E534 - Big Data Applications
Lecture Notes

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https://cloudmesh-community.github.io/book/vonlaszewski-e534.epub

September 30, 2019 - 10:58 AM

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E534 - BIG DATA APPLICATIONS

Geoffrey C. Fox Gregor von Laszewski

E534 - Big Data Applications

1 PREFACE

Mon Sep 30 10:58:10 EDT 2019

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- https://github.com/cyberaide/bookmanager/issues

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2 WEEK 1

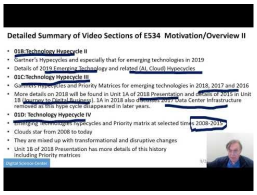
2.1 Part I Motivation I ☁

2.1.1 Motivation

Big Data Applications & Analytics: Motivation/Overview; Machine (actually Deep) Learning, Big Data, and the Cloud; Centerpieces of the Current and Future Economy,

2.1.2 00) Mechanics of Course, Summary, and overall remarks on course

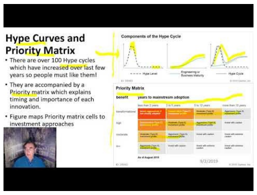
In this section we discuss the summary of the motivation section.



[Video]

2.1.2.1 01A) Technology Hypecycle I

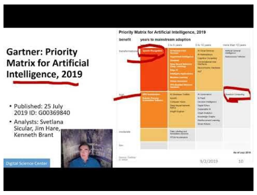
Today clouds and big data have got through the hype cycle (they have emerged) but features like blockchain, serverless and machine learning are on recent hype cycles while areas like deep learning have several entries (as in fact do clouds) Gartner's Hypecycles and especially that for emerging technologies in 2019 The phases of hypecycles Priority Matrix with benefits and adoption time Initial discussion of 2019 Hypecycle for Emerging Technologies



[Video]

2.1.2.2 01B) Technology Hypecycle II

Today clouds and big data have got through the hype cycle (they have emerged) but features like blockchain, serverless and machine learning are on recent hype cycles while areas like deep learning have several entries (as in fact do clouds) Gartner’s Hypecycles and especially that for emerging technologies in 2019 Details of 2019 Emerging Technology and related (AI, Cloud) Hypecycles



Video

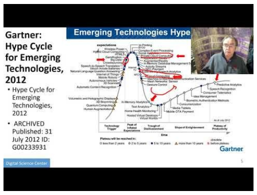
2.1.2.3 01C) Technology Hypecycle III

Today clouds and big data have got through the hype cycle (they have emerged) but features like blockchain, serverless and machine learning are on recent hype cycles while areas like deep learning have several entries (as in fact do clouds) Gartners Hypecycles and Priority Matrices for emerging technologies in 2018, 2017 and 2016 More details on 2018 will be found in Unit 1A of 2018 Presentation and details of 2015 in Unit 1B (Journey to Digital Business). 1A in 2018 also discusses 2017 Data Center Infrastructure removed as this hype cycle disappeared in later years.

Video

2.1.2.4 01D) Technology Hypecycle IV

Today clouds and big data have got through the hype cycle (they have emerged) but features like blockchain, serverless and machine learning are on recent hype cycles while areas like deep learning have several entries (as in fact do clouds) Emerging Technologies hypecycles and Priority matrix at selected times 2008-2015 Clouds star from 2008 to today They are mixed up with transformational and disruptive changes Unit 1B of 2018 Presentation has more details of this history including Priority matrices

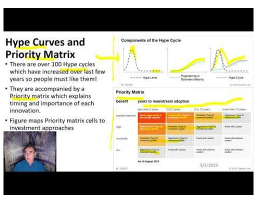


[Video]

2.1.3 02)

2.1.3.1 02A) Clouds/Big Data Applications I

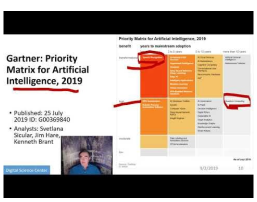
The Data Deluge Big Data; a lot of the best examples have NOT been updated (as I can't find updates) so some slides old but still make the correct points Big Data Deluge has become the Deep Learning Deluge Big Data is an agreed fact; Deep Learning still evolving fast but has stream of successes!



[Video]

2.1.3.2 02B) Cloud/Big Data Applications II

Clouds in science where area called cyberinfrastructure; The usage pattern from NIST is removed. See 2018 lectures 2B of the motivation for this discussion



[Video]

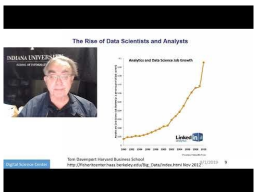
2.1.3.3 02C) Cloud/Big Data

Usage Trends Google and related Trends Artificial Intelligence from Microsoft, Gartner and Meeker

[Video]

2.1.4 03) Jobs In areas like Data Science, Clouds and Computer Science and Computer

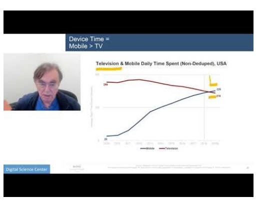
Engineering



[Video]

2.1.5 04) Industry, Technology, Consumer Trends Basic trends 2018 Lectures 4A 4B have

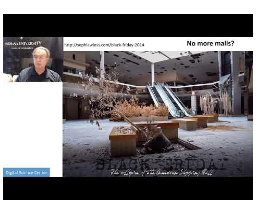
more details removed as dated but still valid See 2018 Lesson 4C for 3 Technology trends for 2016: Voice as HCI, Cars, Deep Learning



[Video]

2.1.6 05) Digital Disruption and Transformation The Past displaced by Digital

Disruption; some more details are in 2018 Presentation Lesson 5



[Video]

2.1.7 06)

2.1.8 06A) Computing Model I Industry adopted clouds which are attractive for data

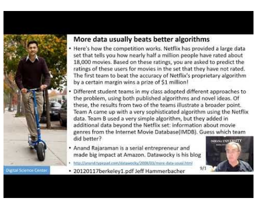
analytics. Clouds are a dominant force in Industry. Examples are given

2.1.8.1 06B) Computing Model II with 3 subsections is removed; please see 2018

Presentation for this Developments after 2014 mainly from Gartner Cloud Market share Blockchain

Video

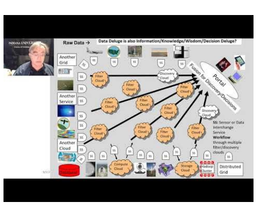
2.1.9 07) Research Model 4th Paradigm; From Theory to Data driven science?



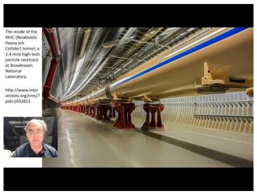
Video

2.1.10 08) Data Science Pipeline DIKW: Data, Information, Knowledge, Wisdom, Decisions.

More details on Data Science Platforms are in 2018 Lesson 8 presentation


Video

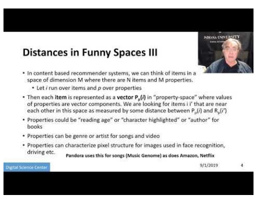
2.1.11 09) Physics: Looking for Higgs Particle with Large Hadron Collider LHC Physics as a big data example

 Video

2.1.12 10) Recommender Systems I General remarks and Netflix example

Video

2.1.13 11) Recommender Systems II Exploring Data Bags and Spaces



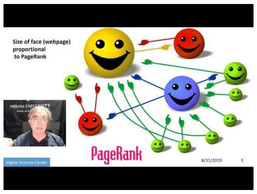
Video

2.1.14 12) Web Search and Information Retrieval Another Big Data Example

Video

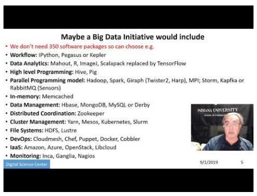
2.1.15 13) Cloud Applications in Research Removed Science Clouds, Internet of Things

Part 12 continuation. See 2018 Presentation (same as 2017 for lesson 13) and Cloud Unit 2019-I) this year



[Video]

2.1.16 14) Parallel Computing and MapReduce Software Ecosystems



[Video]

2.1.17 15) Online education and data science education Removed.

You can find it in the 2017 version. In [Section 3.1] you can see more about this.

[Video]

2.1.18 16) Conclusions

Conclusion contain in the latter part of the part 15.

