Robots that know, but how much do they know?

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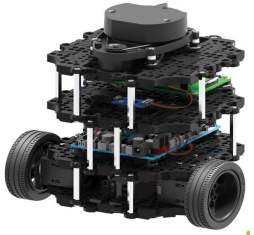
Today's talk

Robots

Because they are cool

Capabilities

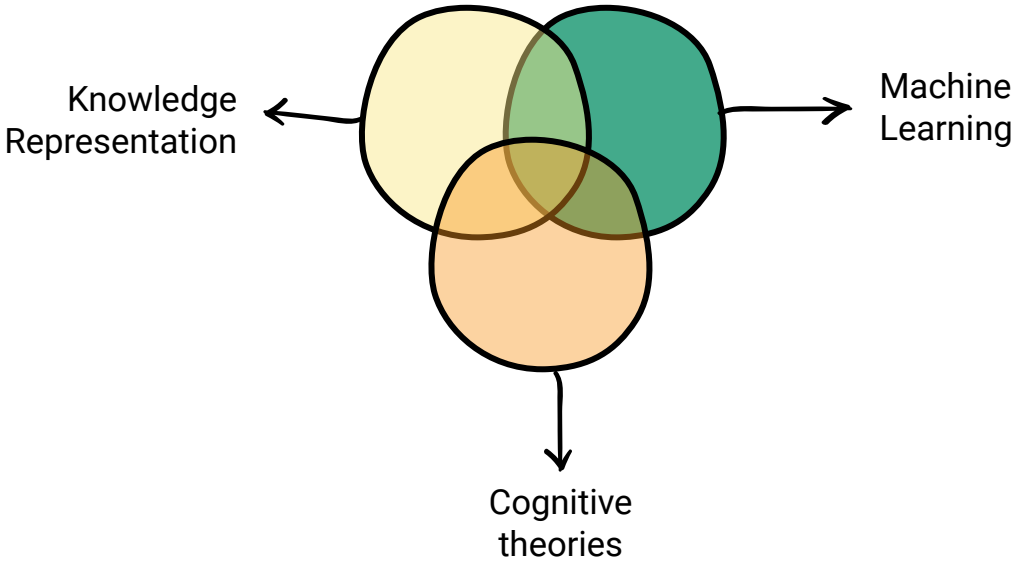
Because we want to play with robots



Ontologies

As they will make our life easier

About myself



eScience

AI to support scientists and their research questions

Robotics

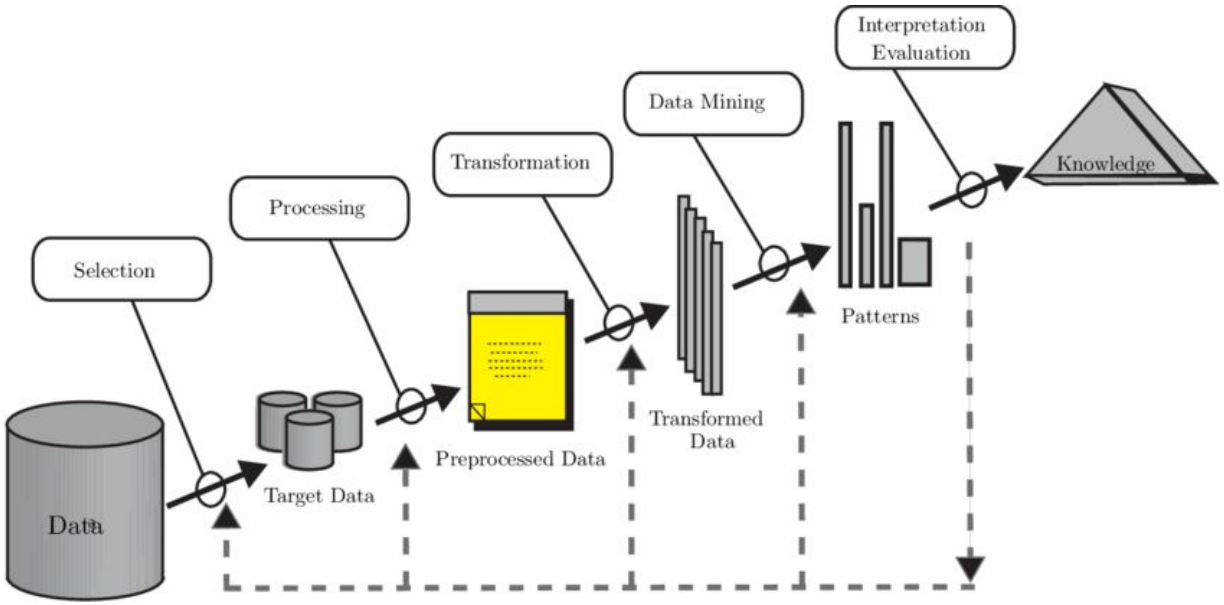
Facilitating tasks of mobile agents with AI

