The Gap Between BDI Agents and Semantic Hypermedia and What We Can Do About It

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INTRODUCTION

Integrating Intelligent Agents and the Web has a renewed interest in the last years thanks to:

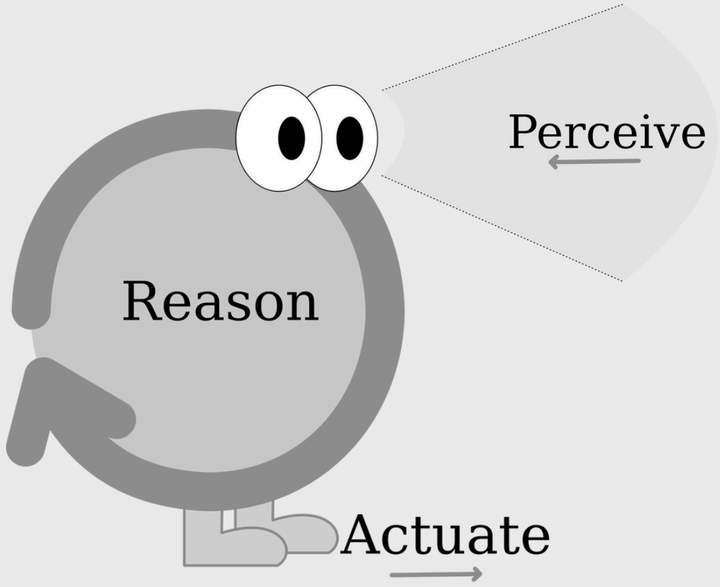
- **Semantic Web**
- **Web of Things** (**WoT**)
- **Hypermedia Multi-Agent System** (**hMAS**)
- LLM-based **Agentic AI** interacting with Web APIs

WHY BDI?

Despite new Agentic approaches being promising, **cognitive models** like BDI retain:

- **controllability** and **predictability**
- **logic reasoning** on semantic resources
- exploitation of existing **APIs**
- **explainable** behavior

BELIEFS, DESIRES, INTENTIONS (BDI) AGENTS



- **Beliefs**: agent's mental state + perception from environment
- **Desires**: motivational state of the system
- **Intentions**: deliberative state of the agent

- **Plans**: selected by **deliberation** process to pursue desires
- **Actions**: execution of one step of the selected plan

THE GAP

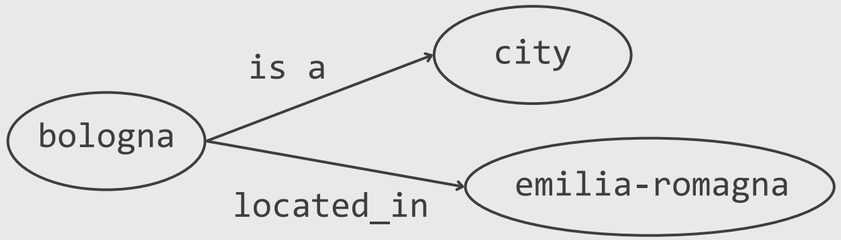
	Reference Logic Model	Possible Actions
BDI Agents	**Logic Programming**	**Pre-defined**
Semantic Web	**Description Logic**	**Discovered at Runtime**

THE GAP

	Reference Logic Model	Possible Actions
BDI Agents	**Logic Programming**	**Pre-defined**
	Gap 1	Gap 2
Semantic Web	**Description Logic**	**Discovered at Runtime**

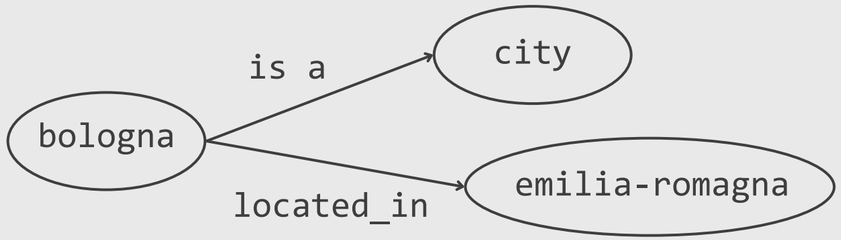
GAP 1 ANALYSIS:

SYNTACTICAL DIFFERENCES

BDI Agents	Semantic Hypermedia
Definite clauses	RDF Triples
`is(bologna, city).` `located_in(bologna, emilia-romagna).`	

