Agents and Components -
An Experience in Composing Agent Behaviors

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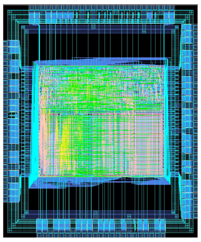
Objectives

- Comparing components and agents
- Independent approaches...
- ...but some common goals for software:
  - Composable
  - Adaptable
  - "Better"
- Considering them within the history/evolution of programming
- What can agents bring to components?
  - Semantic coupling vs syntactic coupling
  - Autonomy
  - Adaptability
- What can components can bring to agents?
  - Self-containedness
  - Conformance control
  - Building blocks

Outline

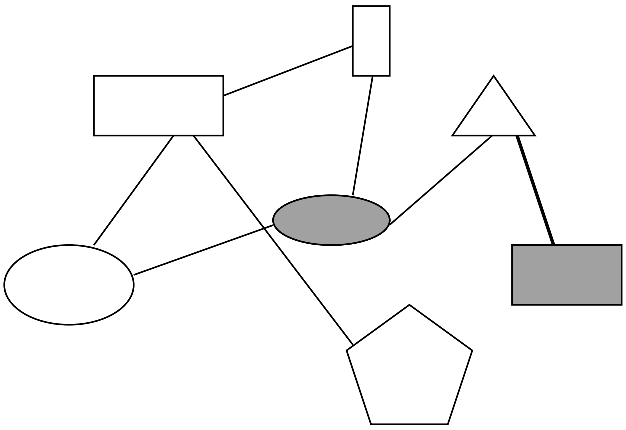
- Components
- Agents and Multi-Agent Systems (MAS)
- Evolution of programming
- What agents can bring to components?
  - Autonomy/Evolvability
  - Assistance to Assemblage
    - » Ex: The COGENTS project
- What components can bring to agents?
  - Self-containedeness
  - Architectural support
    - macro-level, ex: role/agent conformance control
    - micro-level: agent architecture
- Component-based agent architectures
  - Various decomposition rationales (levels, modules, behaviors...)
  - Ex: behavior decomposition: the MALEVA agent component model
- Conclusion

(Software) Components



- Software components
-
- Inspiration from electronics - Integrated Circuits
- Objective: composition and reuse of software components
- Objective: *ease*
  - Replacement
  - Addition
  - Removal

    of
  - Components
  - Connectors



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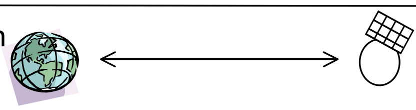
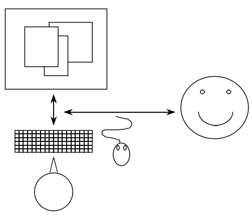
Agents and Multi-Agent Systems (MAS) - AI View

- Limits of direct control/programming approach
  - e.g., autonomous space probe, Internet search,
  - world-level distributed computing



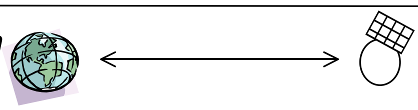
- Delegation of mission - Initiative
- Agents: autonomous entities
  - rational, deliberative...

- Multi-Agent System: distributed interacting agents
  - Distributed AI (e.g., RoboCup) VS Traditional AI (e.g., chess)
- Assistant agent VS single artificial expert (Traditional AI)



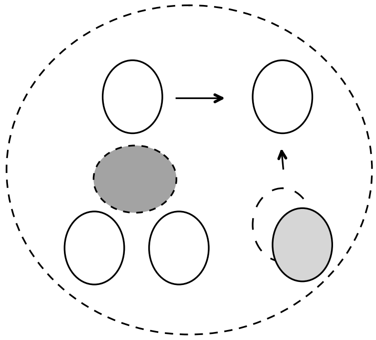
Agents and Multi-Agent Systems (MAS) - Software view

- *Limits of direct control/programming approach*
  - *e.g., autonomous space probe, Internet search,*
  - *world-level distributed computing*



