Applications and Framework

Dr. Fayyaz Minhas

Department of Computer Science
University of Warwick
https://warwick.ac.uk/fac/sci/dcs/teaching/material/cs909/

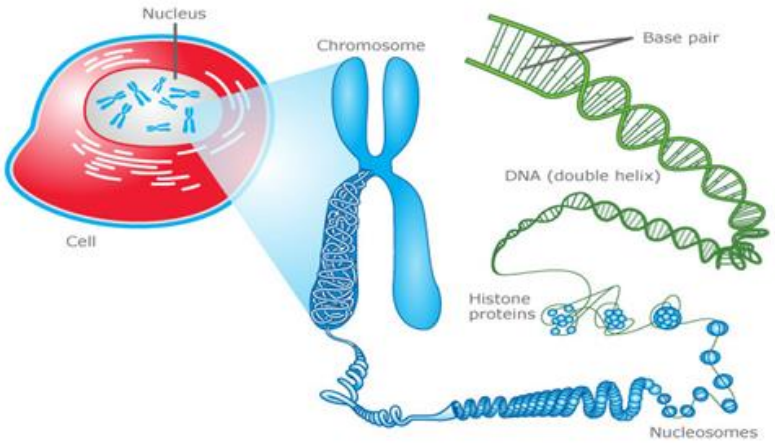
Applications of Machine Learning

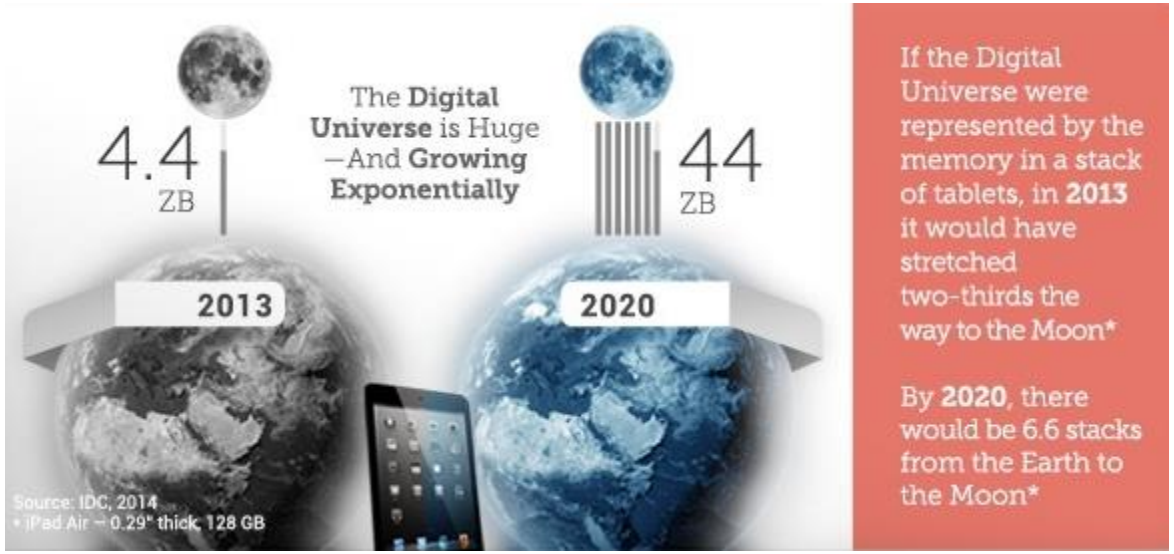
- An ability that I would like you to learn is to identify how to use machine learning in different domains.

- Machine learning can be applied in a wide array of real-world applications

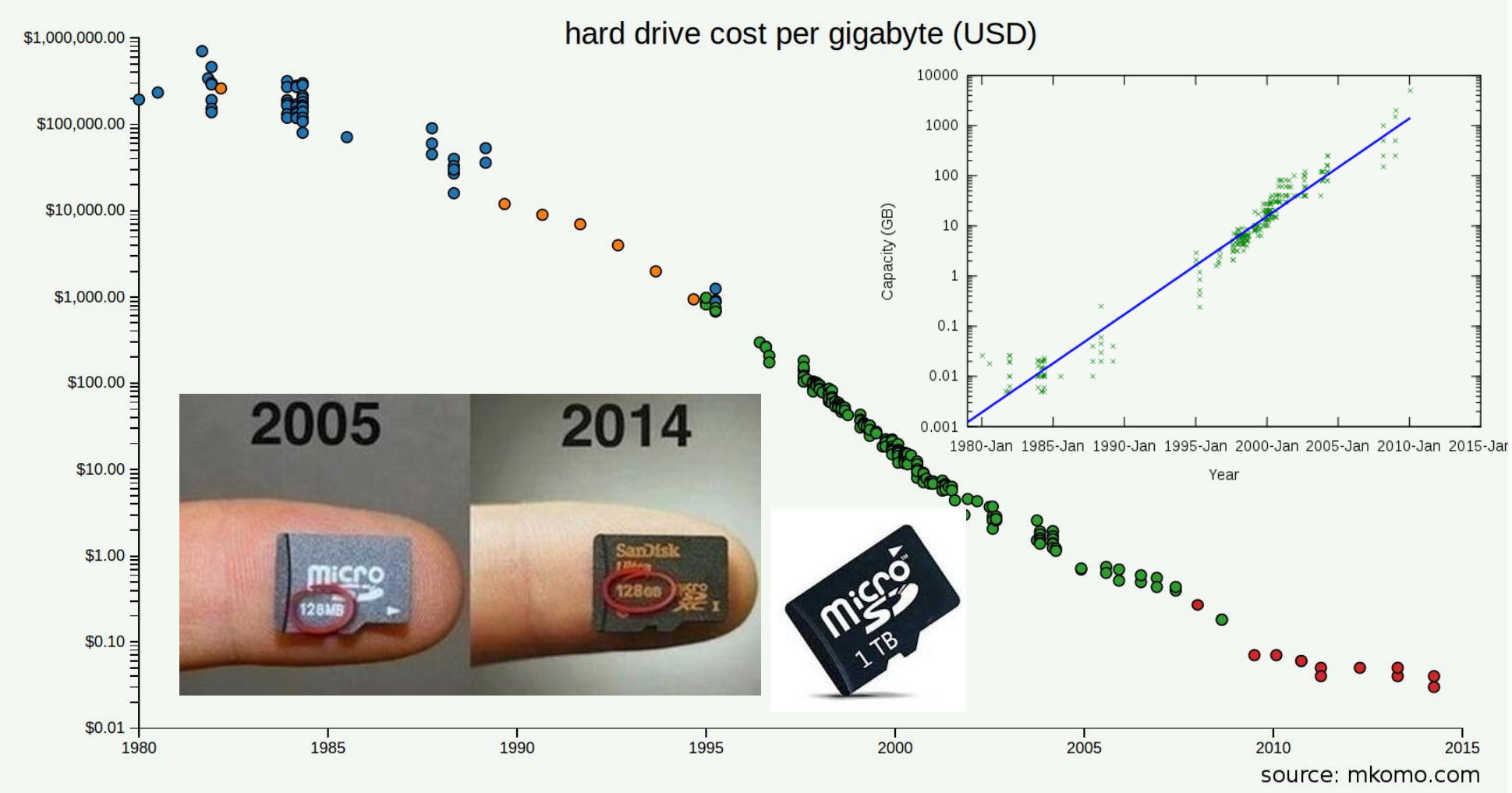
Data, Big Data and Data Science

- We are going through an age of “Big Data”
  - Humans are the only biological entity that can store more data outside its body than inside it



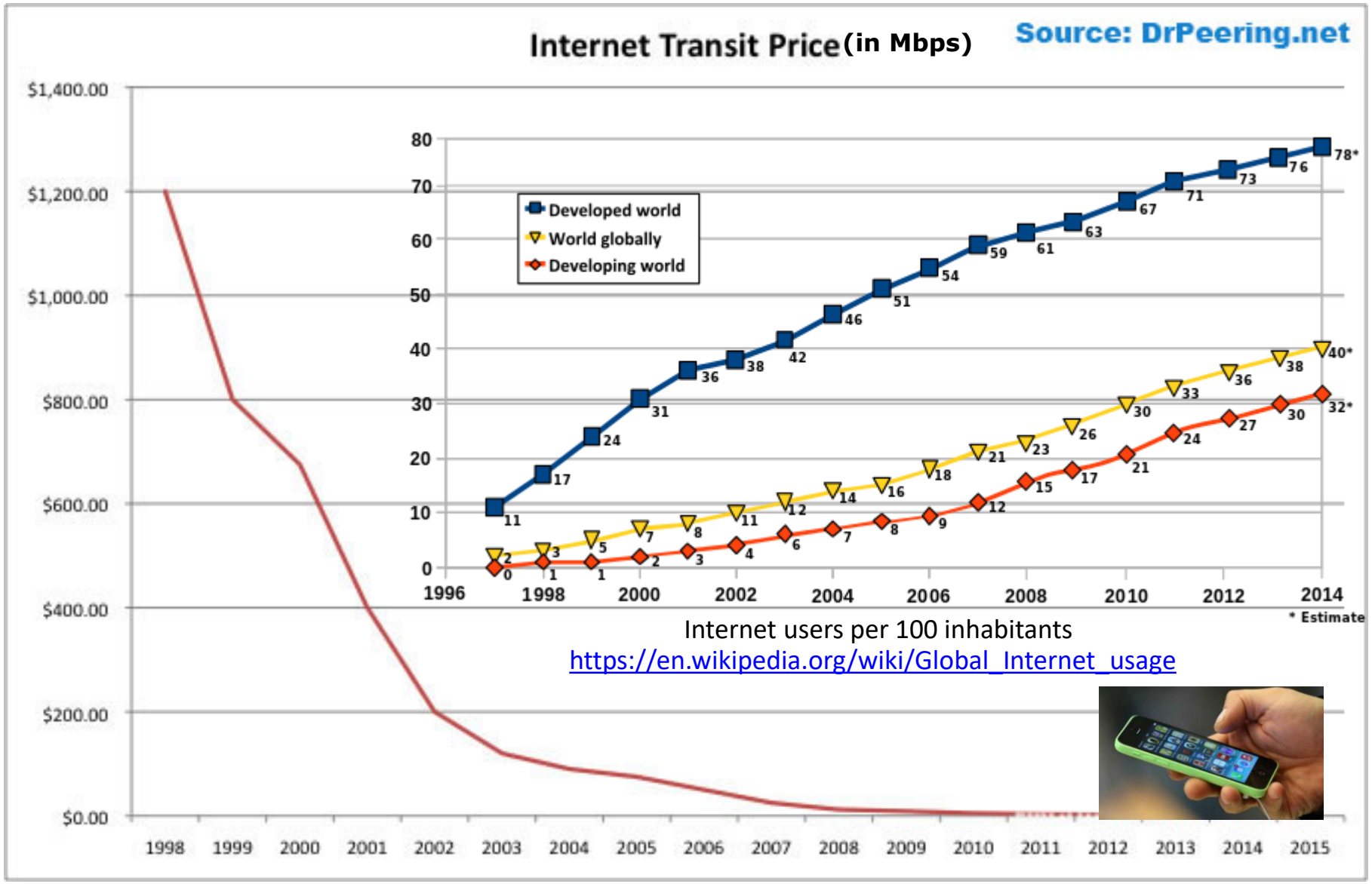


Age of Big Data



Our Emergent Digital Future
http://www.digitaltonto.com/2011/our-emergent-digital-future/

Age of Big Data

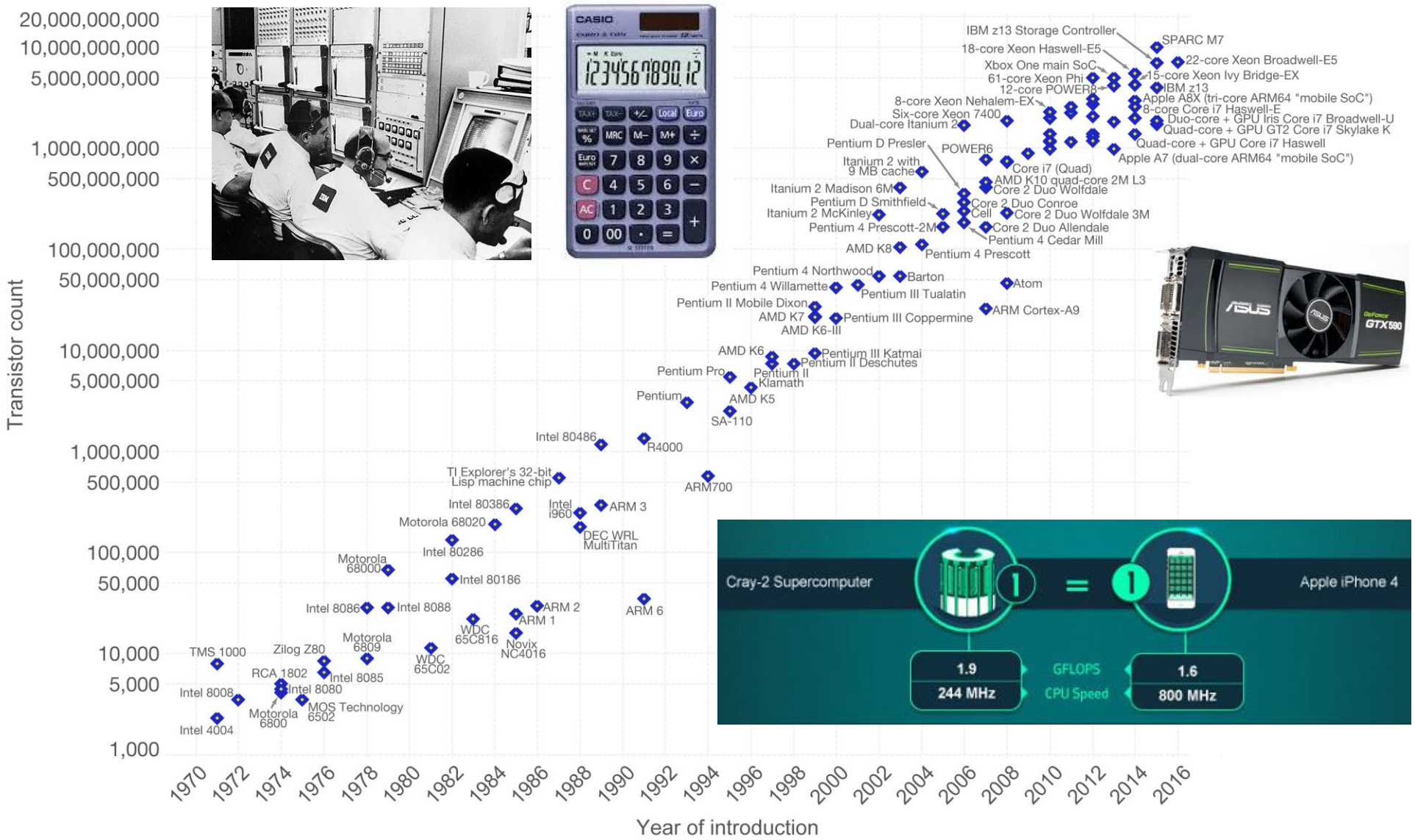


Internet users per 100 inhabitants
https://en.wikipedia.org/wiki/Global_Internet_usage

Moore's Law – The number of transistors on integrated circuit chips (1971-2016)

Our World in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore's law.

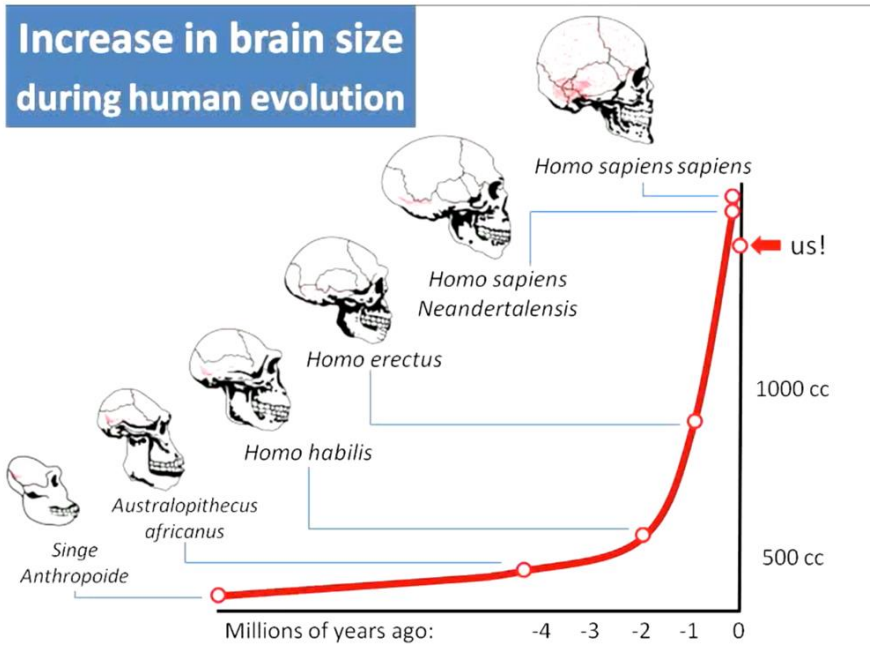


Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

Licensed under CC-BY-SA by the author Max Roser.

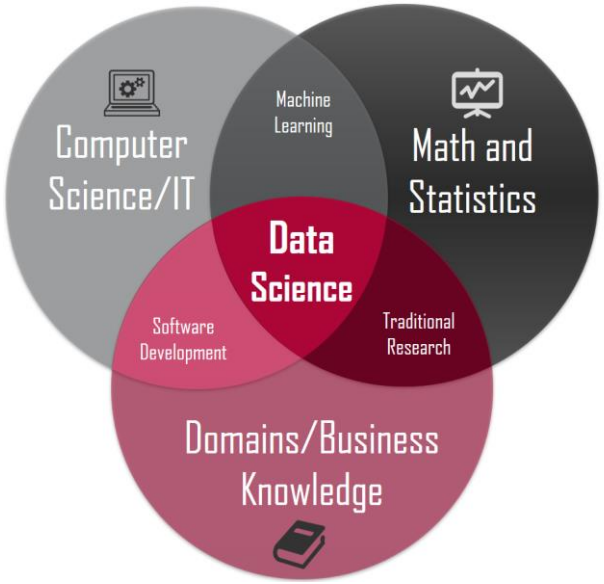
Question

- Where does the bottleneck lie?
  - Data Analysis by Humans
  - Have humans become smarter?
  - How about we automate that?



