Knowledge Representation: Description Logics

Introductory Lecture

Enrico Franconi

franconi@inf.unibz.it
http://www.inf.unibz.it/~franconi

Faculty of Computer Science, Free University of Bozen-Bolzano

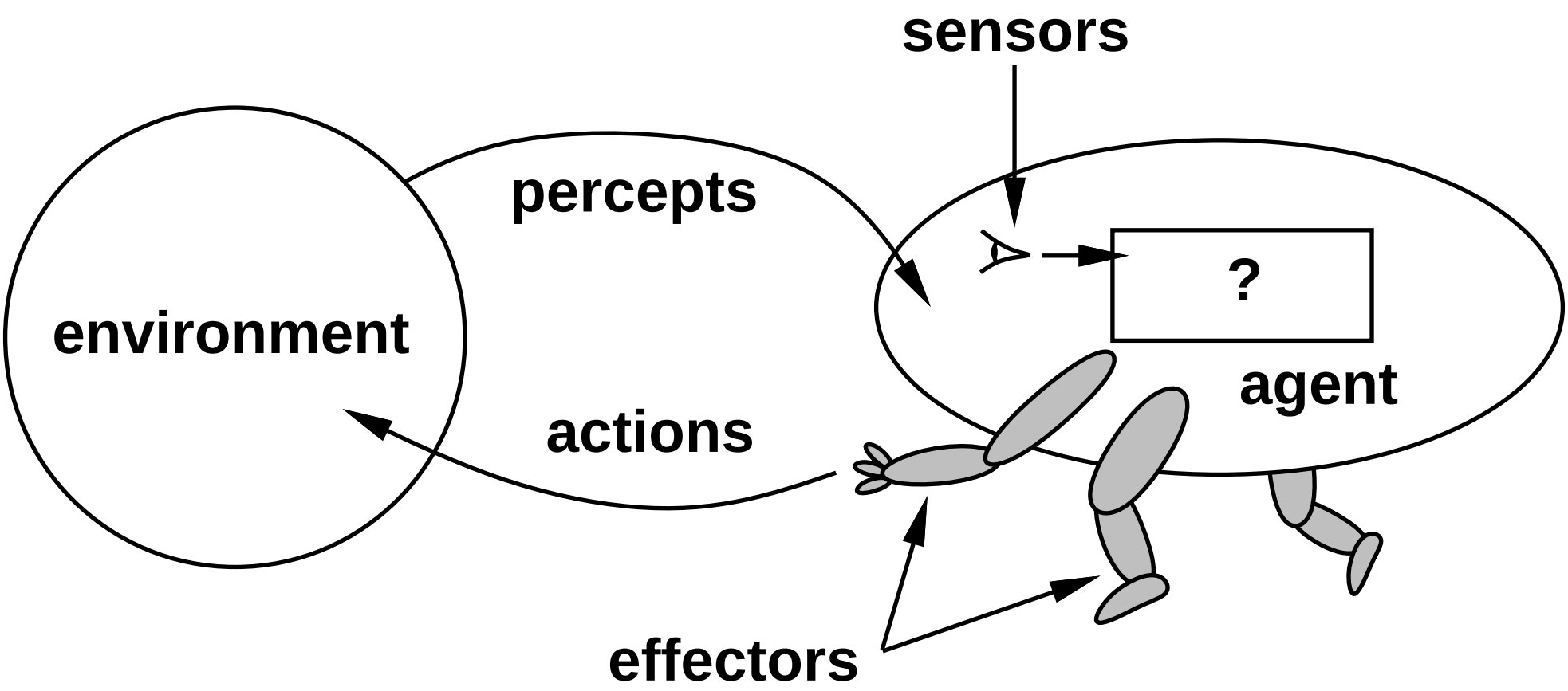
Administrativia

- Home page:

  `http://www.inf.unibz.it/~franconi/dl/course/2004/`

  - Slides, lecture by lecture.
  - Downloadable reference articles.
- Textbook:
  - “Description Logic Handbook”, edited by F. Baader, D. Calvanese, D. McGuinness, D. Nardi, P.F. Patel-Schneider, Cambridge University Press, 2002
- Suggested book on logic:
  - “The Essence of Logic”, by John Kelly. Prentice Hall, 1997.
- Various scientific articles on the topic will be referenced during the course.

Systems $\Longleftrightarrow$ Agents



An agent

Consider, e.g., the task of designing an automated vehicle:

Percepts: video, accelerometers, gauges, engine sensors, keyboard, GPS, . . .

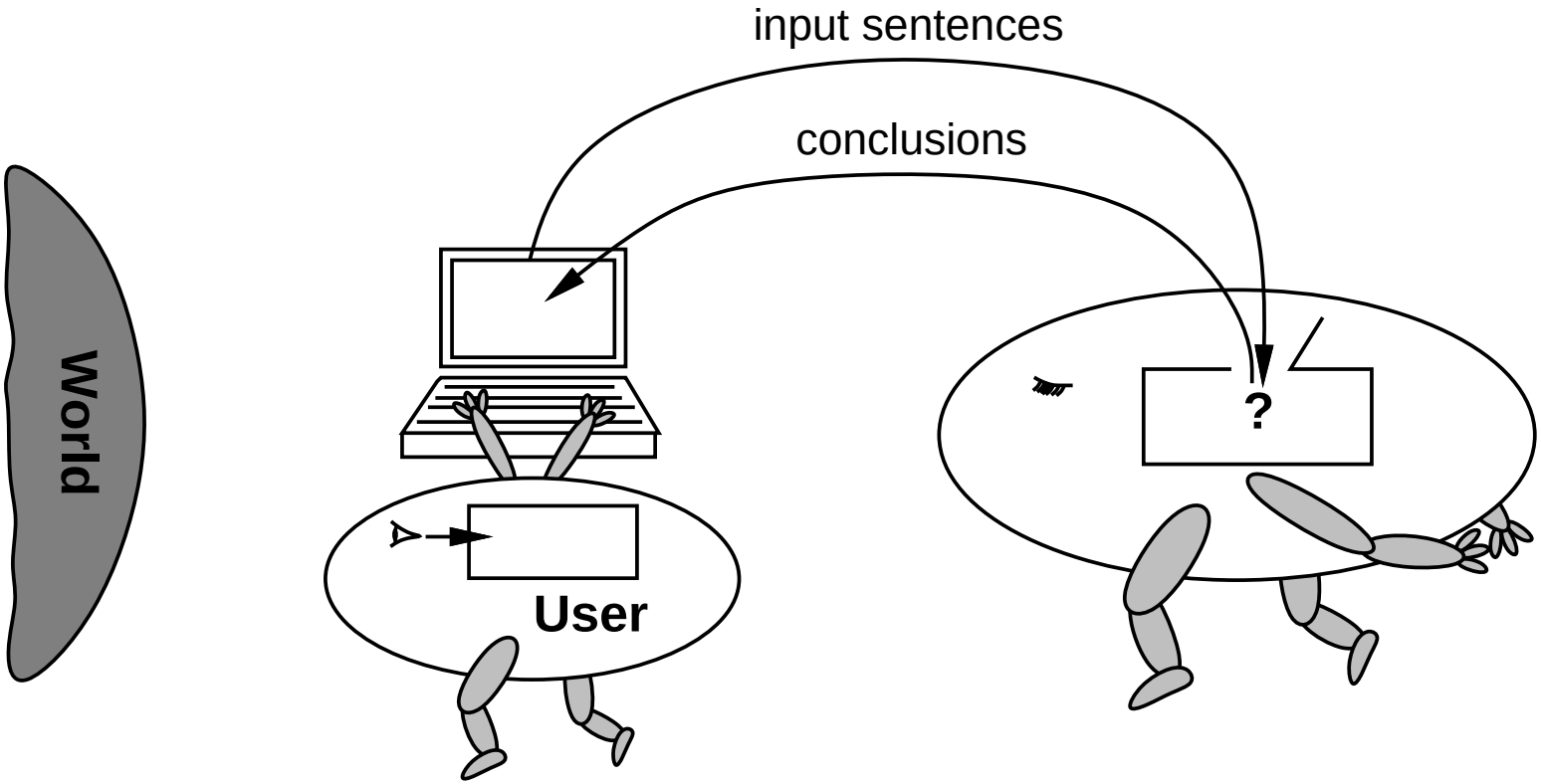
Actions: steer, accelerate, brake, horn, speak/display, . . .

Goals: safety, reach destination, maximize profits, obey laws, passenger comfort, . . .

Environment: US urban streets, freeways, traffic, pedestrians, weather, customers, . . .

Rational Agents

An Agent as Reasoning module of a Rational Agent.



