Research Challenges in CPS

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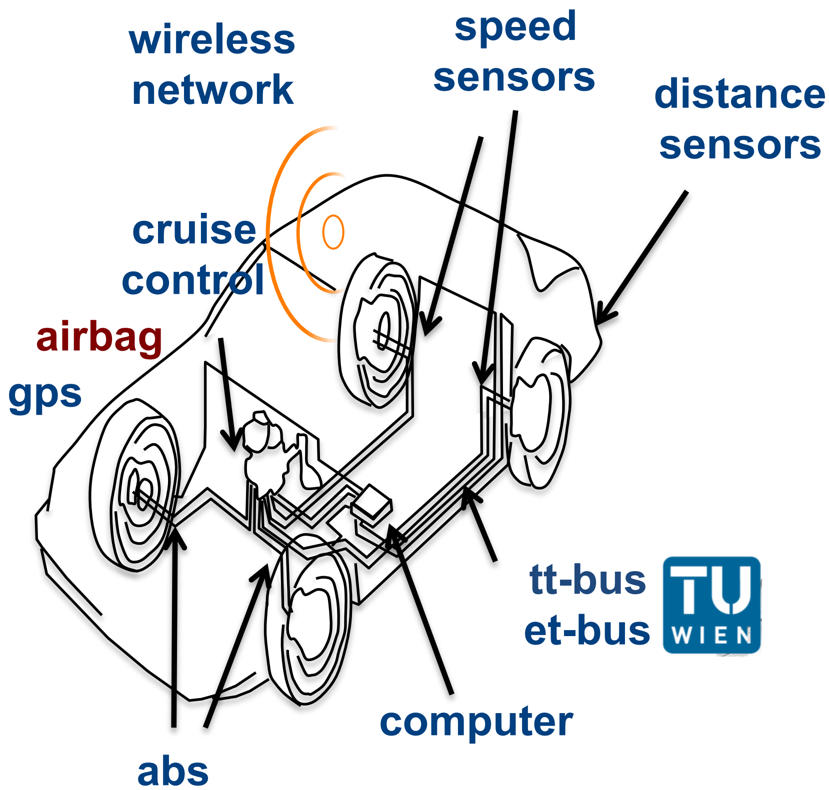
Quick History

Embedded Systems
1980: e.g. airbag

Quick History

> 40 processors, 60 sensors, 40 actuators
> 100 million lines of code controlling them

Networked Embedded Systems **1990: e.g. car**
Embedded Systems **1980: e.g. airbag**

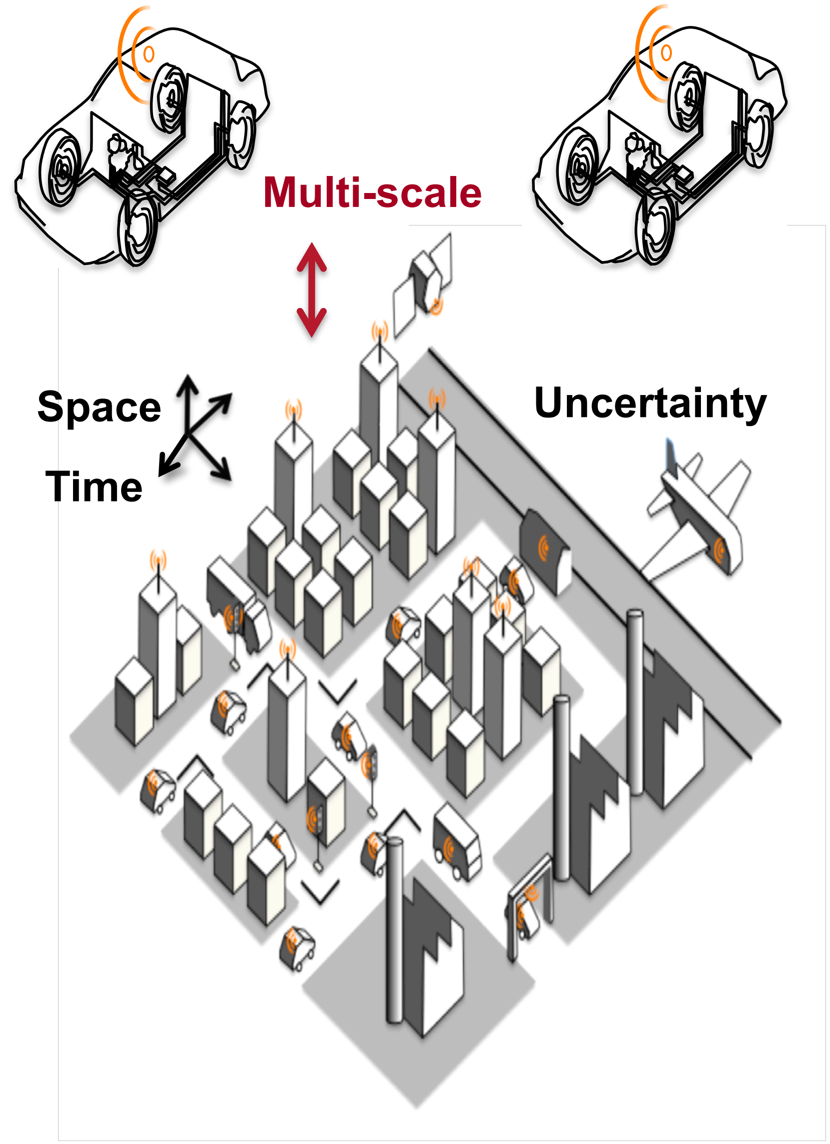


Quick History

Cyber-Physical Systems
2010: e.g. smart mobility

Networked Embedded Systems
1990: e.g. car

Embedded Systems
1980: e.g. airbag



CPS Wake-Up Call

2008: NSF and US-Scientists send CPS-Manifesto to

- The president of the US
- President's Council of Advisors on Science and Technology
- NSF program takes off in February 2009 within the US

2012: Acatech and DE-Scientists send CPS-Manifesto to

- Germany's Federal Ministry of Education and Research
- Program takes off in 2013 in Germany
- H2020 program takes off in 2014 within the EU

It is high time for a Big-Push in Austria, too!

CPS Week 2016

HSCC ICCPS IPSN RTAS

April 12-14, 2016
(Workshop & Tutorials: April 11, 2016)

http://cpsweek2016.ocg.at

Where Are We Now?