Data Science

- Use of the scientific method in the development of:
  - Processes
  - Algorithms
  - Systems
- For extraction of knowledge from structured or unstructured data



- Examples

Forbes

YOUR READING LIST

DEC 11, 2017 @ 08:32 PM

LinkedIn's Fastest-Growing Jobs Today Are In Data Science And Machine Learning

Louis Columbus, CONTRIBUTOR

FULL BIO

Opinions expressed by Forbes Contributors are their own.

JET BRAINS
IntelliJ IDEA

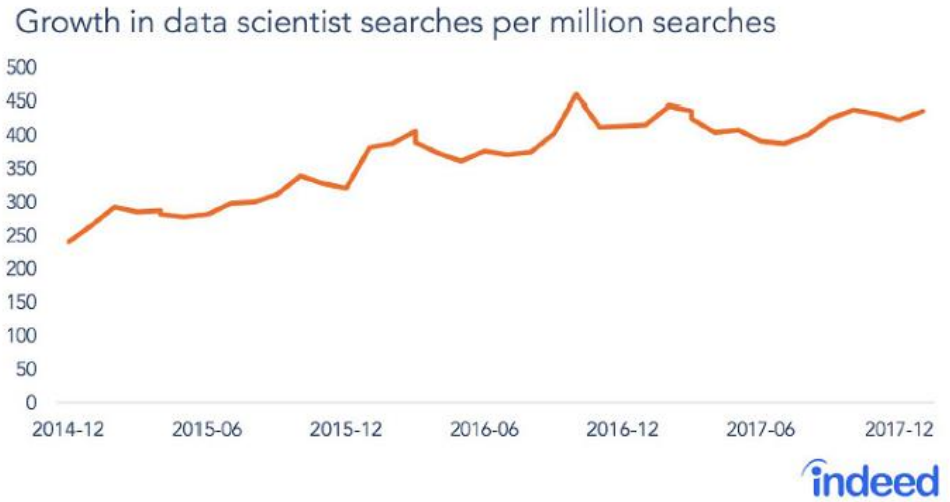
The Economist

Topics | Current edition | More

Regulating the internet giants

The world's most valuable resource is no longer oil, but data

The data economy demands a new approach to antitrust rules



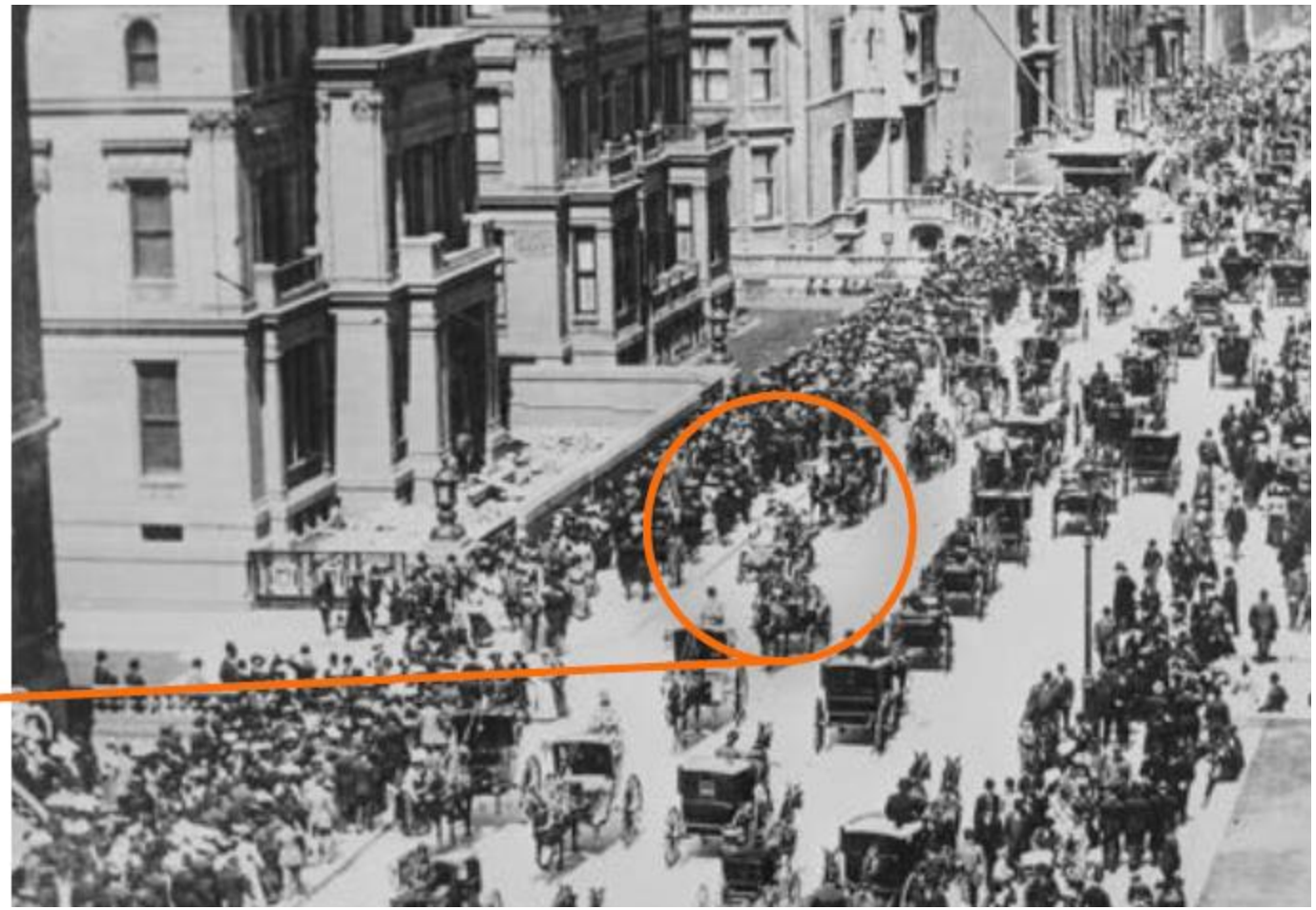
TECH • SCIENCE

'Sexiest Job' Ignites Talent Wars as Demand for Data Scientists Soars

5th AVE NYC

1900

Where is the car?

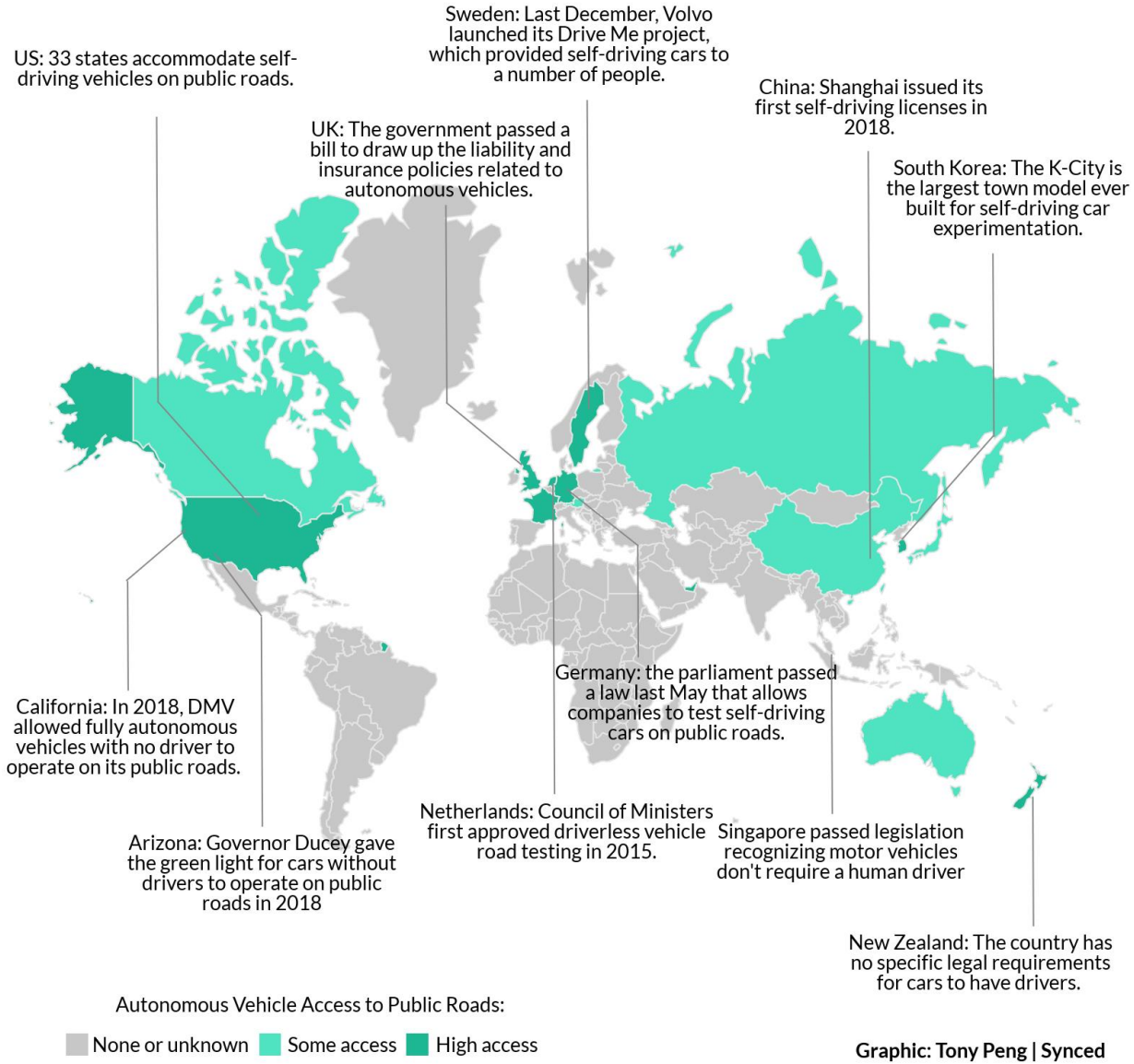


5th AVE NYC

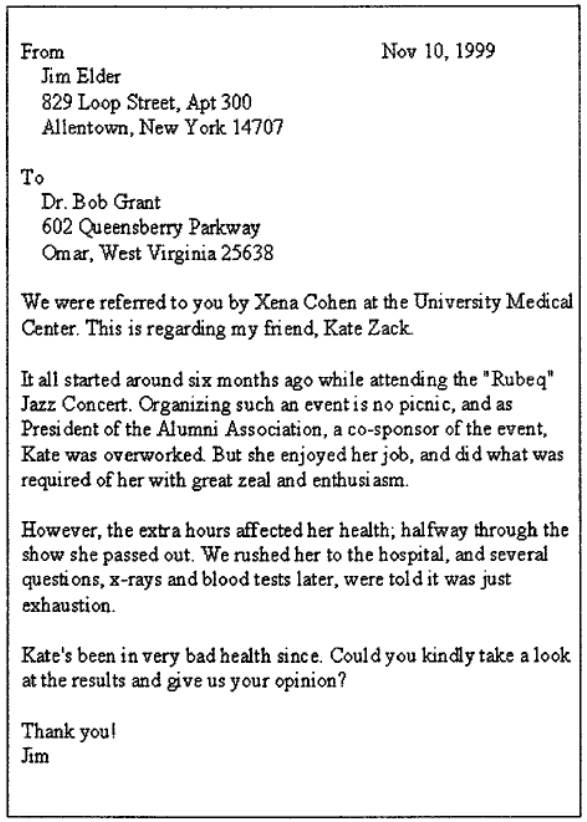
1913

Where is the horse?

Applications



Handwriting Recognition / OCR



From
Jim Elder
829 Loop Street, Apt 300
Allentown, New York 14707

Nov 10, 1999

To
Dr. Bob Grant
602 Queensberry Parkway
Omar, West Virginia 25638

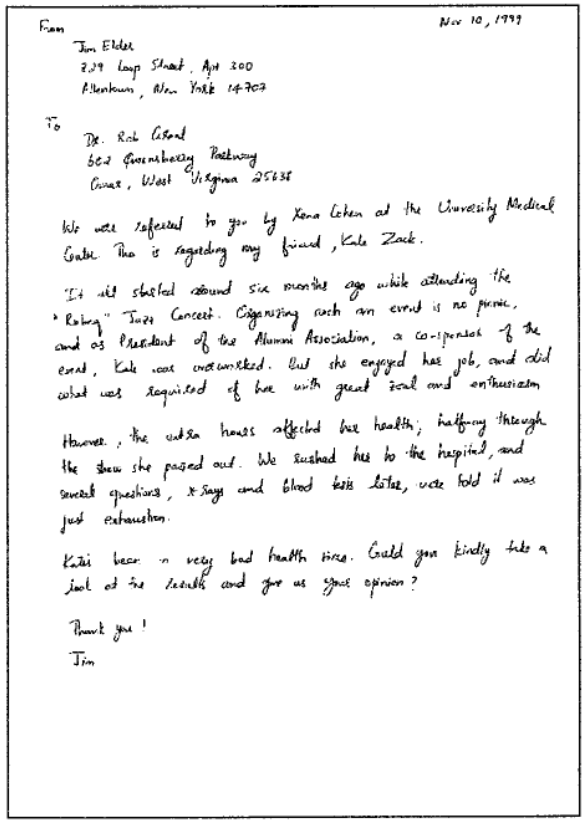
We were referred to you by Xena Cohen at the University Medical Center. This is regarding my friend, Kate Zack.

It all started around six months ago while attending the "Rubeq" Jazz Concert. Organizing such an event is no picnic, and as President of the Alumni Association, a co-sponsor of the event, Kate was overworked. But she enjoyed her job, and did what was required of her with great zeal and enthusiasm.

However, the extra hours affected her health; halfway through the show she passed out. We rushed her to the hospital, and several questions, x-rays and blood tests later, were told it was just exhaustion.

Kate's been in very bad health since. Could you kindly take a look at the results and give us your opinion?

Thank you!
Jim



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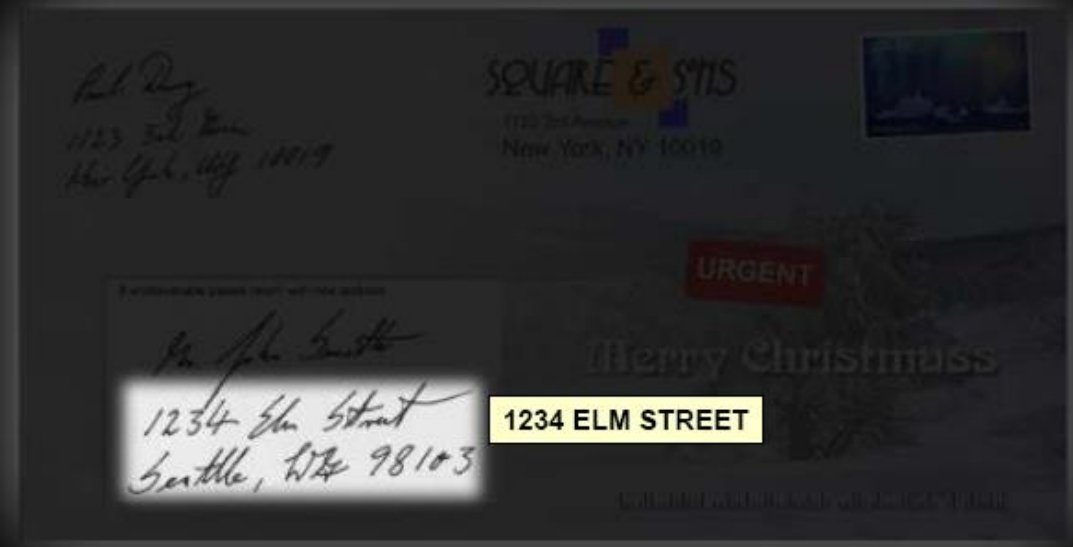
The Letter

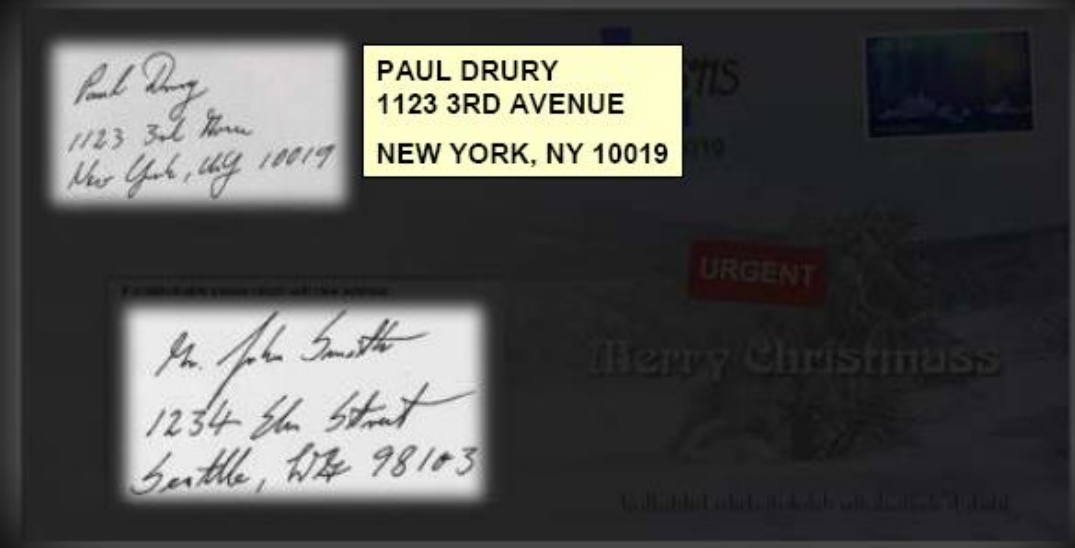
1978: First Postal Code Reader Worldwide

