Consiglio Nazionale delle Ricerche

19/10/2023

Towards Intelligent Urban Decision Support: Cognitive Duality and Digital Twins

A cura di **Riccardo De Benedictis**, Gloria Beraldo, Amedeo Cesta & Gabriella Cortellessa

(Lack of) Planning in Urban Environments

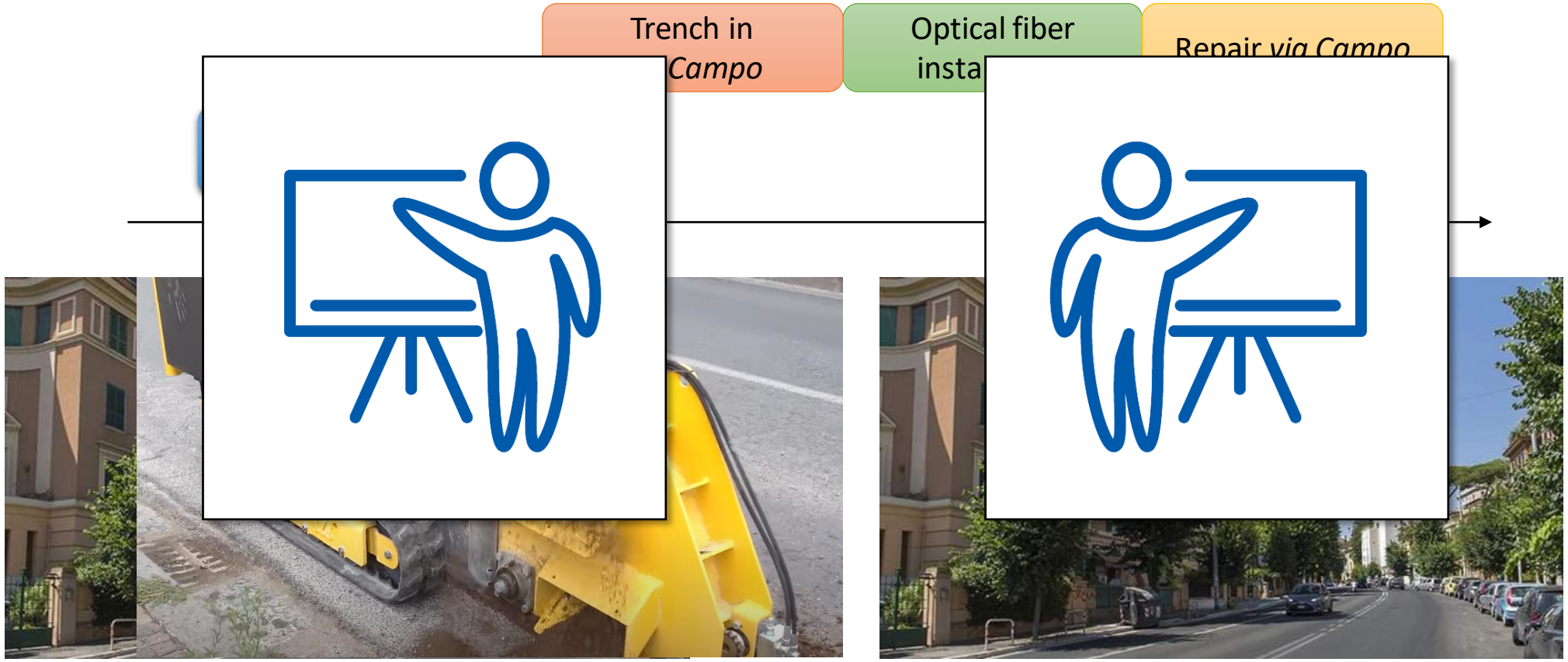
Trench in *via Campo*

Optical fiber installation

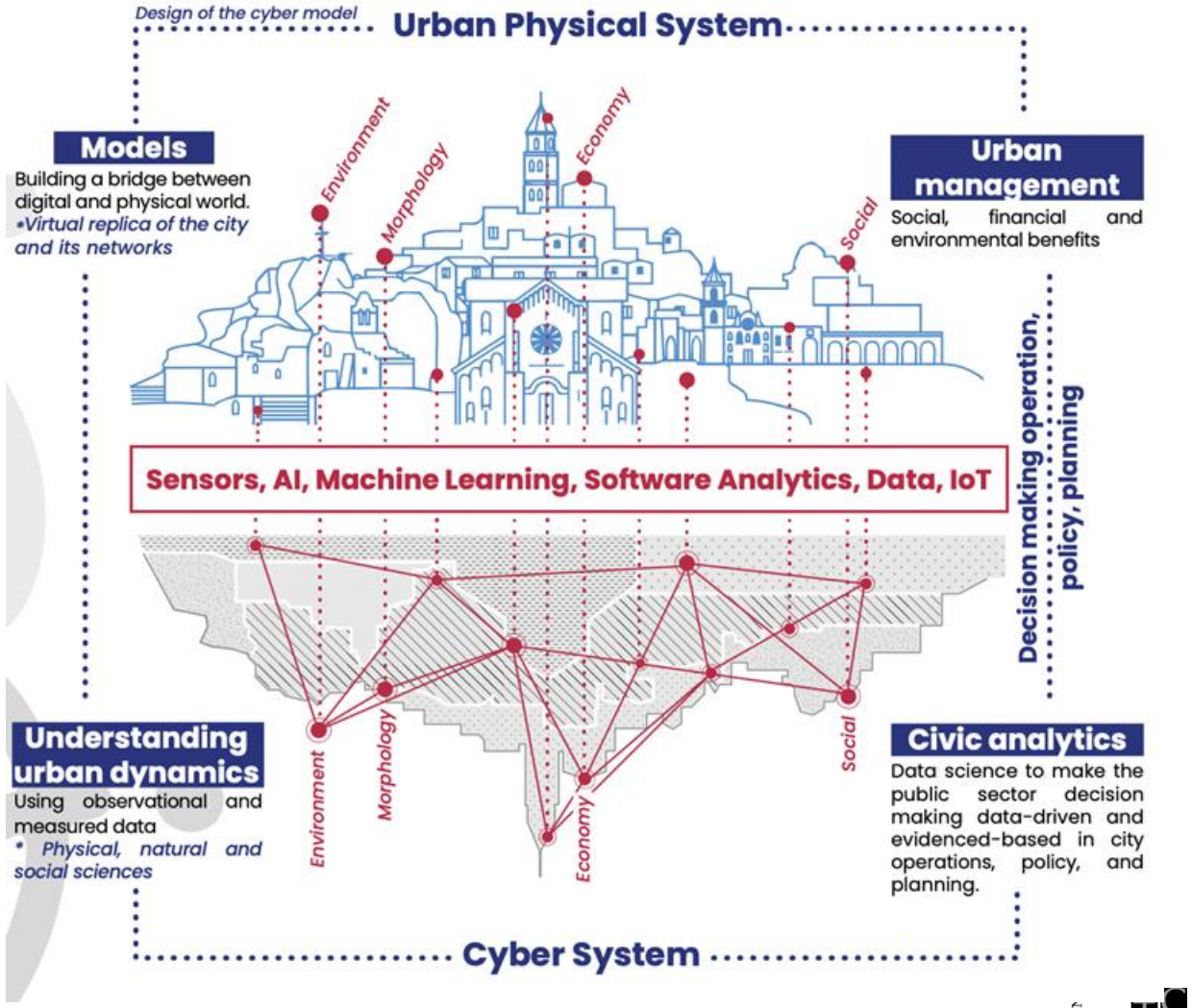
Repair *via Campo*

Maintenance *via Campo*

(Lack of) Planning in Urban Environments



The House of the Emerging Technologies of Matera



A **cognitive architecture** for decision support in urban areas

Maintainance via Dante Alighieri

Maintainance Murgia Timone

Feast of the Brown

tle

Urban Wellness

Abduction

s_d a_d

Deduction
$\pi(s) = a$

a_s s_s a_c s_c

Sensing Tier

s_s

Control Tier (skills)

s_e a_e

Enviror

What's your name?

My name is Ohmni!

What's your name?

What's wrong with you?