- *Delegation of mission - Initiative*

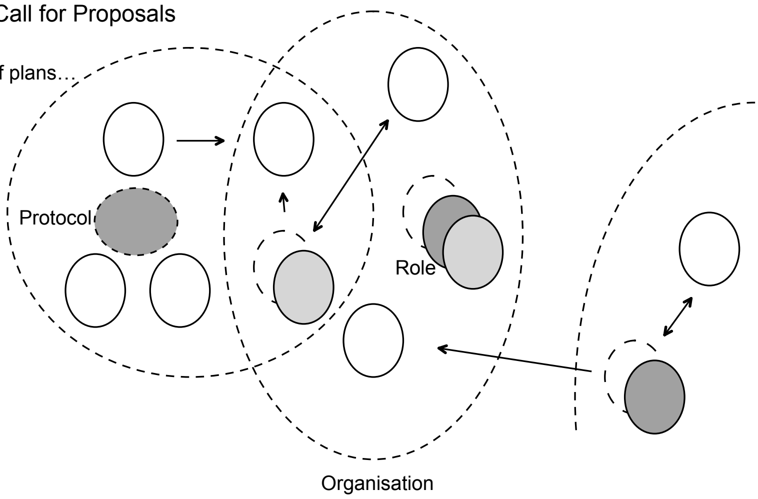
- Agents: autonomous entities/software components
  - Reactive or/and proactive (e.g., goal-driven)
- Knowledge-level coupling vs data-level (typing) coupling
- Adaptative vs Defensive approach (static verification)



- Bottom-up (emergent) VS/AND top-down (Architecture Description Languages) design/organization

Multi-Agent Systems (MAS)

- Autonomous entities
  - Reactive or/and proactive (e.g., goal-driven)
- Coordination
  - Protocols
    - » coordination, negociation, auction...,
    - » e.g., Contract Net Protocol/Call for Proposals
  - Shared knowledge,
    - » e.g., joint intentions, exchange of plans…
- Organizations
  - Division of labor (roles)
  - Inter-agent dependencies
  - Collective actions
  - Regulation (e.g., norms)
- Meta-level
  - Reasoning about and acting upon
    - » Action
      - Individual
      - collective
    - » Interaction
    - » Coordination
    - » Organization