1982: First Address Reader Worldwide

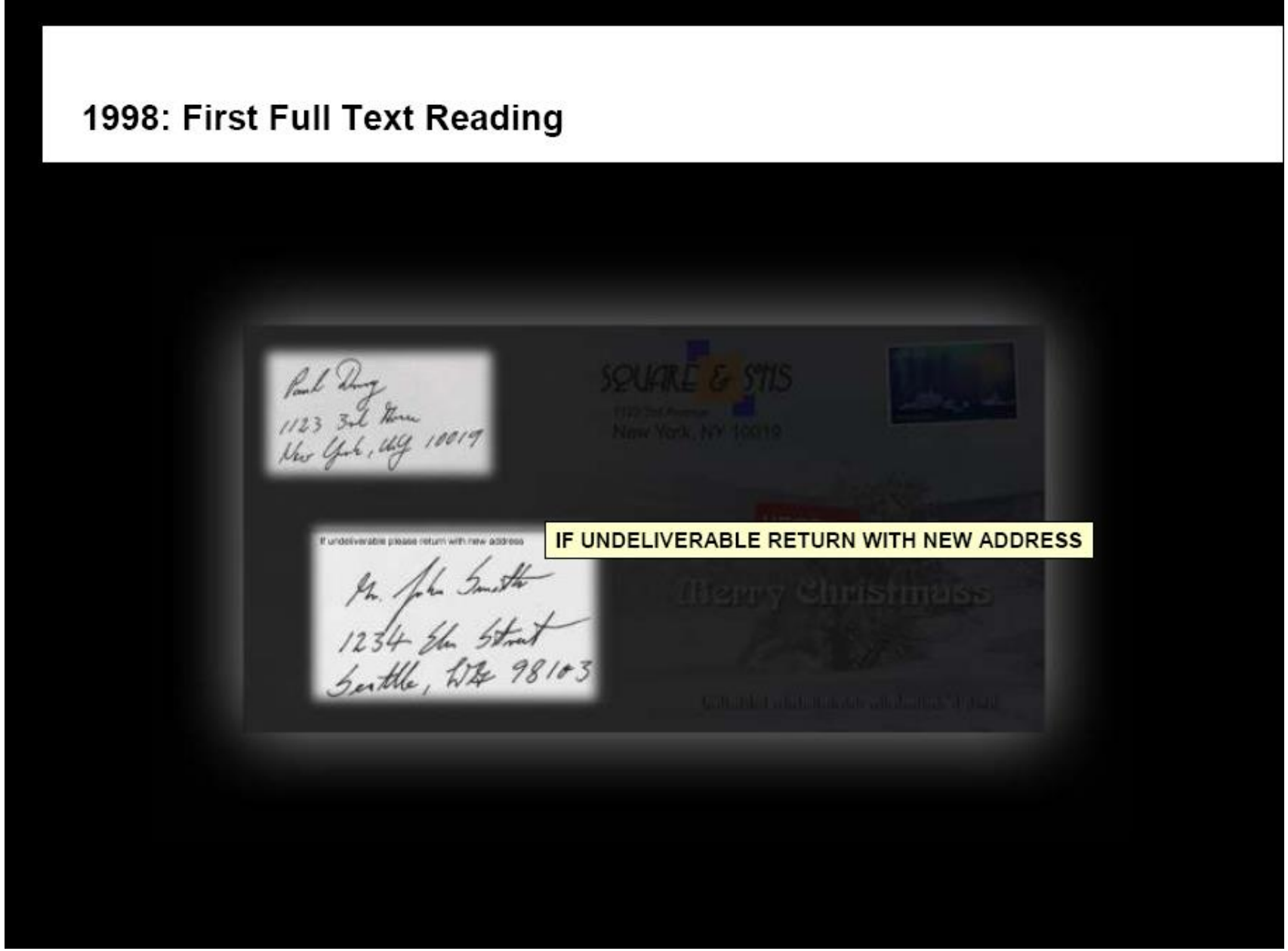


1984: First Multi Line Reader

1996: First Sender's Address Reader



1998: First Full Text Reading

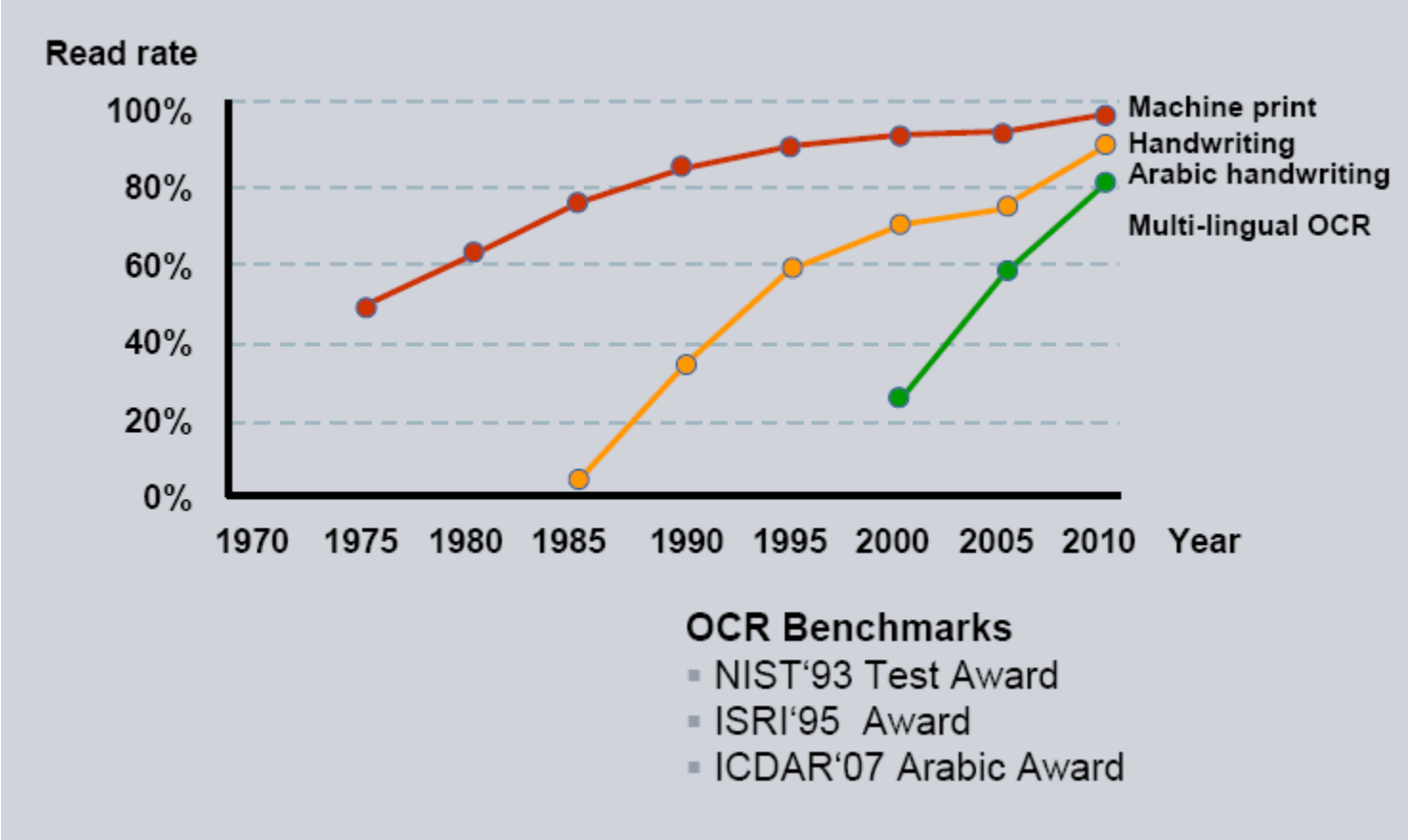


2000: First Graphics Recognition

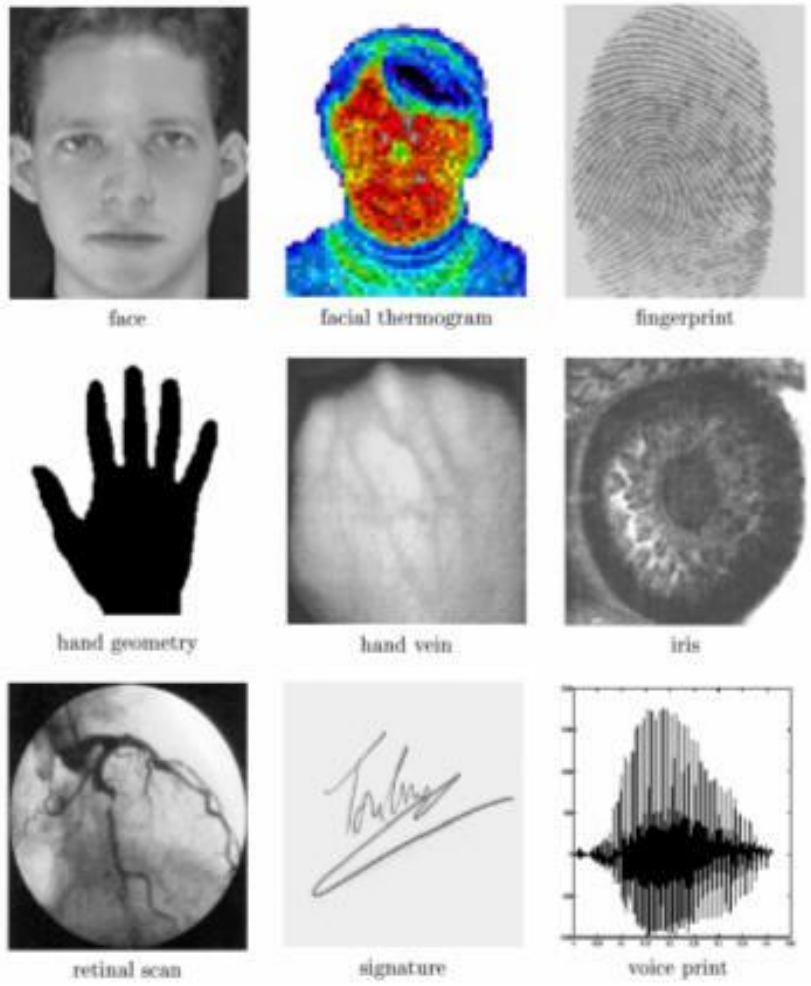
2004: First Full Recognition

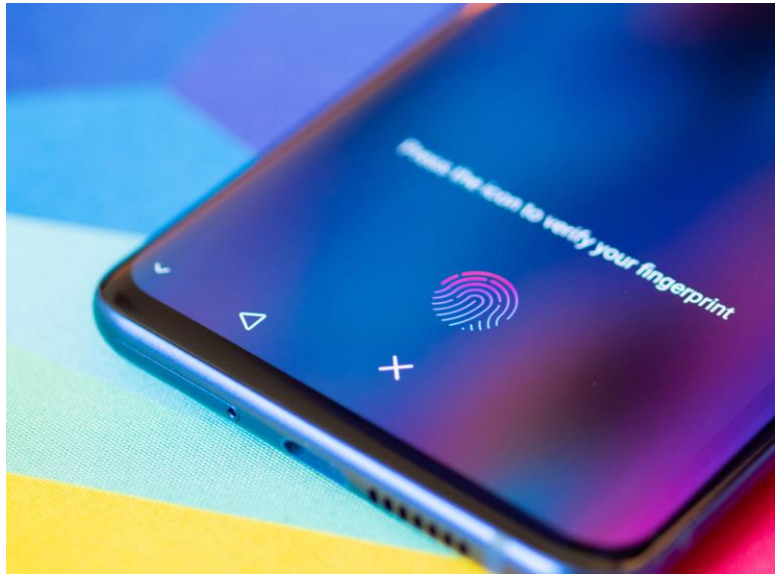
2008: Recognition on Both Sides of Envelope

