MOHAMED BIN ZAYED UNIVERSITY OF ARTIFICIAL INTELLIGENCE

Research with Purpose: Driven by Curiosity, Grounded in Confidence

MBZUAI Research Showcase

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"How do I find a high-impact research topic?"

Identifying Research that Matters

How Knuth's Metafont Sparked Computational Geometry

Identifying Research that Matters

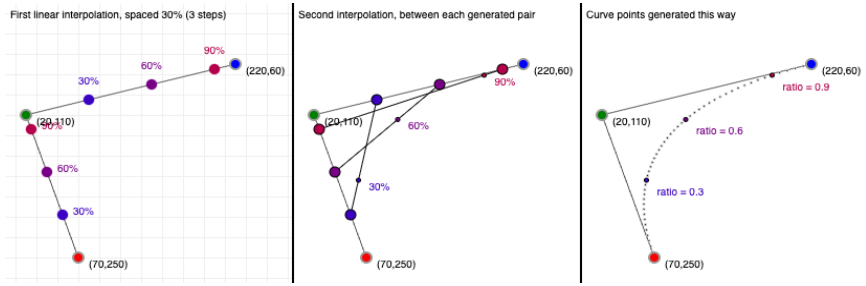
The Problem: Messy Digital Text (Back to the 1970s)

- The Early Days of Digital Typography: A Pixelated Puzzle
  - Displaying text on screens was inconsistent and low quality.
  - Text appearance varied significantly across different devices.
  - Fonts were often hard-coded bitmaps – inflexible and non-scalable.
  - Scaling was ugly—zoomed fonts looked jagged

Identifying Research that Matters

The Question: How to enable computers draw letters?

- Knuth saw the friction (real-world problem)
- He asked: Can we describe letters mathematically?
- Goal: Make fonts flexible, scalable, and universal
- Metafont: A new way to define and design fonts using equations
  - Designers describe letter shapes, not pixels.
  - Letters become “programs” that computers draw.
- Knuth's revolutionary approach: describe character shapes using mathematical equations.
  - Introduced concepts like curves, direction and tension.
  - Use principles from geometry and spline theory.



