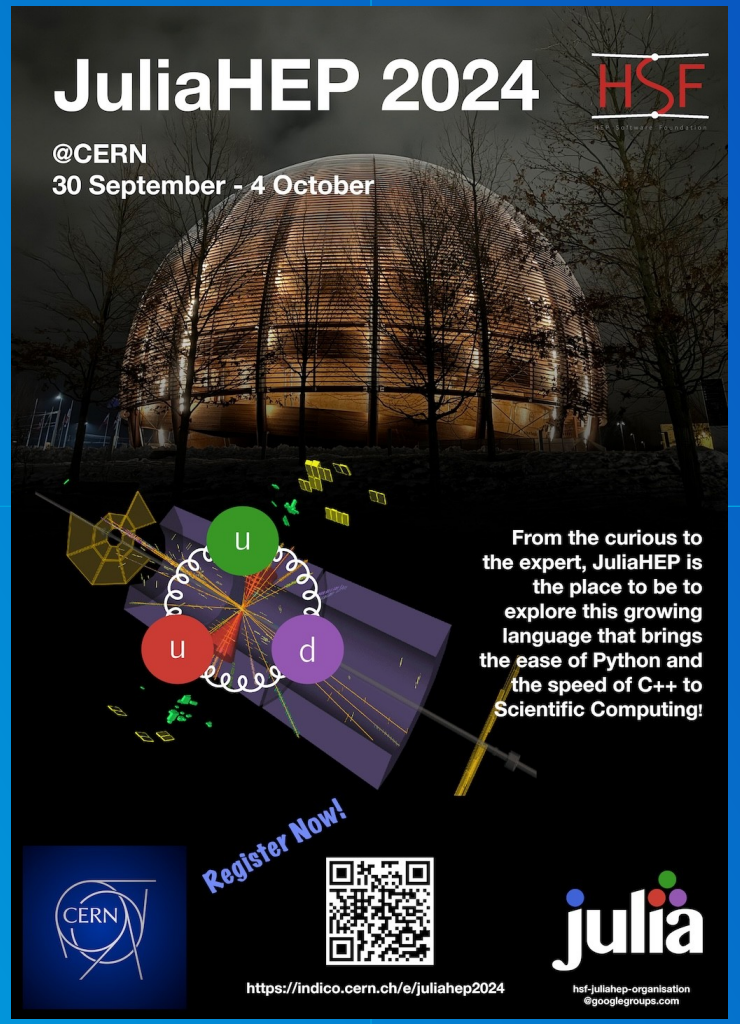


ASML

Using Julia to perform Physics on Time Critical systems

Dr. Evangelos Paradas
Algorithm Deployment Architect

September 30, 2024
CERN, Geneva, CH

Outline

A few words about ASML

General Context

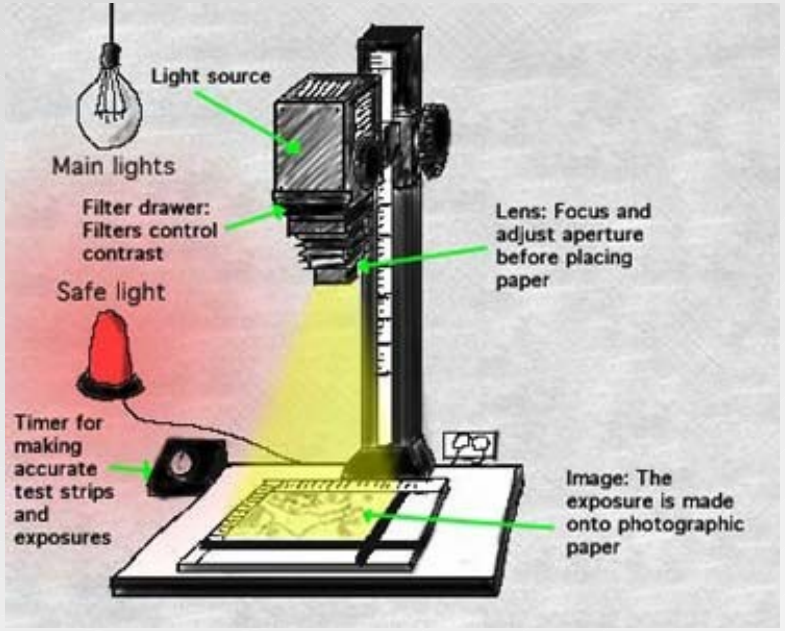
What are the problems in Embedding Algorithms?

Can Julia solve these issues?

