Department of Computer Science

CS3072/CS3605 Final-Year Project: Task 1 - Project Synopsis

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Provisional Title	Airborne Object Sense & Avoid		

Problem Definition

Across the globe, demand for a cheap, reliable, and swift mode of transportation is in desperate need. Various companies such as Amazon have introduced “amazon prime air” services that aim to take advantage of unmanned drone flights to deliver (*Drone Delivery – The Future of Logistics* | *Bray Solutions*, 2017). The extensive usage of drones in the commercial, agricultural, and military sectors (*Commercial Drones: A Guide to the Top Models on the Market*, 2020) has resulted in an increased demand for autonomous drones. The current drone sales surpassed $1.25 billion as of 2020 and are expected to grow to $63.6 billion by 2025. According to business insiders, the market is predicted to sell 2.4 million by 2023 – an increase of 66.8% and in the agricultural sector, the consumption is predicted to rise by 69% between 2010 to 2050 (Intelligence Insider, 2021). However, drones lack sense and avoidance capabilities which are crucial for drones to be able to detect and track airborne objects observed in a planned flight.

Nowadays drones use a range of expensive sensors such as LIDAR, infrared triangulation, lasers, and passive acoustic sensors (for ultrasound). Solving the problem using only a single monocular video feed – from visual cameras, is very attractive as cameras are very lightweight and much cheaper to produce. Tesla and other car manufacturers presently have an implementation of sense and avoid in their self-drive autopilot systems (*Autopilot* | *Tesla UK*, 2016), which uses a set of camera and computer vision models to improve road safety to avoid accidents and help to navigate to the destination.

The project aims to build an airborne object tracking system that will allow drones to sense and avoid obstacles in an autonomous flight. Due to the weight and battery performance constraints, drones lack safety-critical features such as a traffic collision avoidance system (TCAS) (Erwin Tracy, 2015), therefore air traffic controllers (ATC) can’t actively monitor drones in uncontrolled airspace. The airspace is relatively sparse and there is still a chance that a drone will encounter unforeseen object/static object.

The objective of the project is to take an image or a monocular video feed and to perform image analysis to detect any airborne object in the video frame. The detected object then will be classified and tracked throughout multiple frames, where eventually the model will use various factors (such as speed and approach direction) and a decision tree to predict a collision value. Upon further decision making the model will perform the necessary manoeuvre to create a safer route.

The main use cases for the project are the commercial and agricultural sectors, where for example, companies such as Amazon, UPS and Uber Eats can use these drones to deliver packages quickly and reliably. Furthermore, drones can be used in routine security checks for monitoring and surveillance. Most modern drones can fly from anywhere between 2.5km to 7km and military drones with specialised equipment usually can fly up to an altitude of 15km.

In conclusion, with drone demand rapidly escalating and prices getting cheaper, drones at this time are a risk to aviation as they cannot sense and avoid a potential collision and manoeuvre to safety. In an event of system failure, a collision with an aircraft or a falling drone raises a serious safety concern towards the public and passengers.

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Aims and Objectives

The project aim is to create a model that will take an image or a monocular video feed, then detect any airborne object that could potentially collide with our object by tracking its motion across multiple frames. Below are the set objectives that I will need to accomplish.

1) Research to find literature on existing drone sense & avoid systems, research on autonomous flights, pretrained classification models, computer vision algorithms and techniques.

2) Research on methodologies to use (spiral, iterative or agile), create plans to manage and track the project's progress.

3) Research on existing suitable public datasets, validate dataset for any personal/critical information and get approved by Brunel research ethics online (BREO).

4) Perform preprocessing on the dataset (e.g. normalizing, transformation, scaling) and prepare the dataset into training, testing and validation set.

5) Design and build the AI model that detects airborne objects and classifies them. Apply advanced vision algorithms and techniques such as faster R-CNN, logistic regression and decision trees to train.

6) Test the model performance on the validation set and do a thorough analysis to validate if the build model meets the benchmarks.

7) Create prototypes of the user interface, build the web application which implements the trained AI model and carry out testing of the entire app.

8) Evaluate model accuracy at detecting, tracking and predicting collision with the object.

