Rule-based Distributed and Agent Systems

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Rule-Based Distributed (Agent) Systems

- Parallel and Distributed Rule-Based Systems
- Rule-Based Systems as Agent Reasoning Models
- Rule-based Grid/Cloud/High-Performance Computing Systems
- Rule-based P2P and Publish Subscribe Systems
- Rule-based Event Processing

Parallel and Distributed Rule-Based Systems

- Parallel Forward Chaining Production Systems
  - Distributed Jess
- Parallel Backward Chaining Rule-Based Systems
- Parallel Deductive Databases

Parallel Forward Chaining Production Systems (‘80s-’90s)

- Exploit various forms of parallelism in RETE matching algorithm (for OPS5)
- Suitable for multiprocessor systems
- Implemented or simulated as various PSMs – Production Systems Machines
  - DADO
  - NON-VON
  - Oflazer’s machine

Distributed Jess

- Web of Inference Systems (WoIS) = several inference systems with different sets of rules work on a shared working memory (‘05)

- Octopus = Jess engines asynchronously exchange messages via a central server (‘05)

Parallel Backward Chaining Rule-Based Systems

- Backpac – Parallel Goal-Driven Reasoning System (‘92)

- Parallel execution of Prolog – see the overview from ‘01 in ACM Trans. Prog. Lang. and Syst.

Parallel Deductive Databases

- PRACTIC^{KB} (’98)
- Parallel reasoning for DATALOG (’93 and ’95)

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Rule-Based Systems as Agent Reasoning Models

- Multi-Agent Production System
- Multi-Agent Jess

Multi-Agent Production System

- MAGSY (‘92)
  - General-purpose multi-agent framework
  - Agents have facts and rules, provide services to other agents and receive service invocations from other agents
- Multi-Agent Production Systems (’94)
  - Integration of multiple independent production systems that coordinate via a shared working memory (looks related to WoIS)

Multi-Agent Jess

- Integration of JESS into JADE (’07). Conceptually looks similar to MAGSY.

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Rule-based Grid/Cloud/High-Performance Computing Systems

- Scalable Rule Reasoning
- Rule-based Workflow and Resource Management for Grid and Cloud Computing

Scalable Rule Reasoning

- Extending parallelization of DATALOG inference to Semantic Web (’08)
- MARVIN proposes a divide-conquer-swap for P2P systems (’09)
- WebPIE based on Map-Reduce (’10)

Rule-based Workflow and Resource Management for Grid and Cloud Computing

- WS-CAM (’08)
  - Rule-based resource management
- Active Grid Information Server (’09)
  - ECA rules for resource scheduling
- SiLK (Simple Language for worKflows) and OSyRIS (Orchestration System using a Rule-based Inference Solution) (’10)
  - Rule-based representation of grid-scheduling heuristics
- Rule Based Service Level Agreement
  - Rule-based SLA control

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Rule-based P2P Systems

- Heterogeneous Schema Mapping
- Ubiquitous Computing

Heterogeneous Schema Mapping

- LogicPeer = a P2P extension of Prolog ('08)
  - Applied for XML schema mapping in data integration

Ubiquitous Computing

- Intelligent Domotic Environment (IDE) = provides AmI to home environments through rule-based reasoning (’10)
  - DogOnt ontology
  - Direct, recursive and multi-stage rule inference

