Declaration

This report has not been submitted for any other degree at this or any other University. It is solely the work of us except where cited in the text or the Acknowledgements page. It describes work carried out by us for the capstone design project. We are aware of the university's policy on plagiarism and the associated penalties and we declare that this report is the product of our own work.

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Signature:

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Student: Date:

Signature:

Abstract

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Acknowledgment

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Table of Contents

List of Figures

List of Tables

1 Introduction and Motivation

1.1 Problem statement

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

1.2 Project significance

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1.3 Project objectives

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2 Background and Related Work

2.1 Background

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2.2 Related work

The second important concept of the project is the computer simulation. Simulation is a cost-effective, time-saving, flexible and safe way to experiment with a drone at the expense of a reduction in accuracy compared to the real world. The research realm has shown that the use of simulation is highly attractive in deep reinforcement learning (DRL) studies with drones. This is because DRL involves making gradual improvements to a model based on repeated cycles of experience, and computer simulation allows these iterations to be carried out cheaply.

According to the literature review, the combination of Gazebo, the Robot Operating System (ROS) and PX4 are the most widely used software stack for the software-in-the-loop (SITL) development because they are open-source. In contrast, Sphinx and Olympe, which are used in this project, are closed-source. Although open-source software allows for full control and the flexibility to tinker since the source code is freely available, it is less stable and time-consuming to debug when there is an error in the source code. Another conclusion from the literature is that the transfer from simulation to the real world, which this project also aims to accomplish, is lacking in the studies reviewed. As a result, it is not possible to comment on how the simulation findings effectively translate to the physical environment.

The use of simulation makes rapid experiments in realistic settings and iterative unmanned aerial vehicle (UAV) designs possible, both of which are important in artificial intelligence (AI) training. Zhou, Li, Ding, *et al.* demonstrates this by using a combination of the open-source 3D dynamic simulator Gazebo and the autopilot system PX4. Through this, they avoided the time-consuming steps of carrying out physical experiments and adjusting parameters according to the environmental settings [1]. Thanks to the simulation, the authors were also able to propose a generic framework to integrate the Deep Q-Network (DQN) algorithm into the simulated UAV environment [1]. In our work, the same Gazebo physics engine simulation software is used, and DRL is similarly trained for the high-level control of the UAV. However, the authors used the ROS-PX4 as the controller while in our work, the Olympe program is used. The main criticism against this paper is that the operating system, which was Ubuntu 16.04, and the ROS version, which was Kinetic Kame, were old and no longer supported even though the paper was written in 2020. Nevertheless, the explanation and the flowchart illustrating the Q-learning in the context of drone control are instructive for our work going forward.

The time-saving benefit and the ease of experimentation afforded by the use of computer simulation are further emphasized when studying uncertain environments. Dealing with an unknown environment for search and navigation applications, Walker, Vanegas, Gonzalez, *et al.* used simulation to train a UAV to solve a local planning problem by framing the problem as a partially observable Markov decision process (POMDP) using continuous action spaces [2]. Similar to the previous paper, the ROS-PX4 stack and the Gazebo simulation software were used compared to Olympe and Sphinx in this project [2]. In addition, both the paper and this project study path planning with DRL but our work uses it for target visitation in an obstacle-free environment while the authors used it for searching and navigation in both obstacle-free and non-obstacle-free environments. However, the use of a UAV indoor by the authors as an application does not leverage the unique features of UAVs, but it is a good starting point and easier to implement in the real world when the outdoor flight is restricted. A useful lesson that this paper provides for our project is the use of the open AI gym in creating the UAV environment resulting in clearer abstraction in the codebase for the training process.

Yet another UAV research-related applications that profits from the use of computer simulation is the testing of new sensors on the UAV. García and Molina argues that the future of UAVs relies on the use of advanced sensors and the ease of analyzing their functions in real operational conditions [3]. To demonstrate such viability, they connected a LIDAR sensor to a PixHawk flight controller and tested the improvement that the new sensor provided in the application of navigation and obstacle avoidance. Importantly, prior to that, they used QGroundControl and the PX4 platforms to analyze the addition of a LIDAR sensor on a simulated 3DR Iris UAV. Unlike our work, the authors' focus for using the simulation was on sensor integration and not DRL which did not feature in the paper. The main criticism of this work is that the sensor is simulated without noise when in the real world, the data captured by the sensor is invariably noisy. Although the objectives between the authors' and our work are different, it is still very helpful to learn from the extensive software stack and architecture guide presented by the authors.