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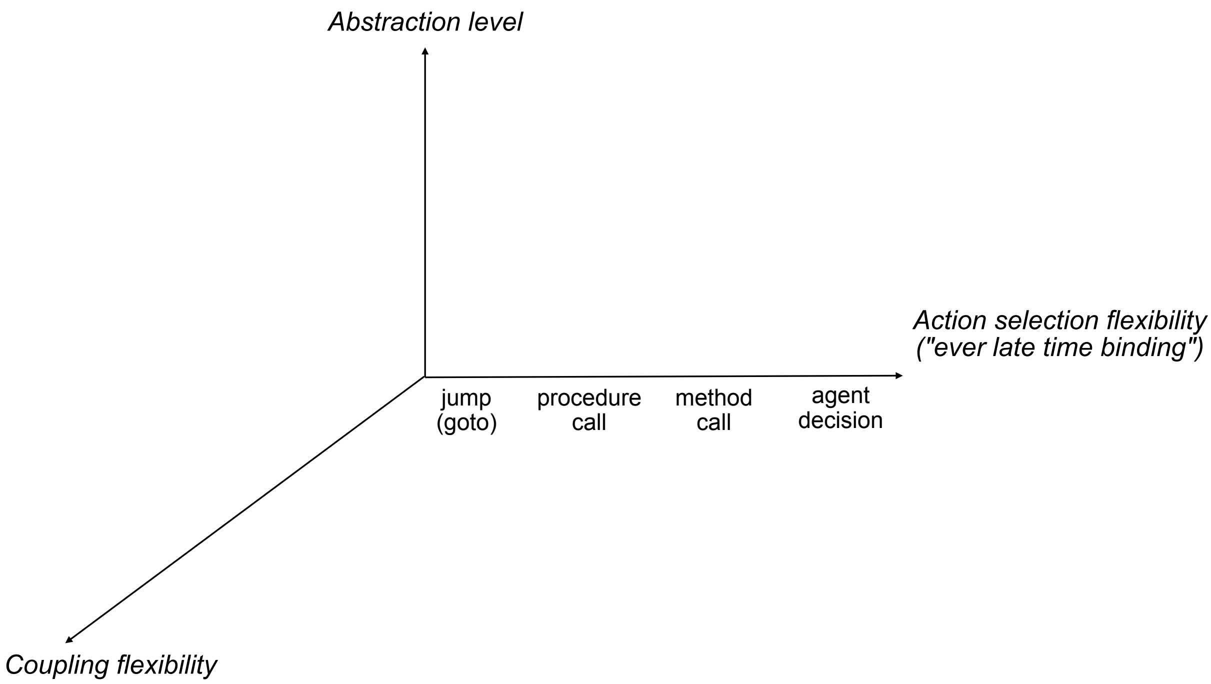
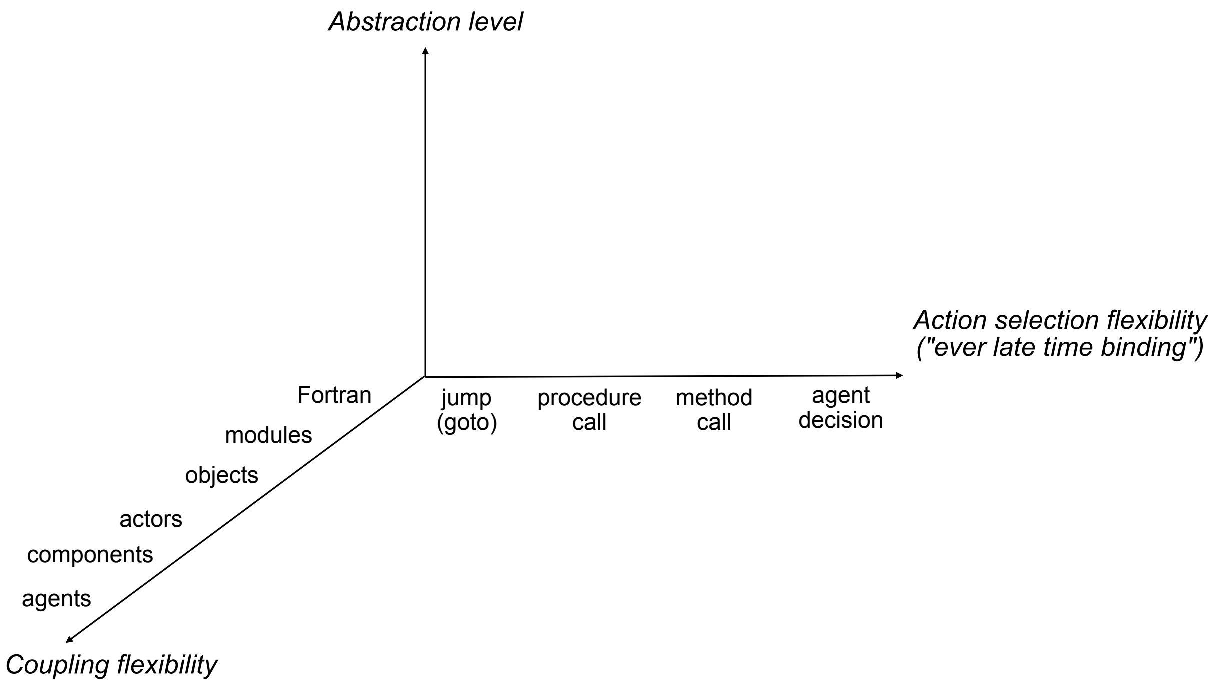
Evolution of programming



