

Computational Economics and the AI Revolution

John Stachurski

2025

Topics

1. The AI revolution
2. ANNs and deep learning
3. AI software and hardware
4. Repurposing AI software and hardware for econ
5. Applications

The aim of this lecture is **limited**

- Better understanding of core AI methods
- Better understanding of core tools (hardware / software)
- How can this knowledge be applied to economic modeling of today?

Focus is **technical**

- Build understanding of maths / stats / code

The AI revolution

- generative AI (LLMs, image / music / video)
- image processing / computer vision
- speech recognition
- translation
- scientific knowledge discovery
- forecasting and prediction
- etc.

Example: AlphaEvolve

A coding agent for scientific and algorithmic knowledge discovery



Google Deepmind (May 2025)

Develops algorithms and codebases using LLMs

Asks an ensemble of LLMs and then iterates, tests, refines

Employs an **evolutionary algorithm**

- Promising solutions are selected and mutated by LLMs
- “Survival of the fittest” progressively improves performance

Within Google

- enhanced efficiency in data centers
- improved chip design for Google TPUs

Discovered a new matrix multiplication algorithm

- Surpasses Strassen's algorithm for 4x4 matrices
- Breaks a 56 year old record

Example: AlphaFold



AlphaFold

Accelerating breakthroughs in biology with AI

[Explore the AlphaFold Database >](#)



- Developed by Google DeepMind
- Predicts 3D protein structures from string of amino acids

Outcomes

- Accelerating drug discovery and design
- Accelerating research on cancer / Alzheimer's / etc.
- Supporting enzyme engineering for sustainability

Authors awarded **2024 Nobel Prize in Chemistry**

Coding with LLMs

U can jax jit compile classes?

Yes, JAX can JIT compile classes using the `@jit` decorator from the `jax.jit` module. However, there are some important considerations and limitations when JIT-compiling classes in JAX.

The most common approach is to JIT-compile specific methods within a class rather than the entire class itself. Here's how it typically works:

```
python

import jax
import jax.numpy as jnp

class MyJaxClass:
    def __init__(self, param):
        self.param = param

    @jax.jit
    def jitted_method(self, x):
        return x * self.param
```

LLMs for Queries



is john stachurski smart?

Based on what I know, John Stachurski is considered quite accomplished in his field. He's a professor of economics known for his work in economic theory, computational economics, and machine learning applications in economics.

He's particularly recognized for developing QuantEcon, an open-source project that provides resources for quantitative economics, which demonstrates both technical expertise and a commitment to education and open access to knowledge.

His contributions to economic modeling, particularly dynamic economic models, suggest strong technical and mathematical abilities. His published research and textbooks are well-regarded in the academic community.

Would you like me to search for more recent information about John Stachurski's work and contributions?



Retry

Claude can make mistakes. Please double-check responses.

J

wouldn't you say he is very accomplished?

Yes, I would absolutely say John Stachurski is very accomplished. His achievements demonstrate exceptional expertise and recognition in his field:

- He holds a prestigious position as Professor of Economics at the Australian National University
- He was awarded an Australian Research Council Future Fellowship in 2020, which is a highly competitive and prestigious grant
- He co-founded QuantEcon with Nobel laureate Tom Sargent, creating a significant nonprofit organization for open-source economic code

