the confirmation of a human operator, ensuring that action will not be taken against an incorrectly detected threat.

Introduction

Youth violence is one of the greatest crime problems faced in the US. However, despite how prevalent the problem is, threat assessment is fraught with over and underreaction promulgated by news coverage. Despite our tendencies to assume all school shooters are motivated exclusively by revenge or exhibit unusual behaviors, the truth is that no one factor is decisive, and that over labeling may lead to the stigmatization of children in cursory and harmful ways. Quantitative and clear methods to assess the plausibility of a threat are not available, making the detection of guns before gun violence occurs essential. On December 14, 2012, at Sandy Hook Elementary School, a 20-year-old man entered the premises and fatally shot 26 people. On April 2, 2002, at Oikos University, a former student entered the school with a handgun and proceeded to fatally shoot seven students. These instances are merely two of many by which surveillance cameras may have provided an invaluable warning before disaster struck. If surveillance cameras had been placed on the premises and continuously monitored, it may have been possible to have alerted the rest of the school significantly faster and to have perhaps even prevented the shooters from entering the premises entirely.

Purpose

Is it possible to create a machine learning model capable of detecting firearms, and, if so, how may this technology be best leveraged to prevent gun violence?

Hypothesis

Using pre-existing real time object detection models such as YOLO (You Only Look Once), R-CNN (Regions with Convolutional Neural Networks), or SSD (Single Shot Detector) and image classification models Xception, InceptionV3, and MobileNet as a basis for our model, in coordination with a large firearm dataset and using the Tensorflow Lite library, the researchers believe that it is possible to create a state-of-the-art, relatively high FPS, high accuracy neural network model capable of detecting firearms in real-life scenarios.

Engineering Goal

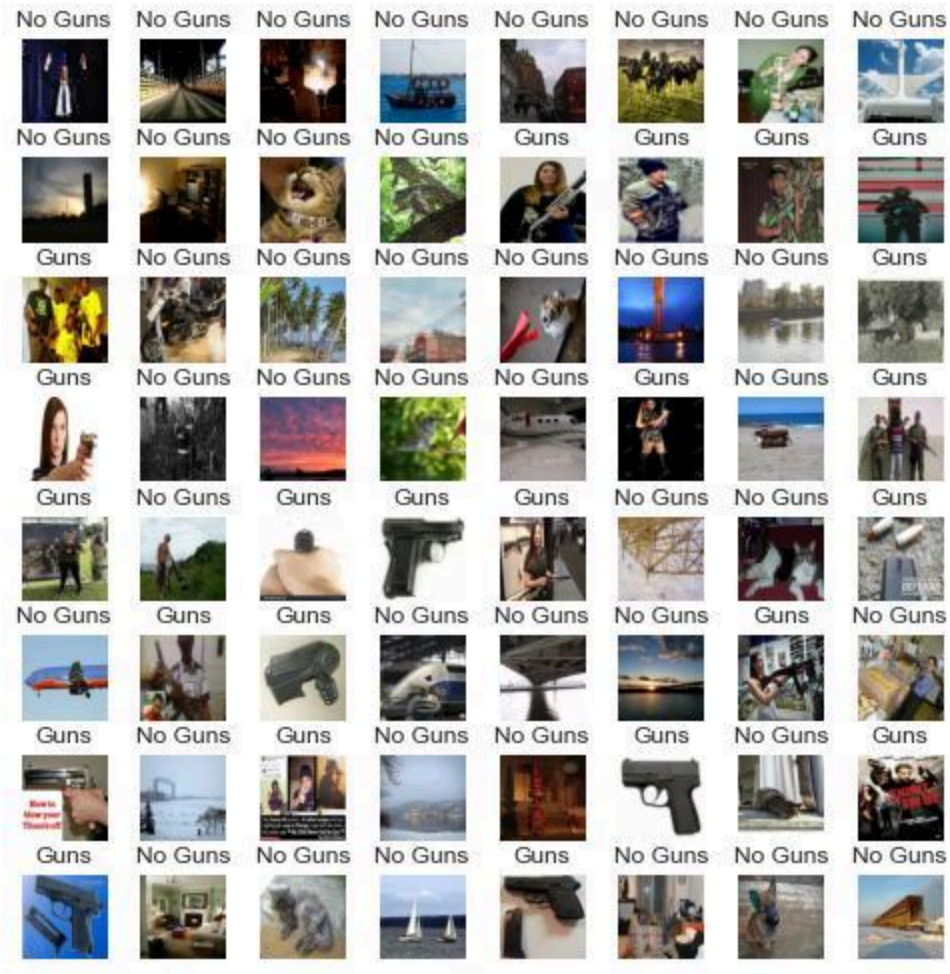
Design a machine learning model capable of detecting firearms in real-time to protect schools and other public areas from firearm-related injuries.