Unmanned Trains

Unmanned Cars


Unmanned Aerial Vehicle

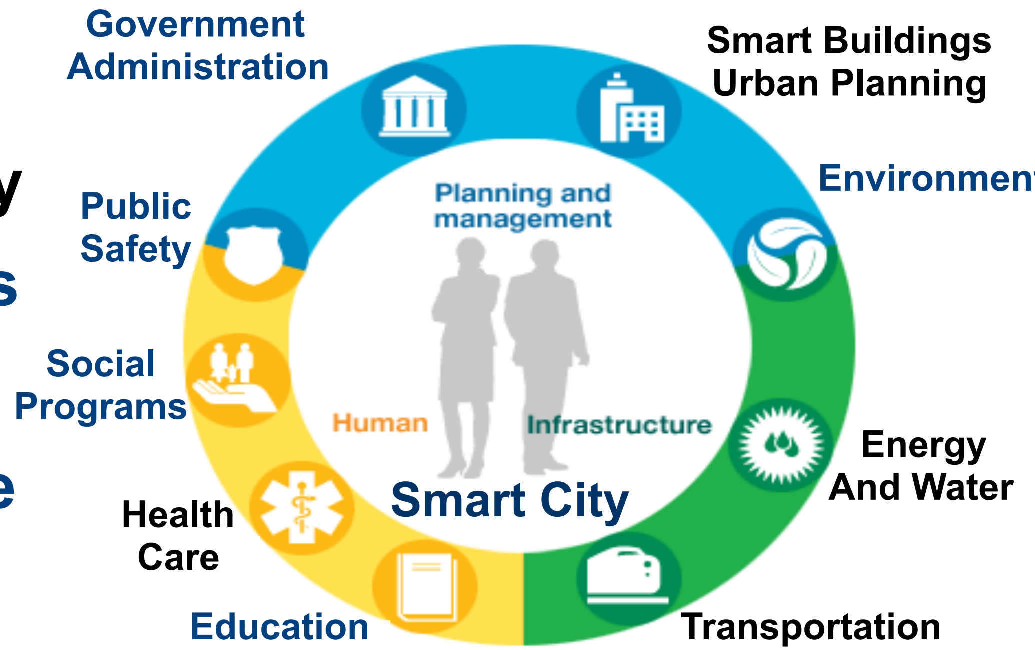
Unmanned Underwater Vehicle


Unmanned Factory

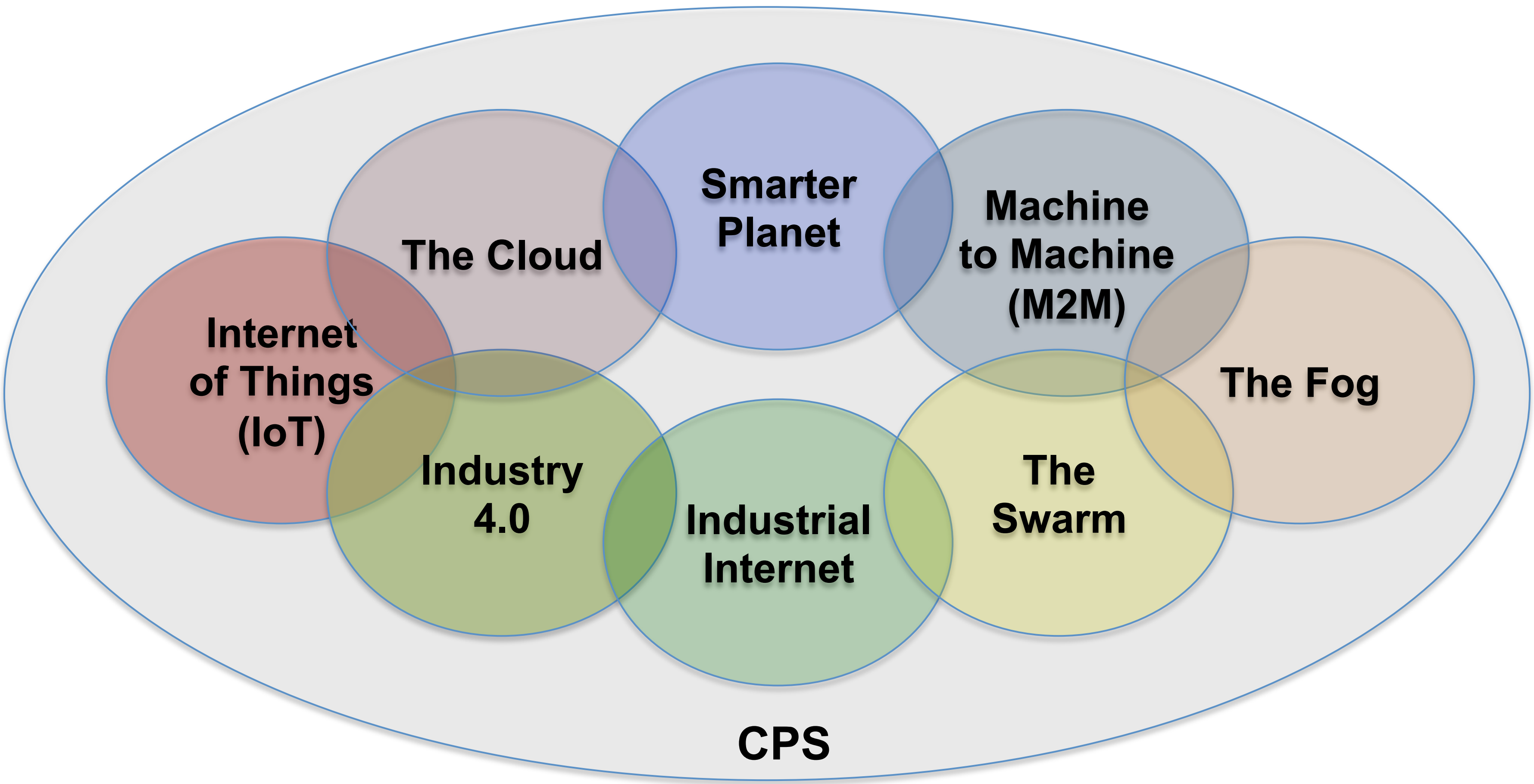

Cyber Biological

What are the Grand Challenges?

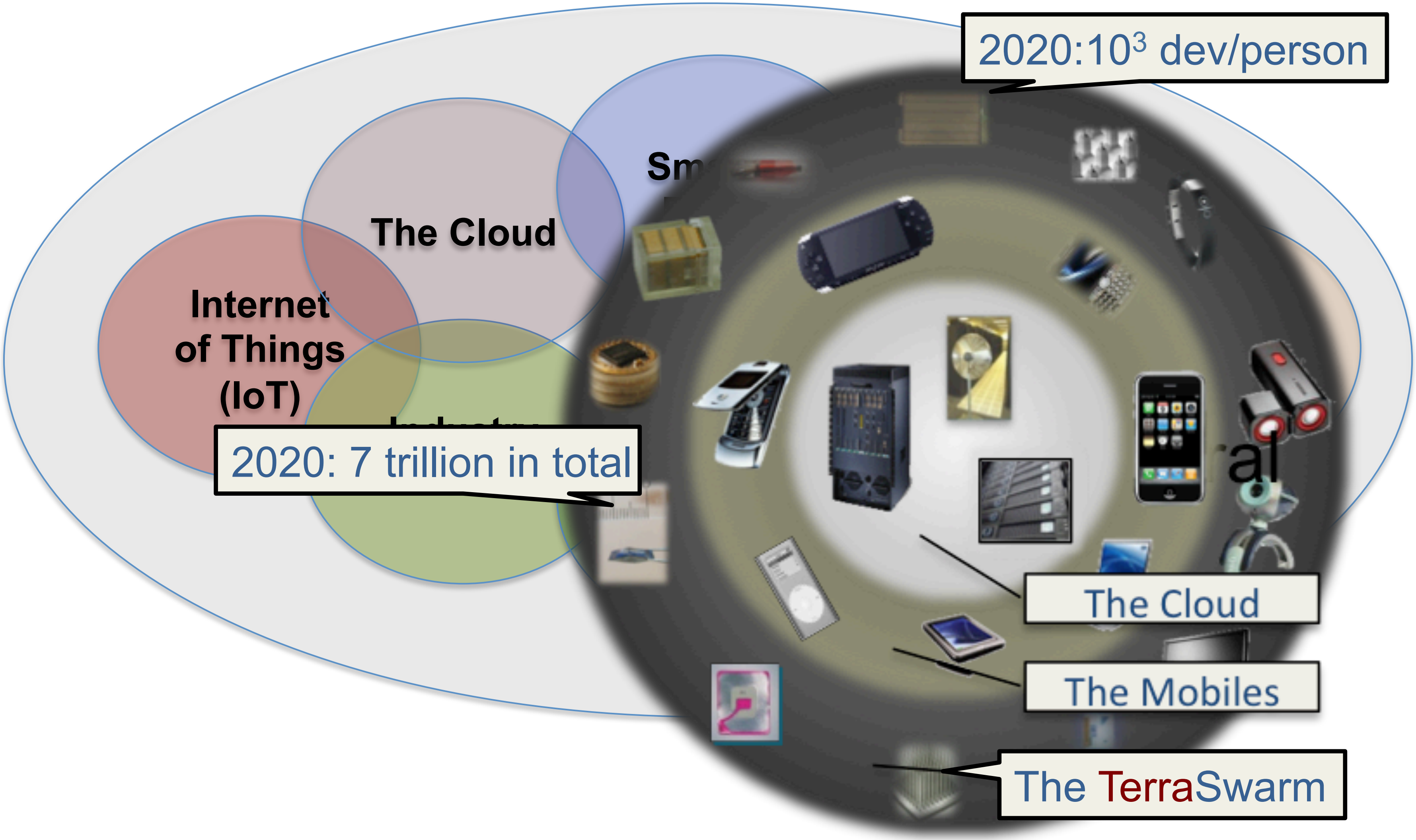
- Zero traffic-fatalities
- Blackout-free electricity
- Energy-aware buildings
- On-the-fly production
- Everywhere health-care
- Max-yield agriculture



The CPS Ecosystem



The CPS Ecosystem

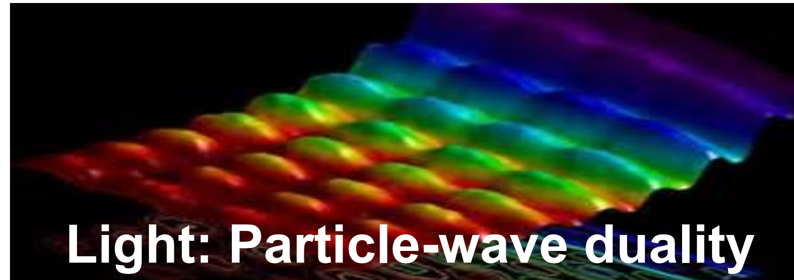


What are the Technical Challenges?

