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Proposal: Robust object tracking using neural network-based instance segmentation

Mechatronics Project 488

DM DE FREITAS 18345662

2020

saam vorentoe · masiye phambili · forward together

Department of Mechanical and Mechatronic Engineering
Departement Meganiese en Megatroniese Ingenieurswese
Privaat Sak X1, Private Bag X1, Matieland, 7602
Tel: +27 21 808 4204 | www.eng.sun.ac.za

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1 Executive Summary:

The executive summary is based off Heilmeier's Catechism.

Title of Project
Robust object tracking using neural network-based instance segmentation
Objectives
Perform instance segmentation on an image and infer the track of each object in a sequence of images.
What is current practice and what are its limitations?
Tracking object location based off bounding boxes has been done in the past. This results in inaccuracy as a rectangular box may not be the best representation of an object's location. Current practice in segmentation uses end-to-end neural networks which can be hard to develop and require large amounts of time for training.
What is new in this project?
The use of probabilistic graphical models applied to an instance segmentation algorithm for the purpose of tracking objects.
If the project is successful, how will it make a difference?
It will provide a solution to object tracking which has many applications.
What are the risks to the project being a success? Why is it expected to be successful?
The major risk is the inability to complete the project on time due to complexity. This risk is mitigated due to rigorous planning to ensure project is delivered on time.
What contributions have/will other students made/make?
N/A
Which aspects of the project will carry on after completion and why?
To be determined
What arrangements have been/will be made to expedite continuation?
To be determined

2 Introduction:

Sight provides humankind with a tool to reason about the world, perform tasks and interact with the environment. Similarly, a mechatronics system can benefit greatly from computer vision. Computer vision aims to describe the world and allow computers to gain an understanding of their environment using an image or sequence of images. One task is that of object detection which detects different objects in an image. Another is object tracking which locates objects throughout a sequence of images.

Advances in neural networks have enabled object detection algorithms to detect, classify and locate objects in an image. For example, Mask R-CNN (Kaiming He, 2017) is a method that performs instance segmentation – the classification and pixel-wise location of objects in an image. An example of instance segmentation is shown below:

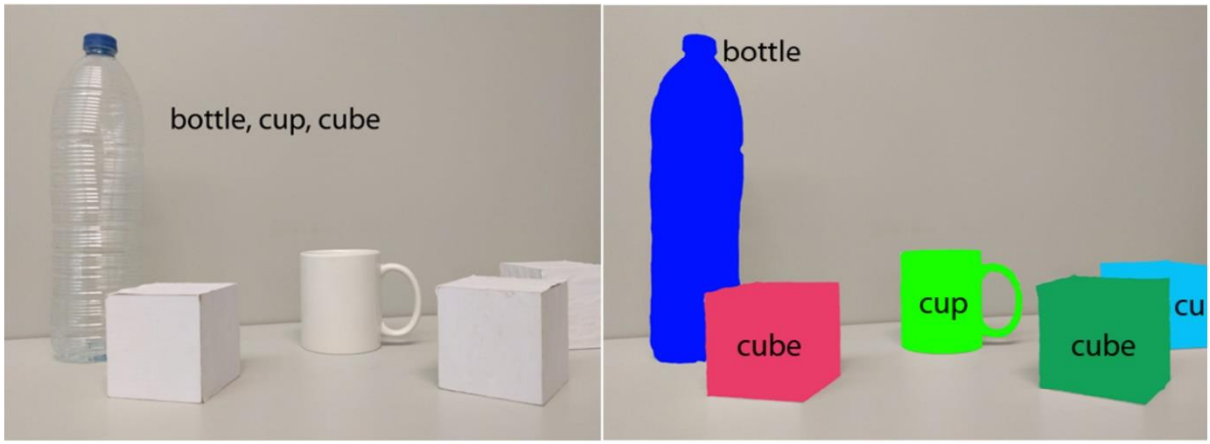

Figure 1: Instance segmentation - taken from A. Garcia Garcia
(A. Garcia-Garcia, 2017)

Object detection can be applied to each image in a sequence of images as a first step towards object tracking. However, there are numerous errors involved with these neural networks. Missed detections, inaccuracies and classification errors lead to uncertainty. Additionally, there needs to be association between an object in one frame and the same object in another frame.

This problem can be modelled using probabilistic graphical models (PGMs). PGMs consist of a graph structure where each node of the graph is associated with a random variable and the edges describe relations between the random variables. Therefore, aspects such as inaccuracy can be modelled as a random variable representing noise. The probabilistic nature of the problem, as well as the need to associate variables, lends itself towards the use of PGMs.

The idea for this final year project was presented by Dr. Van Daalen and will be completed by Mr. De Freitas. It aims to design, implement and test an algorithm that uses neural network-based instance segmentation as an input to robustly infer the trajectory and track all objects in an image sequence.