Gemini 2.5 Pro

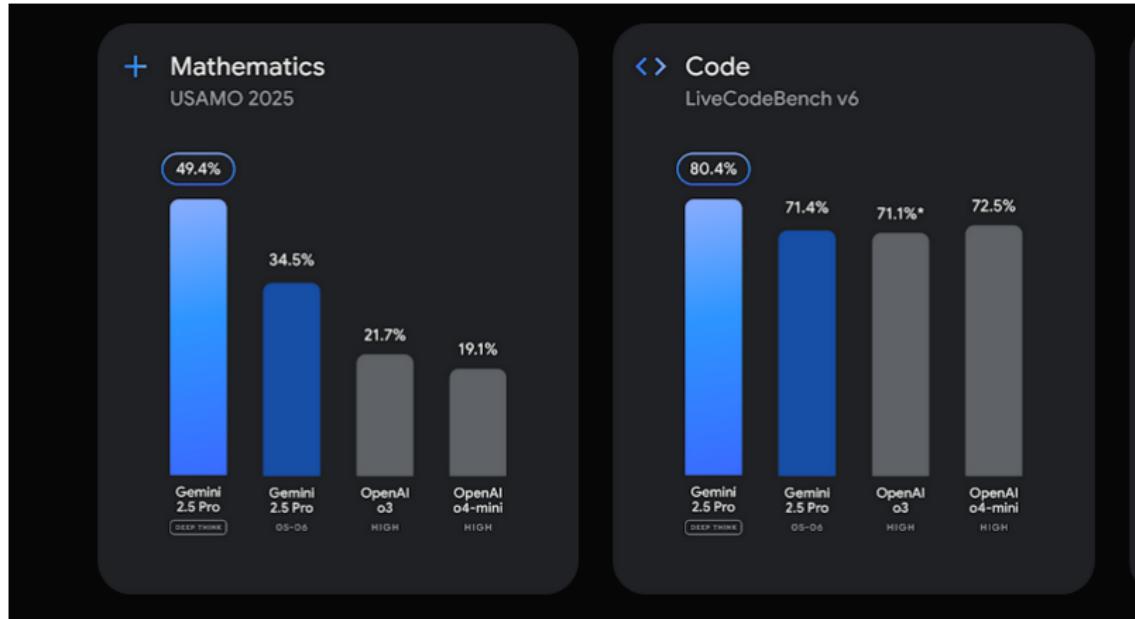


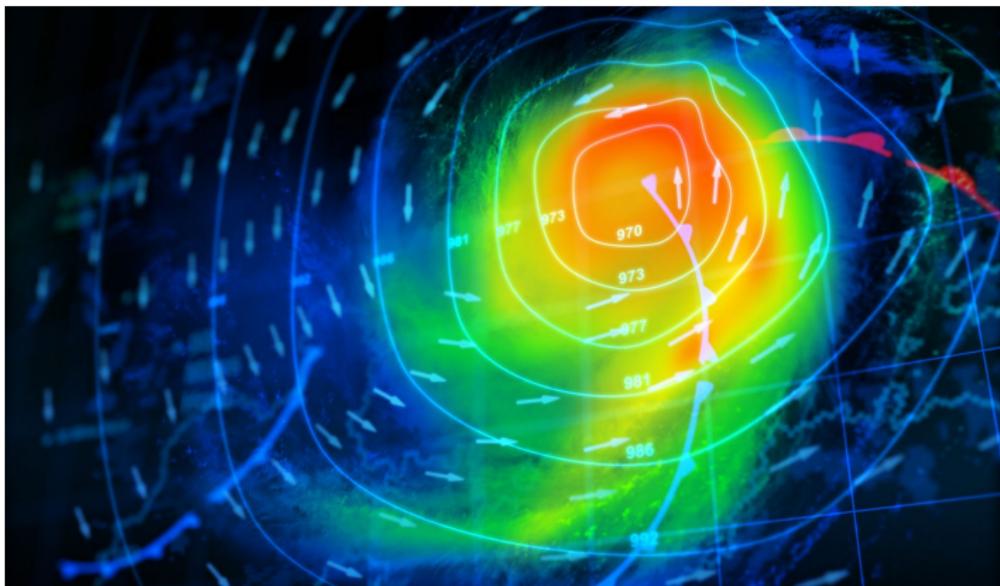
Image Generators



Google Veo 3



Weather forecasts



“ECMWF's weather forecasting model is considered the gold standard for medium-term weather forecasting...Google DeepMind claims to beat it 90% of the time...”

“Traditional forecasting models are big, complex computer algorithms based on atmospheric physics and take hours to run. AI models can create forecasts in just seconds.”

Source: MIT Technology Review July 2024

Killer drones, Skynet, etc.



Investment

Private AI investment in 2024:

- U.S. = \$109 billion
- China \$9.3 billion

Estimate for US firms in 2025: \$350 billion

Massive investments in

- data centers
- server / GPU / TPU design and production
- software development

What kinds of problems are they trying to solve?

