

Artificial Intelligence: From the lab to the real world

Four decades of AI research at the VUB AI Lab



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30 March 2022



ai.vub.ac.be



@aibrussels

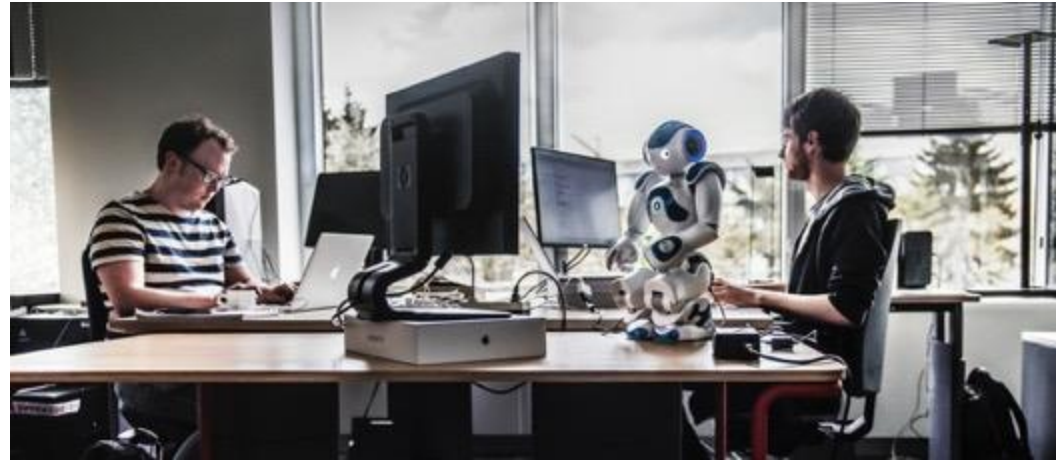
87

Researchers



1983

Year founded



1000+

Publications



60+

Alumni

VUB Artificial Intelligence Lab

Interdisciplinary team, Strong heritage, Leading position



60

Collaborations with companies over last 3 years

5

Spin-offs

14

Active industry-funded projects

5

Active EU projects

2019

VUB AI Experience Center founded



Adaptive Learning & Collaborative AI

Machine control

Autonomous machines

Resource management

Smart grids



VUB Artificial Intelligence Lab

Interdisciplinary team, Strong heritage, Leading position

Human-like AI



Emergent communication

Language and sound processing



Document layout analysis



Explainable AI



Cybersecurity

AI Maturity & Safety



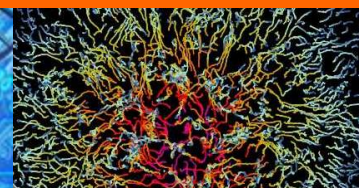
Recommenders



Data analytics & process optimization



Decision making in healthcare

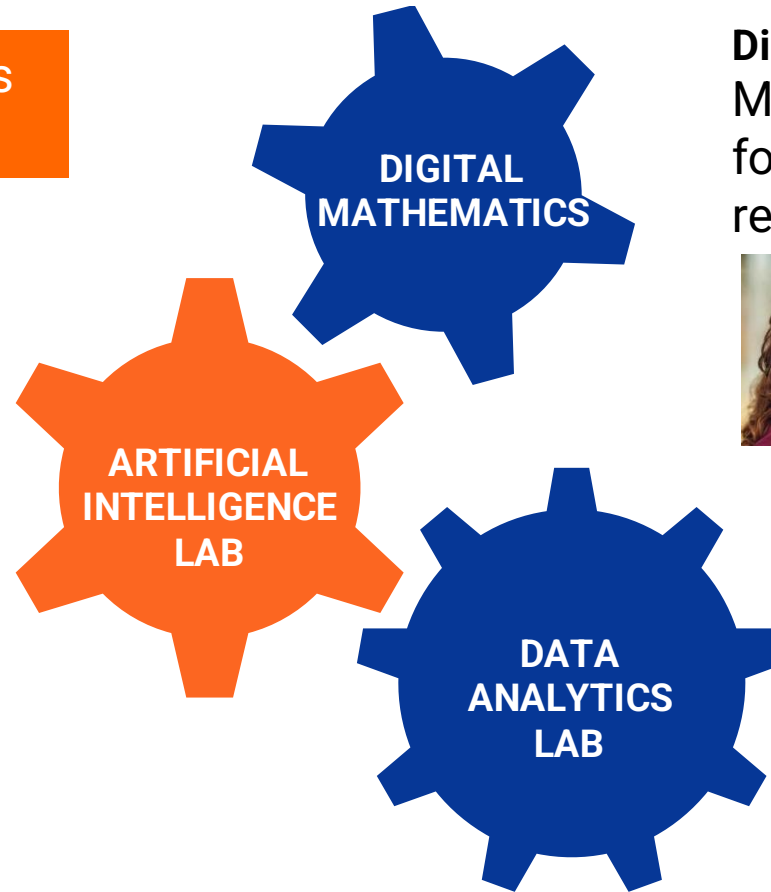
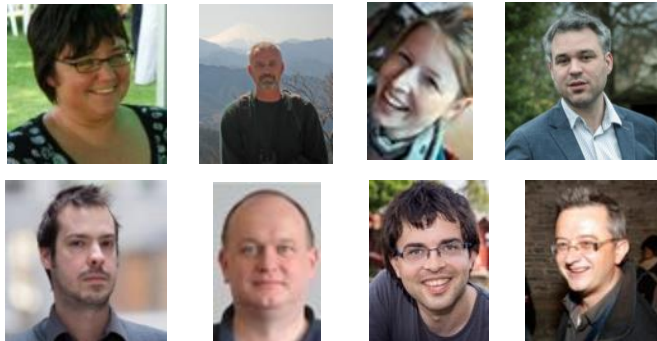


Decision Intelligence

Artificial Intelligence Lab *extended*: Consortium of three VUB research groups

Interdisciplinary team that performs **fundamental** and **applied** research

Artificial Intelligence Lab
Symbolic and subsymbolic AI,
Agnostic and cognitive AI



Digital Mathematics

Mathematical aspects of data science
foundations for data acquisition,
representation and analysis



Data Analytics Lab

Applied data science, business-
oriented



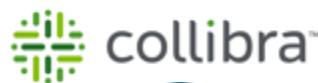
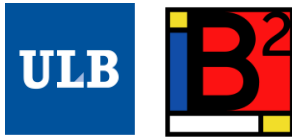
Presentation at 15.30

VUB Artificial Intelligence Lab

Guide enterprises through the AI revolution and help them become more innovative and increase their excellence through the potential of AI

Research

Collaborating **intensively** on fundamental, strategic and applied research



Education

Education programs for (under)graduate students...



Bachelor in AI starting 2022

... and professionals

Lifelong Learning Program



Services to society

Bringing researchers, industry and policymakers **together**



Presentation at 11.10

VUB AI Experience Centre (founded 2019)

- “One-stop shop” for everyone interested in AI
 - Meeting place for researchers, companies, policymakers and the general public
 - Offers training, consultancy, research projects
 - Showcases demonstrators/prototypes and test infrastructure
 - Used for seminars, company visits, events
- Partnership between multiple VUB research groups
 - Not only technological but also sociological and ethical aspects



More info:
experience-centre.ai

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Challenge-based Research with Demand-driven Impact

Generic research challenges

AI-driven data science

Edge AI

Collaborative AI

Human-like AI

Ambition
Increase adoption of AI
Uptake of research results
in companies and
organisations in ALL
DOMAINS

Focus domains and use cases



HEALTH



INDUSTRY



ENERGY



GOVERNMENT & CITIZENS

DEMONSTRATORS
Inspire &
Steer research challenges

1 AS ONE PROGRAM

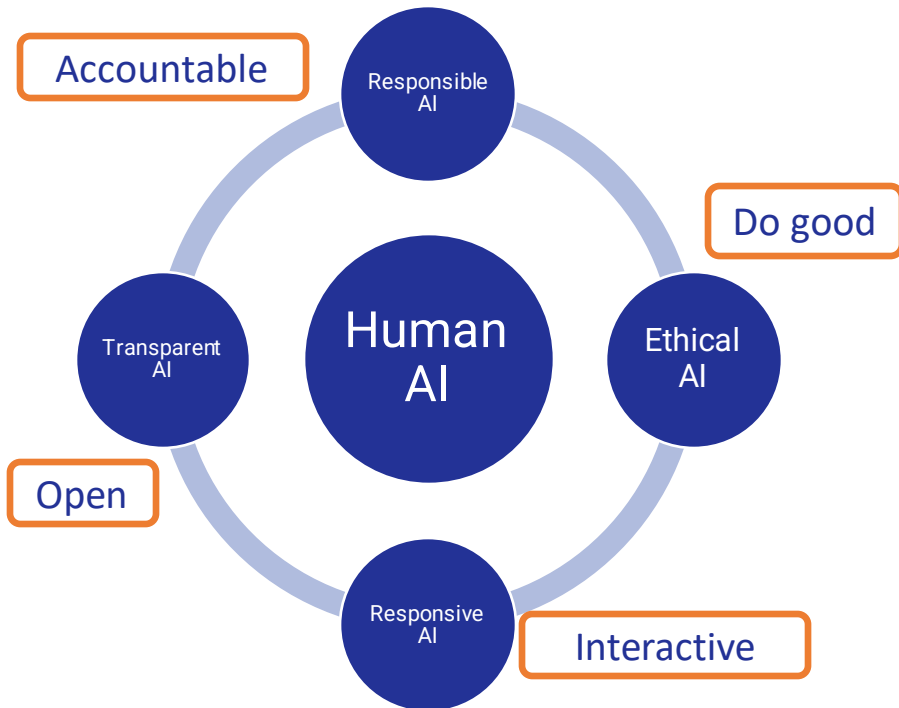
Our research: multi-agent collaborative AI

- AI systems are not standalone
 - they act in an **environment**
 - they **interact** with **humans**