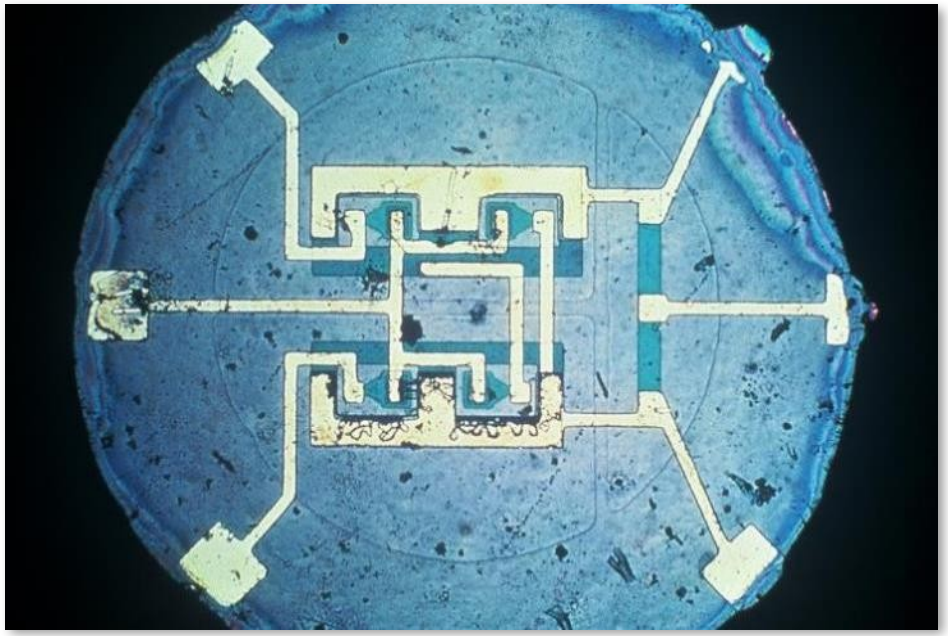
ASML & Lithography

A few words on how electronic chips are produced

A picture from the past



Several manual steps



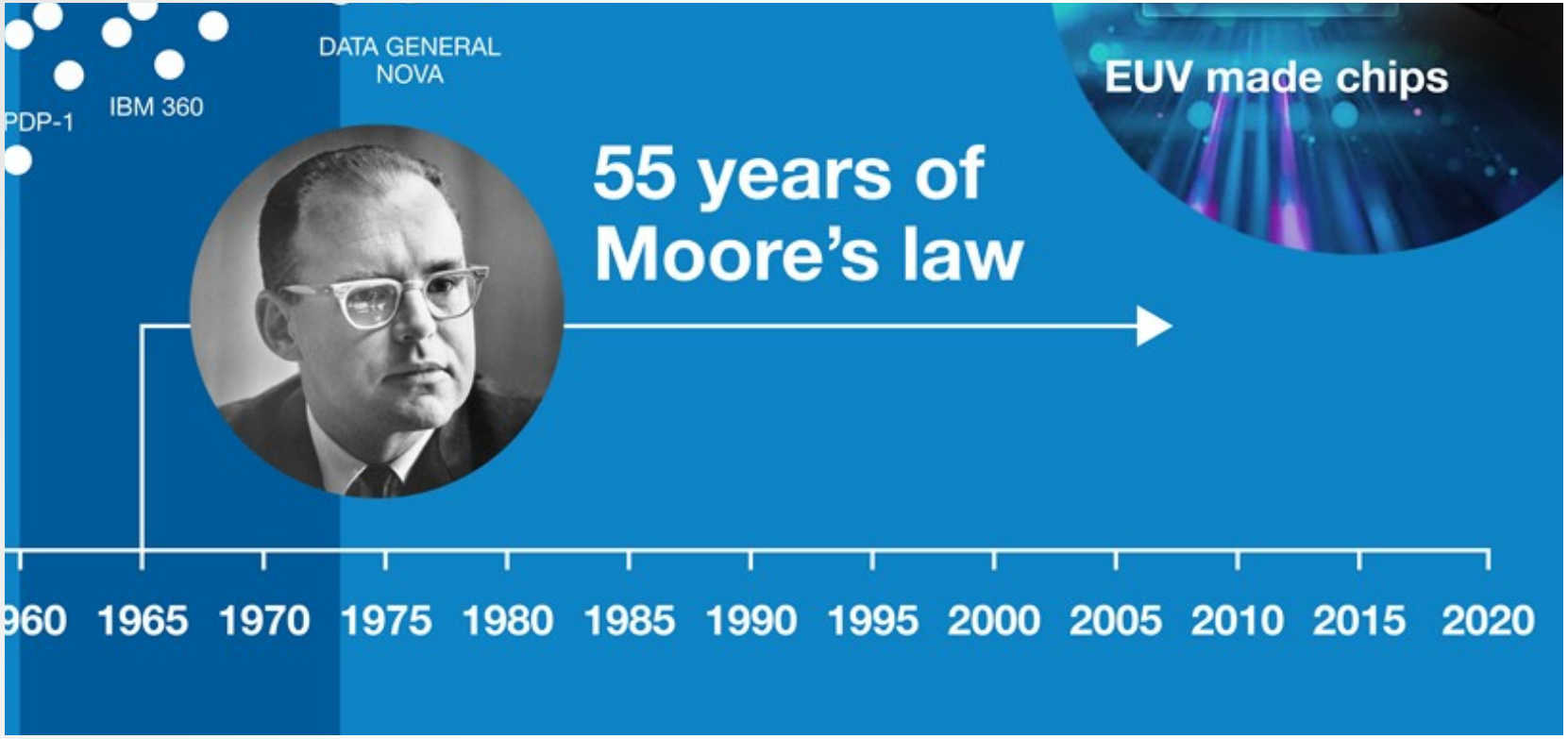
All layers are integrated on 1 layer of silicon

A few words on how electronic chips are produced

Gordon Moore's law

Moore's law: *doubling of components per chip, every two years.*

- Not a law of nature, but a self-fulfilling prediction
- 1950's: first integrated function with one component.
- 74 years later: 37 cycles of doubling every 2 years
- **2^{37} = 137,5 billion transistors**



A few words on how electronic chips are produced

Gordon Moore's law

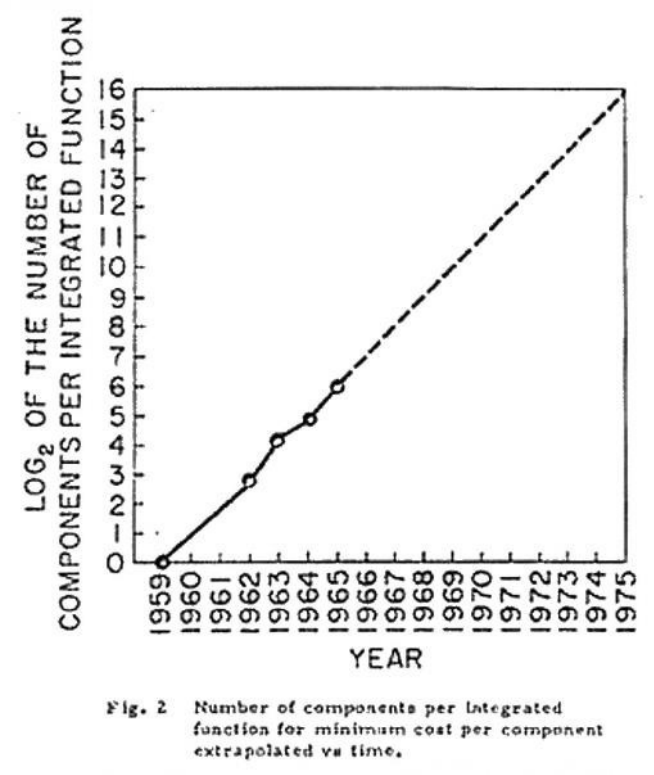
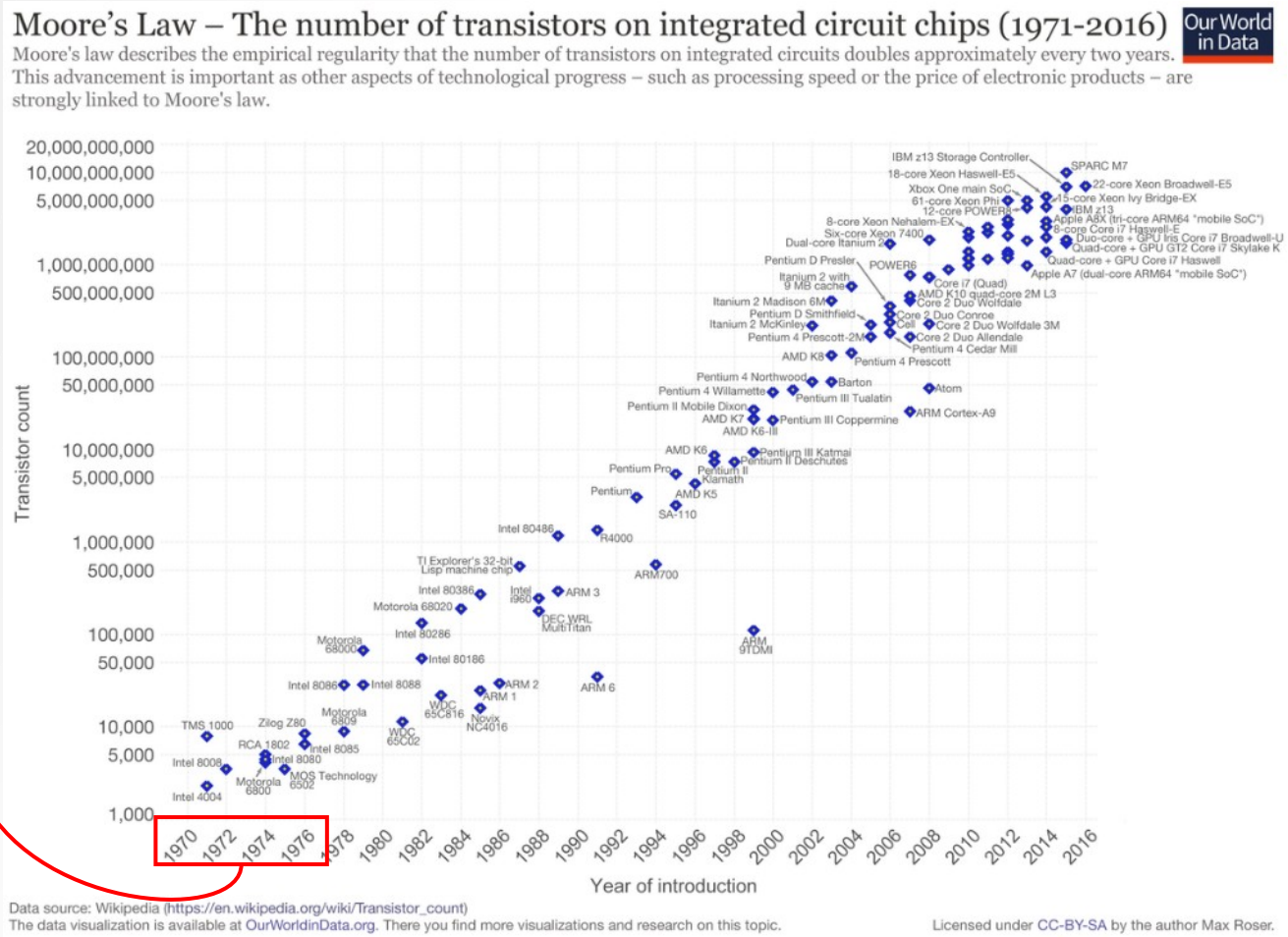
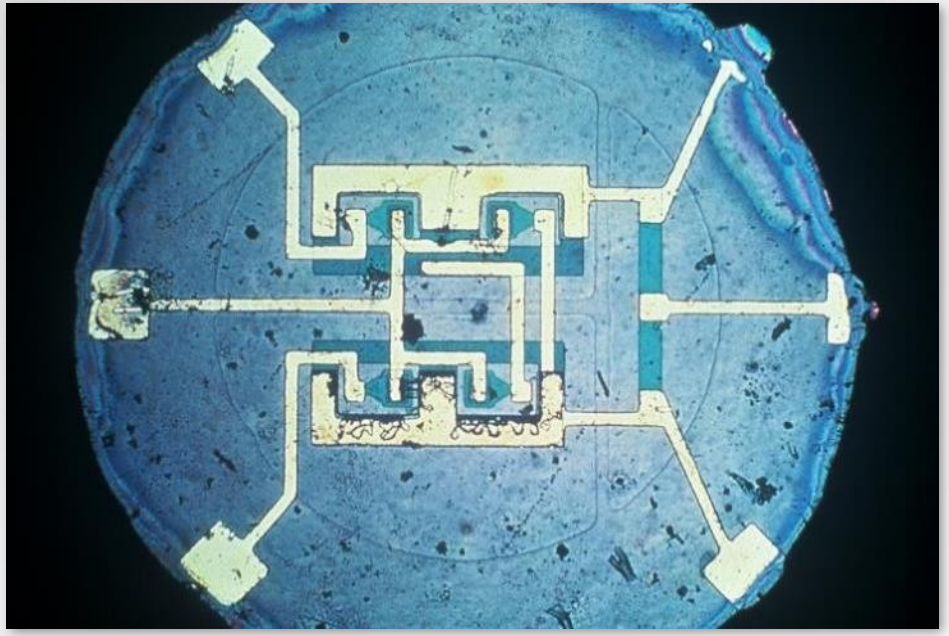