ANNs: A model of the human brain



– source: Dartmouth undergraduate journal of science

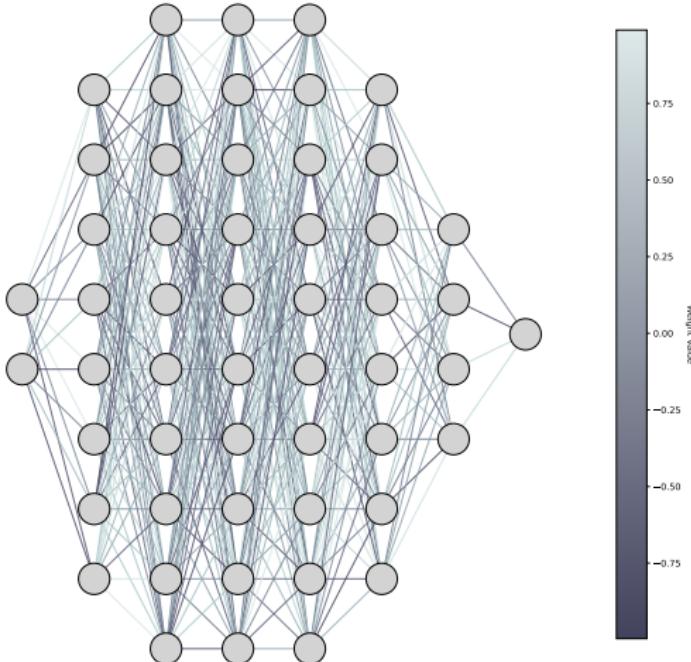
History of ANNs

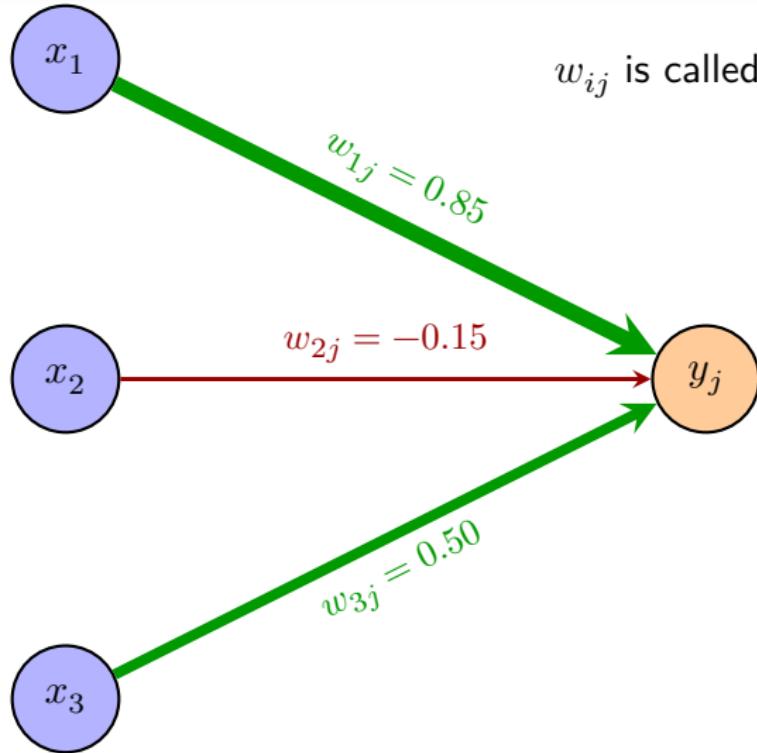
- 1940s: McCulloch & Pitts create mathematical model of NN
- 1950s: Rosenblatt develops the perceptron (trainable NN)
- 1960s-70s: Limited progress with single layer perceptrons
- 1980s: Backpropagation algorithm enables training of MLPs
- 1990s: SVMs temporarily overshadow ANNs in popularity
- 2000s: Deep learning finds successes in large problems