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3 Requirements Analysis

3.1 Functional requirements

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3.2 Design constraints

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3.3 Design standards

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3.4 Professional code of ethics

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3.5 Assumptions

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4 Proposed Solution

4.1 Solution overview

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4.2 High level architecture

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4.3 Hardware/software to be used

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5 Proof of Concept

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6 Market Research and Business Viability

6.1 Business products

Technology and AI advancements have been changing human lives for the better. The possible opportunities for innovation and creativity are unlimited. This project has many aspects that could lead to business opportunities and commercial prototypes. One of the many commercial products that could come out of this project is the DRL object detection model. This model can be used in any system that requires object detection, it could be a UAV, a CCTV camera, or any system that inputs an image to the model after being trained on a similar data set. Depending on the system, the DRL model could be trained using a different data set to detect a different object (e.g. cars, humans, animals). Another possible product is the DRL model responsible for navigating the drone after being trained on a specific movement pattern. Moreover, The entire system developed in this project is a viable product.

6.2 Interested parties

1- Military applications: Drones and object detection models have been used in military operations to detect people of danger or even shoot them.
2- Object tracking could be very helpful for any biological research, i.e. tracking animals' movement and habits in different times could revolutionize biology.
3- Security companies: Personal home security could be established by such object detection models to detect threats or unusual behaviors.

7 Project Plan

7.1 Project milestones

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7.2 Project timeline

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7.3 Anticipated risks

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8 Short Guide

Please read the guides available online about the right way to write LaTeX such as how to include a math symbol in text (e.g. x not x) and a proper noun with all capitals (e.g. SQL not SQL).

Below are examples of different constructs in a report. You can copy-paste and change the content. For more information, refer to the relevant package manual in CTAN.

8.1 Abbreviations

To add an abbreviation (e.g. UAV), append the following line in the list of abbreviations portion in main.tex:

```
\newacronym{uav}{\textsc{uav}}{unmanned aerial vehicle}
```

To use the abbreviation, there are 3 ways to do so:

1. In a normal case: `\gls{uav}`
2. For its plural form: `\glspl{uav}`
3. In the beginning of a sentence: `\Gls{uav}`
4. A combination of cases 2 and 3: `\Glspl{uav}`

For example:

> An UAV has many unique features. UAVs have been used in many different applications.

8.2 Figure

Figure 1: The arch linux logo

8.3 Equations

$$
\begin{aligned}
E_p &= mgh = mg(x_f - x_i) && (1) \\
E_k &= E_t + E_r \\
E_t &= \frac{1}{2}mv^2 && (2) \\
E_r &= \frac{1}{2}I\omega^2 && (3) \\
I &= \frac{1}{2}MR^2 && (4) \\
\omega &= \frac{v}{r} \\
E_k &= \frac{1}{2}mv^2 + \frac{1}{2}I\left(\frac{v}{r}\right)^2 && (5)
\end{aligned}
$$

where E_p is the potential energy, E_k the kinetic energy, E_t the translational energy and E_r the rotational energy.

$$
\begin{aligned}
\frac{\partial E_p}{\partial m} &= \frac{\partial}{\partial m}(mgh) \\
&= gh \\
\frac{\partial E_p}{\partial g} &= \frac{\partial}{\partial g}(mgh) \\
&= mh \\
\frac{\partial E_p}{\partial h} &= \frac{\partial}{\partial h}(mgh) \\
&= mg
\end{aligned}
$$

8.4 Simple table

Table 1: Slope, intercept and their uncertainties

Slope		Intercept (J)	
Value	Error	Value	Error
1.0933	0.0300	0.0148	0.0157

8.5 Table from a csv file

Table 2: Translational and rotational energies.

m	v_m	E_t	δE_t	E_r	δE_r
kg	$\mathrm{m\,s^{-1}}$	J	J	J	J
0.055	0.17	0.000 79	0.000 01	0.280	0.007
0.075	0.20	0.001 50	0.000 02	0.387	0.010
0.095	0.23	0.002 51	0.000 03	0.512	0.013
0.115	0.25	0.003 59	0.000 03	0.605	0.015
0.135	0.27	0.004 92	0.000 04	0.706	0.018