Mathematics
- Discrete-continuous
- Very different math

Architecture
- Huge complexity
- CPS-OS platform

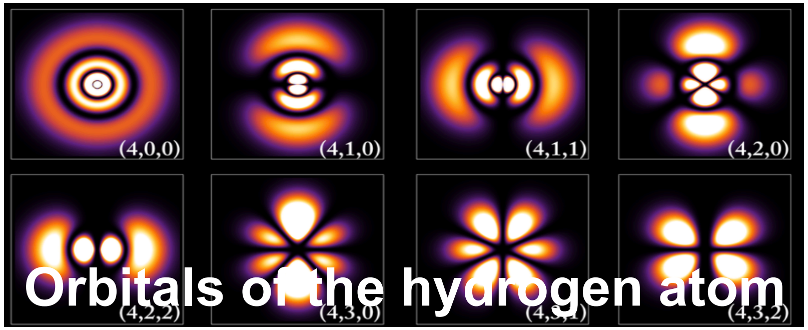
Spacetime
- Various scales of ST
- ST-aware programs



What are the Technical Challenges?

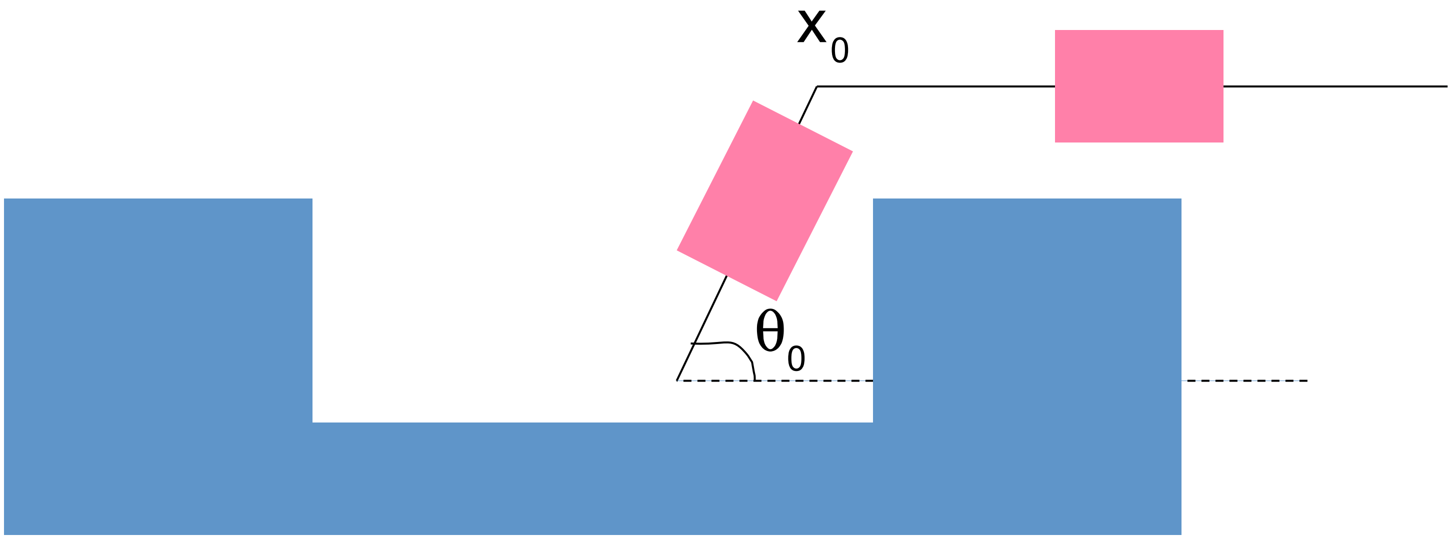
Uncertainty

- **Partial knowledge**
- **Limited resources**



Orbitals of the hydrogen atom

Deterministic Algorithm



while $(x > x_0)$ go back;

while $(\theta > \theta_0)$ turn;

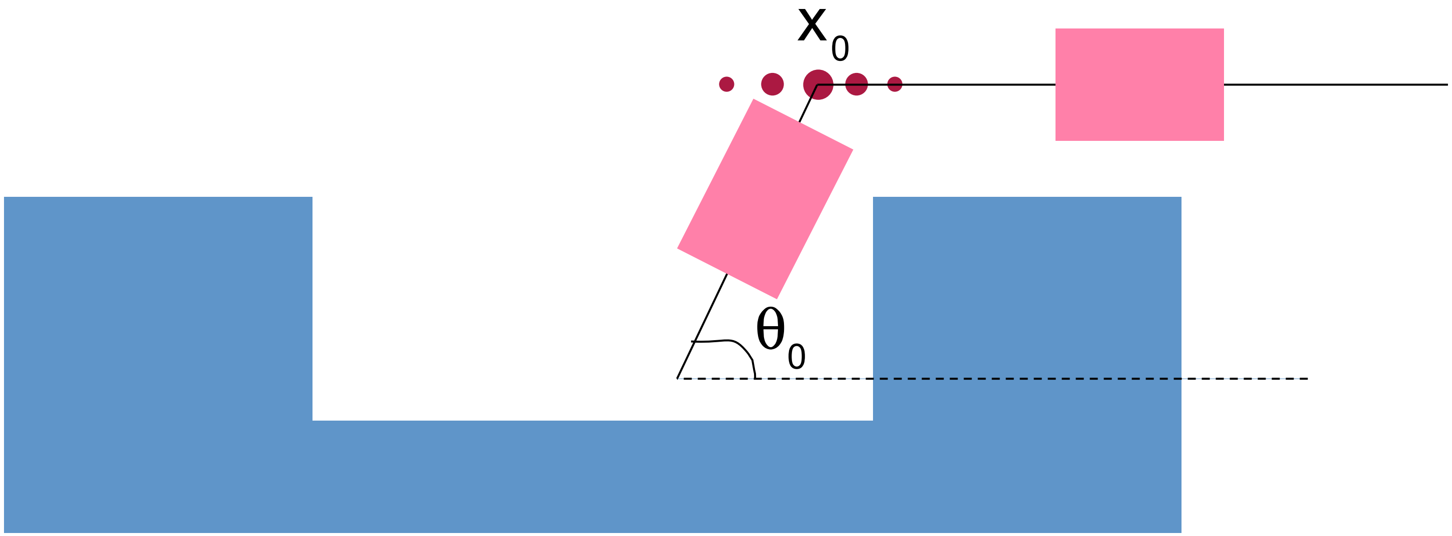
...