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A **cognitive architecture** for decision support in urban areas

Maintainance via Dante Alighieri

Maintainance Murgia Timone

Feast of the Brown

Maintenance Tramontano Castle

Urban Wellness

Thinking slow

Abduction

s_d

a_d

Thinking fast

Deduction

$\pi(s) = a$

a_s s_s a_c s_c

Sensing Tier

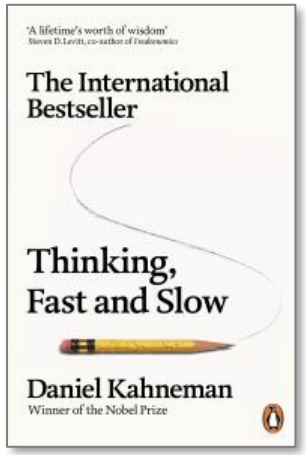
s_s

Control Tier (skills)

s_e

a_e

Enviror



PM10 >= 50 µg/m^3

Warning!
The quality of the air in via … is getting worse!

Humidity < 30%

Turn on sprinkler

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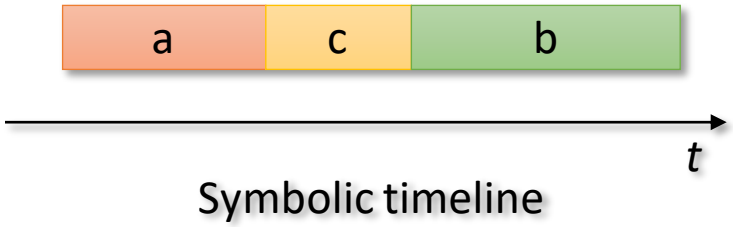
Thinking Slow

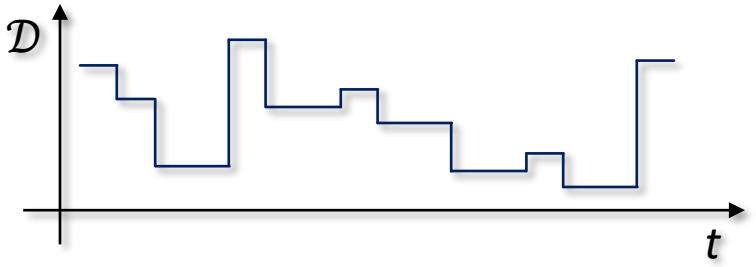
A **timeline** T is a function

$$\mathsf{T}: \mathbb{T} \rightarrow \mathcal{D}$$

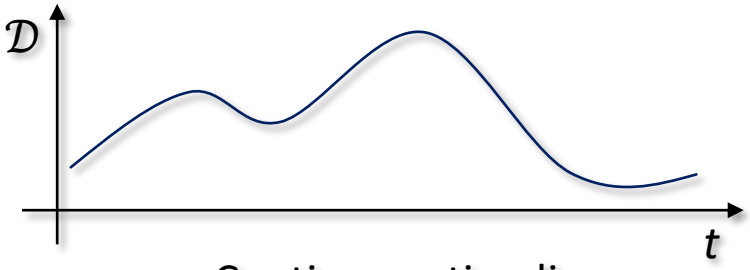
where $\mathbb{T}$ is the (either discrete or continuous) *domain of time* and $\mathcal{D}$ is the (possibly infinite) *domain of the timeline*