Intelligent Agents

- An *Intelligent Agent* is an entity that perceives and acts according to an *internal declarative body of knowledge*.
- Abstractly, an agent is a function from percept histories and internal declarative knowledge to actions:

$$f : \mathcal{P}^* \times \mathcal{K} \rightarrow \mathcal{A}$$

For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

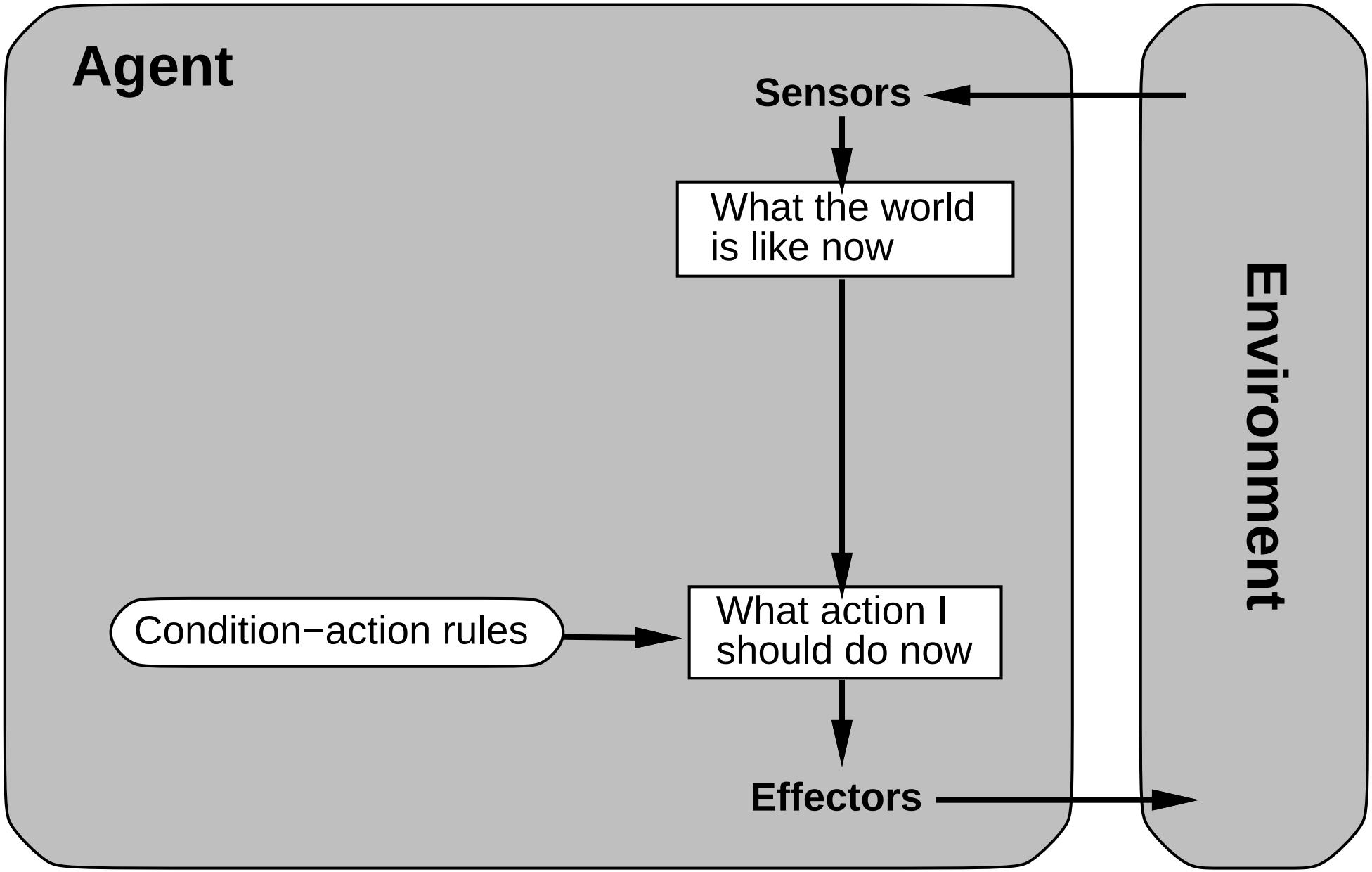
Intelligent Agents

- An *Intelligent Agent* is an entity that perceives and acts according to an *internal declarative body of knowledge*.
- Abstractly, an agent is a function from percept histories and internal declarative knowledge to actions:

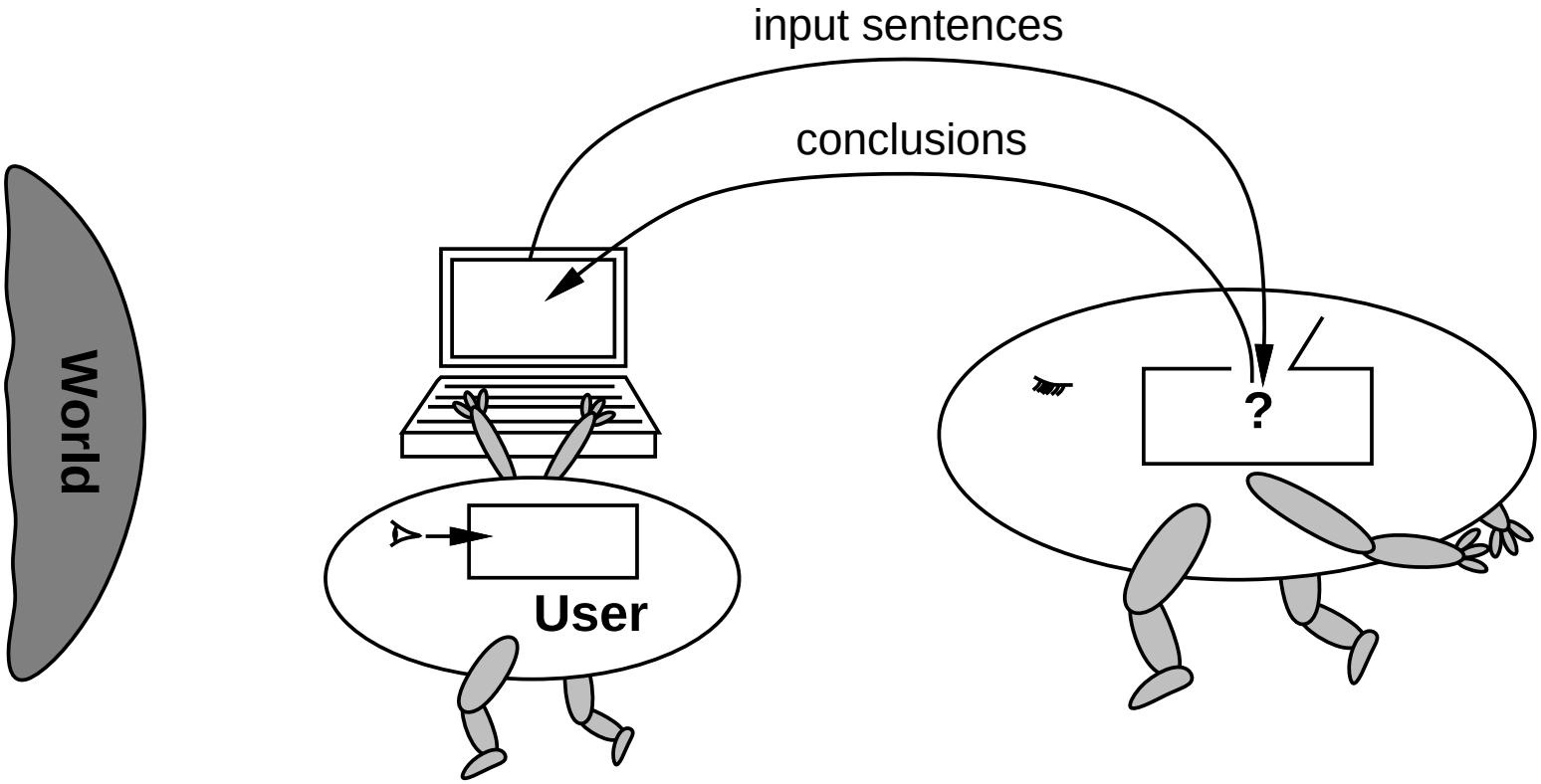
$$f : \mathcal{P}^* \times \mathcal{K} \rightarrow \mathcal{A}$$

  For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- An Intelligent Agent as *Representation and Reasoning* module: a **logic**.
- *Logic*: a well formalized part of agent *knowledge* and *reasoning*.