Agents in a smart grid model

- Focus on **online, adaptive** and **dynamic** learning algorithms
- Not only **learning**, but **acting** from knowledge



AI Lab research

Reinforcement learning and **multi-agent systems**

Language processing & *interaction*

Emergent communication



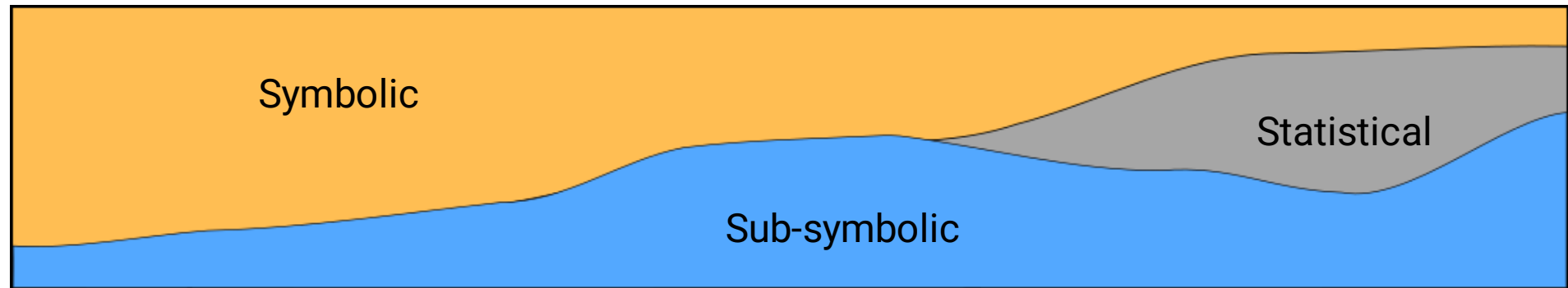
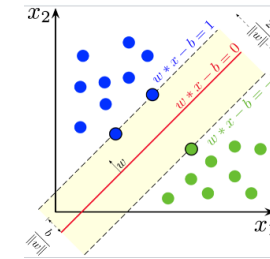
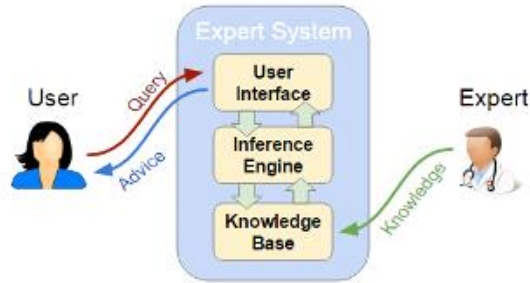
Hybrid AI

Data science and **business** analytics

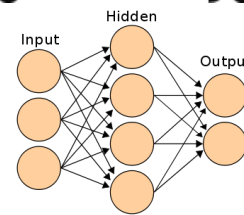
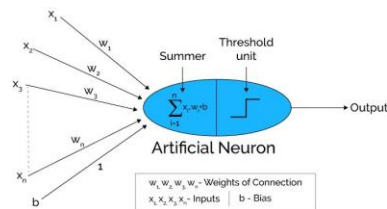
Knowledge **representation** and **reasoning**