Ethical AI

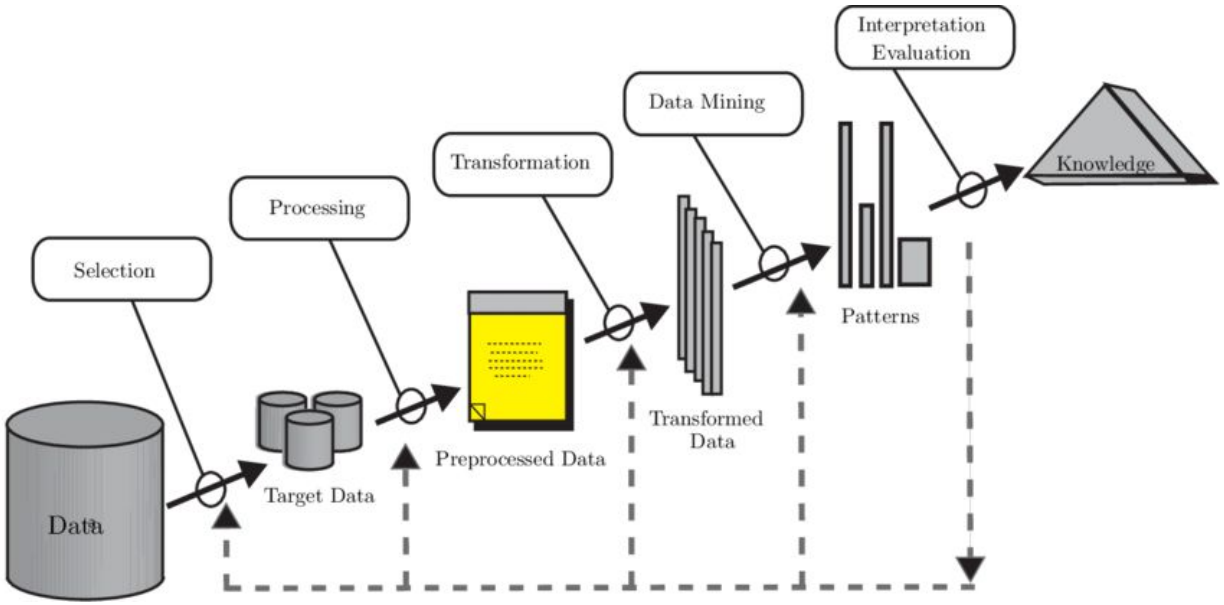
Ethical methods to design intelligent systems

Let’s start with a trivia

What's this?