Symbolic timeline



Step-wise timeline



Continuous timeline

Thinking Slow

- Values on timelines are **extracted** from **tokens**
- A token is an expression of the form

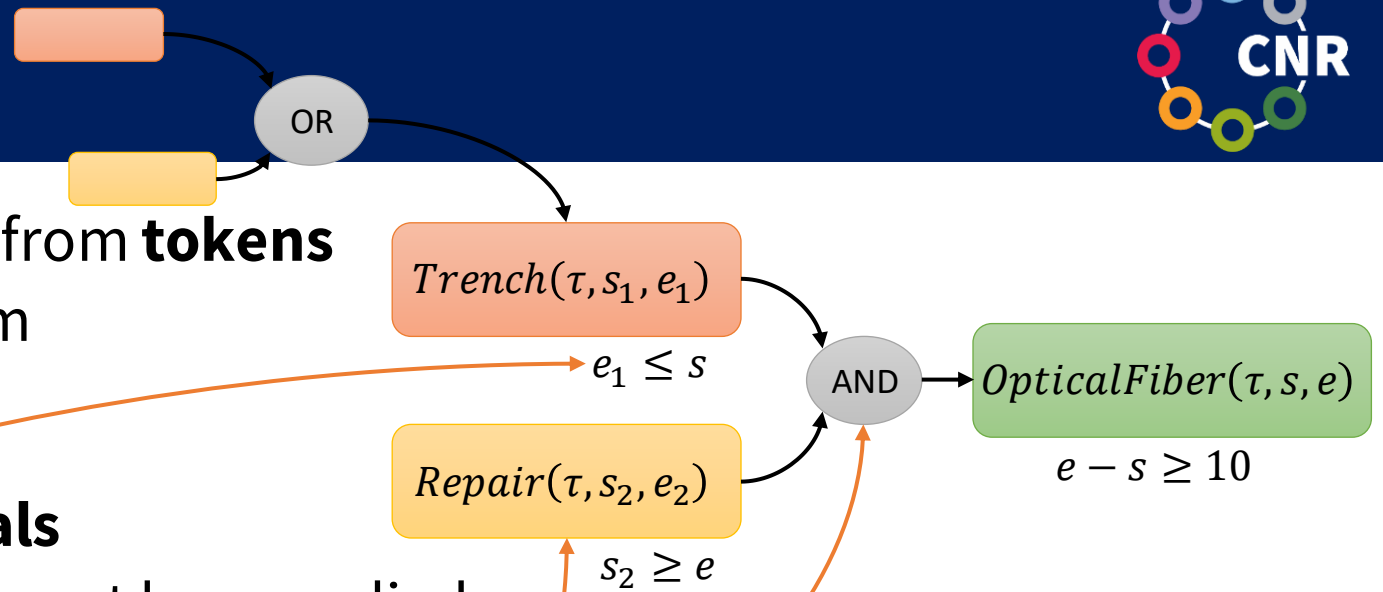
$$n(x_0, \dots, x_k)_\chi$$

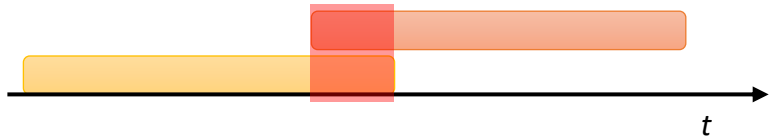
- Two kinds of tokens: **facts** and **goals**
- **Rules** define causal relations that must be complied to in order for a given goal to be achieved

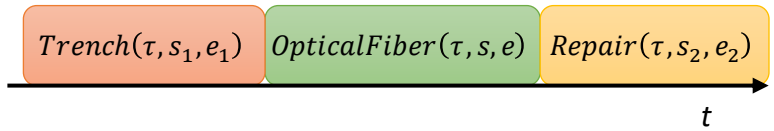
$$n(x_0, \dots, x_k) \Leftarrow \boldsymbol{r}$$

- $\boldsymbol{r}$ is a **requirement**: either a slave (or target) **token**, a **constraint** among tokens (possibly including the $x_0, \dots, x_k$ variables), a **conjunction** of requirements, a (priced) **disjunction** of requirements
- A timeline-based planning **problem** is a triple