Computational **creativity**

Brief history of AI: the different movements

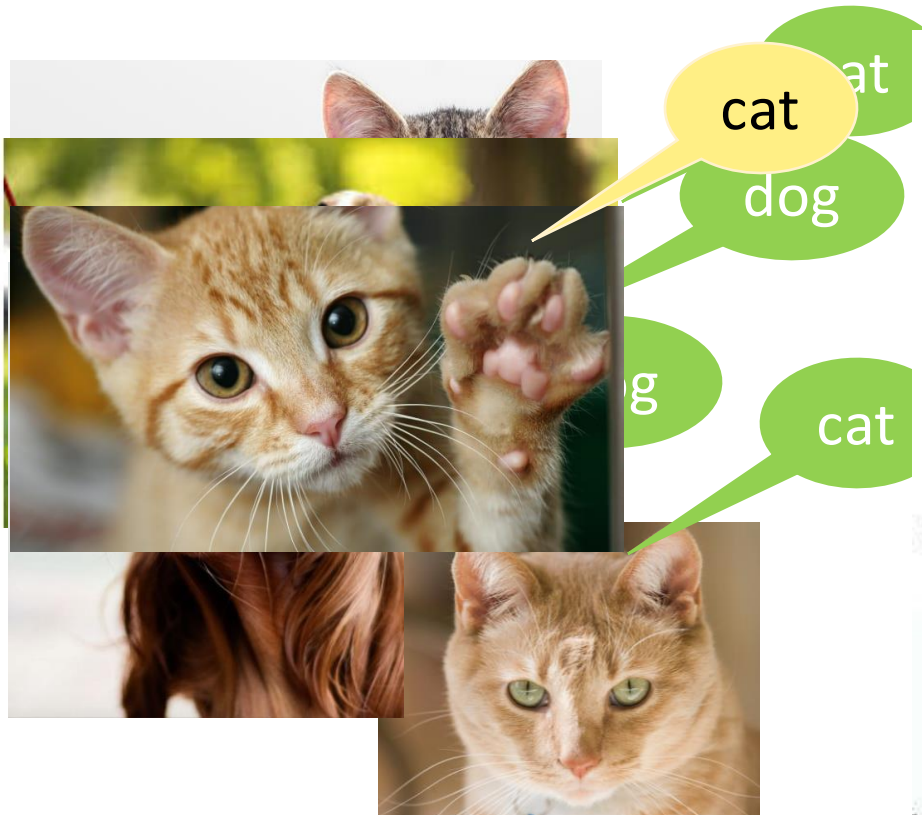


50s 60s 70s 80s 90s 00s 10s 20s



Subfields of Machine Learning

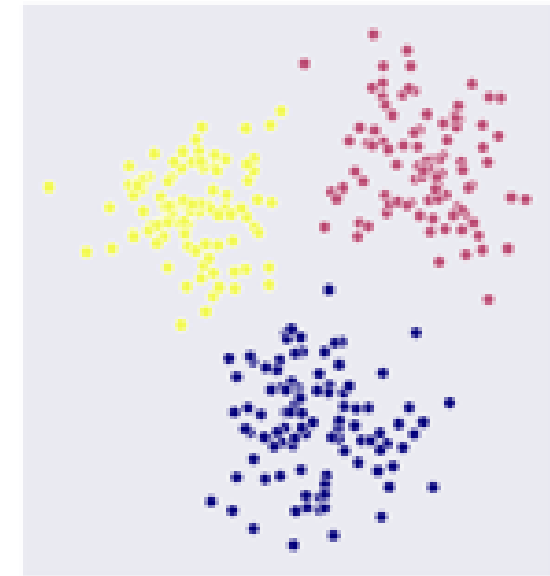
Supervised



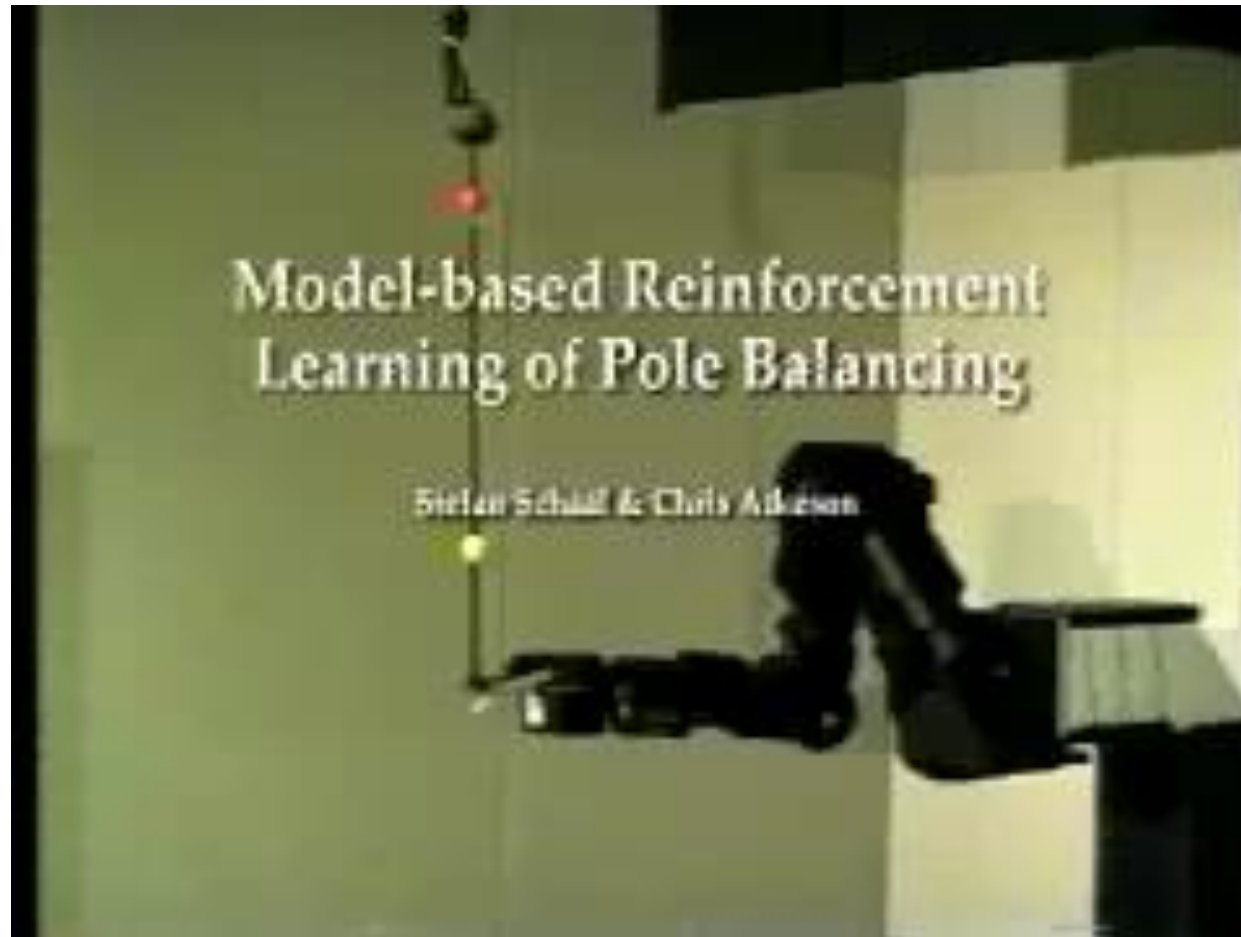
Reinforcement



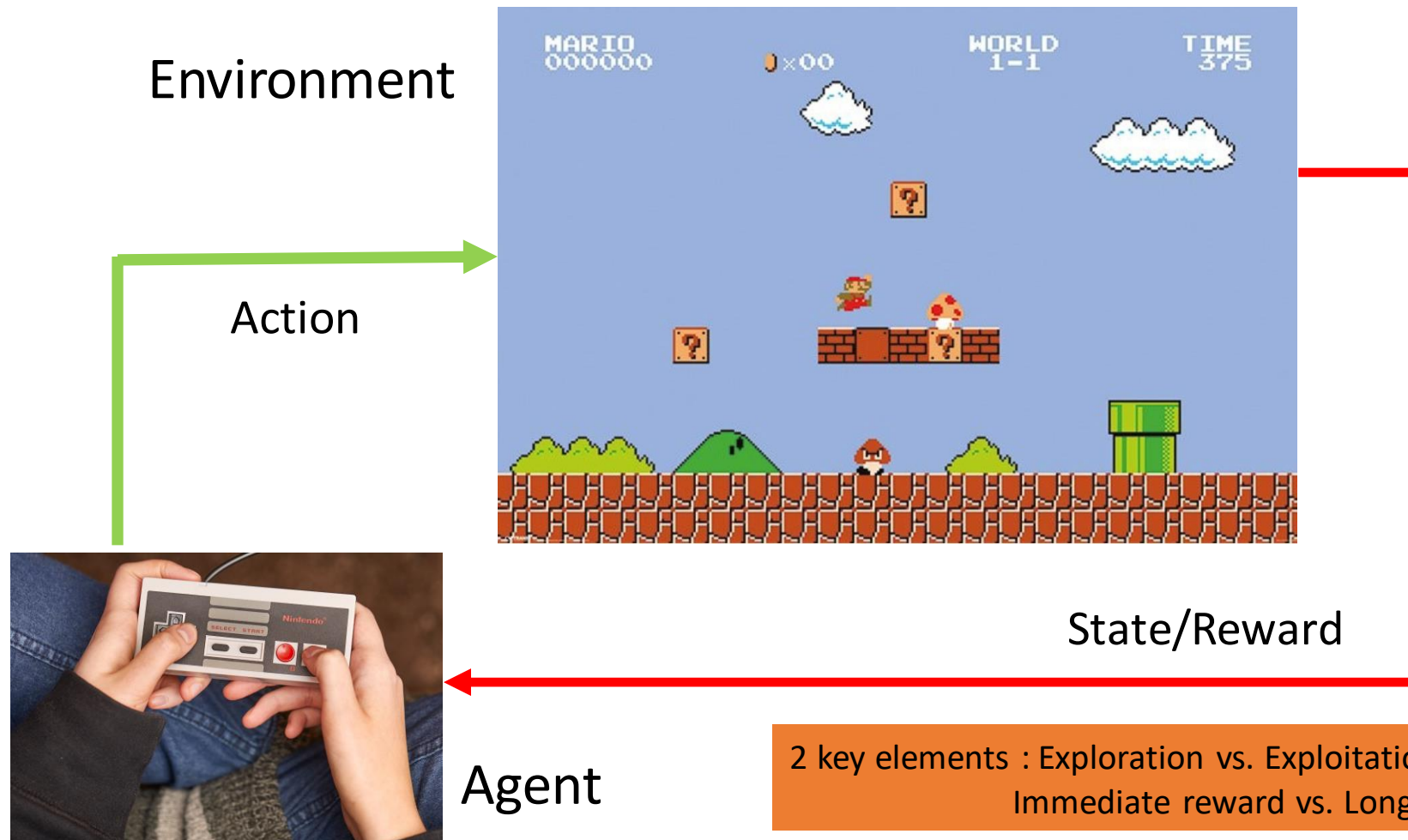
Unsupervised



Reinforcement Learning



Learning from interactions



2 key elements : Exploration vs. Exploitation
Immediate reward vs. Long term reward

Exploration versus exploitation: bandits

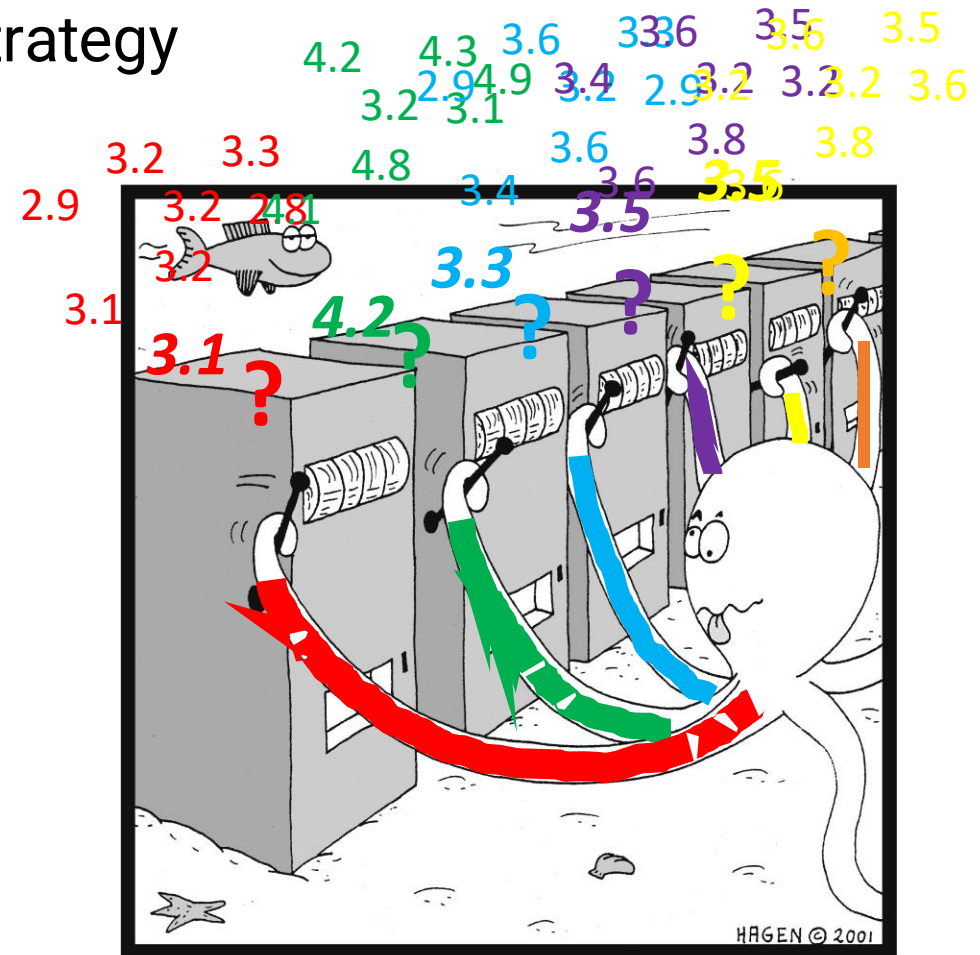
Finding the best epidemic mitigation strategy

Close school

Close restaurants

Close non-essential shops

Close shops & restaurants



Exploration versus exploitation: bandits

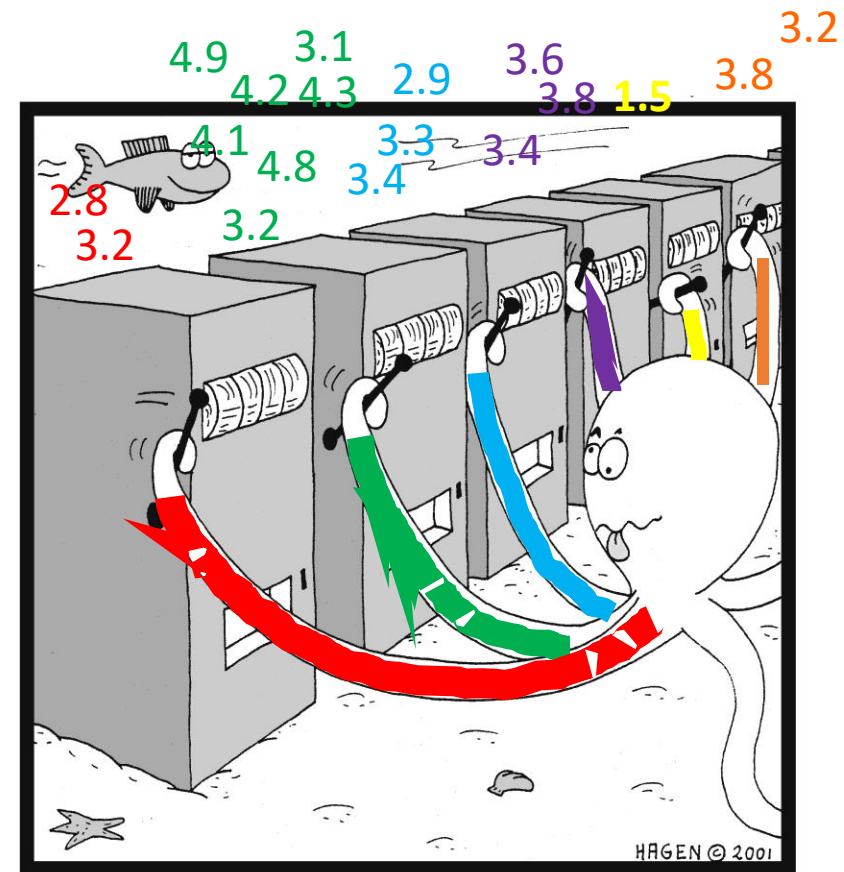
Finding the best epidemic mitigation strategy

