Laser Pointer Turret Based Mosquito Air Defence System

Final Report

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in the Department of Electrical, Electronic and Computer Engineering

University of Pretoria

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Study leader: Prof. P. de Villiers

Part 1. Preamble

This report describes work that I did *<to be completed>*.

Project proposal and technical documentation
This main report contains an unaltered copy of the approved Project Proposal (as Part 2 of the report).

Technical documentation appears in Part 4 (Appendix).

All the code that I developed appears as a separate submission on the AMS.

Project history
This project makes extensive use of existing algorithms on ... Some of the algorithms I used were adapted from ... Where other authors' work has been used, it has been cited appropriately, and the rest of the work reported on here, is entirely my own.

Language editing
This document has been language edited by a knowledgeable person. By submitting this document in its present form, I declare that this is the written material that I wish to be examined on.

My language editor was ______________________________.

Language editor signature *Date*

Declaration

I, A. Hartman understand what plagiarism is and have carefully studied the plagiarism policy of the University. I hereby declare that all the work described in this report is my own, except where explicitly indicated otherwise. Although I may have discussed the design and investigation with my study leader, fellow students or consulted various books, articles or the internet, the design/investigative work is my own. I have mastered the design and I have made all the required calculations in my lab book (and/or they are reflected in this report) to authenticate this. I am not presenting a complete solution of someone else.

Wherever I have used information from other sources, I have given credit by proper and complete referencing of the source material so that it can be clearly discerned what is my own work and what was quoted from other sources. I acknowledge that failure to comply with the instructions regarding referencing will be regarded as plagiarism. If there is any doubt about the authenticity of my work, I am willing to attend an oral ancillary examination/evaluation about the work.

I certify that the Project Proposal appearing as the Introduction section of the report is a verbatim copy of the approved Project Proposal.

A. Hartman	Date

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LIST OF ABBREVIATIONS

MADS mosquito air defence system

Part 2. Project definition: approved Project Proposal

This section contains the problem identification in the form of the complete approved Project Proposal, unaltered from the final approved version that appears on the AMS.

For use by the Project lecturer	Approved		Revision required	

Feedback

Approved

To be completed by the student							
PROJECT PROPOSAL 2023				Project no		Revision no	1
Title	Surname	Initials	Student no	Study leader (title, initials, surname)			
Mr	**Pompies**	**P**	12345678	Mr X. Why			
Project title	**A Smart Green EPR400 Final Report LaTeX digital twin**						

Language editor details	Language editor signature
Student declaration I understand what plagiarism is and that I have to complete my project on my own.	**Study leader declaration** This is a clear and unambiguous description of what is required in this project. Approved for submission (Yes/No)
Student signature	Study leader signature and date

Part 3. Main Report

1. Literature study

Malaria is still one of the leading causes of death in low-income countries according to the World Health Organisation [1]. Mosquitoes that do not carry diseases are also a general nuisance in the everyday life of people living in mosquito-prone areas. Therefore, it is necessary to pursue improvement in our defence against mosquitoes.

To be able to design a laser pointer turret-based mosquito air defence system it is necessary to understand the principles of computer vision object detection and real-time tracking.

One approach towards tracking is to perform pattern matching. In general pattern matching is searching and checking images for the presence of other given images (patterns) to find and mark the patterns' locations (if any) within the given images. However, the study conducted by Hurtik et al. [2] presents results that indicate the best frame rate they achieved was 0.43 frames per second. This is far too slow to be used in a real-time tracking application.

Another approach is to perform particle filter-based tracking. This considers the proximity and behaviour of other targets. In the case of social insect tracking, it is known that two targets cannot occupy the same space, and targets will actively avoid collisions. Unfortunately, the joint particle tracker proposed in [3] suffers from exponential complexity.

A popular approach is to separate the detection and tracking functions. While numerous deep learning algorithms can detect objects based on appearance, it is worth noting that mosquitoes, particularly when not filmed up close, prove too minute to be reliably detected using appearance-based methods. A viable alternative is to detect objects by isolating the background and foreground of the image [4]. The foreground of the image contains the objects of interest. In [5] objects that are too close to one another are split into two and abnormally small objects are merged.

A proposed tracking method is the Simple Online Real-time Tracking (SORT) algorithm [6]. The algorithm is composed of an estimation model which makes use of a Kalman filter and a data association system that is solved optimally using the Hungarian algorithm.