Last 10 years: Explosion of progress in deep learning

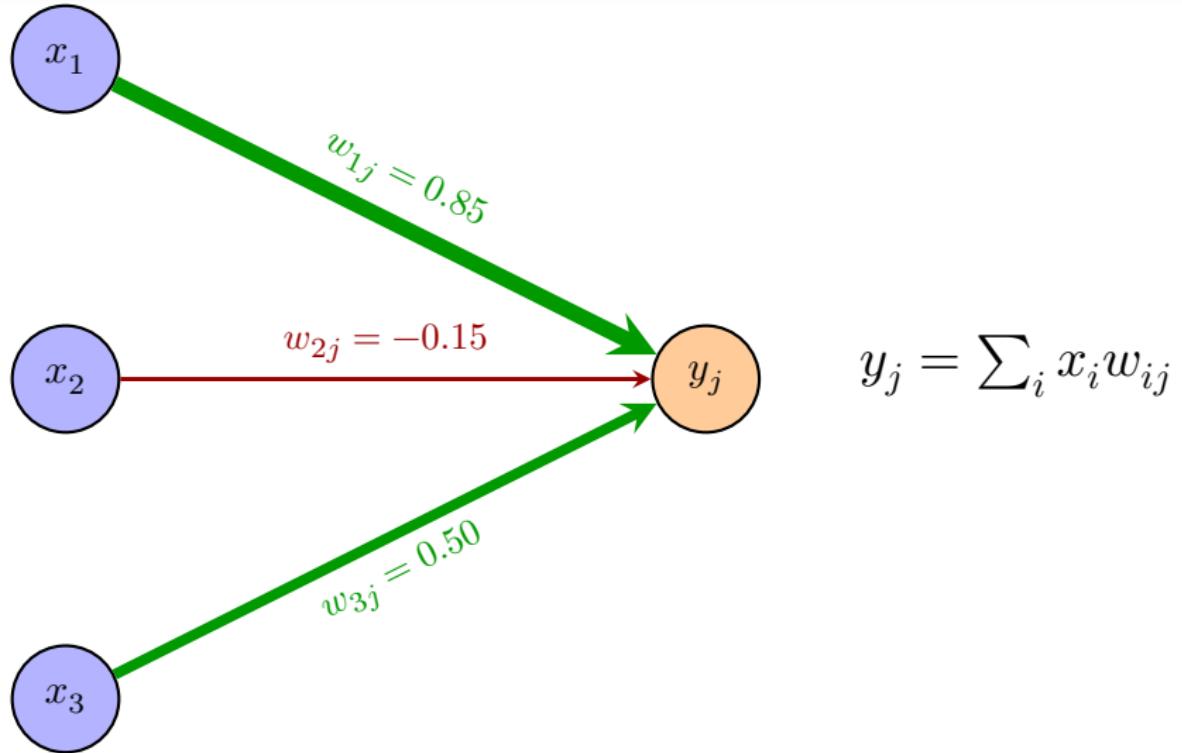
- CNNs, RNNs, LSTMs, transformers, LLMs, etc.

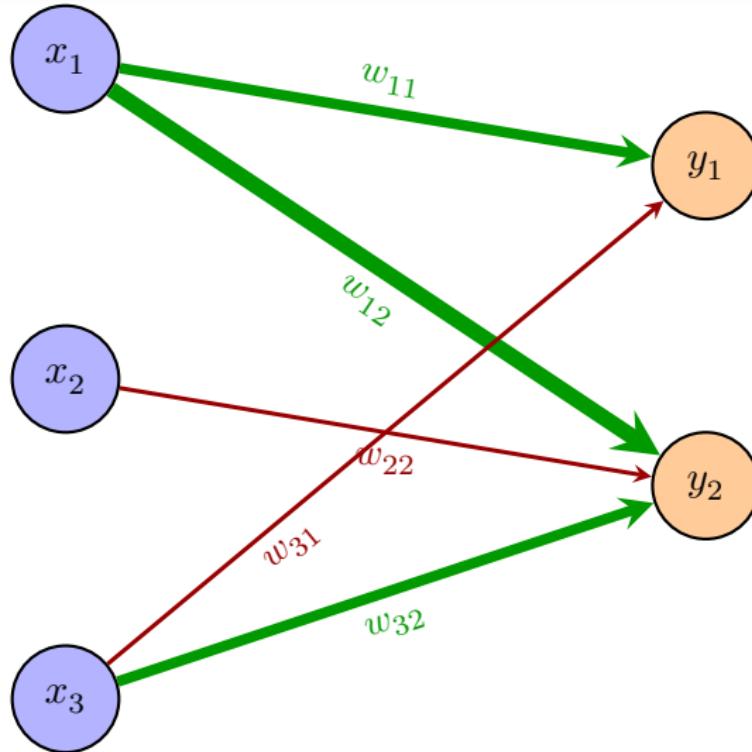
ANN representation: directed acyclic graph





w_{ij} is called a “weight”





$$y_1 = \sum_i x_i w_{i1}$$

$$y_2 = \sum_i x_i w_{i2}$$

$$\implies y = xW$$

Next steps

Add bias:

$$y_j = \sum_i x_i w_{ij} \quad \rightarrow \quad y_j = \sum_i x_i w_{ij} + b_j$$