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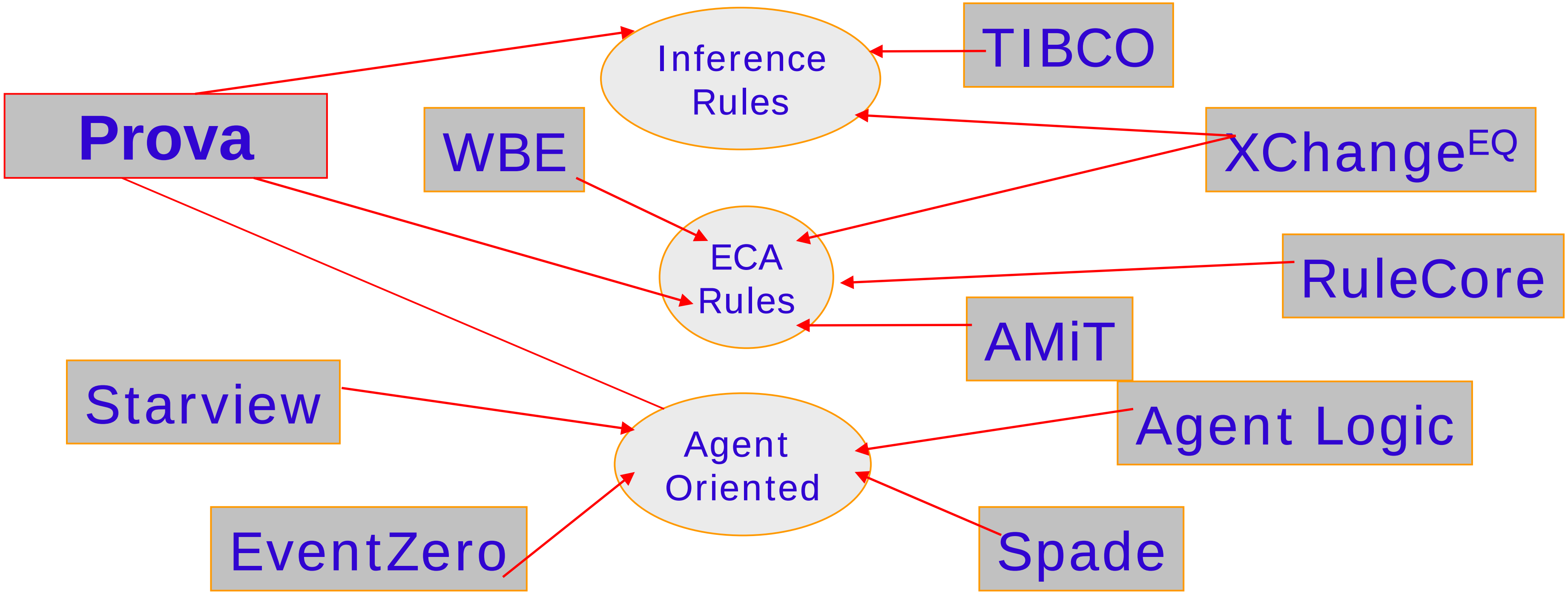
Rule Based EP languages



Roles of Rules in Multi-Agent Systems

- Rules on the Micro Layer
  - Rules used in the internal agent architecture
- Rules on the Macro Layer
  - Rules used for negotiation and coordination

