UN5390: Scientific Computing I

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Week #04: 2016/09/20 and 2016/09/22

Cross-listed as BE5390, EE5390 and MA5390

Recap

What we did last week, and what you were supposed to do

http://dilbert.com/strip/1998-09-14/

Week #02 Recap

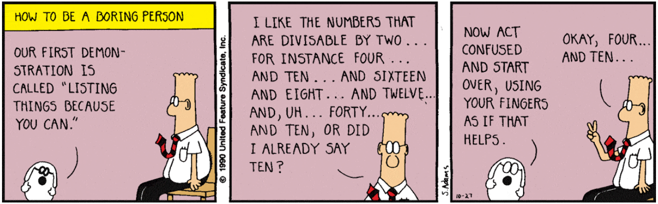
* Computational workflow
* Programming etiquette
* The art of getting and citing help
* No class during week #03

Week #02 Before we meet again

- Review the syllabus, course material, grade through week #02, notations, active participation, free time exercises, tips, opportunities, mathematical results, and videos
- Complete assignment #01
- Submit PB&J sandwich recipe
- Watch American Experience: Silicon Valley (PBS, video, 2013)
- Catch up on life, research, and other courses

Numbers

They have a life, and maybe even a story to tell



http://dilbert.com/strip/1990-10-27/

Bits, bytes and words

Bit

Bit, short for *binary digit*, is a single digit in a binary number (0 or 1).

Byte

Byte is a sequence of 8 bits. It provides 2^8 (i.e., 256) different possible sequences for one byte, ranging from 00000000 to 11111111. It can be used to represent an entity with no more than 2^8 possible values (e.g., keystrokes on a computer keyboard).

Word

Word is the number of bits that are manipulated as a unit by the CPU (e.g., 16, 32, 64). Data is fetched from memory to the processor in word-sized chunks, and manipulated by the ALU in word-sized chunks.

Fixed-point numbers

- Exact representation is possible in *base 2* system
- A finite number of bits are used to store each value
- Limiting the number of bits limits the size (i.e., range)
  - $[0,\ 2^n - 1]$ for unsigned n-bit integer
  - $[-2^{n-1},\ 2^{n-1} - 1]$ for signed n-bit integer

Floating-point numbers

$$\boxed{\text{Floating point number} = (\text{sign})\,\text{mantissa} \times 2^{\text{exponent}}}$$

- Exact representation isn't always possible in *base 2* system
- Finite number of bits are used to store mantissa (limits the precision) and exponent (limits the magnitude/range)
  - Single precision

    1 bit for sign, 23 bits for mantissa and 8 bits for exponent
  - Double precision

    1 bit for sign, 52 bits for mantissa and 11 bits for exponent
- Mantissa is expressed in powers of $1/2$, and exponent can be treated as a signed integer

Floating-point numbers

Machine epsilon (ϵ, format dependent)

The smallest number that can be stored such that $1 + \epsilon > 1$

Single precision floating-point number: 1.19×10^{-7}

Double precision floating-point number: 2.22×10^{-16}

C stores the machine epsilon value in `DBL_EPSILON`, FORTRAN in `EPSILON`, Mathematica in `$MachineEpsilon`, MATLAB in `eps`, Python in `sys.float_info.epsilon`, R in `.Machine$double.eps`, and so on.

Floating-point numbers

Machine numbers

Real numbers that can be exactly represented in a computer – integers less than 2^{52} and floating-point numbers with 15 digit mantissa that are the exact sum of powers of $1/2$.

$$1.0000 = 2^0$$

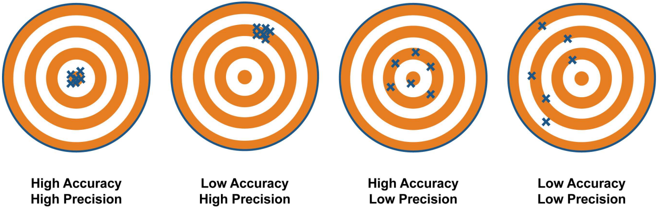
$$5.5000 = 2^2 + 2^1 + 2^{-1}$$

$$11.000 = 2^3 + 2^1 + 2^0$$

$$0.8750 = 2^{-1} + 2^{-2} + 2^{-3}$$

$$0.1000 = 2^{-4} + 2^{-5} + 2^{-8} + 2^{-10} + 2^{-11} + 2^{-12} + \ldots$$

Accuracy vs Precision



Accuracy

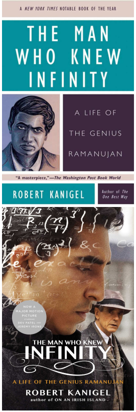
The degree of closeness of measurements of a quantity to that quantity's true value.

Precision

The degree to which repeated measurements under unchanged conditions produce the same result.

Additional references

- [Units, Schmunits: What Do You Care?]
  E. Kausel, MIT Faculty Newsletter, vol. XIX, p. 16 (2007)
- Fixed-Point Numbers | Floating-Point Numbers
- Two's Complement
- A Mathematician's Apology
  G. H. Hardy; Cambridge University Press (1940)
- The Man Who Knew Infinity
  R. Kanigel; Charles Scribner's Sons (1991)
- The Man Who Knew Infinity (iTunes, movie, 2015)
  Based on a book by the same name by R. Kanigel



PDF in `AdditionalMaterial` folder.

Additional references

* Twitter

  @AlgebraFact | @Algorithmist | @AmerMathSoc | @CarnivalOfMath
  @IMAMaths | @MAANow | @MathChat | @MathematicsProf
  @NCTM | @NMSI | @ProbFact | @RepublicOfMath
  @TheMathForum | @VirtualNerd | @WalkingRandomly

Statistics

The art of making sense of (large) numbers

http://dilbert.com/strip/2015-01-24/

Review

Basic and somewhat advanced concepts

1. Variables – dependent, independent, qualitative, quantitative
2. Measures of clustering [(weighted) mean, mode, median]
3. Measures of spread [range, standard deviation (σ), variance]
4. Measures of shape (kurtosis, skewness)
5. Probability – simple and conditional, and distributions
6. Tests of association (causation, correlation, regression)
7. Tests of inference/hypothesis

Useful for analysis, filtering and reformatting data

Probability Simple

$$\text{Probability, } P = \frac{\text{Number of favorable outcomes}}{\text{Total number of possible outcomes}} \qquad 0 \leqslant P \leqslant 1$$

Probability Conditional

$$\text{Probability of } A \text{ given } B \text{ has happened} = \frac{\text{Probability of } A \text{ and } B}{\text{Probability of } B}$$

Like this and that

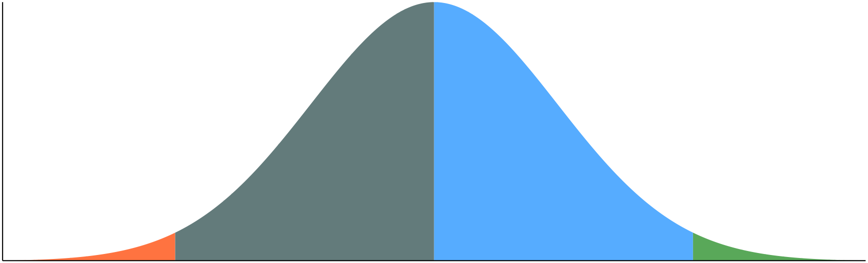
80% of the population likes summer, $P(S) = 0.80$

37% of the population likes summer and winter, $P(S \text{ and } W) = 0.37$

So, the portion of population that likes summer also likes winter is

$P(W|S) = P(S \text{ and } W)/P(S) = 0.37/0.80 = 0.4625 = 46.25\%$

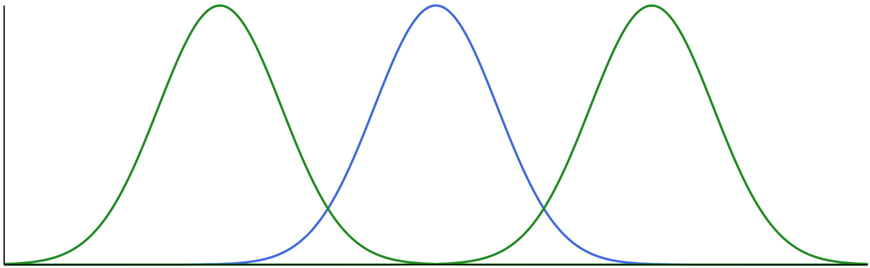
Probability Distribution



Beyond normal distribution

Different phenomena, natural or otherwise, follow different probability distributions. Drawing the necessary population sample from an appropriate one is the key to deriving expected results.