Motivation Archive Big Data Applications & Analytics: Motivation/Overview; Machine (actually Deep) Learning, Big Data, and the Cloud; Centerpieces of the Current and Future Economy. Backup Lectures from previous years referenced in 2019 class

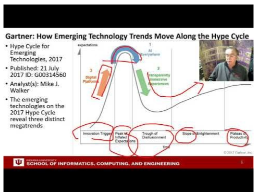

Now we are Artificial Intelligence or Machine Learning or nowadays Deep Learning First
• 2017 Headlines
• The Race For AI: Google, Twitter, Intel, Apple In A Rush To Grab Artificial Intelligence Startups
• Google, Facebook, And Microsoft Are Remaking Themselves Around AI
• Google: The Full Stack AI Company
• Bezos Says Artificial Intelligence to Fuel Amazon's Success
• Microsoft CEO says artificial intelligence is the 'ultimate breakthrough'
• Tesla's New AI Guru Could Help Its Cars Teach Themselves
• Netflix Is Using AI to Conquer the World... and Bandwidth Issues
• How Google Is Remaking Itself As A "Machine Learning First" Company
• If You Love Machine Learning, You Should Check Out General Electric
Digital Science Center
9/1/2019
4
Video

3 WEEK 2

3.1 Part II Motivation Archive

3.1.1 2018 BDAA Motivation-1A) Technology Hypecycle I

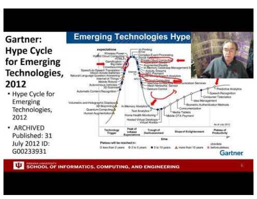
In this section we discuss on general remarks including Hype curves.



Video

3.1.2 2018 BDAA Motivation-1B) Technology Hypecycle II

In this section we continue our discussion on general remarks including Hype curves.



Video

3.1.3 2018 BDAA Motivation-2B) Cloud/Big Data Applications II

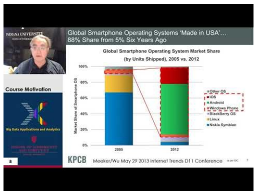
In this section we discuss clouds in science where area called cyberinfrastructure; the usage pattern from NIST Artificial Intelligence from Gartner and Meeker.

Video

3.1.4 2018 BDAA Motivation-4A) Industry Trends I

In this section we discuss on Lesson 4A many technology trends through end of

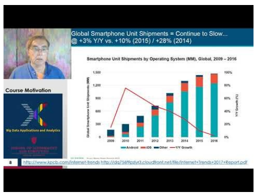
2014.



Video

3.1.5 2018 BDAA Motivation-4B) Industry Trends II

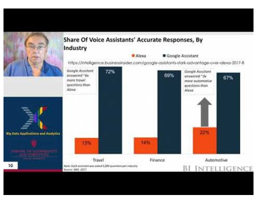
In this section we continue our discussion on industry trends. This section includes Lesson 4B 2015 onwards many technology adoption trends.



Video

3.1.6 2017 BDAA Motivation-4C)Industry Trends III

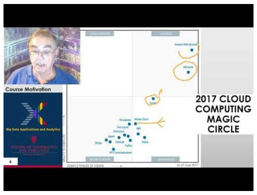
In this section we continue our discussion on industry trends. This section contains lesson 4C 2015 onwards 3 technology trends voice as HCI cars deep learning.



Video

3.1.7 2018 BDAA Motivation-6B) Computing Model II

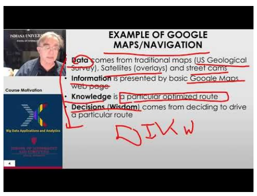
In this section we discuss computing models. This section contains lesson 6B with 3 subsections developments after 2014 mainly from Gartner cloud market share blockchain



[Video](#)

3.1.8 2017 BDAA Motivation-8) Data Science Pipeline DIKW

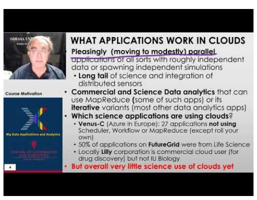
In this section, we discuss data science pipelines. This section also contains about data, information, knowledge, wisdom forming DIKW term. And also it contains some discussion on data science platforms.



[Video](#)

3.1.9 2017 BDAA Motivation-13) Cloud Applications in Research Science Clouds Internet of Things

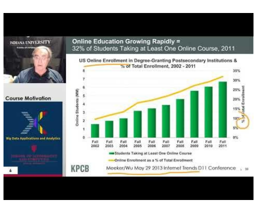
In this section we discuss about internet of things and related cloud applications.



[Video](#)

3.1.10 2017 BDAA Motivation-15) Data Science Education Opportunities at Universities

In this section we discuss more on data science education opportunities.

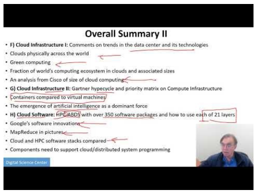


[Video](#)

4 WEEK 3

4.1 Part III Cloud ☁

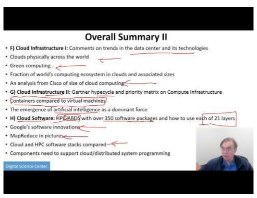
4.1.1 A. Summary of Course



[Video]

4.1.2 B. Defining Clouds I

In this lecture we discuss the basic definition of cloud and two very simple examples of why virtualization is important.

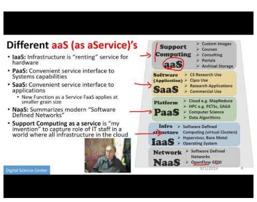


[Video]

In this lecture we discuss how clouds are situated wrt HPC and supercomputers, why multicore chips are important in a typical data center.

4.1.3 C. Defining Clouds II

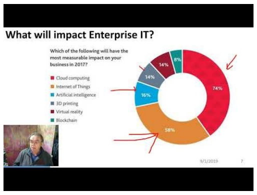
In this lecture we discuss service-oriented architectures, Software services as Message-linked computing capabilities.



[Video]

In this lecture we discuss different aaS's: Network, Infrastructure, Platform, Software. The amazing services that Amazon AWS and Microsoft Azure have Initial Gartner comments on clouds (they are now the norm) and evolution of servers; serverless and microservices Gartner hypecycle and priority matrix on Infrastructure Strategies.

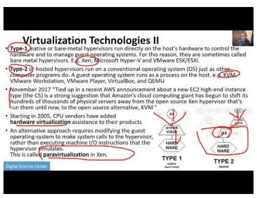
4.1.4 D. Defining Clouds III: Cloud Market Share



Video

In this lecture we discuss on how important the cloud market shares are and how much money do they make.

4.1.5 E. Virtualization: Virtualization Technologies,



Video

In this lecture we discuss hypervisors and the different approaches KVM, Xen, Docker and Openstack.

4.1.6 F. Cloud Infrastructure I

Video

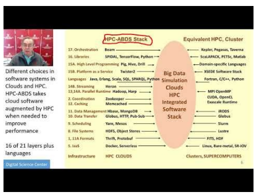
In this lecture we comment on trends in the data center and its technologies. Clouds physically spread across the world Green computing Fraction of world's computing ecosystem. In clouds and associated sizes an analysis from Cisco of size of cloud computing is discussed in this lecture.

4.1.7 G. Cloud Infrastructure II

[Video]

In this lecture, we discuss Gartner hypecycle and priority matrix on Compute Infrastructure Containers compared to virtual machines The emergence of artificial intelligence as a dominant force.

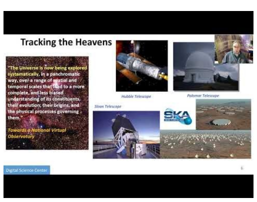
4.1.8 H. Cloud Software:



[Video]

In this lecture we discuss, HPC-ABDS with over 350 software packages and how to use each of 21 layers Google’s software innovations MapReduce in pictures Cloud and HPC software stacks compared Components need to support cloud/distributed system programming.

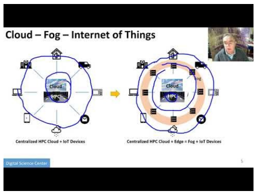
4.1.9 I. Cloud Applications I: Clouds in science where area called



[Video]

In this lecture we discuss cyberinfrastructure; the science usage pattern from NIST Artificial Intelligence from Gartner.

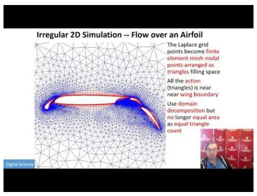
4.1.10 J. Cloud Applications II: Characterize Applications using NIST



Video

In this lecture we discuss the approach Internet of Things with different types of MapReduce.

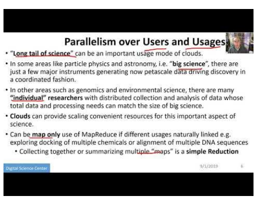
4.1.11 K. Parallel Computing



Video

In this lecture we discuss analogies, parallel computing in pictures and some useful analogies and principles.

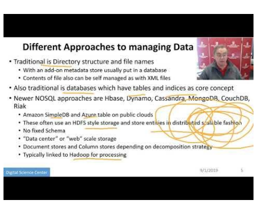
4.1.12 L. Real Parallel Computing: Single Program/Instruction Multiple Data SIMD SPMD



Video

In this lecture, we discuss Big Data and Simulations compared and we furthermore discusses what is hard to do.