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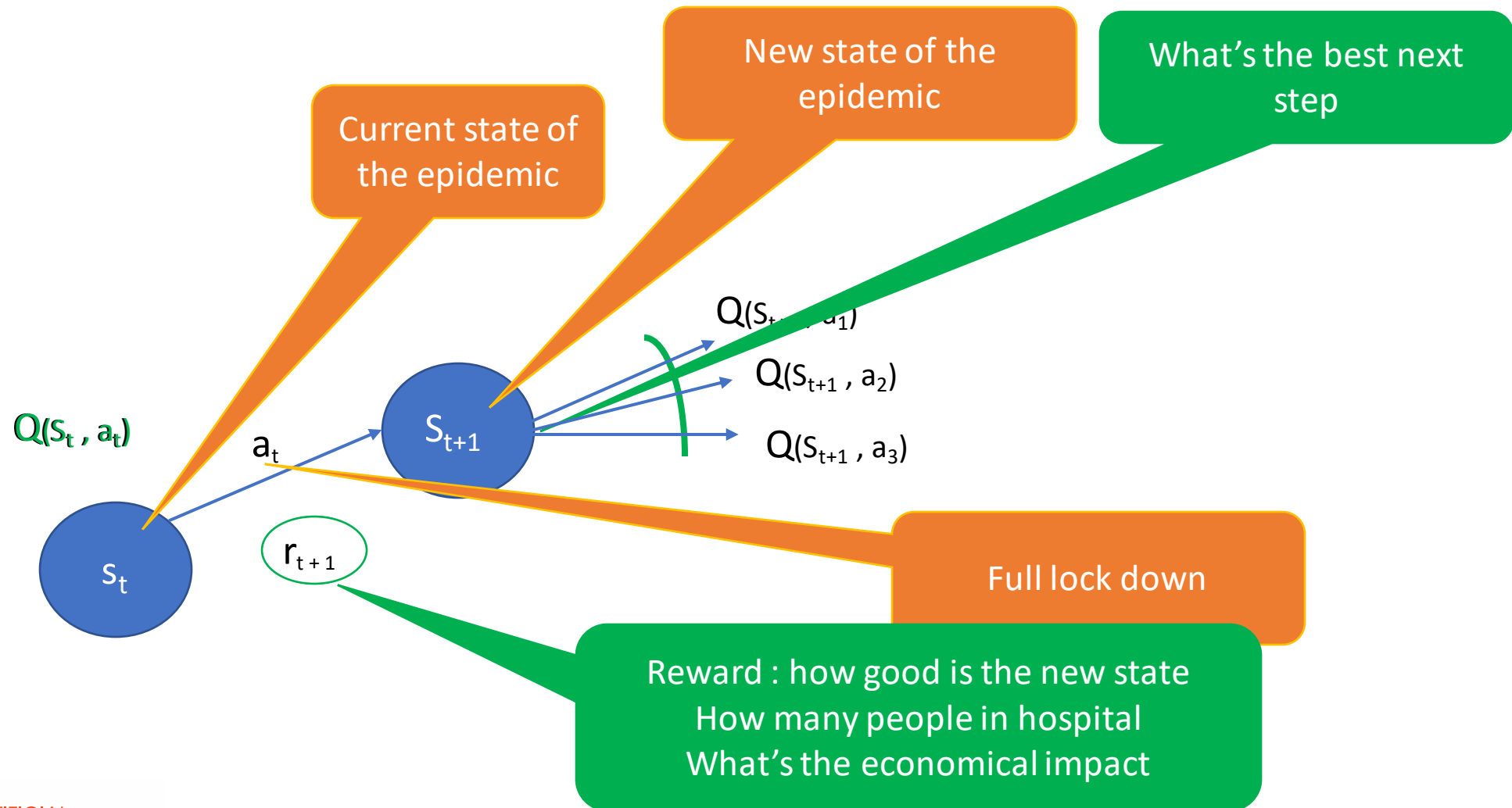
Close restaurants

Close non-essential shops

Close shops & restaurants



Immediate and long-term reward



Applications of reinforcement learning

AlphaGo



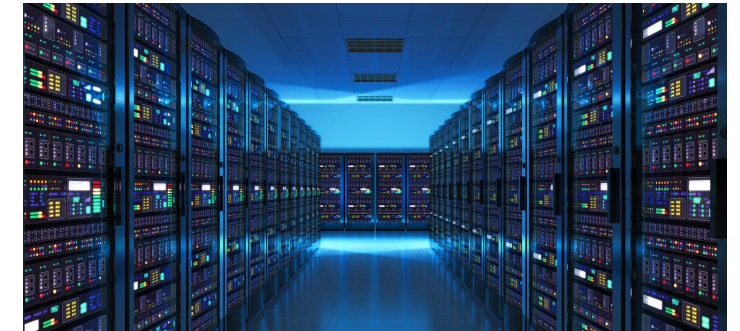
Exploration of 5.12×10^{20} possible configurations of the game

Space Shuttle
Attitude Control



Difficult non-linear controller, higher optimality with RL than classical control

Datacenter cooling



Exploration of the impact of decisions on long time-scales

AlphaFold

NEWS | 30 November 2020

**'It will change everything':
DeepMind's AI makes gigantic leap
in solving protein structures**

Google's deep-learning program for determining the 3D shapes of proteins stands to transform biology, say scientists.

ARTIFICIAL
INTELLIGENCE
RESEARCH GROUP

and other variants

Article | [Published: 09 February 2022](#)

Outracing champion Gran Turismo drivers with deep reinforcement learning

Many constraints and multiple criteria

EVs as Smart Batteries

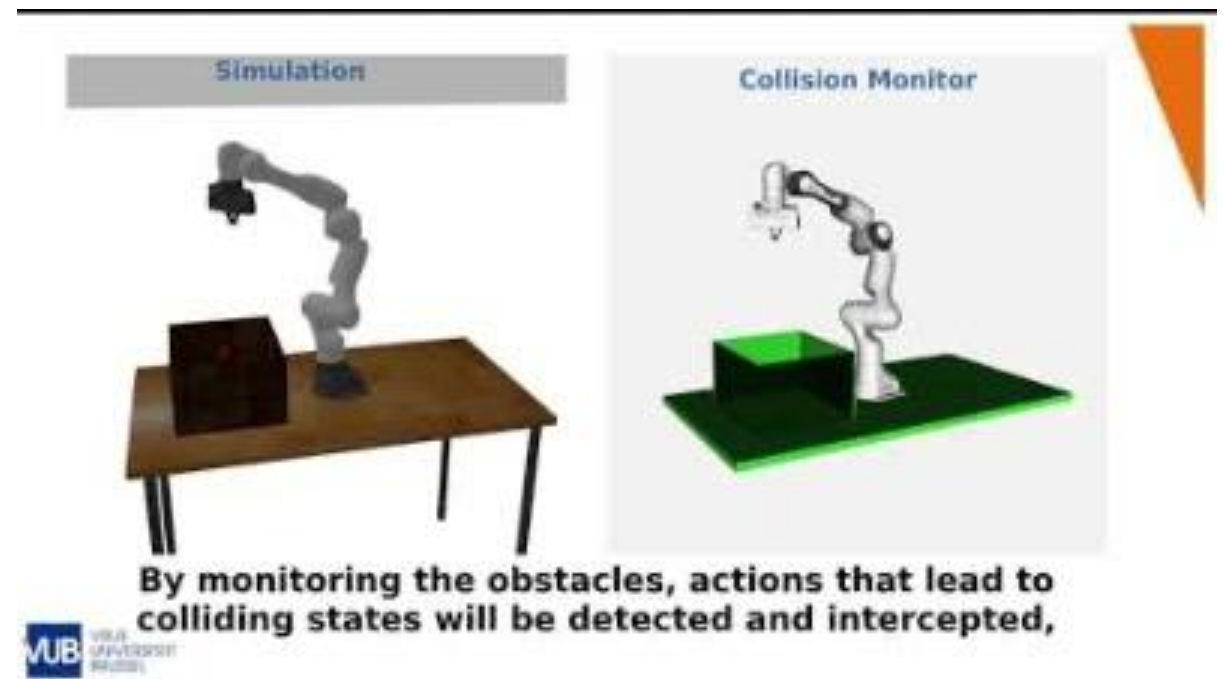
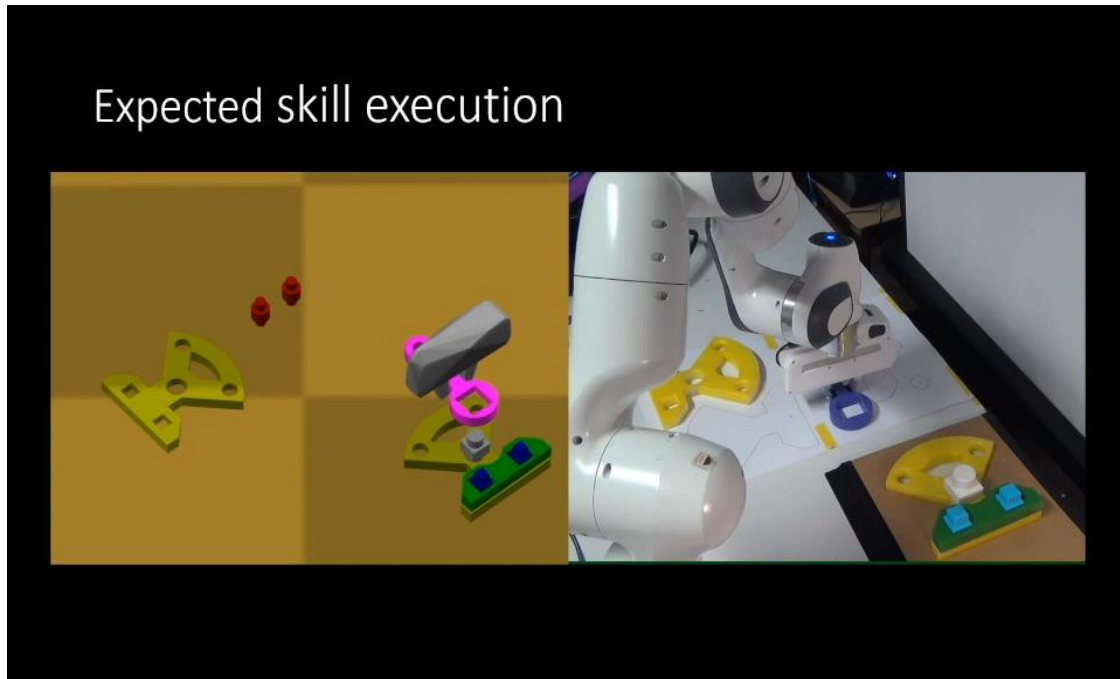


