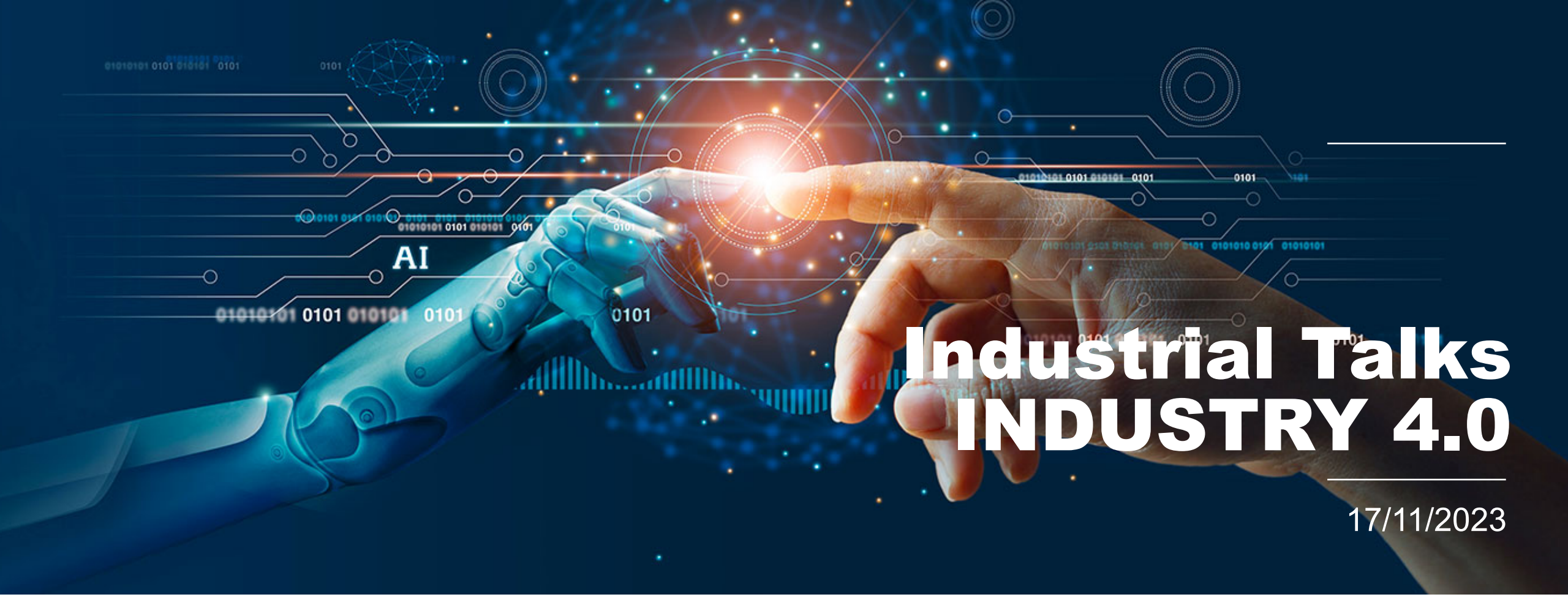


Industrial Talks
INDUSTRY 4.0

17/11/2023

Christophe Merle
Florent Teichteil-Koenigsbuch
Julie Hunter

ANITI

Université de Toulouse

Look around – Collaborative AI

This program develops **AI systems** and **assistants** with advanced capabilities for **improved interaction with humans.**

Researchers also work on **multimodal language** as well as **mobile robotics** with physical interaction capabilities to perform **complex tasks** in a **collaborative** manner. They also focus on the development of methods for efficient and scalable **anomaly detection** and **predictive maintenance**.

The themes:

- Automated reasoning & decision making
- Data & anomalies
- Language
- Robotic & AI
- Neurosciences & AI

Agenda

Part.1- Brief overview

1. **Anomaly detection** in irregularly sampled and distorted time series for cobot **predictive maintenance** @ Vitesco Technologies
2. Christoffel based **anomaly detection** in data streams @ Carl Berger-Levrault
3. On-board dynamic clustering based **anomaly detection** for radiation hardening of space electronics @ CNES
4. Fault and performance loss **diagnosis** in high power photovoltaïc plants @ FEEDGY
5. **Implicit knowledge extraction** from process flows @Vitesco Technologies

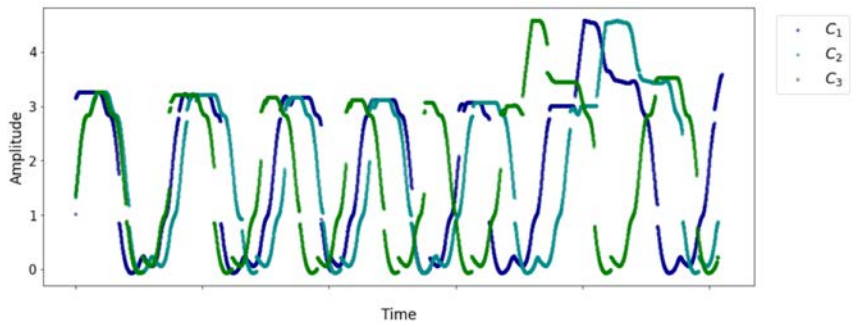
6. Unboxing using vision-based optimal control for versatile robotics manufacturing @ Continental
7. Dynamograde: artificial intelligence for efficient locomotion
8. Challenge CoHoMa

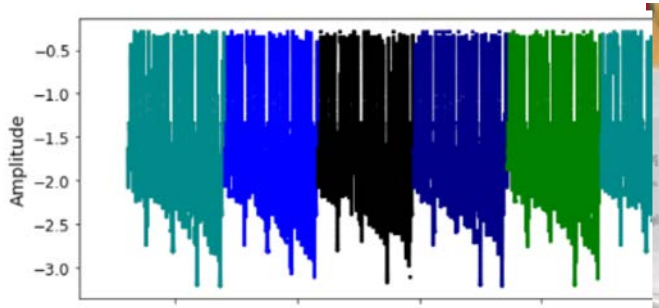
Part.2- Scheduling @Airbus => SPEAKER 🎤 Florent Teichteil

Part.3- Language @ Linagora => SPEAKER 🎤 Julie Hunter

Part 1:
Brief overview

Anomaly detection in irregularly sampled and distorted time series for cobot predictive maintenance



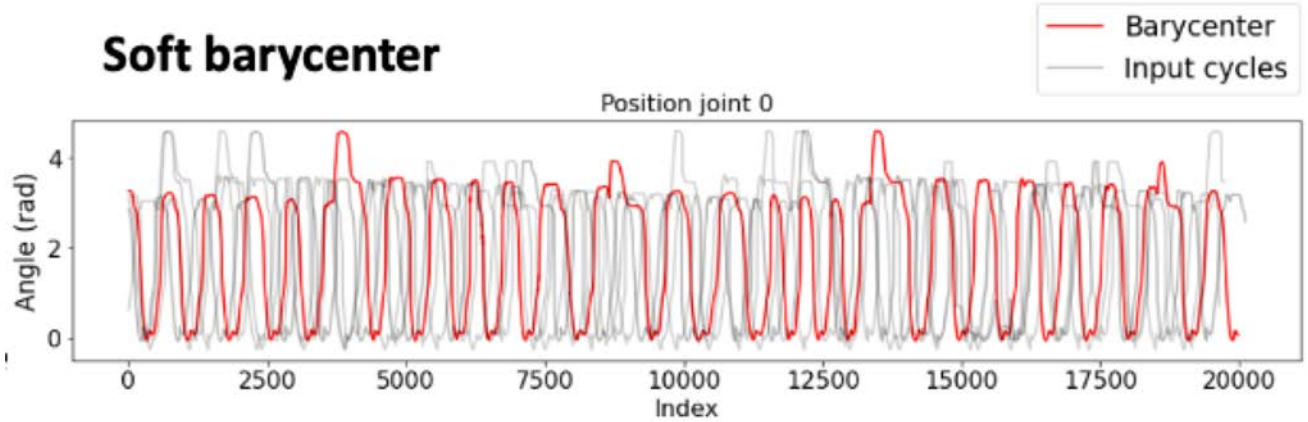


coming soon ☺

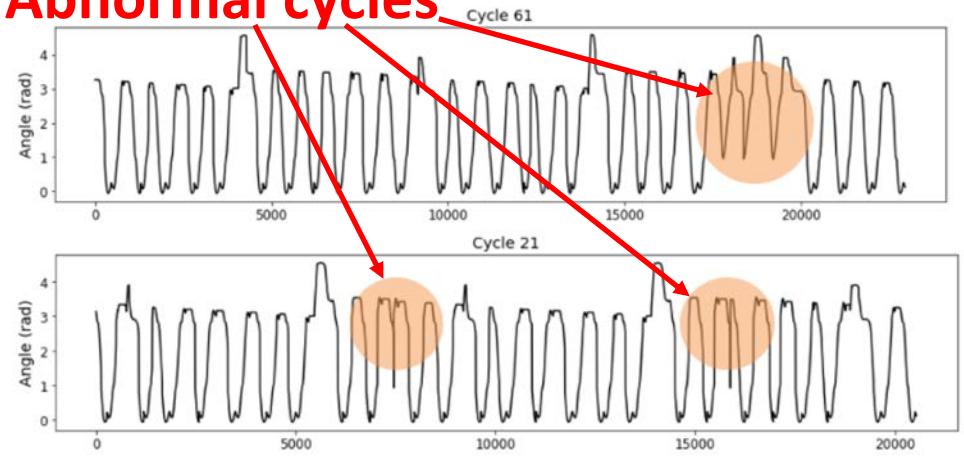
1- Sequence-DTW → segmentation in cycles

