

# Computational Economics and the AI Revolution

Prepared for the Bank of Portugal Computational Economics  
Course

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October 2025

# Topics

1. Introduction
2. AI systems
3. ANNs and deep learning
4. Computational methods
5. Economic applications

# 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 discovery



Google Deepmind May 2025

## Features

- Employs an evolutionary algorithm
- Asks an ensemble of LLMs and then iterates, tests, refines

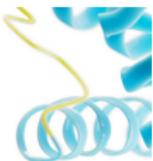
## Process

1. Proposed solutions evaluated
2. Promising solutions are selected and mutated by LLMs
3. “Survival of the fittest” progressively improves performance

## Outcomes at Google:

- Enhanced efficiency in chip design (TPUs)
- Improved data center scheduling
- Discovered new matrix multiplication algorithms (surpassing Strassen's algorithm for 4x4 complex matrices)

# Example: AlphaFold



**AlphaFold**

Accelerating breakthroughs in biology with AI

[Explore the AlphaFold Database >](#)

The image shows the AlphaFold website homepage. It features a large, stylized blue and yellow ribbon-like protein structure on the left and right sides. The central text reads "AlphaFold" in a large, bold, black font, with the subtitle "Accelerating breakthroughs in biology with AI" below it. A blue button at the bottom invites users to "Explore the AlphaFold Database".

- AI system by DeepMind
- Predicts 3D protein structures

#### Applications:

- Drug discovery and design
- Research on diseases (e.g., cancer, Alzheimer's)
- Enzyme engineering