$$\mathcal{P} = (\mathbf{O}, \mathcal{R}, \boldsymbol{r})$$

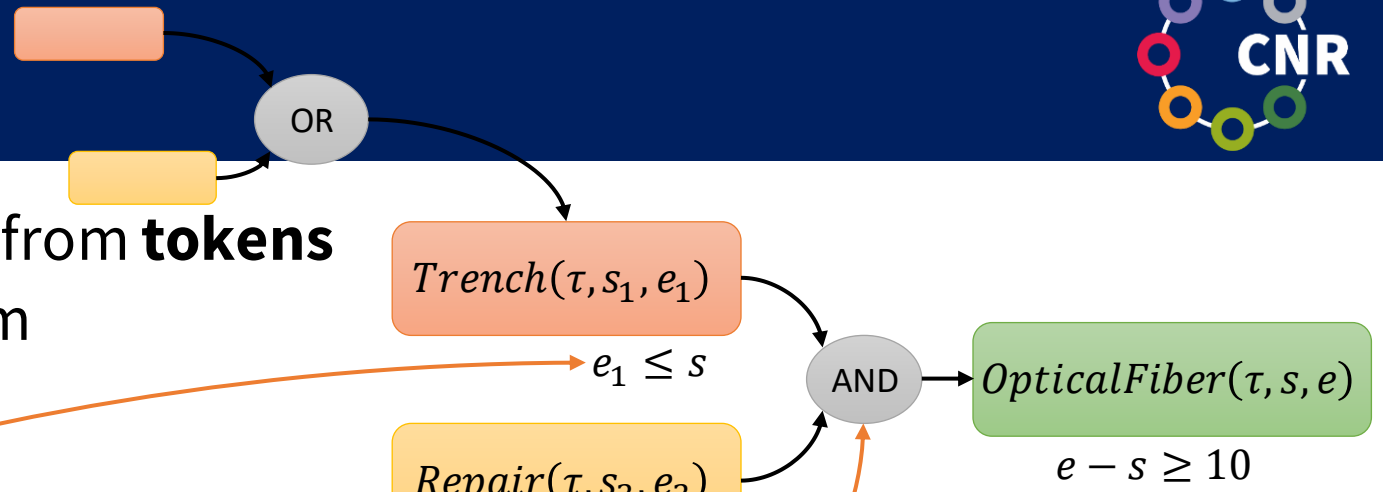






DUM LOQUIMUR, FUGERIT INVIDA AETAS:
CARPE DIEM, QUAM MINIMUM CREDULA
POSTERO. (ORAZIO, ODI, I, 11, 7-8)

Thinking Slow



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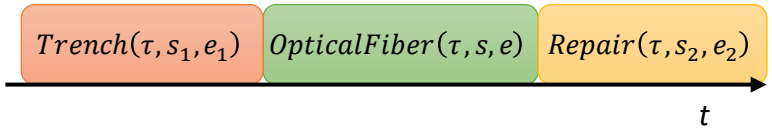

DUM LOQUIMUR, FUGERIT INVIDA AETAS:
CARPE DIEM, QUAM MINIMUM CREDULA
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Thinking Fast … logically

Rule-based systems are a type of **Artificial Intelligence** systems that use a set of "if-then" rules to make decisions or draw conclusions

- $IF\ temp \geq 30 \wedge humidity \leq 70\ THEN\ activate\_sprinkler$

- *new_solver(purpose, files)*
- *start_execution(id)*
- *delay_task(id, time)*
- *extend_task(id, time)*
- *failure(ids)*
- *adapt(id, files)*
- *publish(topic, message)*

MQTT

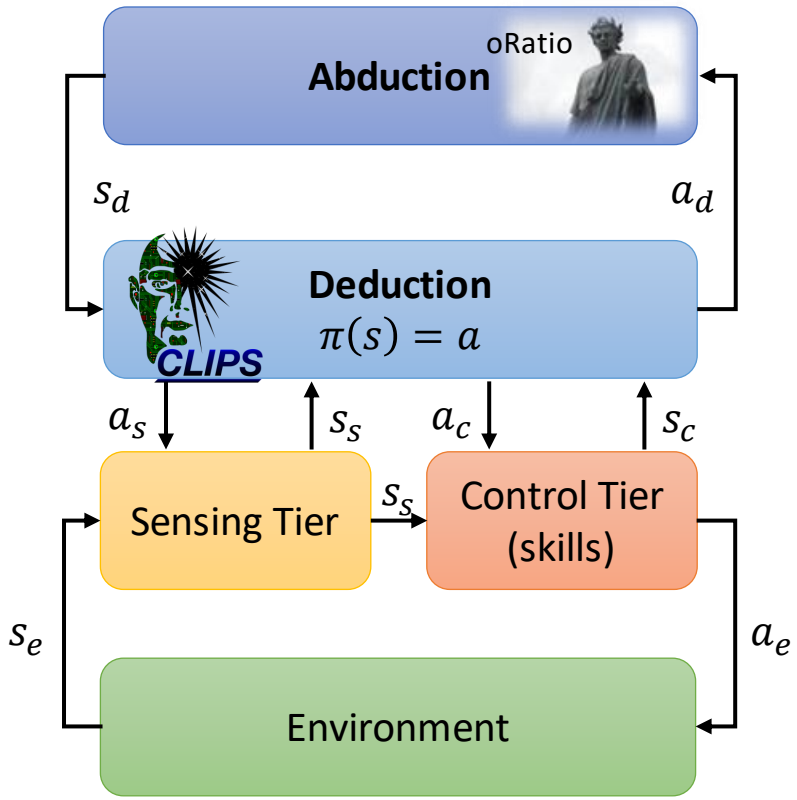
- solver(id, purpose, state)
- sensor_type(id, name)
- sensor(id, type)
- *sensor_data(id, time, data)*
- *sensor_state(id, state)*

mongoDB.

- *starting(type, pars, vals)*
- *start(id, type, pars, vals)*
- *ending(id)*
- *end(id)*