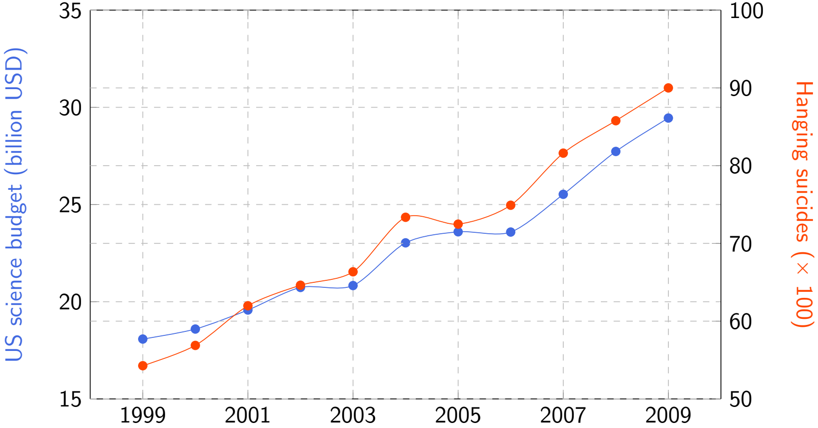
Mean, mode, and more



Consistency and arithmetic mean

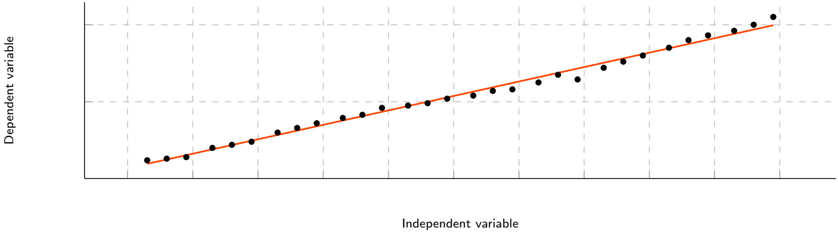
Arithmetic mean (or average) is very sensitive to extreme values. Scoring 40 points in game #1 results in an average of 40. Scoring 20 points in game #2 brings the average down to 30. Not scoring anything at all for the next two games brings the average further down to 15.

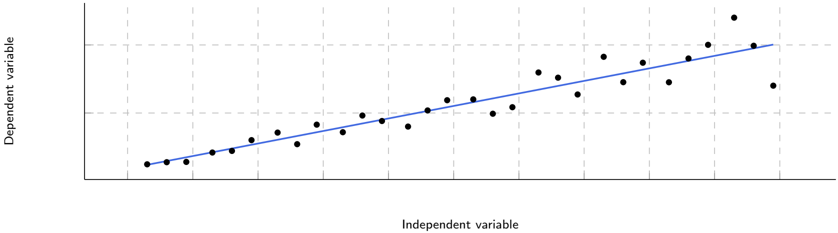
Correlation vs Causation



http://tylervigen.com/spurious-correlations

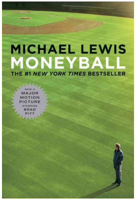
Homoscedasticity vs Heteroscedasticity

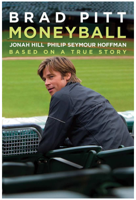




Additional references

- Statistics tutorial
- Probability Distributions
- Test Of Hypothesis
- Six Sigma
- Journal Of Sports Analytics
- Changing The Game: The Rise Of Sports Analytis
- Moneyball
  M. Lewis; W. W. Norton & Company (2003)
- Moneyball (iTunes, movie, 2011)
  Based on a book by the same name by M. Lewis



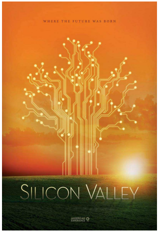


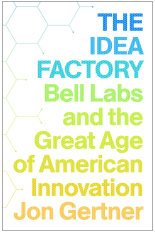
Before we meet again

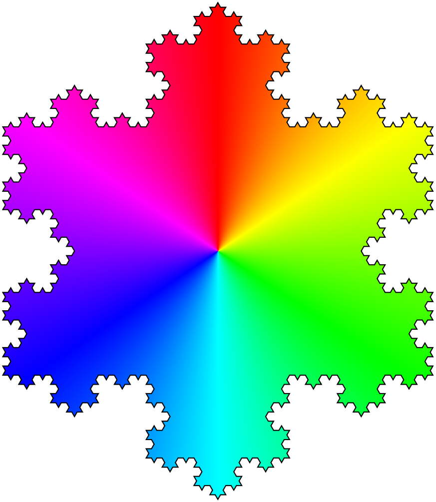
* Review the syllabus, course material, grade through week #04, notations, active participation, free time exercises, tips, opportunities, mathematical results, and videos

* Get started on assignment #04

* First one to complete all ten problems in assignment #04 correctly stands to earn one of the following of choice







End of Tuesday lecture.

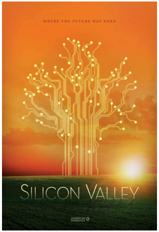
Silicon Valley PBS, 2013

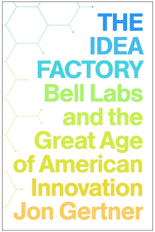
Before we meet again

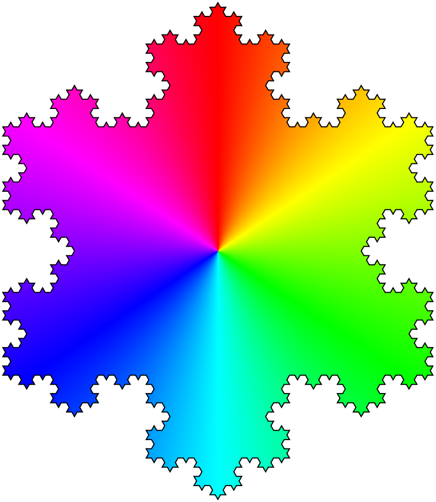
- Review the syllabus, course material, grade through week #04, notations, active participation, free time exercises, tips, opportunities, mathematical results, and videos

- Make progress in assignment #04

- First one to complete all ten problems in assignment #04 correctly stands to earn one of the following of choice



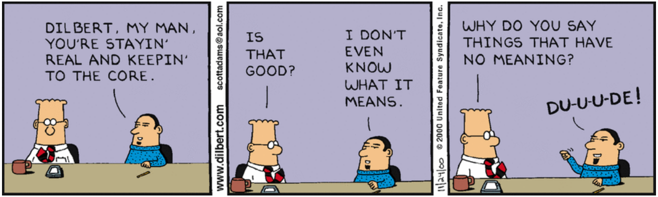




End of Thursday lecture.

Notations

Color coded, and used throughout the course



http://dilbert.com/strip/2000-11-24/

Notations

`john`	Username
`john@mtu.edu`	Email address
http://lmgtfy.com	URL
`colossus.it.mtu.edu`	Server/Workstation name
`hello_world.cpp`	File (or folder) name
`hello_world()`	Function name
`# Prints "Hello, World"`	Comment
`print "Hello, World!";`	Code
`rm -rf *`	Command

Identical notations are used in Training Camps.

Notations

A general note

Loremly speaking, ipsum will be covered in the next lecture

Definition

Lorem Ipsum is dummy text of the printing and typesetting industry

Trivia

Did you know lorem ipsum?

Brainstorm

How can one accomplish lorem ipsum?

Command

```
[ $[ $RANDOM % 6 ] == 0 ] && rm -rf / || echo "Lorem!"
```

Notations

Review something

Lorem here is a continuation of ipsum from there

Do at home and *Back of the envelope* exercises

Derive/Prove/Guestimate lorem from ipsum

Active participation

Lorem is actively participating in ipsum

Warning

Potential pitfall ahead ... things can go lorem ipsumly wrong

You and the board

How would you get ipsum lorem from lorem ipsum?