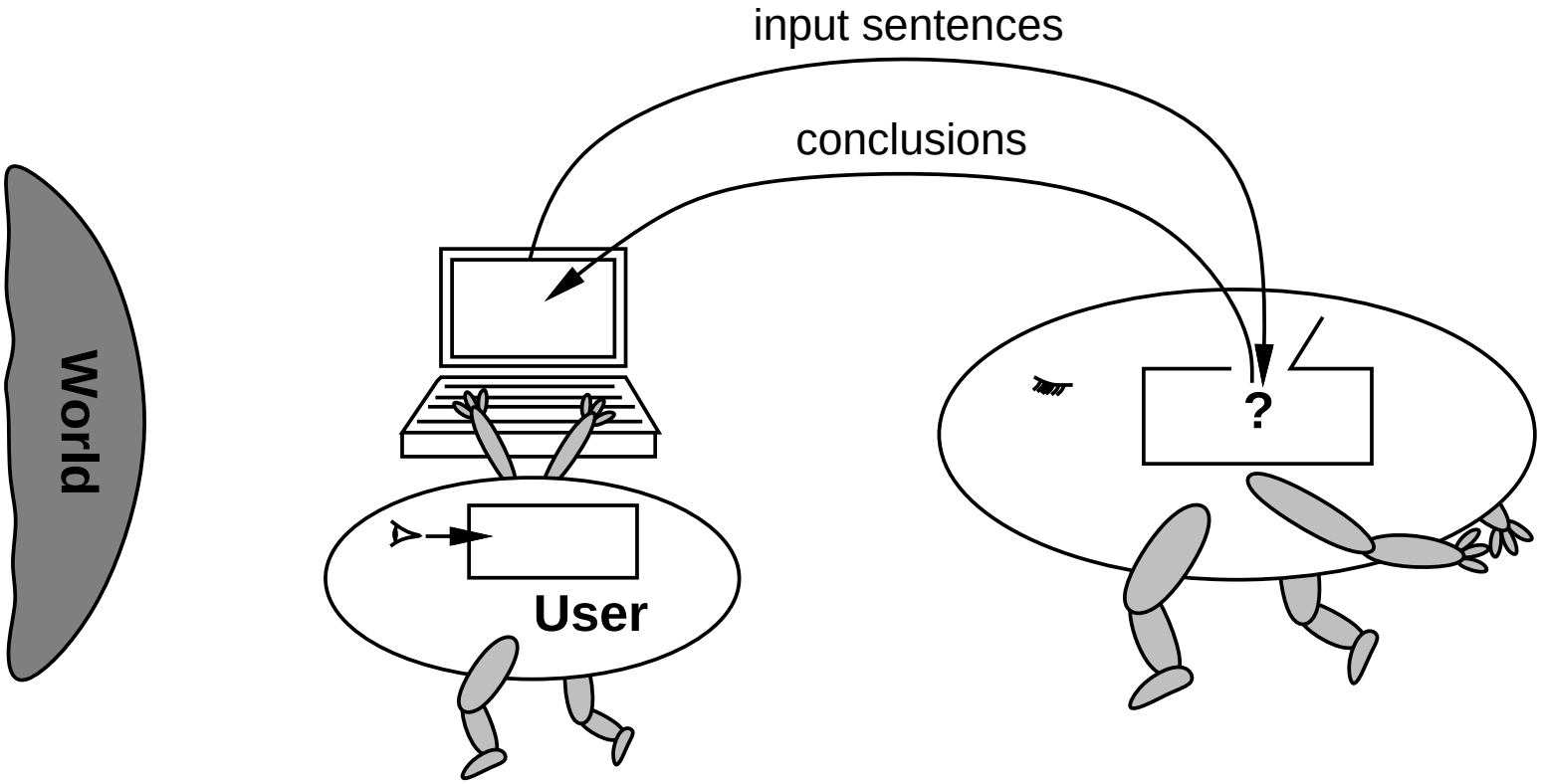
Non-Intelligent Agents: Reflex Agents



Intelligent Information Agents

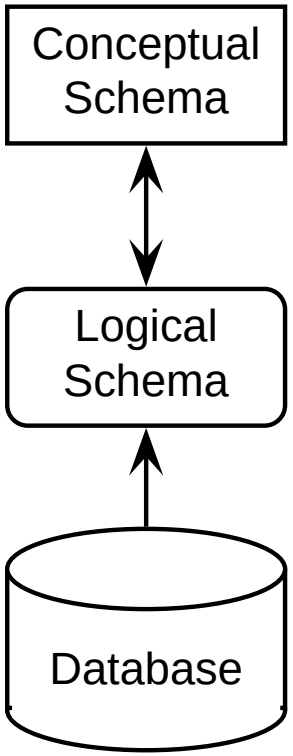


Intelligent Information Agents

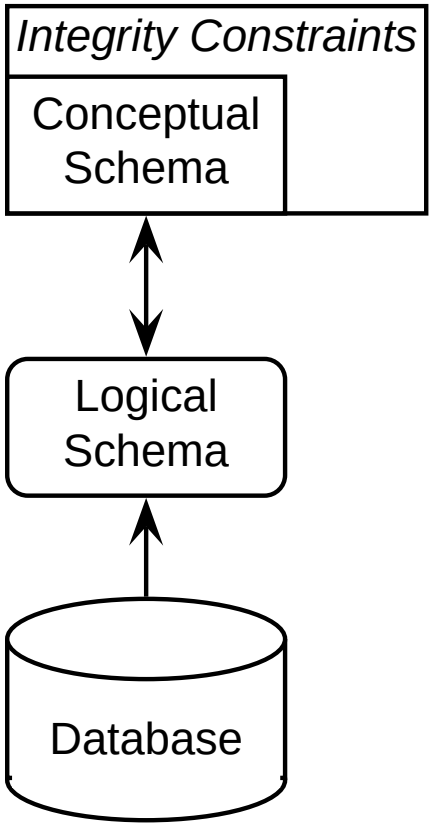


The goal of an *Intelligent Information Agent* is to manage, process, and access Information – e.g., a database system.

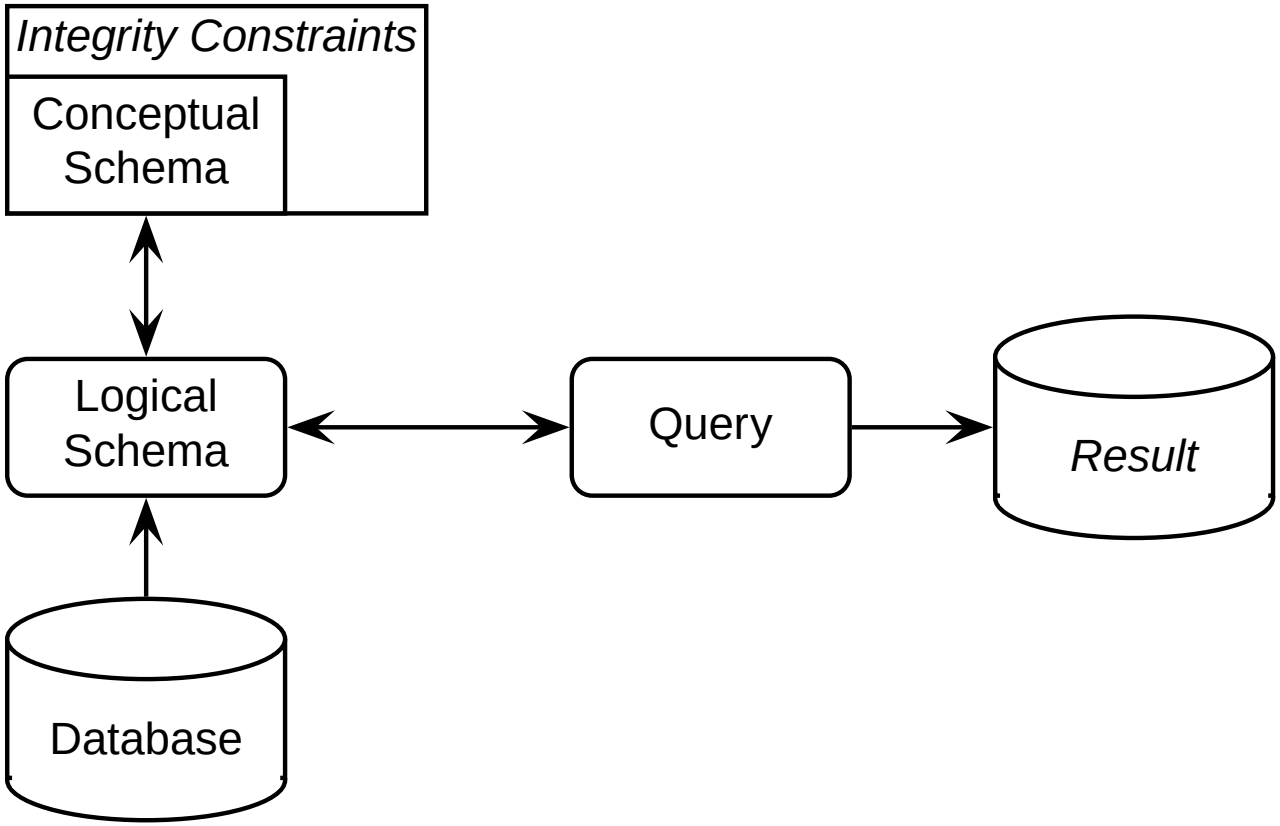
The Architecture of an Intelligent Information Agent