8.6 Graph from a csv file

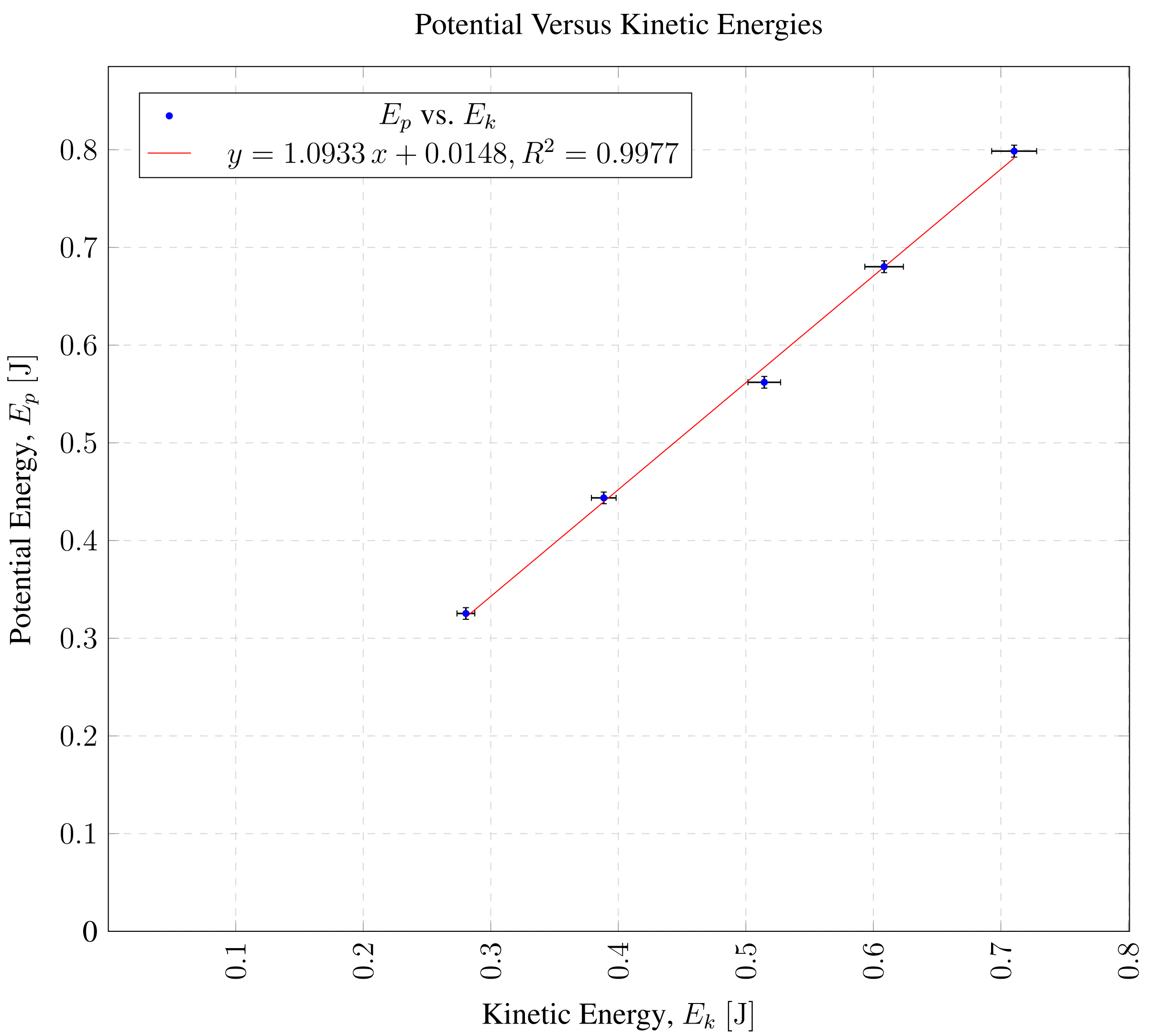

Figure 2: The relationship between potential and kinetic energies.

8.7 Citations

- **in-text citation**: use `\cite{dirac}` to produce [4] or `\textcite{dirac}` to produce Dirac [4]
- **citation in parentheses**: `\parencite{knuthwebsite}` produces [5] (for IEEE, this has no difference to the `\cite{}` command above.)

8.8 Cross-references

Label using suitable names with the following format: figure `\label{fig:<name>}`, tables `\label{tab:<name>}`, sections `\label{sec:<name>}` and equations

\label{eq:<name>}.

Then when cross-referencing, use \cref{<type>:<name>} (or \Cref{<type>:<name>} when used at the beginning of a sentence)

References

[1] S. Zhou, B. Li, C. Ding, L. Lu, and C. Ding, "An efficient deep reinforcement learning framework for UAVs," in *2020 21st International Symposium on Quality Electronic Design (ISQED)*, IEEE, Mar. 2020, pp. 323–328. DOI: 10.1109/isqed48828.2020.9136980.

[2] O. Walker, F. Vanegas, F. Gonzalez, and S. Koenig, "A deep reinforcement learning framework for UAV navigation in indoor environments," in *2019 IEEE Aerospace Conference*, IEEE, Mar. 2019, pp. 1–14. DOI: 10.1109/aero.2019.8742226.

[3] J. García and J. M. Molina, "Simulation in real conditions of navigation and obstacle avoidance with PX4/Gazebo platform," *Personal and Ubiquitous Computing*, Jan. 2020. DOI: 10.1007/s00779-019-01356-4.

[4] P. A. M. Dirac, *The Principles of Quantum Mechanics*, ser. International series of monographs on physics. Clarendon Press, 1981, ISBN: 9780198520115.

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Appendix

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