GAP 1 ANALYSIS:

SYNTACTICAL DIFFERENCES

BDI Agents	Semantic Hypermedia
Definite clauses	RDF Triples
`city(bologna).` `region_of(bologna, emilia_romagna).`	

GAP 1 ANALYSIS:

ONTOLOGICAL INFERENCE

BDI Agents	Semantic Hypermedia
Definite clauses are **NOT** meant for being accessesed remotely	OWL Ontologies **standardize knowledge** across hypermedia documents
Agent A: is(bologna, city). **Agent B:** city(bologna)	**@prefix hh: <http://example.org/cities#> .** :bologna a ct:City .

GAP 1 ANALYSIS:

QUERYING

BDI Agents	Semantic Hypermedia
Selective Linear Definite clause resolution	**SPARQL**

`?- located_in(X, emilia_romagna), city(X).`	`SELECT ?city WHERE {`
	`  ?city a ct:City ;`
	`  ct:locatedIn ex:EmiliaRomagna .`
	`}`

GAP 2 ANALYSIS:

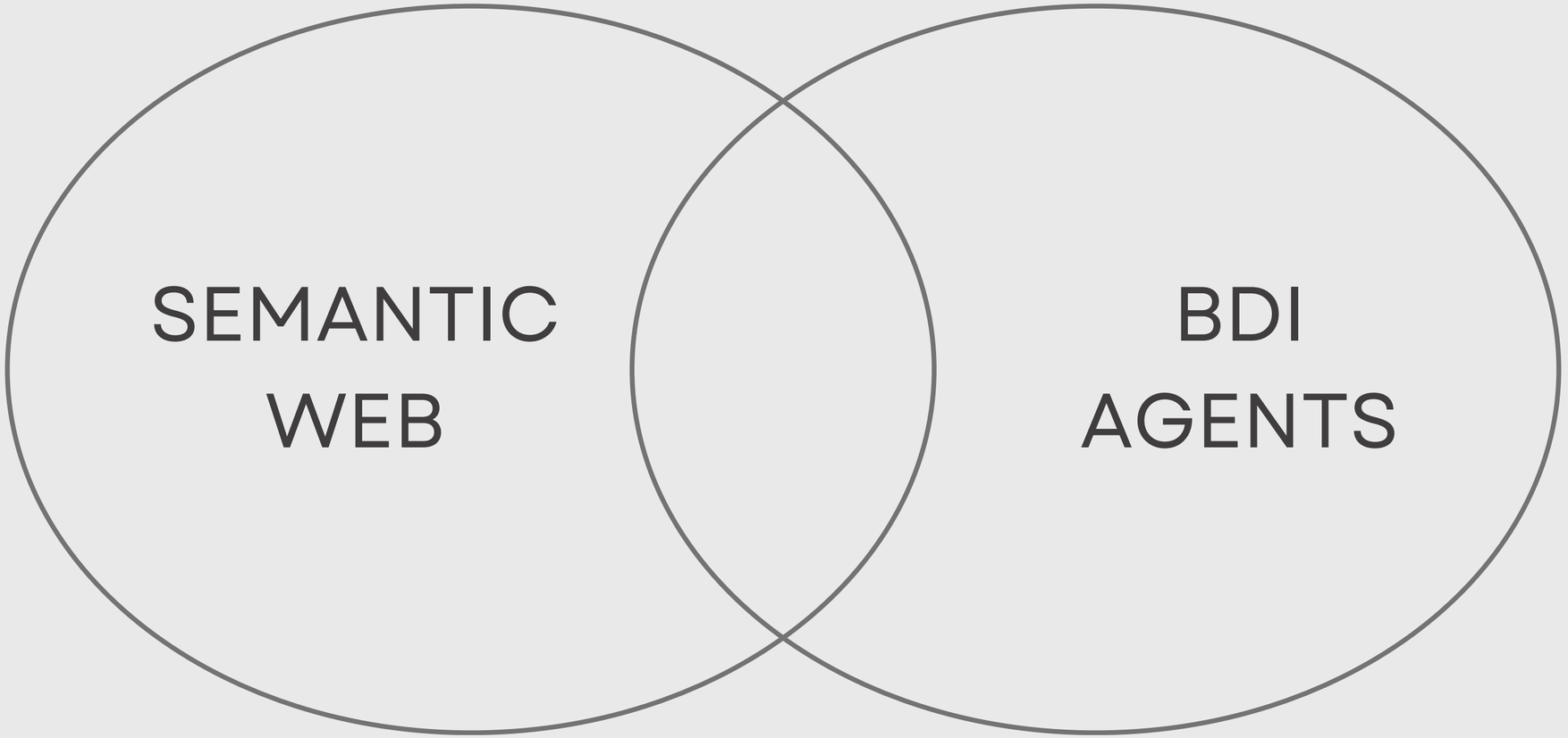
ENVIRONMENT

BDI Agents	Semantic Hypermedia
Close	Open
Predefined set of plans that **anticipates** the relevant **possible settings** an agent may encounter and provides plans to handle them.	Agents may **discover** new affordances **while navigating** through the hypermedia environment (HATEOAS)