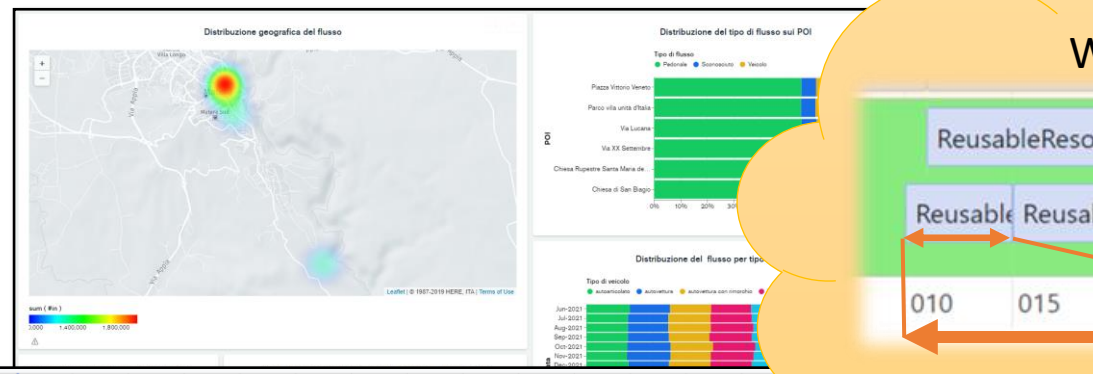
CLIPS

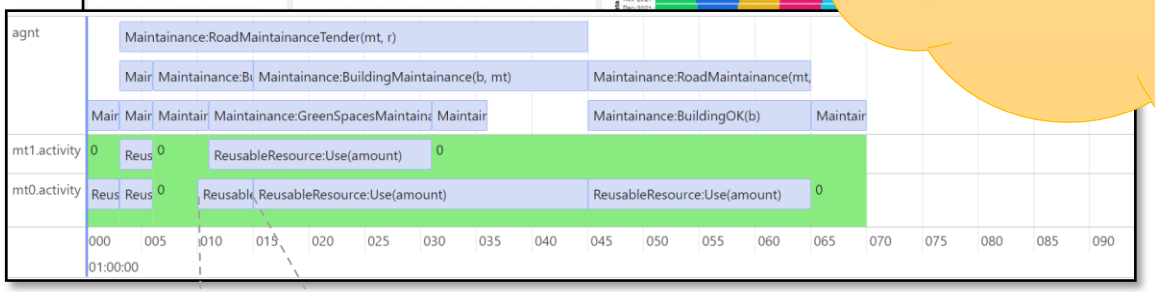
Combined deductiOn and abduCtiOn (CoCo) reasoner