OCR Accuracy

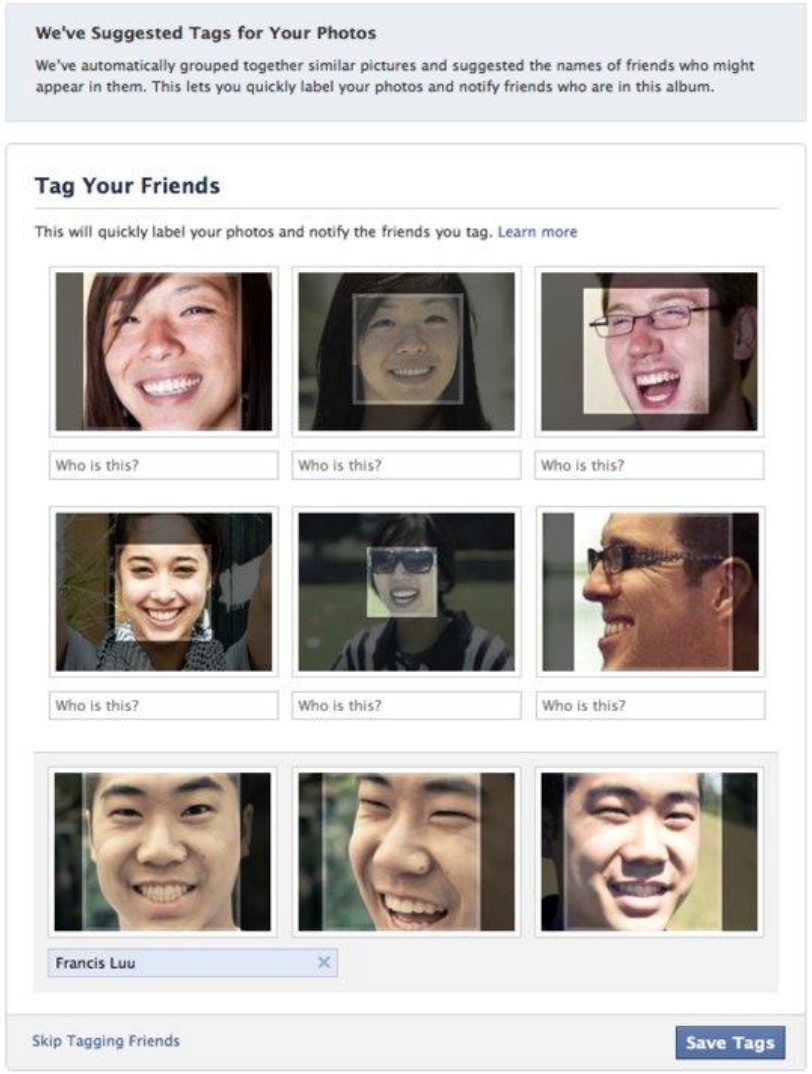


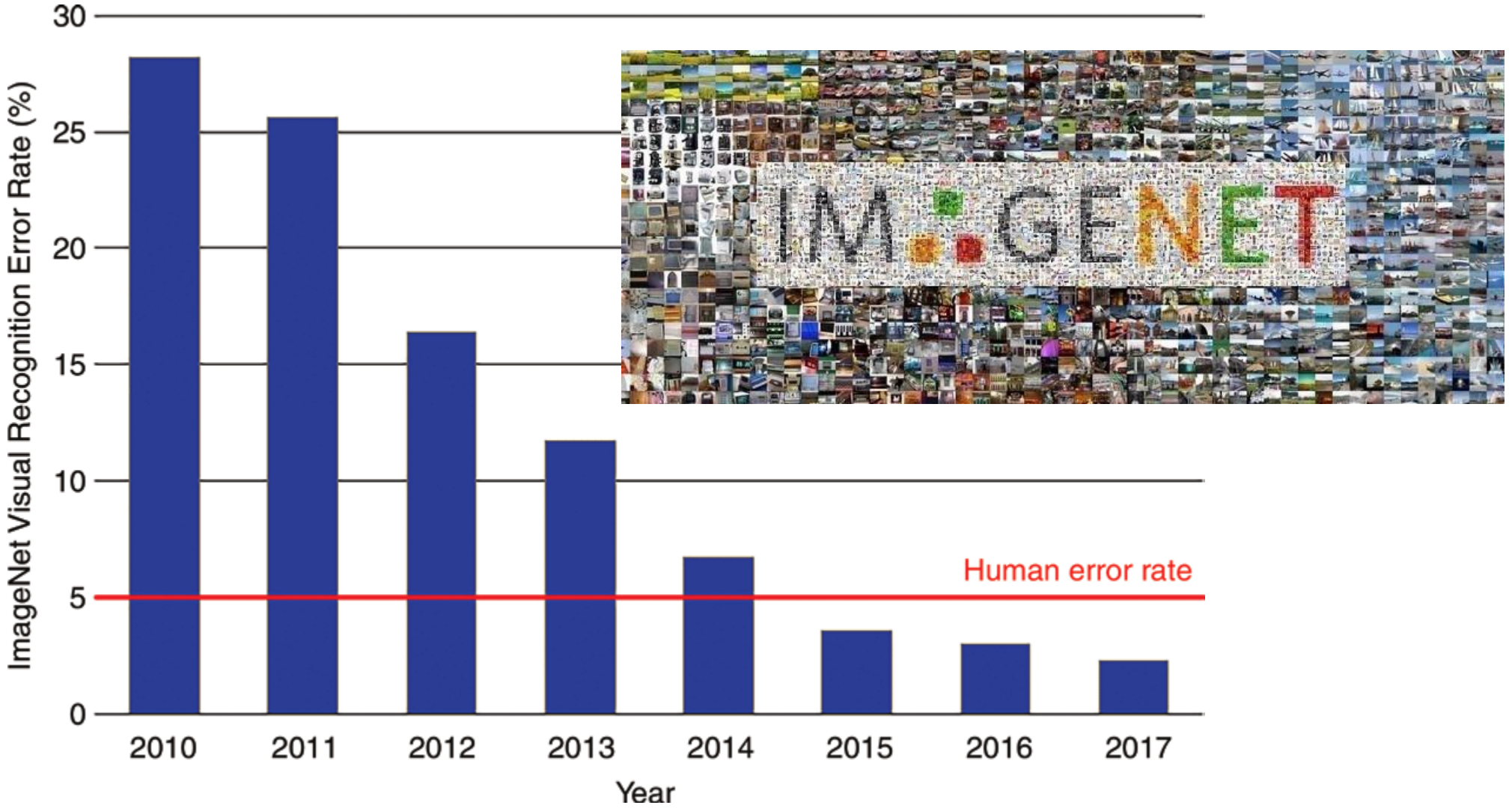
Applications: Biometrics



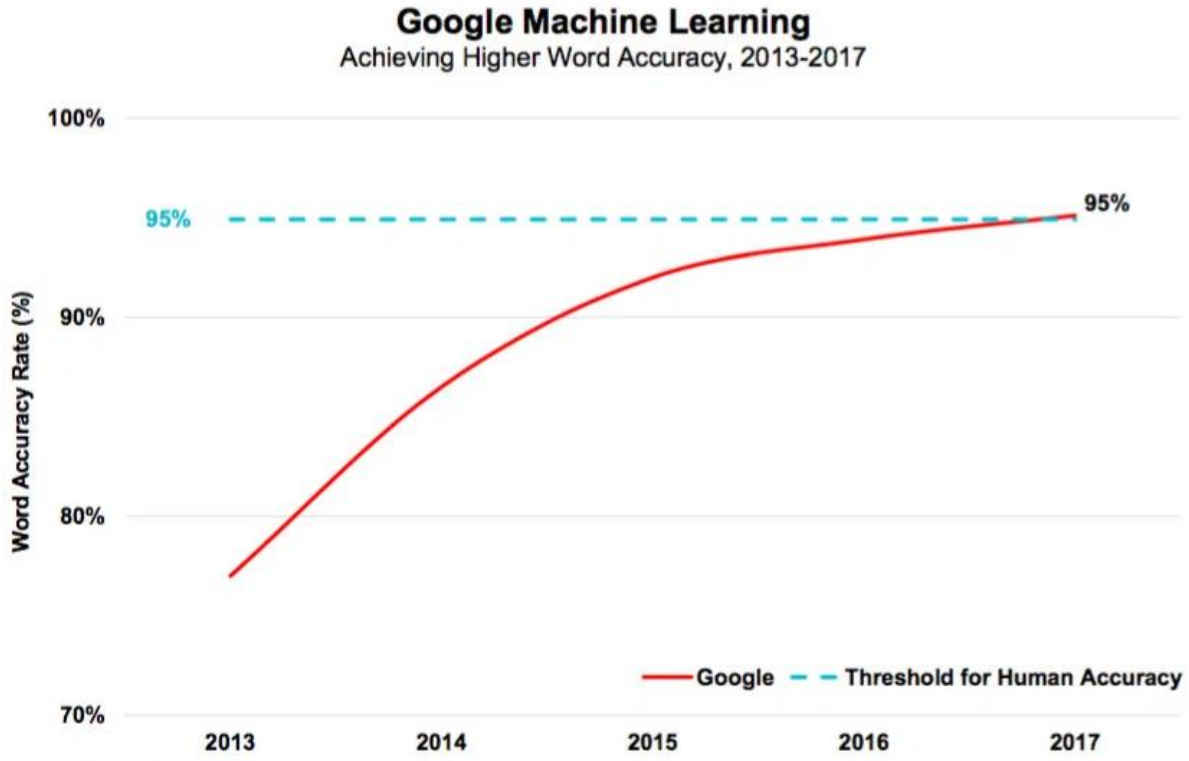


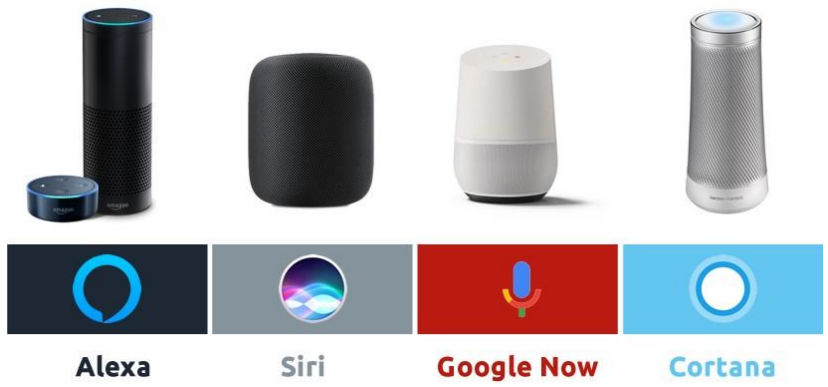
Facebook Friends Tagging



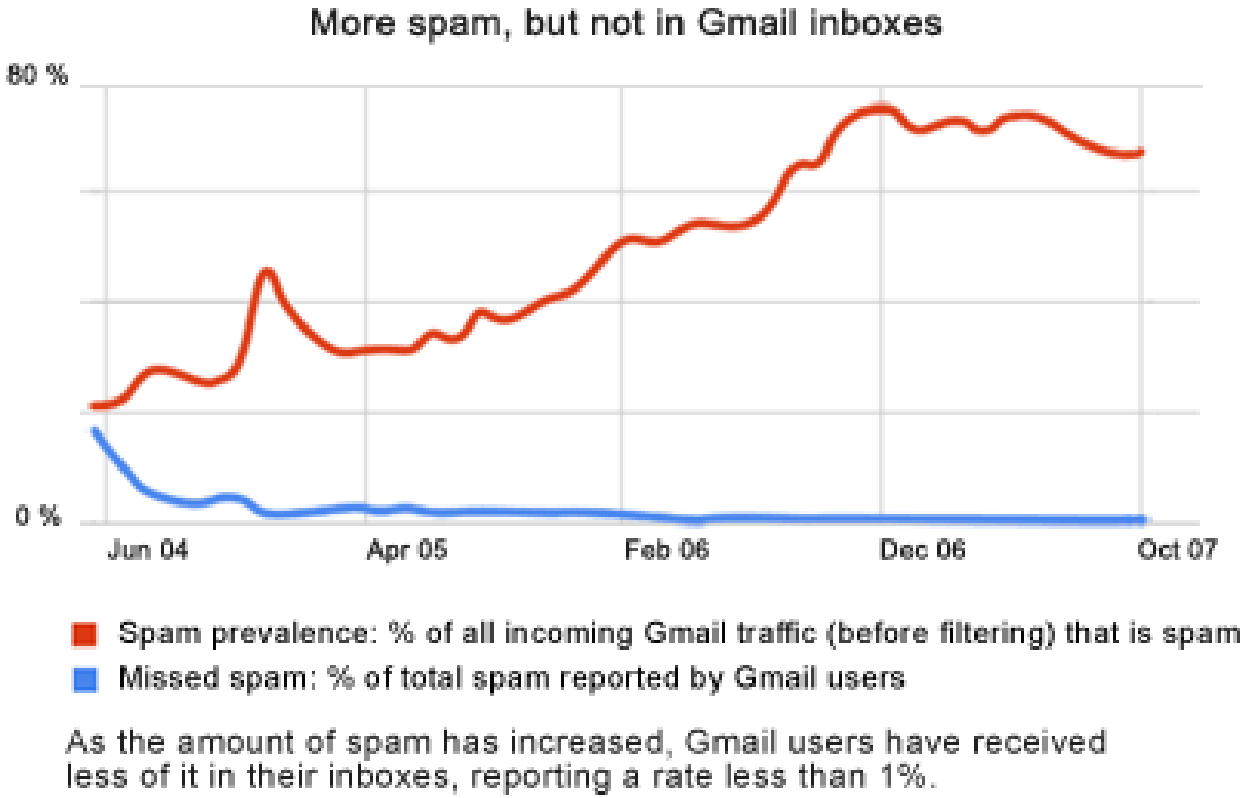

30
25
20
15
10
5
0
ImageNet Visual Recognition Error Rate (%)
Human error rate
2010
2011
2012
2013
2014
2015
2016
2017
Year

Voice Assistants





Gmail: ML in NLP



William Shakespeare ¶

Transformer AI poetry: Poetry classics as reimagined and rewritten by an artificial intelligence.

"Sonnet 18"
William Shakespeare
Shall I compare thee to a summer's day?
Thou art more lovely and more temperate:
Rough winds do shake the darling buds of May,
And summer's lease hath all too short a date;
A winter's day, when beams of sun are few,
And skies are grey with clouds intemperate,
Is to thy beauty somehow sordid grown.
Her lovely-lovely eye is quite shut up,
Like windows pale before a sunny shower.
The earth that's cold and moist, like to my mistress,
When once that she unbrac'd, her lovely jewel,
Grows as both ugly and uncourtly.
Poor soul, the center of my motley host,
See, now they request thy sovereign presence;
The din of merry hearts hath brought me thus
To greet thee, thou unsoil'd and saint-like beauty.

Recommender Systems

- Recommend movies based on user preferences, interests and likes
- Similar ideas for facebook…
  - Find friends that share your interests

Keyboard acoustics

Keyboard Acoustic Emanations Revisited

LI ZHUANG, FENG ZHOU, and J. D. TYGAR
University of California, Berkeley

Text recognized by the HMM classifier, with cepstrum features (underlined words are wrong),

> the big money fight has drawn the shoporo od dosens of companies in the entertainment industry as well as attorneys gnnerals on states, who fear the fild shading softwate will encourage illegal acyivitt, srem the grosth of small arrists and lead to lost cobs and dimished sales tas revenue.

Text after spelling correction using trigram decoding,

> the big money fight has drawn the support of dozens of companies in the entertainment industry as well as attorneys generals in states, who fear the film sharing software will encourage illegal activity, stem the growth of small artists and lead to lost jobs and finished sales tax revenue.

Original text. Notice that it actually contains two typographical errors, one of which is fixed by our spelling corrector.

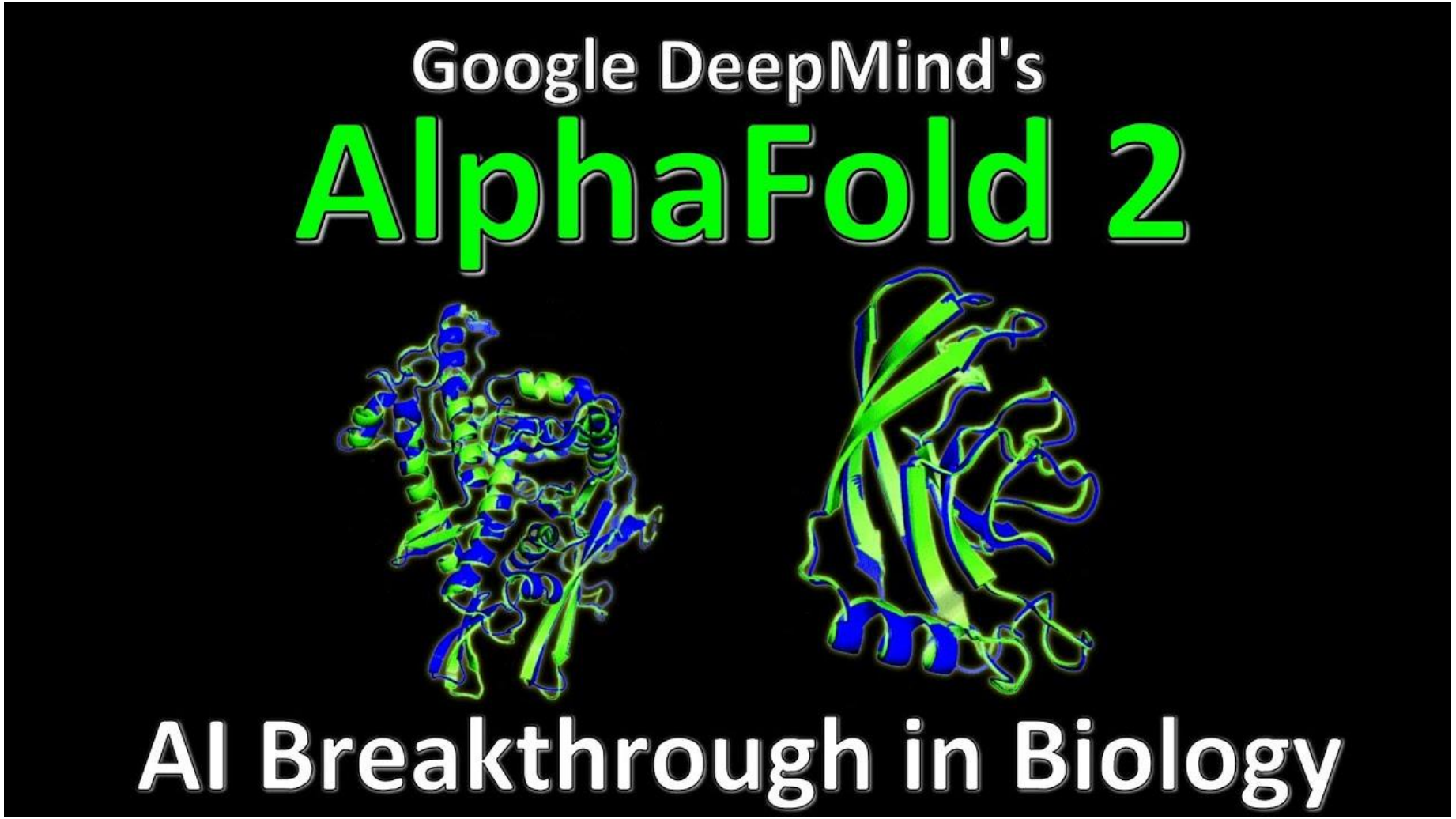
> the big money fight has drawn the support of dozens of companies in the entertainment industry as well as attorneys gnnerals in states, who fear the file sharing software will encourage illegal activity, stem the growth of small artists and lead to lost jobs and dimished sales tax revenue.

PCR in HCI/CV

- Gesture Recognition

Synthesis

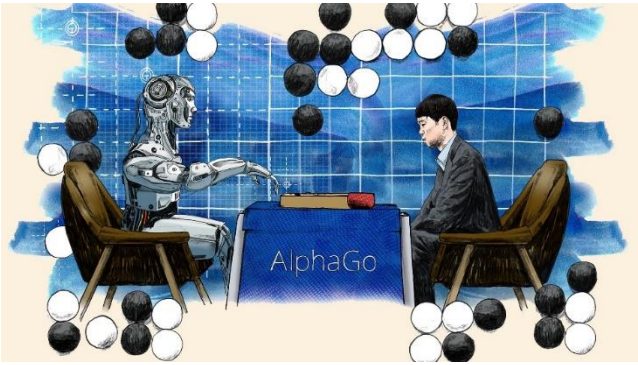
https://deepmind.com/blog/article/Agent57-Outperforming-the-human-Atari-benchmark



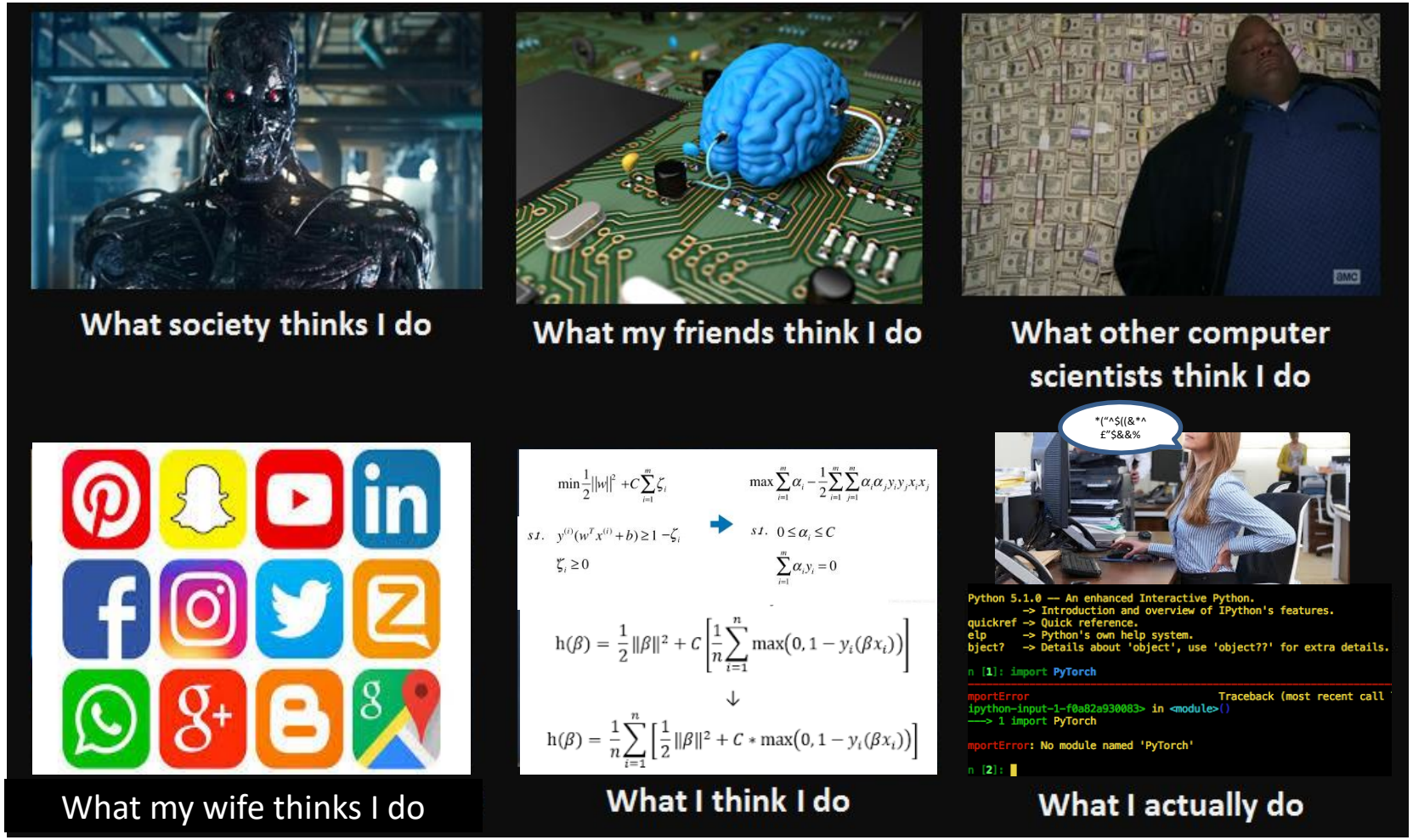
NEWS · 30 NOVEMBER 2020

'It will change everything': DeepMind's AI makes gigantic leap in solving protein structures

Google's deep-learning program for determining the 3D shapes of proteins stands to transform biology, say scientists.