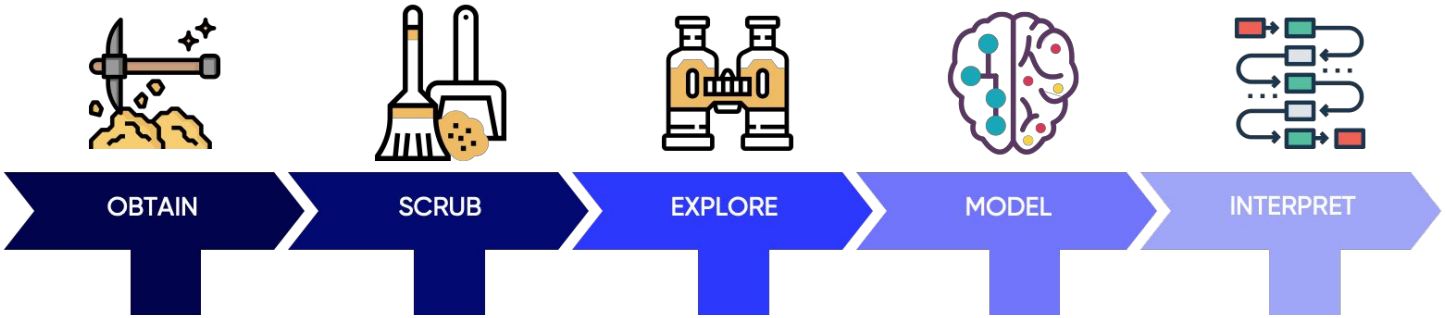

Interpretation
Evaluation
Data Mining
Transformation
Processing
Selection
Knowledge
Patterns
Transformed
Data
Preprocessed Data
Target Data
Data

What's this?



The Knowledge Discovery Process (1996)

And this?



And this?

The Data Science Process (today)

So basically

~30 years later, we have:

- more data
- more advanced techniques
- more scientists

… we are still trying to interpret data

Interpretation is the action of capturing the meaning of something.

[1] Oxford Dictionary : https://www.lexico.com/en/definition/interpretation

Capturing Meaning (1976)

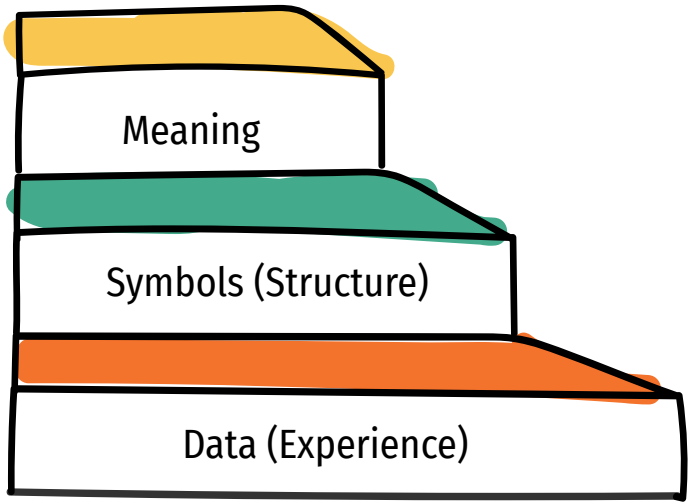
Experience and knowledge structures

are the ingredients

for an intelligent system to

convey understanding and meaning

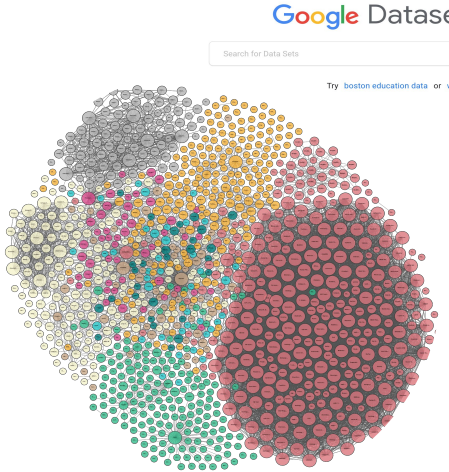
(Newell&Simon, 1976)



Capturing Meaning (today)

Symbols in 2020:

- Plenty of multi-domain sources (knowledge graphs, open data...)
- Connected/centralised hubs and observatories
- Vocabularies for data modelling&sharing
- Large scale knowledge management



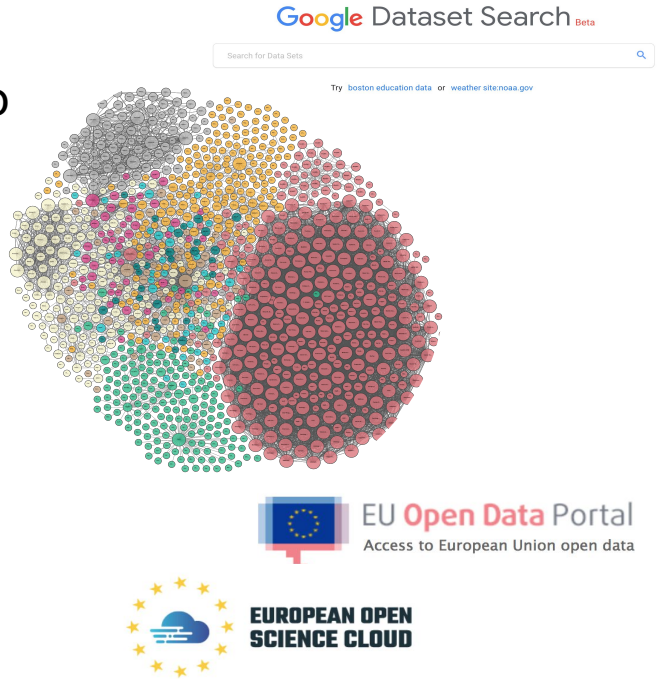
EU Open Data Portal
Access to European Union open data