Non-stationary dynamic system, unexpected events



Wind Turbines

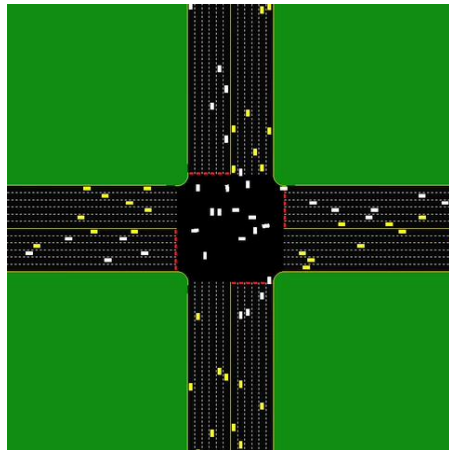
RL and digital twins



Ann Nowé (VUB AI Lab), Bram Vanderborcht (VUB R&MM)

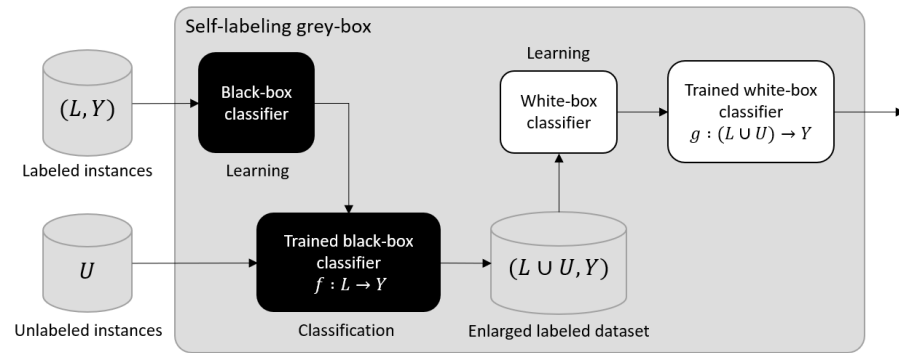
Multiple agents

AI systems are not standalone and have to coordinate between each other



Other research lines

Explainable AI



Document Layout Analysis



Visual Query Answering



AI & Cybersecurity



And many more...

Interested in collaborating? Contact us!



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Manager

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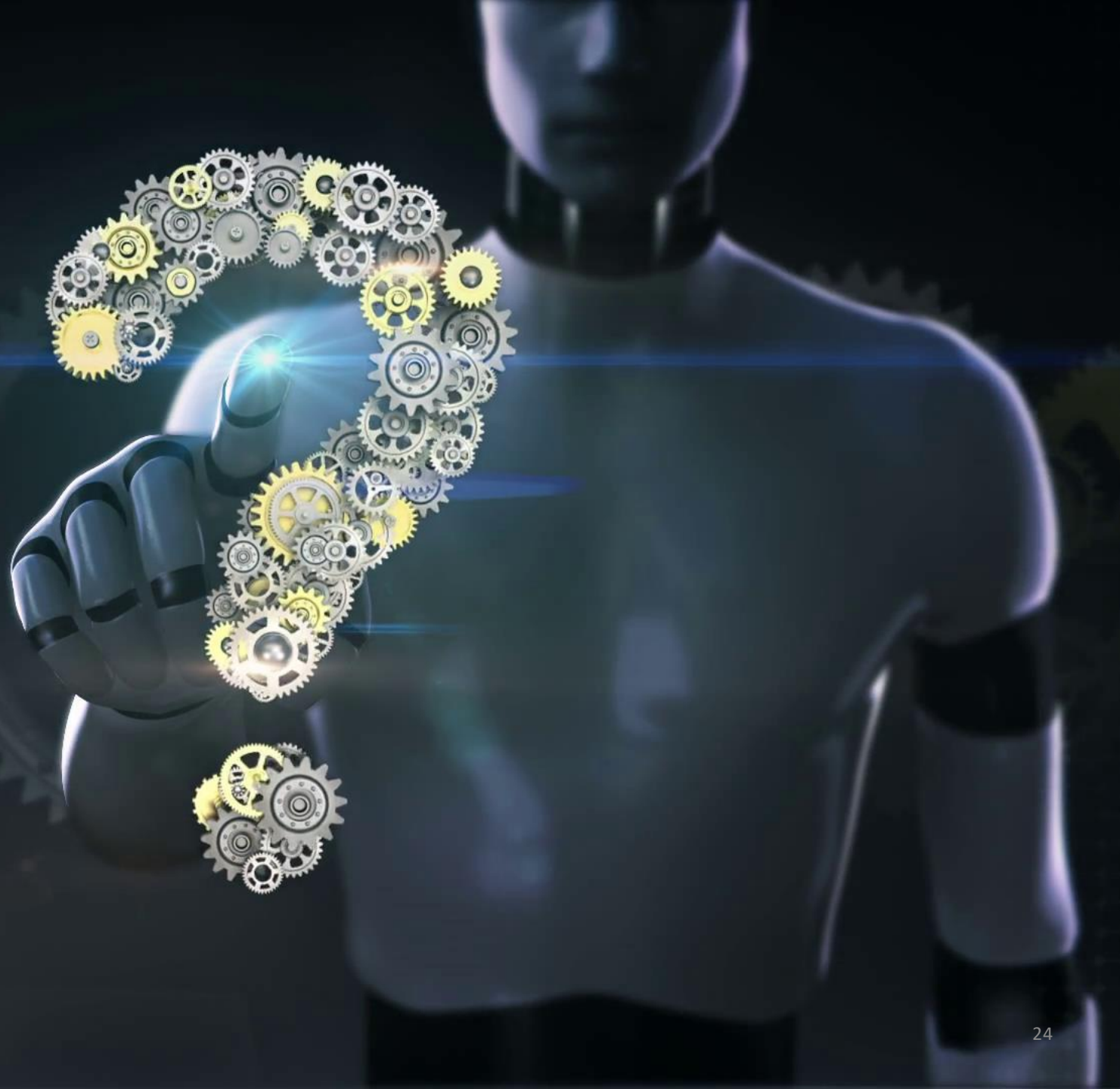


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Business developer

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Thanks for
your attention



AI Lab Expertise

Innovation Tracks

- ❖ Document Layout Analysis
- ❖ Language Processing
- ❖ Reasoning with 'concepts'
- ❖ Signal compression & decompression (sound, EEG, ...)

Human-Like AI

Adaptive Learning & Collaborative AI

- ❖ Control for Industrial Machines
- ❖ Planning and coordination of UAVs and AGVs
- ❖ Resource Optimization (smart grids, logistics, mobility, ...)

Sub-tracks

- ❖ Explainability, transparency, fairness, Bias, Safety, ... in AI
- ❖ Cybersecurity
- ❖ Fraud analytics
- ❖ Digital Forensics
- ❖ AI Coaching, trainings, Audits, testing, consultancy, ...

AI Maturity & Safety

Decision Intelligence

- ❖ Data Analytics
- ❖ Process optimization
- ❖ Inverse Design (Molecules)
- ❖ Recommender Systems
- ❖ Decision Making
- ❖ Define strategies based on models

More on RL?



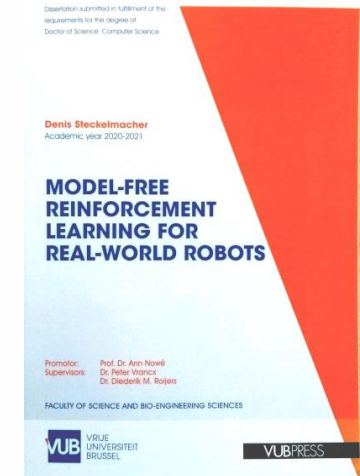
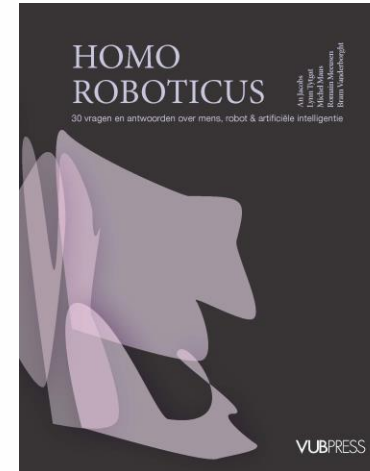
Reinforcement Learning: an introduction