Rules on the Micro Layer

Task Model
Subsumption
Teleo Reactive
Situated Automata
Rule Interaction

SOAR
2/3APL
PRS
GOAL
Vivid
Rule Responder
AOP

MicroPSI
ICARUS

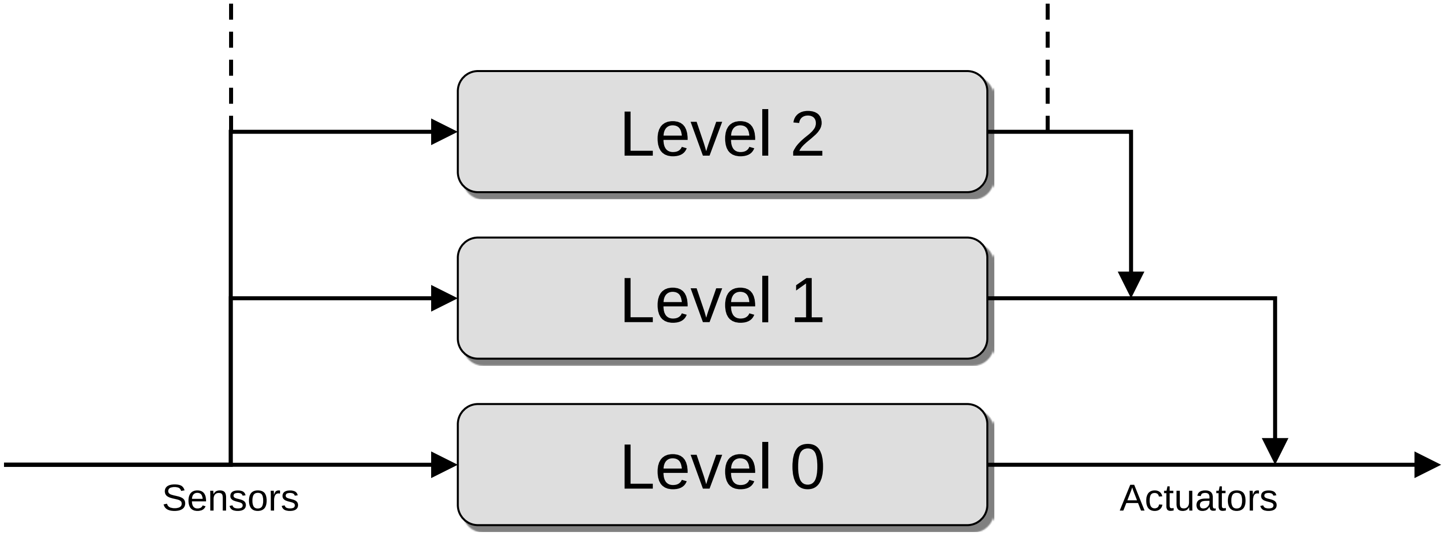
IRMA
PRODIGY

reactive

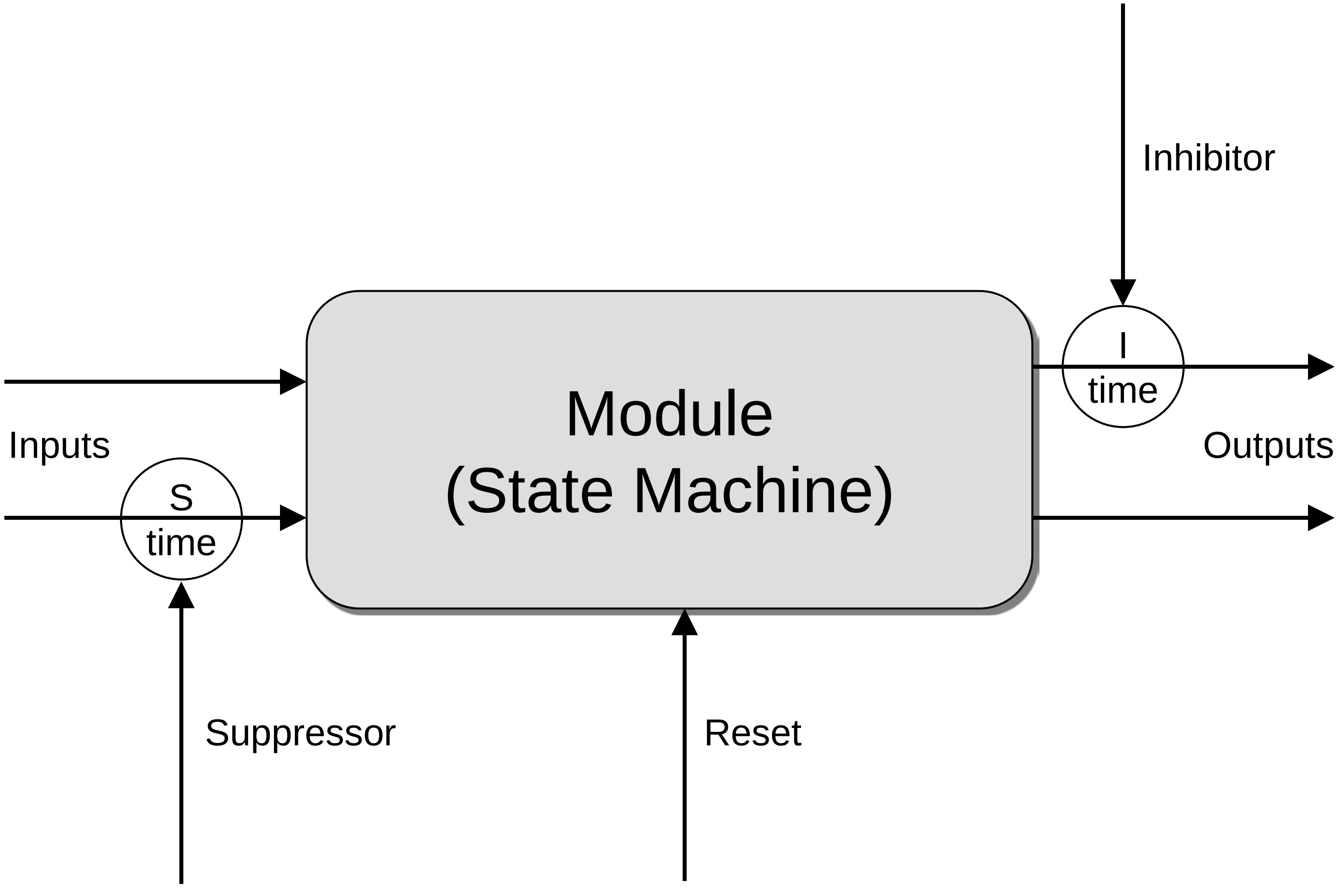
hybrid

deliberative

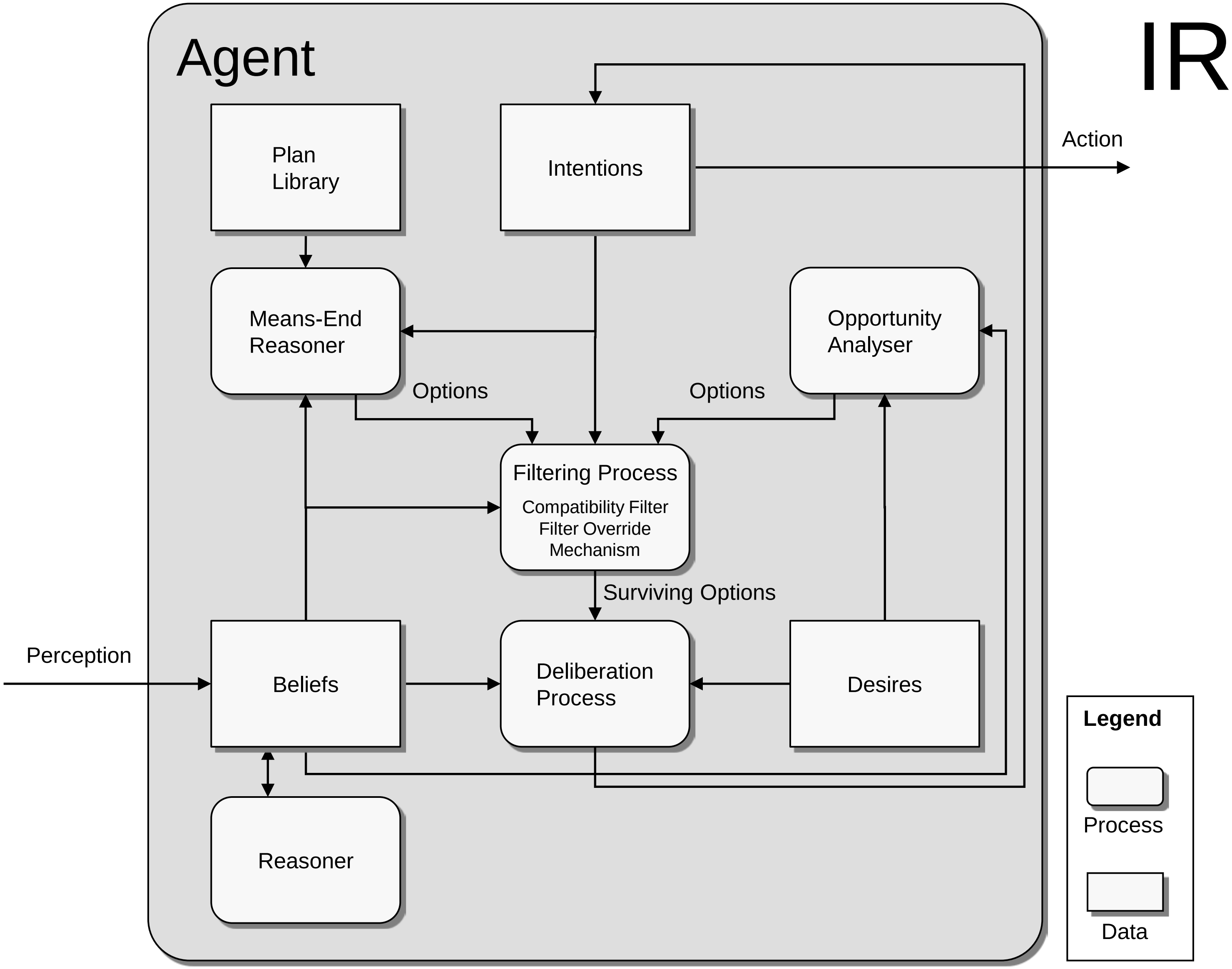
Subsumption Architecture