Fig. 2 Number of components per integrated function for minimum cost per component extrapolated vs time.



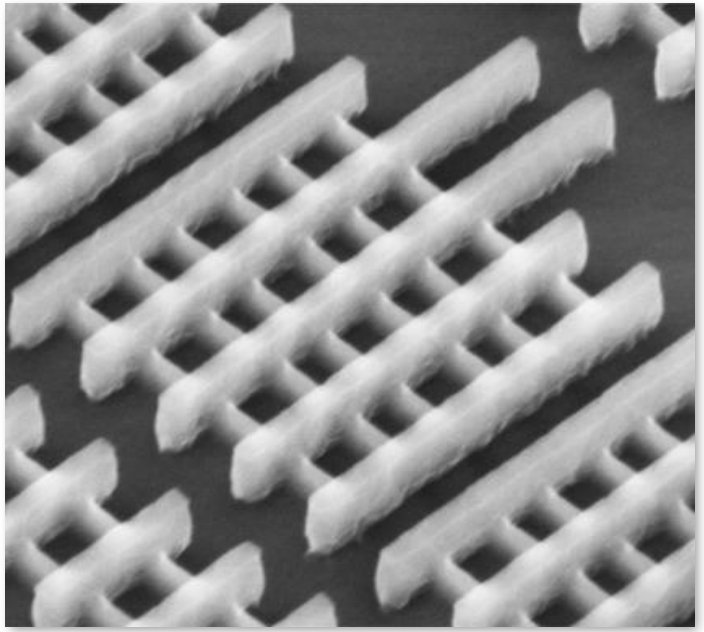
Industry is moving towards 1 billion transistors per mm^2

A few words on how electronic chips are produced



First integrated circuit on silicon, on a wafer size of a fingernail (**Fairchild semiconductor, 1959**)

Transistor's size continuously shrinking



Today: Billions of transistors on the same are.

A few words about ASML

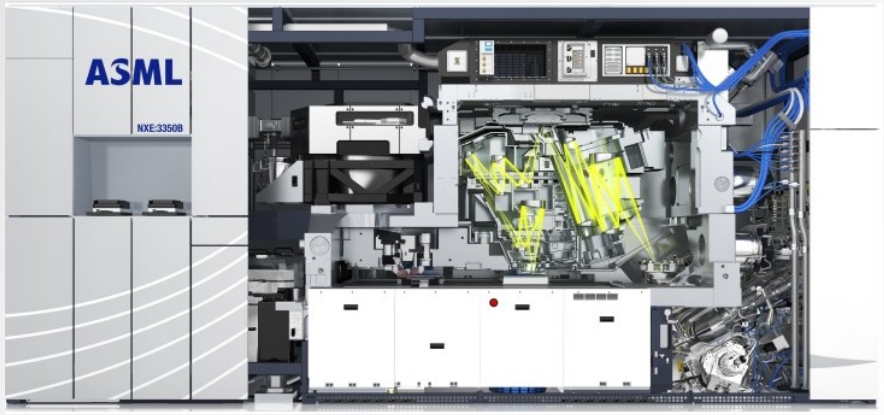
Introducing ASML

ASML is a Dutch multinational company specializing in development and manufacturing of photolithography systems.

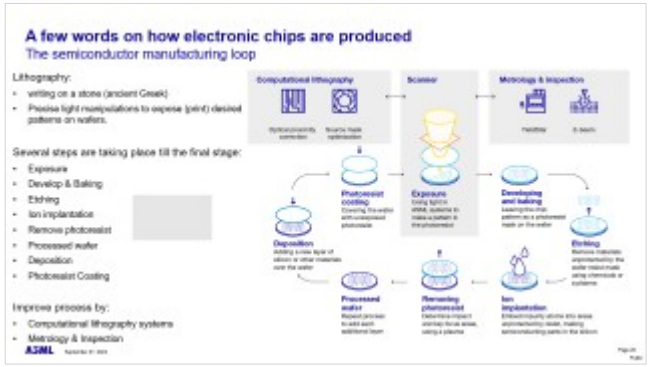
Currently it is the largest supplier of photolithography systems for primarily the semiconductor industry.

The company manufactures machines to produce integrated circuits.

ASML HeadQuarters in Veldhoven



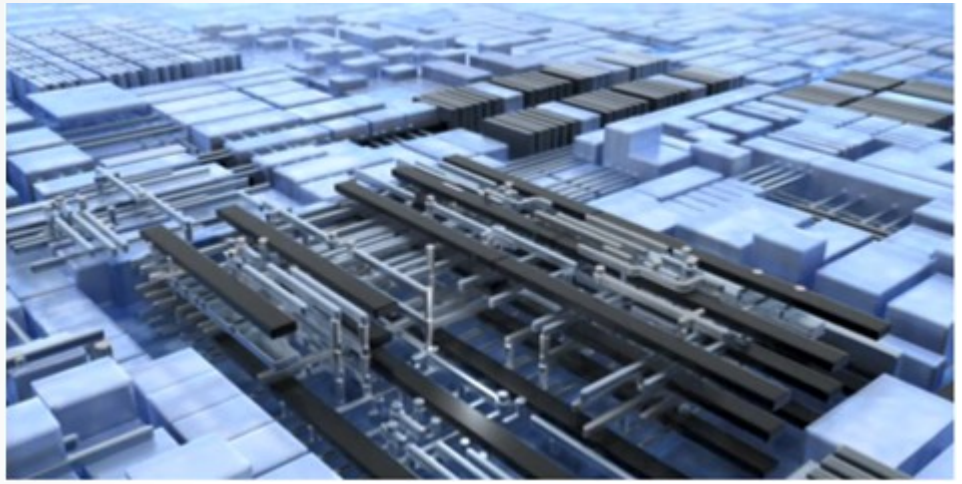
ASML's EUV machine



Complex loop of electronic chip creation

A few words about ASML

ASML makes big systems



for tiny patterns

Software and data science play an increasing role
to optimize the machines and processes

A few words about ASML

How it started

Philips laboratory NatLab (1984)