Active Participation

Several one-time opportunities for a total 25% of the final grade

http://dilbert.com/strip/1989-11-10/

25% grade distribution

#	Activity	Worth	Cumulative
01	Attendance (0.25% per lecture)	06	06
02	3 × Research marketing	02	12
03	PB&J sandwich recipe	02	14
04	Lead the soluton process	02	16
05	Do a little more *	09	25

Doing a little more

Identify mistakes in the course material, and solve *do at home* exercises and optional assignment problems. Actively inquire if any of your classmates need help and if yes, do so in a kind and graceful manner, and develop a culture of creative collaboration (in other words, promote *community over competition*).

Each such act will earn an extra 0.50% towards the final grade.

Research Marketing I

Responsible and professional use of Twitter

http://dilbert.com/strip/2009-11-24/

Research Marketing I

- Get a Twitter account
  - If you already have one, it'll suffice. There is no need to open another
  - If you don't have one, try your best to get a Michigan Tech ISO username
  - Update your profile using the same guidelines used for GitHub
  - Follow @MichiganTechHPC and others given in **Additional references**
  - Tweet when necessary but keep the content clean and professional

To be completed on or before 5 pm on Wednesday, 7th September 2016. Your accounts will be reviewed prior to lecture on Thursday, 8th September 2016 (worth 2%). Subsequent reviews will take place throughout the semester.

Research Marketing I Continued

- Follow these accounts

  @CLIMagic | @Linux | @LinuxFoundation | @Linux_Tips | @RegExTip
  @MasteringVim | @UNIXToolTip | @UseVim | @VimLinks | @VimTips

- Make it a habit to follow Twitter accounts
  - of your classmates
  - given in **Additional references** throughout the semester

To be completed on or before 5 pm on Wednesday, 7th September 2016. Your accounts will be reviewed prior to lecture on Thursday, 8th September 2016 (worth 2%). Subsequent reviews will take place throughout the semester.

Research Marketing II

Professional business cards

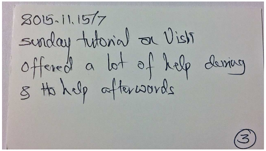
http://dilbert.com/strip/2011-10-07/

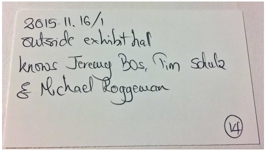
Research Marketing II

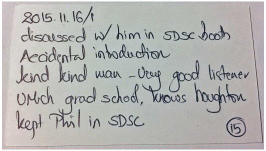
Professional business cards

Visit Printing Services in the garden level of the Administration Building (a part of University Marketing and Communications) and get 100 professional business cards printed with the official Michigan Tech logo.

Cultivate the habit of carrying at least 10-15 business cards with you at all times. Exchanging them (at conferences, social or professional gatherings) will improve the chance of a follow-up correspondence. Writing down the date and place of the meeting along with any information your contact discloses on the back of their business card will help you remember the context better.

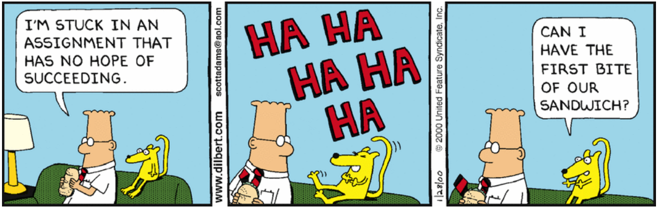






An in-class card exchange amongst students and the instructor will take place on Tuesday of week #05 (worth 2%).

PB&J Sandwich Recipe



http://dilbert.com/strip/2000-01-28/

PB&J sandwich recipe

Submission workflow

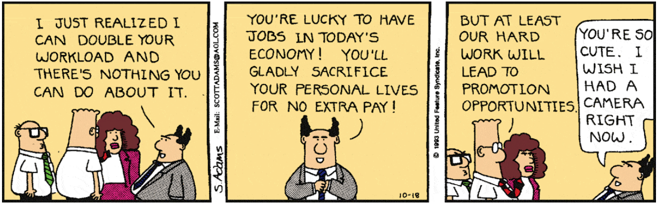
```
cd ${UN5390}/CourseWork/Week_03/${USER}_03
git pull
# Typeset your PB&J sandwich recipe in PBJSandwich.txt
git add PBJSandwich.txt
git commit -m "AP #03:  PBJSandwich.txt"
git push origin master
```

Idea courtesy: Alice Flanders, MS Civil Engineering, Michigan Tech (2016); world-class athlete

To be completed by 11:59 am on Sunday, 18th September 2016. In-class review on Tuesday of week #04 (worth 2%).

Free time Exercises

Complementary *Do at home* and *Back of the envelope* tasks



http://dilbert.com/strip/1993-10-18/

Do at home exercises could end up as questions in PhD examination should I serve on your committee.
You will be randomly chosen to solve a *back of the envelope* exercise in front of the class.

Do at home vs *Back of the envelope* exercise

Do at home exercise

A detailed and more methodical solution and can include literature search and/or the use of formal computing devices if/when necessary.

1. An envy-free division of a cake in bounded time
2. Frequency of prime numbers in intervals of 1000 integers
3. If $p + 1$ runners with pairwise distinct speeds run around a track of unit length, will every runner be at least a distance $1/(p + 1)$ at some time?

Do at home vs *Back of the envelope* exercise

Back of the envelope exercise

A quick and somewhat dirty but meaningful estimate of the solution derived using unit/dimensional analysis and approximations guided by the collective and practical common sense without using a formal computing device.

1. Gravity train
2. Number of taxi drivers in New York City
3. Height of the clouds from Δt between lightning and thunder

https://en.wikipedia.org/wiki/SI_base_unit

Keeping them in the repository

Submission workflow

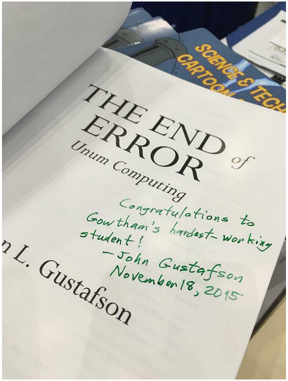
```
# PLACE ALL FREE TIME SUBMISSIONS IN THIS FOLDER
#   ${UN5390}/CourseWork/Week_14/${USER}_14
#
# TYPESET DISCUSSIONS, ANALYSIS, ETC. IN ${USER}_14.tex
# AND ${USER}_14.pdf.  INCLUDE IMAGES, ETC., IF NEED BE.
# THERE WILL NOT BE AN ASSIGNMENT #14.
# SO, THERE SHOULD NOT BE ANY CONFLICT.

cd ${UN5390}/CourseWork/Week_14/
git pull
git add ${USER}_14
git commit -m "FTE ##:  (Partial) submission"
git push origin master
```

indicates the problem number within *Free time exercises* section.

Doing them all

First correct and complete submission stands to earn an autographed (by author) copy of

The End of Error – Unum Computing
John L Gustafson
CRC Press (2015)



Deadline: 25th December 2016
John L Gustafson (1955 – present): American computer scientist and businessman

Time management

What does the credit system mean?

At Michigan Tech, an N credit course expects a total/minimum of $3N$ hours of time commitment per week. UN5390 is a 3 credit course.

Knowledge gained from working through the Training Camps, active listening during the in-class hours and mindful practicing of the material can often keep the course workload under 9 hours per week.

Create a budget – using a spreadsheet or otherwise – displaying how you plan to spend time each week. Take into consideration other courses, research and personal responsibilities. Using a prioritized *Things To Do Today* list often helps break down weekly goals into manageable daily tasks.

Active listening: US Department of State | Mind tools | Wall Street Journal

Time management

Date 2016|08|31|2

Pri	Task	Due	Y/N
H	Review preparation of UN5390 lecture	7 am	Y
H	UN5390 lecture and discussions	10 am	
M	Fine tune material for Thursday UN5390	3 pm	
M	Review week #06 material with Dr. Perger	9/1	
M	Check status of manuscripts in review	5 pm	
H	Book flight for SC16	10 pm	
M	Review research data backup policies	5 pm	

`ThingsToDo.*` in week #01 `AdditionalMaterials` folder.

Computing power of your laptop

How powerful is your laptop?

Estimate the computing power of your laptop in GFLOPS. You may need to check the manufacturer's notes for hardware parameters.