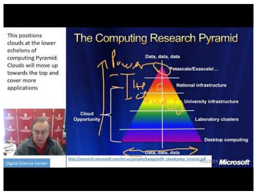
4.1.13 M. Storage: Cloud data



Video

In this lecture we discuss about the approaches, repositories, file systems, data lakes.

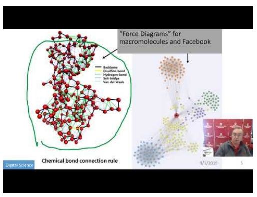
4.1.14 N. HPC and Clouds



[Video]

In this lecture we discuss the Branscomb Pyramid Supercomputers versus clouds Science Computing Environments.

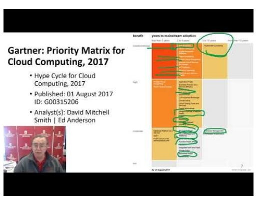
4.1.15 O. Comparison of Data Analytics with Simulation:



[Video]

In this lecture we discuss the structure of different applications for simulations and Big Data Software implications Languages.

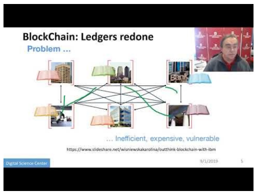
4.1.16 P. The Future I



[Video]

In this lecture we discuss Gartner cloud computing hypecycle and priority matrix 2017 and 2019 Hyperscale computing Serverless and FaaS Cloud Native Microservices Update to 2019 Hypecycle.

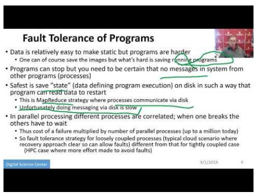
4.1.17 Q. other Issues II



[Video]

In this lecture we discuss on Security Blockchain.

4.1.18 R. The Future and other Issues III



[Video]

In this lecture we discuss on Fault Tolerance.

5 WEEK 4

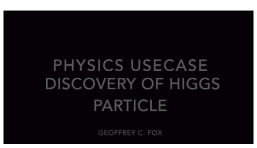
5.1 Physics with Big Data Applications

E534 2019 Big Data Applications and Analytics Discovery of Higgs Boson Part I (Unit 8) Section Units 9-11 Summary: This section starts by describing the LHC accelerator at CERN and evidence found by the experiments suggesting existence of a Higgs Boson. The huge number of authors on a paper, remarks on histograms and Feynman diagrams is followed by an accelerator picture gallery. The next unit is devoted to Python experiments looking at histograms of Higgs Boson production with various forms of shape of signal and various background and with various event totals. Then random variables and some simple principles of statistics are introduced with explanation as to why they are relevant to Physics counting experiments. The unit introduces Gaussian (normal) distributions and explains why they seen so often in natural phenomena. Several Python illustrations are given. Random Numbers with their Generators and Seeds lead to a discussion of Binomial and Poisson Distribution. Monte-Carlo and accept-reject methods. The Central Limit Theorem concludes discussion.

5.1.1 Unit 8:

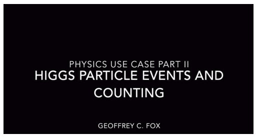
5.1.1.1 8.1 - Looking for Higgs: 1. Particle and Counting Introduction 1

We return to particle case with slides used in introduction and stress that particles often manifested as bumps in histograms and those bumps need to be large enough to stand out from background in a statistically significant fashion.



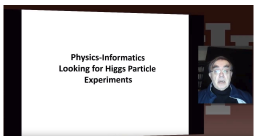
5.1.1.2 8.2 - Looking for Higgs: 2. Particle and Counting Introduction 2

We give a few details on one LHC experiment ATLAS. Experimental physics papers have a staggering number of authors and quite big budgets. Feynman diagrams describe processes in a fundamental fashion.



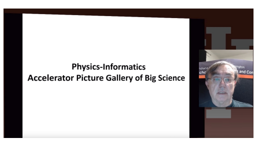
5.1.1.3 8.3 - Looking for Higgs: 3. Particle Experiments

We give a few details on one LHC experiment ATLAS. Experimental physics papers have a staggering number of authors and quite big budgets. Feynman diagrams describe processes in a fundamental fashion



5.1.1.4 8.4 - Looking for Higgs: 4. Accelerator Picture Gallery of Big Science

This lesson gives a small picture gallery of accelerators. Accelerators, detection chambers and magnets in tunnels and a large underground laboratory used fpr experiments where you need to be shielded from background like cosmic rays.

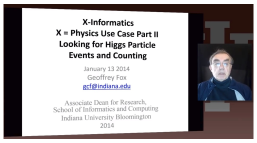


5.1.2 Unit 9

This unit is devoted to Python experiments with Geoffrey looking at histograms of Higgs Boson production with various forms of shape of signal and various background and with various event totals

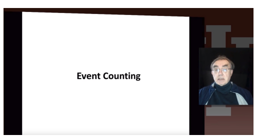
5.1.2.1 9.1 - Looking for Higgs II: 1: Class Software

We discuss how this unit uses Java (deprecated) and Python on both a backend server (FutureGrid - closed!) or a local client. We point out useful book on Python for data analysis. This lesson is deprecated. Follow current technology for class



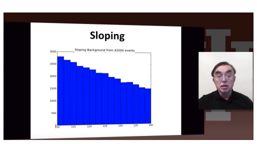
5.1.2.2 9.2 - Looking for Higgs II: 2: Event Counting

We define ‘’event counting’’ data collection environments. We discuss the python and Java code to generate events according to a particular scenario (the important idea of Monte Carlo data). Here a sloping background plus either a Higgs particle generated similarly to LHC observation or one observed with better resolution (smaller measurement error).



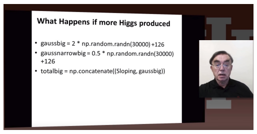
5.1.2.3 9.3 - Looking for Higgs II: 3: With Python examples of Signal plus Background

This uses Monte Carlo data both to generate data like the experimental observations and explore effect of changing amount of data and changing measurement resolution for Higgs.



5.1.2.4 9.4 - Looking for Higgs II: 4: Change shape of background & number of Higgs Particles

This lesson continues the examination of Monte Carlo data looking at effect of change in number of Higgs particles produced and in change in shape of background



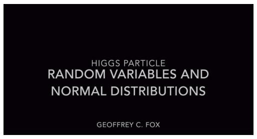
5.1.3 Unit 10

https://www.youtube.com/playlist?list=PLy0VLh_GFyz-Er5TNFj1I8ihPOXnhicj0 In this unit we discuss;

E534 2019 Big Data Applications and Analytics Discovery of Higgs Boson: Big Data Higgs Unit 10: Looking for Higgs Particles Part III: Random Variables, Physics and Normal Distributions Section Units 9-11 Summary: This section starts by describing the LHC accelerator at CERN and evidence found by the experiments suggesting existence of a Higgs Boson. The huge number of authors on a paper, remarks on histograms and Feynman diagrams is followed by an accelerator picture gallery. The next unit is devoted to Python experiments looking at histograms of Higgs Boson production with various forms of shape of signal and various background and with various event totals. Then random variables and some simple principles of statistics are introduced with explanation as to why they are relevant to Physics counting experiments. The unit introduces Gaussian (normal) distributions and explains why they seen so often in natural phenomena. Several Python illustrations are given. Random Numbers with their Generators and Seeds lead to a discussion of Binomial and Poisson Distribution. Monte-Carlo and accept-reject methods. The Central Limit Theorem concludes discussion. Big Data Higgs Unit 10: Looking for Higgs Particles Part III: Random Variables, Physics and Normal Distributions Overview: Geoffrey introduces random variables and some simple principles of statistics and explains why they are relevant to Physics counting experiments. The unit introduces Gaussian (normal) distributions and explains why they seen so often in natural phenomena. Several Python illustrations are given. Java is currently not available in this unit.

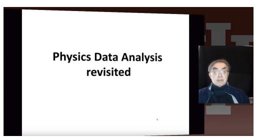
5.1.3.1 10.1 - Statistics Overview and Fundamental Idea: Random Variables

We go through the many different areas of statistics covered in the Physics unit. We define the statistics concept of a random variable.



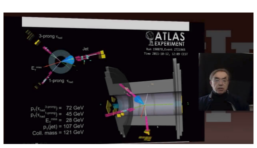
5.1.3.2 10.2 - Physics and Random Variables I

We describe the DIKW pipeline for the analysis of this type of physics experiment and go through details of analysis pipeline for the LHC ATLAS experiment. We give examples of event displays showing the final state particles seen in a few events. We illustrate how physicists decide whats going on with a plot of expected Higgs production experimental cross sections (probabilities) for signal and background.