Not smart/robust

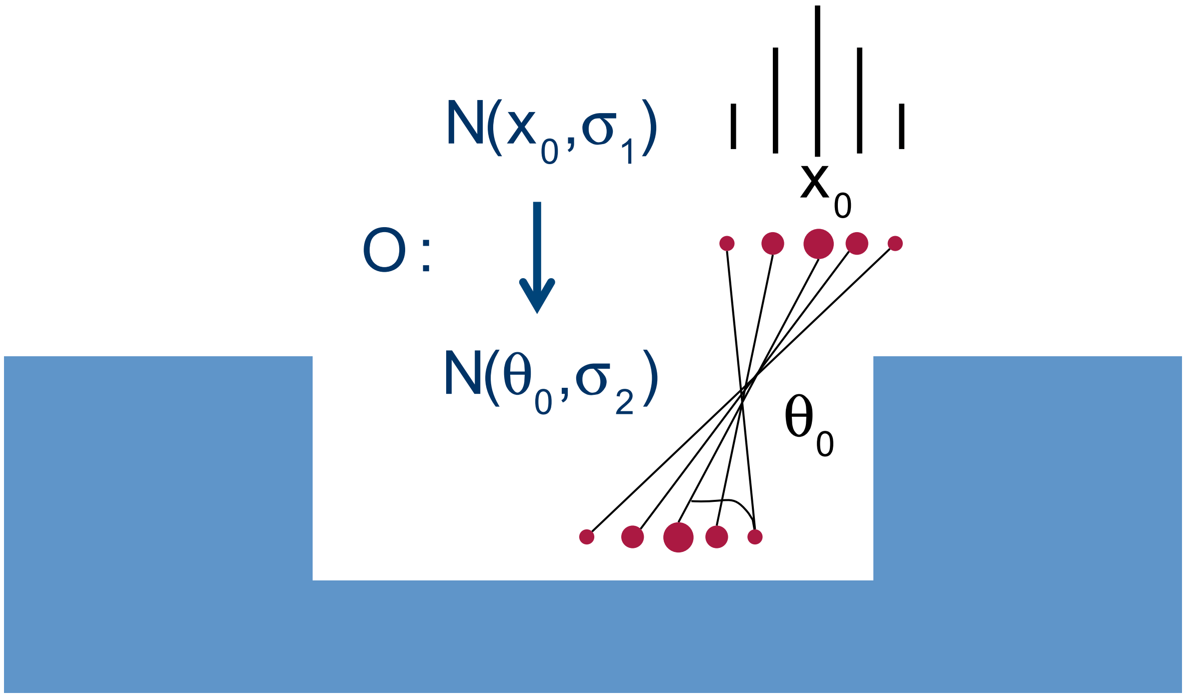
- Optimization tough
- Not robust (slding)