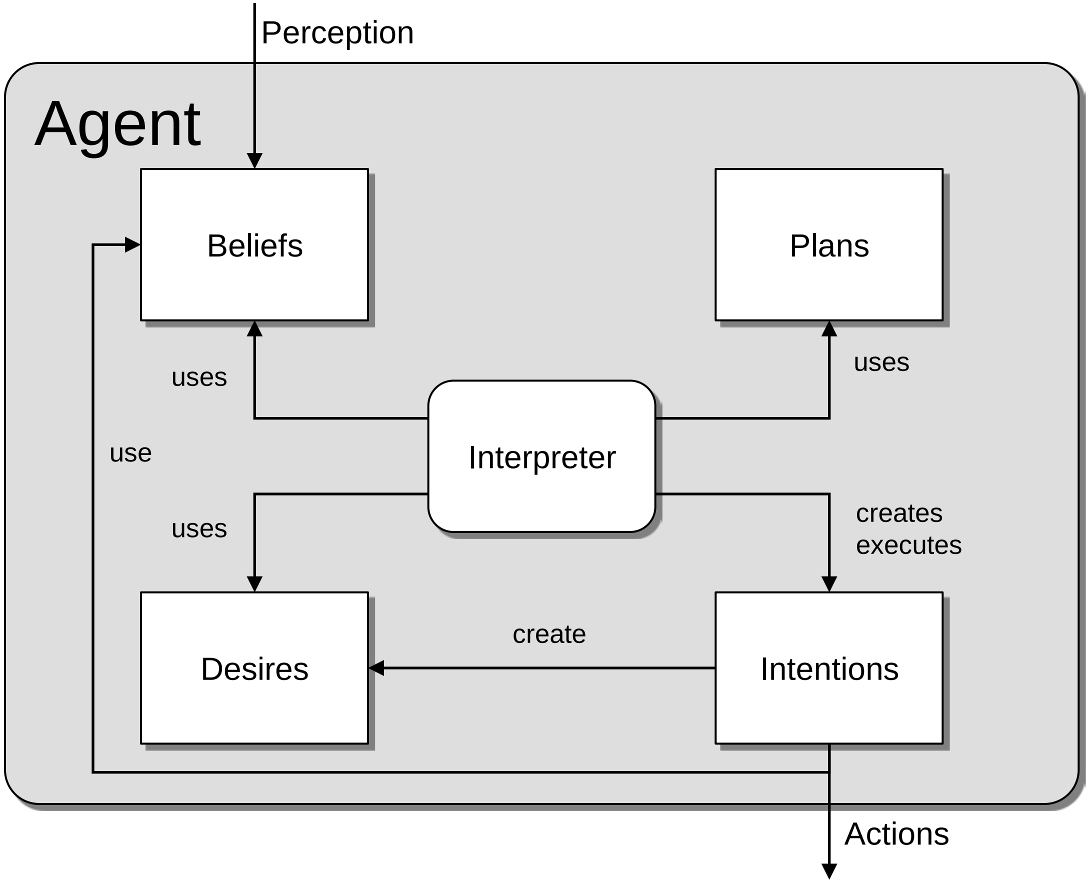
Subsumption Architecture



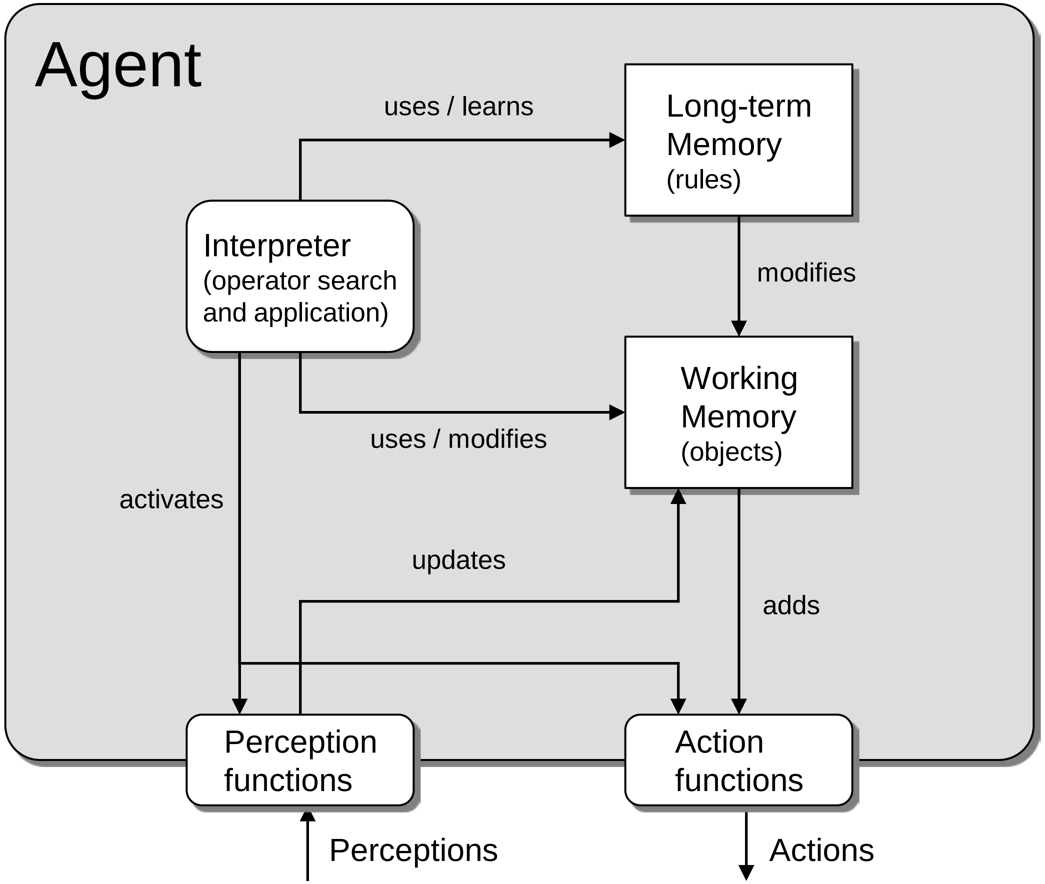
IRMA


Agent
Plan Library
Intentions
Action
Means-End Reasoner
Opportunity Analyser
Options
Options
Filtering Process
Compatibility Filter
Filter Override Mechanism
Surviving Options
Perception
Beliefs
Deliberation Process
Desires
Reasoner
Legend
Process
Data