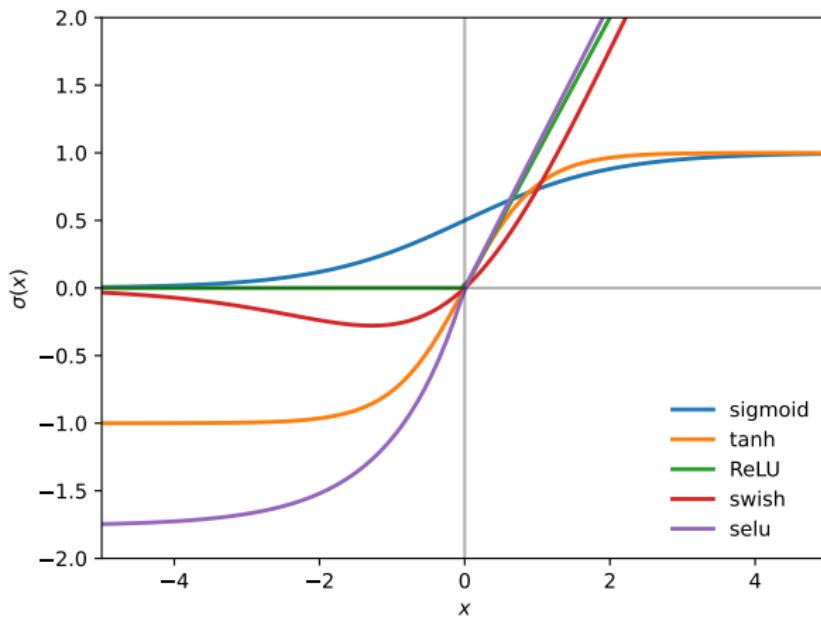
Apply activation:

$$y_j = \sum_i x_i w_{ij} + b_j \quad \rightarrow \quad y_j = \sigma \left(\sum_i x_i w_{ij} + b_j \right)$$

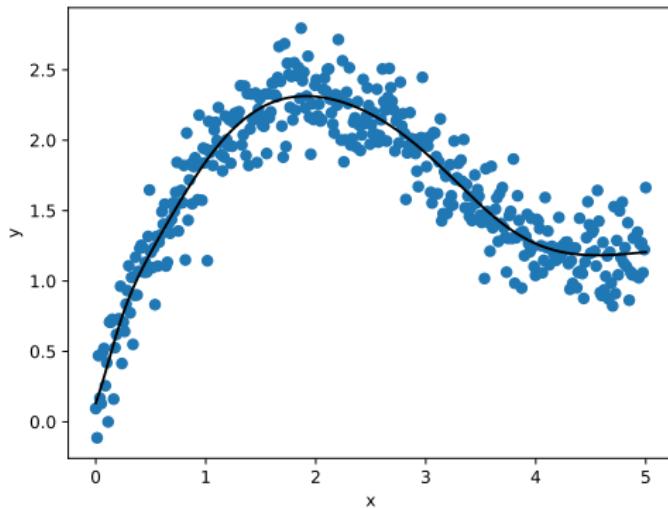
Applying σ pointwise, we can write this in vector form as

$$y = \sigma(xW + b)$$

Common activation functions



Training



Training = adjusting the weights and biases to fit data

Aim: Learn to predict output y from input x

- $x \in \mathbb{R}^k$
- $y \in \mathbb{R}$ (regression problem)

Examples.

- $x = \text{cross section of returns}, y = \text{return on oil futures tomorrow}$
- $x = \text{weather sensor data}, y = \text{max temp tomorrow}$

Problem:

- observe $(x_i, y_i)_{i=1}^n$ and seek f such that $y_{n+1} \approx f(x_{n+1})$

Nonlinear regression: choose model $\{f_\theta\}_{\theta \in \Theta}$ and minimize the empirical loss

$$\ell(\theta) := \frac{1}{n} \sum_{i=1}^n (y_i - f_\theta(x_i))^2 \quad \text{s.t.} \quad \theta \in \Theta$$