2- Soft-DTW → Synthesis of a prototype cycle (soft barycenter)

3- DTW → Outlier detection based on a similarity score between the prototype and monitored cycles



Abnormal cycles



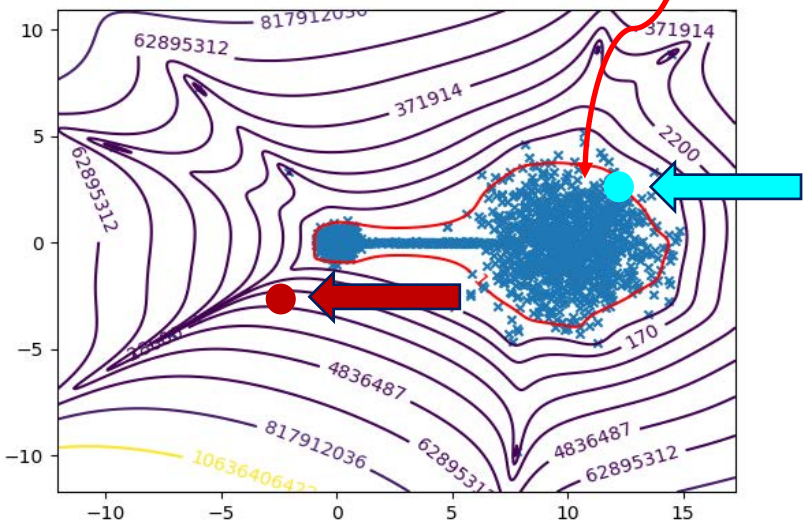
Christoffel based anomaly detection in data streams

https://github.com/kyducharlet/odds

Leveraging the properties of the Christoffel function $\Lambda_d^\mu(\mathbf{x})$

Step 1

Specific level set of $\Lambda_d^\mu(\mathbf{x})^{-1}$
→ captures the support of μ
→ Anomaly candidates



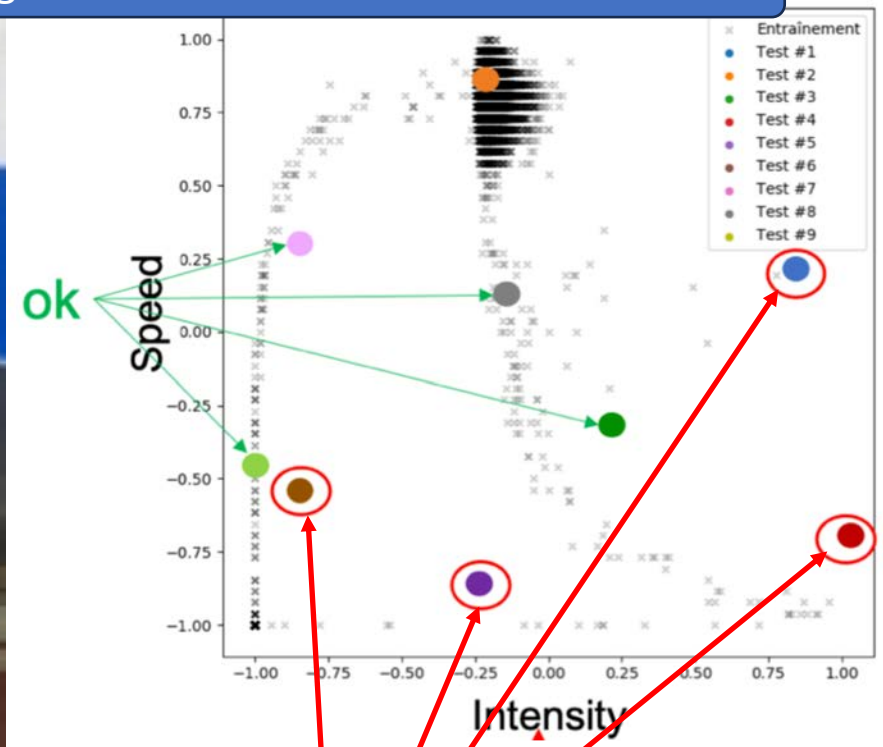
Step 2

As d grows, $\Lambda_d^\mu(\mathbf{x})^{-1}$ has:

POLYNOMIAL growth INSIDE Ω
EXPONENTIAL growth OUTSIDE Ω

→ Anomaly confirmation

Step 1 detecting outliers candidates vs frontier



Step 2 using growth properties to confirm outliers candidates

Multi-mode system, highly non linear data

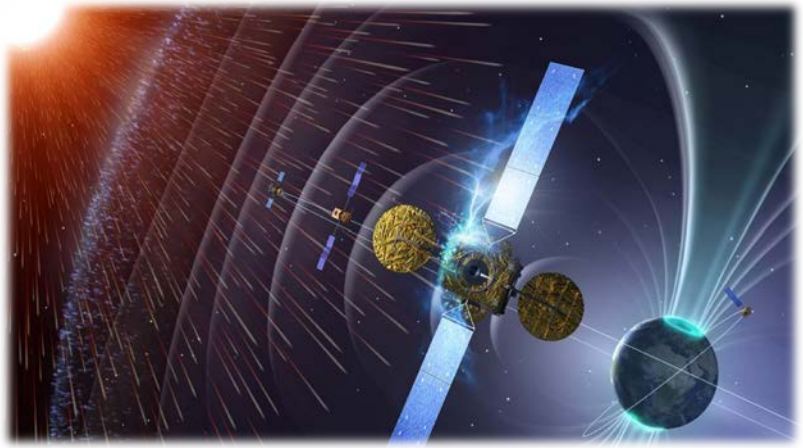
Confirmed anomalies

Cifre thesis of Kevin Ducharlet defended on September 28, 2023

On-board dynamic clustering based anomaly detection for radiation hardening of space electronics

DyD²

- Anomaly detection on the fly and on-board :
- Frugal computation to track the data stream
- Low memory usage
- Dynamicity to adapt to evolving environments