EUROPEAN OPEN SCIENCE CLOUD

Capturing Meaning (today)

Symbols can support intelligent (embodied) agents to

- interpret experiences (behaviours, images, sounds, texts...)
- understand complex situations
- give sense to the world, i.e. convey meaning



Can Robots Capture Meaning?

Pros:

- ✓ highly autonomous
- ✓ modern CV/AI/Navigation&Planning
- ✓ new hardware/software components
- ✓ cheaper platforms (roomba, drones…)

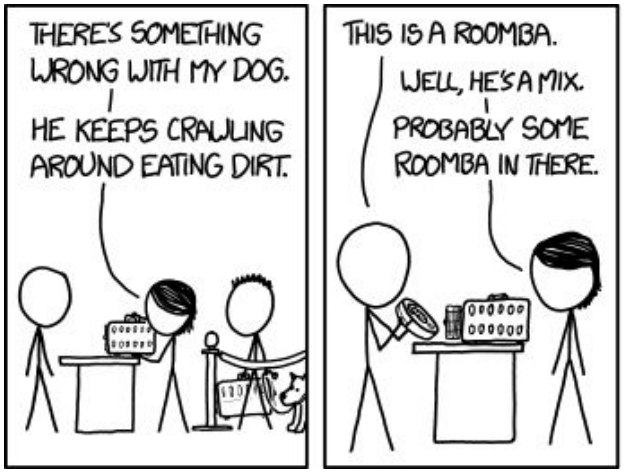
Cons:

- x Knowledge-intensive reasoning
- x Subject to noise (movements)
- x Data hungry (labelled data)
- x Highly task-specific

Our Research Question

Can symbolic AI help robots to improve

- adaptivity
- situation-awareness
- complex meaning capturing?



https://xkcd.com/1558/

Some examples: Adaptation

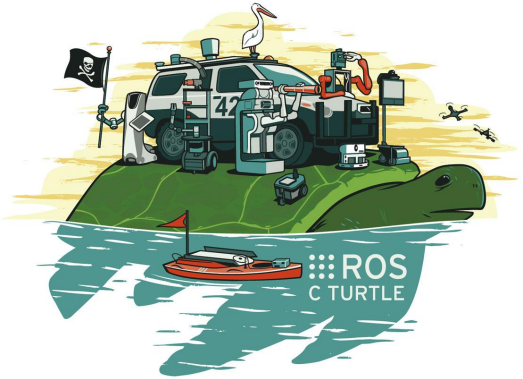
Adapting to Robot Capabilities

Robots became more popular:

- New users approach
- interest in high-level capabilities (speech, navigation, vision…)

How to help them reducing development costs ?

- Can we use ontologies?
- They allow interoperability and domain abstraction



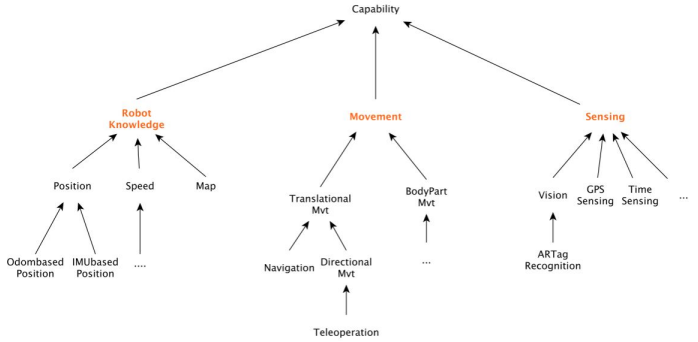
[2] Tiddi et al. (2017) *An ontology-based approach to improve the accessibility of ROS-based robotic systems. KCAP2017,*