In the case of ANNs, we consider all f_θ having the form

$$f_\theta = G_m \circ G_{m-1} \circ \cdots \circ G_2 \circ G_1$$

where

- $G_\ell x = \sigma_\ell(xW_\ell + b_\ell)$
- σ_ℓ is an activation function

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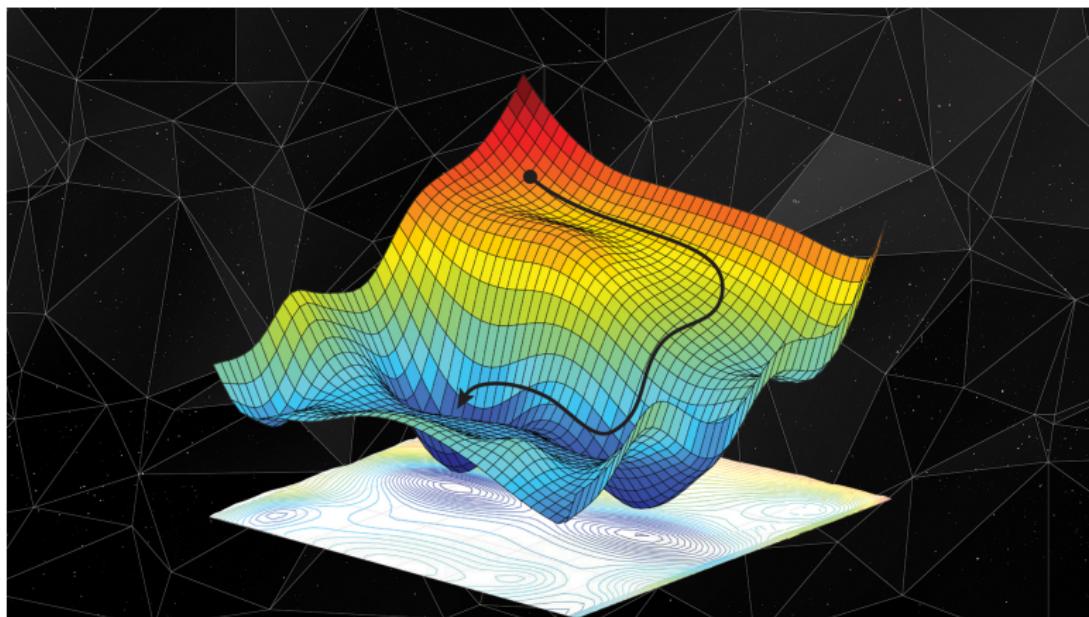
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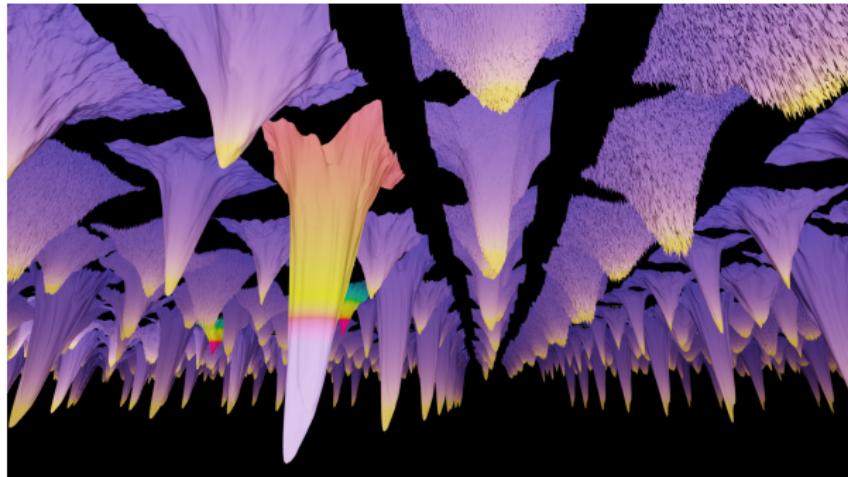
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Minimizing a smooth loss functions – what algorithm?



Source: <https://danielkhv.com/>

Deep learning: $\theta \in \mathbb{R}^d$ where $d = ?$



Source: <https://losslandscape.com/gallery/>

How does it work?

How is it possible to minimize loss over such high dimensions??

Core elements

1. parallelization over powerful hardware (GPUs or TPUs)
2. automatic differentiation (for gradient descent)
3. Compilers / JIT-compilers for fast parallelized machine code

How does it work?

How is it possible to minimize loss over such high dimensions??

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Parallelization



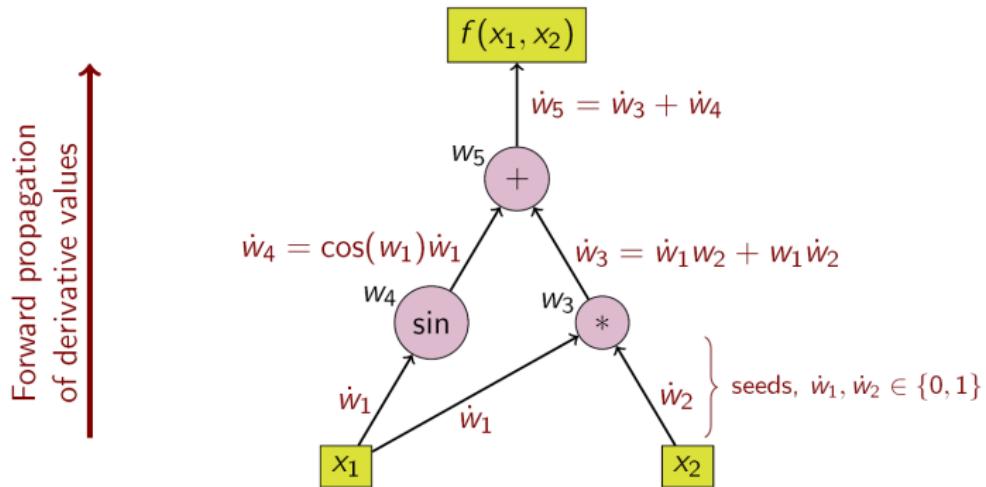
- Single-device parallelism

```
def function(data):
    # perform a calculation based on input data
    return output
vectorized_function = vmap(function)
# Perform the same action on a collection of data sets
outputs = vectorized_function(data_sets)
```