Offline Stage:
Training normal models

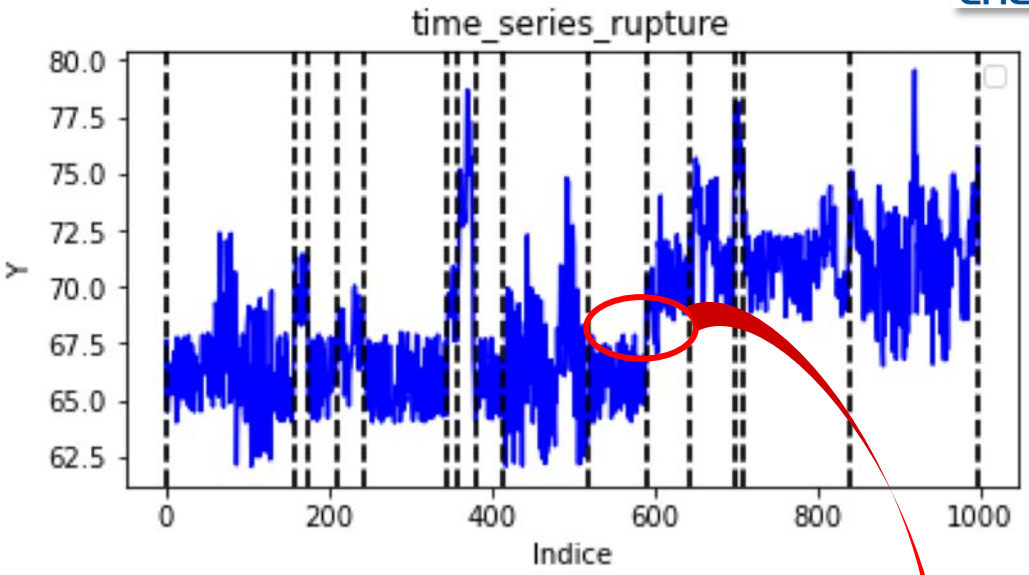
Update

Online

Stage 1:
Detection of signal ruptures

Stage 2:
Fast analysis around detected ruptures

Stage 3:
Deeper analysis around detected ruptures



Outer signal features

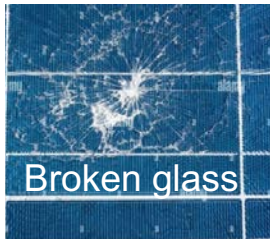
Inner signal statistical features

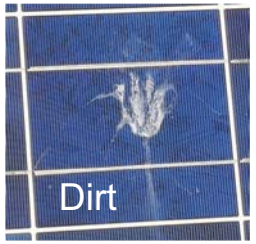
Hierarchical analysis

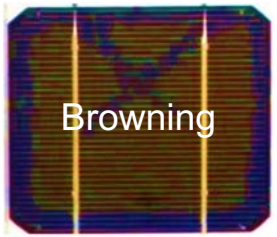
https://github.com/Adrien-Dorise/DyD2_Dynamic_Double_Anomaly_Detection

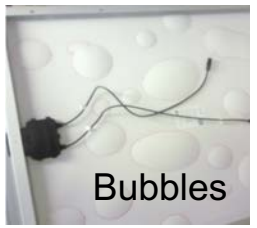
CNES/Occitanie Region thesis of Adrien Dorise defended on December 2, 2022

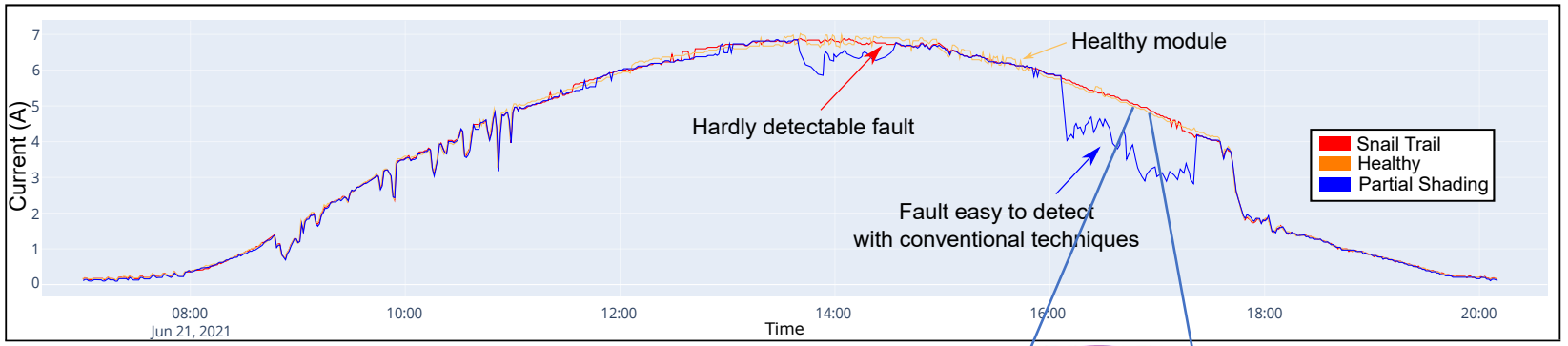
Fault and performance loss diagnosis in high power photovoltaïc plants











Hardware design of an electronic system for on site data acquisition

+

Feature extraction and selection

+

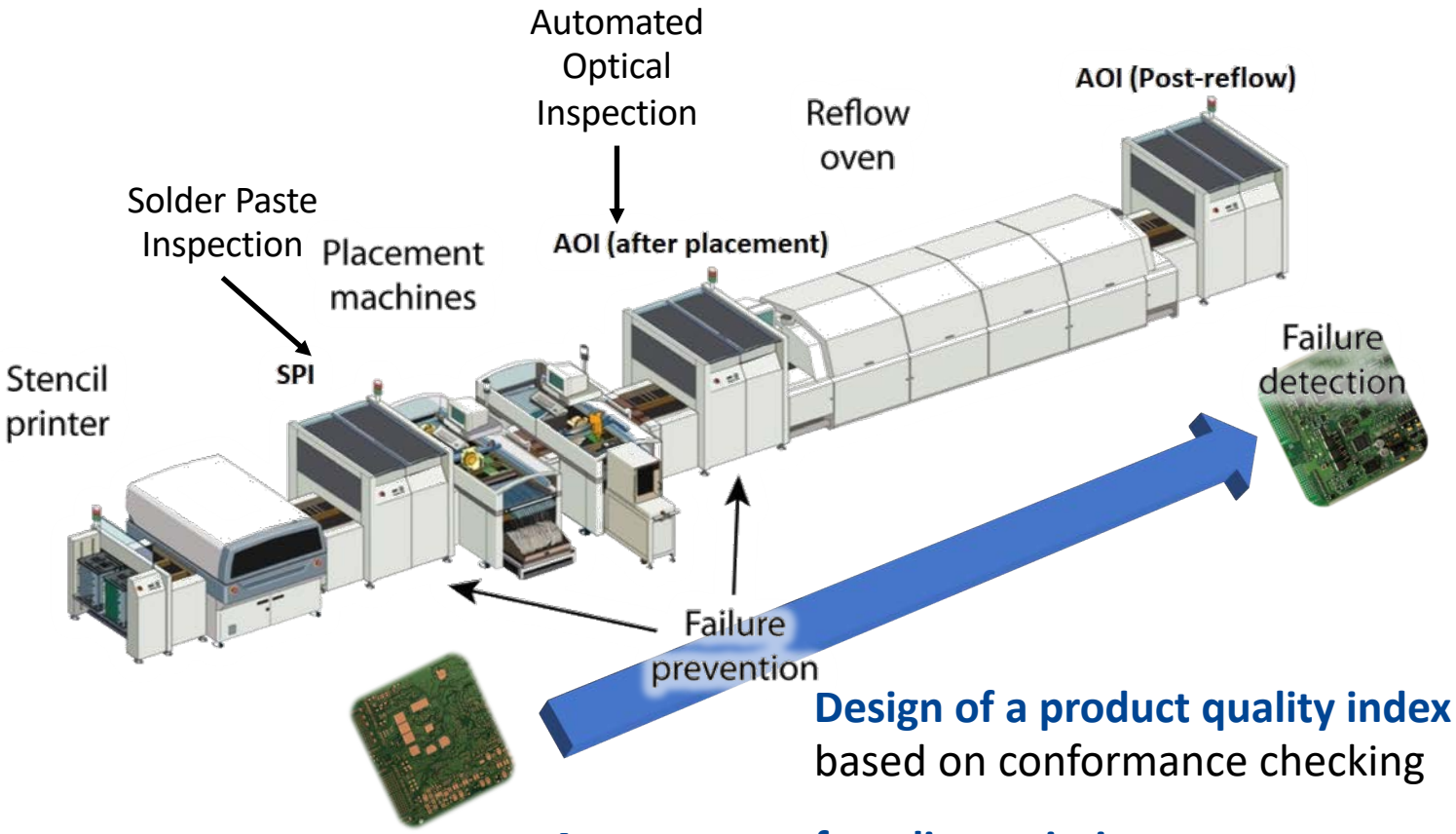
Software design of an adaptive diagnosis algorithm

PATENT PENDING

Confidential (2nd circle)

Cifre thesis of Edgar Sepulveda defended on February 16, 2023
(in collaboration with LAAS/ISGE team)

Implicit knowledge extraction from process flows



- Process mining: analysis of process logs to deduce real behavior
- Machine learning & statistics

- Identify product flows / their quality / the time products will spend on the line
- Identify variations based on different attributes (suppliers, team, batch, etc.)
- Identify weak points on the line to trigger maintenance or optimization actions