R.S. Sutton and A.G. Barto

Available for free online

Reinforcement Learning: State-of-the-Art,
M. Wiering and M. van Otterlo

Covers more advanced topics

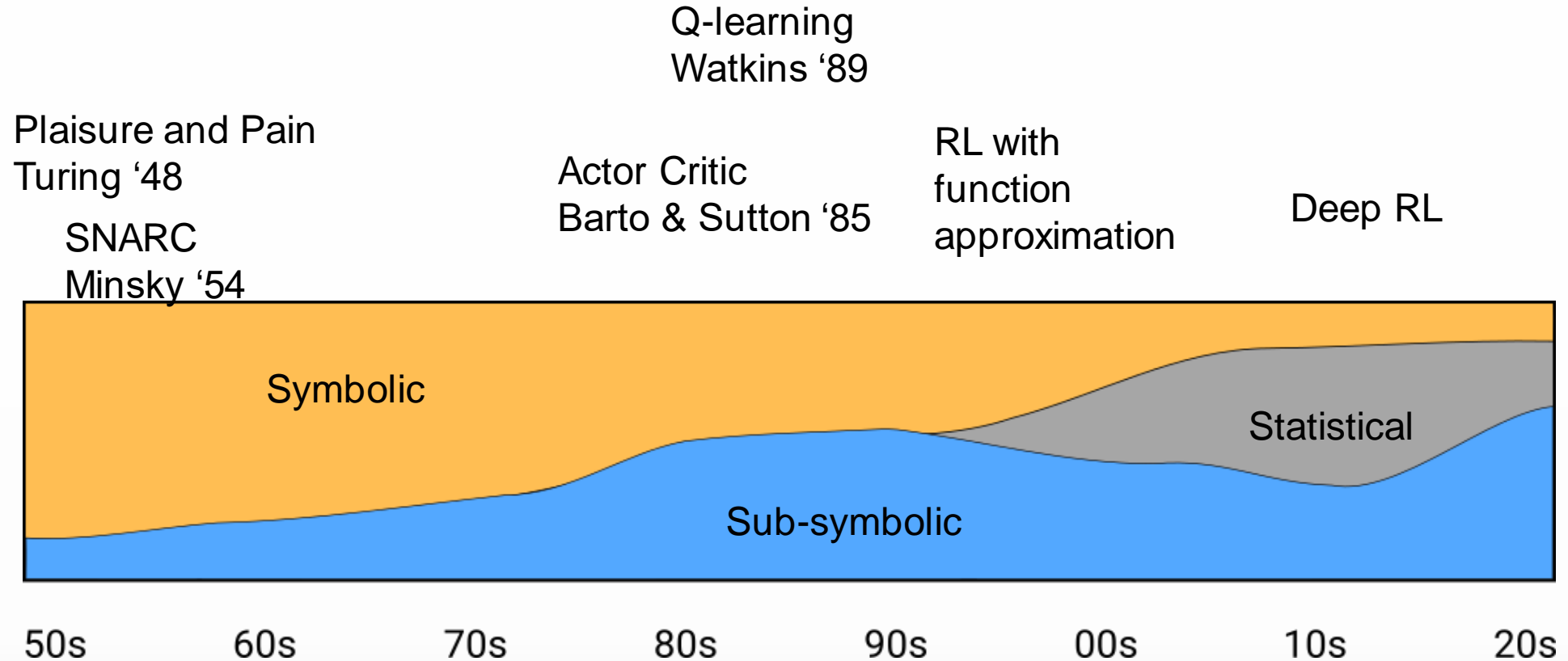


steckdenis.be/phd_thesis.pdf

A Gentle introduction to Reinforcement Learning

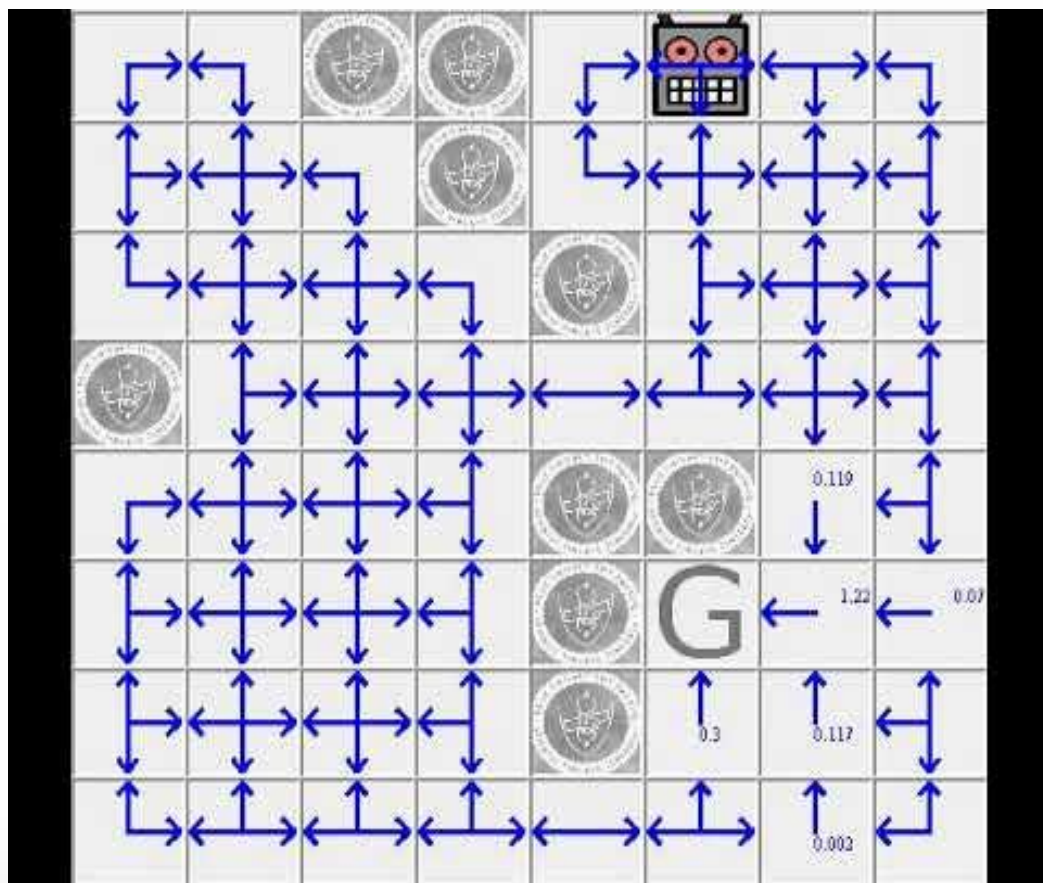
Ann Nowé & Tim Brys

Reinforcement Learning

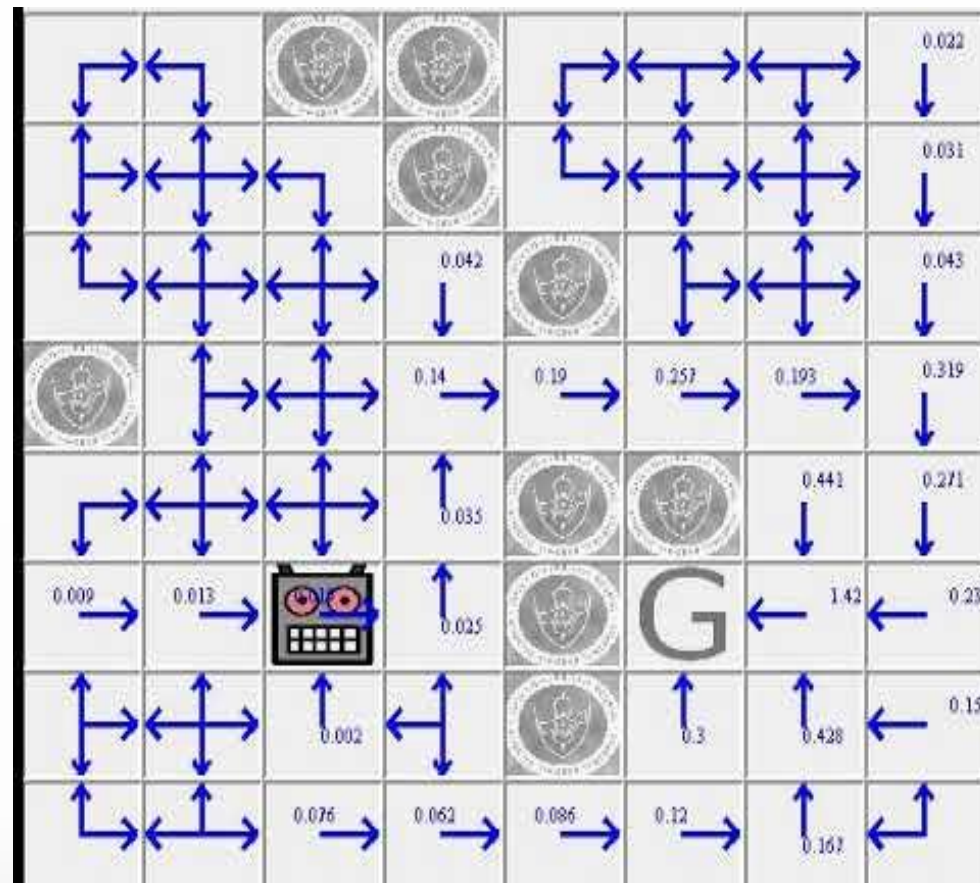


How does RL work?