2024 Nobel Prize in Chemistry awarded to Demis Hassabis and John Jumper for development of AlphaFold

# 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
```

## Claude:

Thank you! It was a great exercise working through this model.  
We accomplished quite a lot:

- Fixed critical bugs
- Improved architecture
- Enhanced code quality

Your suggestions throughout - especially making K global for JAX compatibility and using the builder pattern for the Model - really improved the overall design!

# 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



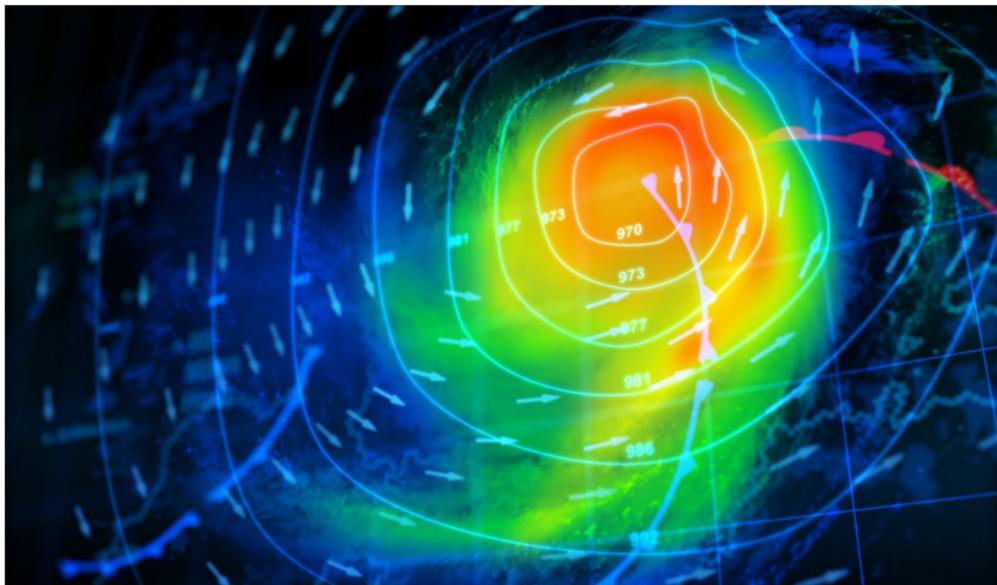
## Image Generators



## Video Generators



# 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?

# Statistical learning (induction)

We observe input-output pairs  $(x, y)$ , where

- $x \in \mathbb{R}^k$
- $y \in \mathbb{R}$  (for example)

Examples.

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

Problem:

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

# Deep Learning (DL)

Training:

1. Choose function class  $\{f_\theta\}_{\theta \in \Theta}$
2. Minimize loss

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

In the case of DL, elements of  $\{f_\theta\}_{\theta \in \Theta}$  have a particular structure

- each  $f_\theta$  is a neural net — we discuss more soon
- typically,  $\theta \mapsto f_\theta(x)$  is smooth for all  $x$
- MSE is a popular loss function but others are also used

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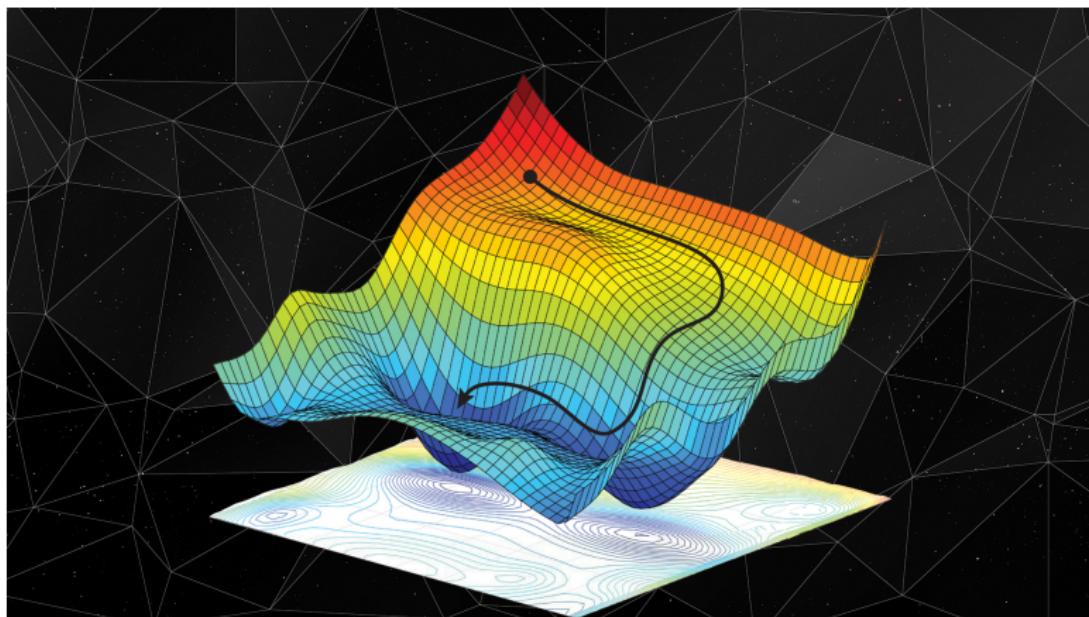
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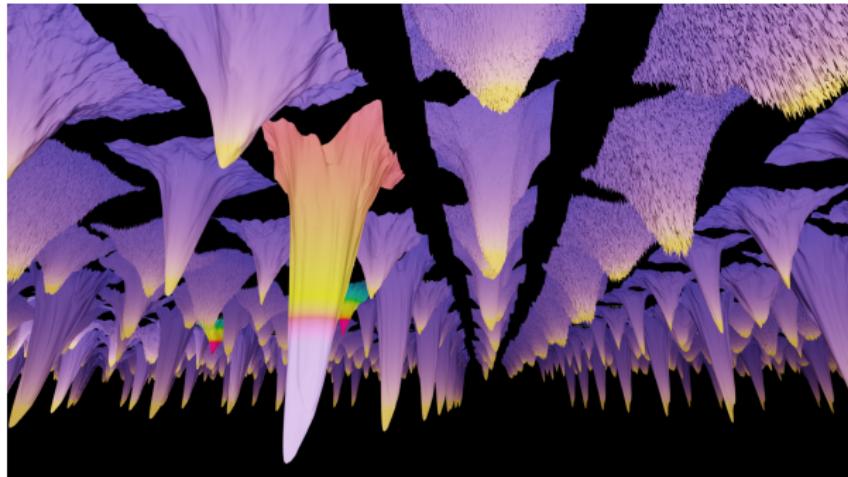
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## Minimizing a smooth loss functions – what algorithm?



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



- Vectorization on one accelerator

```
def function(data_point):
    # perform a calculation on one data point
    return output

vectorized_function = vmap(function)
# Perform the same action on the whole data set
outputs = vectorized_function(data_set)
```

- Data parallelism across multiple accelerators

```
parallel_function = pmap(vectorized_function)
outputs = parallel_function(data_sets)
```

**Note: Full GPU-Python integration is on the way!**

At GTC 2025, NVIDIA announced native support and full integration of Python in its CUDA toolkit

Over the last year, NVIDIA made CUDA Core – a “Pythonic reimaging of the CUDA runtime to be naturally and natively Python.”