Design of a product quality index based on conformance checking

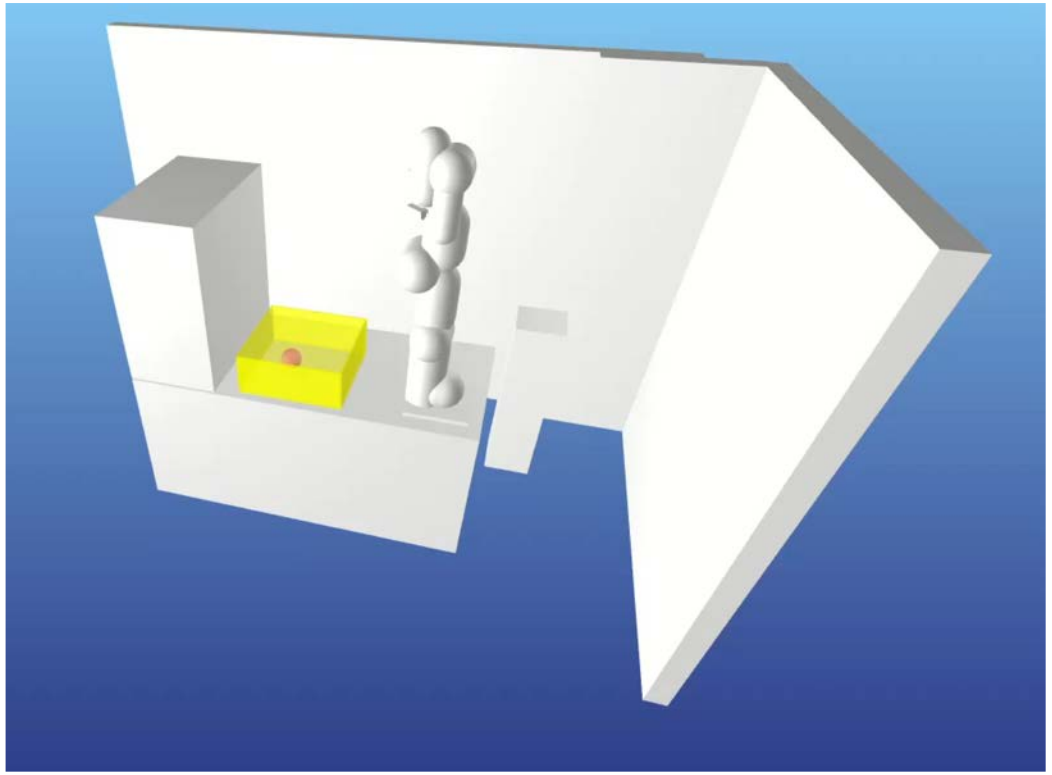
Assessment of quality variation over work shifts based on KDE

Prediction of the remaining cycle time based on GNNs

https://github.com/duongtoan261196/RemainingCycleTimePrediction

Unboxing using vision-based optimal control for versatile robotics manufacturing

- Unboxing: known objects unsorted in a box, to be accurately disposed at the input of the production chain
- Planning: task-and-motion planning (mixed-integer) using HPP
  https://humanoid-path-planner.github.io/hpp-doc/
- Control: model predictive control using full robot model using Crocoddyl
  https://github.com/loco-3d/crocoddyl/
- Vision: model-based object pose (6d) tracking using HappyPose
  https://github.com/agimus-project/happypose



Aniti PhD Thesis of Arthur Haffemayer, started Nov 2022
Supervised by Florent Lamiraux, Nicolas Mansard (LAAS-CNRS), Mathieu Fabre & Fabrice Decasal (Continental)

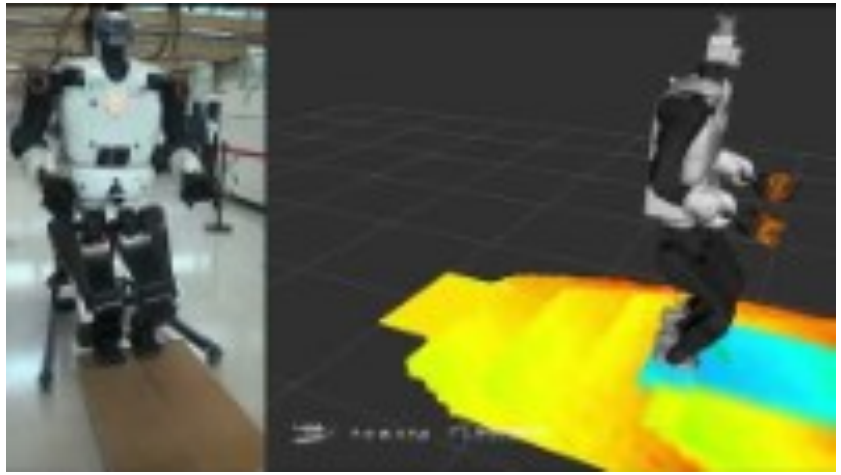
Dynamograde: artificial intelligence for efficient locomotion

Joint laboratory between LAAS-CNRS (Gepetto) and Toward (French office of PAL-Robotics)

DYNAMOGRADE
LA FORCE DE LA MARCHE

- Shared development of locomotion algorithms
- Production of the open-source design Solo
- Exploration of advanced learning-based formulations for robust locomotion
- Technological support for academic projects

https://open-dynamic-robot-initiative.github.io/



https://toward.fr/projets-collaboratifs/dynamograde/

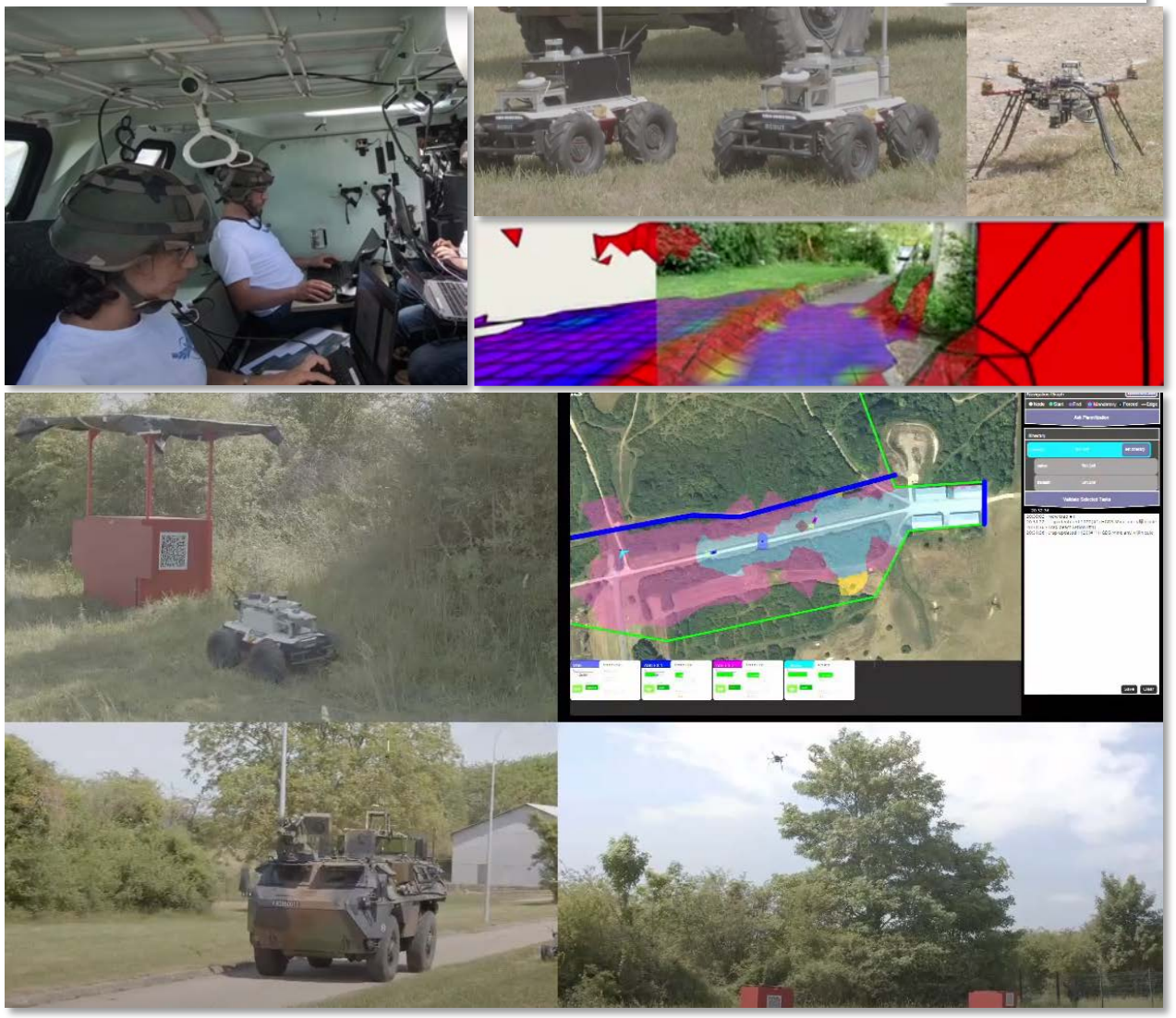
Challenge CoHoMa

Challenge organisé par le Battle Lab Terre (Section Technique de l'Armée de Terre) pour évaluer des solutions technologiques dans le cadre de la **co**llaboration **ho**mme-**ma**chine.