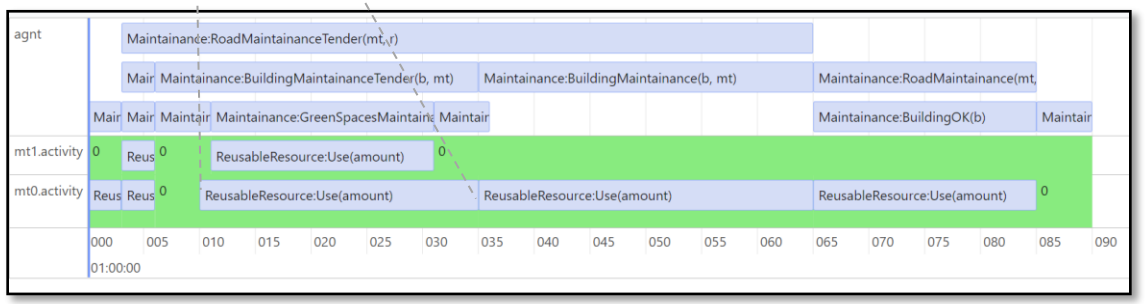
CoCo

Dashboard

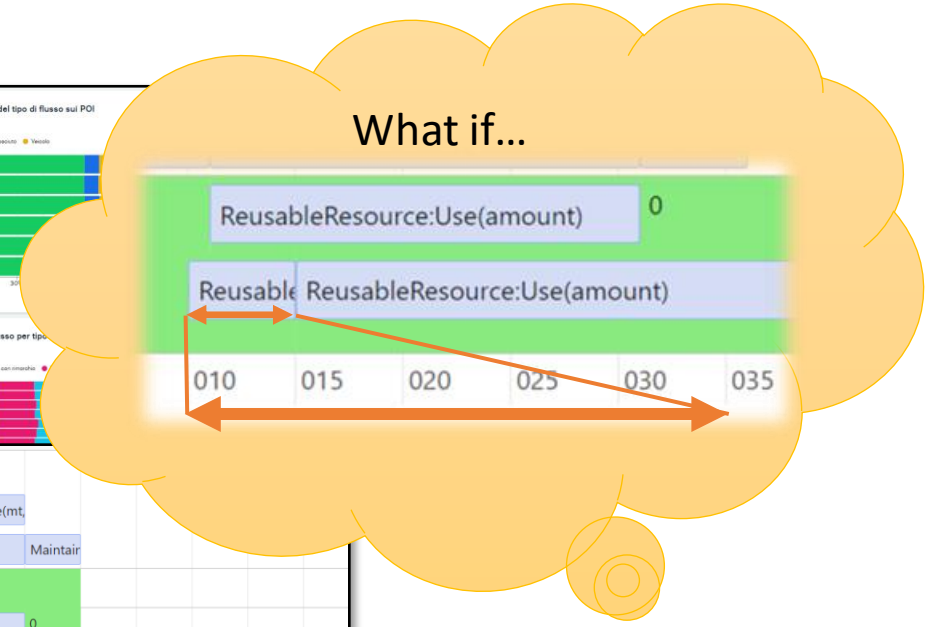




Proposed solution



What-if solution



User

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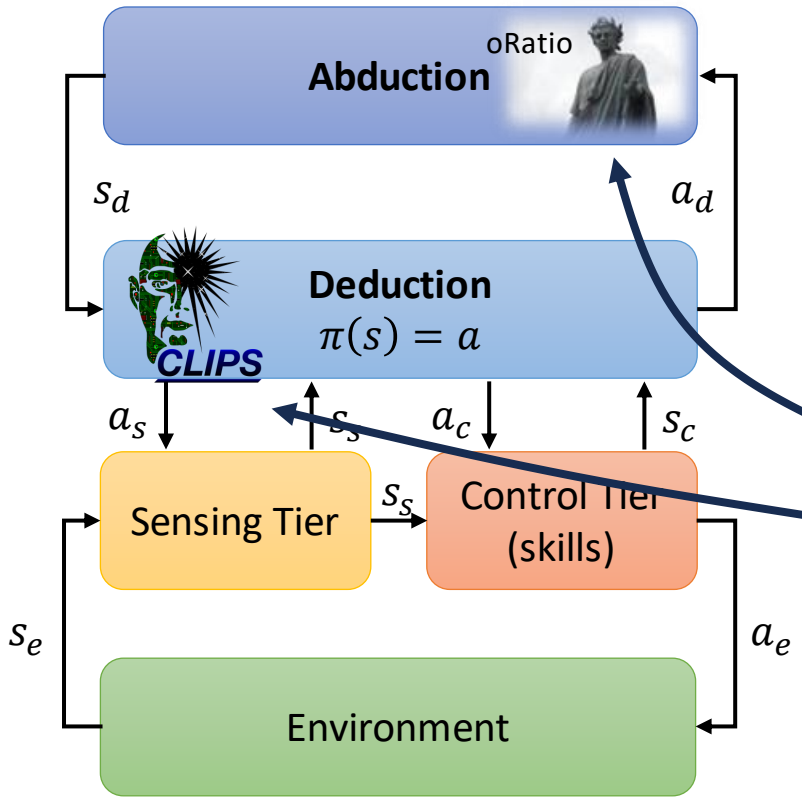
Combined deductiOn and abduCtiOn (CoCo) reasoner

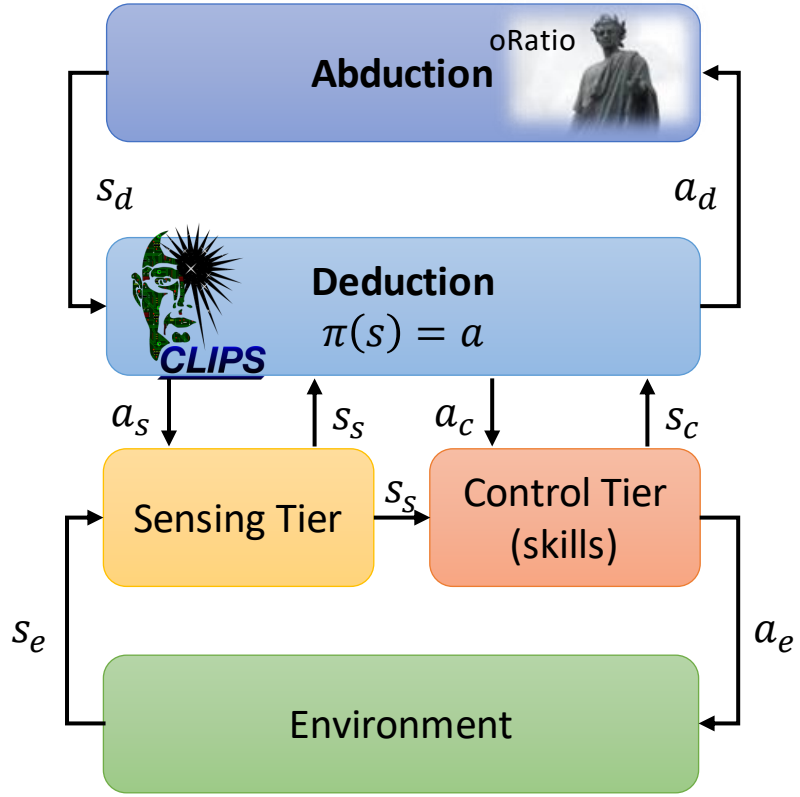


CoCo

Who defines the **rules**?

(**Induction** reasoning)

Multi-level Inference with Model-based Induction (MiMi)