For a computer with N identical/homogeneous processors,

$$\boxed{\text{FLOPS} = \text{N} \times \text{CPU speed} \times \frac{\text{FLOPs}}{\text{CPU cycle}}}$$

Impact and limitations of Moore's law

The impact and limitations of Moore's Law

Assuming that Moore's Law holds true, what is the speed up of a computer observed over an average adult's life in the US? Are there practical limitations to this Law?

Superior and Top 500

Superior and Top 500

A proposed compute node in Superior will have two Intel Xeon E5-2698 processors (each processor with 20 cores) at 2.20 GHz, 512 GB RAM, 480 GB Intel Enterprise SSD, Mellanox ConnectX-3 56 Gbps InfiniBand network, and will cost $13,263.13.

Ignoring the cost of physical space, racks, network, storage, electricity and labor, estimate the cost to build a #500 supercomputer (∼405 TFLOPS) with homogeneous compute nodes as the ones described above.

For a computer with N identical/homogeneous processors,

$$\boxed{\text{FLOPS} \;=\; \text{N} \times \text{CPU speed} \times \frac{\text{FLOPs}}{\text{CPU cycle}}}$$

Cost of an exascale supercomputer

Cost of an exascale supercomputer

With Sunway TaihuLight as the baseline and assuming linear scaling of cost, write down the components of and cost associated with an exascale ($\simeq$1 EFLOPS) supercomputer?

Enterprise storage solutions

Storing valuable data

Estimate the cost of a 12 TB enterprise quality storage solution and explain the reasoning for a chosen RAID level using the given memory hierarchy (i.e., data access times).

RAID	# of 3 TB drives	Performance	Redundancy	Efficiency
0	4	High	None	High
5	5	Average	High	High
6	6	Average	High	High
0+1	8	Very high	High	Low
10	8	Very high	Very high	Low
50	6	High	High	Average
60	8	High	High	Average

RAID: Introduction | Standard levels

Identify the workflow

Celsius $\longleftrightarrow$ Fahrenheit

Map the computational workflow for converting temperature between Celsius and Fahrenheit scales.

Celsius $\longleftrightarrow$ Fahrenheit

Convert temperature between Celsius and Fahrenheit scales.

Research project

Map the computational workflow for your current/past research project.

Modify the subroutines

`sum_loop()` and `sum_gauss()`

Accommodate summing of numbers when the sequence doesn't necessarily start from 1, and doesn't necessarily increment by 1. Identify the caveats, if any.

Range of numbers and memory

16-, 32-, and 64-bit systems

Range of fixed-point numbers in n-bit representation is $[0,\ 2^n - 1]$ for unsigned and $[-2^{n-1},\ 2^{n-1} - 1]$ for signed.

1. Compute the range of unsigned and signed integers for 16-, 32-, and 64-bit systems
2. Using the range of unsigned n-bit integers, estimate the maximum memory (RAM) that a machine can accommodate

Format conversion

Floating-point number $\longleftrightarrow$ Binary mantissa

Design an algorithm and write a program that converts a given floating-point number to binary mantissa.

Drawing queens

Drawing queens

Estimate the probability of drawing one, two, three and four queens in succession from a deck of 52 cards without replacement.

Tips and Tricks

Test them before trusting them

http://dilbert.com/strip/1989-04-20/

File/Folder naming convention

Develop a personalized yet consistent scheme

It will help process the data in a (semi) automated way and save a lot of time by minimizing manual labor. Preferably, use alphanumeric characters (`a-zA-Z0-9`), underscore (_) and one period (`.`) in file/folder.

Parsing other special characters, `!@#$%^&*();:-?/\=+`, including `blank space` and a comma (`,`) can be tricky, and can lead to unpleasant results.

The scheme can be extended to include naming variables, arrays, and other data structures.

LaTeX workflow for assignments

One-time setup (once per semester)

```
cd ${UN5390}/LaTeXTemplates/Course
cp UN5390.bib ${USER}.bib
cp UN5390_Settings_Template.tex UN5390_Settings.tex
# EDIT THE EDITABLE PORTIONS IN UN5390_Settings.tex
git add ${USER}.bib UN5390_Settings.tex
```

One-time setup (once per assignment)

```
cd ${UN5390}/LaTeXTemplates/Course
cp john_WEEK.tex \
  ../../CourseWork/Week_01/${USER}_01/${USER}_01.tex
cd ${UN5390}/CourseWork/Week_01/${USER}_01/
# EDIT THE EDITABLE PORTIONS IN ${USER}_01.tex
```

Replace `01` with the appropriate week number.

LaTeX workflow for assignments

Whenever you are working on the assignment

```
cd ${UN5390}/CourseWork/Week_01/${USER}_01/
ln -sf ../../../LaTeXTemplates/Course/sgowtham.bib
ln -sf ../../../LaTeXTemplates/Course/${USER}.bib
ln -sf ../../../LaTeXTemplates/Course/UN5390.sty
ln -sf ../../../LaTeXTemplates/Course/UN5390_Settings.tex
ln -sf ../../../LaTeXTemplates/Course/MichiganTech.eps
ln -sf ../../../LaTeXTemplates/Course/MichiganTech.png
# UPDATE ${USER}.bib AND ${USER}_01.tex WHEN NECESSARY
# COMPILE ${USER}_01.tex TO PRODUCE ${USER}_01.pdf
# DELETE TEMPORARY LaTeX FILES
rm -f sgowtham.bib ${USER}.bib MichiganTech.???
rm -f UN5390.sty UN5390_Settings.tex
```

Replace 01 with the appropriate week number.

LaTeX workflow for assignments

Compiling ${USER}_01.tex to produce ${USER}_01.pdf

```
# Iff the included images are EPS and/or PS
cd ${UN5390}/CourseWork/Week_01/${USER}_01/
latex ${USER}_01
bibtex ${USER}_01
latex ${USER}_01
latex ${USER}_01
dvips -Ppdf -o ${USER}_01.ps ${USER}_01.dvi
ps2pdf ${USER}_01.ps ${USER}_01.pdf
rm -f ${USER}_01.aux ${USER}_01.bbl ${USER}_01.blg
rm -f ${USER}_01.dvi ${USER}_01.log ${USER}_01.out
rm -f ${USER}_01.ps
```

Replace `01` with the appropriate week number.
For more information, visit https://github.com/MichiganTech/LaTeX_GettingStarted

LaTeX workflow for assignments

Compiling ${USER}_01.tex to produce ${USER}_01.pdf

```
# Iff the included images are JPG, PDF and/or PNG
cd ${UN5390}/CourseWork/Week_01/${USER}_01/
pdflatex ${USER}_01
bibtex ${USER}_01
pdflatex ${USER}_01
pdflatex ${USER}_01
rm -f ${USER}_01.aux ${USER}_01.bbl ${USER}_01.blg
rm -f ${USER}_01.dvi ${USER}_01.log ${USER}_01.out
```

Replace 01 with the appropriate week number.
For more information, visit https://github.com/MichiganTech/LaTeX_GettingStarted

Timing a task

date command

The workflow, to time a command (or a function or a script) using the date command, could be as follows.

```
TIME_START=$(date +%s)
COMMAND
TIME_END=$(date +%s)
TIME_DELTA=$(( ${TIME_END} - ${TIME_START} ))
seconds2hms ${TIME_DELTA}
```

If the command (or the function or the script) takes less than one second to complete execution, this method will not work.

`seconds2hms()` was discussed in Training Camp #08.

Timing a task

`time` and `/usr/bin/time`

`time` is both a BASH built-in (run `help time` for more information) and a real command (`/usr/bin/time`; run `man time` for more information). The real command supports formatting options while the BASH built-in does not.

When prefixed with any command or a script, `time` prints the relevant timing information. Common usage is as follows:

```
time COMMAND
time SCRIPT
```

```
/usr/bin/time COMMAND
/usr/bin/time SCRIPT
```

Random numbers in BASH

$RANDOM

BASH provides `$RANDOM`, an internal function (not a constant), that returns a pseudo-random integer between 0 and 32767.

```
echo $(($RANDOM % N))
```

generates a random number between 0 and `(N-1)`. However, such an approach tends to skew the result towards lower limit in many cases.

`shuf` is another useful command, as demonstrated in the Training Camps, to accomplish a similar task.