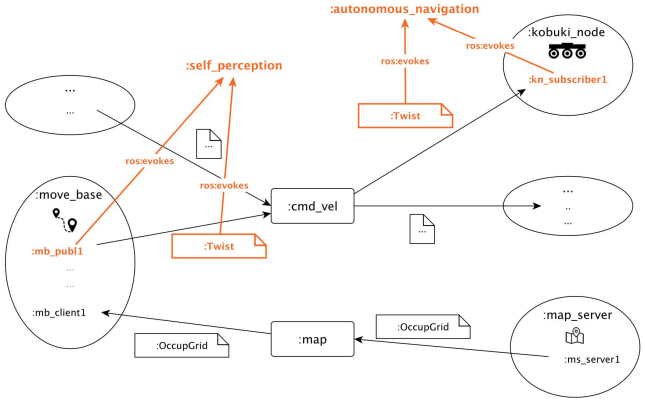
Adapting to Robot Capabilities

An ontology-based approach to abstract ROS architectures:

- Taxonomy of high-level capabilities
- Description of robot components in a KG
- Map robot components to capabilities

Allow reasoning on the capabilities of any robot





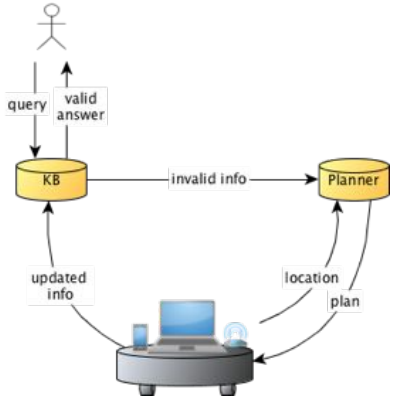
[2] Tiddi et al. (2017) *An ontology-based approach to improve the accessibility of ROS-based robotic systems. KCAP2017,*

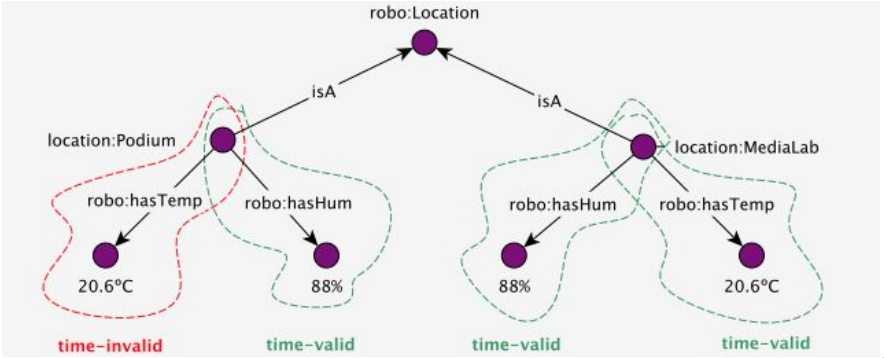
Updating Outdated Knowledge Bases

Goal : adapt robot planning based on temporal contexts

A KR-based framework to assess time-validity efficiently

- a mobile sensor for updates
- at query time
- time-stamped triples
- SPARQL language





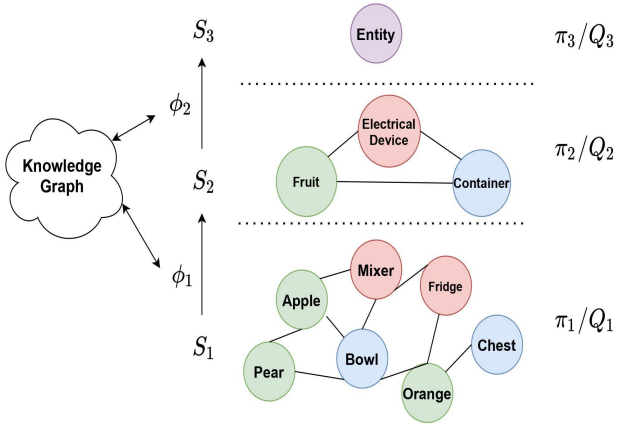
[3] Tiddi et al. (2016) *Update of time-invalid information in Knowledge Bases through Mobile Agents. Mirror Workshop@IROS2016,*