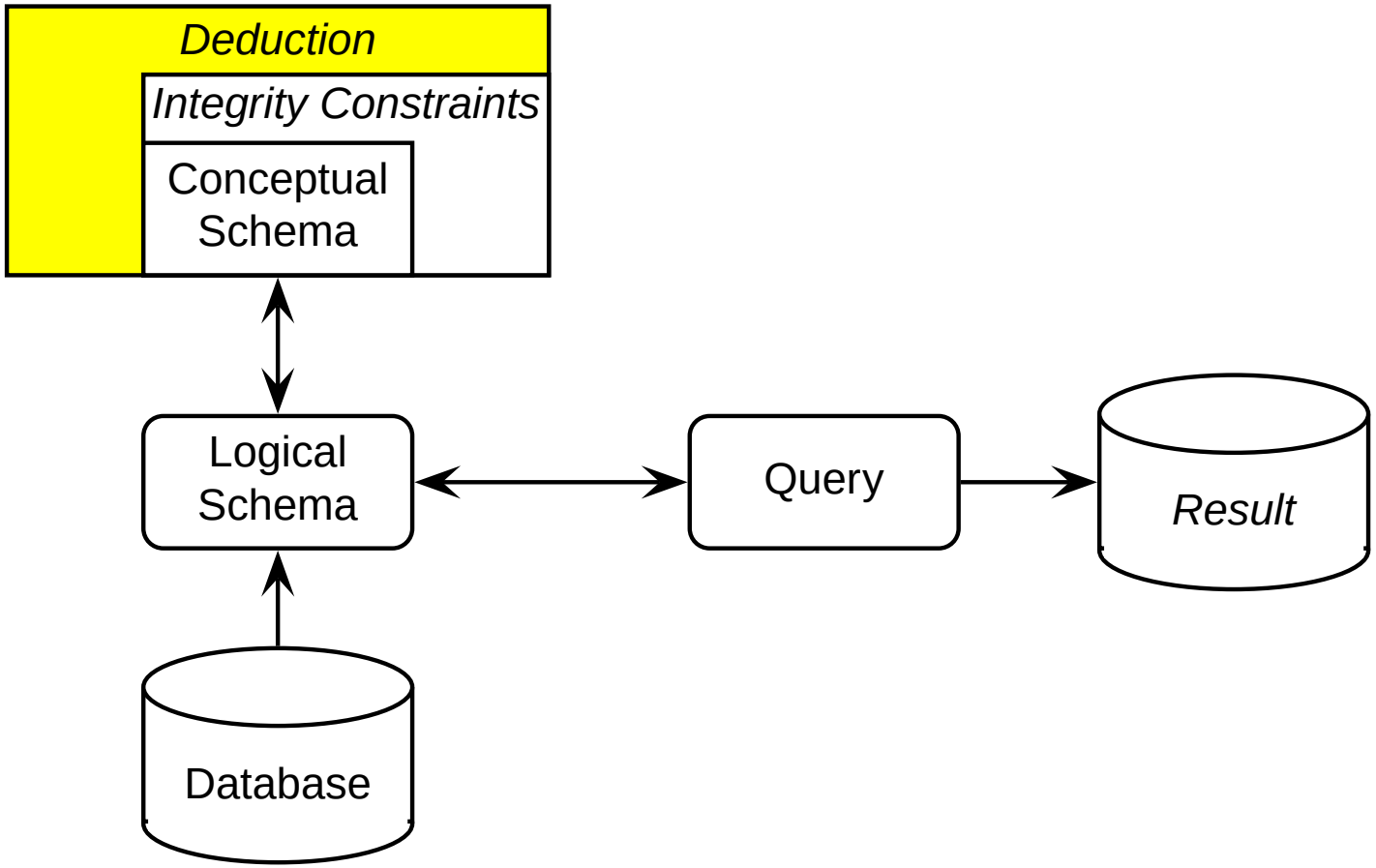
The Architecture of an Intelligent Information Agent



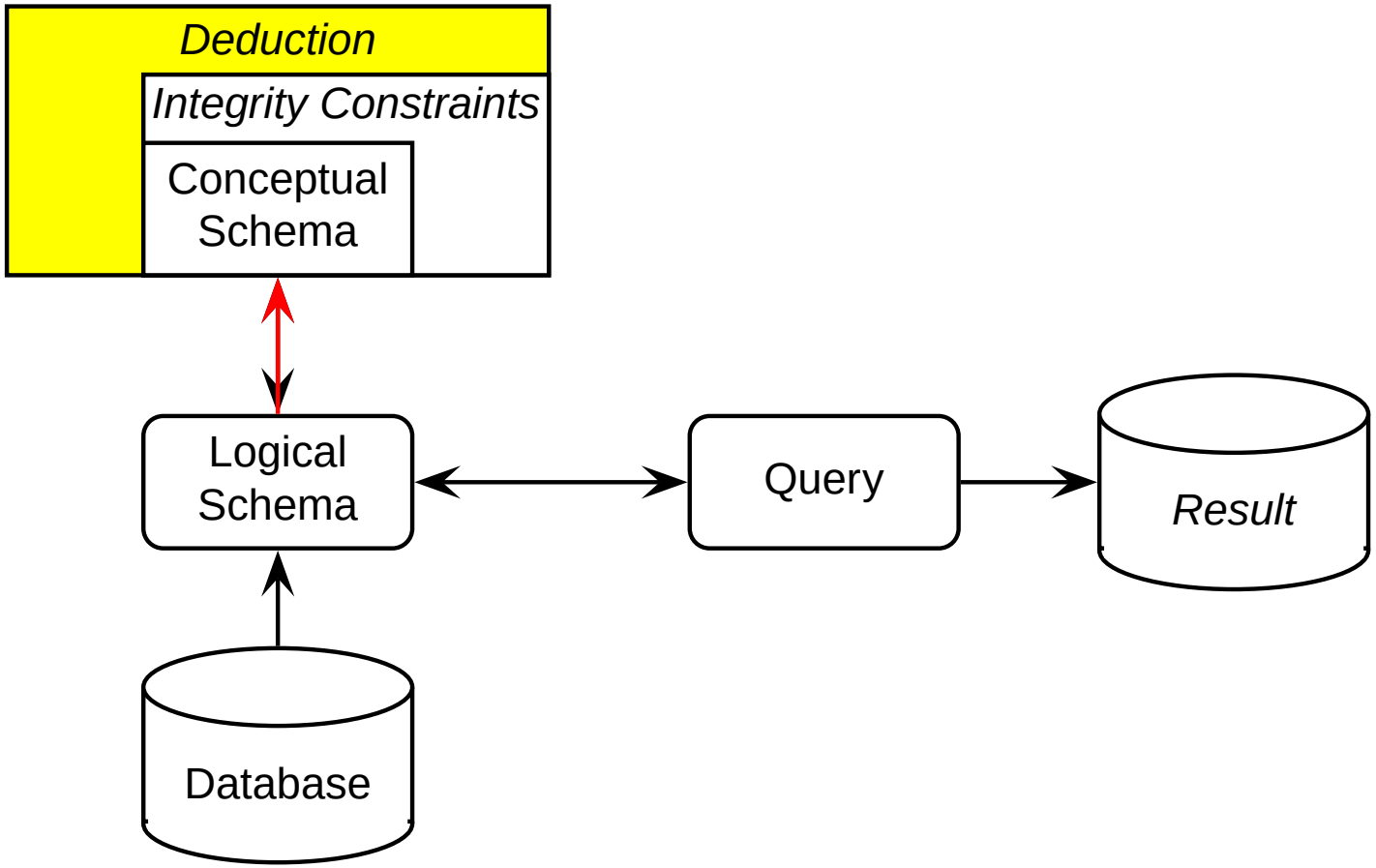
The Architecture of an Intelligent Information Agent