1st Axis - Action selection

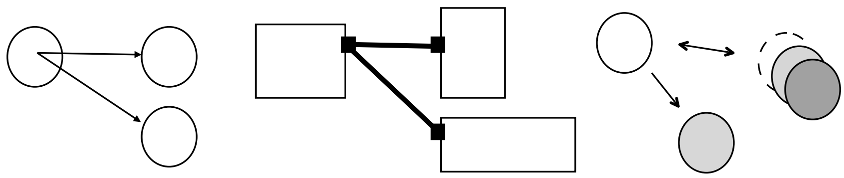
	"Monolithic" programming *e.g.,* Fortran	*Modular programming* *e.g.,* Pascal	*Object-oriented programming* *e.g.,* Java	*Agent-oriented programming* *e.g.,* AgentSpeak
Behavior	Non modular	modular	modular	modular
State	external	external	internal	internal
Invocation (and action selection)	***jump (goto)*** external	***procedure call*** external	***method call*** external	***agent decision*** *(ex: goal-driven)* internal

Evolution of programming

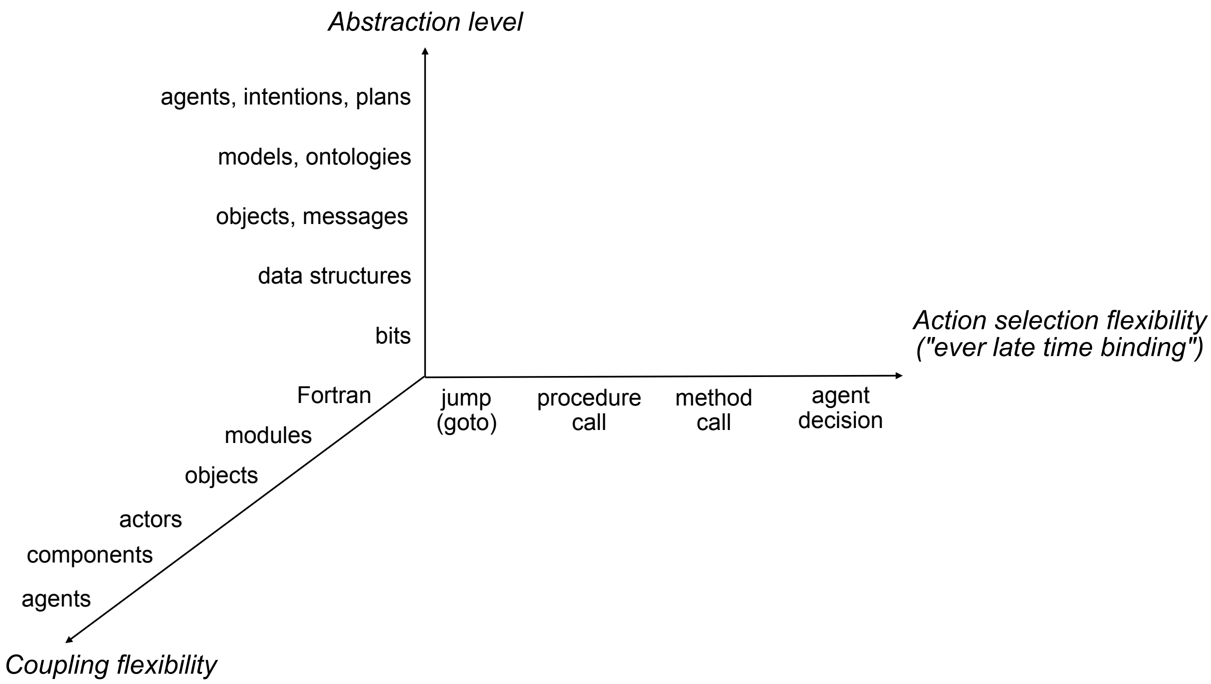


2nd Axis - Coupling flexibility

	objects	*components*	*agents*
structure	implicit, internal (object references)	explicit, external (connectors)	implicit, external (indexed by organizational roles)
communication	procedure call (bidirectional, return value)	unidirectional (events) or bidirectional	protocol
synchronization	synchronous	synchronous or asynchronous	protocol



Evolution of programming



3rd Axis - Abstraction level

- Agents, not purely data/procedural
  - knowledge (beliefs, goals...)
- Semantic/Knowledge-level coupling rather than data-type-level coupling
-
- Communication (e.g., FIPA ACL vs OMG CORBA)
  - content language (e.g., KIF, FIPA SL)
  - performative (intention of communication, e.g., inform, recruit)
  - ontology
  - protocol