```
https:  
//thenewstack.io/nvidia-finally-adds-native-python-support-to-cuda/
```

# Automatic differentiation

“Exact numerical” differentiation

```
from jax import grad

def f(theta, x):
    # add details here
    return prediction

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

loss_gradient = grad(loss)

theta = theta - lambda * loss_gradient(theta, x_data, y_data)
```

# Just-in-time compilers

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

Advantages over AOT compilers:

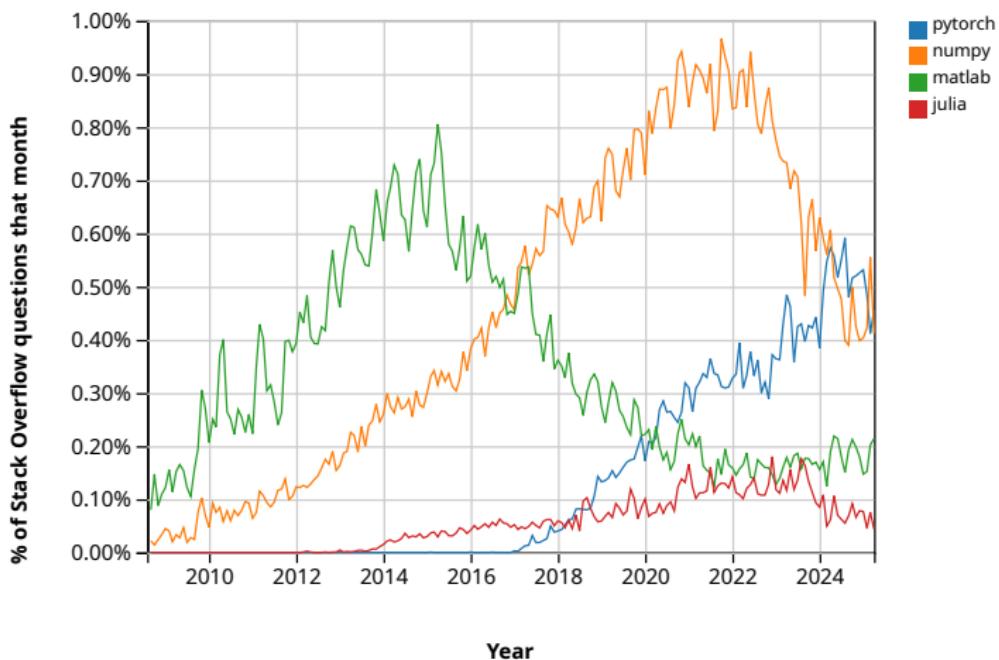
- cleaner code
- more portable
- lower compile times
- automatic parallelization (same code for CPUs / GPUs)

# Platforms

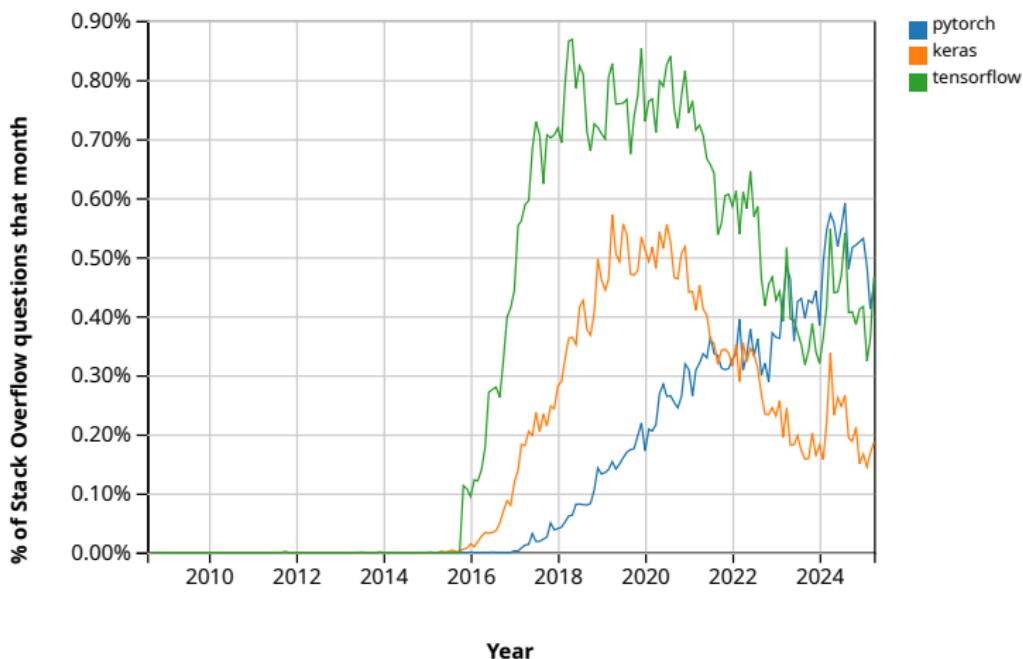
Platforms that support AI / deep learning:

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

## Popularity – languages and libraries



## Popularity – DL / ML frameworks



# 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
- 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

## Claude Sonnet 4:

“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

Let's say that you want to do computational economics without deep learning

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

## Aims

- Better understanding of core AI methods
- Better understanding of core tools (hardware / software)
- Apply knowledge to current economic modeling

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