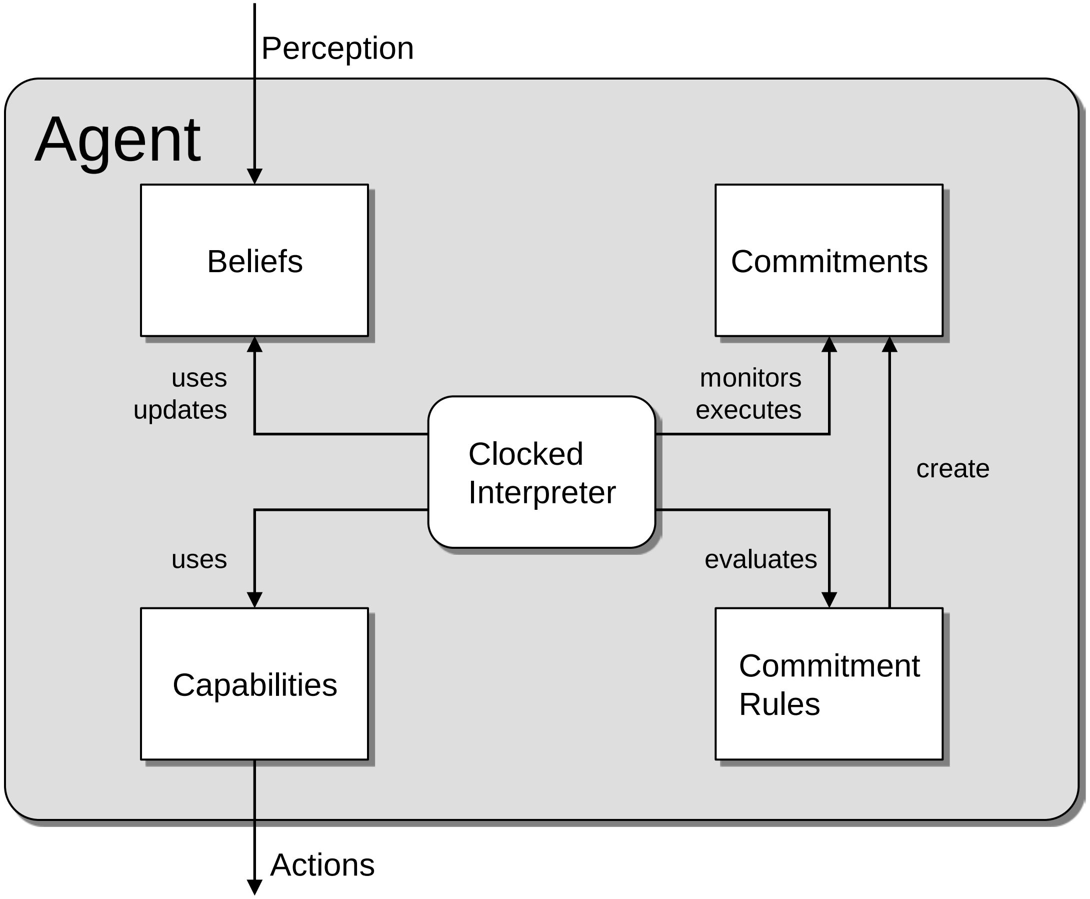
PRS Agent


Perception
Agent
Beliefs
Plans
uses
uses
use
Interpreter
uses
creates
executes
create
Desires
Intentions
Actions

Soar Agent


Agent
uses / learns
Long-term Memory (rules)
Interpreter (operator search and application)
modifies
Working Memory (objects)
uses / modifies
activates
updates
adds
Perception functions
Action functions
Perceptions
Actions

AOP Agent


Perception
Agent
Beliefs
Commitments
uses
updates
monitors
executes
Clocked
Interpreter
create
uses
evaluates
Capabilities
Commitment
Rules
Actions