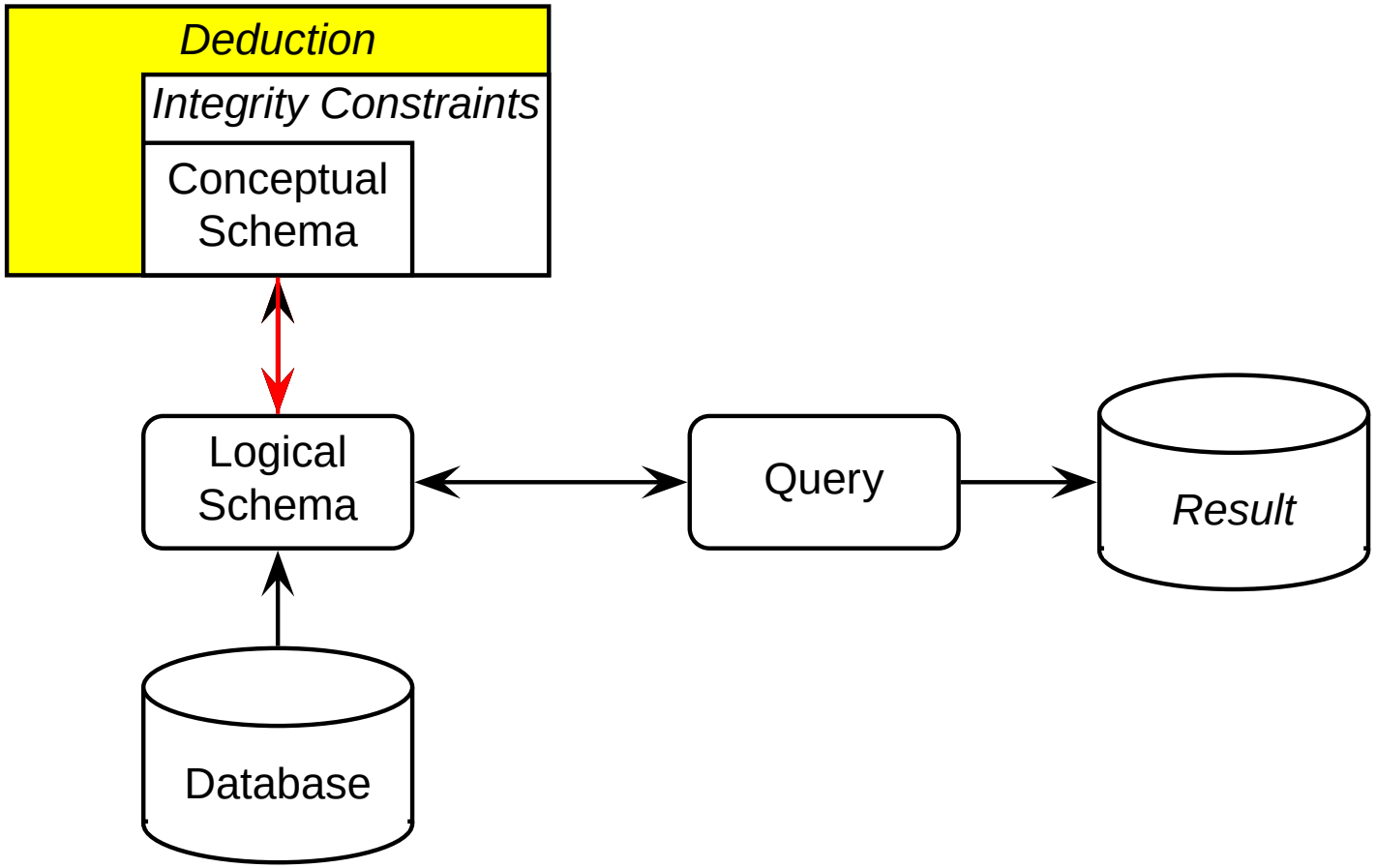
The Architecture of an Intelligent Information Agent



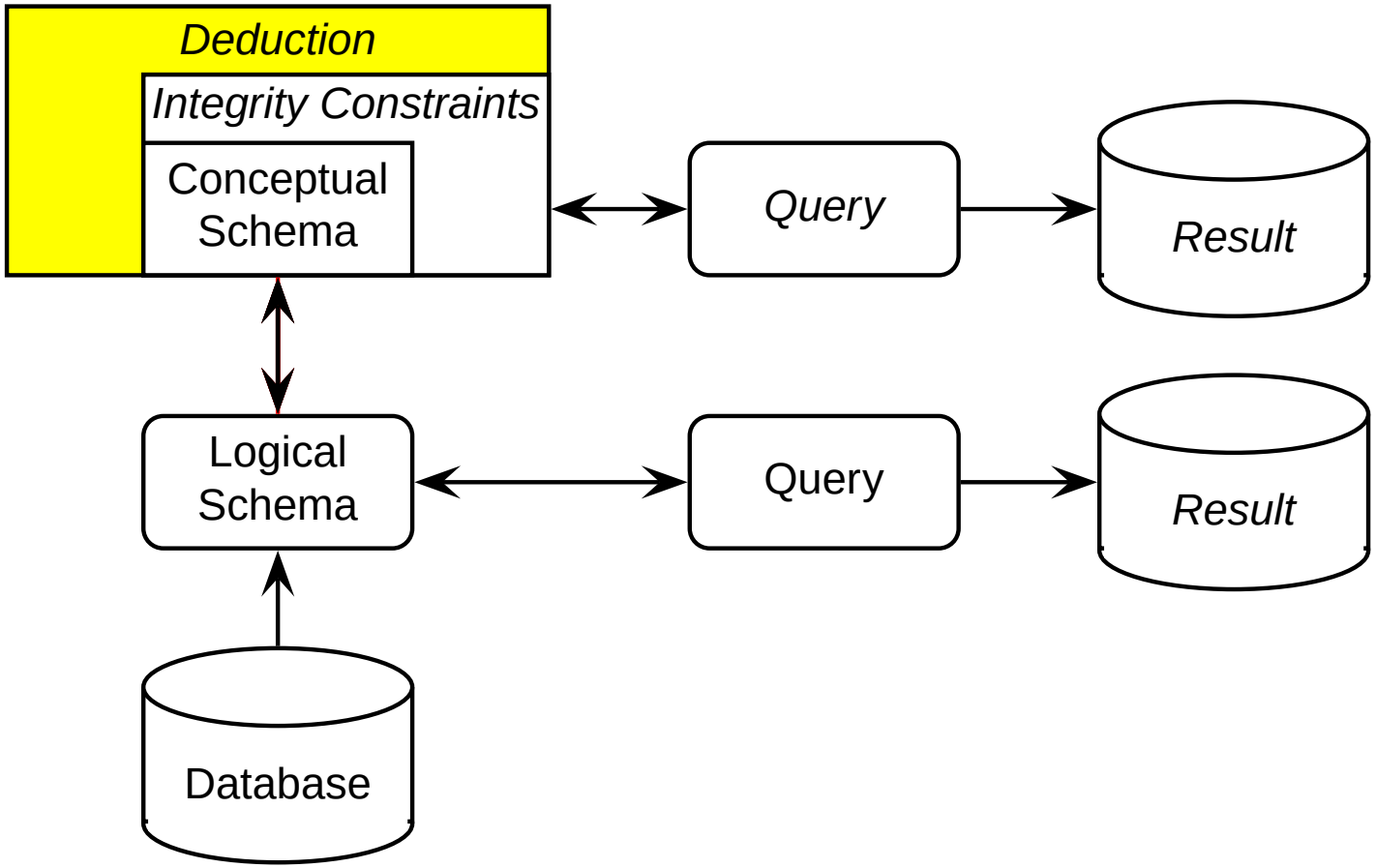
The Architecture of an Intelligent Information Agent