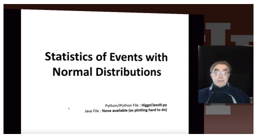
5.1.3.3 10.3 - Physics and Random Variables II

We describe the DIKW pipeline for the analysis of this type of physics experiment and go through details of analysis pipeline for the LHC ATLAS experiment. We give examples of event displays showing the final state particles seen in a few events. We illustrate how physicists decide whats going on with a plot of expected Higgs production experimental cross sections (probabilities) for signal and background.



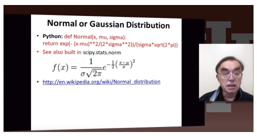
5.1.3.4 10.4 - Statistics of Events with Normal Distributions

We introduce Poisson and Binomial distributions and define independent identically distributed (IID) random variables. We give the law of large numbers defining the errors in counting and leading to Gaussian distributions for many things. We demonstrate this in Python experiments.



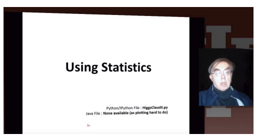
5.1.3.5 10.5 - Gaussian Distributions

We introduce the Gaussian distribution and give Python examples of the fluctuations in counting Gaussian distributions.



5.1.3.6 10.6 - Using Statistics

We discuss the significance of a standard deviation and role of biases and insufficient statistics with a Python example in getting incorrect answers.



5.1.4 Unit 11

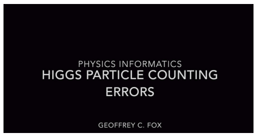
https://www.youtube.com/playlist?list=PLy0VLh_GFyz_I7ILsaGab-NNhLuiqVpIs

In this section we discuss;

E534 2019 Big Data Applications and Analytics Discovery of Higgs Boson: Big Data Higgs Unit 11: Looking for Higgs Particles Part IV: Random Numbers, Distributions and Central Limit Theorem Section Units 9-11 Summary: This section starts by describing the LHC accelerator at CERN and evidence found by the experiments suggesting existence of a Higgs Boson. The huge number of authors on a paper, remarks on histograms and Feynman diagrams is followed by an accelerator picture gallery. The next unit is devoted to Python experiments looking at histograms of Higgs Boson production with various forms of shape of signal and various background and with various event totals. Then random variables and some simple principles of statistics are introduced with explanation as to why they are relevant to Physics counting experiments. The unit introduces Gaussian (normal) distributions and explains why they seen so often in natural phenomena. Several Python illustrations are given. Random Numbers with their Generators and Seeds lead to a discussion of Binomial and Poisson Distribution. Monte-Carlo and accept-reject methods. The Central Limit Theorem concludes discussion. Big Data Higgs Unit 11: Looking for Higgs Particles Part IV: Random Numbers, Distributions and Central Limit Theorem Unit Overview: Geoffrey discusses Random Numbers with their Generators and Seeds. It introduces Binomial and Poisson Distribution. Monte-Carlo and accept-reject methods are discussed. The Central Limit Theorem and Bayes law concludes discussion. Python and Java (for student - not reviewed in class) examples and Physics applications are given.

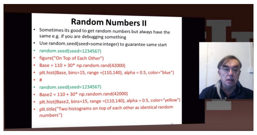
5.1.4.1 11.1 - Generators and Seeds I

We define random numbers and describe how to generate them on the computer giving Python examples. We define the seed used to define to specify how to start generation.



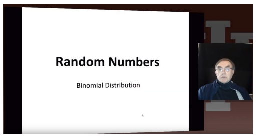
5.1.4.2 11.2 - Generators and Seeds II

We define random numbers and describe how to generate them on the computer giving Python examples. We define the seed used to define to specify how to start generation.



5.1.4.3 11.3 - Binomial Distribution

We define binomial distribution and give LHC data as an eaxmple of where this distribution valid.

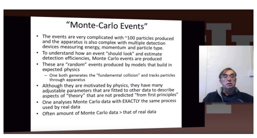


5.1.4.4 11.4 - Accept-Reject

We introduce an advanced method – accept/reject – for generating random variables with arbitrary distrubitions.

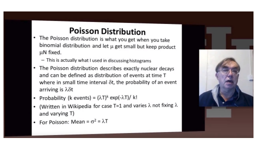
5.1.4.5 11.5 - Monte Carlo Method

We define Monte Carlo method which usually uses accept/reject method in typical case for distribution.



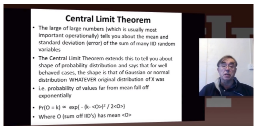
5.1.4.6 11.6 - Poisson Distribution

We extend the Binomial to the Poisson distribution and give a set of amusing examples from Wikipedia.



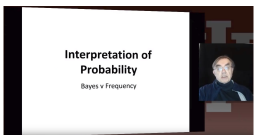
5.1.4.7 11.7 - Central Limit Theorem

We introduce Central Limit Theorem and give examples from Wikipedia.



5.1.4.8 11.8 - Interpretation of Probability: Bayes v. Frequency

This lesson describes difference between Bayes and frequency views of probability. Bayes's law of conditional probability is derived and applied to Higgs example to enable information about Higgs from multiple channels and multiple experiments to be accumulated.

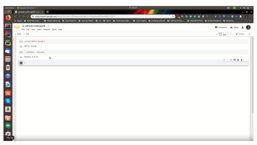


6 WEEK 5

6.1 Google Colab ☁

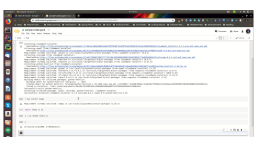
In this section we are going to introduce you, how to use Google Colab to run deep learning models.

6.1.1 Introduction to Google Colab

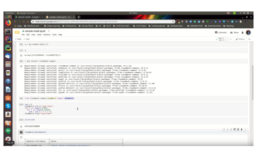


In this vide we explain you ….

6.1.2 Programming in Google Colab



6.1.3 Benchamrking in Google Colab with Cloudmesh



7 WEEK 6

7.1 Introduction to Deep Learning

7.1.1 MNIST Classification Version 1

7.1.2 Using Cloudmesh Common

Here we do a simple benchmark. We calculate compile time, train time, test time and data loading time for this example. Installing cloudmesh-common library is the first step. Focus on this section because the ** Assignment 4 ** will be focused on the content of this lab.

```
!pip install cloudmesh-common
```

```
Collecting cloudmesh-common
[?25l  Downloading https://files.pythonhosted.org/packages/42/72/3c4aabce294273db9819be4a0a350f506d2b50c19b7177fb6cfe1cbb
[K     |████████████████████████████████| 61kB 4.1MB/s
[?25hRequirement already satisfied: future in /usr/local/lib/python3.6/dist-packages (from cloudmesh-common) (0.16.0)
Collecting pathlib2 (from cloudmesh-common)
  Downloading https://files.pythonhosted.org/packages/e9/45/9c82d3666af4ef9f221cbb954e1d77ddbb513faf552aea6df5f37f1a4859/
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.6/dist-packages (from cloudmesh-common) (2.5.3)
Collecting simplejson (from cloudmesh-common)
[?25l  Downloading https://files.pythonhosted.org/packages/e3/24/c35fb1c1c315fc0fffe61ea00d3f88e85469004713dab488dee4f35b
[K     |████████████████████████████████| 81kB 10.6MB/s
[?25hCollecting python-hostlist (from cloudmesh-common)
  Downloading https://files.pythonhosted.org/packages/3d/0f/1846a7a0bdd5d890b6c07f34be89d1571a6addbe59efe59b7b0777e44924/
Requirement already satisfied: pathlib in /usr/local/lib/python3.6/dist-packages (from cloudmesh-common) (1.0.1)
Collecting colorama (from cloudmesh-common)
  Downloading https://files.pythonhosted.org/packages/4f/a6/728666f39bfff1719fc94c481890b2106837da9318031f71a8424b662e12/
Collecting oyaml (from cloudmesh-common)
  Downloading https://files.pythonhosted.org/packages/00/37/ec89398d3163f8f63d892328730e04b3a10927e3780af25baf1ec74f880f/
Requirement already satisfied: humanize in /usr/local/lib/python3.6/dist-packages (from cloudmesh-common) (0.5.1)
Requirement already satisfied: psutil in /usr/local/lib/python3.6/dist-packages (from cloudmesh-common) (5.4.8)
Requirement already satisfied: six in /usr/local/lib/python3.6/dist-packages (from pathlib2->cloudmesh-common) (1.12.0)
Requirement already satisfied: pyyaml in /usr/local/lib/python3.6/dist-packages (from oyaml->cloudmesh-common) (3.13)
Building wheels for collected packages: simplejson, python-hostlist
  Building wheel for simplejson (setup.py) ... [?25l[?25hdone
  Created wheel for simplejson: filename=simplejson-3.16.0-cp36-cp36m-linux_x86_64.whl size=114018 sha256=a6f35adb86819ff
  Stored in directory: /root/.cache/pip/wheels/5d/1a/1e/0350bb3df3e74215cd91325344cc86c2c691f5306eb4d22c77
  Building wheel for python-hostlist (setup.py) ... [?25l[?25hdone
  Created wheel for python-hostlist: filename=python_hostlist-1.18-cp36-none-any.whl size=38517 sha256=71fbb29433b52fab62
  Stored in directory: /root/.cache/pip/wheels/56/db/1d/b28216dccd982a983d8da66572c497d6a2e485eba7c4d6cba3
Successfully built simplejson python-hostlist
Installing collected packages: pathlib2, simplejson, python-hostlist, colorama, oyaml, cloudmesh-common
Successfully installed cloudmesh-common-4.2.13 colorama-0.4.1 oyaml-0.9 pathlib2-2.3.5 python-hostlist-1.18 simplejson-3.
```