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Rules on the Macro Layer

- Rule-Based Negotiation
- Rule-Based Verification of Agent Systems and Workflows

Rule-Based Negotiation

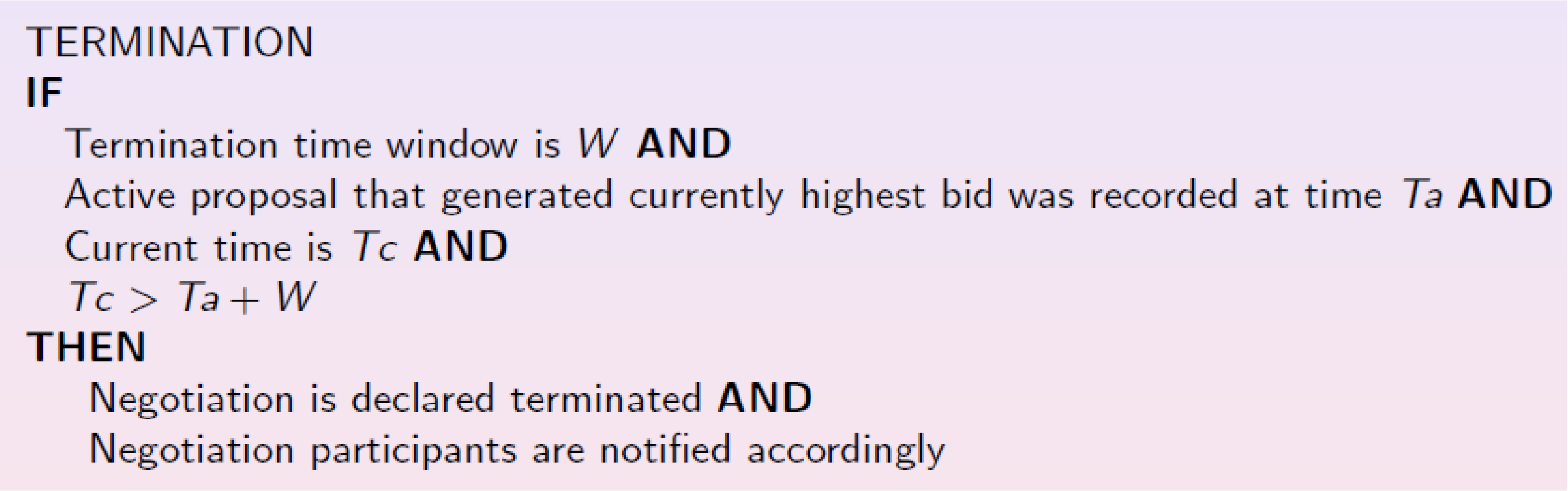
- Negotiation Protocols
- Negotiation Strategies

Negotiation Protocols

- Negotiation protocol = Generic protocol implemented in Rules
- Rules
  - Biding Rules
  - Information Rules
  - Clearing Rules

Negotiation Rules

- Example: terminating an English auction



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TERMINATION
IF
  Termination time window is $W$ AND
  Active proposal that generated currently highest bid was recorded at time $Ta$ AND
  Current time is $Tc$ AND
  $Tc > Ta + W$
THEN
    Negotiation is declared terminated AND
    Negotiation participants are notified accordingly
```

- Dictates auction termination whenever a given period of bidding inactivity is observed.

Negotiation Strategies

- DR-NEGOTIATE ('07)
  - Bargaining strategies expressed in defeasible logics

Rule-Based Verification of Agent Systems and Workflows

- Rule-based representation of property patterns for verification

- “If a *Requester* issues a request to the *Matchmaker* then the *Matchmaker* will process the request until it will reply with the set of matching providers”
- $\mathit{RESP}(\mathrm{r}) = \mathbf{G}\ (\mathit{request}(r) \rightarrow (\mathit{PROC\_REQ}(r)\ \mathbf{U} \vee_{P\ \subseteq M(r)} \mathit{reply}(r,P)))$