Identifying Research that Matters

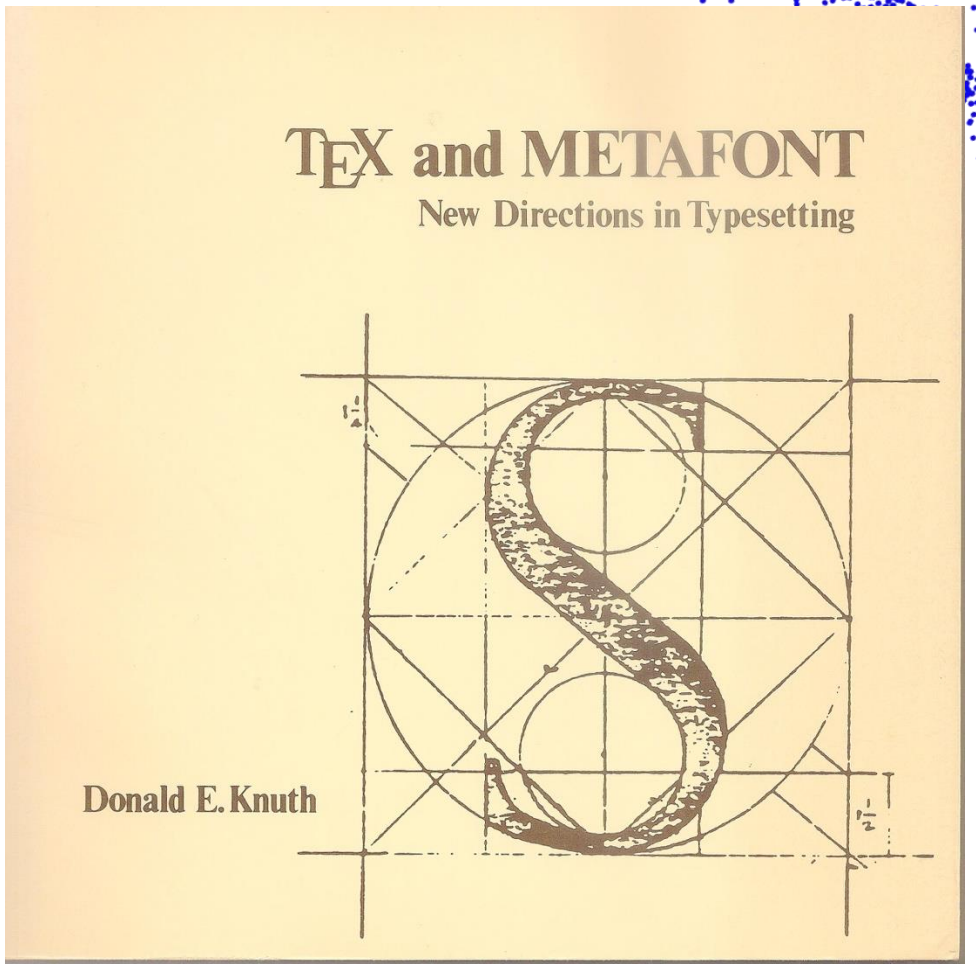
The Magic and Impact

- Math creates beauty—smooth letters, perfectly scaled.
  - Relies on spline theory for smooth shapes.
  - Closely tied to Hermite splines: precise, flexible curves.
- Power Without Complexity
  - Knuth hides the math from users.
    - Artists didn't need to know equations—just design.
  - Metafont gave creative freedom with technical precision.
- Impact
  - Laid groundwork for modern typography (e.g., PostScript, TrueType)
  - Mathematical techniques developed for curve and shape representation found broader applications.
    - Applications include computer graphics, CAD/CAM, robotics, and more.
  - Computational geometry deals with algorithms and data structures for geometric problems.

Identifying Research that Matters

Lessons Learned

- Work on a Real Problem, Not Chasing Trends
  - At the time, font technology wasn't a "hot" research area.
  - Knuth focused on a fundamental, practical problem: the poor quality and inflexibility of digital fonts.
- Identify areas of "friction" or inefficiency.
- Ask fundamental, insightful questions.
- Reward: Solving a real-world problem in a novel way leads to significant impact.



"How to come up with an novel solution?"

2025 MBZUAI Research Showcase

The Importance of Intuition

- Research isn't purely linear; it involves leaps of thought.
- Intuition allows researchers to make connections that logic might miss.
- Intuition helps formulate hypotheses and identify promising directions.
- "Read enough to develop your intuitions, then trust your intuitions." -- Geoffrey Hinton

From Intuitions to Great Solutions

2013/02/22

Laureate in Engineering – Dr. Geoffrey Hinton, University of Toronto

Brains, Sex and Machine Learning. University of Toronto, Redpath Hall, McGill University

Dropout: An Intuitive Solution to Overfitting

- **Problem**: Overfitting in neural networks, where the model performs well on training data but poorly on unseen data.
- **Hinton's Intuition**: Inspired by the idea of sexual reproduction in biological systems, where mixing of genes creates robustness.
  - Offspring can adapt to diverse environments because they don’t inherit a single, rigid set of genes.
- **Solution:** Randomly "dropping out" neurons during training, forcing the network to learn more robust features.
  - Dropout introduces "variability"
  - Forcing the network to not rely too heavily on any single neuron and to develop more robust, distributed representations.
- **Impact**: Dropout became a fundamental technique for regularizing neural networks, improving generalization.

ACM Turing Award 2018 Citation

Improvements to convolutional neural networks.

In 2012, with his students, Alex Krizhevsky and Ilya Sutskever, **Hinton** improved convolutional neural networks using rectified linear neurons and dropout regularization.