Some examples: Prior Knowledge

Knowledge Graphs as (Robot) Prior Knowledge

Improving generalisation and sample efficiency of RL agents:

- Classes = aggregation of common objects
- Open-source KGs include subclass relations



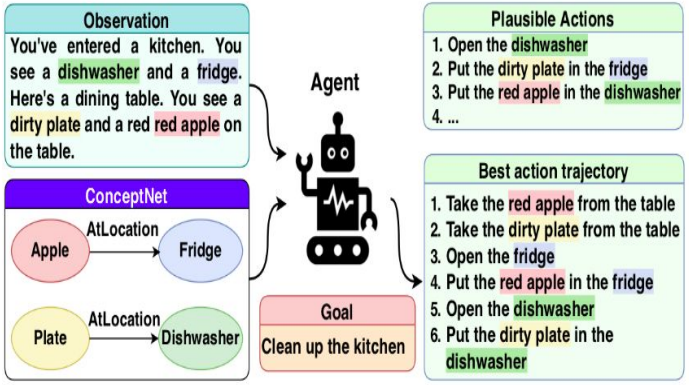
Method:

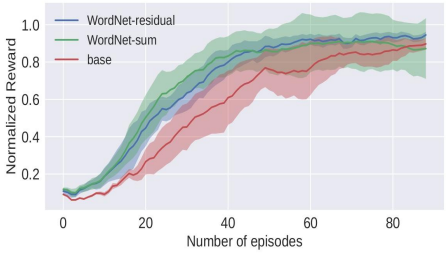
- Extract a subclass tree from a KGs
- Learn a policy that leverages the abstract states

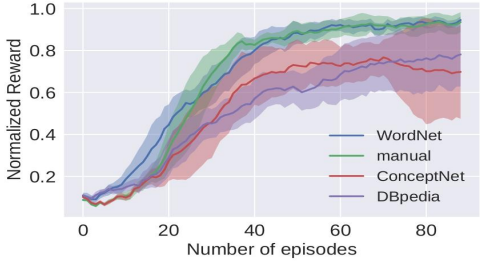
[4] *Hôpner et al.* (2022). ***Leveraging class abstractions for commonsense reinforcement learning via residual policy gradient methods*** (Under review).

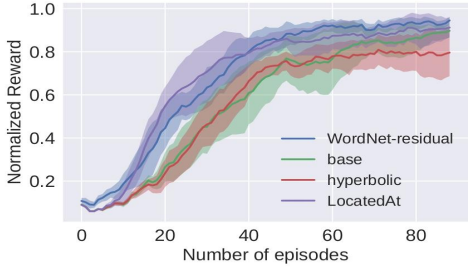
Knowledge Graphs as (Robot) Prior Knowledge

- Text-based common-sense games
- 3 settings (basic, noisy, ambiguous)
- 2 policy methods (sum-, residual-based)
- 3 KGs (ConceptNet, DBpedia, WikiData)





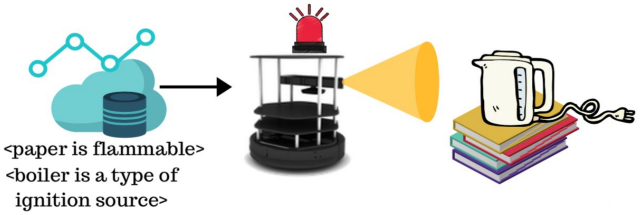


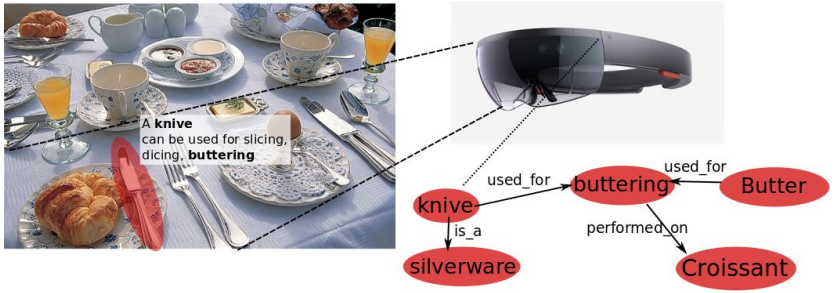


[4] *Hôpner et al.* (2022). ***Leveraging class abstractions for commonsense reinforcement learning via residual policy gradient methods*** (Under review).