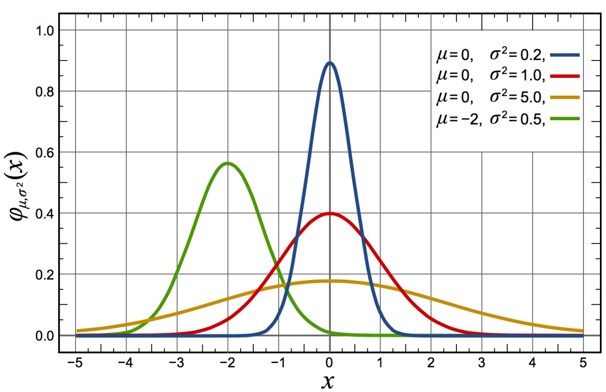
Optimization goal: Learn x_0, θ_0, …

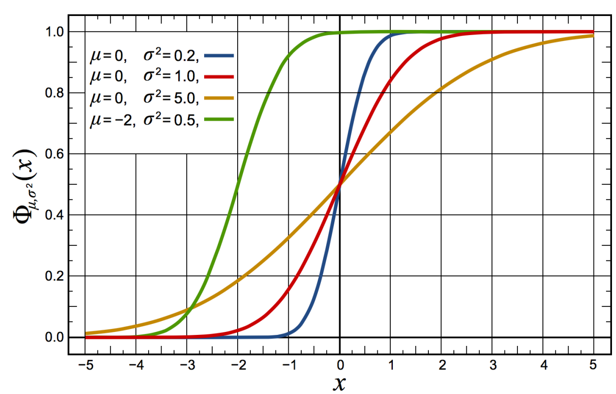
Capturing freedom



Capturing freedom: Neural Network

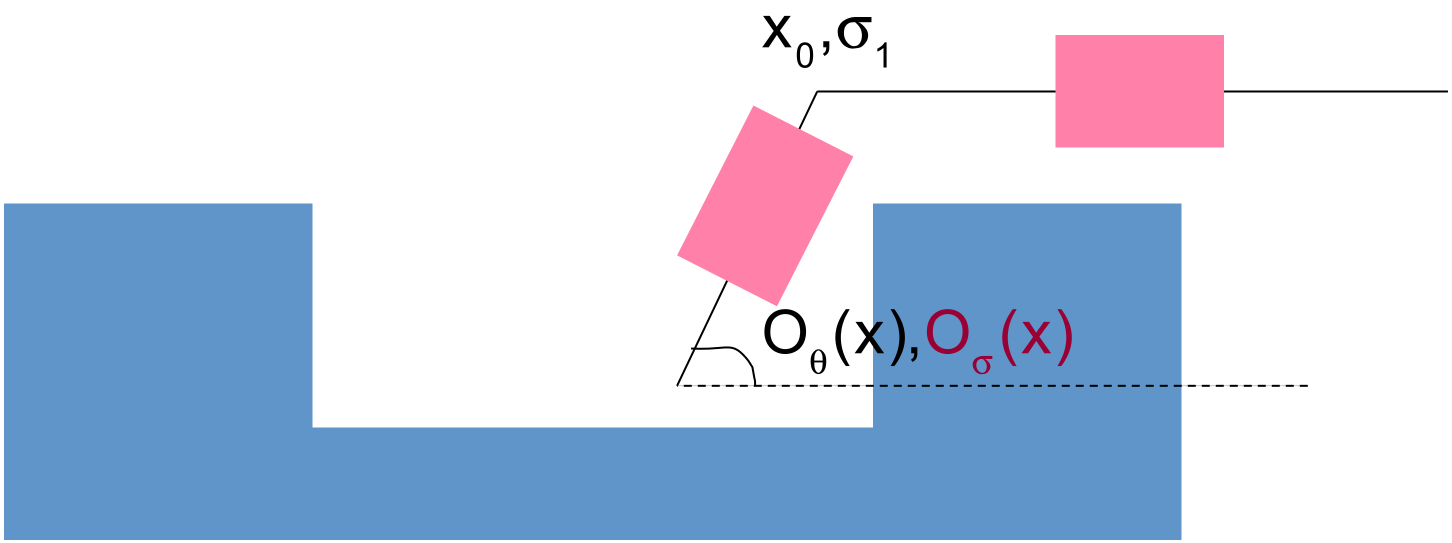






Stochastic Algorithm

- **Ontology O: Neural Network of guard dependencies**

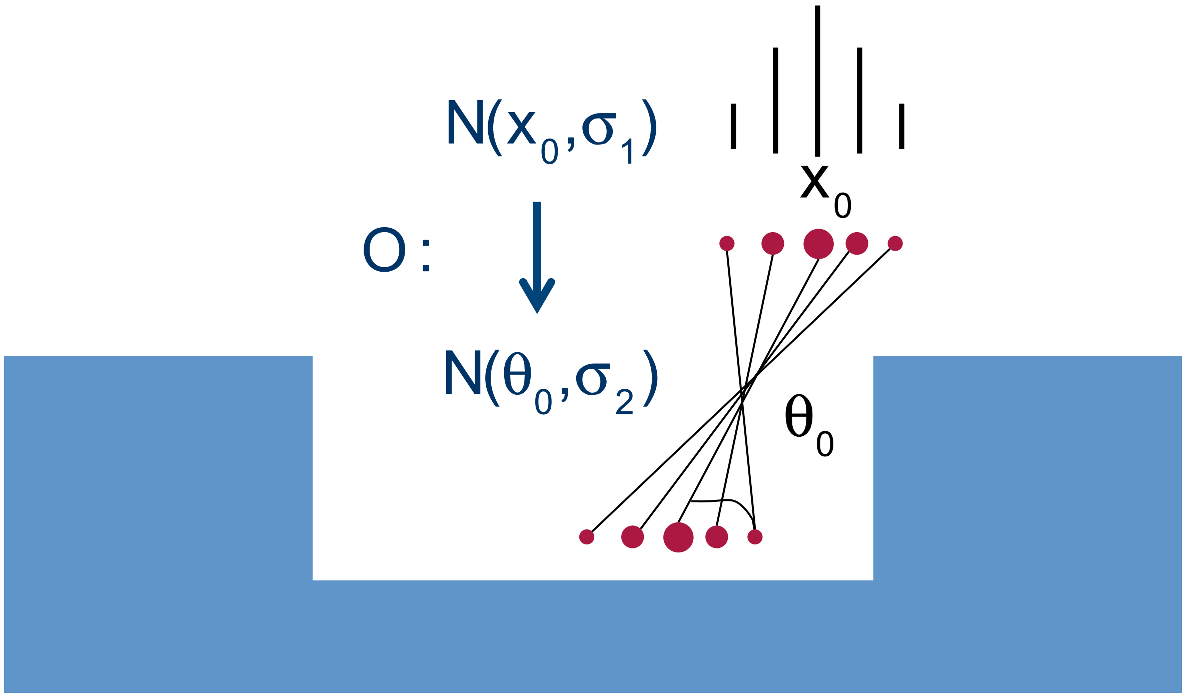


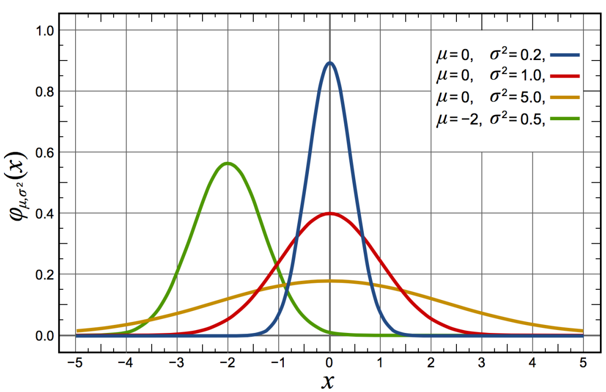
nwhile $(x > x_0, \sigma_0)$ go back; $\theta_1 = O_\theta(x)$

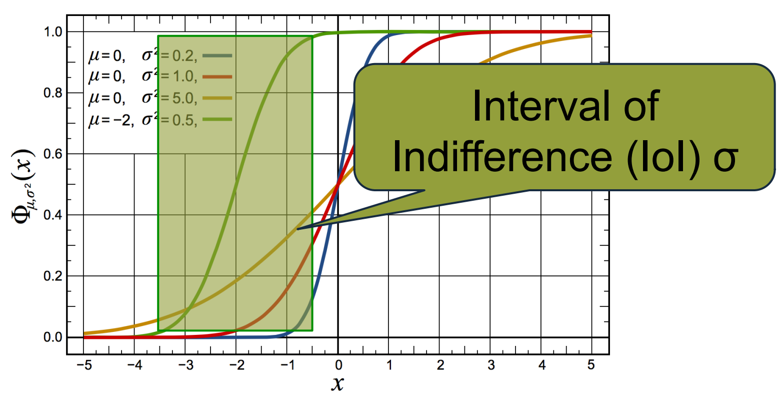
nwhile $(\theta > \theta_1, \sigma_1)$ turn; $\sigma_1 = O_\sigma(x)$

...

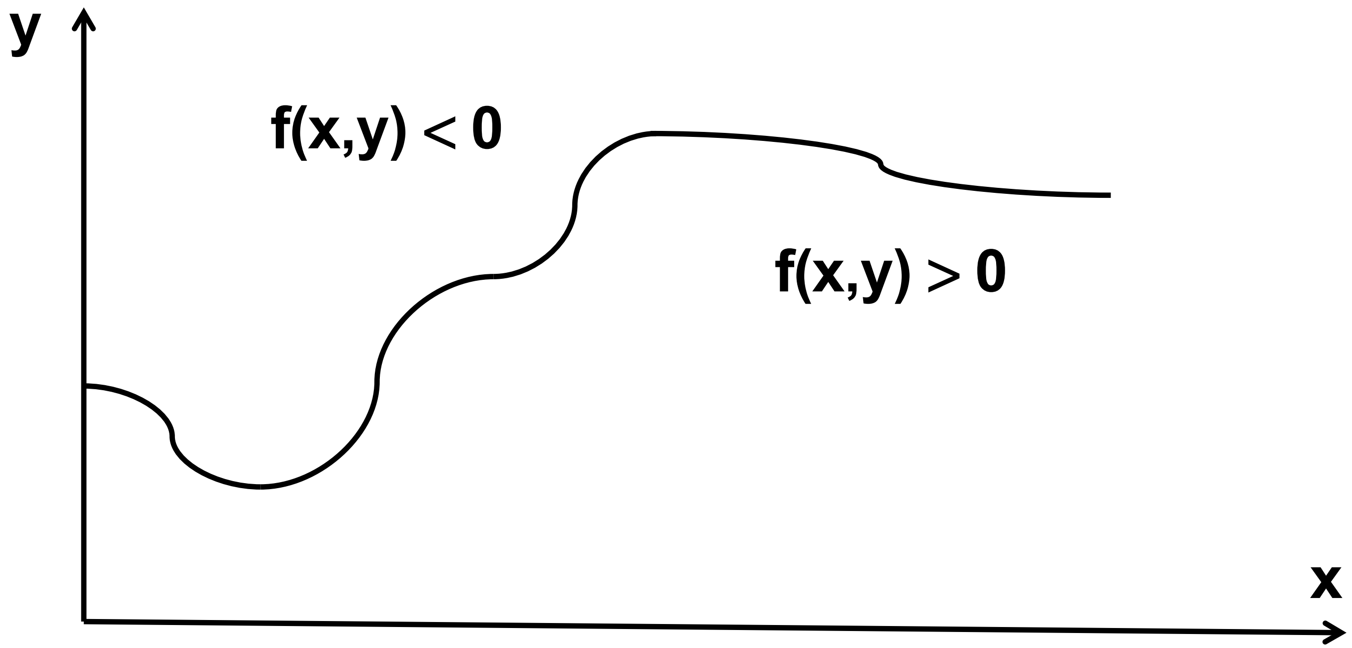
Determinization Trick (e.g. In Time): Use IoI







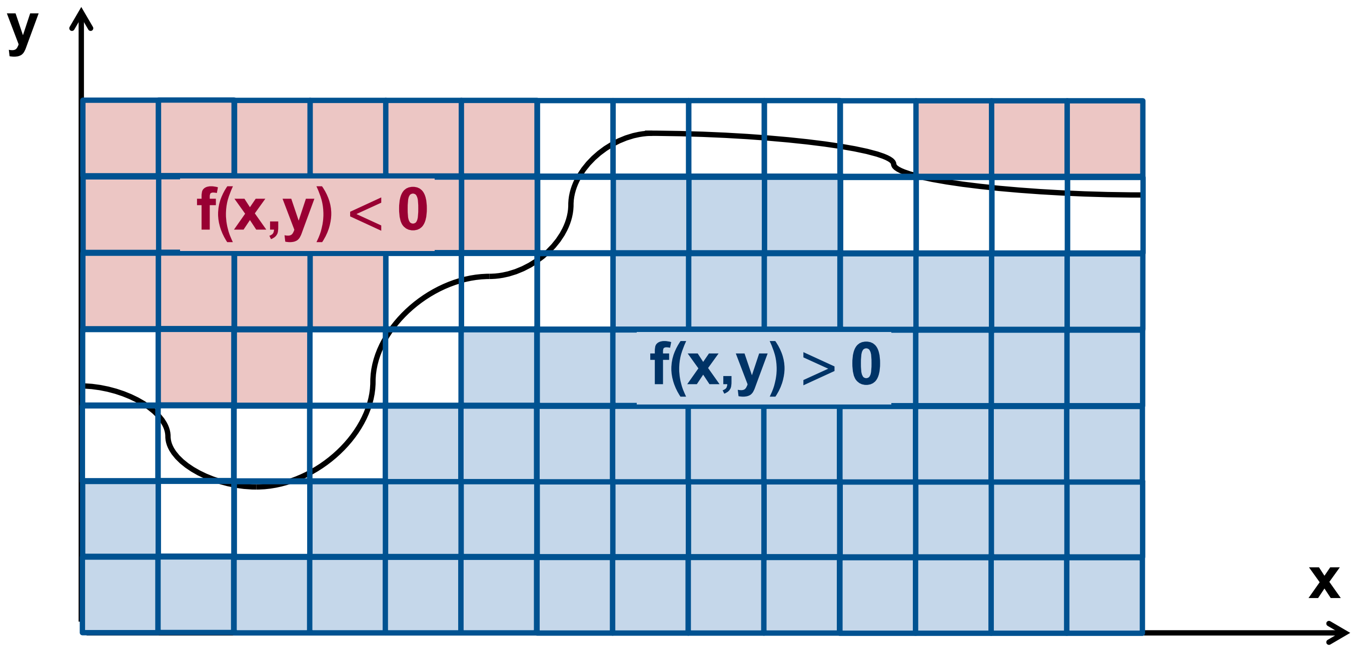
Classification (Prediction) Limits in FOT



What about: First Order Theory ($\mathbb{R}, \leq, +, \times, \sin$) ?