Background Sources

I will be using a combination of google and google scholar to find the relevant background sources and to carry out the research needed. I have looked at a variety of datasets, algorithms, and models that I could use and apply to the model.

Firstly, I began by looking at a variety of datasets (*CIFAR-10 and CIFAR-100 datasets*, 2015; *Birds 200 | Kaggle*, 2020; *Airborne Object Tracking Dataset - Registry of Open Data on AWS*, 2021) i.e., datasets of aeroplanes, birds, and helicopters. Upon further comparison of the datasets, I determined that I will be mainly utilising the (*Airborne Object Tracking Dataset - Registry of Open Data on AWS*, 2021) as it has huge data diversity - terrains, time of day, lighting/sky conditions, altitudes, and distance of object encounters. The dataset includes sets of images and videos, which I will be using to train and evaluate the model.

Upon further research, I found the government's statistical report which mentioned aircraft proximity (AIRPROX): the number of incidents reported (*Aviation (TSGB02) - GOV.UK*, 2013). The report emphasised that the reported number of incidents caused by drones has been steadily increasing over the past decade, of which some could have been easily prevented with sense and avoid technology. Furthermore, there have been many articles reporting that the lack of sense and avoid feature in drones have caused expensive and deadly failures (*AAIB investigation to Quest Q-200 (UAS, registration n/a) - GOV.UK*, 2017; *Drone in near miss with plane near Edinburgh Airport - BBC News*, 2017).

Lastly, I researched the existing drone technologies and their implementation of sense and avoid (*Obstacle Sensing & Collision Avoidance for Autonomous Drones*, 2019) and found out that all current

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technologies utilised a range of expensive sensors such as LIDAR, sonar, and laser. Thus, using a single video camera is an attractive solution. LIDAR and laser are used to capture a high-resolution map and a 3D model of their surrounding.

Approach

I will be using rapid application (RAD) development to structure, plan and control the development of the web application. I have chosen RAD as it follows an iterative approach with a great flexible approach, as this provides me with an opportunity to further refine the final product. Furthermore, it is aimed to be used for small teams and has a low-risk involvement thus, producing a superior quality app. I will be executing the 4 phases of RAD:

1. Planning: carrying out research on problem definition and finalising the requirements.
2. User design(repeated): design and build prototypes of machine learning models and web applications.
3. Rapid construction(repeated): train, test and evaluate/refine the model and build/refine the app.
4. Cutover: finalise and launch the application.

I will need to get ethics approval from Brunel research ethics online (BREO). I will not require a full ethics approval as my dataset does not contain any personal/critical information which could be used to identify any individual. Furthermore, I do not require any human participants for testing or evaluation purposes as I will be comparing the model accuracy against a benchmark.

I will be using git control and GitHub for version control and to keep track of my project files. Apps such as GitHub and Trello will allow me to monitor and keep the project on track by comparing current progress against the set timeframe. GitHub will further enable to me keep backups at set milestones and reinforce the project documentation.

The project will be using python extensively to train the model using supervised learning techniques. I will also be using algorithms such as faster R-CNN, logistic regression and multi-class object classifier, to firstly, detect objects and then actually track them across several frames. The front-end will be built using ReactJS and the back end will be implemented using python. The input will be taken from the front-end in an image. The output will then be returned from backend to front-end and then displayed.

I will be using OpenCV, which is aimed at real-time computer vision processing, and this will allow me to perform object detection and motion tracking. I will be using TensorFlow which will enable classification and collision prediction. These libraries will reduce project complexity as it reuses existing prebuilt components and utilise present techniques.

Evaluation

For evaluating the accuracy of the model, I will be comparing the results against the validation set and checking against the benchmarks/metrics. The higher the accuracy value, the better the model is at detecting, tracking, and predicting future collisions. Thorough testing will be done to check if the final application meets the aim of the project.

A few examples of benchmarks are:

- The number of successfully detected encounters out of the total number of encounters detected.
- The number of false positives reports out of the total number of reports per hour.
- The rate of false positives reports per hour.
- The ratio of the number of detected airborne objects against all airborne objects that should be detected.
- The ratio between the number of false positives against the total number of images in the dataset (false positives per image)

- F1 score value to understand how precise the classifier is.
- Mean absolute error – the average difference between actual and predicted values.

References

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