Machine Learning

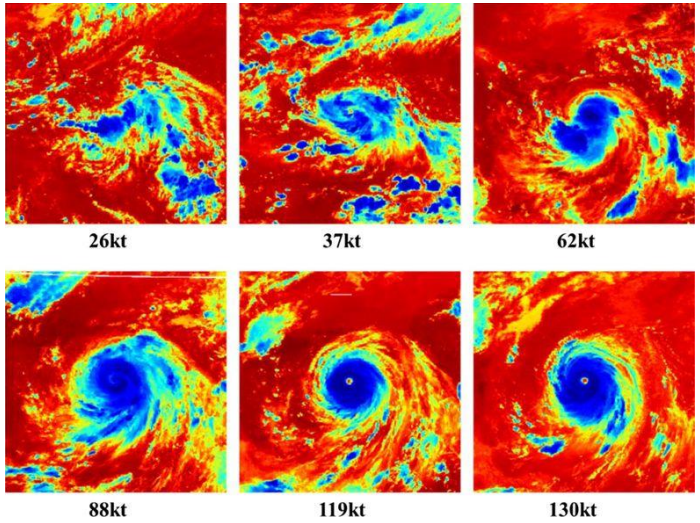


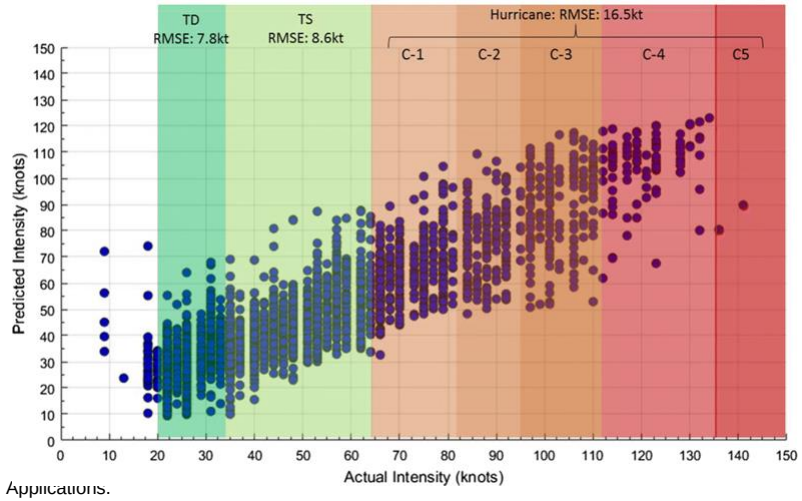
Applied Machine Learning

- Examples from my research

Data Science: Hurricane Intensity Prediction

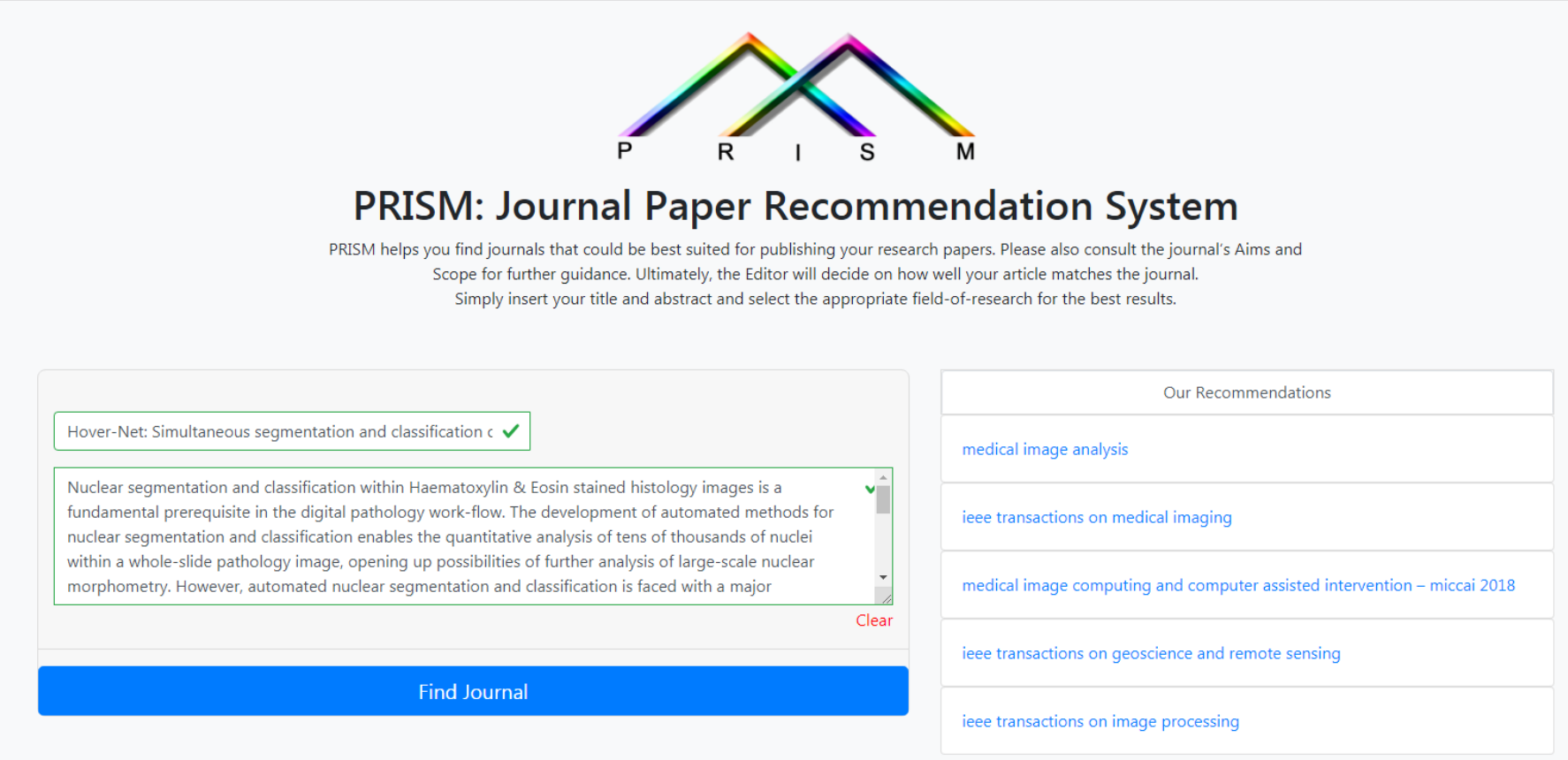
- Hurricane Intensity Prediction
  - In collaboration with National Hurricane Center, USA
  - Deep-PHURIE





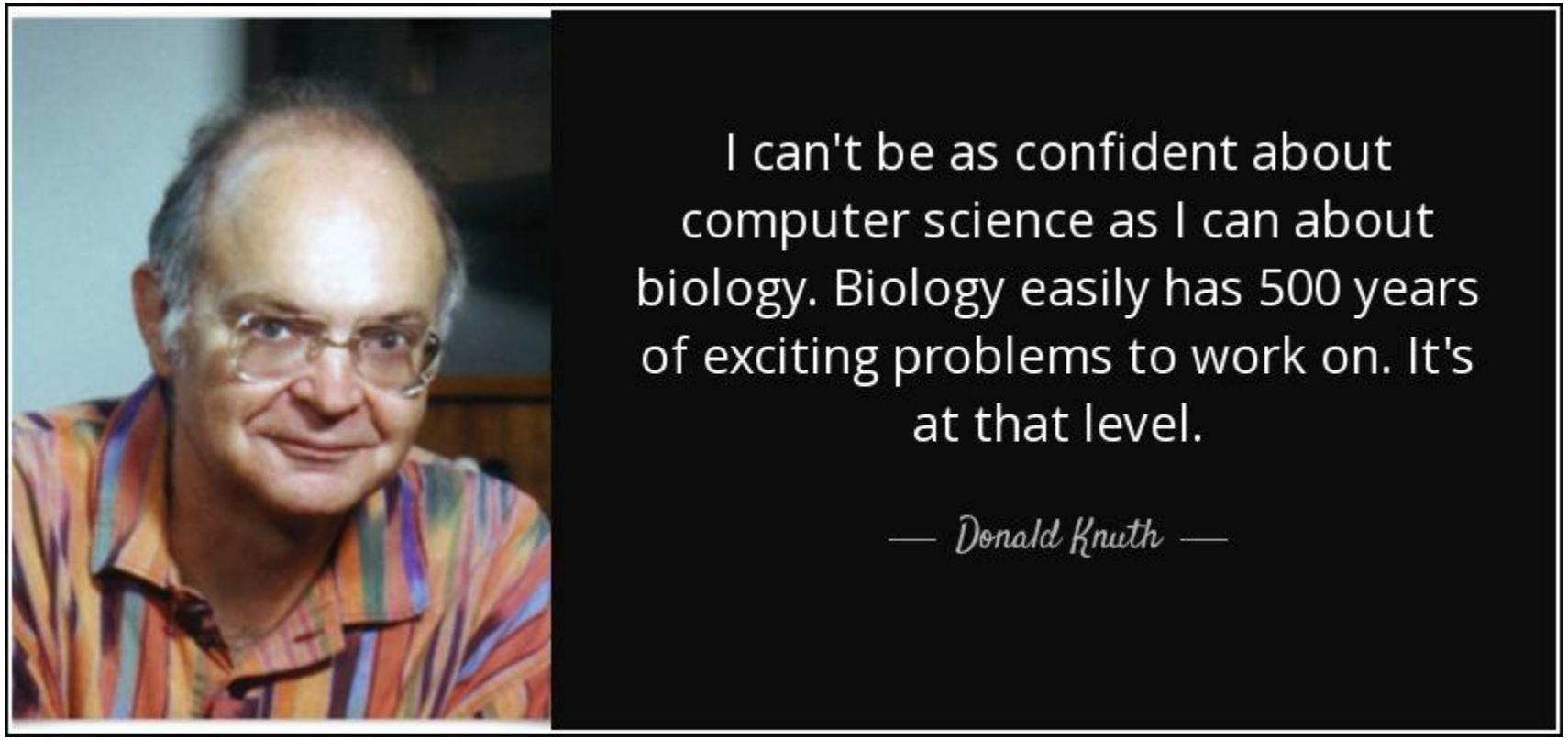
Deep-PHURIE: Deep Learning based Hurricane Intensity Estimation from Infrared Satellite Imagery, M. Dawood, A. Asif and Fayyaz Minhas, in Neural Computing and Applications. pp. DOI: 10.1007/s00521-019-04410-7, July 2019.
PHURIE: Hurricane Intensity Estimation from Infrared Satellite Imagery using Machine Learning, Amina Asif, Muhammad Dawood, Bismillah Jan, Javaid Khurshid, Mark DeMaria, and Fayyaz ul Amir Afsar Minhas, in Neural Computing and Applications, DOI: http://dx.doi.org/10.1007/s00521-018-3874-6, 2018

Data Science: Journal Recommendation System

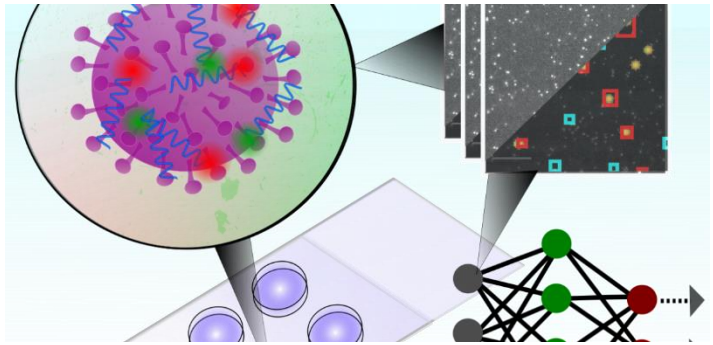


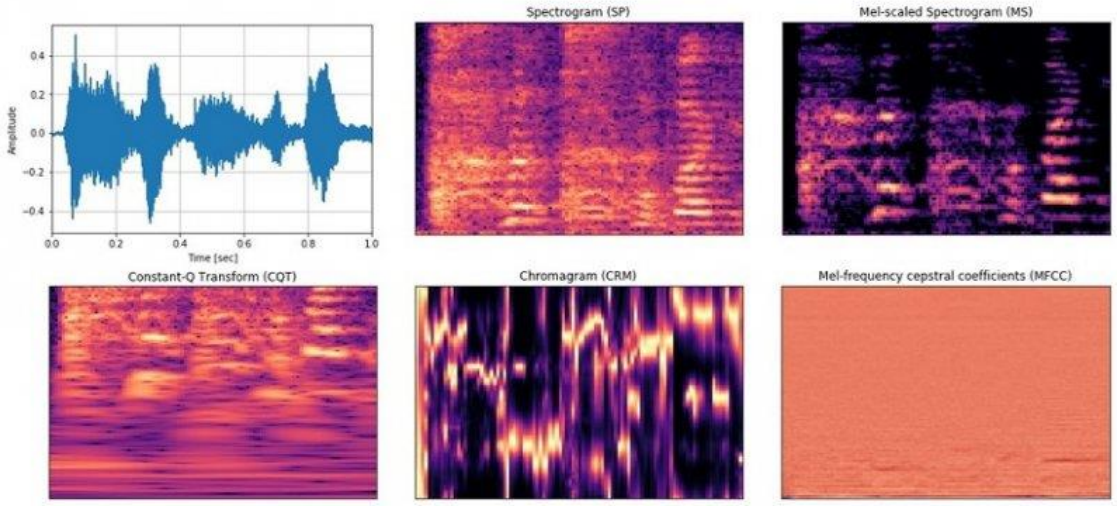
- Using classical NLP
- Using BERT

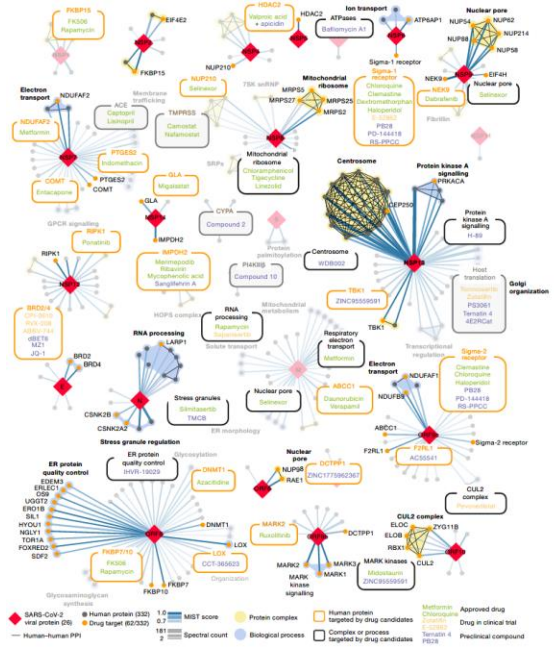
End to end Learning-based Journal Recommendation System by M. Bilal and Fayyaz Minhas (in prep.)


I can't be as confident about computer science as I can about biology. Biology easily has 500 years of exciting problems to work on. It's at that level.
— Donald Knuth —