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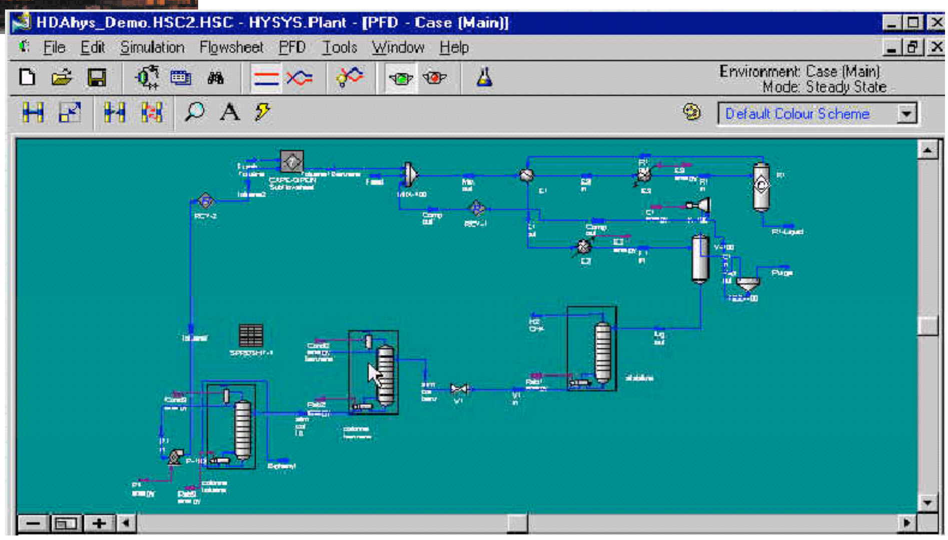
What agents could bring to components ?

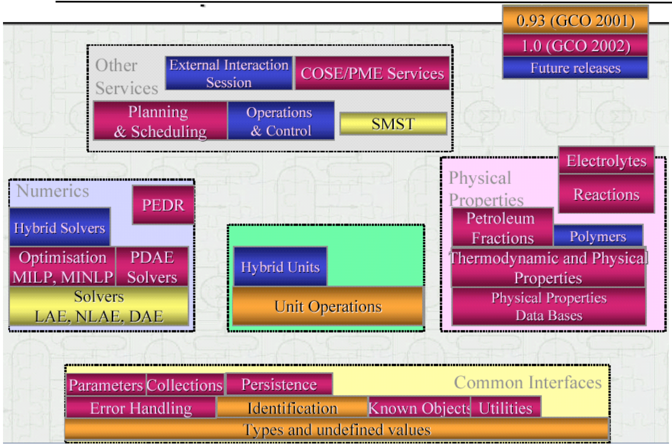
- More flexibility for assembling (match-making)
-
- Mechanisms (reorganization) for dynamic reconfiguration
-
- *More "intelligent" behavior (intelligent/adaptive cooperative components)*

Example: components match-making

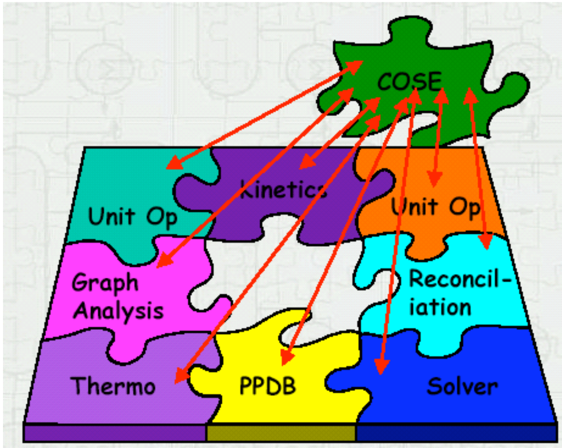
Petrochemical process engineering (design, simulation, *control*)



