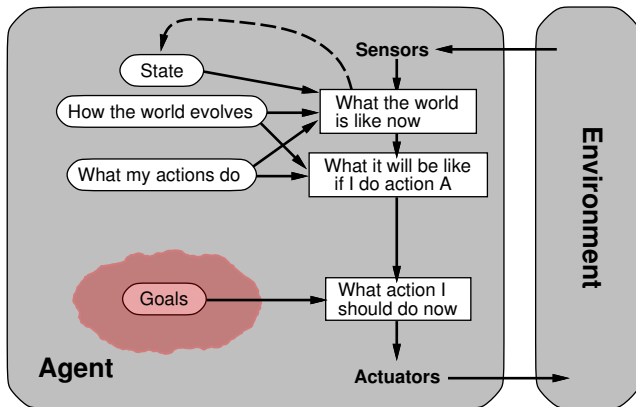


Agent-oriented programming

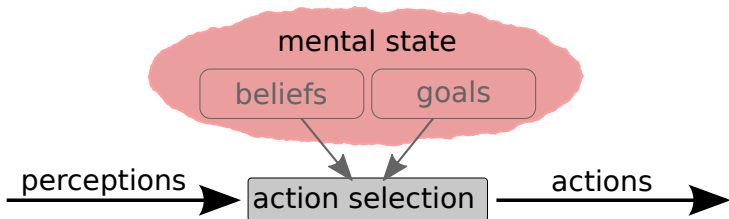
Goal-oriented agents



goals + state + actions' consequences \rightsquigarrow

action selection

Structure of cognitive agents



beliefs a database of agent's information about itself, the world (environment), other agents, etc.

~> **NOW**

goals description of states the agent "wants" to bring about

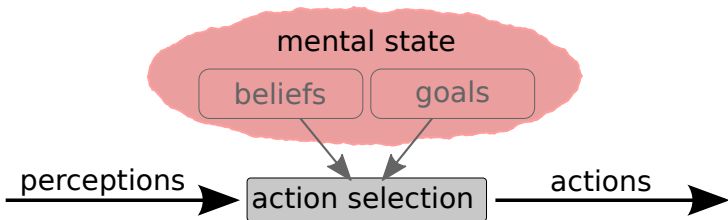
~> **FUTURE**

How to select actions leading
from **NOW** to the **FUTURE**

?

~> **Planning!!!**

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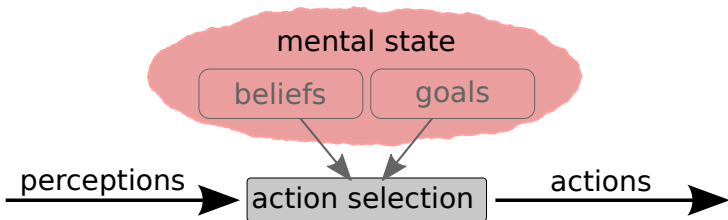
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**How to select actions leading
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~> **Planning!!!**

Planning

Definition (planning)

... is the process of generating (possibly partial) representations of **future behavior** prior to the use of such plans to constrain or control that behavior. The outcome is usually **a set of actions**, with temporal and other constraints on them, **for execution by some agent** or agents.

(The MIT Encyclopedia of the Cognitive Sciences)

plan - execute - monitor cycle

- 1 **plan** from the current state to a goal state(s)
- 2 sequentially **execute** actions from the plan
- 3 **monitor** success of action execution
 - in the case of action failure, (re-)**plan again** (goto 1)

The issue with planning

to arrive to a valid plan, in the worst case, the planner has to explore all the possible action sequences!!!

↪ high computational complexity (\approx PSPACE)



speed of planning vs. environment dynamics

planning ^{speed} > environment can perform relatively well

planning ^{speed} < environment can lead to fatal inefficiencies

↪ the system “suffocates” in (re-)planning

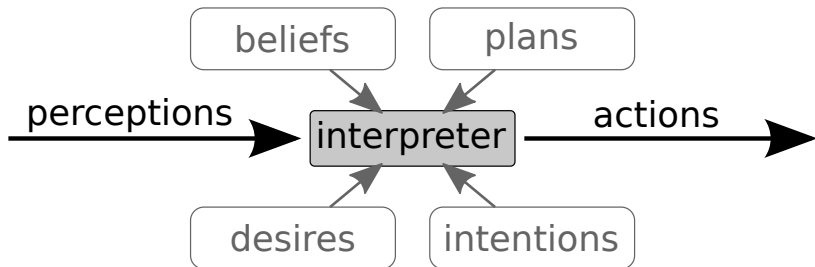
A way out: reactive planning & BDI

Structural decomposition:

- **(B)eliefs:** agent's static information about the world
- **(D)esires:** situations the agent wants to bring about
- **(I)ntentions:** courses of action, plans

System dynamics:

- **reactive planning:** instead of plan-execute-monitor cycle, **select partial plans reactively** on the ground of the current state of the world, beliefs and goals



Agent-oriented programming

Agent-oriented programming

Promotes programming with **mentalistic notions** and **intentional stance** as an abstraction. Provides a realization of the BDI agent architecture in pragmatic programming languages.

AOP system:

- 1 a logical system for *mental states*
- 2 an interpreted *programming language*
- 3 an '*agentification*' process

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What can APLs do for us?

1 mentalistic abstractions for agent system specification

- beliefs, desires, intentions, plans, practical reasoning rules, etc.,
- operationalization of the BDI architecture
- *tools for encoding the system dynamics*

2 agent-oriented language semantics

- syntax & model of execution
- loosely corresponds to temporal modal logics

3 means to tackle the pro-activity vs. reactivity problem

- deliberation/planning vs. handling events & interruptions ~~~ hybrid architectures

Historical overview

Hybrid architectures:

1987: PRS

1988: IRMA

1991: Abstract BDI architecture

1994: INTERRAP

– *incomplete* –

(Georgeff and Lansky)

(Bratman, Israel and Pollack)

(Rao and Georgeff)

(Müller and Pischel)

Agent-Oriented Programming Languages:

1990: AGENT-0

1996: AgentSpeak(L)

1996: Golog

1997: 3APL

1998: ConGolog

2000: JACK

2000: GOAL

2002: Jason

2003: Jadex

2008: BSM/Jazzyk

2008: 2APL

– *incomplete* –

(Shoham)

(Rao)

(Reiter, Levesque, Lesperance)

(Hindriks et al.)

(Giacomo, Levesque, Lesperance)

(Busetta et al.)

(Hindriks et al.)

(Bordini, Hubner)

(Braubach, Pokahr et al.)

(Novák)

(Dastani)

BDI: the underlying principles

Structure of agent's internal state

- beliefs $\rightsquigarrow \mathcal{B}$
- goals $\rightsquigarrow \mathcal{G}$
- intentions/plans $\rightsquigarrow \mathcal{I}$ (optional)
- + an interface to the environment $\rightsquigarrow \mathcal{E}$

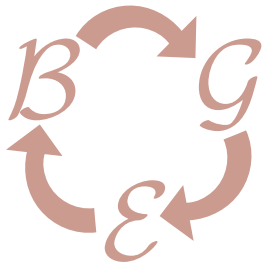
Minimal flow of information

- 1 agent perceives the environment and reflects it in the belief base
- 2 its beliefs about the world determine the goals it pursues
- 3 pursuing goals triggers behaviors aimed at fulfilling them

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