Started as a joint venture by Philips and ASMI

Just 31 employees with a can-do attitude

It took a decade of perseveranc e to break into the market

A few words about ASML

How it started

ASML HQ and main Campus

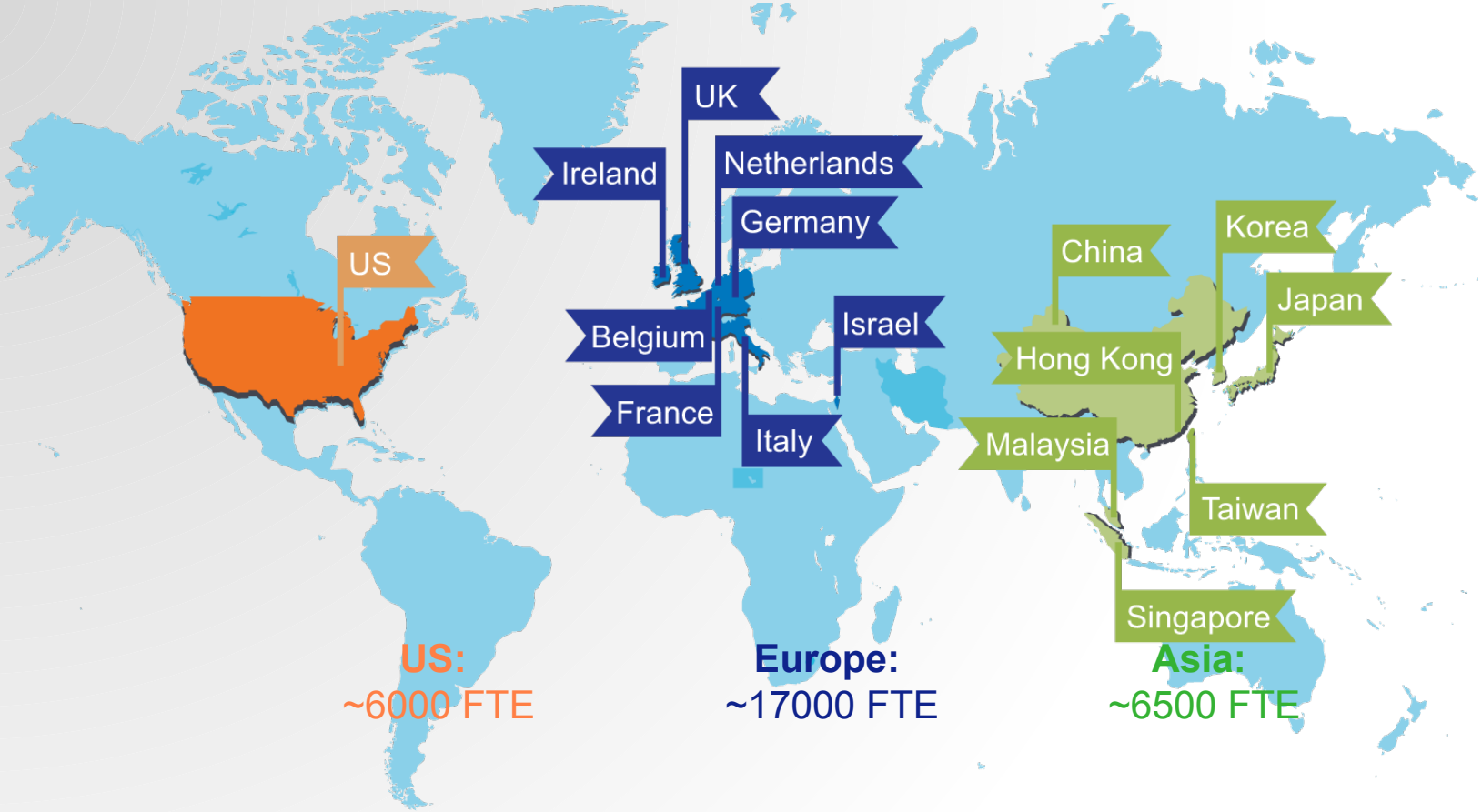
All major chip makers use ASML's machines

Europe's biggest tech company by market cap

Annual R&D budget ~2.2B€

A few words about ASML

A global presence with ~30k employees



US: ~6000 FTE

Europe: ~17000 FTE

Asia: ~6500 FTE

Offices in over 60 cities in 16 countries worldwide

Source: ASML FY 2021

A few words about ASML

Our main locations

Wilton (CT)

Veldhoven

Korea

Silicon Valley (CA)

San Diego(CA)

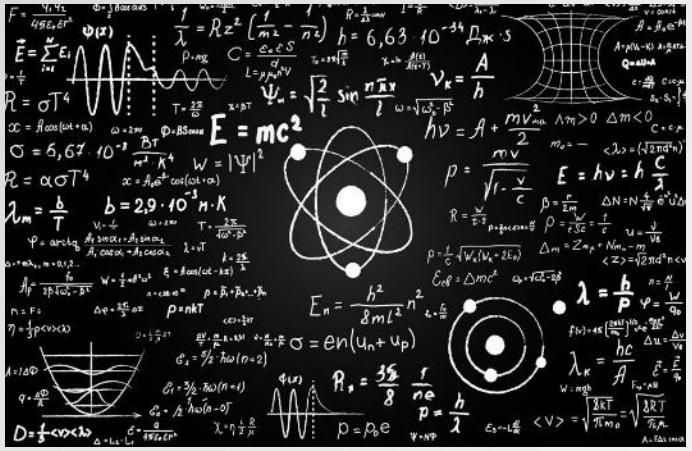
Chandler (AZ)

