Distributed Machine Learning Systems

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Bachelor

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Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 40,000 words including appendices, bibliography, footnotes, tables and equations and has fewer than 100 figures.

Christopher Hopkins
October 2020

Declaration

This is where you write your abstract ...

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1 Introduction

1.1 Motivation and Context

Machine Learning algorithms have become ubiquitous in modern life. Powering social media feeds, email spam filters, advertising personalisation and even identifying breast cancer more accurately and earlier than doctors. [1] To train these Machine Learning algorithms large datasets are needed. The more nuanced and complex the problem being solved the more data is necessary. As the scale of problems we are trying to solve dramatically increase, the scale of datasets are becoming truly gargantuan. Since 2008 Google has been processing more 20PB of data a day using their MapReduce algorithm. [2] While services like the Internet Archive as of 2020 contain over 70PB in its database. We now have labeled datasets such as AViD have 467k videos and 887 action classes, which is in the order of terabytes. [3] Whilst the data grows the as does the Machine Learning models in order to to obtain ever more accurate results. The cutting edge GTP-3 Natural Language Processing model contains 175 Billion parameters. [4] And efforts are being made to create models with trillions of parameters. [5]

Deriving meaning from these vast quantities of data to obtaining nuanced insights from them is a difficult task. Not only because deeper insights into data require a larger Machine Learning models. But because more data is needed to populate the parameters of these models. Both of these factors contribute to the need to distribute the computation of the model across multiple nodes otherwise known as Distributed Machine Learning. Distributed Machine Learning is often a pre-requisite for training models now datasets and models are becoming so large. [**?**]

The popular current solution is to have multiple machines compute the model together, communicating the improvements that they've made to each other. The model goes from operating on a single machine possessing all the data and needing to do all the computation, to a worker and parameter server paradigm. In which the parameter server contains the model and the workers perform operations on it using test data segmented between them. [6]

There are two main variations with respect to the operation of the workers in parameter server model: 1) The parameter server has to wait for the last worker to be finished before it can calculate the new global parameters. much like the MapReduce algorithm. [2] 2) The workers operate asynchronously constantly updating the parameter server, the parameter

server calculating new global parameters periodically. [7] Whilst this method is the most common method of machine learning with many benefits, there are 3 key drawbacks:

- The model sacrifices efficiency in either time or computation. Either it must wait for all workers to be done each round, or redundant computations must be made. [8]
- when the parameter server is calculating the new global parameters the workers are idle or otherwise computing on stale data. [9]
- Each time the parameter server calculates a new global parameters, these parameters must be broadcast to each worker simultaneously, consuming vast network bandwidth. [6]

As has already been addressed frequently models can get so large that they can no longer feasibly be held within one worker. Therefore there are also variations with respect to how much of the model each worker operates on: 1) The model is segmented and split between worker. This is known as *Model Parallelism* 2) The data is split between the workers which have their own full local models, but are synced with each other at periodic intervals. This is known as *Data Parallelism* [10] Though model parallelism shows promise it has its own set of drawbacks:

- Often in model parallelism nodes do not communicate with each other, this makes it performing algorithms such as Stochastic Gradient Decent difficult as clusters of nodes are isolated.
- some model parameters take more algorithmic iterations to converge than others, so that they converges at the same rate, this means that some nodes may be idle, not spreading the load equally or efficiently. [11]
- Because some parameters converge at different rates, a scheduler is needed. However this in turn require more computational overhead and communication and reduces iteration throughput. [12]

1.2 Aims

My solution to address these issues raised above is to introduce a new model for Distributed Machine Learning: *Distiller*. Distiller is a Ring Topological, Model Parallel Distributed Machine Learning framework focusing on optimising Distributed Stochastic Gradient Descent.

Each of the limitations I have described before I aim to address with the Distiller Framework:

- Distiller aims to reduce the time workers are idle to lower than the parameter server model. This will manifest itself by distributing the work between workers more proportionally, This means each computers resource is used more efficiently and training should be faster per iteration.
- The system will also not have a global parameter store, meaning there will be no need for communication of weights across the network
- As the node network has a ring topology not a star topology due the lack of a need of a parameter server prevents one node getting flooded with data each iteration. This isn't scalable, as when the workers increase so does the data flooding the parameter server leading to bottlenecks. In contrast the ring topology allows data to flow in lockstep, with no bottlenecking
- There will be no isolated nodes as can be an issue in many model parallel designs, but they can communicate with each other by design.
- The convergence rate will be consistent across all nodes, and they are all sharing a global problem rather than working on their own subproblems.
- Because the convergence rate is the same across all nodes no scheduler is necessary. Instead scheduling is managed in a decentralised manner via communication with adjacent nodes.

1.3 Problem

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1.4 Overview

This document is split up into the following sections:

- **Section 1** Current section. Introduce the project and its aims.
- **Section 2** Presents related research material and similar applications and areas.
- **Section 3** Gives an overview on the technological choices that will be used.
- **Section 4** Project plan and time management.
- **Section 5** Summary of previous sections.

2 Background Research

Hello there

3 Technological Choices

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4 Project Plan and Time Management

example of reference is [13]

5 Design

5.1 subsection1

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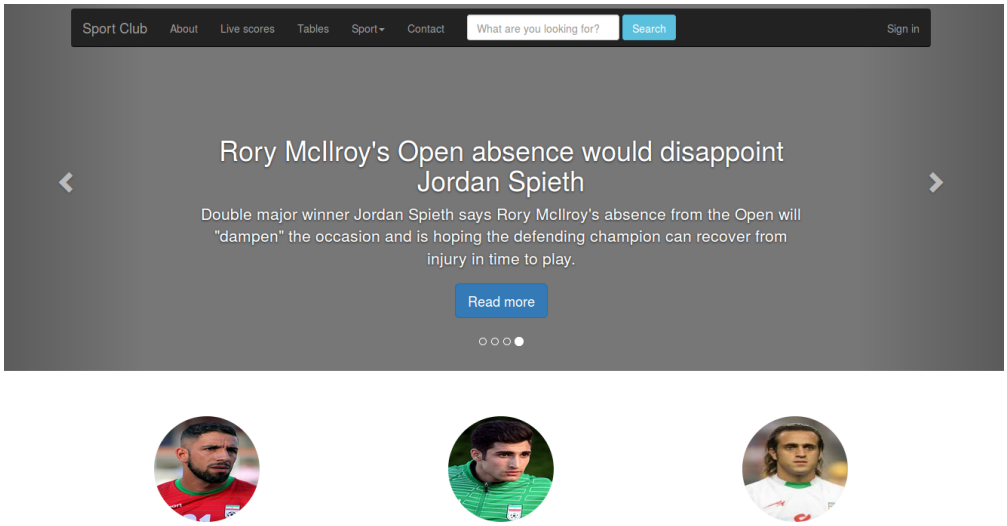

Figure 1: Project Homepage

6 Requirement and Specification

6.1 Keywords

Keyword	Definition
Completed	The requirement is implemented or fulfilled
Partial	The requirement is partially implemented or fulfilled
Not Completed	The requirement is not implemented or fulfilled
FR	Functional Requirement
NFR	Non Functional Requirement
FS	Functional Specification
NFS	Non Functional Specification

Table 1: Keywords

6.2 Requirements

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6.4 Cross-References

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7 Implementation

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8 Reflection

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9 Future Work

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10 Conclusion

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Appendices

A one

B two