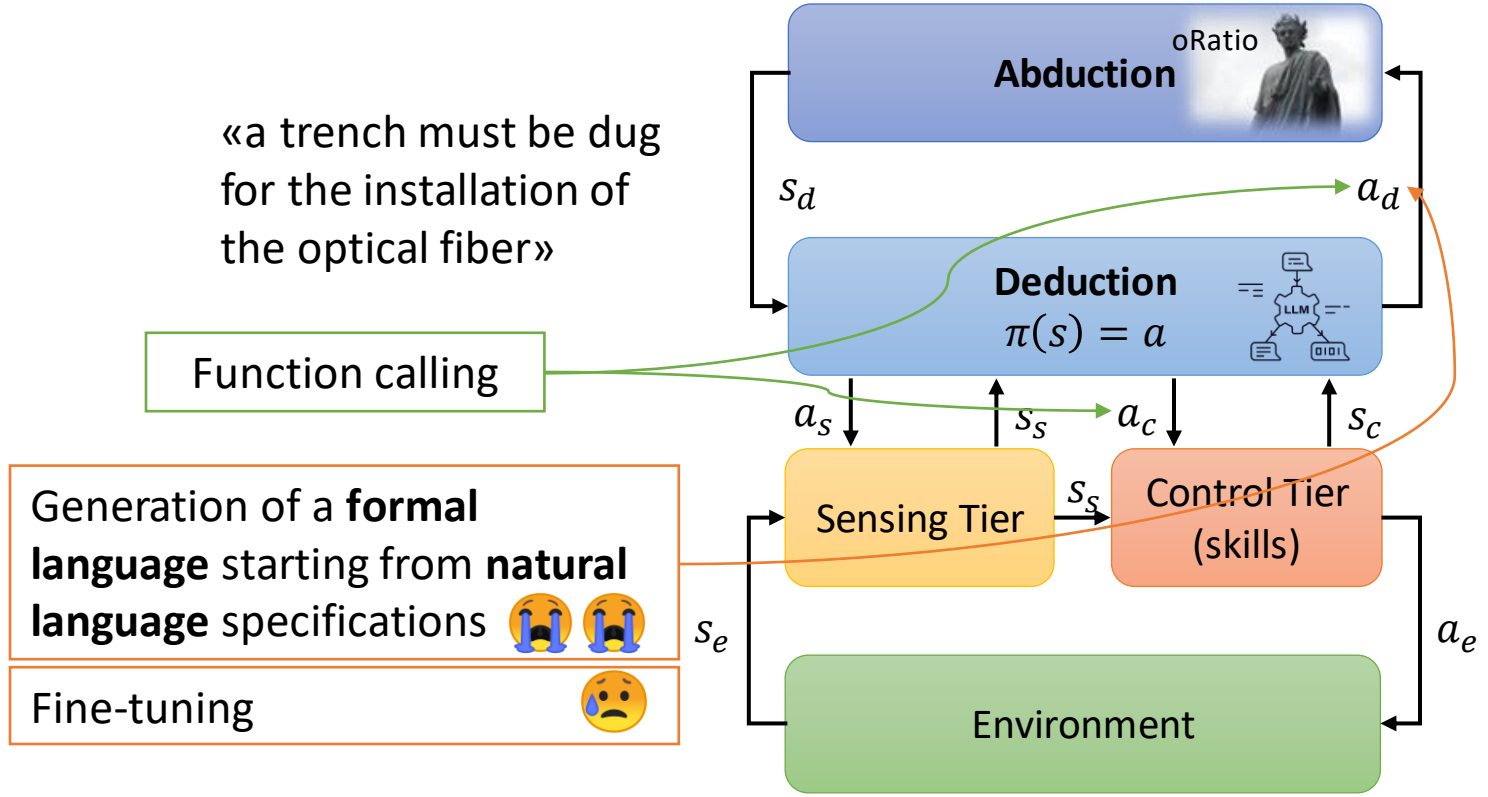
CoCo

«a trench must be dug for the installation of the optical fiber»

Function calling

Generation of a **formal language** starting from **natural language** specifications 😭😭

