Sparse Linear Algebra in the Deeplearning4j Framework

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par

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Prof Name Surname, rapporteur

Lausanne, EPFL, 2011

Wings are a constraint that makes
it possible to fly.
— Robert Bringhurst

To my parents. . .

Acknowledgements

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Lausanne, 12 Mars 2011 D. K.

Abstract

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Key words:

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Introduction

A non-numbered chapter...

Nowadays Machine learning is very popular and widely-used to resolve daily life problem

- deeplearning, neural net, self driving car etc

To work correctly and expect a accurate result, those machine learning problems require a huge amount of data. Such datasets are challenging regarding the execution time of the algorithms, the memory space required, the network usage when working imn a distributed environnement, etc

A big part of those problems used sparse datasets. For example a recommender system typically works with a dataset high-sparsity. This dataset contains the rating of movies or products given by the users. But usually the user only rated a very small subset of products.

That means, that if we know that our dataset will be sparse, we can used the sparse linear algebra to resolve the problem to optimized the memory used and the executing time.

Deeplearing4j didn't support any sparse format for vectors, matrices or tensors, neither the operations.

1 Deeplearning4j Library

Deeplearning4j is a open-source Deep Learning library for the JVM. It runs on distributed CPU's and GPU's.

Structure of the library

The library is composed by several sub-libraries:

Deeplearning4j provides the tools to implement neural networks and build computation graphs

Nd4j is the mathematical back-end of Deeplearning4j. It provides the data structures for the n-dimensional arrays and allow Java to access the native libraries via Libnd4j.

Libnd4j is the computing library that provides native operations on CPU and GPU. It's written in C++ and Cuda.

Datavec provides the operations for the data processing such that data ingestion, normalization and transformation into feature vectors.

2 Sparse Linear Algebra

A sparse matrix is matrix that contains only a very few non-zero element. Conversly, a matrix which contains mostly non-zero elements are dense.

The sparsity coefficient is defined by the number of non-zero element divided by the total number of element in the array.

density = 1 - sparsity

For example the matrix ...

has a sparsity of $\frac{4}{15}$ and a density of $\frac{11}{15}$.

3 Sparse Formats

Vectors and Matrices

There exists several different formats to store a sparse array. The idea behind using a sparse format instead of the classic dense one, is to reduce the memory space and the executing time of the operations. Knowing that a matrix is sparse allows to shortcut some operation steps. For example during a matrix multiplication, we can avoid to perform the multiplication for the zero elements of the sparse matrix.

Coordinate format (COO)

This format is the simplest format to encode a sparse array. The coordinates and the value of each non-zero entry are stored in arrays. Typically each element are encoded in a tuple (row, column, value)

Some implementation variations of the COO format exist. The elements can be sorted along a dimension, or it can be some duplicate indexes.

$$A_{(M\times N)} = \begin{bmatrix} 0 & 2 & 0 \\ 0 & 0 & 3 \\ 1 & 0 & 4 \\ 0 & 0 & 0 \end{bmatrix} \quad \rightarrow \quad \begin{aligned} Values_{(1\times NNZ)} &= \begin{bmatrix} 2 & 3 & 1 & 4 \end{bmatrix} \\ Rows_{(1\times NNZ)} &= \begin{bmatrix} 0 & 1 & 2 & 2 \end{bmatrix} \\ Columns_{(1\times NNZ)} &= \begin{bmatrix} 1 & 2 & 0 & 2 \end{bmatrix} \end{aligned}$$

With this format it's easy and fast to retrieve the value given an index and to insert a new non-zero element.. It's also fast and simple to convert into a dense format.

But this format don't minimize the memory space. It can be reduced with a compressed format such as CSR or CSC as described below.

Compressed Row Format (CSR)

The Compressed Row and the Compressed Column formats are the most general format to store a sparse array. They don't store any unnecessary element. But it requires more steps to access the elements than the COO format.

Each non-zero element of a row are stored contiguously in the memory. Each row are also contiguously stored.

The format requires four arrays:

values All the nonzero values are store contiguously in an array. The array size is NNZ.

column pointers This array keeps the column position for each values.

Beginning of row pointers Each pointer i points to the first element of the row i in the values array. The array size is the number of rows of the array.