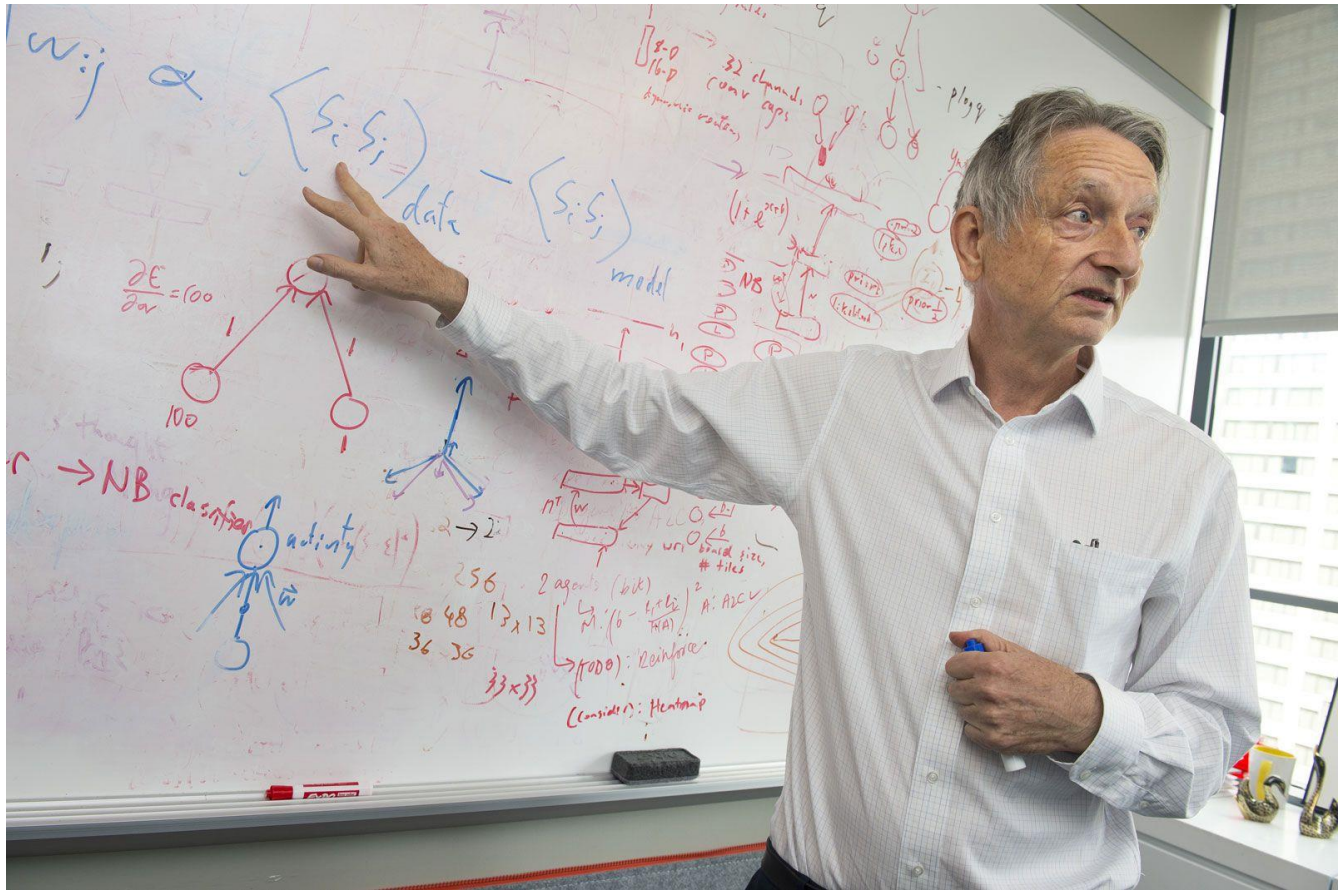
In the prominent ImageNet competition, Hinton and his students almost **halved the error rate** for object recognition and reshaped the computer vision field.