Déploiement de systèmes multi-robots aérien/terrestre pour explorer une zone inconnue et guider un véhicule habité sur le terrain.

Opérateurs dans le véhicule habité n'ont pas de vue sur l'extérieur autre que via les systèmes robotiques.

- Participation équipe ICARE en 2022 et 2023
- ONERA, ISAE-Supaero, ENAC, LAAS-CNRS, Scalian
- Contributions sur :
  - Navigation autonome et analyse de traversabilité
  - Modélisation et conception de comportements autonomes
  - Planification automatique de tâches pour l'opérateur et interaction homme-système
- Vidéo 2022 : https://youtu.be/cUyyPkD8JkA?si=8zq7_VTGdbdWcoO-

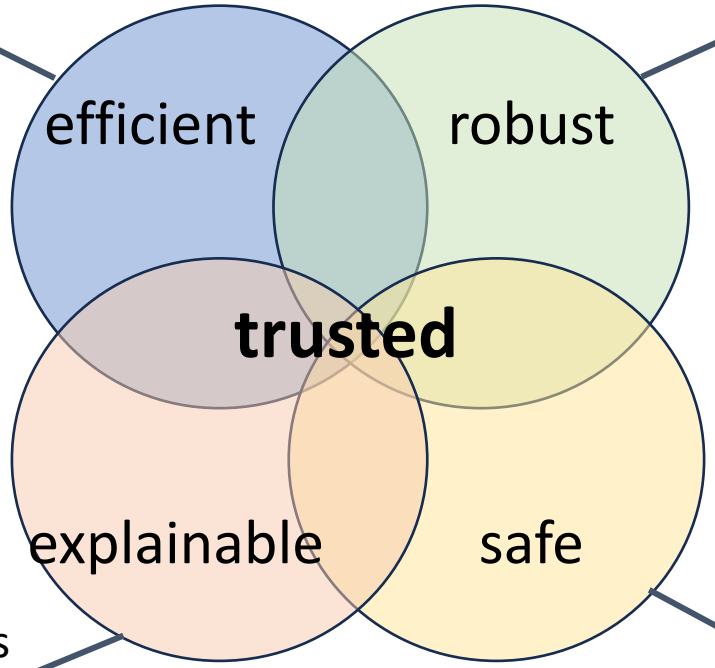


Part 2:
Scheduling @Airbus

TUPLES: Trustworthy Planning & Scheduling with Learning and Explanations

Scale to industry-size problems
Accurate representation of the world

Proactively reason about uncertainties
Adapt to unseen situations and users

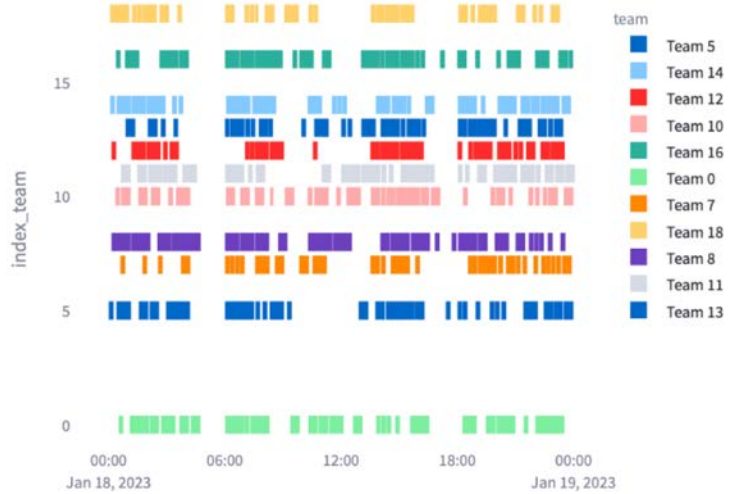


Explain decisions *w.r.t.* long-term objectives
Explain infeasibilities and resolving strategies

Decisions don't endanger people
Decisions reach business objectives

Airbus Manufacturing Use Cases @TUPLES

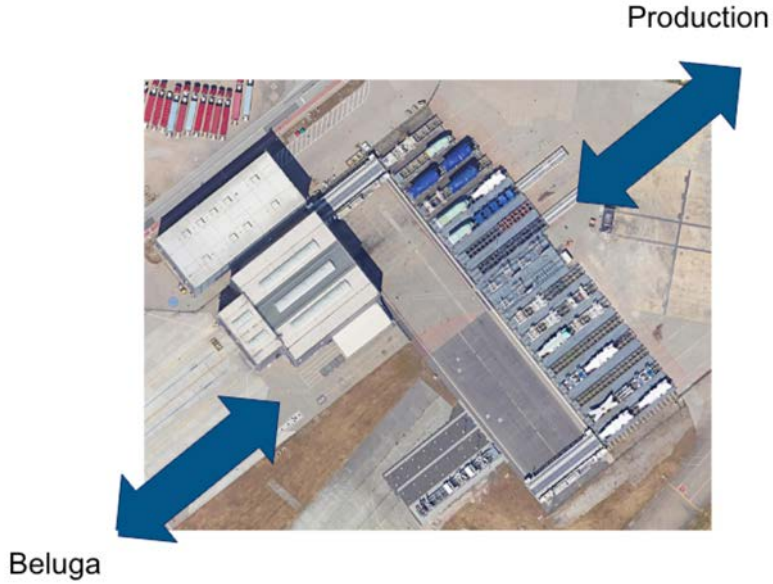
Use Case I
Worker Allocation & Scheduling



CHALLENGES

Efficiency: hybrid scheduling/routing
Explainability: multi-objective tradeoffs elicitation, infeasibility recovering, constraint acquisition
Robustness: minimise schedule adaptations on disruptions

Use Case II
Beluga Logistics Planning

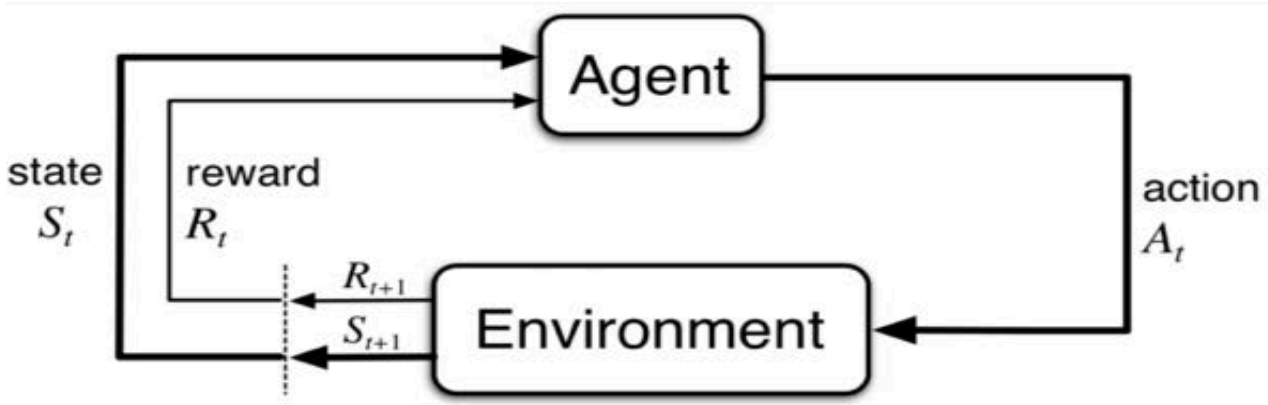


CHALLENGES

Efficiency: scale to large realistic problems
Explainability: multi-objective tradeoffs elicitation, infeasibility recovering
Robustness: handle uncertain Beluga arrivals and factory demands