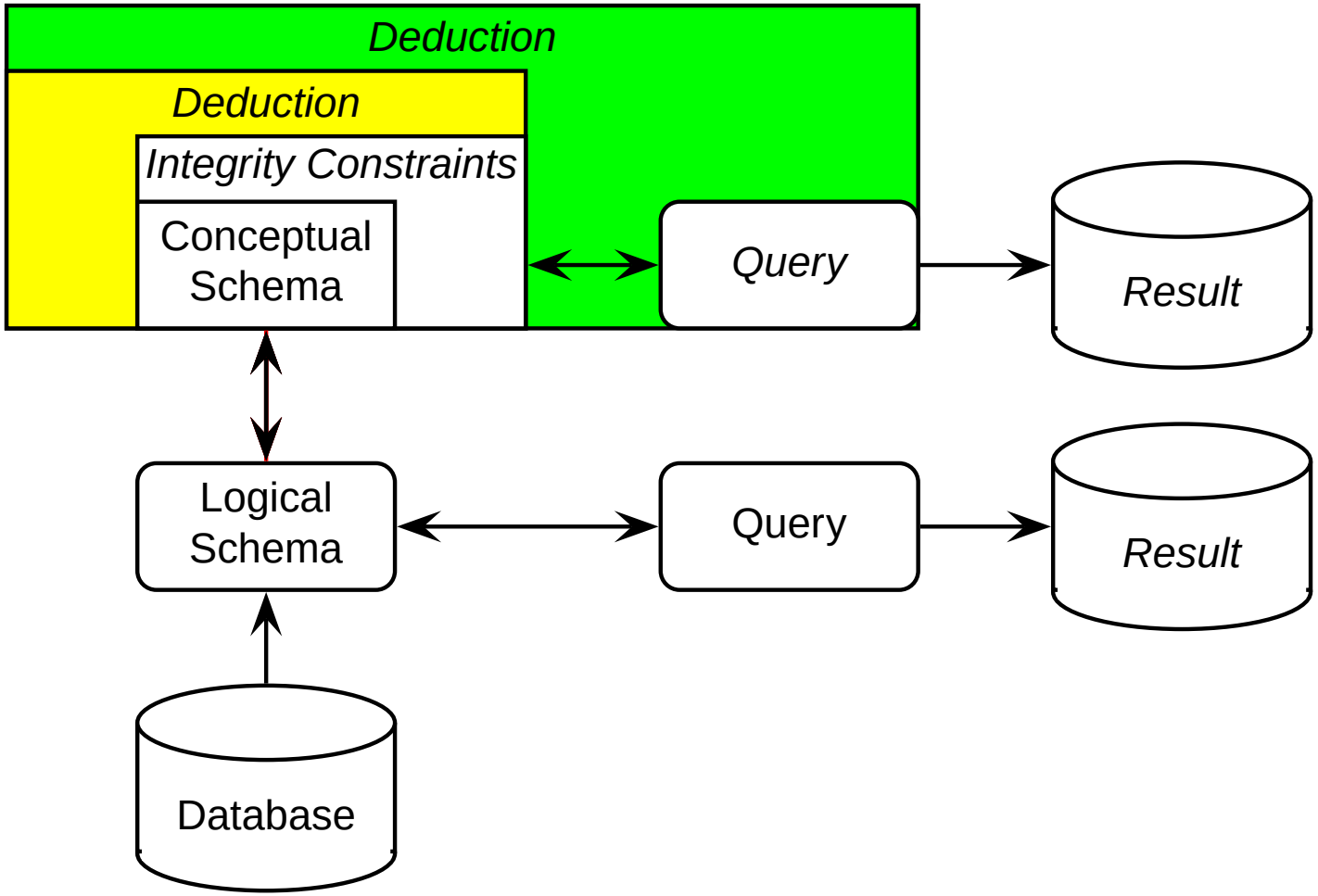
The Architecture of an Intelligent Information Agent



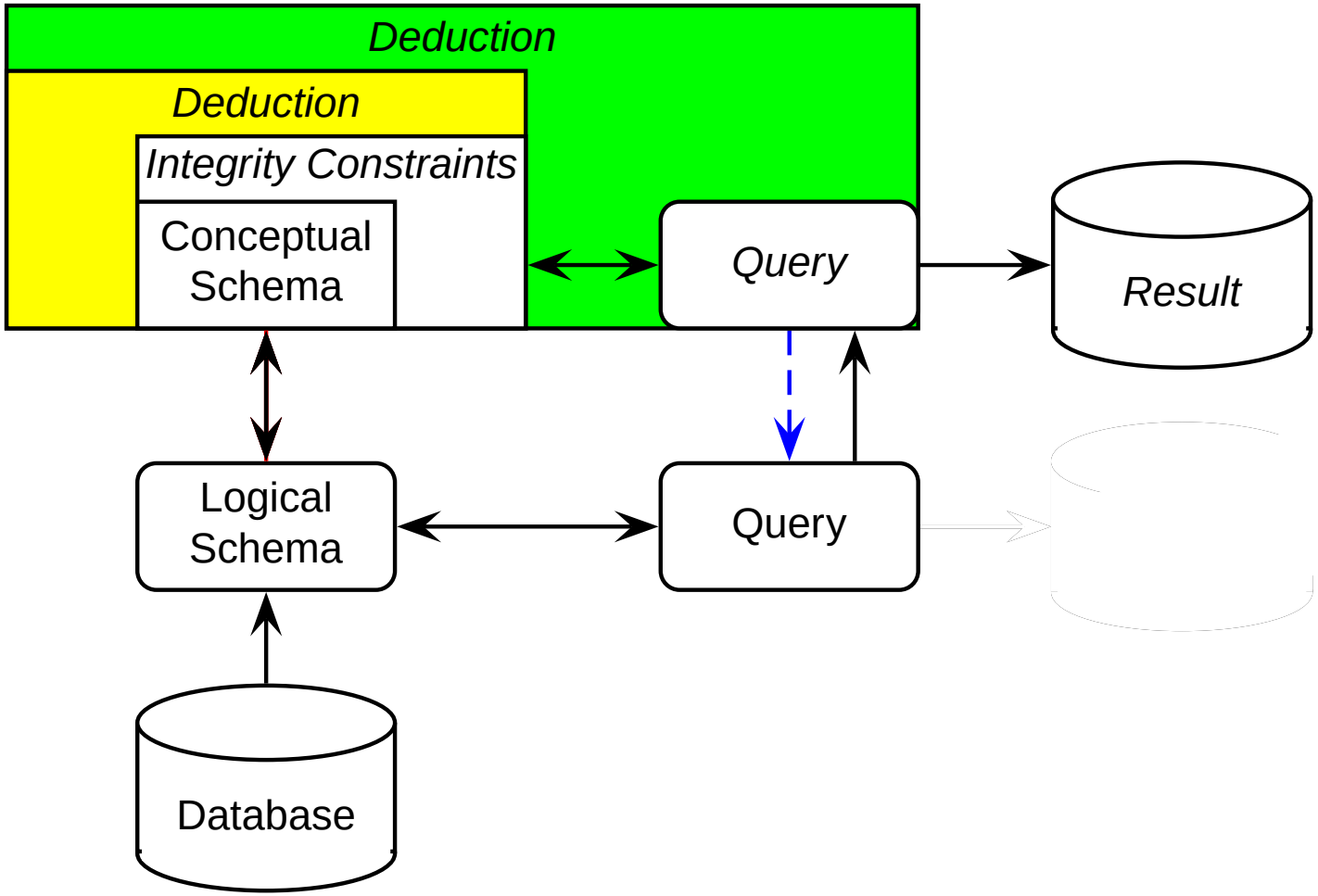
The Architecture of an Intelligent Information Agent