In this lesson we discuss in how to create a simple IPython Notebook to solve an image classification problem. MNIST contains a set of pictures

```
! python3 --version
```

```
Python 3.6.8
```

```
! pip install tensorflow-gpu==1.14.0
```

```
Collecting tensorflow-gpu==1.14.0
[?25l  Downloading https://files.pythonhosted.org/packages/76/04/43153bfdfcf6c9a4c38ecdb971ca9a75b9a791bb69a764d652c359ac
[K     |████████████████████████████████| 377.0MB 77kB/s
[?25hRequirement already satisfied: six>=1.10.0 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (
Requirement already satisfied: grpcio>=1.8.6 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (1.1
Requirement already satisfied: protobuf>=3.6.1 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (3
Requirement already satisfied: keras-applications>=1.0.6 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==
Requirement already satisfied: gast>=0.2.0 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (0.2.2
Requirement already satisfied: astor>=0.6.0 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (0.8.
Requirement already satisfied: absl-py>=0.7.0 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (0.
Requirement already satisfied: wrapt>=1.11.1 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (1.1
Requirement already satisfied: wheel>=0.26 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (0.33.
Requirement already satisfied: tensorflow-estimator<1.15.0rc0,>=1.14.0rc0 in /usr/local/lib/python3.6/dist-packages (from
Requirement already satisfied: tensorboard<1.15.0,>=1.14.0 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu
Requirement already satisfied: numpy<2.0,>=1.14.5 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0)
Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0) (
Requirement already satisfied: keras-preprocessing>=1.0.5 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu=
Requirement already satisfied: google-pasta>=0.1.6 in /usr/local/lib/python3.6/dist-packages (from tensorflow-gpu==1.14.0
Requirement already satisfied: setuptools in /usr/local/lib/python3.6/dist-packages (from protobuf>=3.6.1->tensorflow-gpu
Requirement already satisfied: h5py in /usr/local/lib/python3.6/dist-packages (from keras-applications>=1.0.6->tensorflow
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.6/dist-packages (from tensorboard<1.15.0,>=1.14.
Requirement already satisfied: werkzeug>=0.11.15 in /usr/local/lib/python3.6/dist-packages (from tensorboard<1.15.0,>=1.1
Installing collected packages: tensorflow-gpu
Successfully installed tensorflow-gpu-1.14.0
```

7.1.3 Import Libraries

Note: https://python-future.org/quickstart.html

```
from __future__ import absolute_import
from __future__ import division
from __future__ import print_function

import time

import numpy as np
from keras.models import Sequential
from keras.layers import Dense, Activation, Dropout
from keras.utils import to_categorical, plot_model
from keras.datasets import mnist

from cloudmesh.common.StopWatch import StopWatch
```

```
Using TensorFlow backend.
```

7.1.4 Pre-process data

7.1.4.1 Load data

First we load the data from the inbuilt mnist dataset from Keras

```
StopWatch.start("data-load")
(x_train, y_train), (x_test, y_test) = mnist.load_data()
StopWatch.stop("data-load")
```

```
Downloading data from https://s3.amazonaws.com/img-datasets/mnist.npz
11493376/11490434 [==============================] - 1s 0us/step
```

7.1.4.2 Identify Number of Classes

As this is a number classification problem. We need to know how many classes are there. So we'll count the number of unique labels.

```
num_labels = len(np.unique(y_train))
```

7.1.4.3 Convert Labels To One-Hot Vector

|Exercise MNIST_V1.0.0: Understand what is an one-hot vector?

```
y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
```

7.1.5 Image Reshaping

The training model is designed by considering the data as a vector. This is a model dependent modification. Here we assume the image is a squared shape image.

```
image_size = x_train.shape[1]
input_size = image_size * image_size
```

7.1.6 Resize and Normalize

The next step is to continue the reshaping to a fit into a vector and normalize the data. Image values are from 0 - 255, so an easy way to normalize is to divide by the maximum value.

|Execrcise MNIST_V1.0.1: Suggest another way to normalize the data preserving the accuracy or improving the accuracy.

```
x_train = np.reshape(x_train, [-1, input_size])
x_train = x_train.astype('float32') / 255
x_test = np.reshape(x_test, [-1, input_size])
x_test = x_test.astype('float32') / 255
```

7.1.7 Create a Keras Model

Keras is a neural network library. Most important thing with Keras is the way we design the neural network.

In this model we have a couple of ideas to understand.

|Exercise MNIST_V1.1.0: Find out what is a dense layer?

A simple model can be initiated by using an **Sequential** instance in Keras. For this instance we add a single layer.

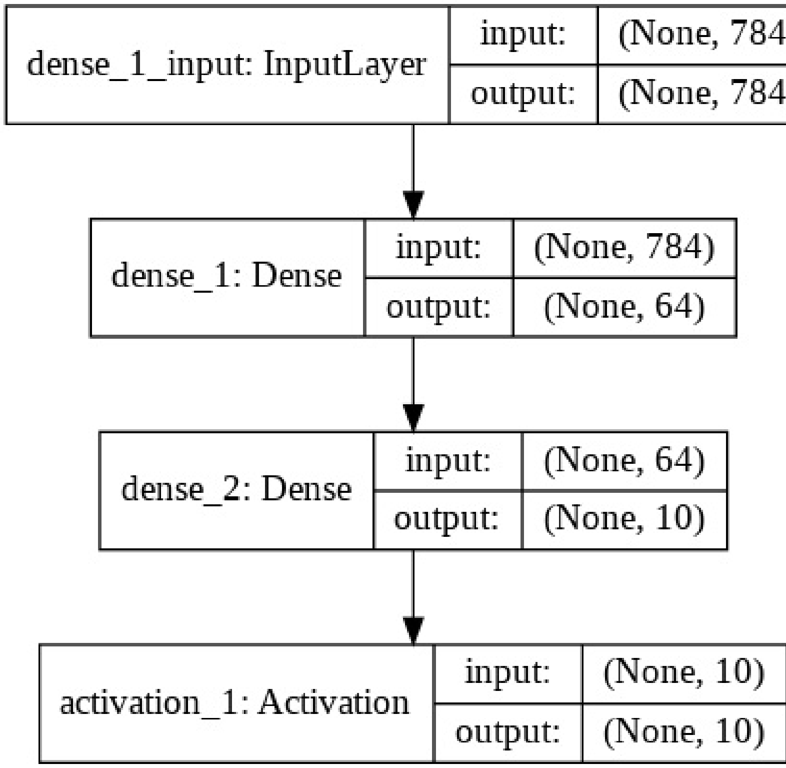
1. Dense Layer
2. Activation Layer (Softmax is the activation function)

Dense layer and the layer followed by it is fully connected. For instance the number of hidden units used here is 64 and the following layer is a dense layer followed by an activation layer.

|Execrcise MNIST_V1.2.0: Find out what is the use of an activation function. Find out why, softmax was used as the last layer.

```
batch_size = 4
hidden_units = 64

model = Sequential()
model.add(Dense(hidden_units, input_dim=input_size))
model.add(Dense(num_labels))
model.add(Activation('softmax'))
model.summary()
plot_model(model, to_file='mnist_v1.png', show_shapes=True)
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:66: The name tf.get_de

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:541: The name tf.place

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4432: The name tf.ranc

Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_1 (Dense)              (None, 64)                50240
_________________________________________________________________
dense_2 (Dense)              (None, 10)                650
_________________________________________________________________
activation_1 (Activation)    (None, 10)                0
=================================================================
Total params: 50,890
Trainable params: 50,890
Non-trainable params: 0
_________________________________________________________________
```



images

7.1.8 Compile and Train

A keras model need to be compiled before it can be used to train the model. In the compile function, you can provide the optimization that you want to add, metrics you expect and the type of loss function you need to use.

Here we use the adam optimizer, a famous optimizer used in neural networks.

Exercise MNIST_V1.3.0: Find 3 other optimizers used on neural networks.

The loss funtion we have used is the categorical_crossentropy.

Exercise MNIST_V1.4.0: Find other loss functions provided in keras. Your answer can limit to 1 or more.