In the proposed mosquito air defence system mosquito detection will be based on background and foreground isolation. This method is suitable because the system will operate in a known test environment where the background will change minimally. The online real-time nature of this system makes the case for pattern matching and particle filtering unfavourable because of the computationally intensive nature of these techniques. The methods in [4], [5], and [6] will be further investigated for the proposed system.

2. Approach

The aim of this project was to develop a system that would to illuminate flying mosquitoes with a laser. Throughout the remained of this document this system will be referred to as the mosquito air defence system (MADS). This project encompasses the design and implementation of the mosquito detection, laser detection and tracking algorithm

3. Design and implementation

3.1 Design summary

This section summarises the project design tasks and how they were implemented (see Table 1).

Deliverable or task	**Implementation**	**Completion of deliverable or task, and section in the report**
The mosquito detection subsystem had to be designed and implemented by the student.	The mosquito detection subsystem was designed and implemented from first principles.	Completed.
The laser detection subsystem had to be designed and implemented by the student.	The laser detection subsystem was designed and implemented from first principles.	Completed.
The laser turret control subsystem had to be designed and implemented by the student.	The laser turret control subsystem was designed and implemented from first principles.	Completed.
The mosquito tracking subsystem had to be designed and implemented by the student.	The mosquito tracking subsystem was designed and implemented from first principles.	Completed.
The various subsystems had to be integrated on a real-time embedded system.	The various subsystems were integrated on a real-time embedded system.	Completed.
Appropriate motors needed to be selected for the laser turret.	The stepper motors were selected based on the requirements of the laser turret.	Completed.

Table 1.
Design summary.

3.2 Theoretical analysis and modelling

3.3 Mapping camera pixels to real-world coordinates

3.4 Simulation study and optimisation

3.5 Hardware design

3.6 Hardware implementation

3.7 Software design

3.8 Software implementation

3.9 Final system integration and testing

4. Results

4.1 Summary of results achieved

4.2 Qualification tests

5. Discussion

5.1 Critical evaluation of the design

5.1.1 Interpretation of results

5.1.2 Critical evaluation

5.1.3 Unsolved problems

5.1.4 Strong points of the design

5.1.5 Expected failure conditions

5.2 Considerations in the design

5.2.1 Ergonomics

5.2.2 Health and safety

5.2.3 Environmental impact

5.2.4 Social and legal impact

5.2.5 Ethics clearance

6. Conclusion

6.1 Summary of the work completed

6.2 Summary of the observations and findings

6.3 Contribution

6.4 Future work

7. References

[1] W. H. Organisation. (2020, 12) The top 10 causes of death. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death

[2] P. Hurtik, D. Číž, O. Kaláb, D. Musiolek, P. Kočáek, and M. Tomis, "Software for visual insect tracking based on f-transform pattern matching," in *IEEE Second International Conference on Data Stream Mining & Processing*, Lviv, Ukraine, 2018.

[3] Z. Khan, T. Balch, and F. Dellaert, "Efficient particle filter-based tracking of multiple interacting targets using an mrf-based motion model," in *Proceedings of the 2003 IEEE/RSJ Intl. Conference on Intelligent Robots and Systems*, Las Vegas, Nevada, USA, 2003.

[4] W. Liang, H. Wang, and H. Krim, "A behaviour-based evalutation of product quality," in *International Conference on Acoustics, Speech, and Signal Processing*, 2016.

[5] Y. Bao and H. Krim, "Video tracking of insect flight path: Towards behavioral assessment," in *IEEE*, 2018.

[6] A. Bewley, Z. Ge, L. Ott, F. Ramos, and B. Upcroft, "Simple online realtime tracking," Queensland University of Technology, University of Sydney, Tech. Rep., 2017.

Part 4. Appendix: technical documentation

HARDWARE part of the project

Record 1. System block diagram

Record 2. Systems level description of the design

Record 3. Complete circuit diagrams and description

Record 4. Hardware acceptance test procedure

Record 5. User guide

SOFTWARE part of the project

Record 6. Software process flow diagrams

Record 7. Explanation of software modules

Record 8. Complete source code

Complete code has been submitted separately on the AMS.

Record 9. Software acceptance test procedure

Record 10. Software user guide

EXPERIMENTAL DATA

Record 11. Experimental data