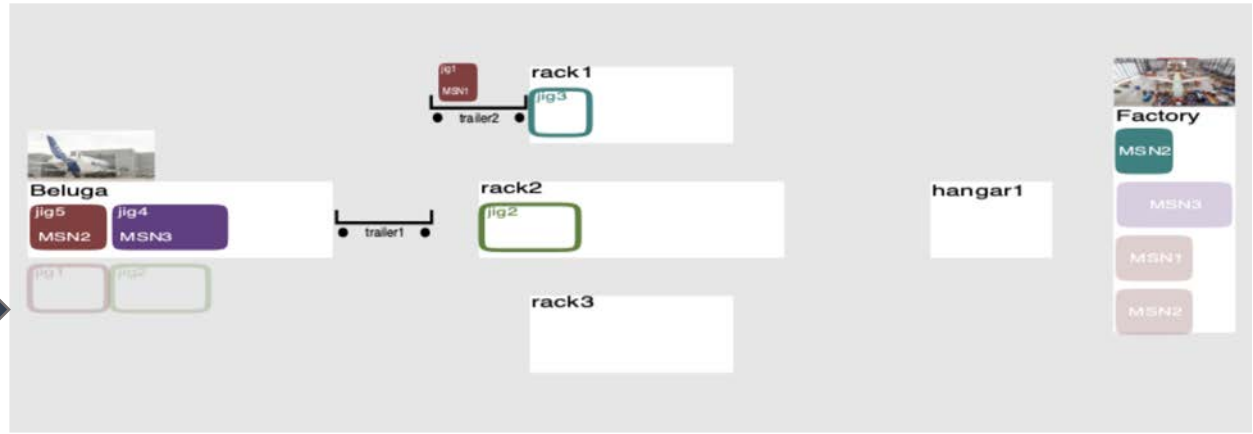
Beluga Logistics Planning: an MDP problem

#states = $O(2^{\#jigs \times \#trailers} \times (2 \times \#racks + \#hangars)^{\#trailers} \times !\#jigs^{\#racks})$

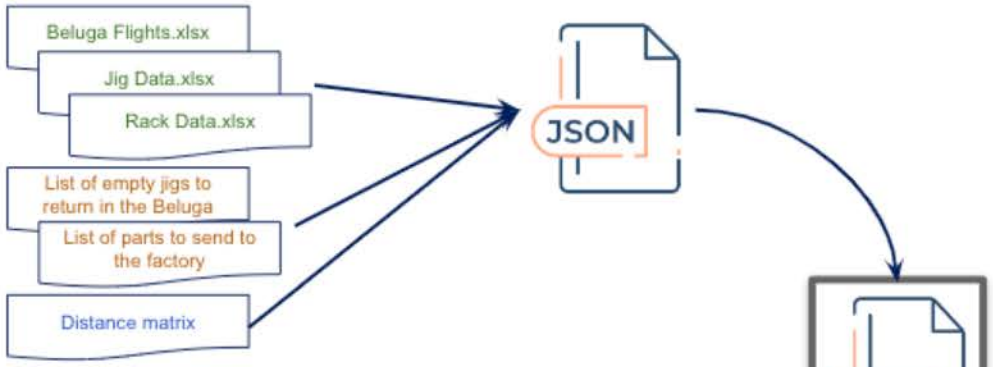


#actions = $O(\#jigs \times \#racks \times \# trailers)$

Pull-back jig1 from rack1 using trailer2



Beluga Logistics: exploit domain knowledge




```
(:action unload ; unload ?jig from Beluga using ?trailer and ?nextjig is next to
    :parameters (?jig ?nextjig - jig ?trailer - trailer)

    :precondition (and
        (NEXT-UNLOAD ?jig ?nextjig)
        (unload-ready ?jig)
        (>= (TRAILER-LENGTH ?trailer) (JIG-LENGTH ?jig))
        (clear ?trailer)
        (at-rack ?trailer BELUGA BACK)
    )

    :effect (and
        (not (unload-ready ?jig))
        (unload-ready ?nextjig)
        (not (clear ?trailer))
        (on ?jig ?trailer)
        (increase
            (total-cost)
            (UNLOAD-COST ?jig ?trailer))
    )
)
```

```
(define (problem rack-problem_example)
    You, last month
    (:domain rack)
    You, 2 weeks ago | 1 author (You)
    (:objects
        jig1 jig2 jig3 jig4 jig5 - jig
        rack1 rack2 rack3 - rack
        trailer1 trailer2 - trailer
        hangar1 - hangar
    )
    You, 2 weeks ago | 1 author (You)
    (:init
        (= (RACK-CAPACITY BELUGA) 150)
        (= (RACK-CAPACITY rack1) 100)
        (= (RACK-CAPACITY rack2) 150)
        (= (RACK-CAPACITY rack3) 100)
```

AIPLAN 4EU

SOLVE

Scikit-decide

```
returned: OPT-enhsp status: INTERMEDIATE
engine: OPT-enhsp
plan: SequentialPlan:
    move-from-storage-to-rack(trailer1, rack1, front)
    pull-front(jig1, nulljig, rack1, trailer1)
    move-from-storage-to-rack(trailer2, rack1, back)
    move-between-racks(trailer2, rack1, beluga, back, back)
    move-between-racks(trailer2, beluga, rack3, back, back)
    pull-back(nulljig, nulljig, rack3, trailer2)
    move-between-racks(trailer2, rack3, beluga, back, back)
    move-between-racks(trailer2, beluga, beluga, back, front)
    push-front(nulljig, jig3, beluga, trailer2)
    move-between-racks(trailer2, beluga, beluga, front, back)
    pull-back(nulljig, nulljig, beluga, trailer2)
    move-between-racks(trailer2, beluga, rack2, back, front)
    push-front(nulljig, jig2, rack2, trailer2)
    move-between-racks(trailer2, rack2, beluga, front, back)
    unload(jig3, jig4, trailer2)
    send-to-factory(jig3, jig4, beluga, trailer2, hangar1)
    push-front(jig1, nulljig, rack1, trailer1)
    move-from-hangar-to-rack(trailer2, hangar1, beluga, front)
    move-between-racks(trailer1, rack1, beluga, front, back)
    unload(jig4, jig5, trailer1)
    send-to-factory(jig4, jig1, beluga, trailer1, hangar1)
```

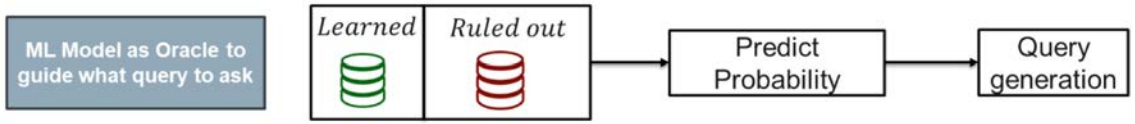
PDDL plan found by ENHSP

Hybrid model-based / data-driven decisions

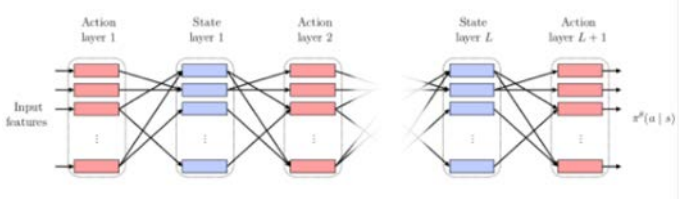
Use Case I
Worker Allocation & Scheduling

Use Case II
Beluga Logistics Planning

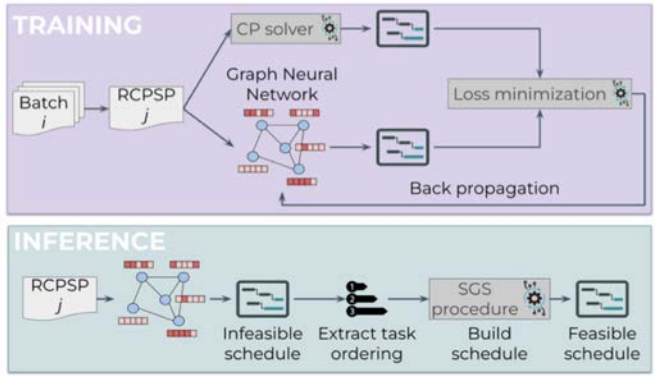
- Active Learning of Constraints



- Learn To Plan with ASNets

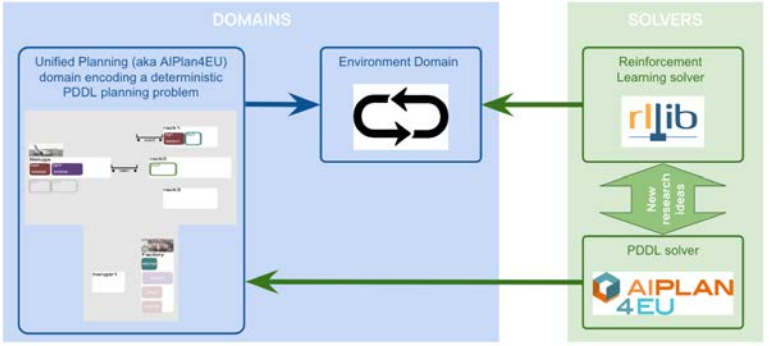


- Learn to Schedule



See talk of the knowledge compilation chair on scheduling with GNNs

- Hybrid Planning / Reinforcement Learning



Explainable infeasible schedule relaxations

- Exploring *Minimum Unsatisfiable Sets*, *Minimal Correction Subsets*
- Interactive constraints relaxation