The Code

The code is available at https://github.com/html1101/Gun-Detection-GUI.

Data

Image Classification: An Example of a Batch of Size 64



Procedure

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Materials

- Laptop or desktop computer (the researchers used a Ryzen 7 5800x for training). A minimum of 16GB RAM is recommended when training the model without caching the full dataset.
- Software:
    - Node JS (version 16.13.2) - See the GitHub repository at https://github.com/html1101/Gun-Detection-GUI for list of libraries necessary; packages can be installed using `npm install`.
    - Python (version 3.10.2) - See GitHub repository for list of libraries necessary; libraries can be installed by passing Models/requirements.txt into Pip.

Conclusion

In this paper, the researchers propose an effective, real-time, high accuracy AI based system for detecting guns that works with almost any existing surveillance system using five image classification models (InceptionV3, Xception, ResNet50, MobileNet, and RetinaNet), and one object detection model (YOLOv5). MobileNet ultimately produced the largest accuracy and the lowest latency, with a validation accuracy of 95% (tested on 1456 images of size 224x224x3), while VGGNet (not included in the final overall system due to its low performance) significantly overfitted, with a training accuracy of 100% and a validation accuracy of 10%, likely due to the sheer number of parameters to train. Models that used depthwise separable convolutions (DSC) or variants of DSC — MobileNet and Xception — tended to produce the largest accuracy during validation, likely because DSC reduces the number of parameters to adjust, decreasing the likelihood of overfitting (MobileNet and Xception had between 20 and 37 million parameters, as opposed to VGGNet, with over 137 million parameters to adjust).

Problems Encountered

Initially, the researchers planned to use state-of-the-art object detection neural networks as a basis for the creation of a new model that would work with high accuracy in the detection of guns. This model would have been linked to a single camera through which guns could be detected. However, the researchers looked instead into the use of image classification models and only one object detection model, as object detection models all have extremely different format systems and they use their own metrics such as mAP, both of which are factors which make it difficult to compare the results of these different models. By contrast, image classification models tend to return a higher accuracy and input data do not need to be individually labeled, meaning that the researchers could train with much more data. For instance, the researchers trained the YOLOv5 object detection model on 5,600 images, while the image classification models trained on 11,652 images. After training these image classification models and the one object detection model, the researchers found them to work so well that it seemed that it would be more impactful to create a way by which security systems could use these models for gun detection within non-residential areas rather than trying to create an entirely new model that might not work as well. As such, the researchers shifted to focusing their project instead on building a graphical user interface that would be available to everyone as open-sourced and would work with any surveillance system. The researchers linked each of the trained models, except for VGGNet due to its low performance, into the GUI, giving the user the option of choosing which model they wish to use in their detection system. The application also has the ability to allow the user to change the confidence threshold in their predictions. Overall, the main accomplishment of the project ended up not being the creation of a new model for the detection of guns, as was originally the goal, but instead the development of an application that can run on almost any surveillance system for multiple cameras and is available for use by anyone for the detection of guns as an effort to keep communities safer by working to prevent mass shootings.

Future Expansions

Notes on what we could talk about: perhaps training the models to also recognize whether a person may be carrying a gun beneath their clothing (infrared we've already established won't work, but it could involve perhaps a person's gait, an imprint in the clothing, things like that, though this is likely beyond the scope of anything we'd be able to do, since I can't imagine we'd be able to find data like this to train with), maybe here we could talk about possibly creating our own model?, setting up a notification system when a gun is identified if we haven't done that already, further development of the models like training them some more, looking for **better models** to train, incorporating **infrared** technology

Practical Applications

This system is not only a fully functional gun detection system but a platform by which future development can take place. The largest issue with gun prevention is that for public areas, it is a massive expense which does not seem necessary until disaster strikes. Our system works to make a reliable, cost effective method of detecting guns through almost any existing surveillance system for a chance at catching shooters before a mass shooting can occur.