Taiwan

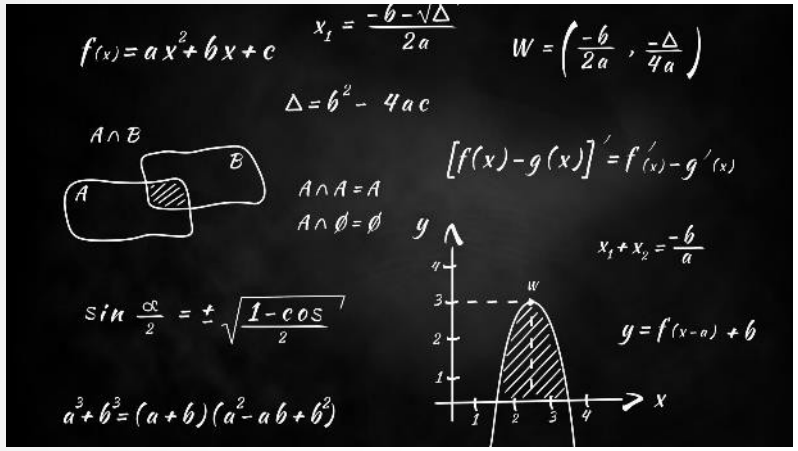
General Context

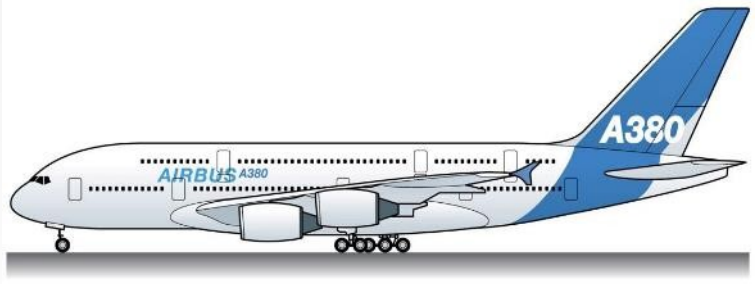
General Context

Physics



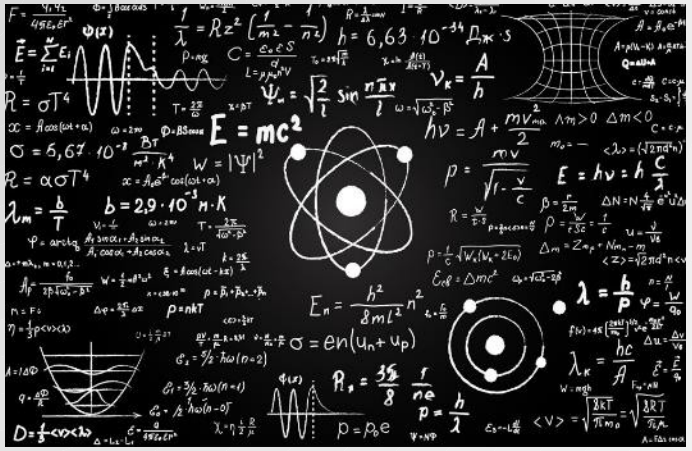
Mathematics



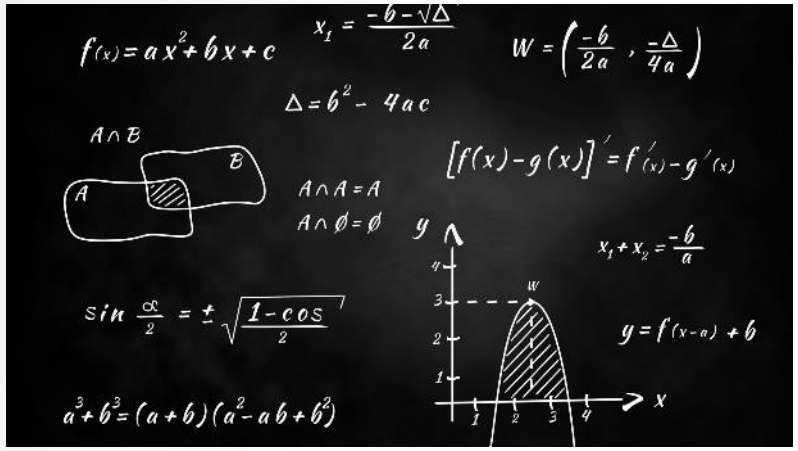


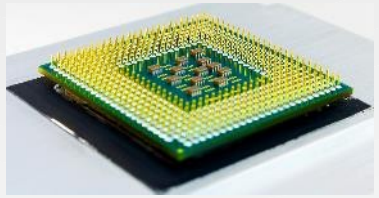
General Context

Physics



Mathematics

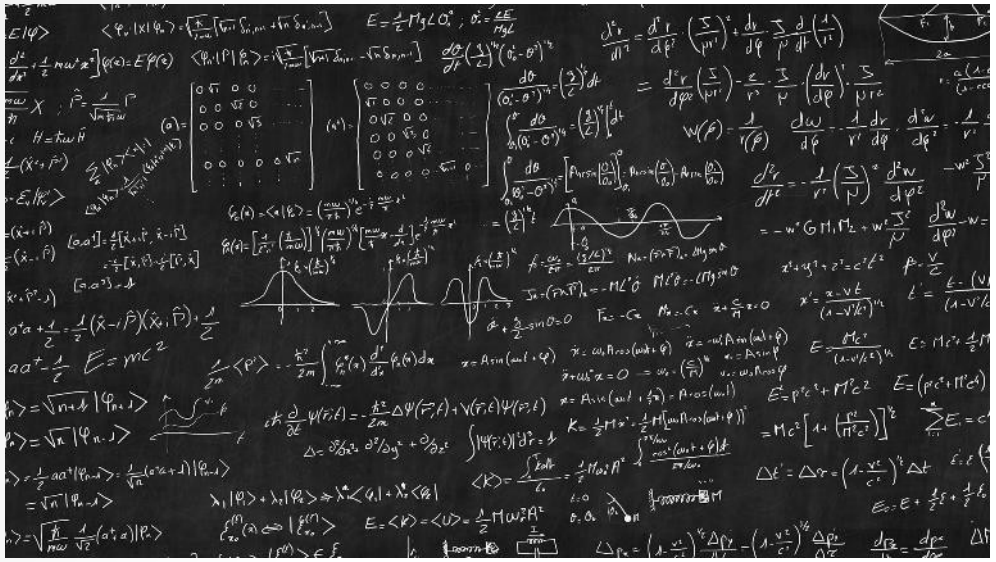




What are the problems in Embedding Algorithms

What are the problems in Embedding Algorithms

Transforming Ideas into Models



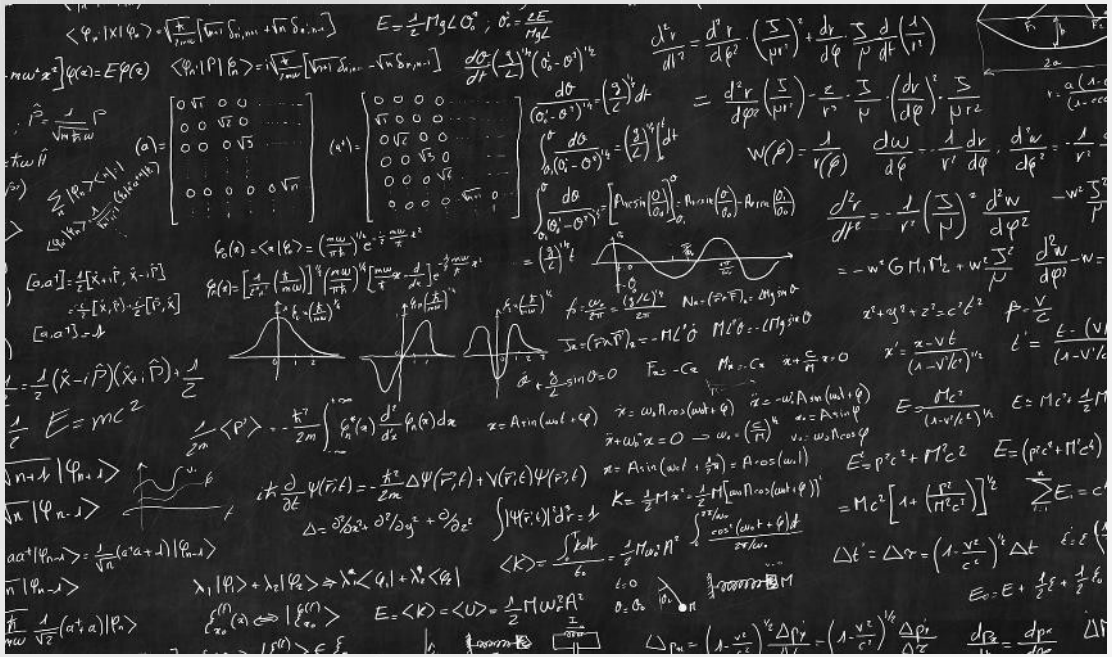
A team of physicists/mathematicians wants to introduce/improve a behavior of/to the machine:

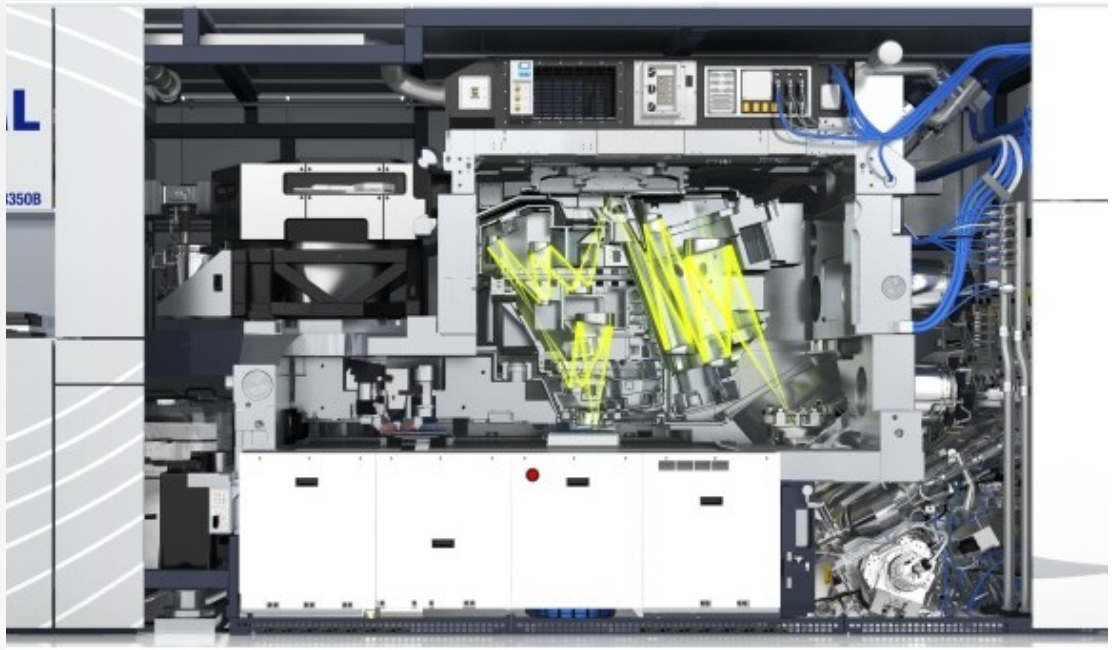
- Performs several experiments
- Collects data and try to fit it on a theory

