

## **CERTIFICATE**

It is certified that **ANINDYA GHOSAL (Enrollment No.: 2020PSP3007)** has carried out their search work presented in this thesis entitled “**Bounding Box Refinement Agent For Overlapping Objects**” for the award of **Master of Technology** from Netaji Subhas University of Technology, New Delhi, under my supervision. The thesis embodies the results of original work, and studies are carried out by the student himself/herself (print only that is applicable) and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

\_\_\_\_\_  
**Prof. Jyotsna Singh**  
**Professor**

**Division of Electronics and Communication Engineering**  
**Netaji Subhas University Of Technology, New Delhi**

Date:

# **BOUNDING BOX REFINEMENT AGENT FOR OVERLAPPING OBJECT**

**ANINDYA GHOSAL**

## **ABSTRACT**

With the advancement in the field of computer vision and neural networks, it feels like every day a new architecture with better performance than the previous architectures is being created. Massive networks with multiple layers and skip connections with a plethora of loss functions and approaches are being used. One of the most important areas of the use of convolutional neural networks is in the field of object detection. Now in a business use case when an object detection algorithm is used, all the compatible packages are installed and the functioning of the business is smooth. Now it is not possible for the organizations to scrap the framework they put in place every time a new detection algorithm is in the market.

So to save cost, effort, and time, the work in this literature is aimed at correcting incorrect bounding boxes. Incorrect bounding boxes in the context of this literature are the change in the target object of object detection. If the target object in a detection algorithm is changed, it is not possible to re-annotate the complete dataset and retrain the complete detection model. So the approach in this work aims at using the concept of reinforcement learning on a subset of data annotated separately. Using the agent trained on the subset of data, make it learn how to correct the bounding boxes and then used the agent to correct the changed target object detection over the complete dataset. An object detection algorithm is used to first detect target objects, then based on ground truth boxes the agent learns to correct the boxes on the training dataset, and the knowledge it learns is transferred for testing and correcting other bounding boxes.

## ACKNOWLEDGEMENTS

I would like to express our sincere gratitude to Prof. Jyotsna Singh, Department of Electronics and Communication Engineering, Netaji Subhas University of Technology, for granting me this chance to work on a trending research area as a part of my Master's Thesis Project. Without her thoughtful guidance, meticulous supervision, and incessant encouragement, this thesis would not have emerged as it has. Her insights and experience have been the guiding source for our research and study. I would also like to thank the entire Department of ECE for providing an opportunity to study this project and enhance my knowledge of relevant industrial skills. I also want to thank the department for ensuring an environment conducive to learning. This project has not only provided me with in-depth knowledge of relevant and new-age technologies but also provided a platform for me to work together with her as a team. I would like to thank my parents and family members for encouraging and supporting me in the pursuit of my thesis work.

---

ANINDYA GHOSAL

2020PSP3007

Master of Technology, Signal Processing

Department of Electronics and Communication Engineering

Netaji Subhas University of Technology

New Delhi – 110078

## CONTENTS

Title	Page No.
<b>Certificate</b>	<b>ii</b>
<b>Abstract</b>	<b>iii</b>
<b>Acknowledgment</b>	<b>iv</b>
<b>List of Tables</b>	<b>vii</b>
<b>List of Figures</b>	<b>viii</b>
<b>CHAPTER 1: INTRODUCTION</b>	<b>1-4</b>
1.1. PRELIMINARY INSIGHT	1
1.2. BRIEF SURVEY OF LITERATURE	3
1.3. PROBLEM STATEMENT	3
1.4. ORGANIZATION OF THESIS	3
<b>CHAPTER 2: MACHINE LEARNING TECHNIQUES</b>	<b>5-13</b>
2.1. BACKGROUND	5
2.2. SUPERVISED LEARNING	7
2.3. UNSUPERVISED LEARNING	11
2.4. REINFORCEMENT LEARNING	12
<b>CHAPTER 3: CONVOLUTIONAL NEURAL NETWORKS</b>	<b>14-32</b>
3.1. NEURONS	14
3.2. PERCEPTRON	16
3.3. BACKPROPAGATION	17
3.4. NEOCOGNITRON	18
3.5. LeNet : THE FIRST MAINSTREAM CNN	20
3.6. AlexNet AND GoogleNet	21
3.7. VGG	23
3.8. ResNet	25
3.9. OBJECT DETECTION	27
3.10. FASTER R-CNN	30