Doxygen Generate documentation from comments in source code

C/C#/C++/FORTRAN/IDL/Java/PHP/Python, LaTeX, and Doxygen

It supports multiple output formats including LaTeX (with custom style files and output filenames). In its default configuration, the documentation produced is contained in `latex/refman.pdf`.

```
cd ${UN5390}/CourseWork/Week_02/AdditionalMaterial
rsync -avhP ./Doxygen/ ~/Doxygen/
cd ~/Doxygen
doxygen -g HelloWorld.cfg  # Generates config file
# Edit HelloWorld.cfg, if necessary
doxygen HelloWorld.cfg     # Generates necessary files
cd latex
make                       # Generates documentation
```

Official website | GitHub

Refer to `man doxygen` for more information. `make` command will be discussed in detail in subsequent weeks. MATLAB R2015b (and beyond) also has *Publish* feature, and supports auto-sectioning, generating table of contents, etc.

Repeating commands

!!, !STRING, !N and CMD !*

!! repeats the previous command. !STRING repeats the most recent command that started with STRING. !N repeats the Nth command in command history. CMD !* runs CMD command with options used for the previous command.

```
cd ${UN5390}
!!
date -R
!da
!cd
history
!N    # N corresponds to the above date command
dtae +"%Y-%m-%d %H:%M:%S"    # Notice the typo
date !*
```

Converting seconds to human readable format, `hh:mm:ss`

A quick workaround for long-tailed mathematics

```
# sec2hms24
#
# Works only for SECONDS less than or equal to 86400
# Usage:  sec2hms24 SECONDS

sec2hms24() {
   # User input; ADD INPUT VALIDATION, ETC.
   local seconds=$1

   # Print the result
   date -u -d @${seconds} +"%T"
}
```

Add this function to `${HOME}/bin/functions.sh` and run `source ${HOME}/.bashrc`.

Opportunities

They do knock every once in a while

http://dilbert.com/strip/2009-09-24/

IT-managed Linux labs

- colossus.it.mtu.edu and guardian.it.mtu.edu
  - Intel Xeon X5675 3.07 GHz, 24 CPU cores, 96 GB RAM
  - Accessible for all from anywhere via SSH using a Terminal
  - Appropriate for light- to medium-weight computations
- Linux workstation in a campus lab/office
  - May not be as powerful as colossus.it or guardian.it
  - May not be directly accessible from off-campus
  - https://www.it.mtu.edu/computer-labs.php

All IT-managed workstations in Linux labs run RHEL 7.x and will mount the campus home directory.

Network of expertise

UN5390; CRN: 84758

#	Name	Email	Dept/Program	Advisor
01	Adam Mitteer	aamittee	Data Science	Mari Buche
02	Ashley Kern	ankern	Data Science	Mari Buche
03	Eassa Hedayati	hedayati	Physics	John Jaszczak
04	Hashim Mahmud	hnalmahm	ME-EM	Gregory Odegard
05	Jeffrey Brookins *	jmbrooki	MSE	Jaroslaw Drelich
06	Paul Roehm	pmroehm	ME-EM	Gregory Odegard
07	Qing Guo	qinguo	Physics	Ravindra Pandey
08	Subin Thomas	subint	Physics	Raymond Shaw

* Undergraduate students

Network of expertise

BE5390: Biomedical Engineering CRN: 84759

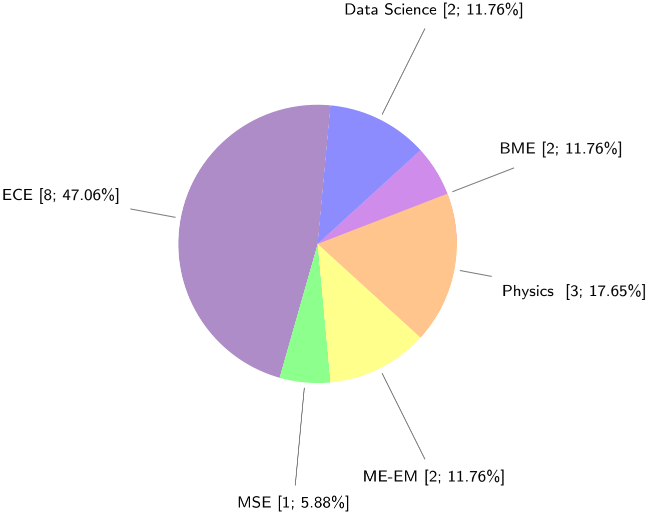
#	Name	Email	Advisor
09	Cal Riutta *	cdriutta	Jinfeng Jiang

EE5390: Electrical and Computer Engineering; CRN: 84760

10	Akhil Kurup	amkurup	Michael Roggemann
11	Avinaash Kovvuri	askovvur	Michael Roggemann
12	Ian Cummings	itcummin	Timothy Havens
13	Prithvi Kambhampati	pkambham	Michael Roggemann
14	Sandeep Lanka	slanka	Michael Roggemann
15	Sameer Saraf	svsaraf	Michael Roggemann
16	Shuo Wang	wshuo	Jeremy Bos
17	Zhiqiang Zhao	qzzhao	Zhuo Feng

* Undergraduate students

Network of expertise



17 registered students.

NSF Graduate Research Fellowship Program 2017

- Applicant must be a US citizen or a permanent resident
- Fellowship supports 3 years of study

  \$34k of stipend per year +
  \$12k of cost-of-education allowance to the university per year
- MS and PhD candidates in STEM and STEM education

  Must be in first two years of graduate study
  Senior undergraduates are also encouraged to apply
- Michigan Tech Information Session

  5 pm, 7th September 2016 (Wednesday), Admin 404

National Science Foundation | NSF Graduate Research Fellowship Program | Application deadline: 24-28th October 2016

CareerFEST and Career Fair

- More details at http://www.mtu.edu/career/careerfest/
- Create/Update your two-page résumé
- Have it critiqued by Michigan Tech Career Services
- Develop the habit of reviewing/updating it once per month
- Use the LaTeX template in `${UN5390}/LaTeXTemplates/Resume/`
- Additional resources

  http://www.mtu.edu/career/students/toolbox/resumes/examples/
  http://owl.english.purdue.edu/owl/resource/719/1/
  http://www.sharelatex.com/templates/cv-or-resume
  http://www.latextemplates.com/cat/curricula-vitae

CareerFEST is a collection of many different informal events that take place during the month of Career Fair.

CareerFEST and Career Fair Los Alamos National Laboratory

- Commonly used Linux commands
- Extensive shell scripting
- Revision control (Git)
- Workflow development
- Statistical analysis (Python, R and Gnuplot)
- Visualization (Python, R and Gnuplot)
- White papers and internal publications (LaTeX)

Los Alamos National Laboratory | Los Alamos National Laboratory on GitHub

CareerFEST and Career Fair MIT Lincoln Laboratory

- Commonly used Linux commands
- Extensive shell scripting
- Revision control (Git/Subversion)
- Workflow development
- Domain-specific expertise
- Modeling, simulation, analysis and visualization

  Choice of language/toolset depends on a project
- White papers, internal and external publications (LaTeX)

Keweenaw Climate Science Event #1 of four-part event

The Orpheum Theater

6 – 8 pm on Thursday, 8th September 2016

Subsequent events

6th October 2016

3rd November 2016

1st December 2016

No admission fee

Free pizza and soft drinks

More information

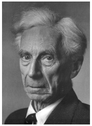
Organized by Keweenaw Climate Community, and sponsored by the local chapter of the American Chemical Society and the Department of Social Sciences at Michigan Tech.

Mathematical Results

Standing the test of time

Mathematics, rightly viewed, possesses not only truth, but supreme beauty – a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show.

– Bertrand Russell, A History of Western Philosophy (1945)



Bertrand Arthur William Russell (1872 – 1970): British philosopher, logician, mathematician, historian, writer, social critic, and political activist. 1950 Nobel Laureate in Literature.

Fundamental theorem of algebra

Every non-constant single-variable polynomial with complex coefficients has at least one complex root. Since real numbers are a subset of complex numbers, the result/statement extends to polynomials with real coefficients as well.

Alternate statement #1 (proved using successive polynomial division)

Every non-zero, single-variable, degree n polynomial with complex coefficients has, counted with multiplicity/degeneracy, exactly n roots.

Alternate statement #2

The field of complex numbers is algebraically closed.