…extract a complex mathematical expression

What are the problems in Embedding Algorithms

Converting Models into Code





And then transfer it to the machine

What are the problems in Embedding Algorithms

Interoperability with low level programming languages

Deterministic execution

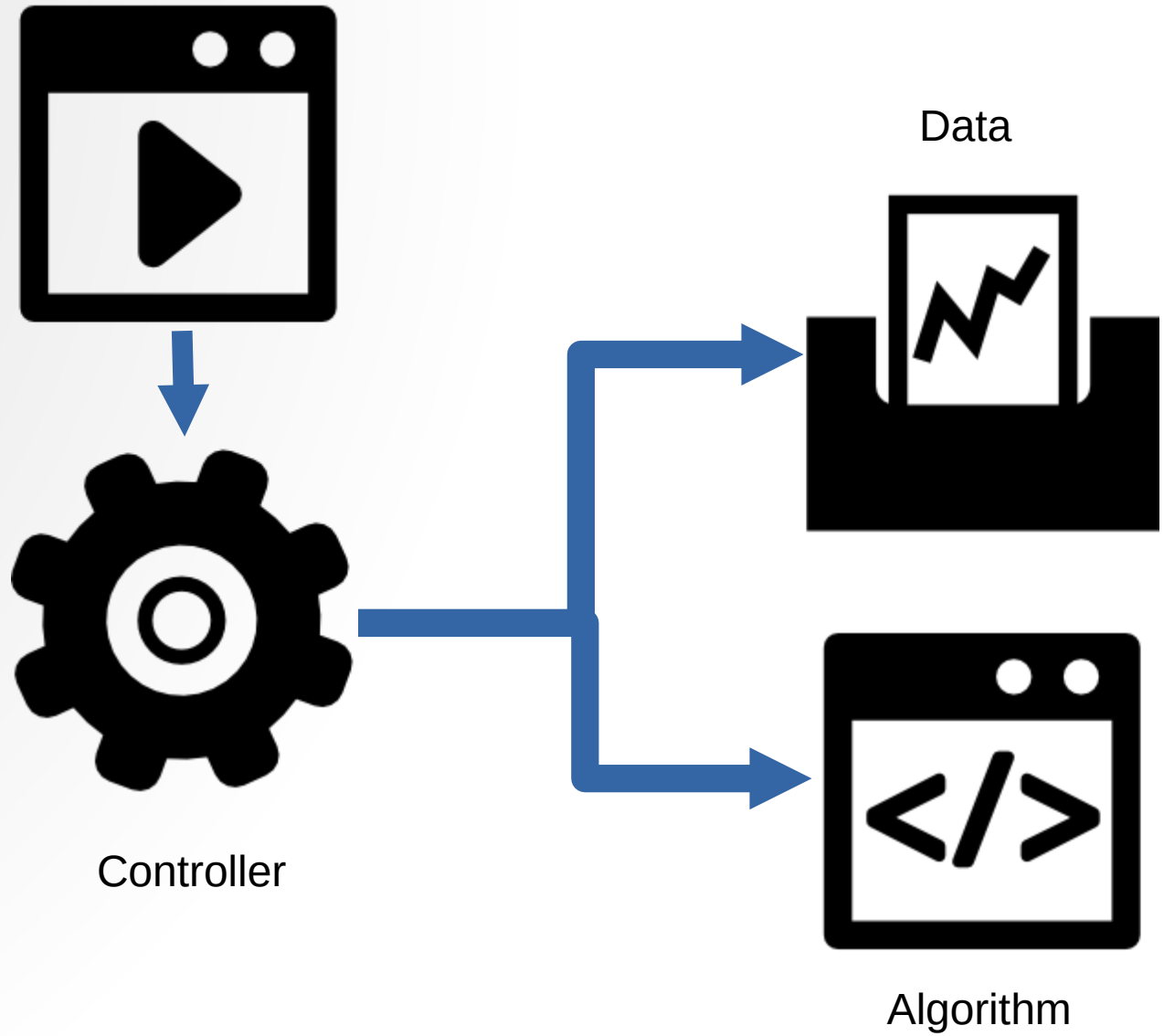
Can Julia solve these issues?

First comes the architecture

Break down the system

An application can be split to:

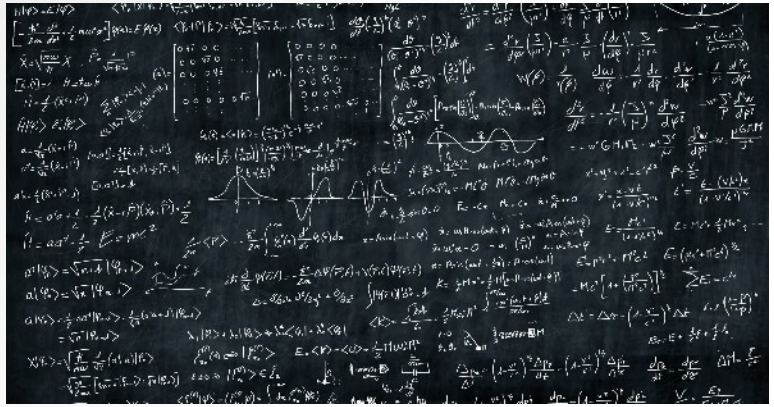
- Controller
- Data
- Algorithm



Fast Deployment with Julia

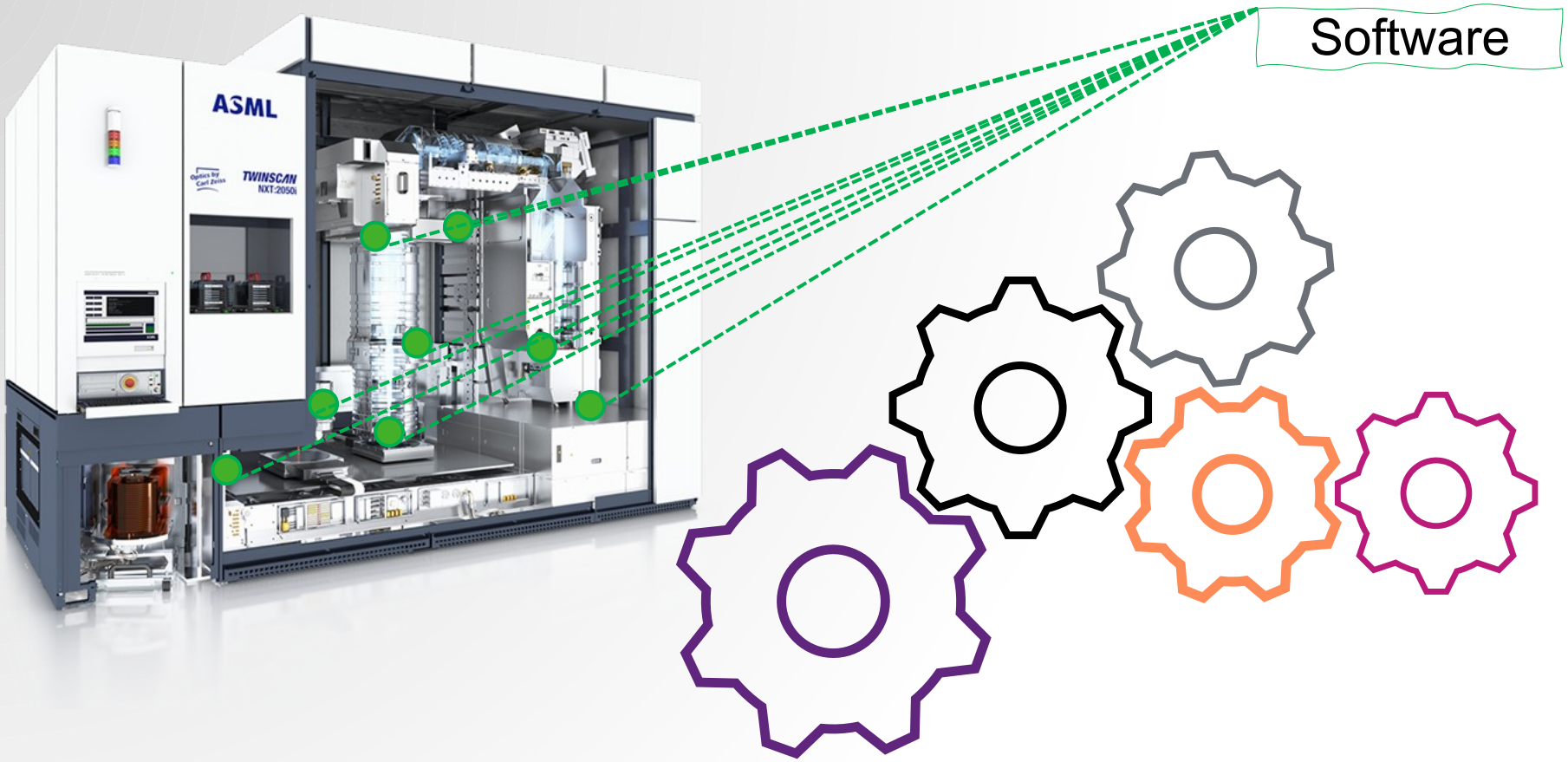
Software

Algorithms



Low level coding

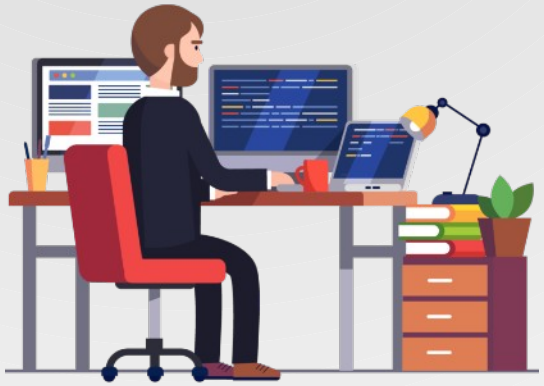
Interoperability & Determinism



Developing an algorithm

An example from ASML

I have the solution!
C is amazing and you can do everything!



Highly skilled SW engineer

I cannot find the fitting function in C! Also, what is this * in front of variable?

Frustrated physicist

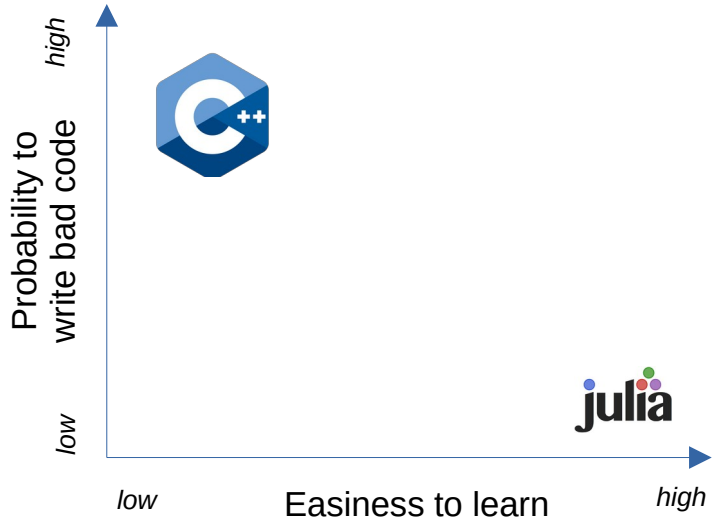
What is the actual problem here?

Developing an algorithm

An example from ASML

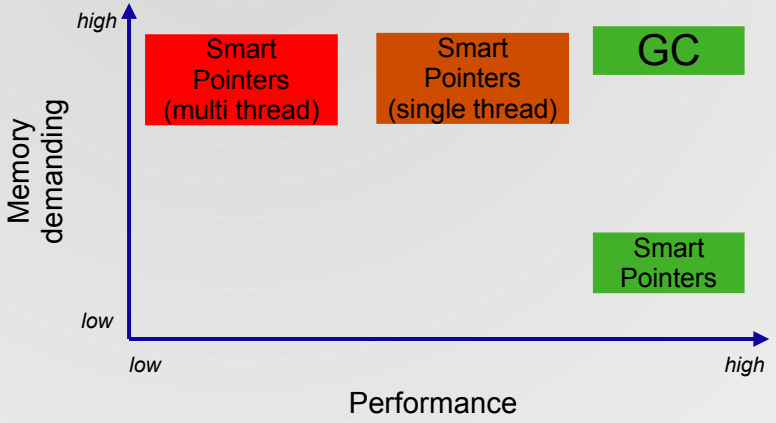
Each one should:

- Use the technology that is better for their purpose.
- Be able to deliver their work without thinking about the deployment difficulties.
- Not think about interoperating with other languages

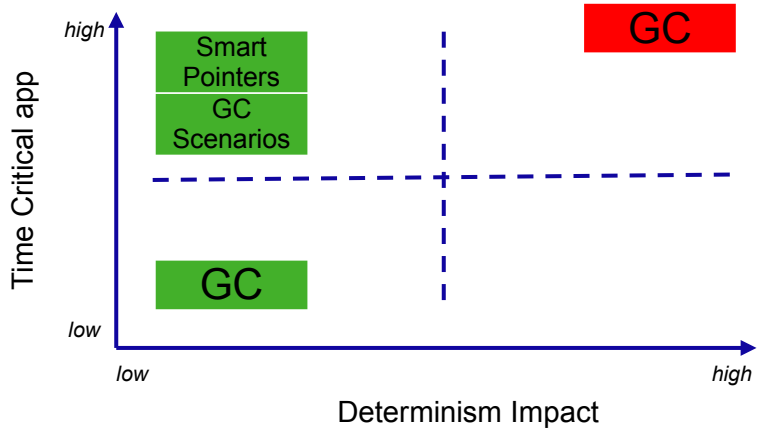


Deterministic Execution

Controlling GC



Is GC a good or bad choice?



Control GC by disabling it by default and enable under certain moments: (a few examples)