Once the model is compiled, then the fit function is called upon passing the number of epochs, traing data and batch size.

The batch size determines the number of elements used per minibatch in optimizing the function.

Note: Change the number of epochs, batch size and see what happens.

Exercise MNIST_V1.5.0: Figure out a way to plot the loss function value. You can use any method you like.

```
StopWatch.start("compile")
model.compile(loss='categorical_crossentropy',
              optimizer='adam',
              metrics=['accuracy'])
StopWatch.stop("compile")
StopWatch.start("train")
model.fit(x_train, y_train, epochs=1, batch_size=batch_size)
StopWatch.stop("train")
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name tf.train.Optimizer is de

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3576: The name tf.log

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/ops/math_grad.py:1250: add_dispatch_supp
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:1033: The name tf.assi

Epoch 1/1
60000/60000 [==============================] - 20s 336us/step - loss: 0.3717 - acc: 0.8934
```

7.1.9 Testing

Now we can test the trained model. Use the evaluate function by passing test data and batch size and the accuracy and the loss value can be retrieved.

Exercise MNIST_V1.6.0: Try to optimize the network by changing the number of epochs, batch size and record the best accuracy that you can gain

```
StopWatch.start("test")
loss, acc = model.evaluate(x_test, y_test, batch_size=batch_size)
print("\nTest accuracy: %.1f%%" % (100.0 * acc))
StopWatch.stop("test")
```

```
10000/10000 [==============================] - 1s 138us/step

Test accuracy: 91.0%
```

```
StopWatch.benchmark()
```

```
+---------------------+------------------------------------------------------------------+
| Machine Attribute   | Value                                                            |
+---------------------+------------------------------------------------------------------+
| BUG_REPORT_URL      | "https://bugs.launchpad.net/ubuntu/"                             |
| DISTRIB_CODENAME    | bionic                                                           |
| DISTRIB_DESCRIPTION | "Ubuntu 18.04.3 LTS"                                             |
| DISTRIB_ID          | Ubuntu                                                           |
| DISTRIB_RELEASE     | 18.04                                                            |
| HOME_URL            | "https://www.ubuntu.com/"                                        |
| ID                  | ubuntu                                                           |
| ID_LIKE             | debian                                                           |
```

```
| NAME                 | "Ubuntu"                                                           |
| PRETTY_NAME          | "Ubuntu 18.04.3 LTS"                                               |
| PRIVACY_POLICY_URL   | "https://www.ubuntu.com/legal/terms-and-policies/privacy-policy"  |
| SUPPORT_URL          | "https://help.ubuntu.com/"                                         |
| UBUNTU_CODENAME      | bionic                                                             |
| VERSION              | "18.04.3 LTS (Bionic Beaver)"                                      |
| VERSION_CODENAME     | bionic                                                             |
| VERSION_ID           | "18.04"                                                            |
| cpu_count            | 2                                                                  |
| mac_version          |                                                                    |
| machine              | ('x86_64',)                                                        |
| mem_active           | 973.8 MiB                                                          |
| mem_available        | 11.7 GiB                                                           |
| mem_free             | 5.1 GiB                                                            |
| mem_inactive         | 6.3 GiB                                                            |
| mem_percent          | 8.3%                                                               |
| mem_total            | 12.7 GiB                                                           |
| mem_used             | 877.3 MiB                                                          |
| node                 | ('8281485b0a16',)                                                  |
| platform             | Linux-4.14.137+-x86_64-with-Ubuntu-18.04-bionic                    |
| processor            | ('x86_64',)                                                        |
| processors           | Linux                                                              |
| python               | 3.6.8 (default, Jan 14 2019, 11:02:34)                             |
|                      | [GCC 8.0.1 20180414 (experimental) [trunk revision 259383]]        |
| release              | ('4.14.137+',)                                                     |
| sys                  | linux                                                              |
| system               | Linux                                                              |
| user                 |                                                                    |
| version              | #1 SMP Thu Aug 8 02:47:02 PDT 2019                                 |
| win_version          |                                                                    |
+----------------------+--------------------------------------------------------------------+
+-----------+-------+---------------------+-----+-------------------+------+--------+-------------+-------------+
| timer     | time  | start               | tag | node              | user | system | mac_version | win_version |
+-----------+-------+---------------------+-----+-------------------+------+--------+-------------+-------------+
| data-load | 1.335 | 2019-09-27 13:37:41 |     | ('8281485b0a16',) |      | Linux  |             |             |
| compile   | 0.047 | 2019-09-27 13:37:43 |     | ('8281485b0a16',) |      | Linux  |             |             |
| train     | 20.58 | 2019-09-27 13:37:43 |     | ('8281485b0a16',) |      | Linux  |             |             |
| test      | 1.393 | 2019-09-27 13:38:03 |     | ('8281485b0a16',) |      | Linux  |             |             |
+-----------+-------+---------------------+-----+-------------------+------+--------+-------------+-------------+

timer,time,starttag,node,user,system,mac_version,win_version
data-load,1.335,None,('8281485b0a16',),,Linux,,
compile,0.047,None,('8281485b0a16',),,Linux,,
train,20.58,None,('8281485b0a16',),,Linux,,
test,1.393,None,('8281485b0a16',),,Linux,,
```

7.1.10 Final Note

This programme can be defined as a hello world programme in deep learning. Objective of this exercise is not to teach you the depths of deep learning. But to teach you basic concepts that may need to design a simple network to solve a problem. Before running the whole code, read all the instructions before a code section. Solve all the problems noted in bold text with Exercise keyword (Exercise MNIST_V1.0 - MNIST_V1.6). Write your answers and submit a PDF by following the **Assignment 5**. Include codes or observations you made on those sections.

7.1.10.1 Reference:

[Mnist Database]

Advanced Deep Learning Models

Minist Deep Learning

8 ASSIGNMENTS

8.1 Assignments

Due dates are on Canvas. Click on the links to checkout the assignment pages.

8.2 WEEKLY ASSIGNMENTS

8.2.1 Assignment 1

In the first assignment you will be writing a technical document on the current technology trends that you're pursuing and the trends that you would like to follow. In addition to this include some information about your background in programming and some projects that you have done. There is no strict format for this one, but we expect 2 page written document. Please submit a PDF.

Go to Canvas

8.2.2 Assignment 2

In the second assignment, you will be working on Week 1 (see Section 2.1) lecture videos. Objectives are as follows.

1. Summarize what you have understood. (2 page)
2. Select a subtopic that you are interested in and research on the current trends (1 page)
3. Suggest ideas that could improve the existing work (imaginations and possibilities) (1 page)

For this assignment we expect a 4 page document. You can use a single column format for this document. Make sure you write exactly 4 pages. For your research section make sure you add citations to the sections that you are going to refer. If you have issues in how to do citations you can reach a TA to learn how to do that. We will try to include some chapters on how to do this in our handbook. Submissions are in pdf format only.

Go to Canvas

8.2.3 Assignment 3 ☁

In the third assignment, you will be working on (see Section 4.1) lecture videos. Objectives are as follows.

1. Summarize what you have understood. (2 page)
2. Select a subtopic that you are interested in and research on the current trends (1 page)
3. Suggest ideas that could improve the existing work (imaginations and possibilities) (1 page)

For this assignment we expect a 4 page document. You can use a single column format for this document. Make sure you write exactly 4 pages. For your research section make sure you add citations to the sections that you are going to refer. If you have issues in how to do citations you can reach a TA to learn how to do that. We will try to include some chapters on how to do this in our handbook. Submissions are in pdf format only.

Go to Canvas

8.2.4 Assignment 4 ☁

In the fourth assignment, you will be working on (see Section 5.1) lecture videos. Objectives are as follows.

1. Summarize what you have understood. (2 page)
2. Select a subtopic that you are interested in and research on the current trends (1 page)
3. Suggest ideas that could improve the existing work (imaginations and possibilities) (1 page)

For this assignment we expect a 4 page document. You can use a single column format for this document. Make sure you write exactly 4 pages. For your research section make sure you add citations to the sections that you are going to refer. If you have issues in how to do citations you can reach a TA to learn how to do that. We will try to include some chapters on how to do this in our handbook. Submissions are in pdf format only.

Go to Canvas

8.2.5 Assignment 5

In the fifth assignment, you will be working on (see Section 7.1) lecture videos. Objectives are as follows.

Run the given sample code and try to answer the questions under the exercise tag.

Follow the Exercises labelled from **MNIST_V1.0.0 - MNIST_V1.6.0**

For this assignment all you have to do is just answer all the questions. You can use a single column format for this document. Submissions are in pdf format only.

Go to Canvas

9 GITHUB

9.1 Track Progress with Github

We will be adding git issues for all the assignments provided in the class. This way you can also keep a track on the items need to be completed. It is like a todo list. You can check things once you complete it. This way you can easily track what you need to do and you can comment on the issue to report the questions you have. This is an experimental idea we are trying in the class. Hope this helps to manage your work load efficiently.