- **Undecidable:** Would allow encoding of polynomial diophantine equations (PDE)
- **PDE:** Known to be undecidable (Matiyasevich, 1970)

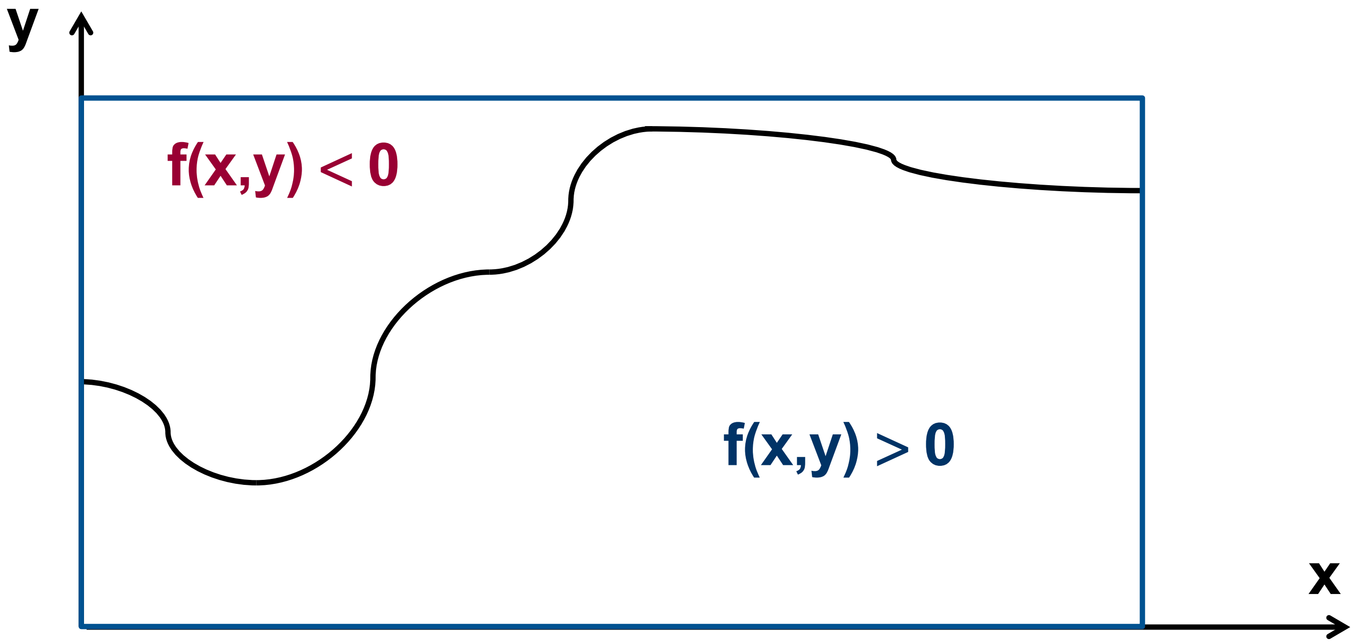
Fixing Precision (i.e. Use lol)



What about: **FOT ($\mathbb{R}, \leq, +, \times,$ sin) ?**

Decidable: But exponential in the number of boxes!

Top-Down Algorithm



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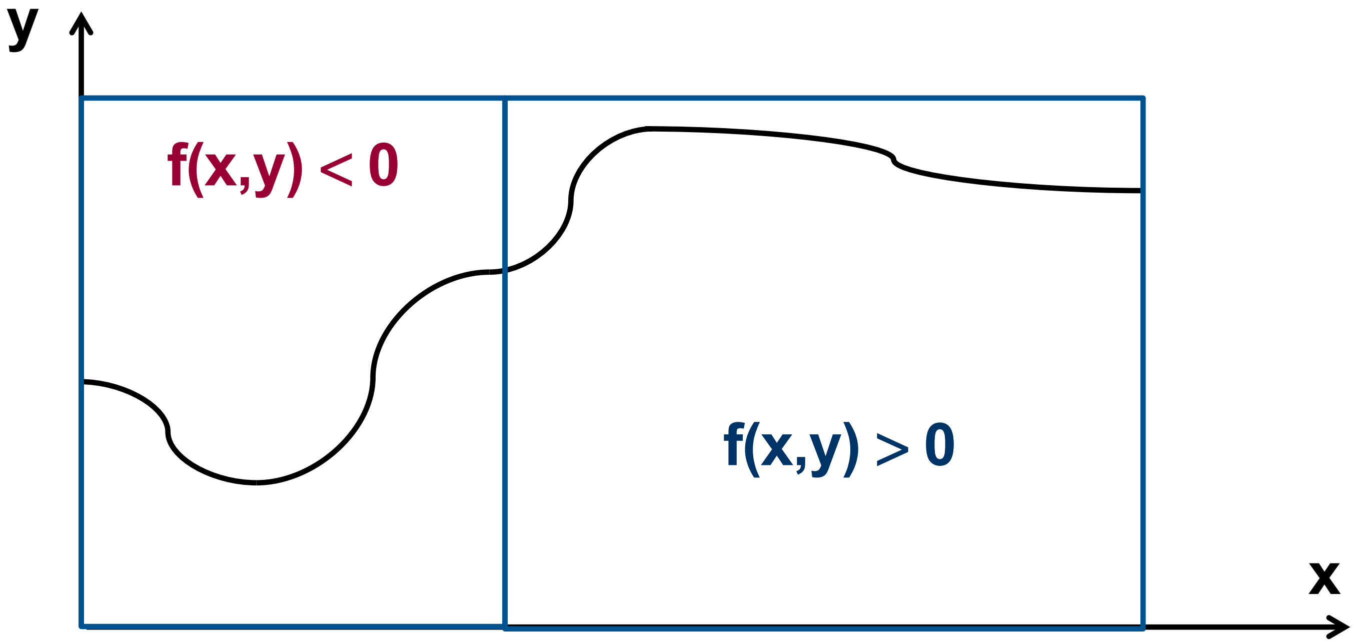