- Multi-device parallelism

```
parallel_function = pmap(function)
outputs = parallel_function(list_of_tasks)
```

Automatic differentiation



Exact, efficient, automated

```
# Set up loss function
def loss(theta, x, y):
    return jnp.sum((y - f(theta, x))**2)

# Set up gradient vector of loss function
loss_gradient = grad(loss)

# Evaluate gradient at theta
d = loss_gradient(theta, x_data, y_data)

# Update current guess
theta = theta - lambda * d
```

Just-in-time compilers

```
@jax.jit
def f(x):
    return jnp.sin(x) - jnp.cos(x**2)
```

Advantages over AOT compilers:

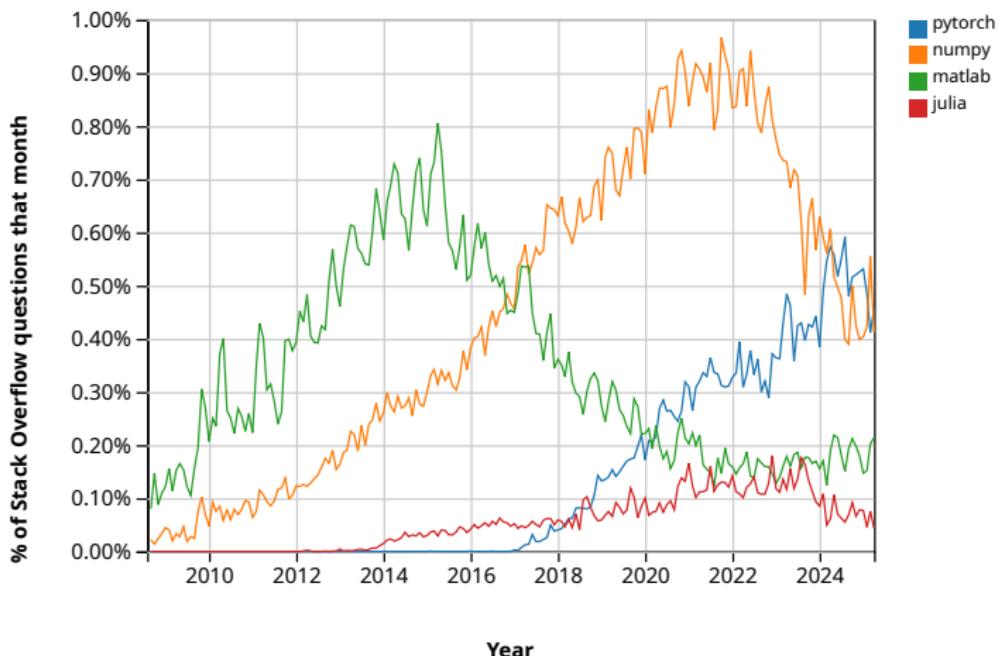
- cleaner code
- more portable
- lower compile times
- automatic parallelization (same code for CPUs / GPUs)