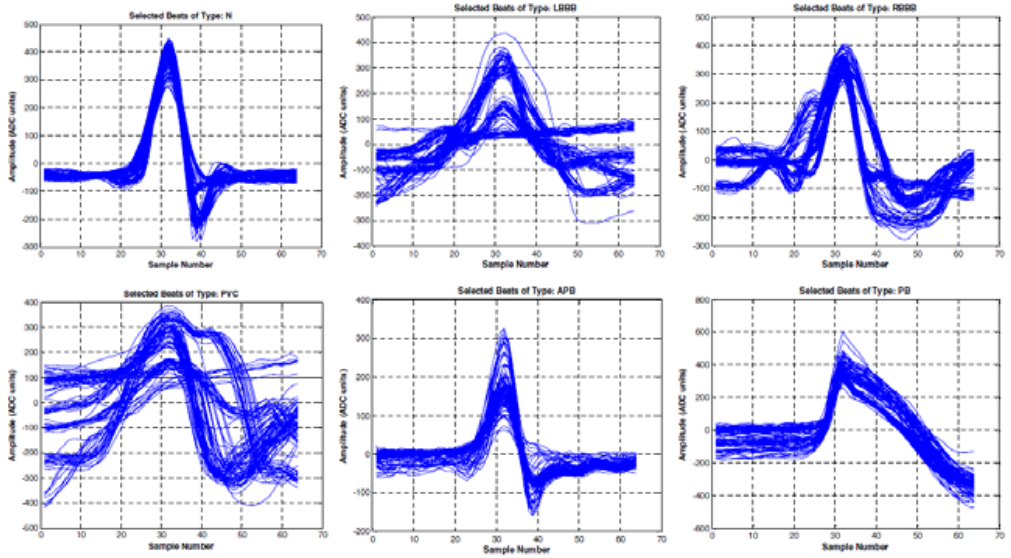
COVID19 Meets Machine Learning

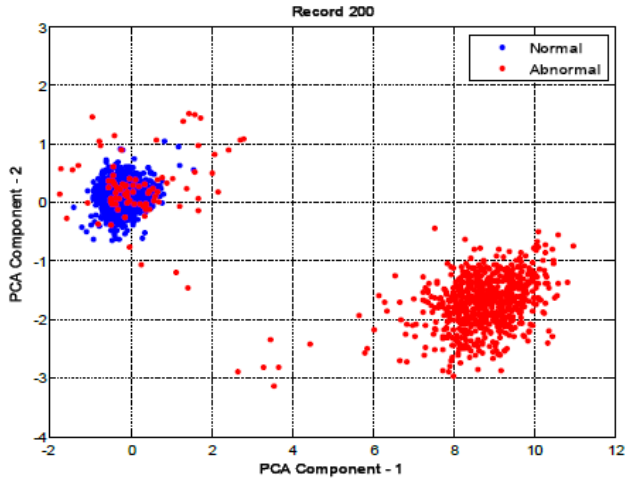


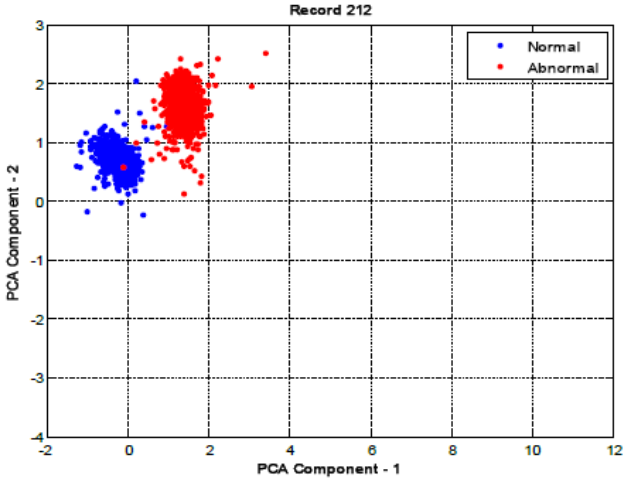




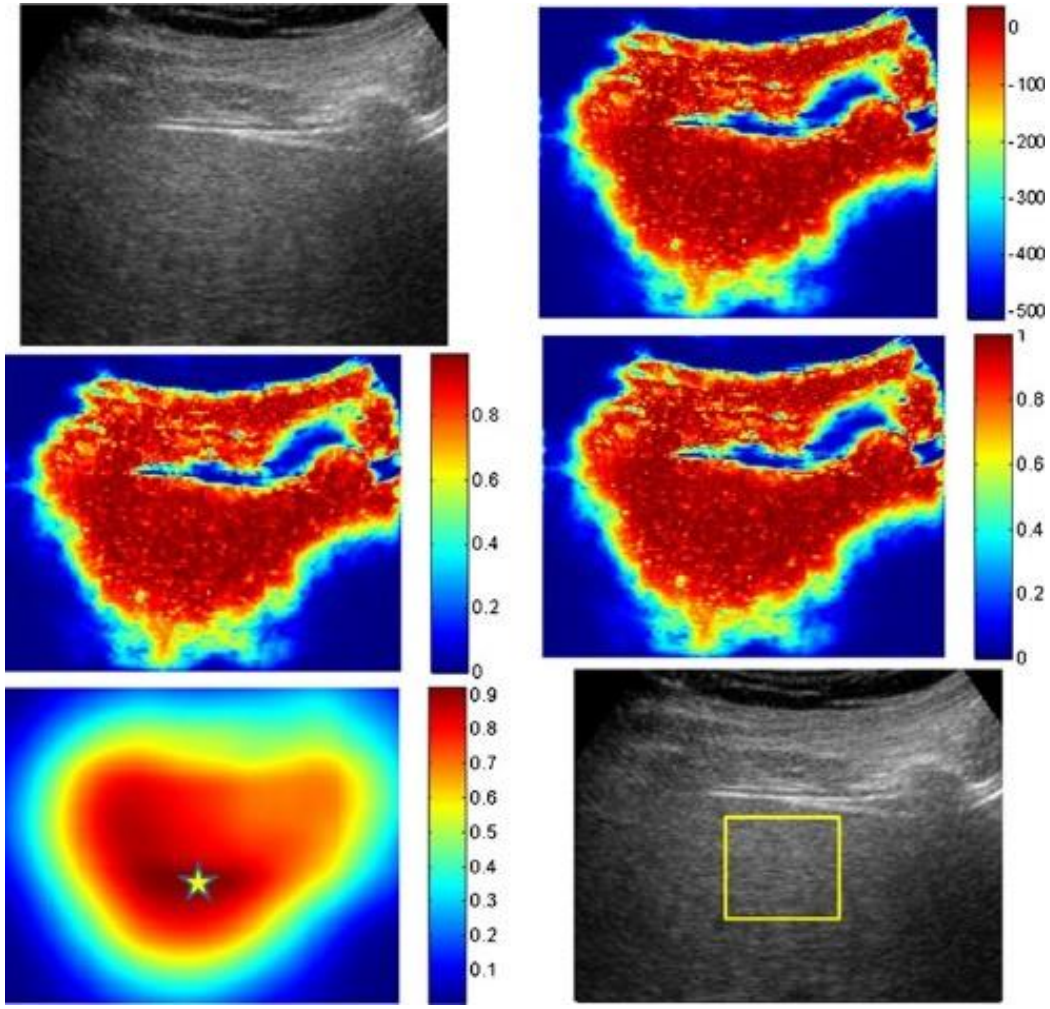
ECG Classification





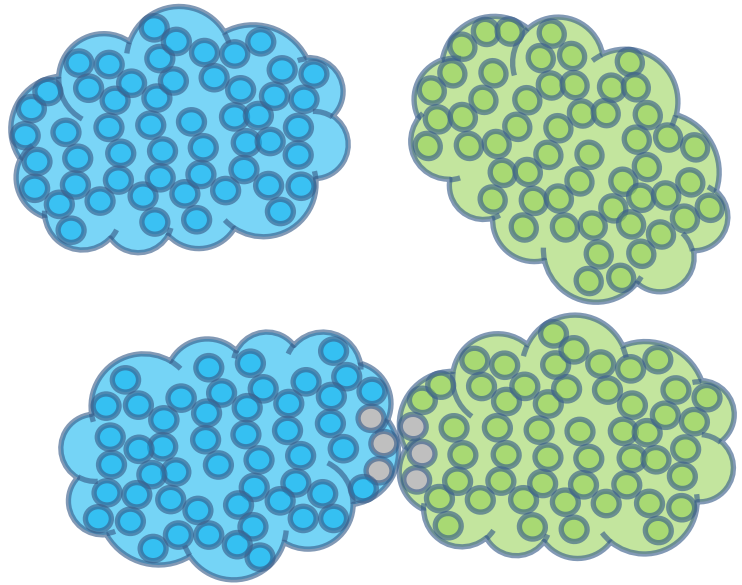


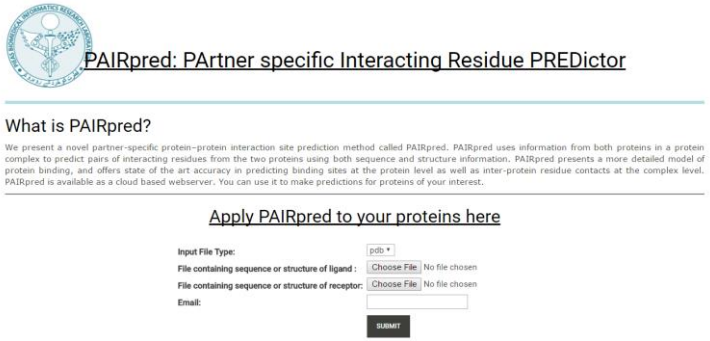
Medical Data Classification

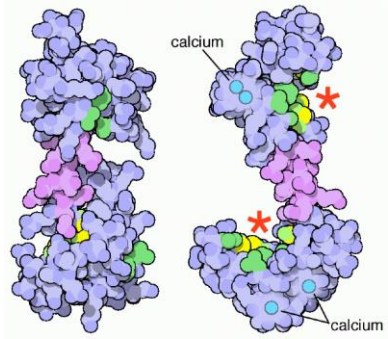


Predicting Protein interactions, interfaces and affinity

- Input: Two protein structures or sequences
- Output: What residue pairs interact



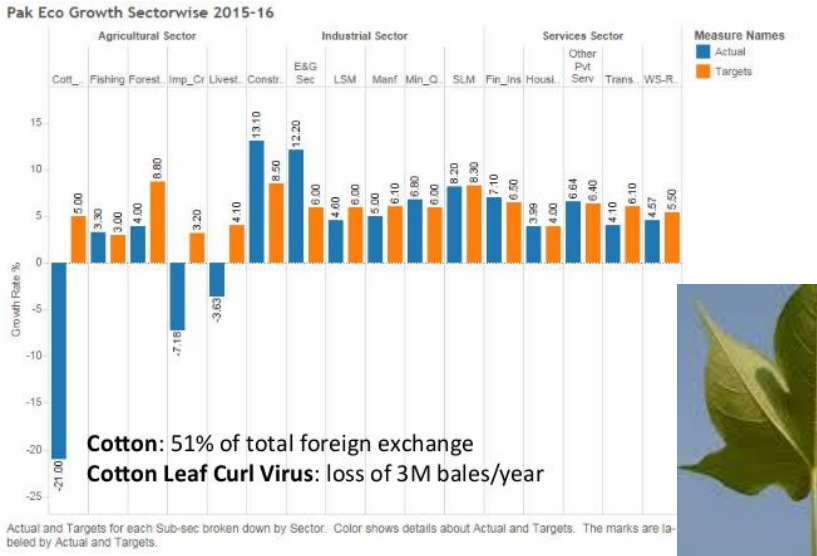




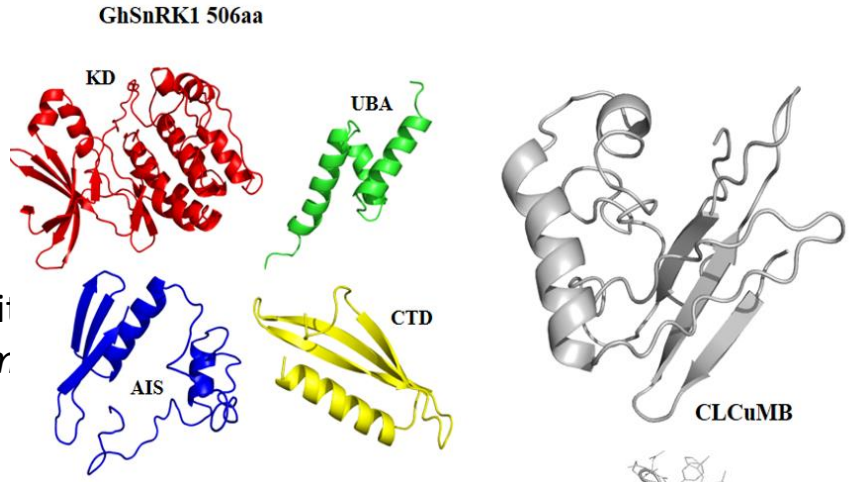
[1] Fayayz Minhas and Asa Ben-Hur, Multiple instance learning of Calmodulin binding sites. **Bioinformatics** 28, i416, 2012.
[2] Wajid Abbasi, Amina Asif, Saiqa Andleeb, and Fayyaz Minhas, CaMELS: In silico Prediction of Calmodulin Binding Proteins and their Binding Sites, in **Proteins: Structure, Function and Bioinformatics**, 2017.
[3] Issues In Performance Evaluation for Host-Pathogen Protein Interaction Prediction, Wajid A. Abbasi and Fayyaz Minhas, in **Journal of Bioinformatics and Computational Biology**, vol. 14, no. 3, 1650011, January 2016.
[4] Training host-pathogen protein–protein interaction predictors , Abdul Hannan Basit, Wajid Arshad Abbasi, Amina Asif, Sadaf Gull and **Fayyaz Minhas**, in **Journal of Bioinformatics and Computational Biology**, Vol. 16, No. 04, 1850014 (2018).
[5] Issues In Performance Evaluation for Host-Pathogen Protein Interaction Prediction, Wajid A. Abbasi and Fayyaz Minhas, in **Journal of Bioinformatics and Computational Biology**, vol. 14, no. 3, 1650011, January 2016.
[6] Training host-pathogen protein–protein interaction predictors , Abdul Hannan Basit, Wajid Arshad Abbasi, Amina Asif, Sadaf Gull and **Fayyaz Minhas**, in **Journal of Bioinformatics and Computational Biology**, Vol. 16, No. 04, 1850014 (2018).

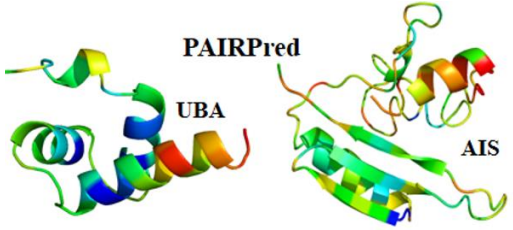
Experimental Validation: SnRK1- βC1

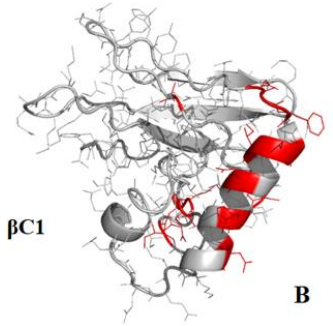
- In Silico Prediction and Validations of Domains Involved in Gossypium hirsutum **SnRK1** Protein Interaction with Cotton leaf curl Multan betasatellite encoded **βC1**
- βC1, pathogenicity determinant encoded by Cotton leaf curl Multan betasatellite interacts wi calmodulin-like protein 11 (CML11) in *Gossypium hirsutum*

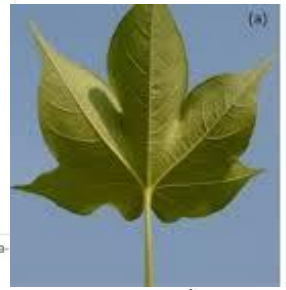


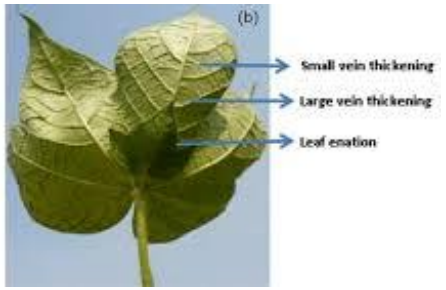
http://www.dawn.com/news/1201323

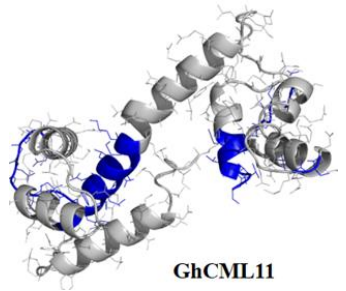












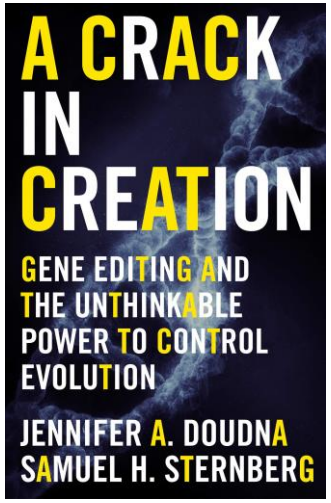
4

In Silico Prediction and Validations of Domains Involved in Gossypium hirsutum SnRK1 Protein Interaction with Cotton leaf curl Multan betasatellite encoded βC1, Kamal, Hira, Fayyaz ul Amir Afsar Minhas, Hanu Pappu, Imran Amin et al., in **Frontiers in Plant Science** 10 (2019): 656.

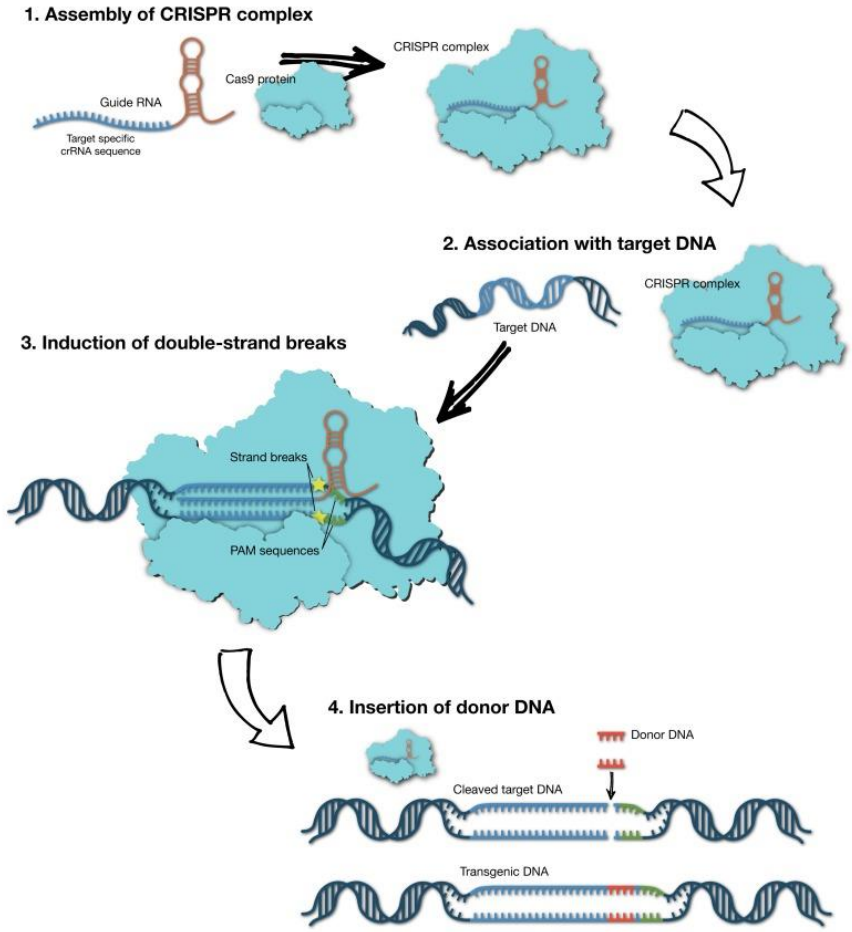
Bioinformatics and molecular analysis of Gossypium hirsutum calmodulin-like protein (CML11) interaction with begomovirus-transcription activator protein C2. Hira Kamal, Fayyaz Minhas, et al., in PLoS One (In press).