Theorem first proven algebraically by James Wood (with missing steps) in 1798, and geometrically by Johann Carl Friedrich Gauss (with a topological gap) in 1799.

Fundamental theorem of calculus

Suppose that $f(x)$ is defined and continuous on $[a, b]$. Suppose that $y(x)$ is an anti-derivative of $f(x)$. Then

$$\boxed{\int_a^b f(x)\,dx = y(b) - y(a)}$$

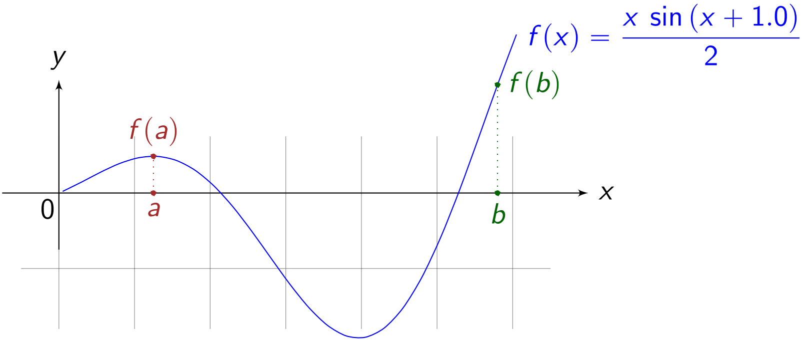
Changing the notations while retaining the underlying essence,

$$\int_{t_n}^{t_{n+1}} f(y,t)\,dt = y_{n+1} - y_n$$

Re-arranging the terms,

$$\boxed{y_{n+1} = \boxed{y_n} + \boxed{\int_{t_n}^{t_{n+1}} f(y,t)\,dt}}$$

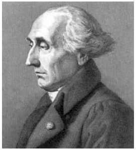
Intermediate value theorem (IVT)

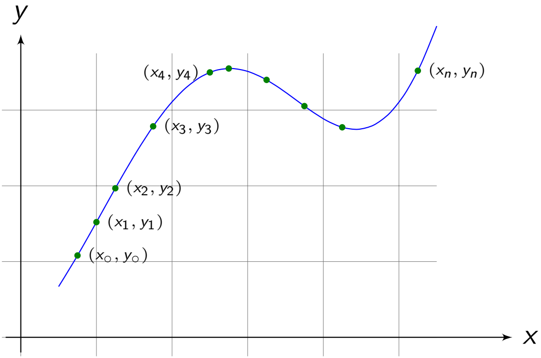


For any function $f(x)$ that is continuous on $[a, b]$, and has values $f(a)$ and $f(b)$ at a and b respectively, then $f(x)$ also takes any value between $f(a)$ and $f(b)$ at some point within the interval.

Lagrange polynomial interpolation

Suppose that (x_i, y_i), with $i = 0 : 1 : n$, are a set of $n + 1$ unique points





Joseph-Louis Lagrange (1736 – 1813): Italian mathematician and astronomer
Interpolating Polynomials, L. Shure, MathWorks
Lagrange Interpolating Polynomial, B. Archer, Wolfram

Lagrange polynomial interpolation

The general form of Lagrange interpolating polynomial, one that passes through $n + 1$ points

$$\boxed{\mathcal{L}_n(x) \; = \; \sum_{i=0}^{n} l_i(x)\, y_i}$$

Lagrange basis polynomials are given by

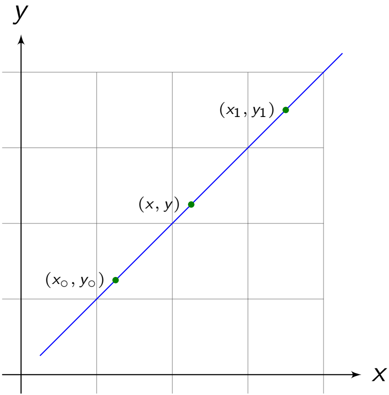
$$l_i(x) \; = \; \prod_{\substack{m=0 \\ m \neq i}}^{n} \frac{x - x_m}{x_i - x_m}$$

and are built to have the *Kronecker delta* property

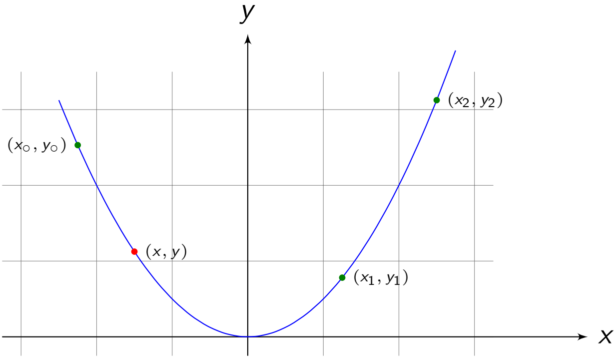
$$l_i(x_j) \; = \; \delta_{ij}$$

Lagrange polynomial interpolation Linear

Suppose that $(x_\circ, y_\circ)$ and (x_1, y_1) are two known points. The linear interpolant is then a straight line between these two points.



Lagrange polynomial interpolation Quadratic



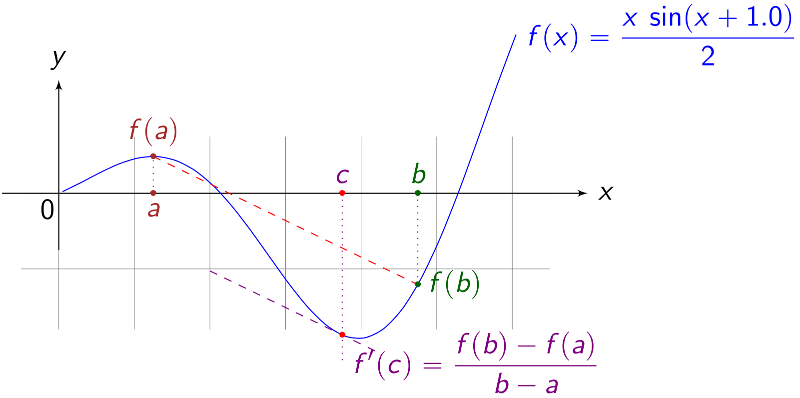
$$\mathcal{L}_2(x) = \frac{(x - x_1)(x - x_2)}{(x_\circ - x_1)(x_\circ - x_2)}\, y_\circ + \frac{(x - x_\circ)(x - x_2)}{(x_1 - x_\circ)(x_1 - x_2)}\, y_1 + \frac{(x - x_\circ)(x - x_1)}{(x_2 - x_\circ)(x_2 - x_1)}\, y_2$$

Lagrange polynomial interpolation Error analysis

If $f(x)$ is $n+1$ times continuously differentiable on a closed interval $[a, b]$, and $p_n(x)$ is a polynomial of degree at most n that interpolates $f(x)$ at $n+1$ distinct points x_i, $(i = 0, 1, 2, ..., n)$ in that interval. Then

$$\boxed{\epsilon_n = \int_a^b [f(x) - p_n(x)]\, dx = \int_a^b \frac{f^{(n+1)}}{(n+1)!} \prod_{i=0}^{n} (x - x_i)\, dx}$$

Mean value theorem



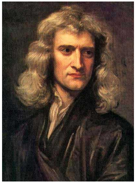
For any function that is continuous on $[a, b]$ and differentiable on (a, b), there exists a point c in (a, b) such that the line joining $f(a)$ and $f(b)$ (i.e., the secant) is parallel to the tangent at c.