3 Objectives:

To satisfy the aim of this project two objectives need to be met:

3.1 Perform instance segmentation on an image using a pretrained neural network.

3.2 Use probabilistic methods to robustly infer the track of every object in an image sequence.

4 Motivation:

Object detection and tracking has many applications. Vehicle navigation, surveillance, robot vision and video indexing all require object tracking. Additionally, different scales of imagery can be investigated. I.e. Neural networks could be trained to identify objects in a microscopic environment. A microscopic image sequence could then be the input into the proposed algorithm which could, for instance, track how cells move. Similarly, astrological object tracking may also be performed.

While the proposed method of solving object detection is unlikely to work in real-time, it will still be able to provide valuable insights into the path that an object has taken over a video sequence. Currently state-of-the-art object tracking is done in end-to-end neural networks whereas object tracking using PGMs and neural networks has not been extensively studied. Therefor this project will provide a proof of concept. Graphical models provide more of an insight into the relationships between variables as opposed to neural networks which can be difficult to understand due to complexity and hidden layers.

This project requires little cost and resources in achieving its goals and the risk for failure is low due to the ability to be performed on any standard laptop with internet access.

5 Planned Activities:

The following activities have been planned to ensure project completion. A Gannt chart has been attached in Appendix A.

5.1 Review neural network literature

Study neural network basic architecture and terminology. Discover the state-of-the-art algorithms that implement instance segmentation.

5.2 Review probabilistic techniques literature

Study introduction to probability theory and probabilistic graphical models (PGMs). Find how to represent models as PGMs and how inference can be performed.

5.3 Determine applicability of probabilistic techniques and instance segmentation

Determine how probabilistic techniques and instance segmentation can be combined to solve the problem of object tracking.

5.4 Implement pretrained neural network-based instance segmentation

Download and implement a pretrained neural network capable of performing instance segmentation. A suitable programming language such as python, R or C will be used.

5.5 Model the object tracking problem

Using the output from the neural network as an input, model how object tracking can be performed. This can begin by looking at a single object. Once this step and the proceeding steps [until 9] have been completed, update the model if necessary. Each iterative update should include new sources of uncertainty and build on the model to include multiple objects, sources of errors and association through frames.

5.6 Represent the model as a PGM

Represent the model using the PGM framework. Most commonly Bayesian Networks and/or Markov Networks.

5.7 Perform inference

Once the model has been represented perform inference.

5.8 Review algorithm design
Test and review the algorithm with respect to the objectives.

5.9 Iterate algorithm design
If necessary, update the model to solve outstanding errors or consider more conditions.

5.10 Finalize algorithm
Once all the objectives are met finalize algorithm design.

5.11 Compare results
Compare the performance of this algorithm with that of other object tracking algorithms

5.12 Finalize report
Document the design process and discuss the effectiveness of the proposed algorithm. Recommend how the proposed solution can be improved and where it might be applicable.

6 Project Risk Assessment:

This section outlines the possible risks associated with this project.

The primary risk with this project is lack of completion due to technical complexity. Significant research will need to be undertaken as many concepts in this project will be new to the assigned project undertaker, Mr. DM De Freitas. This results in uncertainty and the inability to predict what issues may present themselves over the project.

Risk mitigation is primarily in the form of rigorous planning and budgeting extra time that may be needed. Hence there has been 585Hrs of allocated work as opposed to the recommended amount of 450Hrs (based off 10 hours per credit and a 45-credit project).

The security risk of losing valuable work due to damaged memory or loss of laptop has been mitigated by live backing up to One Drive. Therefor all work will be available from any computer which has internet access.

There are no hardware or manufacturing requirements which could present a safety risk or timing risk. No foreseeable ethical issues could be identified.

7 Budget:

One source of expenditure has been identified – engineering time spent by the junior engineer. No premium software is needed. There is no expected facility usage or material costs.

The running costs are omitted due to being negligible. Electricity consumed by a laptop is approximated as 0.05kWh and a price of R1 per kWh for 580Hrs of work results in a negligible R30.74.

There is no capital required. The budget is included below in Appendix B

8 Conclusion

Object tracking is a powerful tool that can be used by many systems across disciplines. The use of graphical models applied to a pretrained neural network may provide a suitable solution without the complexities associated with the development of an end-to-end neural network.

All risks and costs have been identified and found to be at low levels. A duration of 6 months should see the full completion of this project with time mitigation included.

9 References

A. Garcia-Garcia, S. O.-E.-M.-R. (2017). A Review on Deep Learning Techniques Applied to Semantic Segmentation.

Kaiming He, G. G. (2017). Mask R-CNN. *The IEEE International Conference on Computer Vision (ICCV)*, 2961-2969.