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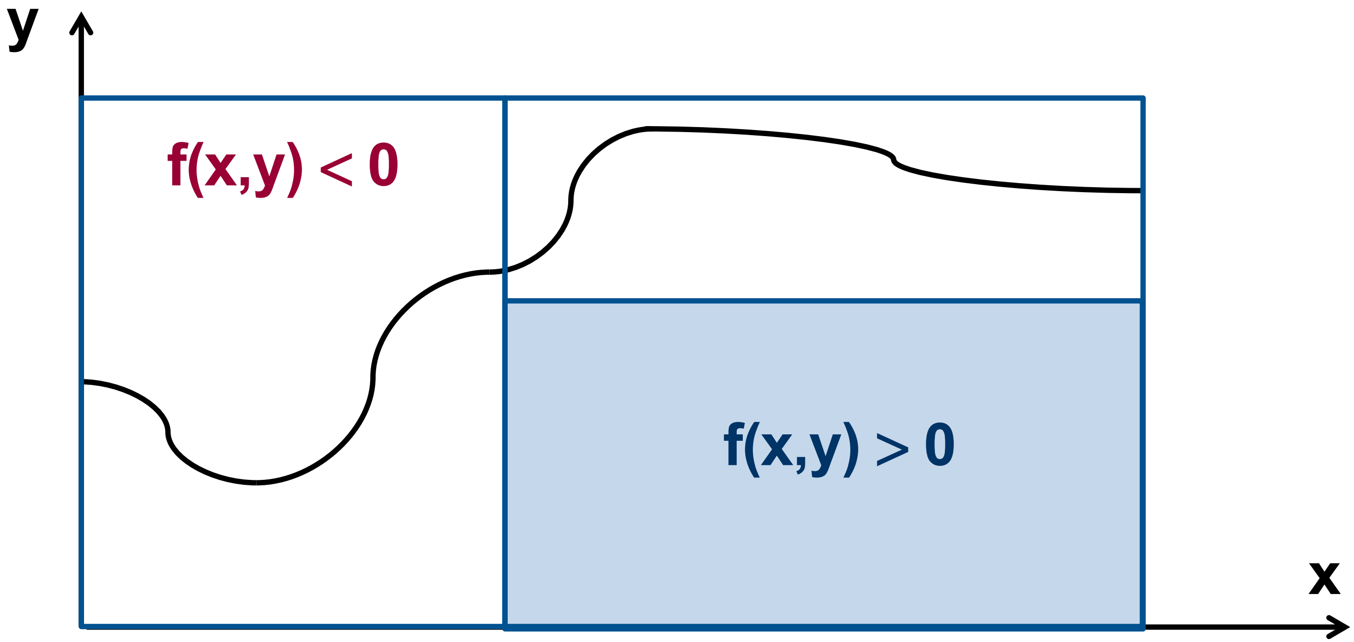

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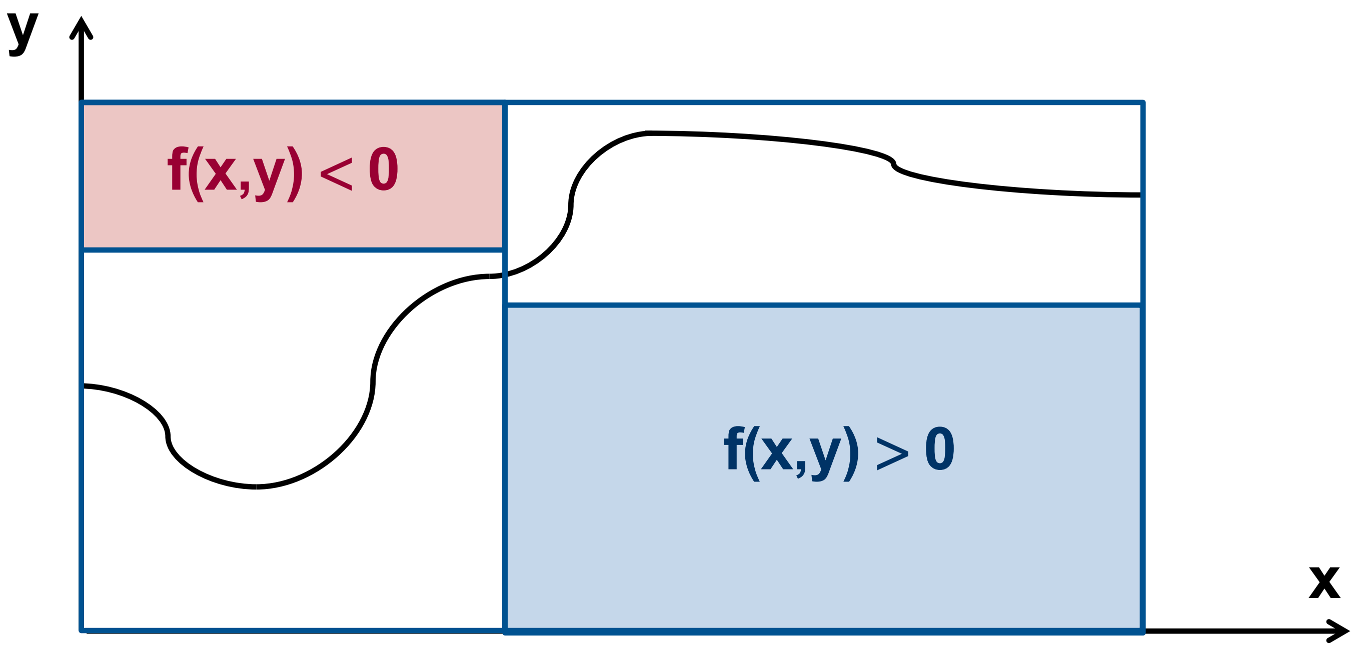

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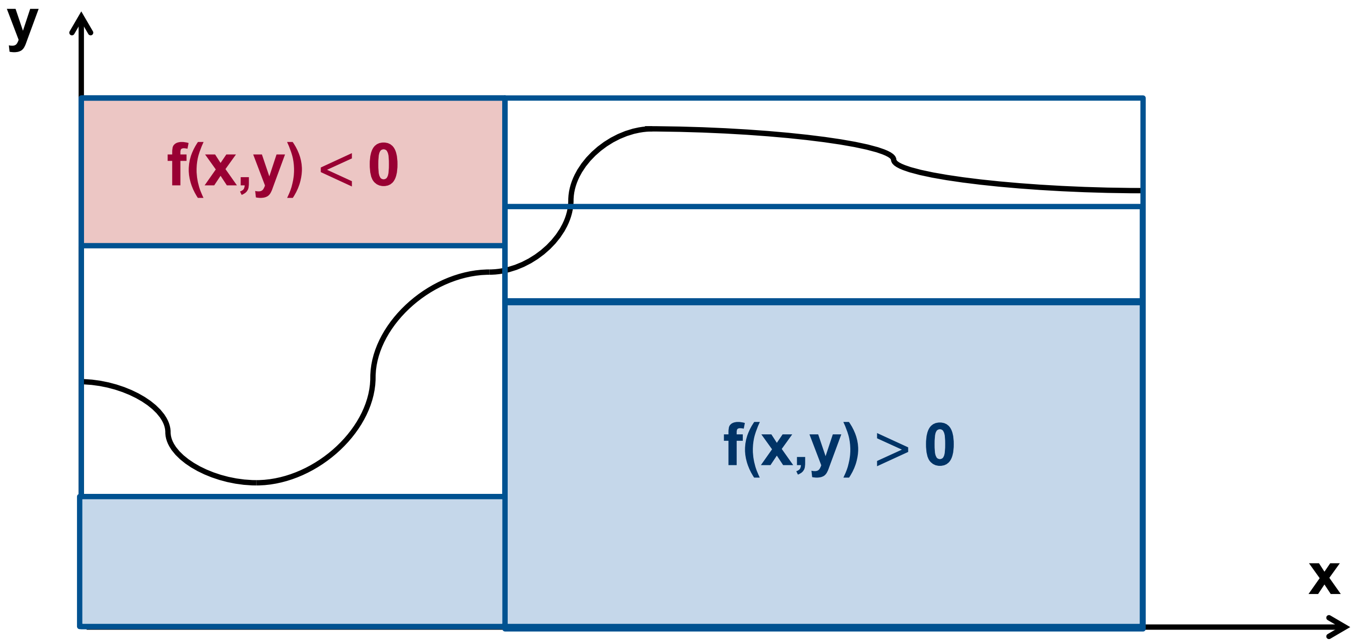