Predicting anti-CRISPR proteins

- 20 proteins for training
- Identified 3 new anti-CRISPR proteins using a ranking ML model



Jennifer Doudna

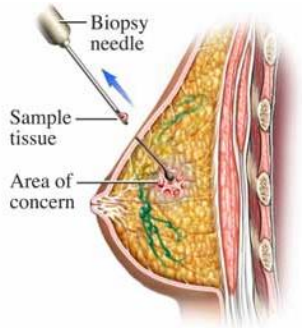


Eitzinger, Simon, Amina Asif, Kyle E. Watters, Anthony T. Iavarone, Gavin J. Knott, Jennifer A. Doudna, and Fayyaz ul Amir Afsar Minhas. "Machine Learning Predicts New Anti-CRISPR Proteins." *Nucleic Acids Research* 48, no. 9 (May 21, 2020): 4698–4708. https://doi.org/10.1093/nar/gkaa219.

Current Focus: PATHLake

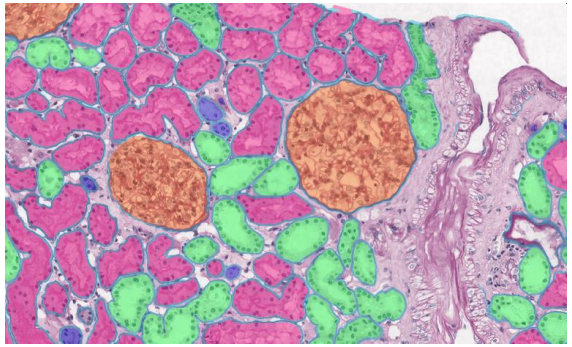
- PATHology data Lake, Analytics, Knowledge and Education
- UK Research and Innovation
- £15.7 million
- Objective:
  - Improve speed and accuracy of cancer diagnosis

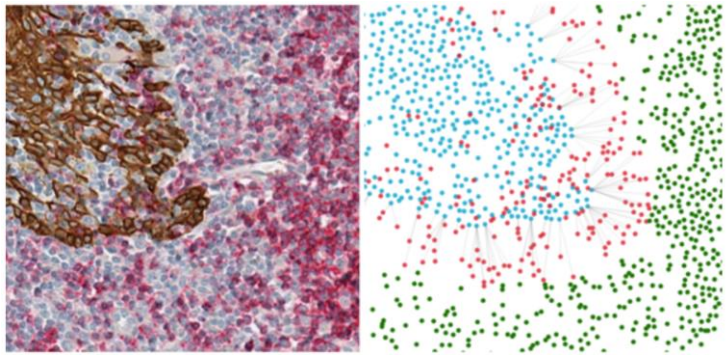
The Revolution in Pathology



Conventional Microscope Pathology

Digital Pathology

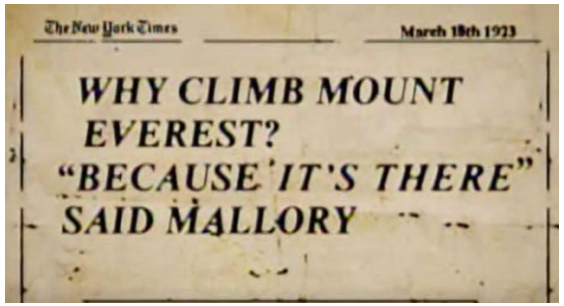




Computational Pathology

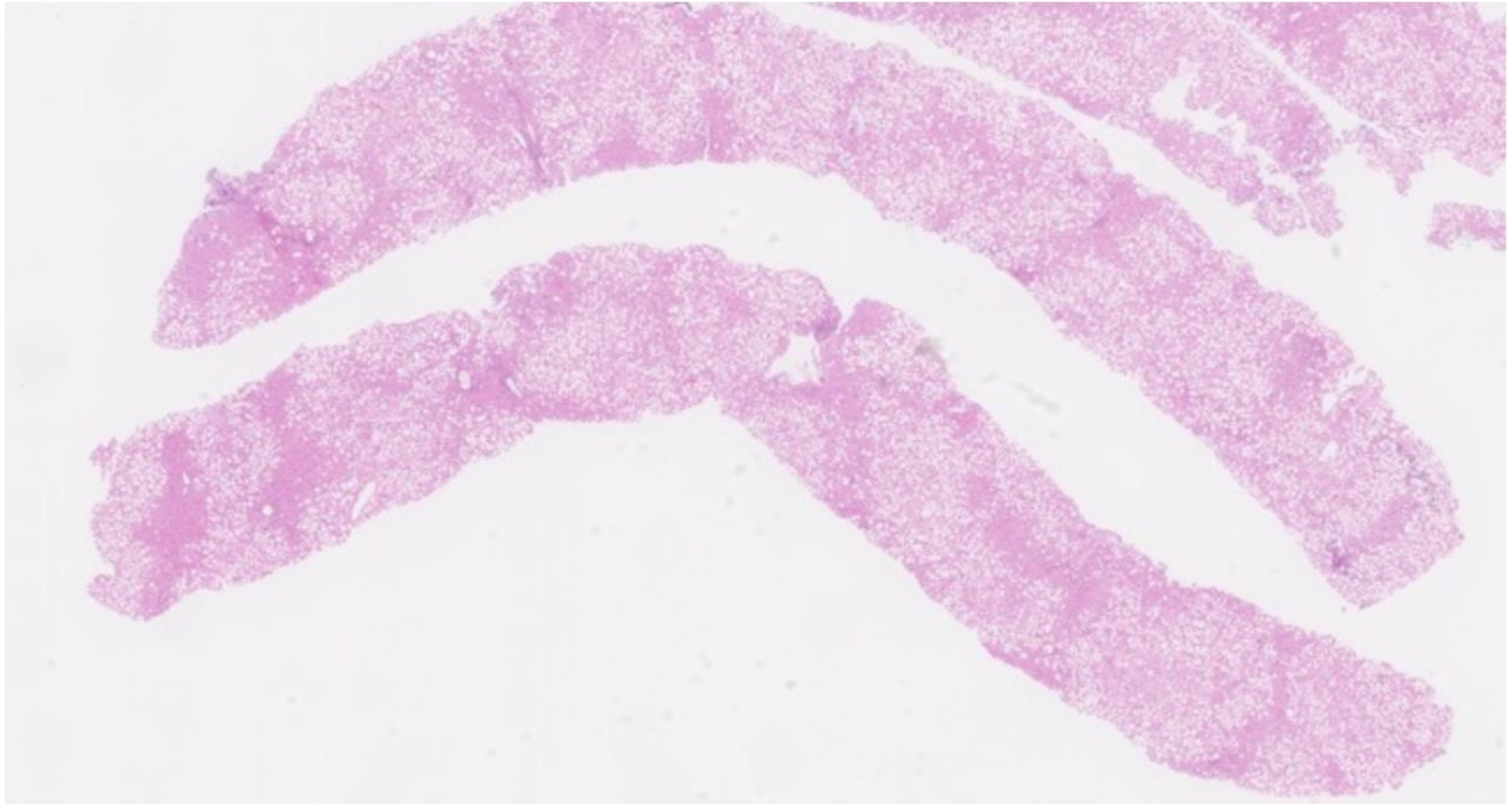
Why?

- Shortage of Pathologists
- Quantification is difficult
- Subjectivity
- Inter-observer variability

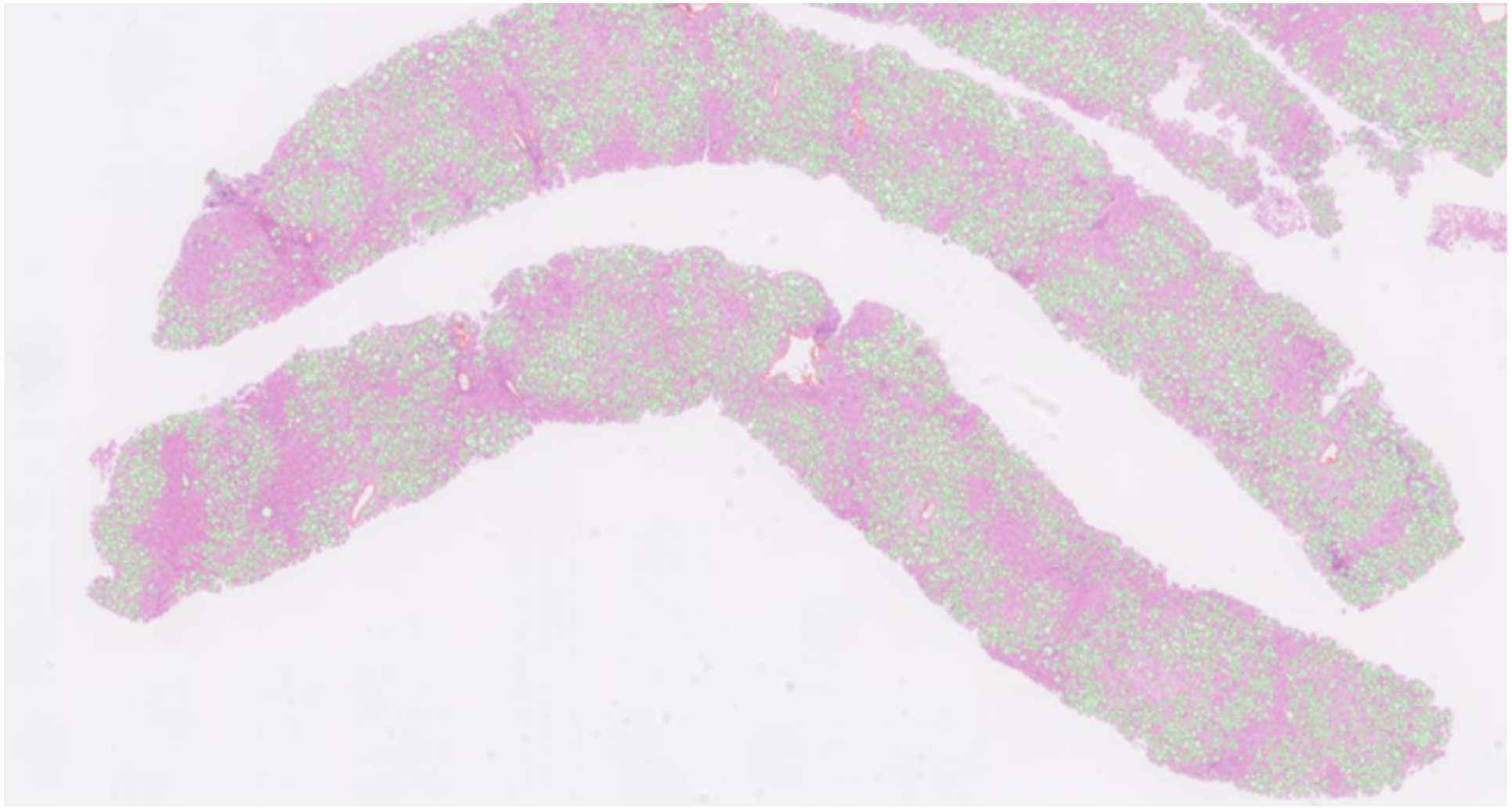

The New York Times March 18th 1923

WHY CLIMB MOUNT EVEREST?
"BECAUSE IT'S THERE"
SAID MALLORY

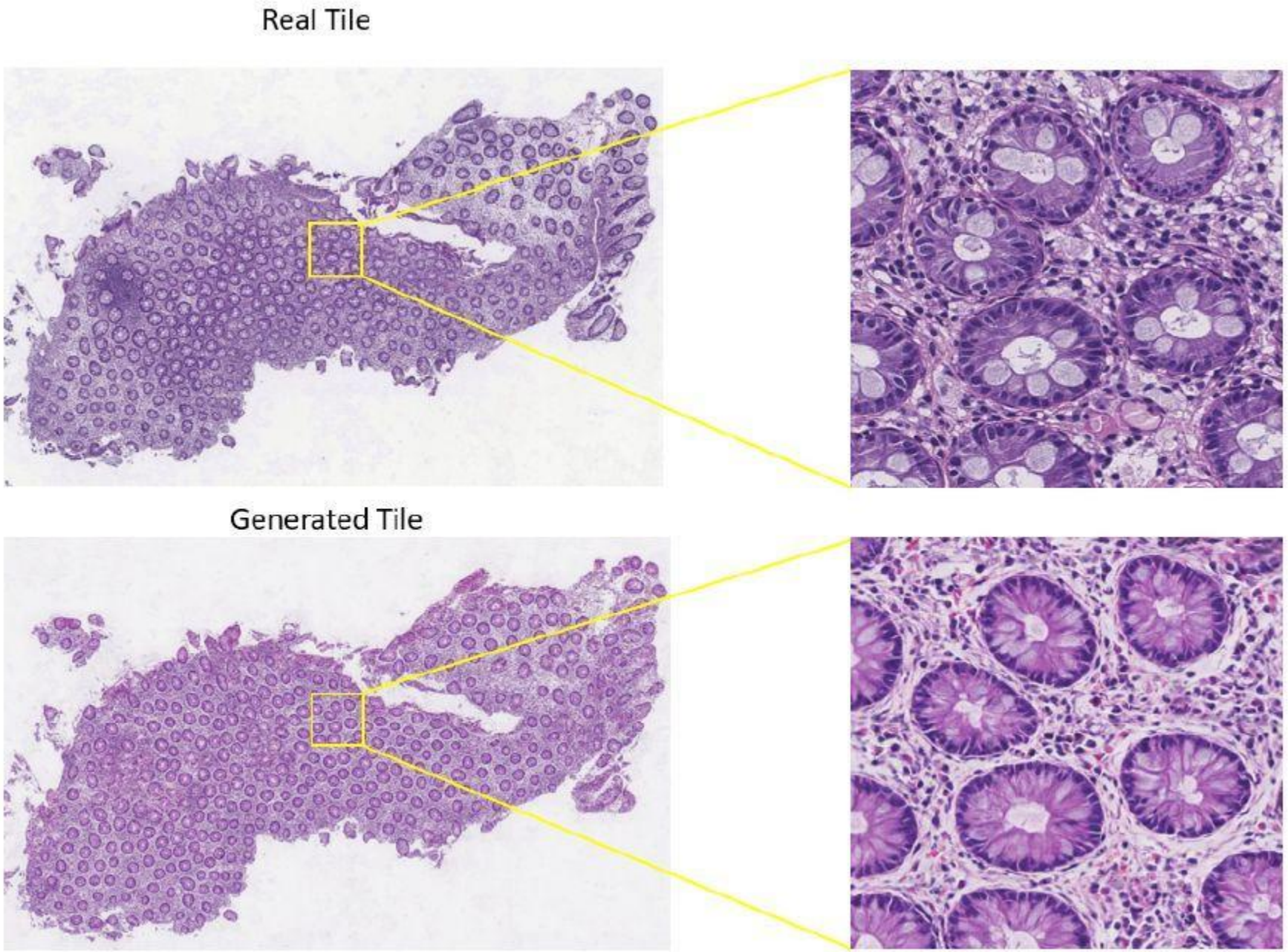
How much fat?