Constraints: Team 0 can do activity 6 and ac

```
Already Relaxed Constraints:

 - Team 0 can do activity 4 and activity 8 at the same time. Constraint in 83 muses out of 170, if this constraint is relaxed you will need to relax atleast 1 more constraints
 - Team 0 can do activity 8 and activity 10 at the same time. Constraint in 160 muses out of 297, if this constraint is relaxed you will need to relax atleast 1 more constraints
INFO:allocation.solvers.allocation_cpmpy_solver:Solver finished, found solution=True, status=ExitStatus.OPTIMAL (0.0022161570000000003 seconds)

 - Team 0 can do activity 6 and activity 8 at the same time. Constraint in 192 muses out of 192, if this constraint is relaxed problem will be solvable


Problem is now solvable!
```

And much more…

- Explaining tradeoffs between conflicting objectives
- Checking deep learning scheduling policy performance
- User study experiments and acceptability properties elicitation

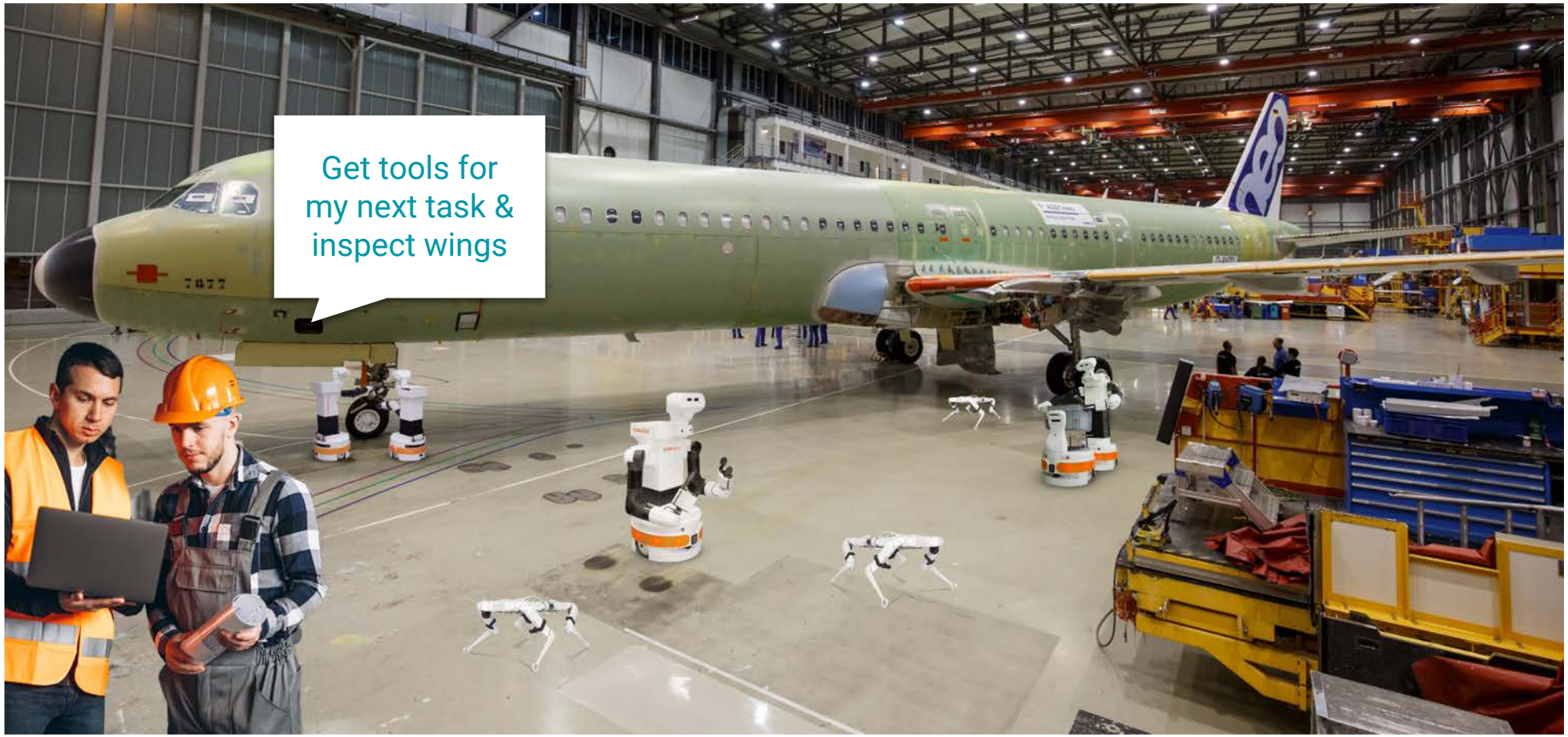
Towards ANITI-2 HEROIC - *Hybridizing lEarning, seaRch and combinatorial Optimization for Industrial deCision-making*

- Industrial chair
- 6 academic labs + 4 industrial use cases in the initial proposal; we're happy to welcome more!

Part 3:
Language @Linagora

Programming through conversation

Industrial moonshot:



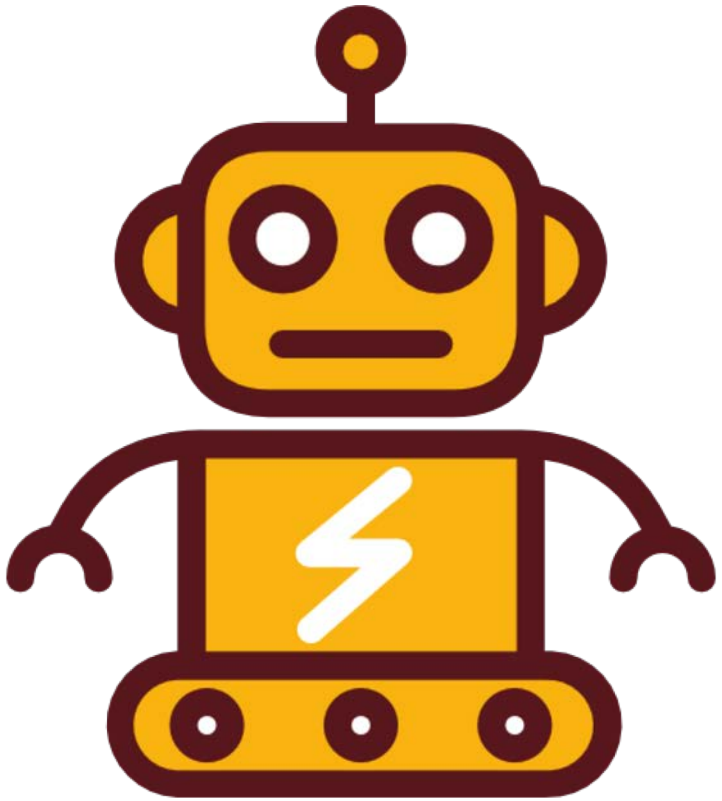
Interdisciplinary, hybrid approach

Camera vision
& other sensors

Multimodal grounding

Natural Language
for instructions/goals/knowledge

PERCEIVE



ACT

Actions

Hybrid AI
to keep compositionality from language symbols/structure to actions

RL & semantic grounding for robotics in industrial environments

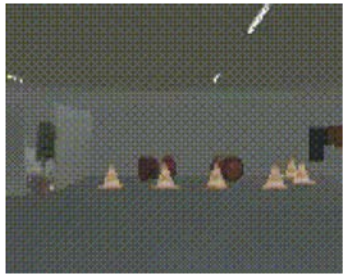
Building a playground

- Virtual factory-like environment
- Scripts for randomization & language generation