<b>CHAPTER 4: REINFORCEMENT LEARNING</b>	<b>33-40</b>
4.1. INTRODUCTION	33
4.2. BASIC REINFORCEMENT LEARNING PROBLEM	34
4.3. MARKOV DECISION PROCESS	35
4.4. Q-LEARNING	38
4.5. DEEP Q-NETWORKS	39
<b>CHAPTER 5: PROBLEM STATEMENT</b>	<b>41-44</b>
5.1. MOTIVATION	41
5.2. INTERSECTION OVER UNION AND BOUNDING BOX	42
5.3. METHODOLOGY	42
<b>CHAPTER 6: RESULT AND DISCUSSION</b>	<b>45-52</b>
6.1. MODIFIED Faster R-CNN IMPLEMENTATION	45
6.2. DQN IMPLEMENTATION	49
<b>CHAPTER 7: FUTURE SCOPE</b>	<b>54</b>
<b>REFERENCES</b>	<b>55-60</b>
<b>PUBLICATIONS</b>	<b>61</b>

## List of Tables

	Page No.
<b>Table 1:</b> mAP values corresponding to modified implementation Faster R-CNN	51
<b>Table 2:</b> AP values corresponding to DQN agent refinement	51

## List of Figures

	Page No.
Fig 1.1: Evolution of the field of machine learning and artificial intelligence as we know it to date	2
Fig 2.1: Examples of handwritten digits	6
Fig 2.2: Different types of machine learning algorithms	7
Fig. 2.3: Organizing input dataset into known classes	7
Fig. 2.4: A pictorial representation of a supervised learning process	8
Fig. 2.5: A pictorial representation of a Supervised model	9
Fig. 2.6: An example of a logistic function	9
Fig. 2.7: Support Vector Machine	10
Fig. 2.8: A decision tree approach	11
Fig. 2.9: Example of KNN	12
Fig. 2.10: An example of how reinforcement learning works	13
Fig. 3.1: A schematic representation of a biological neuron	15
Fig. 3.2: A basic perceptron model	16
Fig. 3.3: A perceptron learning algorithm	17
Fig. 3.4: Backpropagation algorithm for a neural network	18
Fig. 3.5: Figure denoting the relationship between the hierarchical model and neocognitron	19
Fig 3.6: Diagram outlining the interconnections layerwise in neocognitron	19
Fig. 3.7: LeNet Architecture	21
Fig. 3.8: Architecture of AlexNet	22
Fig. 3.9: Inception Block	23
Fig. 3.10: Inception Block with dimension reduction	23
Fig. 3.11: The Layer structure of various VGG types	24
Fig. 3.12: 34 Layered ResNet Architecture	25
Fig. 3.13: A residual block from the ResNet Architecture	26
Fig. 3.14: Different varieties of residual blocks	26
Fig. 3.15: R-CNN Object Detection Method	28
Fig. 3.16: Spatial Pyramid Pooling Layer	29
Fig. 3.17: Fast R-CNN Object Detection	30
Fig. 3.18: A Region Proposal Network Architecture in Faster R-CNN	31
Fig. 4.1: Agent-Environment Interaction in a Markov Decision Process	36
Fig. 4.2: A working flow of an MDP in action	37
Fig. 4.3 Different reinforcement learning approaches	38
Fig. 4.4: A Q-learning algorithm	39
Fig. 4.5: A Deep Q-Network	40
Fig. 5.1: Intersection-Over-Union and Bounding box coordinates	42
Fig. 6.1.1: RoI and RPN box losses	45

Fig. 6.1.2: RoI and RPN class loss	45
Fig. 6.1.3: Total Loss in the approach	46
Fig. 6.1.4: RoI and RPN box losses for Approach 1	46
Fig. 6.1.5: RoI and RPN class loss for Approach 1	46
Fig. 6.1.6: Total Loss in Approach 1	47
Fig. 6.1.7: RoI and RPN box losses for Approach 2	47
Fig. 6.1.8: RoI and RPN class loss for Approach 2	47
Fig. 6.1.9: Total Loss in Approach 2	48
Fig. 6.1.10: RoI and RPN box losses for Approach 3	48
Fig. 6.1.11: RoI and RPN class loss for Approach 3	48
Fig. 6.1.12: Total Loss in Approach 3	49
Fig. 6.2.1: IoU Loss Plot for Approach 1	49
Fig. 6.2.2: Average IoU after correction in Approach 1	49
Fig. 6.2.3: Average predicted Q-Value of Approach 1	50
Fig. 6.2.4: IoU Loss Plot for Approach 2	50
Fig. 6.2.5: Average IoU after correction in Approach 2	50
Fig. 6.2.6: Average predicted Q-Value of Approach 2	50
Fig. 6.2.7: IoU Loss Plot for Approach 3	51
Fig. 6.2.8: Average IoU after correction in Approach 3	51
Fig. 6.2.9: Average predicted Q-Value of Approach 3	51
Fig. 6.2.10: Ground Truth Annotations	52
Fig. 6.2.11: Faster R-CNN Detections	52
Fig. 6.2.12: Corrected Bounding Boxes by DQN agent	52