Weighted mean value theorem for integrals

Suppose that $f(x)$ and $g(x)$ are continuous on $[a, b]$. If $g(x)$ never changes sign and is positive, $g(x) \geqslant 0$, in $[a, b]$, then for some c in $[a, b]$

$$\boxed{\int_a^b f(x)\, g(x)\, dx \;=\; f(c)\, \int_a^b g(x)\, dx}$$

Newton-Cotes formula



Suppose that $f(x)$ is defined and continuous on $[a, b]$. Consider the integral

$$\boxed{I = \int_a^b f(x)\, dx}$$

If $f(x)$ can be approximated by an n^{th} order polynomial

$$\boxed{p_n(x) = \alpha_\circ + \alpha_1\, x + \alpha_2\, x^2 + \ldots + \alpha_{n-1}\, x^{n-1} + \alpha_n\, x^n}$$

then the integral, I, takes the form

$$\boxed{I = \int_a^b \left[\alpha_\circ + \alpha_1\, x + \alpha_2\, x^2 + \ldots + \alpha_{n-1}\, x^{n-1} + \alpha_n\, x^n\right] dx}$$

Isaac Newton (1642 – 1727): English physicist and mathematician
Roger Cotes (1682 – 1716): English mathematician (no photo)

Taylor series expansion

If $f(x)$ is infinitely differentiable at $x_\circ$, then

$$\boxed{f(x) = \sum_{n=0}^{\infty} \frac{(x - x_\circ)^n}{n!} \frac{d^n}{dx^n} f(x) \Big|_{x=x_\circ}}$$

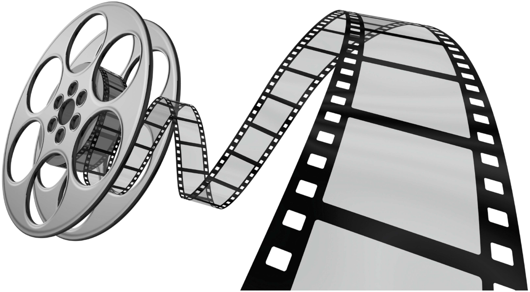
A more general form that clearly identifies the error term is given by the p^{th} order Taylor series expansion of $f(x)$ with $\tilde{x} \in [x, x + \Delta x]$

$$\boxed{f(x + \Delta x) = \boxed{\sum_{n=0}^{p} \frac{(\Delta x)^n}{n!} \frac{d^n}{dx^n} f(x)} + \boxed{\frac{(\Delta x)^{p+1}}{(p+1)!} \frac{d^{p+1}}{dx^{p+1}} f(\tilde{x})}}$$

Brook Taylor (1685 – 1731): English mathematician

Videos

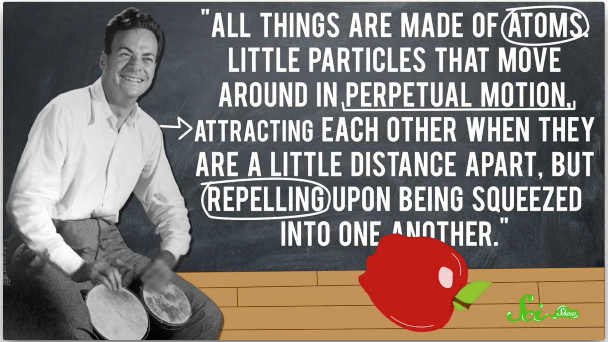
If a picture is worth a thousand words ...



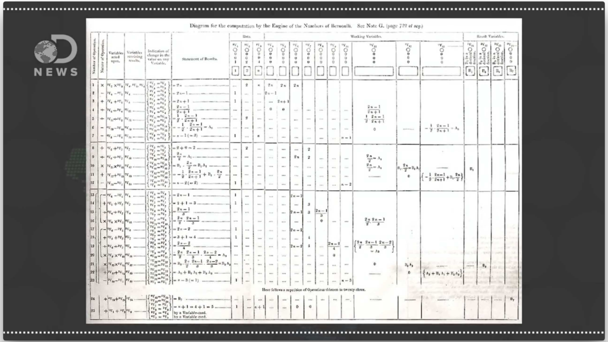
People and Personalities

and their stories

Richard Phillips Feynman 1918 – 1988

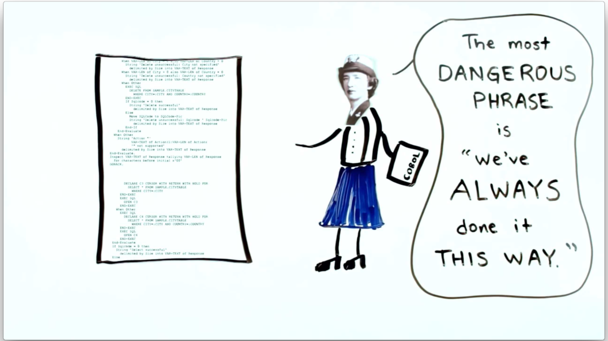


Ada August King, Countess of Lovelace 1815 – 1852



Alan Mathison Turing 1912 – 1954

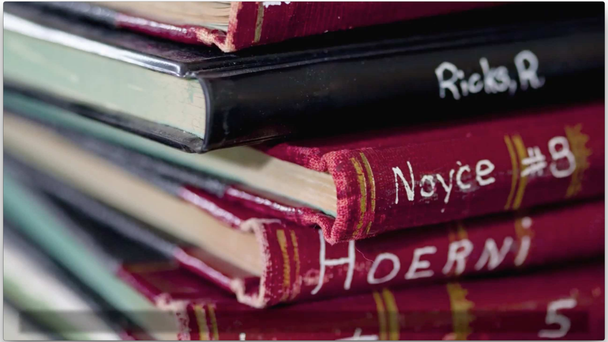
Grace Brewster Murray Hopper 1906 – 1992