10 Appendix A: Gannt Chart

Task Name	Durati	Start	Finish	Predec
Skripsie Project	**104 day**	**Mon 20/01/**	**Thu 20/06/1**	
1 Review neural network	5 days	Mon 20/01/20	Fri 20/01/24	
2 Review probabilistic	10 days	Mon 20/01/27	Fri 20/02/07	
3 Determine applicability of probabilistic	7 days	Wed 20/02/05	Thu 20/02/13	
4 Implement pretrained neural network-based	14 days	Fri 20/02/14	Wed 20/03/04	
5 Model the object tracking	14 days	Wed 20/03/04	Mon 20/03/23	
6 Represent the model as a PGM	10 days	Wed 20/03/11	Tue 20/03/24	
7 Perform inferen	7 days	Wed 20/03/2	Thu 20/04/02	
8 Review algorithr	3 days	Fri 20/04/03	Tue 20/04/07	
9 Iterate algorithm	18 days	Wed 20/04/0	Fri 20/05/01	
10 Finalize algorith	3 days	Mon 20/05/0	Wed 20/05/06	
11 Compare result	7 days	Thu 20/05/07	Fri 20/05/15	
12 Finalize report	23 days	Tue 20/05/12	Thu 20/06/11	

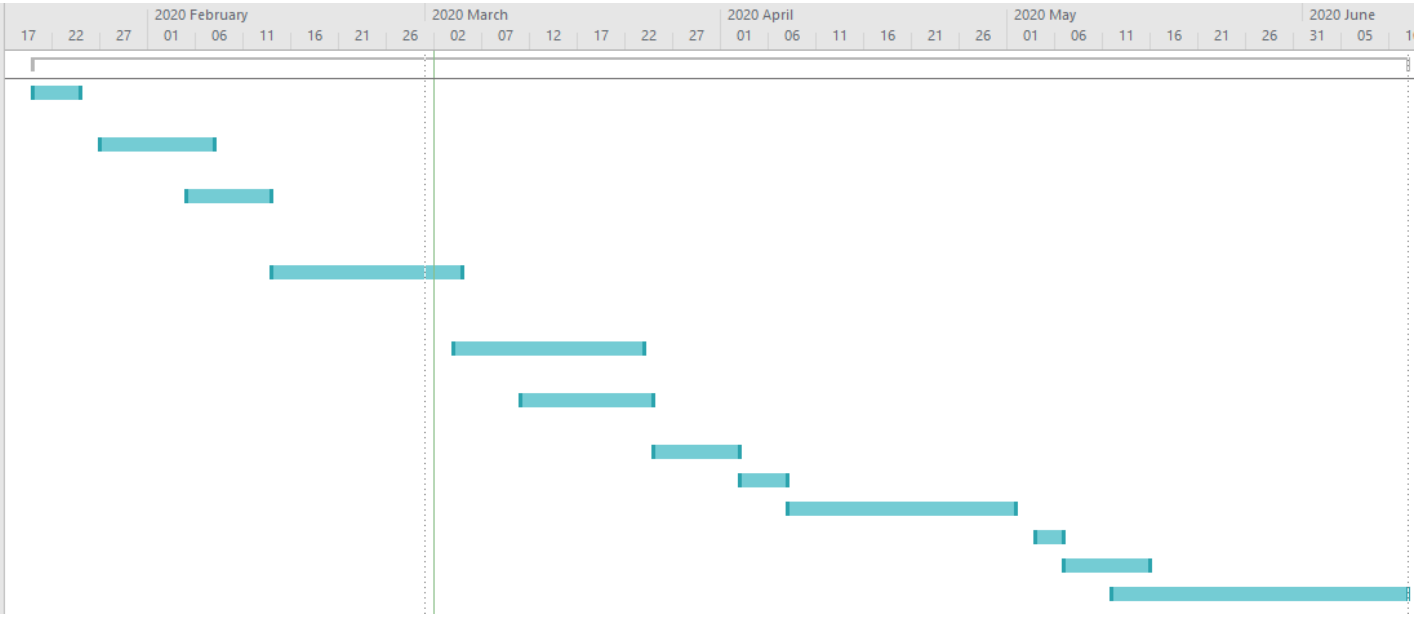

Figure A.2: Gannt Chart

11 Appendix B: Budget

Table B.1: Estimated cost per activity

Activity	**Hours**	**Junior engineer cost [R]** (@ R400/Hr)
Review neural network literature	25	R10 000,00
Review probabilistic techniques literature	50	R20 000,00
Determine applicability of probabilistic techniques and instance segmentation	35	R14 000,00
Implement pretrained neural network-based instance segmentation	70	R28 000,00
Model the object tracking problem	70	R28 000,00
Represent the model as a PGM	50	R20 000,00
Perform inference	35	R14 000,00
Review algorithm design	15	R6 000,00
Update algorithm design	70	R28 000,00
Finalize algorithm	15	R6 000,00
Compare results	35	R14 000,00
Finalize report	115	R46 000,00
Total	**585**	**R234 000,00**