Q-Learning



Q(lambda)



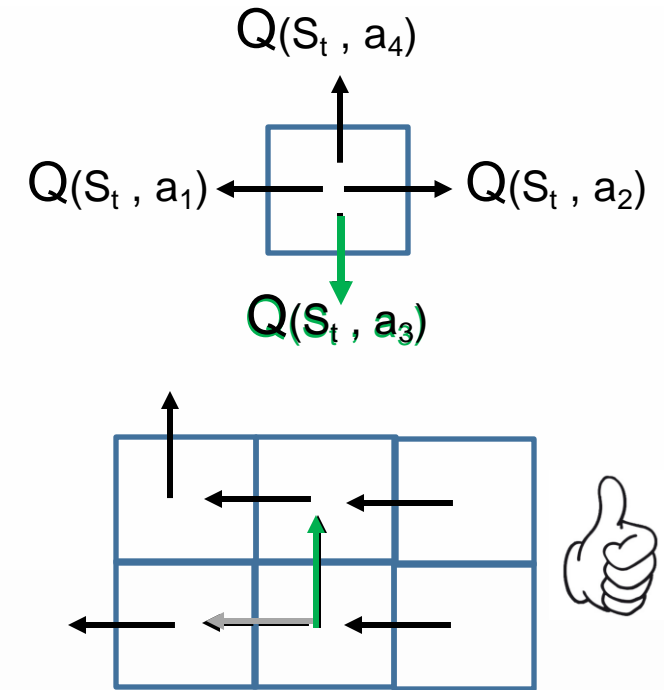
Two main approaches

- Learn how good it is to apply a certain action in a given state (**value-based approaches**)

Q-learning → DQN, Rainbow

- Evaluate a given policy, and try to improve the policy (**actor critic methods**)

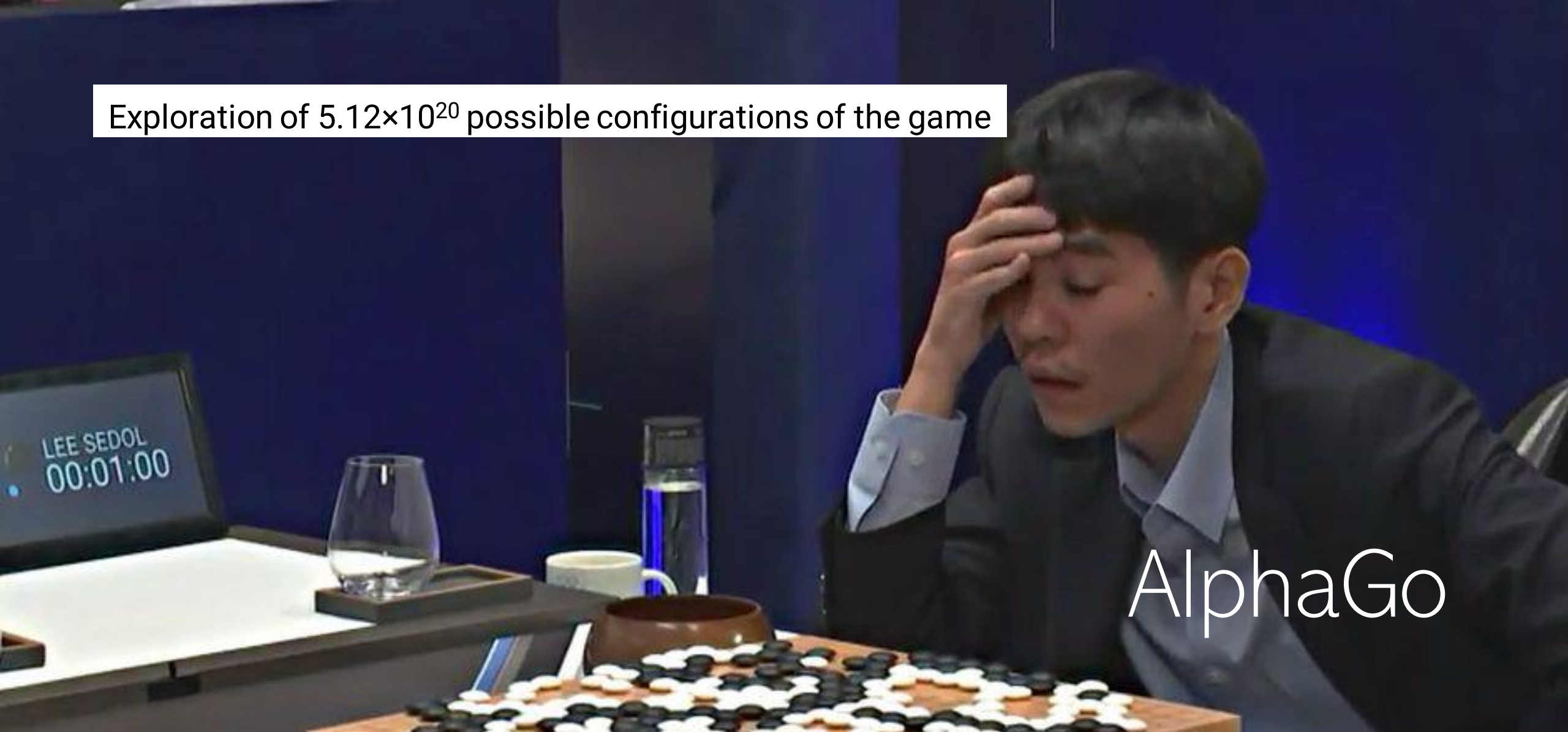
Policy Gradient → Soft Actor-Critic



BDPI

Applications of Reinforcement Learning

Exploration of 5.12×10^{20} possible configurations of the game



AlphaGo

Difficult non-linear controller, higher optimality with RL than classical control

Space Shuttle attitude control (1993)

Exploration of the impact of decisions on long time-scales

Datacenter cooling

Material- and temperature-dependent complex fluid dynamics (air)

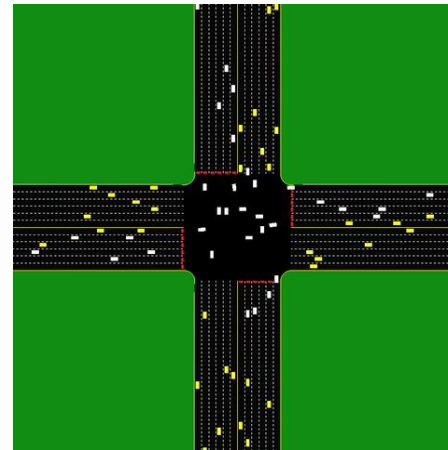
Weaving Machine

Multi-agent collaborative AI

- **Multi-agent learning:** AI systems are not standalone and have to coordinate between each other
- **Reinforcement learning:** AI systems are embedded in an environment and can learn from interacting with that environment



real-life traffic interactions



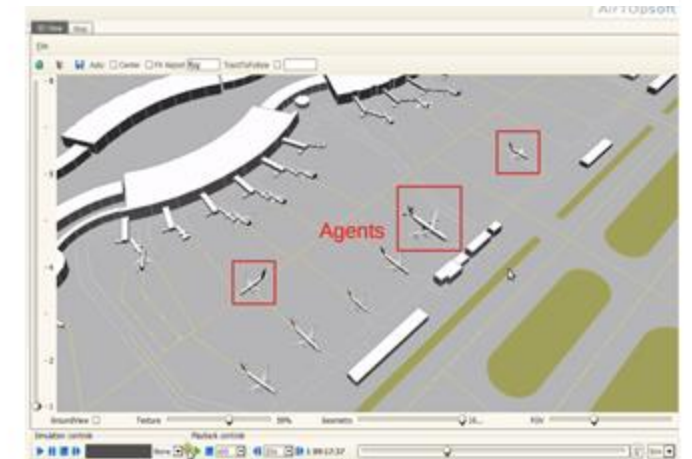
AI agents interactions



Departure management of planes in airports using multi-agent reinforcement learning

- Goal: learn **optimal scheduling** of departing planes
- Optimizing different constraints
 - Maximizing on-time departures
 - Minimizing fuel consumption
 - Minimizing noise emissions
- Particularly difficult for **complex airport layouts** with many different runways
- On a simulator of CDG and JFK airports, the algorithm was able to significantly **improve the number of on-site departures**, compared to a human controller using traditional heuristics
- The multi-agent algorithms can also be used for on-route and arrival scheduling of planes

Paris Charles de Gaulle Airport (CDG)



New York John F. Kennedy Airport (JFK)



Reinforcement learning to optimize charging of electric vehicles

Scheduling algorithm for charging of EVs (electric vehicles)

Challenges

- **Constraints** (# charging connectors, maximum load of the grid, minimize charging time, maximize battery lifetime, minimize charging cost, etc.)
- **Uncertainties** (arrival and departure of EV, amount of energy needed to charge battery, available green energy, etc.)

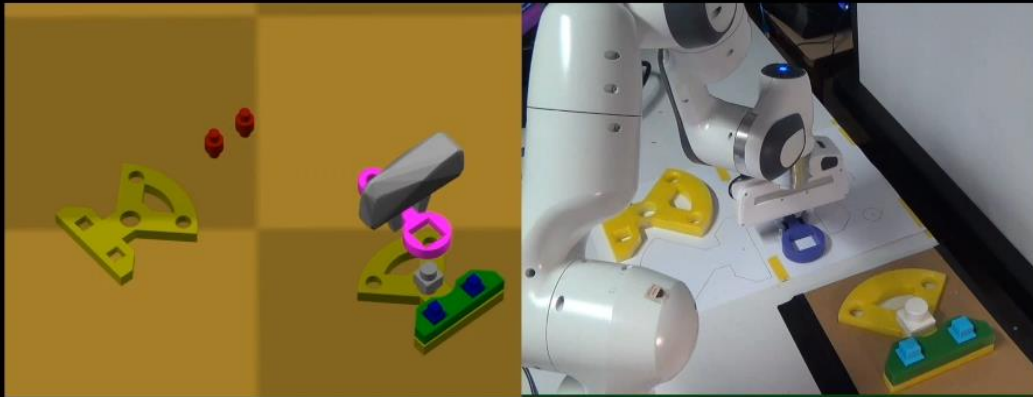
Solution

- **Dynamic** algorithm needed
- Reinforcement learning learns the optimal scheduling through a simulator, taking into account **changing and implicit behavior** and **external factors** such as weather, traffic, etc.