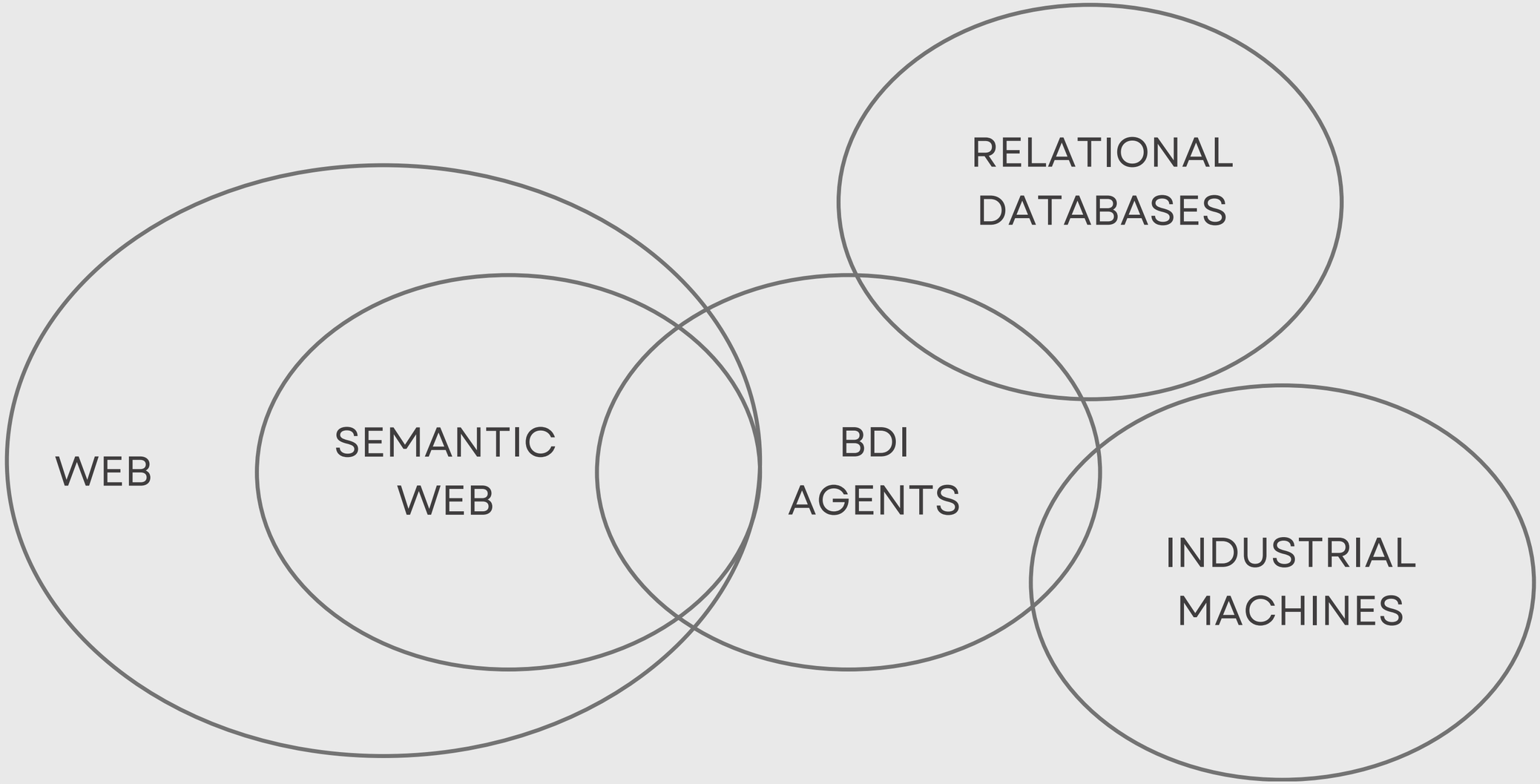
INTEGRATION REQUIREMENTS

1. **Direct manipulation of** RDF and OWL **triples** in the agent's belief base
2. **Ontological inference** for deliberation (e.g., plan selection and execution)
3. **Querying** the belief base via **SPARQL**
4. Ability to exploit **affordances** discovered in the environment to dynamically **adapt** the agents' plans.

ZOOMING OUT



ZOOMING OUT


RELATIONAL
DATABASES
WEB
SEMANTIC
WEB
BDI
AGENTS
INDUSTRIAL
MACHINES

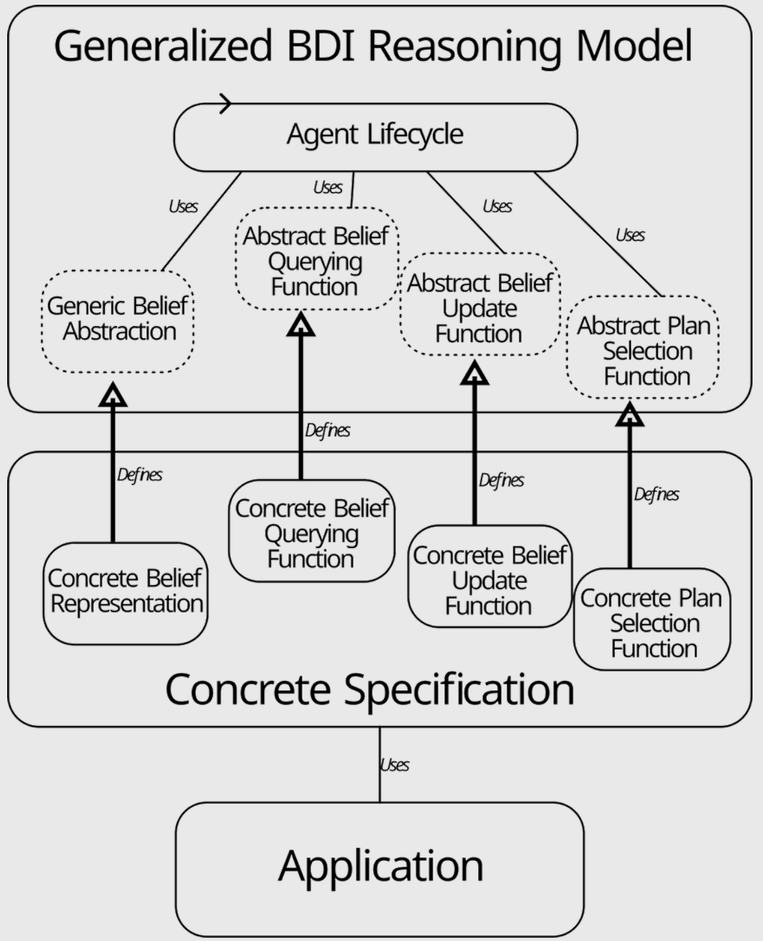
PROPOSAL

- A ***generic* BDI interpreter** decoupling:
  - knowledge representation
  - knowledge manipulation
- Decoupling Logic contructs from BDI is complex, because they are deeply intertwined.
  - Each specialization of the generic BDI interpreter would rely on a custom **matching** strategy

PROPOSAL

Layered Architecture:

- **Layer 1**: common implementation of BDI agent *deliberation* process *agnostic* to how beliefs and goals are represented and manipulated.
- **Layer 2**: provides belief and goal representations and *matching* operations.
- **Layer 3**: application layer, defined to tackle some specific use case.



WHAT ABOUT ADAPTABILITY?

If you’re staying for the main conference check out:

M454 Exploiting GenAI for Plan Generation in BDI Agents
Giovanni Ciatto, Gianluca Aguzzi, Riccardo Battistini, Martina Baiardi, Samuele Burattini and Alessandro Ricci

Multi-Agent System #4
Wednesday, October 29th - 11am
Turchese

THANK YOU