9.1.1 How to check this?

All you have to do is go to your git repository.

Here are the steps to use this tool effectively.

9.1.1.1 Step 1

Go to the repo. Here we use a sample repo.

Sample Repo

Link to your repo will be https://github.com/cloudmesh-community/fa19-{class-id}-{hid}

class-id is your class number for instance 534. hid is your homework id assigned.

9.1.1.2 Step 2

In Figure 1 the red colored box shows where you need to navigate next. Click on issues.

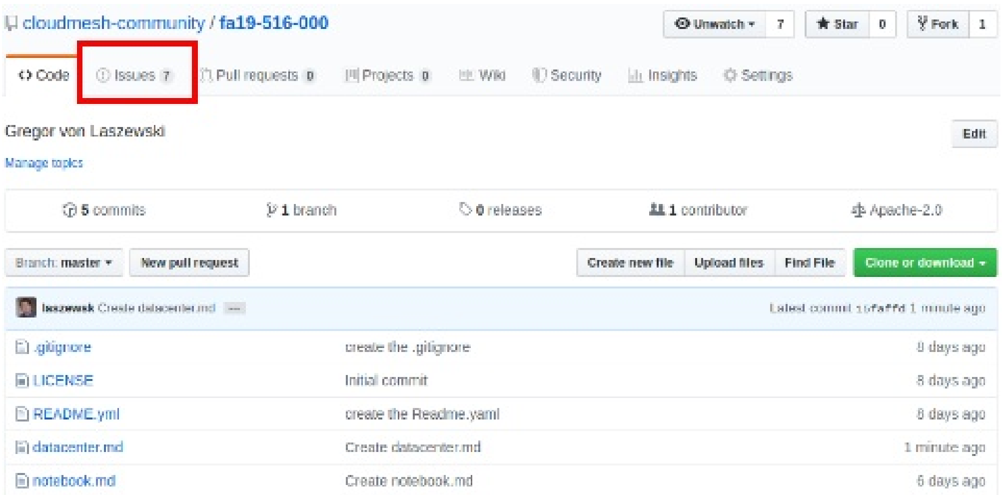


Figure 1: Git Repo View

9.1.1.3 Step 3

In Figure 2, Git issue list looks like this. The inputs in this are dummy values we used to test the module. In your repo, things will be readable and identified based on week. This way you know what you need to do this week.

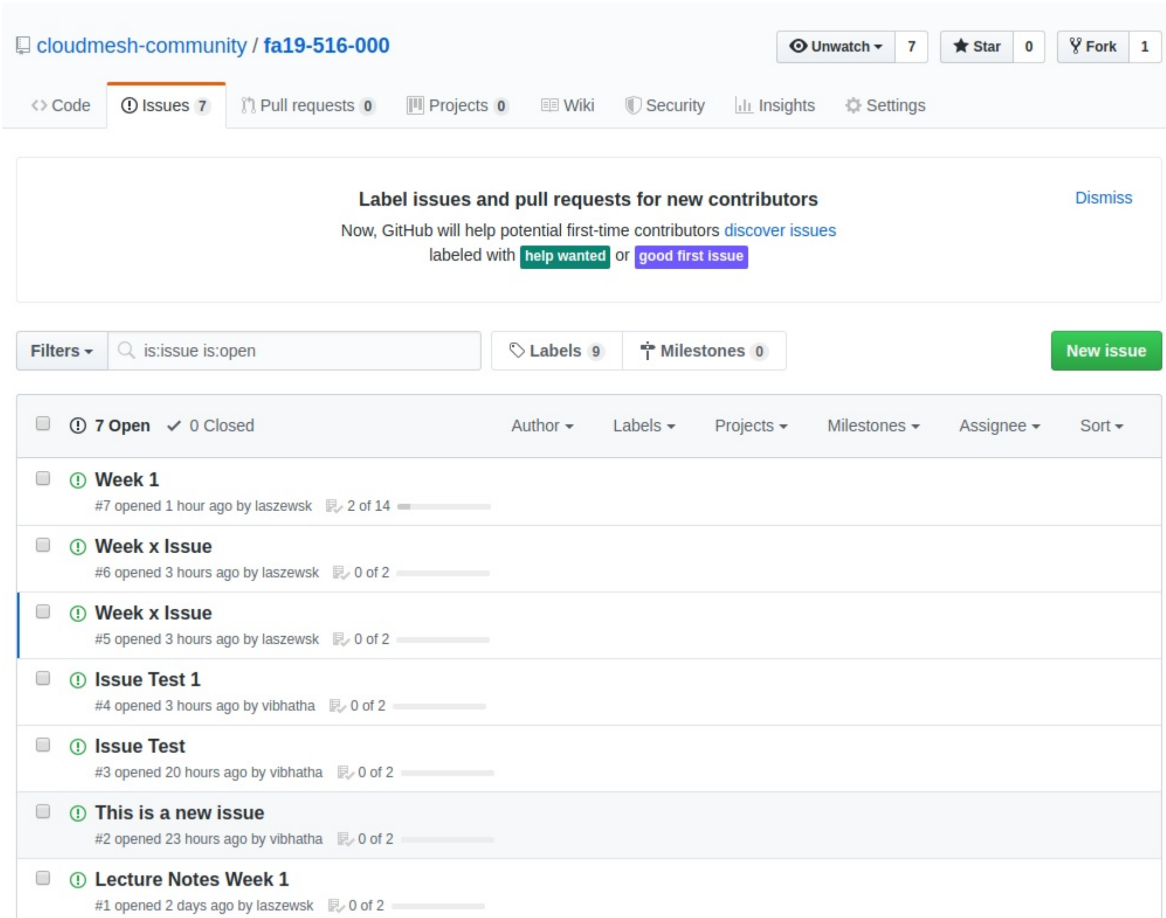


Figure 2: Git Issue List

9.1.1.4 Step 4

In Figure 3 this is how a git issue looks like.

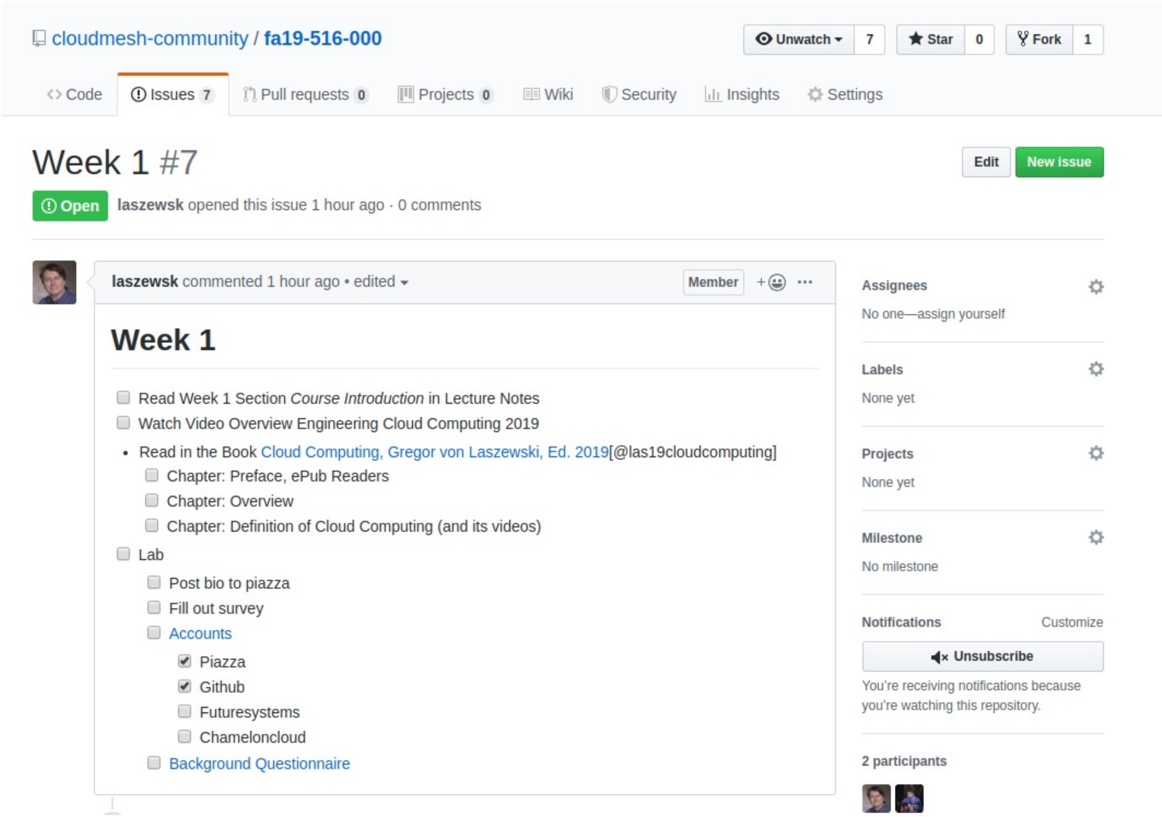


Figure 3: Git Issue View

In here you will see the things that you need to do with main task and subtasks. This looks like a tood list. No pressure you can customize the way you want it. We'll put in the basic skeleton for this one.