Cultivating Intuition in Research

- Intuition is powerful in scientific discovery.
- Deeply immerse yourself in the subject matter.
- Explore ideas from diverse fields.
  - insights often stemmed from drawing analogies to other fields (e.g., biology).
- Allow time for reflection and incubation.
- Don't be afraid to trust your hunches, but always validate them.

Get Your Hands Dirty

Get Your Hands Dirty



https://www.cs.toronto.edu/~hinton/

TUTORIALS

....Tutorial (2009) Deep Belief Nets (3hrs) ppt pdf readings

....Workshop Talk (2007) How to do backpropagation in a brain (20mins) ppt2007 pdf2007 ppt2014 pdf2014

2012 COURSERA COURSE LECTURES:
Neural Networks for Machine Learning

....Lectures(.mp4)

....Lecture Slides(.pptx or .pdf))

OLD UNIVERSITY OF TORONTO COURSES

....csc321 Spring 2013(undergrad)

....csc2535 Spring 2013(graduate)

OLD TUTORIAL SLIDES

....2011 NIPS workshop talk pdf ppt
.....paper on Transforming Autoencoders

....2007 NIPS tutorial html ppt ps pdf
.....Readings: 2007 NIPS tutorial

....CIFAR Summer School 2007

....CIAR Summer School 2006

....CIFAR Summer School 2005

....List of Past Tutorials

MOVIES

....generating digits

....speaking with a glove (Sidney Fels)

MATLAB CODE

.... Matlab for Science paper

....t-SNE software

....trajectory from motor program

....ink from trajectory

....introduction to python

SUPERVISION

Get Your Hands Dirty

Training a deep autoencoder or a classifier on MNIST digits

Code provided by Ruslan Salakhutdinov and Geoff Hinton
Permission is granted for anyone to copy, use, modify, or distribute this program and accompanying programs and documents for any purpose, provided this copyright notice is retained and prominently displayed, along with a note saying that the original programs are available from our web page. The programs and documents are distributed without any warranty, express or implied. As the programs were written for research purposes only, they have not been tested to the degree that would be advisable in any important application. All use of these programs is entirely at the user's own risk.

How to make it work:

1. Create a separate directory and download all these files into the same directory
2. Download from http://yann.lecun.com/exdb/mnist the following 4 files:
   - train-images-idx3-ubyte.gz
   - train-labels-idx1-ubyte.gz
   - t10k-images-idx3-ubyte.gz
   - t10k-labels-idx1-ubyte.gz
3. Unzip these 4 files by executing:
   - gunzip train-images-idx3-ubyte.gz
   - gunzip train-labels-idx1-ubyte.gz
   - gunzip t10k-images-idx3-ubyte.gz
   - gunzip t10k-labels-idx1-ubyte.gz

   If unzipping with WinZip, make sure the file names have not been changed by Winzip.
4. Download Conjugate Gradient code minimize.m
5. Download Autoencoder_Code.tar which contains 13 files OR
   download each of the following 13 files separately for training an autoencoder and a classification model:
   - mnistdeepauto.m Main file for training deep autoencoder
   - mnistclassify.m Main file for training classification model
   - converter.m Converts raw MNIST digits into matlab format

Believe in Yourself

Believe in Yourself

- Bengio, Hinton, and LeCun believed in (deep) neural networks even when most of the scientific community dismissed them.
  - Despite years of skepticism, they stayed committed to their vision
- Their persistence led to breakthroughs that now drive the AI revolution.
- Believing in yourself, even when no one else does, could change the world.

Take Away Messages

- Identify Research That Matters
- Trust Your Instincts
- Get Your Hands Dirty
- Believe in Yourself

Wishing everyone great success in your studies and future careers!

Joint My Group!

I am recruiting

- Students
- Postdocs
- Visiting students/researchers
- steve.liu@mbzuai.ac.ae

Thank You