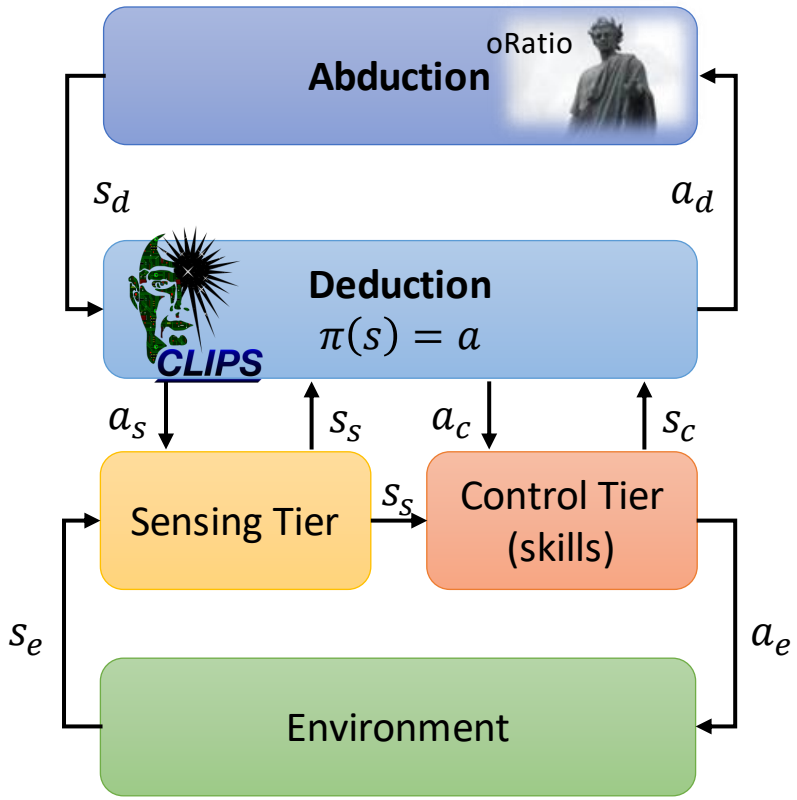
Fine-tuning 😢

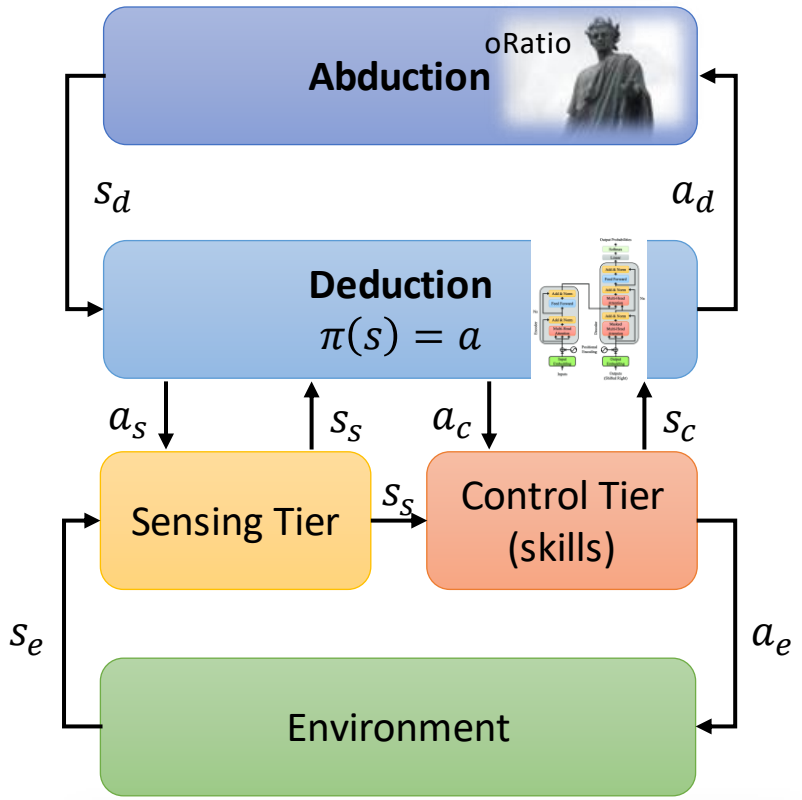


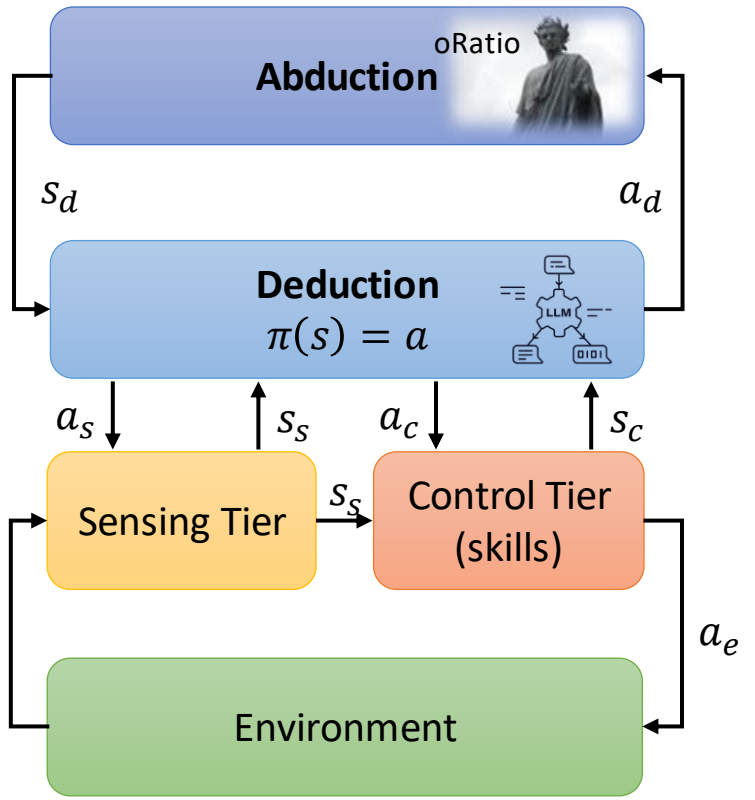
«It seems that a trench needs to be dug for the installation of optical fiber. Can I help you?»

MiMi

A Transformer-Based Approach for Choosing Actions in Social Robotics







CoCo

A Transformer-Based Approach for Choosing Actions in Social Robotics

Riccardo De Benedictis, Gloria Beraldo, Gabriella Cortellessa, Francesca Fracasso, and Amedeo Cesta

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MiMi

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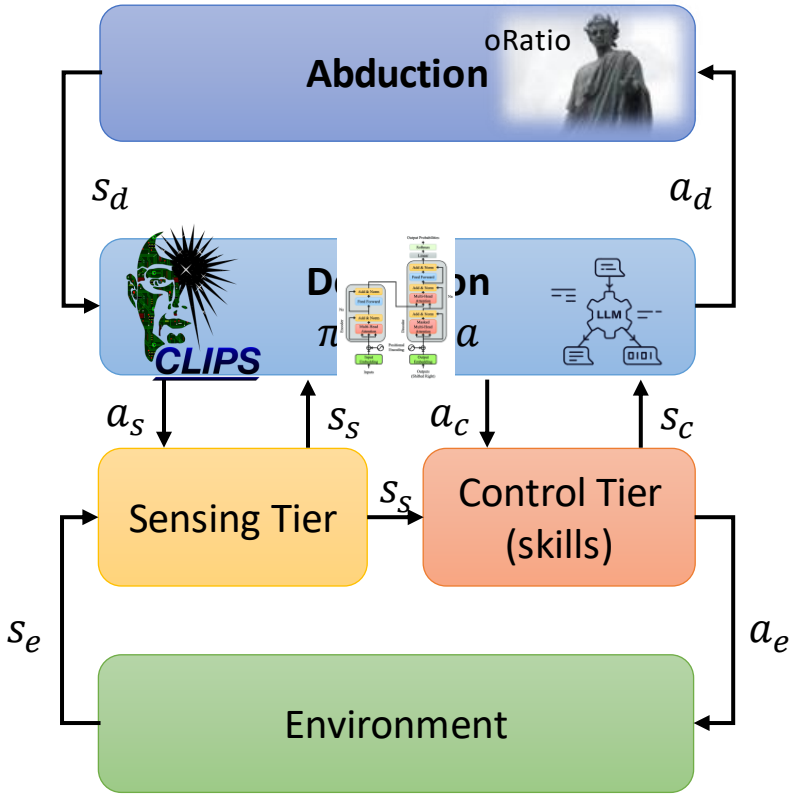
Conclusions

- The CoCo system combines a **rule-based system** and **automated planning** to support decision-making in urban management
- Rule-based systems excel at **responding** to environmental changes, while automated planning generates **task-oriented plans** for achieving desired goals.
- By merging these two approaches, **urban managers** and **decision-makers** gain a comprehensive and efficient solution for managing diverse aspects of urban life.
- Both System 1 and System 2 heavily rely on **defining rules**, which can be a challenging and time-consuming task.



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Thank you!

A cura di **Riccardo De Benedictis**, Gloria Beraldo, Amedeo Cesta & Gabriella Cortellessa