Knowledge Graphs as (Robot) Prior Knowledge

- End-to-end object recognition is limited
- KGs provide prior knowledge about shapes and colours (ShapeNet+WordNet)
- Can we augment DL with commonsense KGs for robotic tasks?





Approach	Known				Novel				Mixed			
	A	P	R	F1	A	P	R	F1	A	P	R	F1
Baseline NN	0.76	0.91	0.76	0.79	0.84	0.93	0.84	0.85	0.80	0.85	0.80	0.79
N-net [25]	0.70	0.97	0.70	0.78	0.74	0.83	0.74	0.75	0.72	0.79	0.72	0.72
K-net [25]	0.76	0.94	0.76	0.81	0.70	0.78	0.70	0.73	0.78	0.73	0.73	0.73
SiamResNet50 [10] [8]	0.76	0.91	0.76	0.79	0.84	0.93	0.84	0.85	0.78	0.83	0.78	0.77
Imprinted K-Net	0.74	**0.98**	0.74	0.82	0.80	0.86	0.80	0.82	0.77	0.83	0.77	0.77
L2norm L1 SiamResNet50	**0.80**	0.91	**0.80**	**0.83**	**0.84**	**0.95**	**0.84**	**0.87**	**0.82**	**0.86**	**0.82**	**0.81**

[5] *Chiatti et al.* (2020) *Task-agnostic Object Recognition for Mobile Robots through Few-shot Image Matching.* Journal of Electronics.

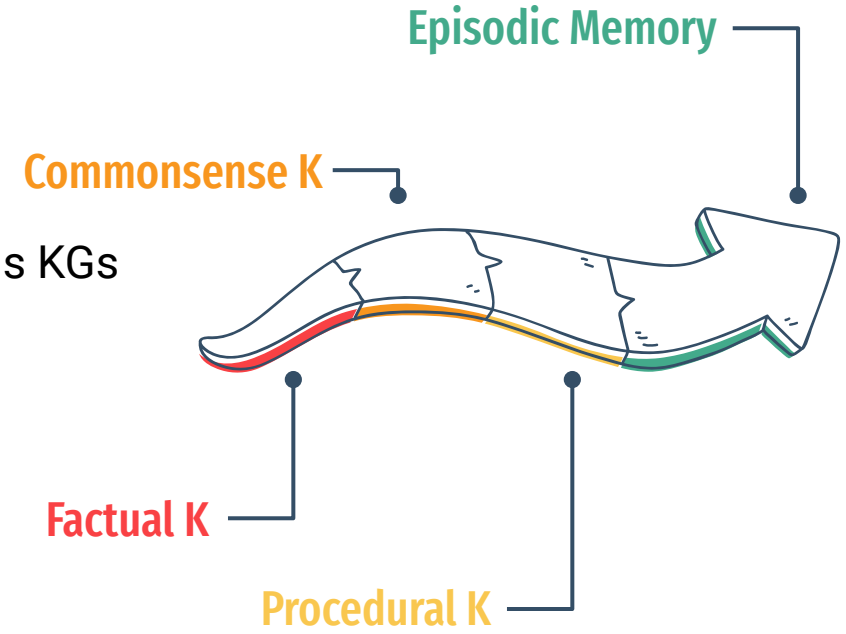
Knowledge Graphs to close the Reality Gap?

Robots operating in the real world are brittle (reality gap).

How much can KGs help?