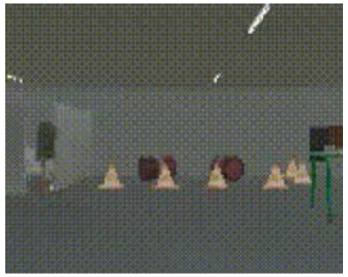
Experimenting learning algorithms

- Visual-based RL (inspired by DrQ v2, Dreamer v3…)
- Augmented with language modality (e.g. with pretrained LLM encoders)

Early results:

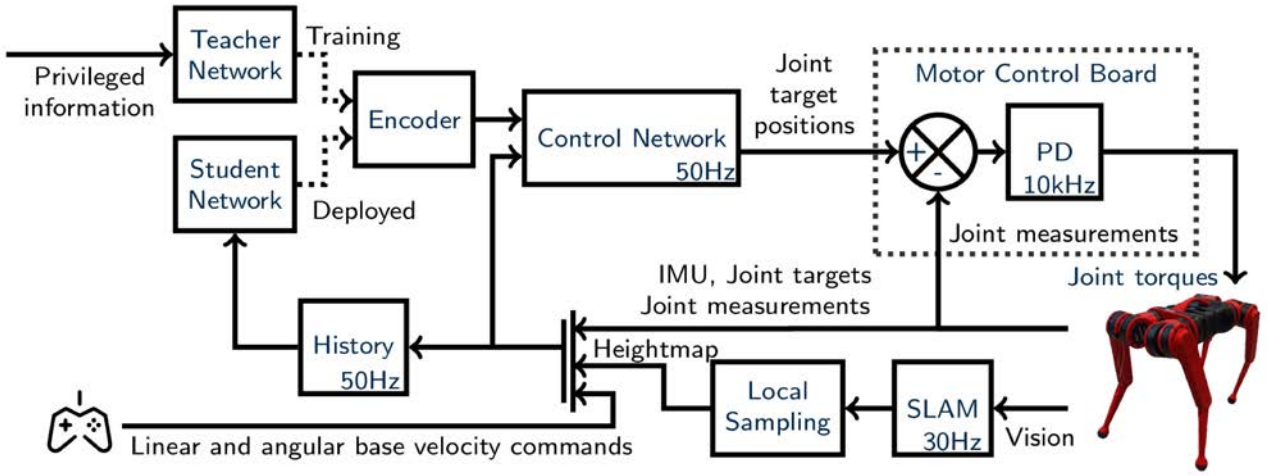


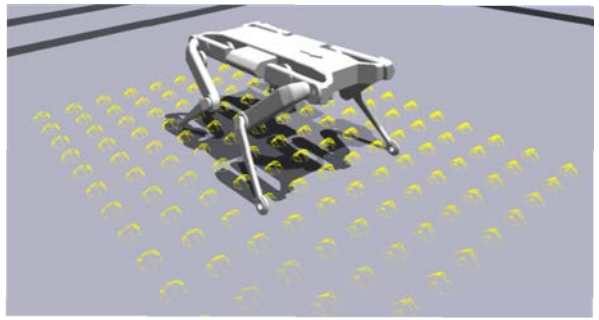
Go to the hammer located on blue table



Drive to the wrench on top of the red table

Reinforcement learning for quadruped locomotion





4096 Solo-12 learning in parallel in Isaac Gym simulator (on GPU)

RL as alternative to MPC for quadruped locomotion

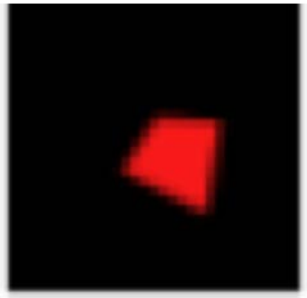
Manipulated data:

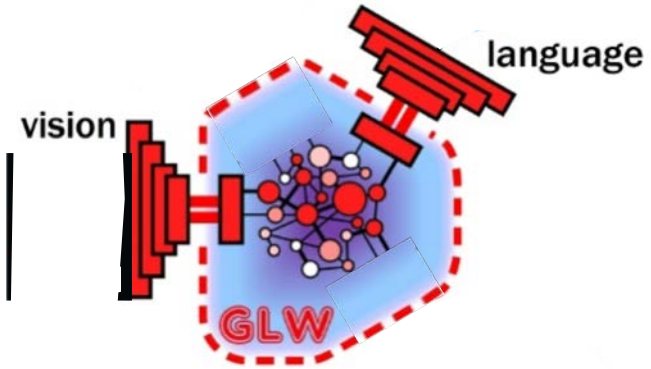
- **sensor data + heightmap**
- **point cloud for reconstruction of heightmap (real robot)**

Methodology:

- RL with PPO + teacher-student
- curriculum (terrain diff)
- Simulated sensor noise, domain randomization

Multimodal systems

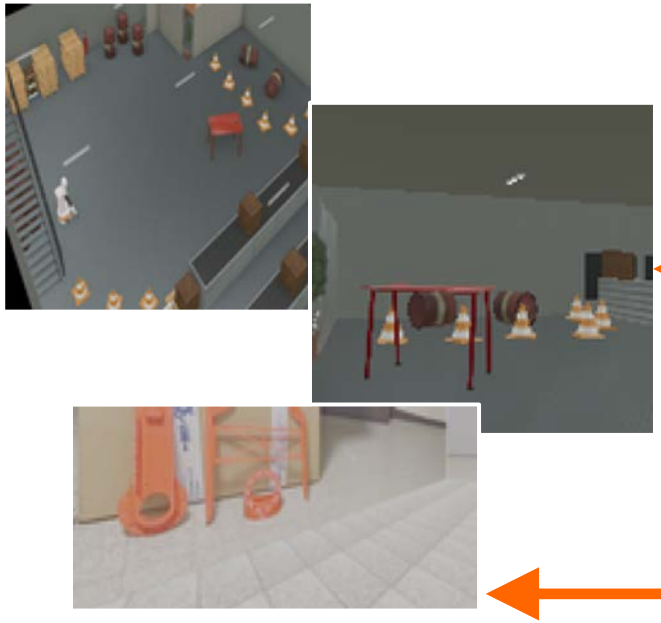




A bright red diamond, pointing to the bottom right
A green triangle at the top, towards left
An egg-shaped oval, dark-blue, pointing up, on the bottom-left of the image

Attributes = [1,0,0,-1,-0.5,-60,2,1,0,0]

shape | position | rotation | size | color



attributes	values
position x robot	-3.333
position y robot	3.101
rotation z robot	-0.286
position x table	1.933
position y table	2.220
rotation z table	-0.575
color (R,G,B)	(1, 0, 0.107

attributes	values
position x	1.767
position y	-0.853
rotation z	-2.042
color (R,G,B)	(1, 0.343, 0)

attributes	values
position x	-1.674
position y	-0.099
rotation z	2.651
pitch	-1.24
roll	-0.232

sim2real (with LAAS)

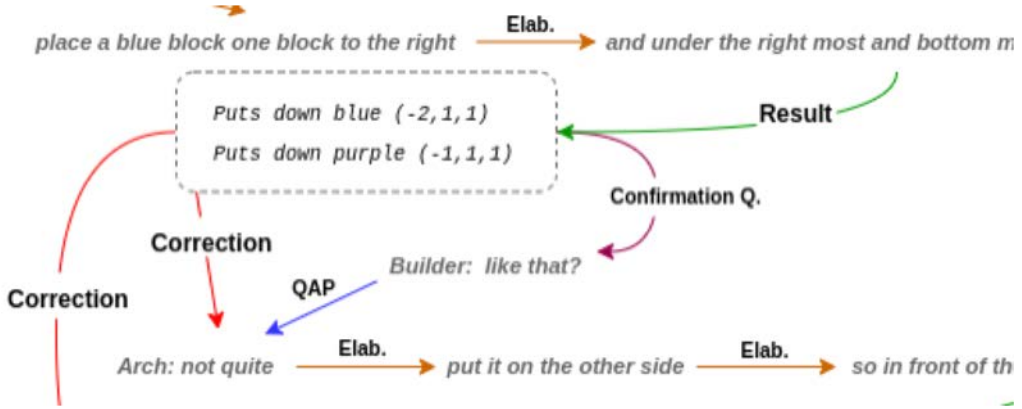
LLMs and semantic faithfulness:

- remove or shift predicate argument structure on which Q&As depend. LLMs even GPT DaVinci 002 003 don't do very well.
- Limits for learning for LLMs. Logical and precise concepts

Conversation to build cooperatively

The Minecraft Dialogue Corpus

- represent semantic relations between utterances
- discourse parser for automatically building discourse structure
- integration with builder



Thank you for your attention !