9.1.1.5 Step 5 (Optional)

In Figure 4, assign a TA, once you have completed the issues, you can assign a TA to resolve if you have issues. In all issues you can make a comment and you can use @ sign to add the specific TA. For E534 Fall 2019 you can add **???** as an assignee for your issue and we will communicate to solve the issues. This is an optional thing, you can use canvas or meeting hours to mention your concerns.

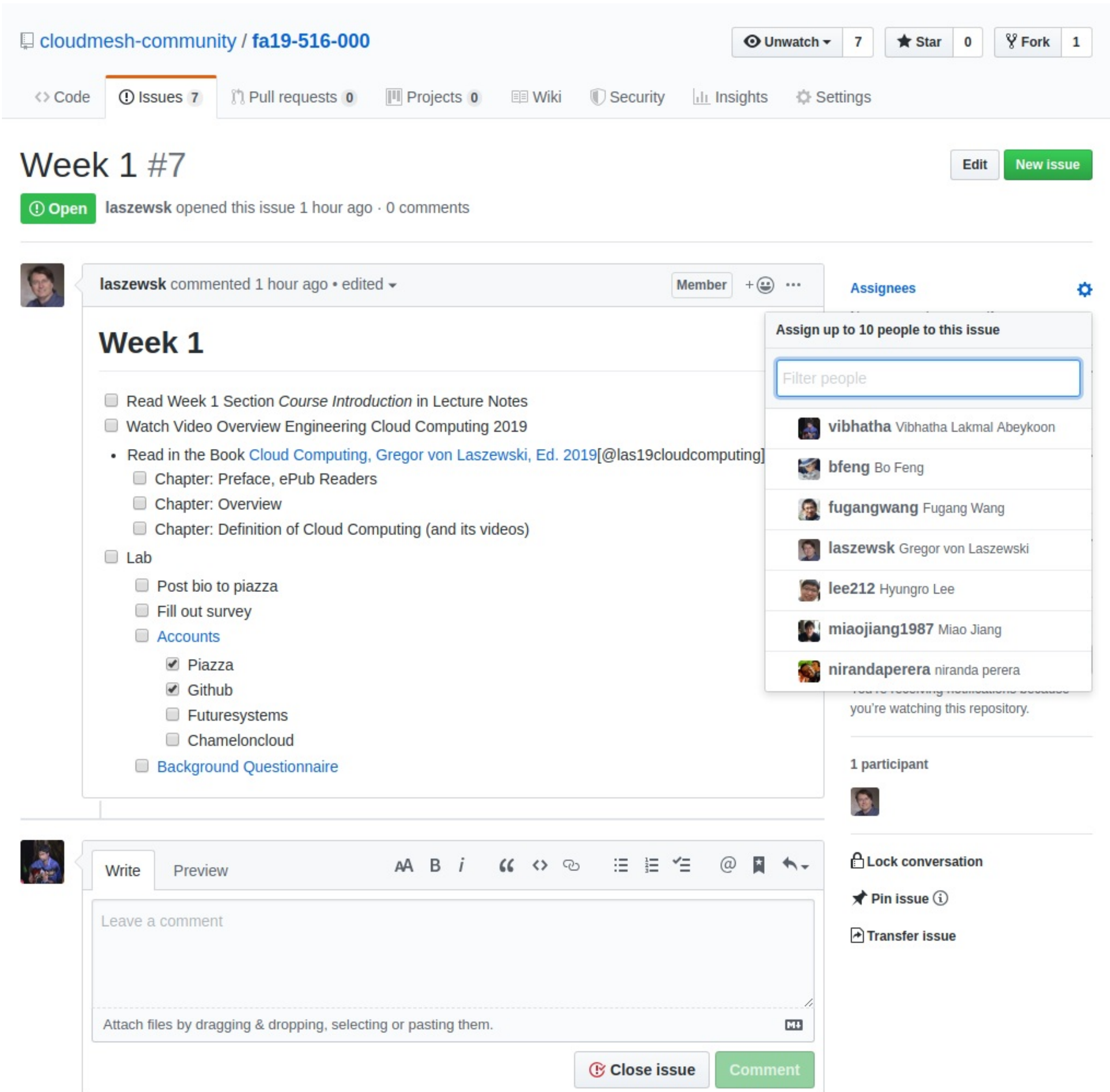


Figure 4: Git Issue View

9.1.1.6 Step 6 (Optional)

In Figure 5, you can add a label to your issue by clicking labels option in the right hand size within a given issue.

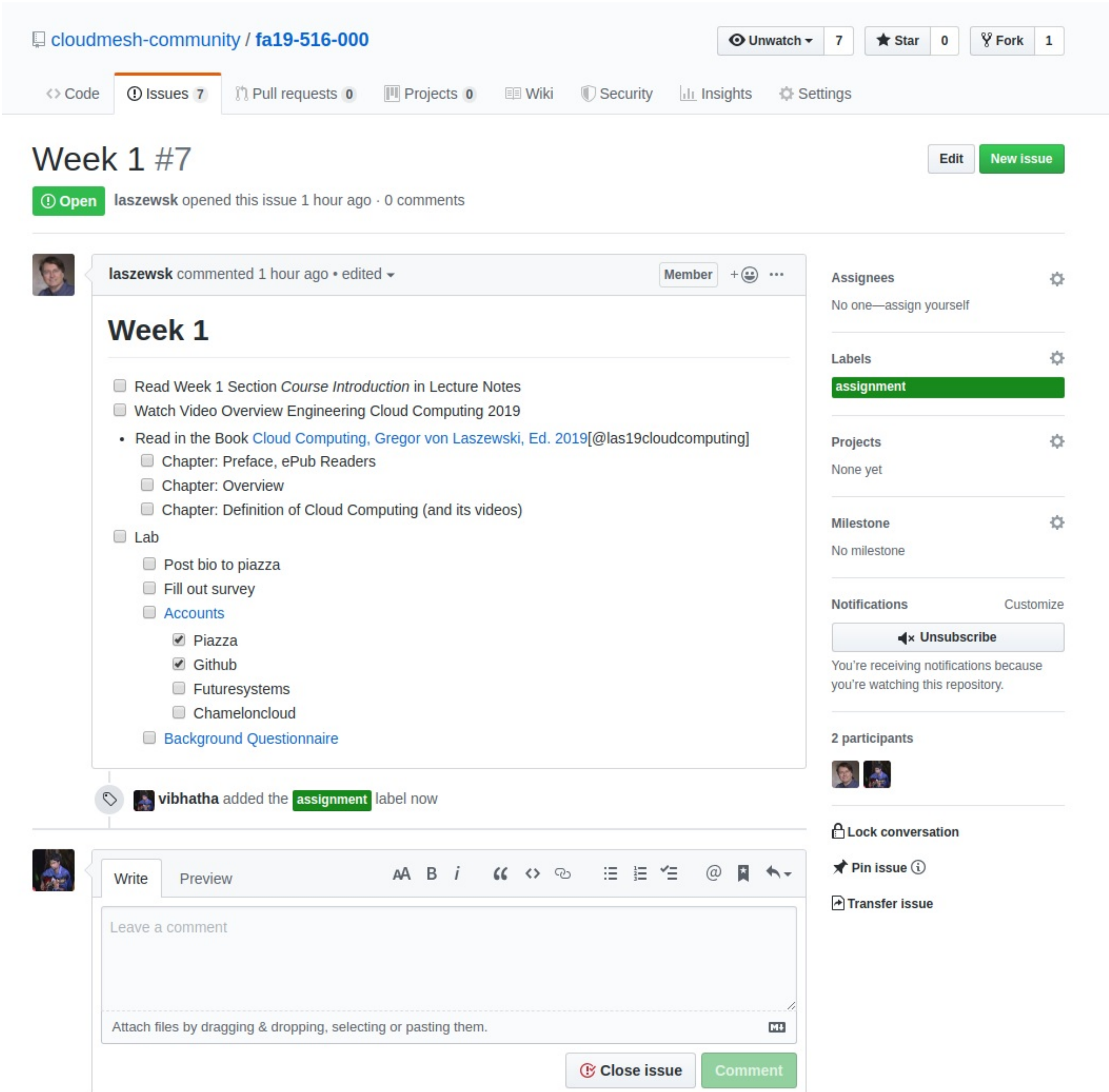


Figure 5: Git Issue Label

10 REFERENCES