End of row pointers Each pointer i points to the first element in the values array that does not belong to the row i . The array size is the number of rows of the array.

$$A_{(N\times M)} = \begin{bmatrix} 0 & 2 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 1 & 0 & 4 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \rightarrow \begin{aligned} Values_{(1\times NNZ)} &= \begin{bmatrix} 2 & 3 & 1 & 4 & 1 \end{bmatrix} \\ Columns_{(1\times NNZ)} &= \begin{bmatrix} 1 & 2 & 0 & 2 & 2 \end{bmatrix} \\ pointersB_{(1\times N)} &= \begin{bmatrix} 0 & 1 & 2 & 4 \end{bmatrix} \\ PointersE_{(1\times N)} &= \begin{bmatrix} 1 & 2 & 4 & 5 \end{bmatrix} \end{aligned}$$

Tensors / N-dimensional arrays

Coordinate format(COO)

4 Mathematics

In this chapter we will see some examples of mathematics.

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Very important formulas

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$$\frac{\mathrm{d}}{\mathrm{d}t}\begin{bmatrix} P_0 \\ P_1 \\ P_T \end{bmatrix} = \begin{bmatrix} \frac{P_1}{\tau_{10}} + \frac{P_T}{\tau_T} - \frac{P_0}{\tau_{ex}} \\ -\frac{P_1}{\tau_{10}} - \frac{P_1}{\tau_{isc}} + \frac{P_0}{\tau_{ex}} \\ \frac{P_1}{\tau_{isc}} - \frac{P_T}{\tau_T} \end{bmatrix} \tag{4.1}$$

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libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

$$\bar{I_f}(\vec{r}) = \gamma(\vec{r}) \left(1 - \frac{\tau_T P_T^{eq} \left(1 - \exp\left(-\frac{(T_p - t_p)}{\tau_T} \right) \right)}{1 - \exp\left(-\frac{(T_p - t_p)}{\tau_T} + k_2 t_p \right)} \times \frac{\left(\exp\left(k_2 t_p \right) - 1 \right)}{t_p} \right) \tag{4.2}$$

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A An appendix

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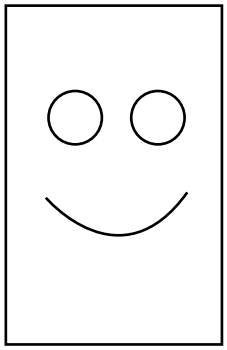
Personal details:



Name :	Mr. Sample CV
Address :	Samplestreet 70 6005 Luzern Switzerland
Date of Birth :	2nd of October 1981
Nationality :	Swiss
Legally work :	legally work in EU
Marital status :	with partner
Children :	none
Languages :	Chinese/Mandarin, English, French, German
Education level :	Bachelors degree
Hospitality work experience :	3-5 years
Special experience :	Europe work experience
Date of availability :	September 2009
Current location :	Africa
Travelling Status :	will be travelling single status
Telephone :	0041 41 370 6759
Email address :	jeff@h-g-r.com
Position(s) sought :	Permanent position for graduates
Department(s) sought :	Food & Beverage Bar/Sommelier

Personal profile:

As a Bachelor of Business Administration and after obtaining first relevant international work experience within the hospitality industry, I am now ready to take on new responsibilities to further my professional career.
My key strengths include strong analytical and logical skills, an eye for detail, communication and interpersonal skills.
I enjoy working in a team and help others progress. At the same time I work well independently.
As a highly motivated and driven individual I strive on taking up challenges.

Interests:

Travelling
Foreign Cultures
Photography
Sports

Educational qualifications:

Oct 99 - Feb 02	Higher Diploma (Hotel Management) Swiss Hotelmanagement School, SHL

Employment history:

Mar 04 - Ongoing	Assistant Manager (Rooms Division/Food & Beverage)
	Hotel Atlantic Kempinski Hamburg www.kempinski.com 5 star business hotel, part of Leading Hotels of the World 412 guest rooms, large function facilities, 3 food & beverage outlets
	Optimization of bar procedures, reinforcing SOPs
	Developing & implementing promotions
	Responsible for day-to-day operations
	Optimization and streamlining of housekeeping and laundry procedures
	Implementation of new SOPs
	Analyzing monthly reports for rooms division performance and sub departments
Mar 03 - Mar 04	Management Trainee
	Hospitality Graduate Recruitment www.h-g-r.com Leading company for placements within the Hospitality industry.
	Traineeship covering all aspects of an online recruitment agency.
Mar 02 - Mar 03	Management Trainee (Rooms Division)
	Hyatt Regency Xian, China www.hyatt.com 5 star business hotel 404 guest rooms, 4 food & beverage outlets
	Traineeship covering all rooms division departments on operational as well as supervisory level.

Training courses attended:

Mar 02 - Ongoing	OpenOffice - IT Courses
May 01 - Jan 03	Language Course - Chinese

References:

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