RL and digital twins

Expected skill execution



Learning
Quadrupedal
Locomotion
over
Challenging
Terrain



PhD Joris De Winter
Ann Nowé (VUB AI Lab), Bram Vanderborcht (VUB R&MM)

Multiple agents



To find the MOST CHALLENGING
problems to solve

To EXTEND the reach of what is KNOWN
and FEASIBLE in the field of AI

→ Our **RESPONSIBILITY** to society

→ What **DRIVES** our people

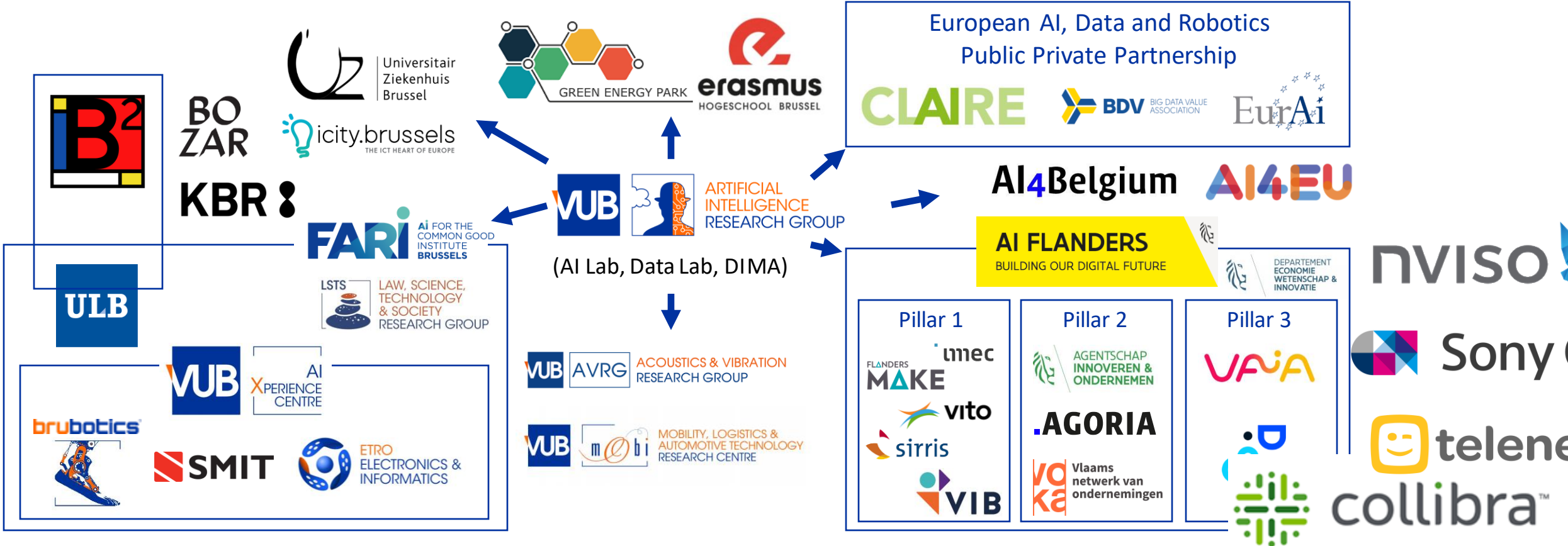
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Networks and partners



How we do this?

1. Attract **great people**
2. **Focus** on our expertise fields within AI
3. The right **interdisciplinary network**
4. Collaboration with **private sector**

IOF GEAR Proposal 2022-2026: Consolidator (200K / year)

Context

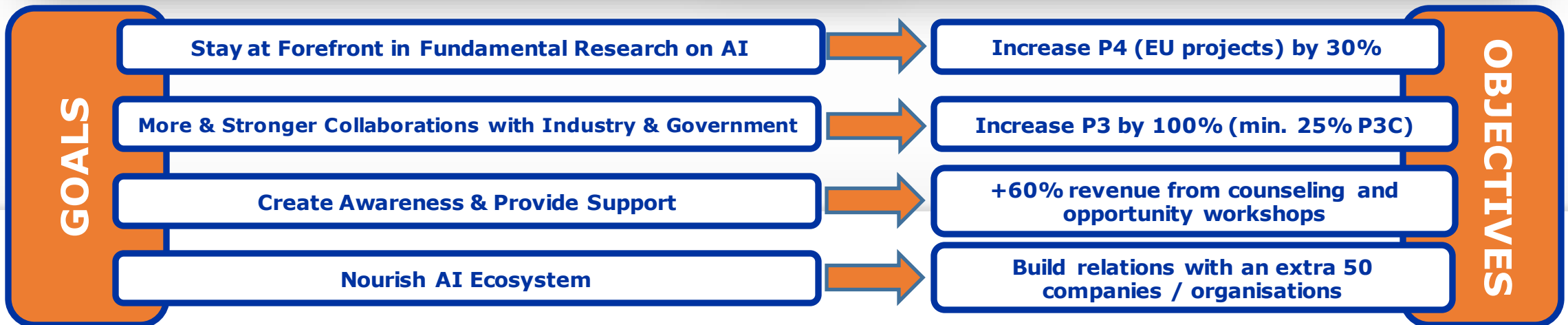
- Interdisciplinary team
- Long-standing expertise & heritage
- Strong reputation

Rationale

- Overwhelmed with AI
 - Joint Research of high-quality AI technologies
 - Provide guidance

Vision & Mission

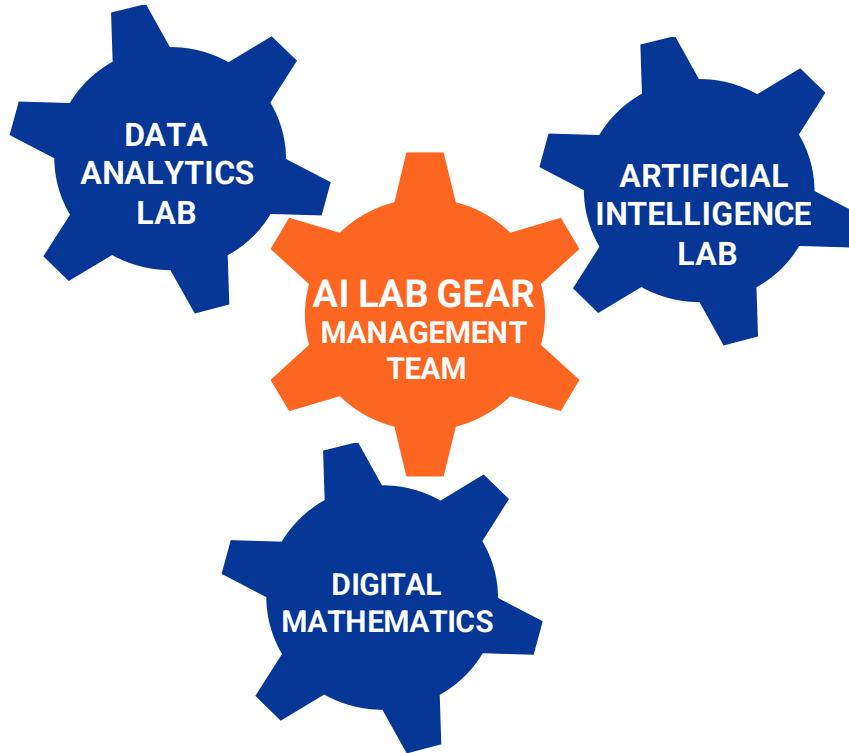
- Initiate and mature **high quality AI technologies** (through research)
- **Interact and collaborate** with decision takers at different steps to ensure relevancy



VUB Artificial Intelligence Lab

Interdisciplinary team, Strong heritage, Leading position

- Academic network



- Outreach to industry and policymakers



- Unique interdisciplinary team

- With **complementary** AI expertise
- Collaborating **intensively** on fundamental, strategic and applied research
- Bringing researchers, industry and policymakers **together**



AI Experience Center

- **One-stop-shop** for all AI research & training needs
 - **Legal, ethical** aspects of AI (LSTS)
 - **Sociological**, ethical side of AI (AI Lab, Data Lab, SMIT)
 - **Smart city, mobility** (SMIT, MOBI, Data Lab, AI Lab)
 - **Industry 4.0 & Robotics** (Brubotics, MFYS, AI Lab)
 - **Health** (AI Lab, ETRO, Brubotics)
 - Broader **VUB Network**
- **Broker** for innovation & implementation
 - **AI Opportunity** Workshops, Deep Dive sessions, ...

AI Lab Mission

Guide enterprises through the AI revolution and help them become **more innovative** and **increase their excellence** through the potential of AI

- Types of collaborations:
 - internships, bachelor and master theses, training, consultancy, applied PhDs, R&D projects, etc.



fwo



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INNOVEREN &
ONDERNEMEN

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empowering research

Demos Showcase

- 20 Demos from AI Lab, SMIT, Brubotics & Etro
 - NRGCoin: Smart Energy Grid
 - Autonomous Wheelchair
 - VR Maze: Reinforcement Learning Navigation
 - Robotic Hand & Foot
 - Baxter Robot: Collaborative Robot
 - Exoskeletons
 - Pepper Robot: Care / Diabetic cases
 - SARA: Augmented Reality Neuro Surgery
 - Virtual Reality Brussels City Map
 - And many more ...



Adaptive Learning & Collaborative AI

Machine control

Autonomous machines

Resource management

Smart grids



VUB Artificial Intelligence Lab

Interdisciplinary team, Strong heritage, Leading position

Human-like AI



Emergent communication

Language and sound processing



Document layout analysis



Explainable AI



Cybersecurity

AI Maturity & Safety



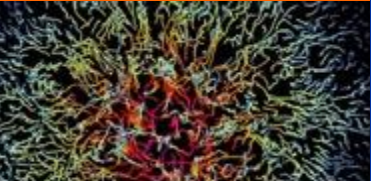
Recommenders



Data analytics & process optimization



Decision making in healthcare



Decision Intelligence

Networks and partners



APICBASE.COM



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We continuously investigate how we can help companies become **more innovative** and **increase their excellence** through the potential of AI.



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