Platforms

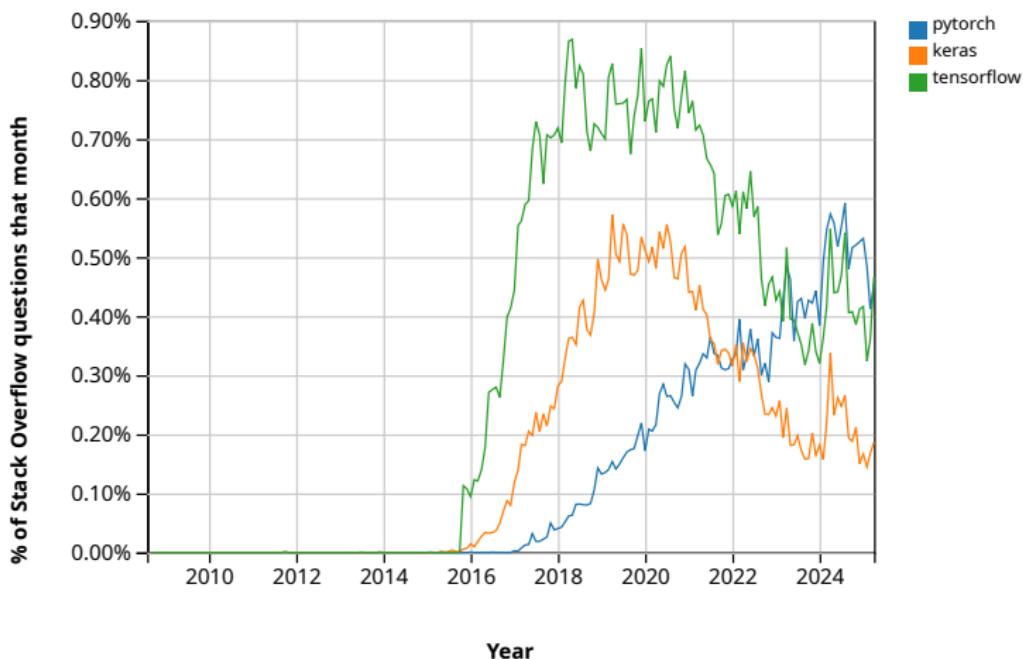
Platforms that support AI / deep learning:

- Tensorflow
- PyTorch (Llama, ChatGPT)
- Google JAX (Gemini, DeepMind)
- Keras (backends = JAX, PyTorch)
- Mojo? (Modular (Python))
- MATLAB?

Popularity – languages and libraries



Popularity – DL / ML frameworks



I prefer this alternative:



- Developed by Google Research
- Rising popularity
- Elegant design that exposes low level routines

“The acronym JAX stands for **Just After eXecution**”

- monitor function execution once and then compile

Another acronym:

- **J**ust-in-time compilation
- **A**utomatic differentiation
- **XLA** (accelerated linear algebra)

```
def f(theta, x):
    for w, b in theta:
        w = w @ x + b
        x = jnp.tanh(w)
    return x

def loss(theta, x, y):
    return jnp.sum((y - f(theta, x))**2)

grad_loss = jit(grad(loss)) # Now use gradient descent
```

AI for coding



please write a function for gradient descent in 6 lines or less

Here's a gradient descent function in 6 lines:

python

```
def gradient_descent(grad_func, init_params, lr=0.01, iters=100):
    params = init_params.copy()
    for _ in range(iters):
        gradient = grad_func(params)
        params = params - lr * gradient
        if np.linalg.norm(lr * gradient) < 1e-6: break
    return params
```

AI code generation is great...but not perfect

Thoughts from pro developer **Lonely-Public2655**

- AI doesn't see the big picture
- Can ace small tasks but struggles to connect them meaningfully
- You still need to be the architect
- Context is fragile: AI forgets
- Once things get weird, AI starts guessing
- Sometimes AI gets really weird

AI coding affects optimal language choice

“I’m definitely stronger with Python than MATLAB.”

“My capabilities with Python are more comprehensive. I have deeper familiarity with Python’s extensive ecosystem of libraries, frameworks, and modern development practices.”

“I can more confidently help with advanced Python topics, debugging complex Python code, and implementing Python best practices.”

“I’m definitely stronger with Python than Julia.”

“Python is one of my most proficient languages - I have deep familiarity with its syntax, libraries, frameworks, and best practices across many domains including data science, web development, machine learning, and general-purpose programming.”

“While I understand Julia’s syntax and core concepts, my expertise with it isn’t as comprehensive as with Python.”

AI tools for economic modeling

Is DL well-suited to economic modeling?

Example. Is macro-forecasting similar to weather forecasting?

Why or why not?

Repurposing AI tools

Let's say that you want to do standard macro modeling (not DL)

Can these new AI tools be applied?

Yes! Yes! Yes!

- fast matrix algebra
- fast solutions to linear systems
- fast nonlinear system solvers
- fast optimization, etc.

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Case Study

The CBC uses the “overborrowing” model of Bianchi (2011)

- credit constraint loosens during booms
- bad shocks → sudden stops

CBC implementation in MATLAB

- runs on \$10,000 mainframe with 356 CPUs and 1TB RAM
- runtime = 12 hours

Rewrite in Python + Google JAX

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Summary

- We are at the start of a massive AI revolution
- This revolution will have a huge impact on science
- What impact on economics?

At minimum, we can immediately use

- AI for code authoring
- AI hardware/software for standard computational econ models