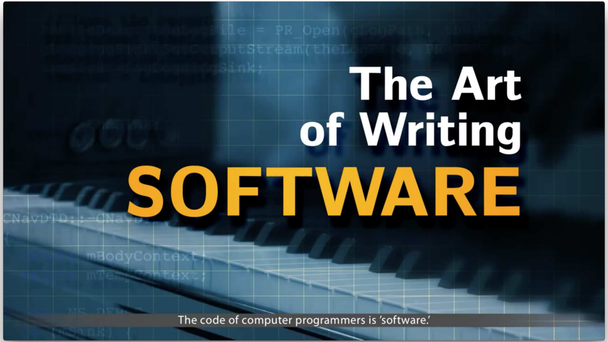
Computer History Museum

1401 N. Shoreline Blvd., Mountain View, CA 94043
(650) 810-1010

The Fairchild Notes



The Art of Writing Software

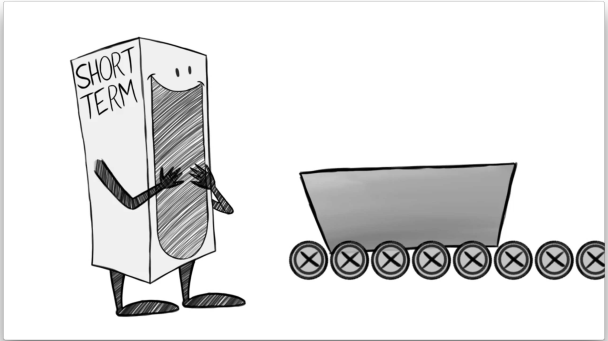


TED Ed

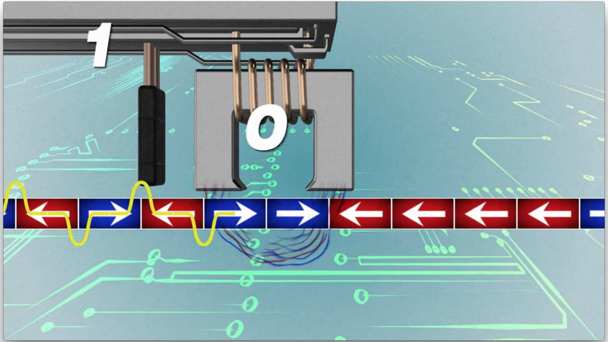
TED Ed

LESSONS WORTH SHARING

Computer Memory

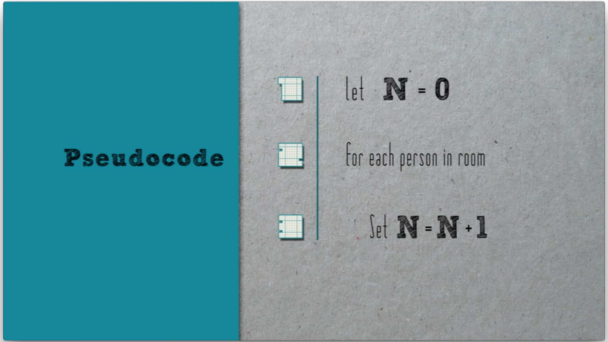


Hard Drives

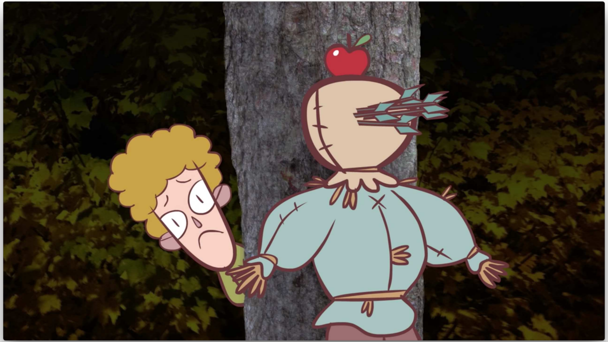


Turing Test

Algorithm



Accuracy vs Precision

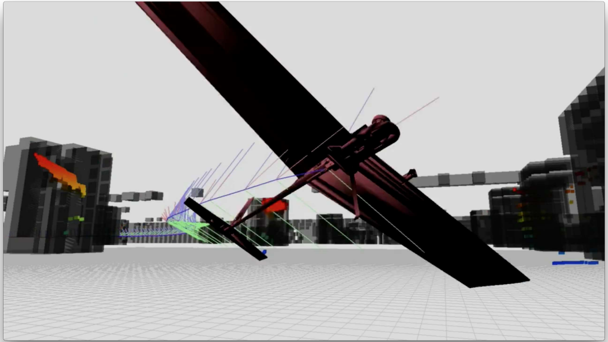


Supercomputing

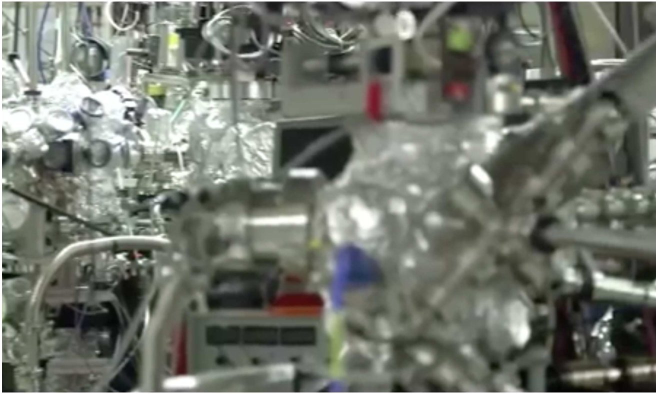
The International Conference for High Performance Computing, Networking, Storage and Analysis

An overview

Aerospace

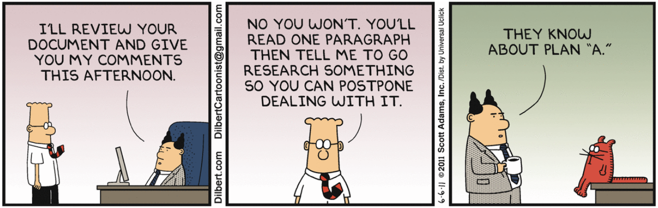


Batteries



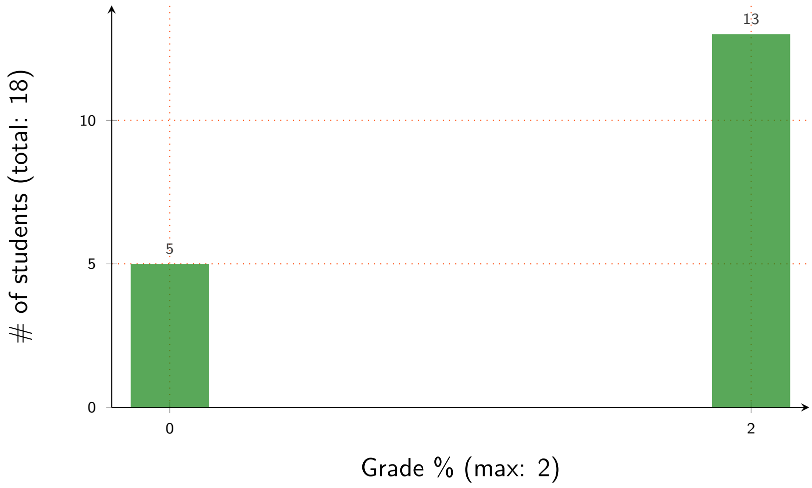
Review of Performance

How well have we been performing?

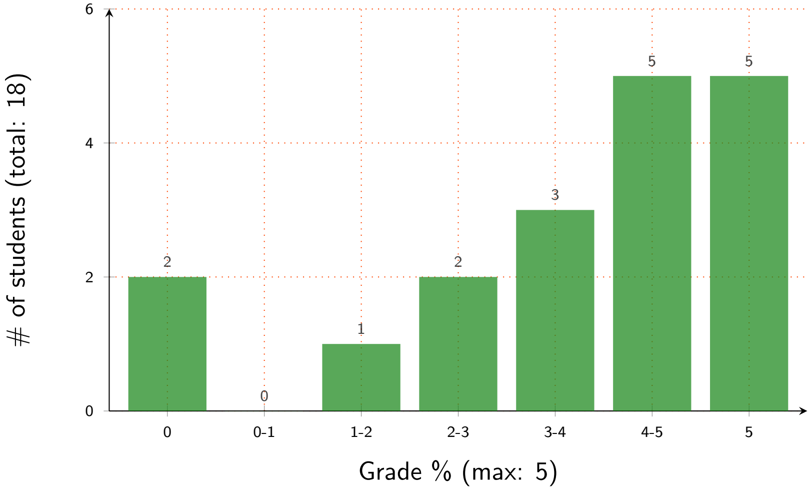


http://dilbert.com/strip/2011-06-06/

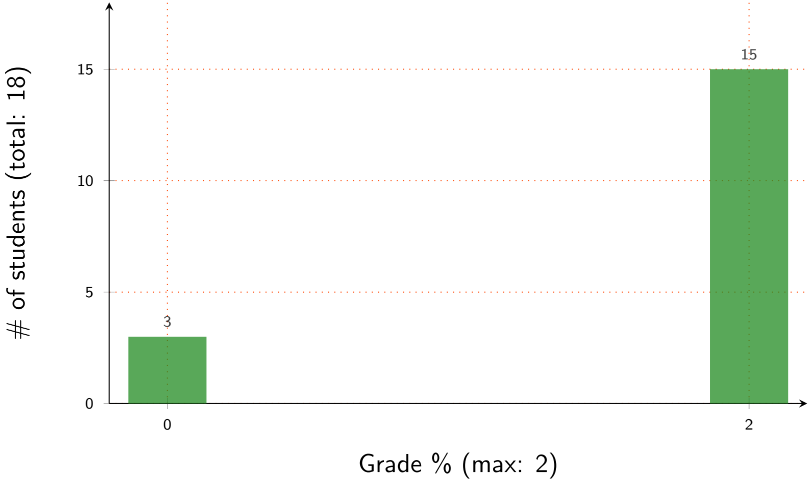
Active Participation #01 Research Marketing I: Twitter



Assignment #01



Active Participation #02 PB&J Sandwich Recipe



Superior and Top 500

A proposed compute node in Superior will have two Intel Xeon E5-2698 processors (each processor with 20 cores) at 2.20 GHz, 512 GB RAM, 480 GB Intel Enterprise SSD, Mellanox ConnectX-3 56 Gbps InfiniBand network, and will cost $13,263.13.

Ignoring the cost of physical space, racks, network, storage, electricity and labor, estimate the cost to build a #500 supercomputer (~405 TFLOPS) with homogeneous compute nodes as the ones described above.

For a computer with N identical/homogeneous processors,

$$\boxed{\text{FLOPS} \;=\; \text{N} \times \text{CPU speed} \times \frac{\text{FLOPs}}{\text{CPU cycle}}}$$

You and The Board Week #02: Sameer Saraf

Celsius $\longleftrightarrow$ Fahrenheit

Convert temperature between Celsius and Fahrenheit scales.

Is there a well-known technique to verify the conversion scheme?

Matrix elements

How many elements in a square matrix of order N? How will this number change if the matrix is upper (or lower) triangular?

$$\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix} \qquad \begin{pmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ 0 & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & b_{nn} \end{pmatrix}$$

The impact and limitations of Moore's Law

Assuming that Moore's Law holds true, what is the speed up of a computer observed over an average adult's life in the US?

Got questions?

If you do, find a way to contact me; and do so sooner than later

EERC B39 · (906) 487-4096 · g@mtu.edu · @sgowtham