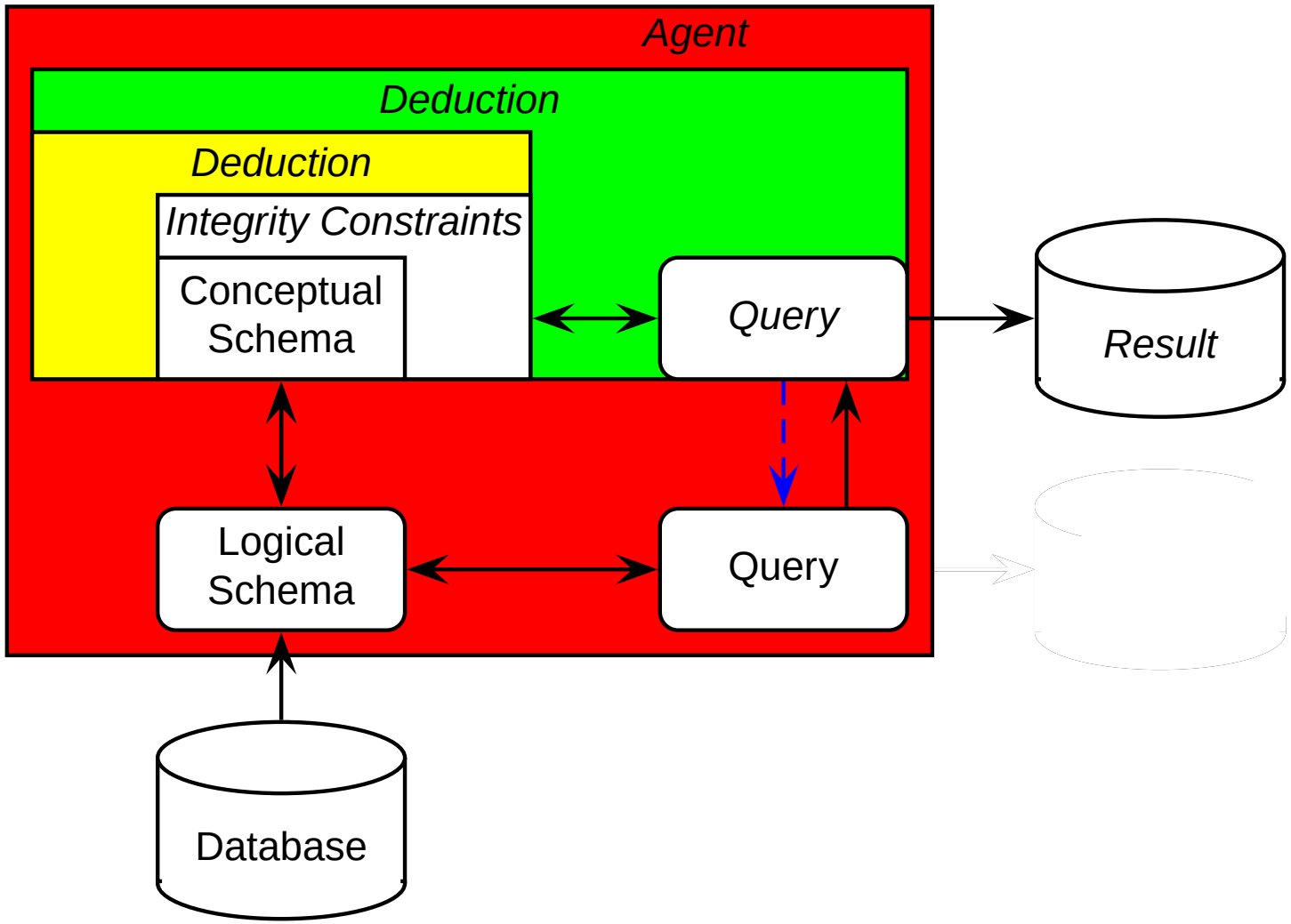
The Architecture of an Intelligent Information Agent



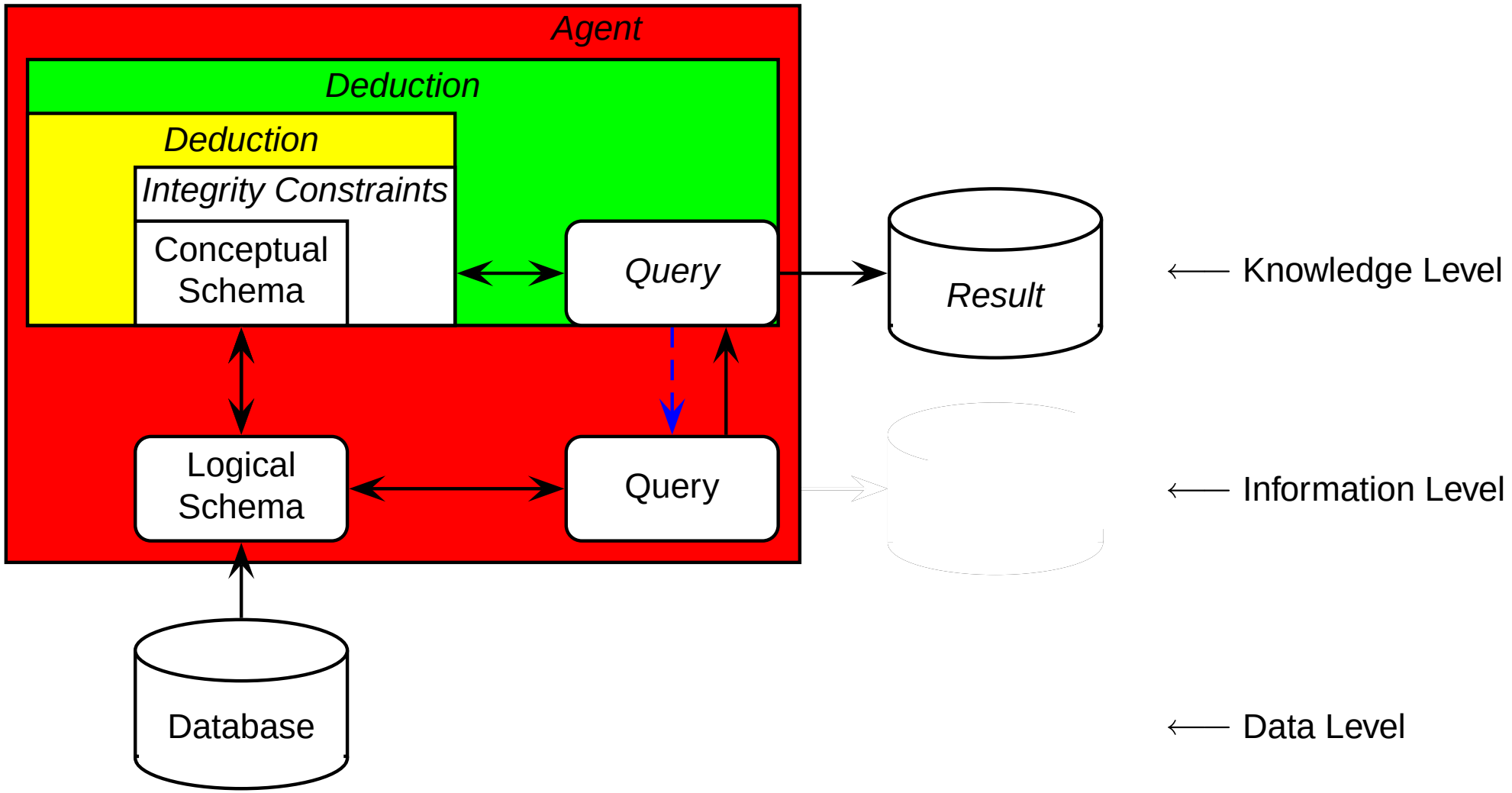
The Architecture of an Intelligent Information Agent



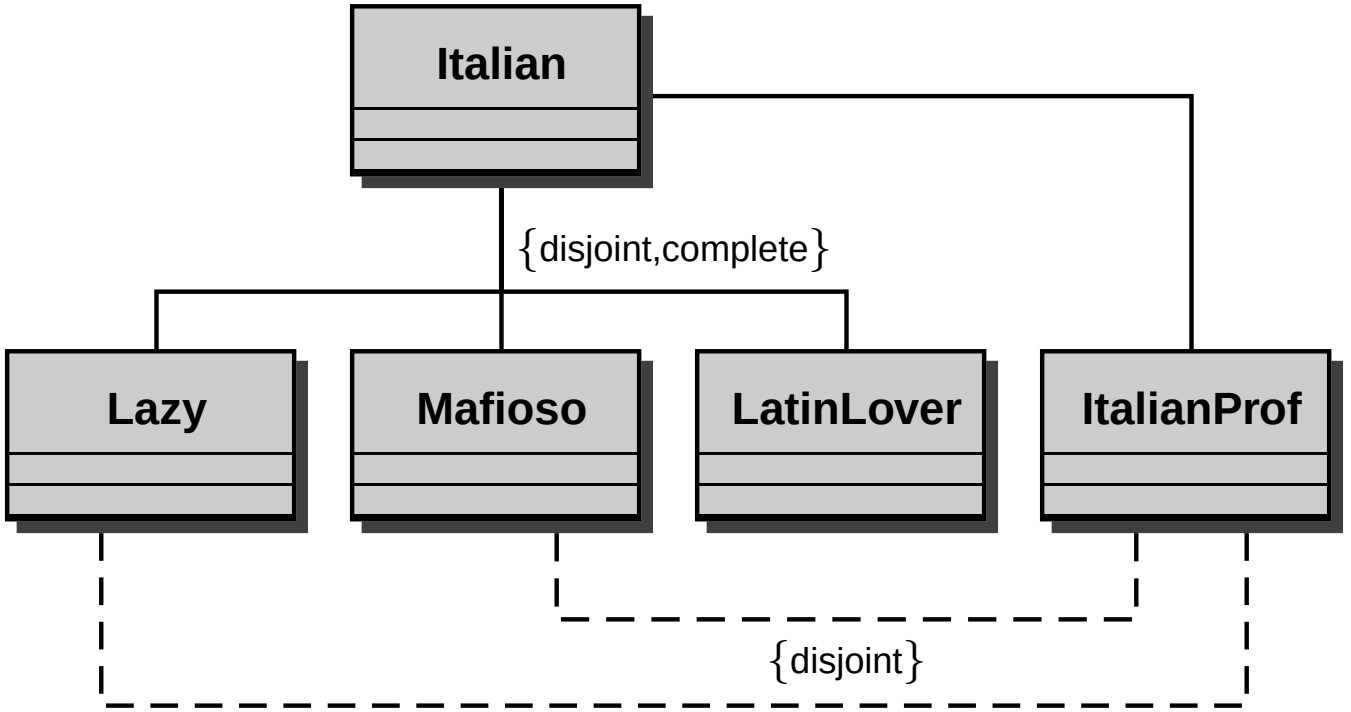
The Architecture of an Intelligent Information Agent