- after every algo execution
- after certain amount of algo calls

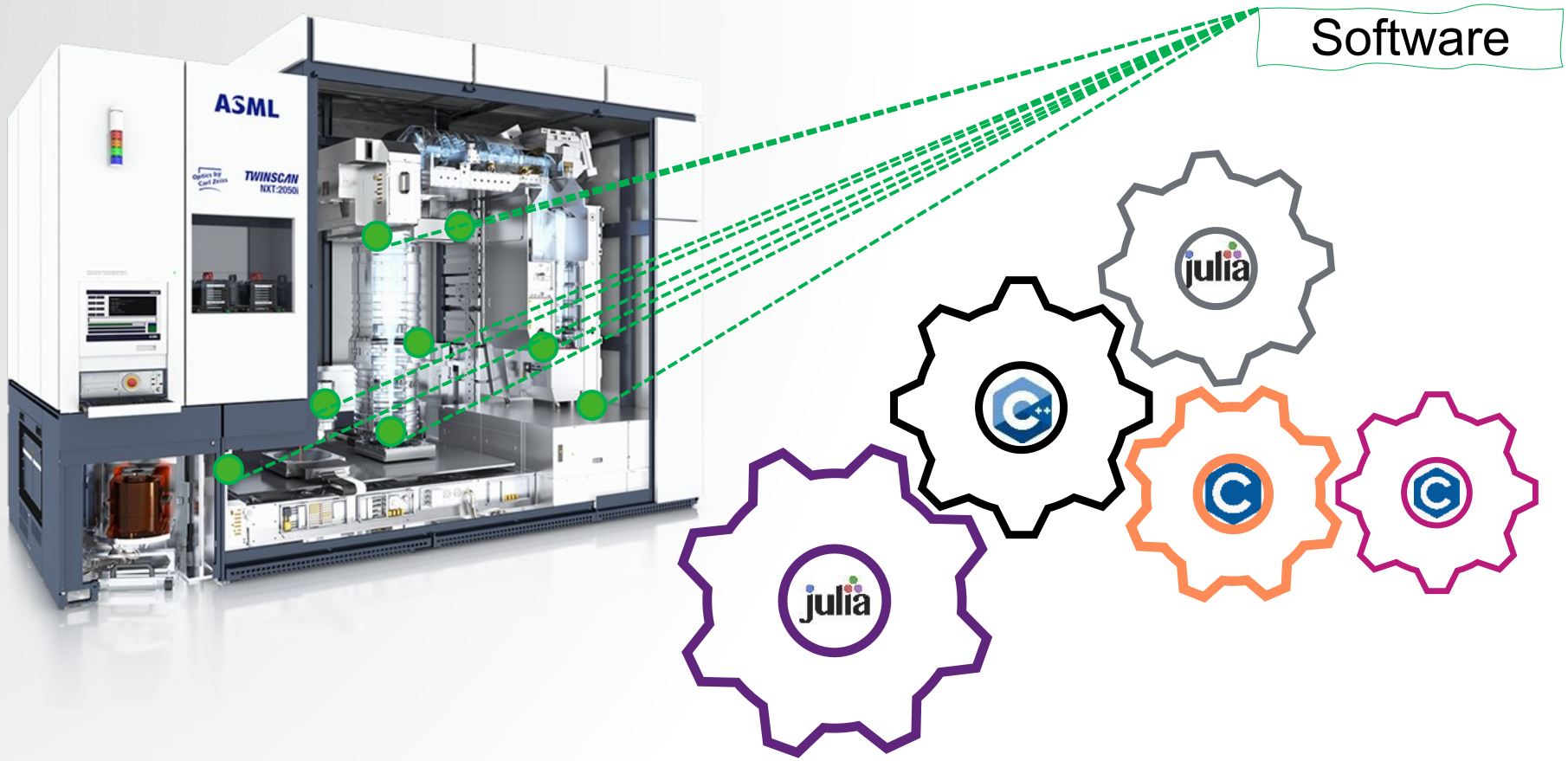
Interoperability & Determinism

C++ API:

- Retrieve Julia functions
- Add/Remove variables to GC
- Matrix manipulation

CCallable:

- Pure C interface
- Julia aligns properly to C
- Passing data by reference



Julia & C++ (*on time critical applications*)

Not *versus*

When it comes to time critical applications, it is a matter of mindset.

- Fully compiled code:
  - Strongly typed interfaces
  - no need for JiT
- Defined memory usage.
  - No unexpected memory allocations.
  - Predefined memory de-allocations.
- Consistent performance.
- Standard interoperability.

Using Julia to perform physics in time critical systems

Julia enables direct deployment towards platforms, by:

- Strongly typed interfaces.
- Fully compiled code.
- C memory alignment / C API.
- Controllable Garbage Collector.
- Multithread support.

There is still room for improvement:

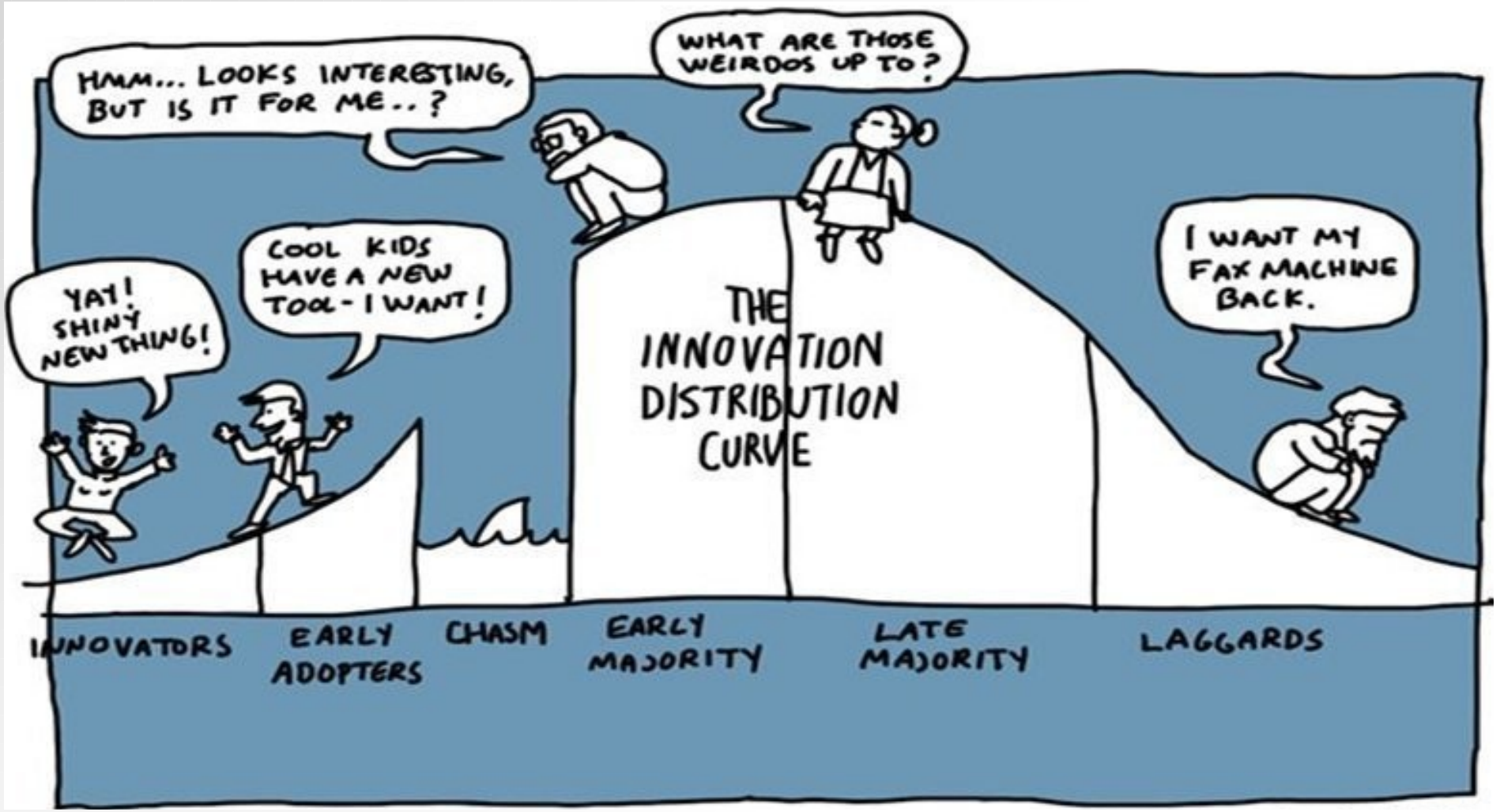
- Small binaries.
- Statically typed compilation.
- Load multiple images.

} **SCG** in 1.12

Join us on Thursday's morning workshop!

- Tutorial on:
  - Test driven compilation.
  - Issues with compile=all.
  - SCG early access.
- Bring in your use cases to be fully compiled.

Using Julia to perform physics in time critical systems



ASML


Salamat
Dakujem
GRACIAS
धन्यवाद
TAKK
ASANTE
HVALA
Ευχαριστώ
감사합니다
GRAZZii
DANKE
GRAZAS
Salamat
Рахмет
kiitos
ARIGATO
Thank You
Suwun
धन्यवाद
HVALA
MERCI
teşekkür ederim
mahalo
GRACIAS
kiitos
ありがとう
DANKE
Благодарам
TAKK
ASANTE
gracie
спасибо
多謝
gracias
teşekkür ederim
TAK
hvala
Salamat
SUWUN
شكرا
جزيل
kiitos
merci
TAKK
MAHALO
arigato
takk
GRAZIE
DAKUJEM
hvala
TAKK
GRAZAS
Salamat
SUWUN
SALAMAT

A few words on how electronic chips are produced

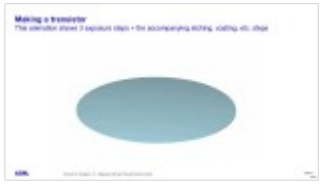
The semiconductor manufacturing loop

Lithography:

- writing on a stone (ancient Greek)
- Precise light manipulations to expose (print) desired patterns on wafers.

Several steps are taking place till the final stage:

- Exposure
- Develop & Baking
- Etching
- Ion implantation
- Remove photoresist
- Processed wafer
- Deposition
- Photoresist Coating



Improve process by:

- Computational lithography systems
- Metrology & Inspection