1. store facts as KGs
2. learn commonsense from heterogeneous KGs
3. model procedures at scale
4. build episodes as memories

Evaluate the gap for each type of knowledge



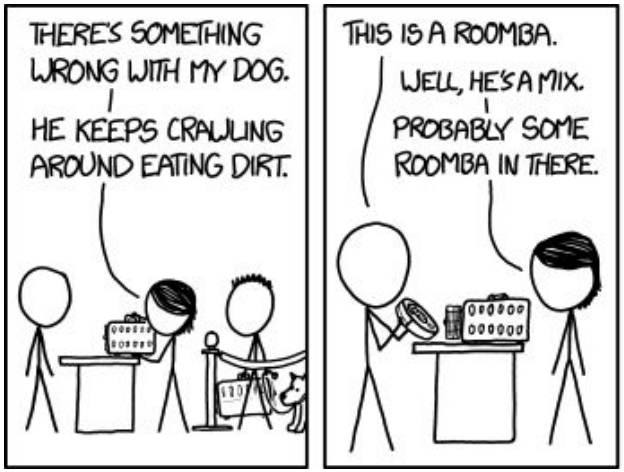
[6] *Adamik M.* (2022, early-stage PhD) Knowledge-aware robots.

Wrapping Up

Our Research Question

Can symbolic AI help robots to improve :

- Adaptivity
  → Ontology Engineering for task abstraction
- Situation-awareness
  → Context-based reasoning through Knowledge Management
- Capturing complex meaning
  → Knowledge Graphs as prior knowledge



https://xkcd.com/1558/

Knowledge scientists for intelligent robots

Role : create reliable data (meaningful, explainable, reproducible, maintainable)

Achieved

- ✓ Standardised : ROS framework operating on all platforms
- ✓ Maintained : up-to-date, community effort, reproducible
- ✓ Data in context: sourced, the rights to use it

Not there yet

- ❌ Clean : well defined schemas
- ❌ Shared meaning : shared understanding, human-understandable

Open Challenges

1. **Fusion**: multi-modal knowledge (KGs+sensors)
2. **Acquisition**: from heterogeneous sources
3. **Validation**: ensuring validity of the KG
4. **Access** : finding relevant info in KGs (e.g. spatio-temporal)
5. **Scalability**: large KGs vs. small-size processing units

Going Beyond : Hybrid Intelligent Robots (2020-2030)

Robots do not replace humans, but collaborate with them

- Explainable HI (data+knowledge-driven explanations)
- Adaptive HI (knowledge-based RL)
- Collaborative HI (shared theories of the world)
- Responsible HI (ethics-in-design)

Shameless plug

Interested? Join us at HHAI2022 (@hhai_conference)

VU Vrije Universiteit Amsterdam · TU Delft · UvA · university of groningen · Universiteit Leiden · Universiteit Utrecht

Thank you very much

Questions?

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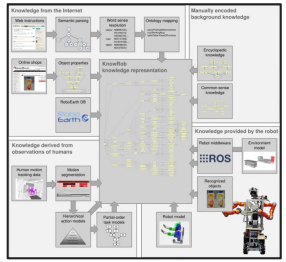
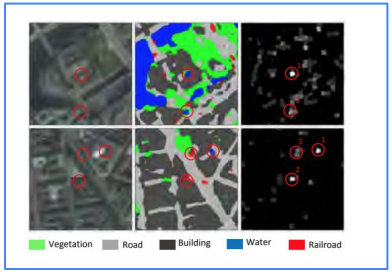
Stuff other people do…

- Robots as data consumers&contributors of **smart cities** (= KGs) : http://sciroc.eu
- **Online encyclopedic knowledge** for robots: http://knowrob.org
- KGs to **explain robots behaviours**:
  Alirezaie et al., 2018, A Symbolic Approach for Explaining Errors in Image Classification Tasks





What can I do with all this?

Stuff I did…

- Ontology-based techniques to **simplify robot control**

Tiddi et al., 2018, A User-friendly Interface to Control ROS Robotic Platforms
Tiddi et al., 2017, An ontology-based approach to improve the accessibility of ROS-based robotic systems

- Knowledge Graphs as **background knowledge** for robots

Chiatti et al., 2019, Exploring Task-agnostic, ShapeNet-based Object Recognition for Mobile Robots
Mensio et al., ongoing, Towards Explainable Language Understanding for Human Robot Interaction

- Robots to tackle the problem of **information dynamism** in KGs

Tiddi et al., 2016, Update of time-invalid information in Knowledge Bases through Mobile Agents
Tiddi et al., 2016, DKA-robo: dynamically updating time-invalid knowledge bases using robots