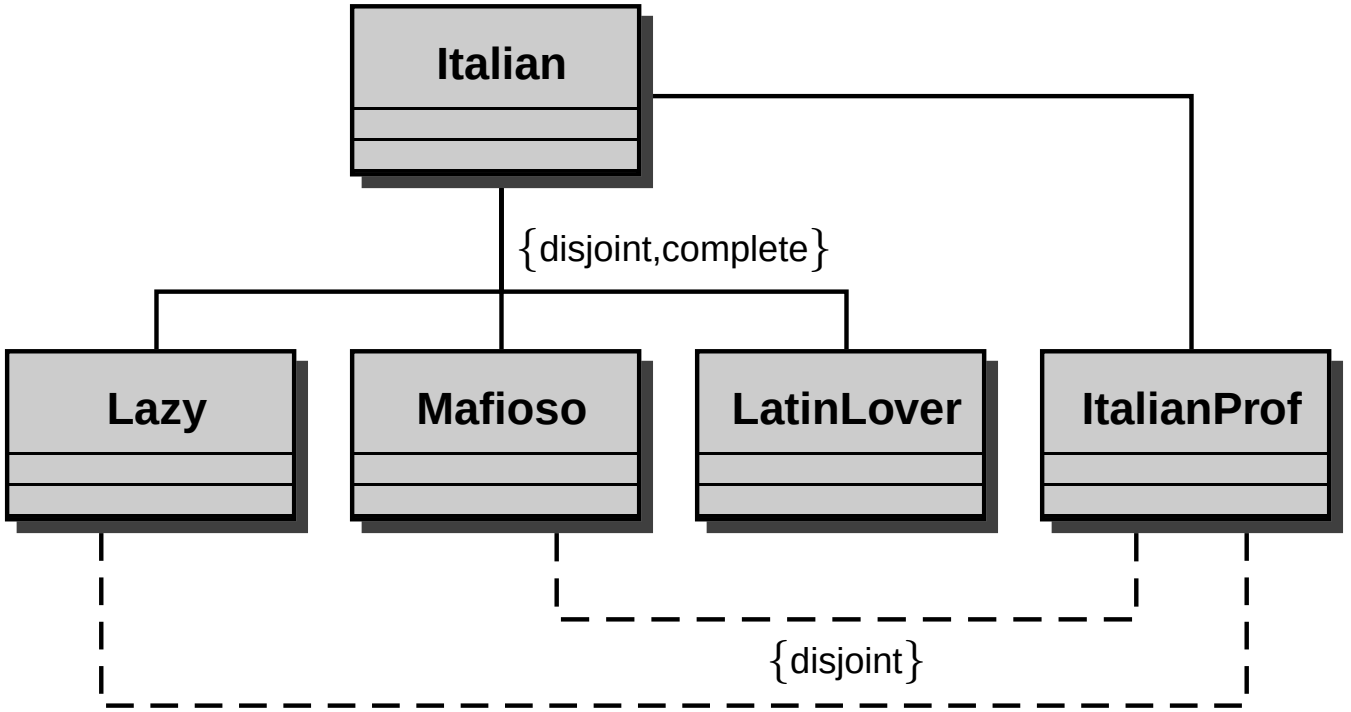
The Architecture of an Intelligent Information Agent



Reasoning at the Conceptual Level



Reasoning at the Conceptual Level



implies

ItalianProf $\Longrightarrow$ LatinLover

Processing Knowledge = “Reasoning”

Representation alone is not useful.

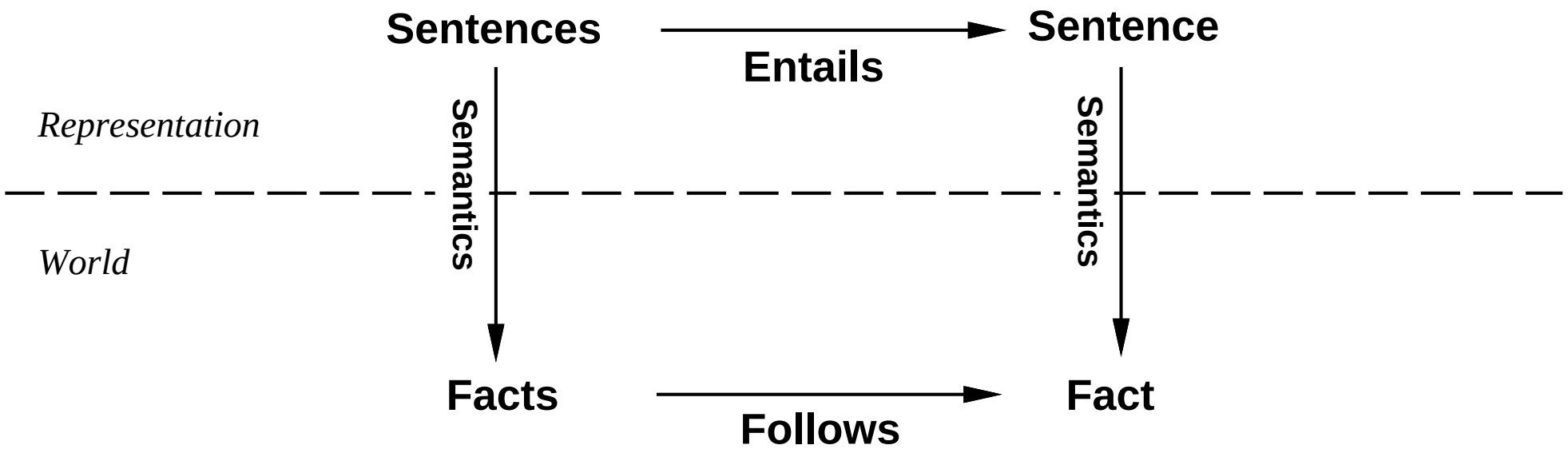
We want to be able to access represented knowledge and to *process* it.

- access alone is, in general, insufficient
- *implicit* knowledge has to be made explicit

$\rightsquigarrow$ *deduction methods*

- the results should only depend on the semantics . . .
- and not on accidental syntactic differences in representations

Logic



A logic allows the axiomatization of the domain information, and the drawing of conclusions from that information.

- Syntax
- Semantics
- Logical inference = *reasoning*

Important Questions

- **Expressive Power** of representation language

$\rightsquigarrow$ able to *represent* the problem

- **Correctness** of entailment procedure

$\rightsquigarrow$ *no false* conclusions are drawn

- **Completeness** of entailment procedure

$\rightsquigarrow$ *all correct* conclusions are drawn

- **Decidability** of entailment problem

$\rightsquigarrow$ there exists a (terminating) algorithm to compute entailment

- **Complexity**

$\rightsquigarrow$ resources needed for computing the solution

What is a Logic

Clearly distinguish the definitions of:

- the *formal language*
  - Syntax
  - Semantics
  - Expressive Power
- the *reasoning problem* (e.g., entailment)
  - Decidability
  - Computational Complexity
- the *problem solving procedure*
  - Soundness and Completeness
  - (Asymptotic) Complexity

The ideal Logic

- Expressive
- With decidable reasoning problems
- With sound and complete reasoning procedures
- With efficient reasoning procedures – possibly sub-optimal

Goals of research in the field

- Study how **declarative knowledge** can be *formally defined* using a logic-based approach.
- Give a *computational* account to it, in order to reproduce it in a computing device.

Main topics of the course

- Structural Description Logics
  - The need for a Logic in knowledge representation
  - Examples from Object-Oriented languages
  - The simplest Structural Description Logic: FL-
- Propositional Description Logics
  - Adding Expressivity to Description Logics
  - Instances and Knowledge Bases
  - Reasoning with Knowledge Bases
- Building Knowledge Bases
  - Understanding Knowledge Bases
  - Using Knowledge Bases
  - Ontology Engineering
- Description Logics and Logics
  - Modal Logics
  - Temporal Logics
  - FOL Fragments
- Description Logics and Databases
  - Conceptual Data Models
  - Query Management
  - Information Integration

Conclusions

- A warning
  - Rigorous and formal course

Conclusions

- A warning
  - Rigorous and formal course
- Two promises
  - Many examples
  - Only few main important topics