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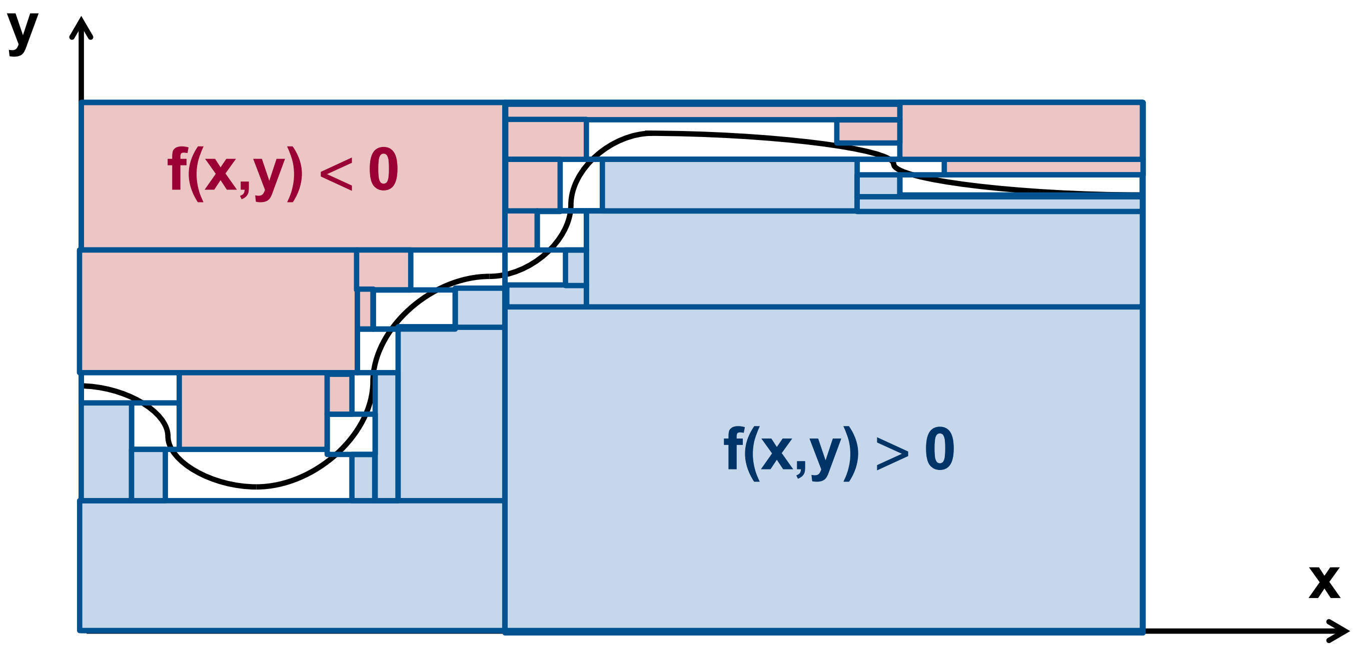
Top-Down Algorithm



By fixing precision: Always terminates!

- **Consequence:** Uncertainty within white boxes (lol)
- **Time Domain:** Time triggered approach
- **Value Domain:** Similar to time domain abstraction

What are the Technical Challenges?

Uncertainty

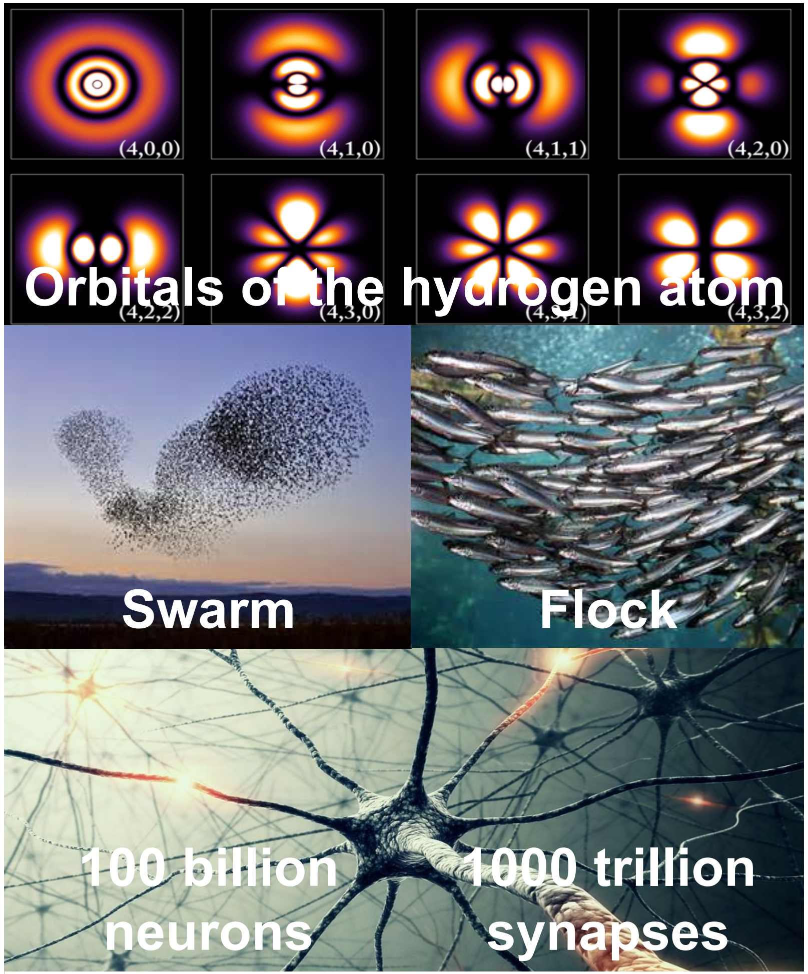
- Partial knowledge
- Limited resources

Safety

- Safety is in big no
- Emergent behavior

Smartness

- Adapting is in big no
- Neural circuits



What About Education?

Recent past (1980-2010s)

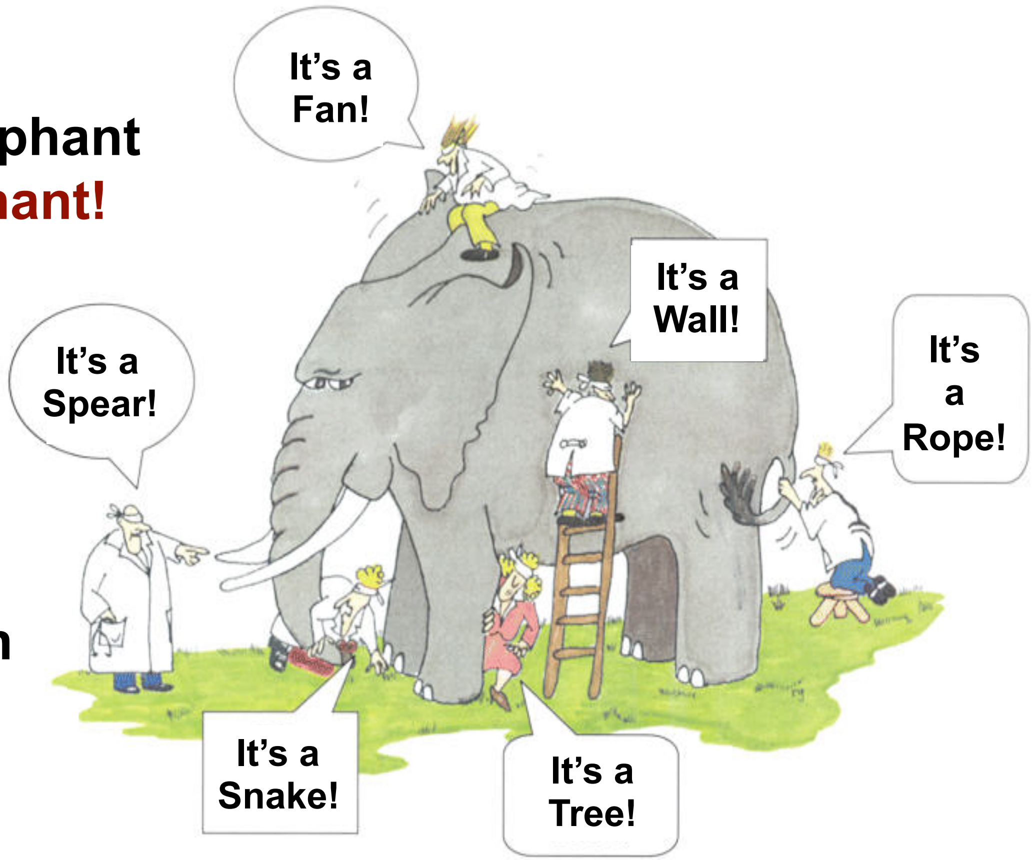
- Blind man assessing an elephant
- Blind man building an elephant!

What about now?

- Age of system building!
- Engineering converges

Back in the future (1950s)

- Computation: von Neumann
- Sensing/inference: Wiener
- Actuation/Control: Kalman
- Communication: Shannon



What is in Store for Us?