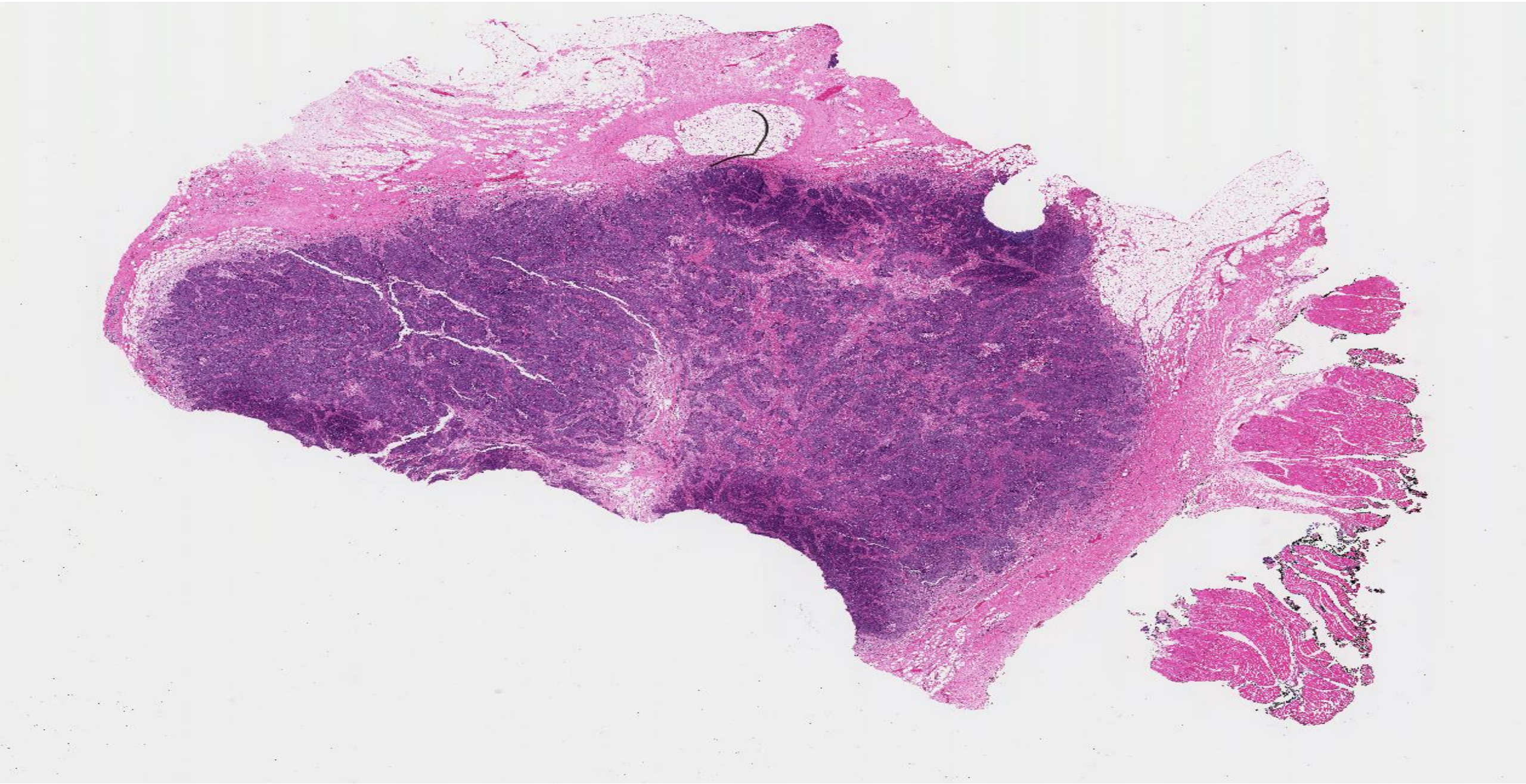
45.9%

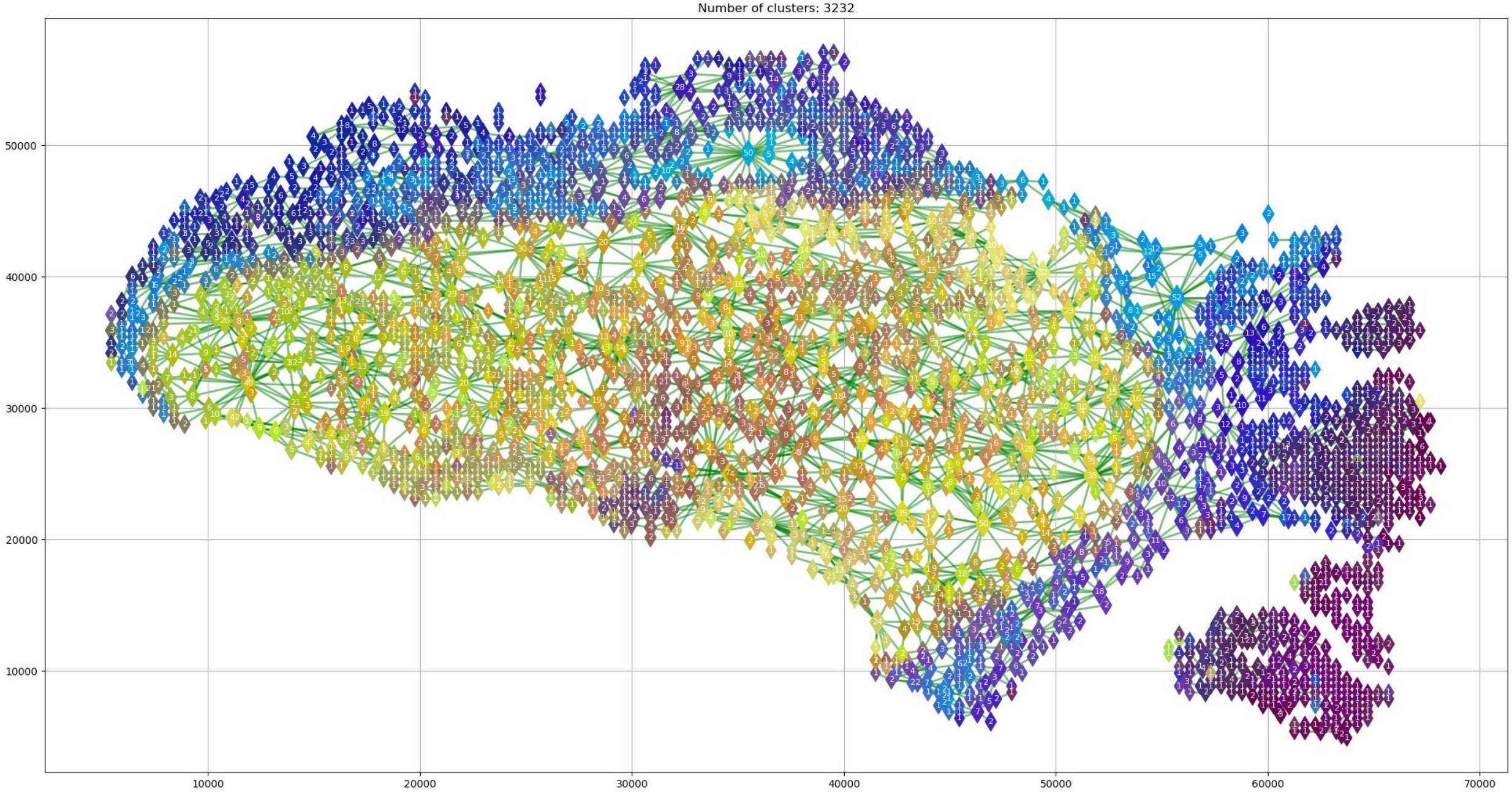


R. Glodin, “The Clinical Challenge of Image Analysis and AI”, CRUK Early Detection Sandpit, Royal College of Pathologists, London, UK, 20 Nov. 2019

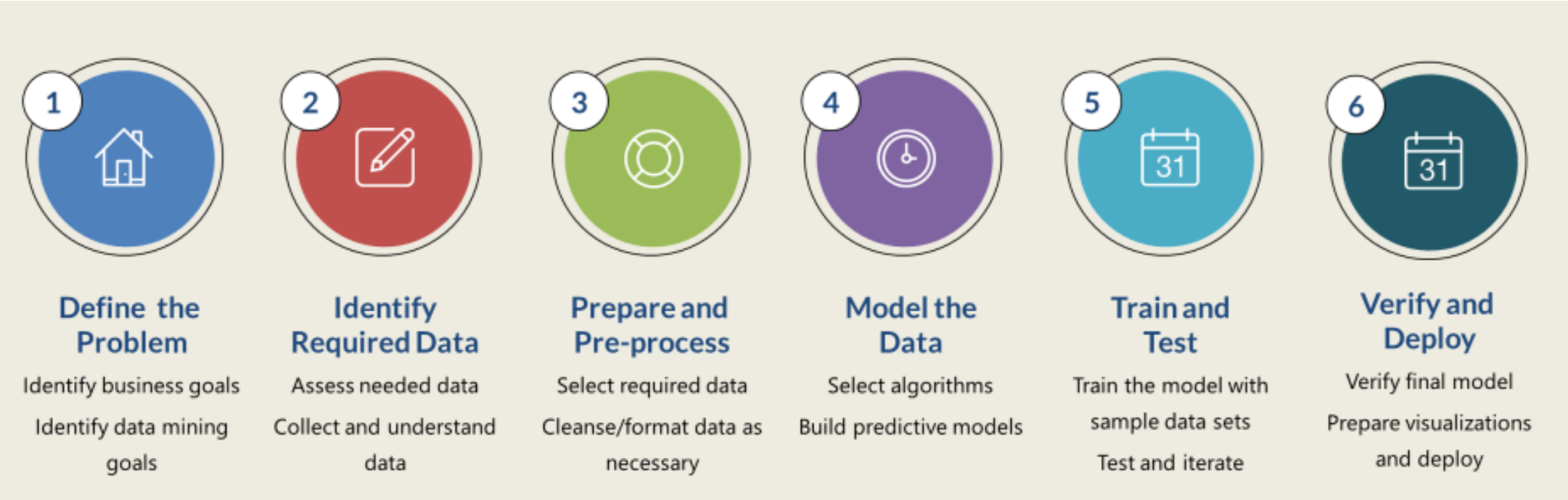


Deshpande, Srijay, Fayyaz Minhas, Simon Graham, and Nasir Rajpoot. “SAFRON: Stitching Across the Frontier for Generating Colorectal Cancer Histology Images.” *ArXiv:2008.04526 [Cs, Eess]*, August 11, 2020. http://arxiv.org/abs/2008.04526.



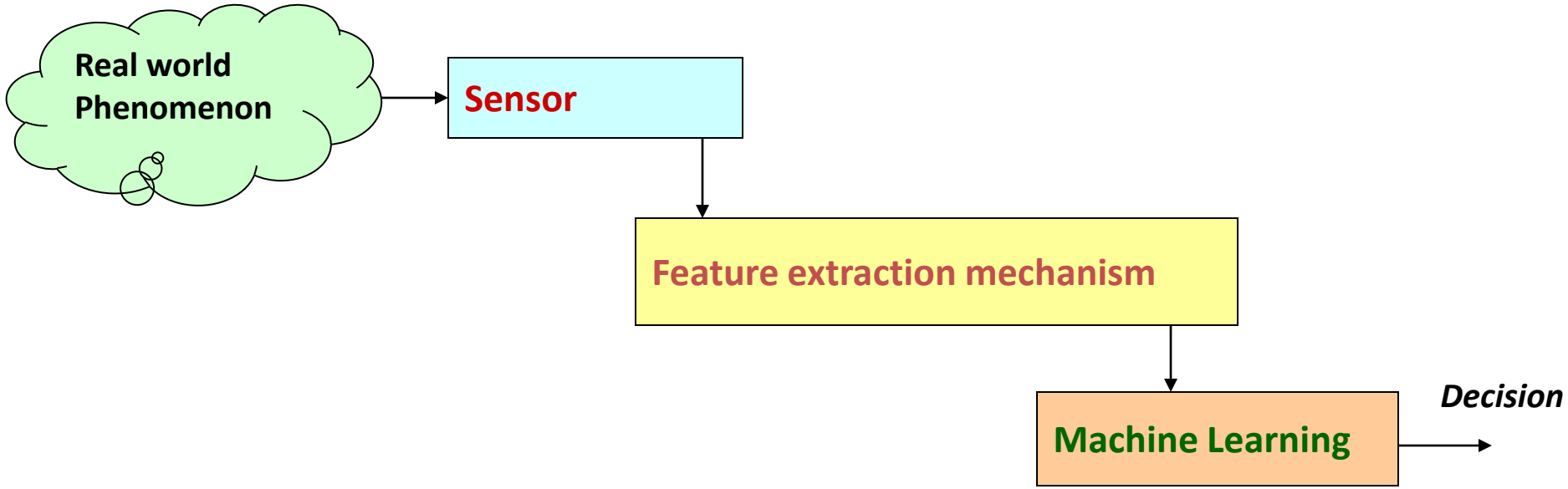

Number of clusters: 3232
50000
40000
30000
20000
10000
10000
20000
30000
40000
50000
60000
70000

Steps in the development of a data science model



Constructs of a Data Mining System for Prediction

- Identify the objective
  - Identify the unit of classification (example)
    - Image block, protein sequence, ….



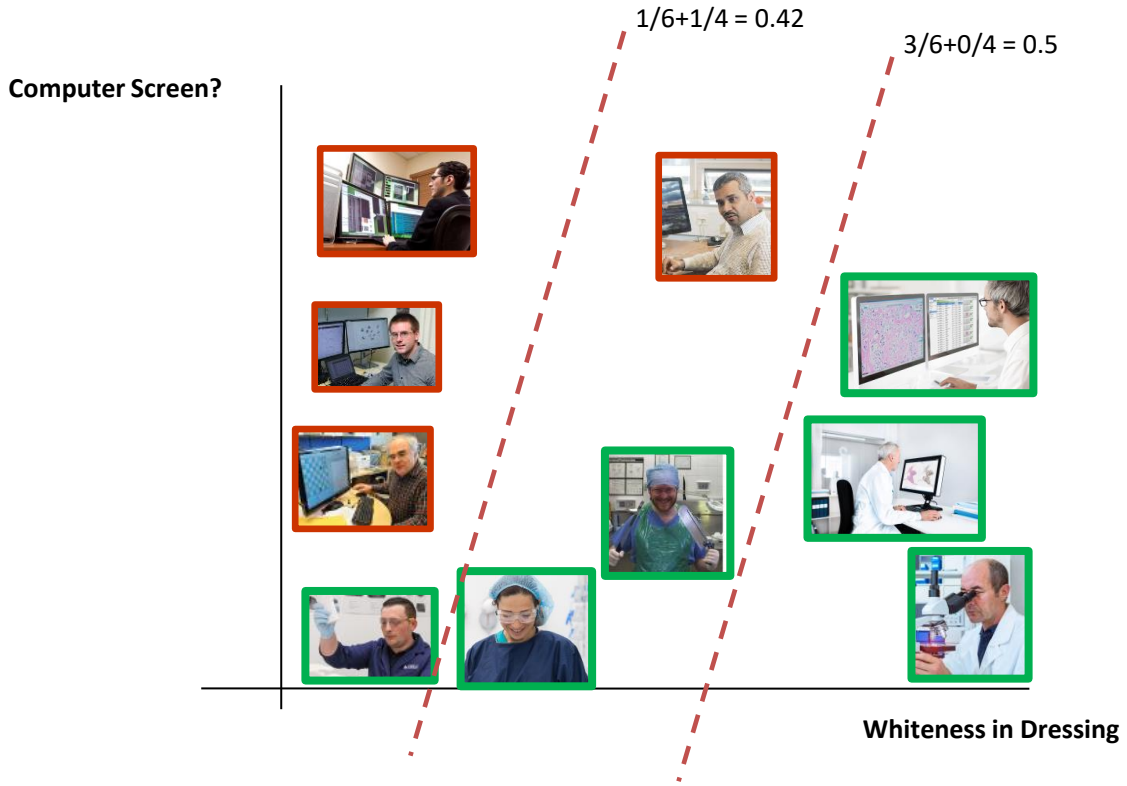
Learning from Data

- Example Case
  - Pathologists vs. Computer Scientists
    - Hypothetical!
    - Classify a person in their "native" environment

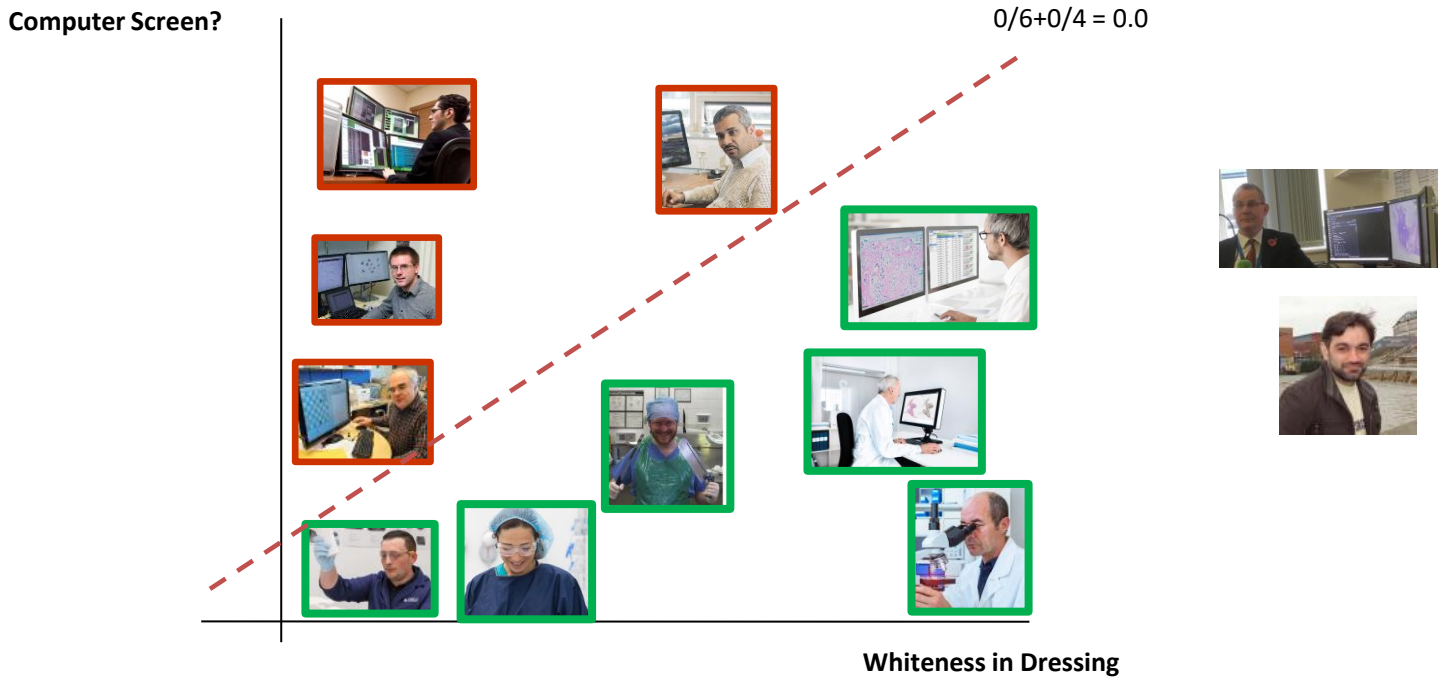
Constructs

- Sensor(s)
  - Camera
- Feature Extraction
  - White coats or lap aprons?
  - Computer Screen or microscopes?
  - Income?
- Machine Learning

Feature Space

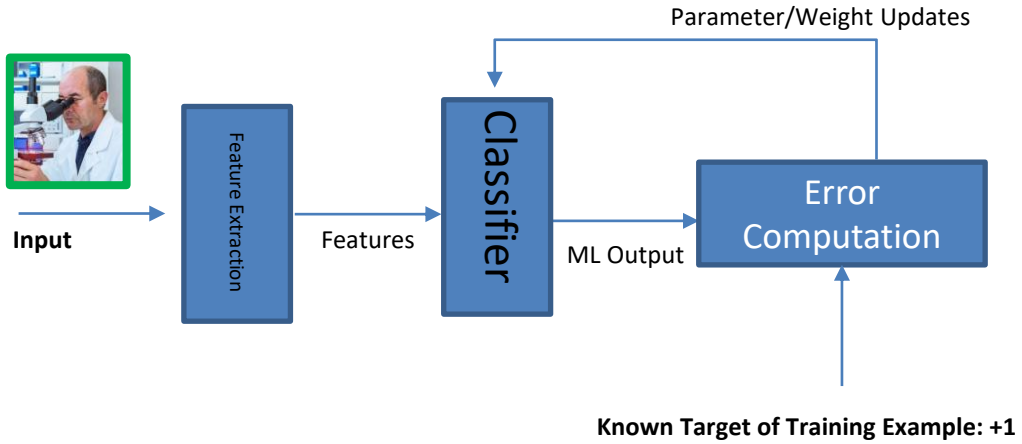


Feature Space Classification



So far?

- **R**epresentation
  - Represent examples in a feature space
  - Define a classification function
    - Line: $f(\mathbf{x};\mathbf{w}) = w_1x^{(1)}+w_2x^{(2)}+b = 0$
- **E**valuation
  - Define an error function
    - Misclassifications
- **O**ptimize
  - Reduce error
- Real Test (Generalization)
  - How does it perform on unseen data?



End of Lecture-2

We want to make a machine that will be proud of us.

- Danny Hillis