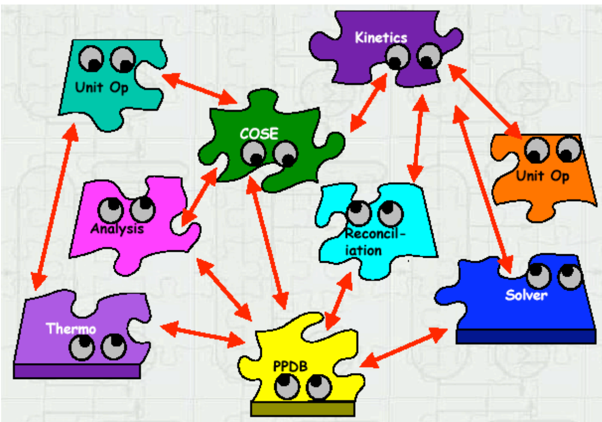
Initial step: Interoperability: CAPE-OPEN Project [Braunschweig et al. 02]

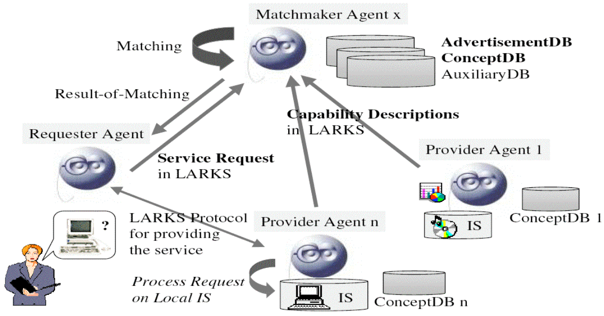


- Componentification of Process units
- Interoperability
- Interfaces standards
- OTS Components



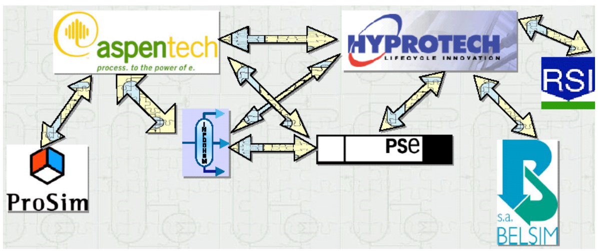
Second step: Assistance to Assemblage: COGENTS Project [Braunschweig et al. 04]





E.g., LARKS matchmaking [Sycara et al. 98]

- Match-making
- Assistance for assemblage
- Instantiation (actual Software products)



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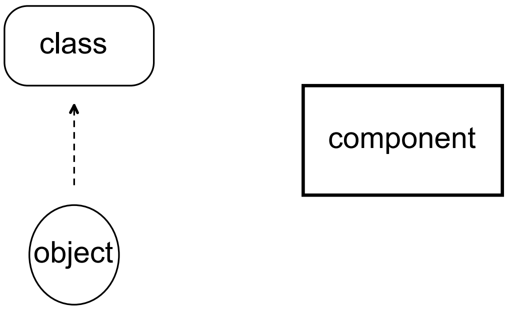
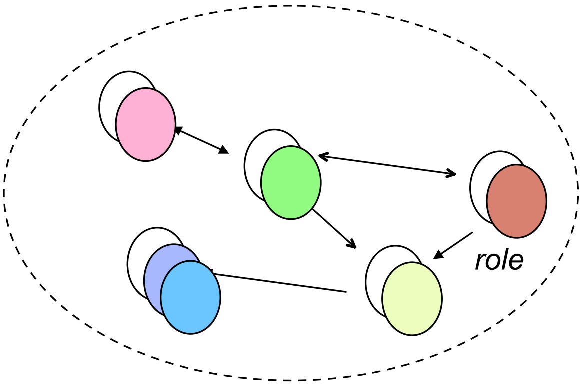
"Self-containedness"

- Includes all the code
- "Ready to use"
- “Ready to deploy”
- Includes documentation



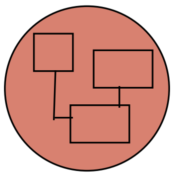
Architectural support

- **At the macro / system / organizational level**



organization

- **At the micro / (single) agent level**



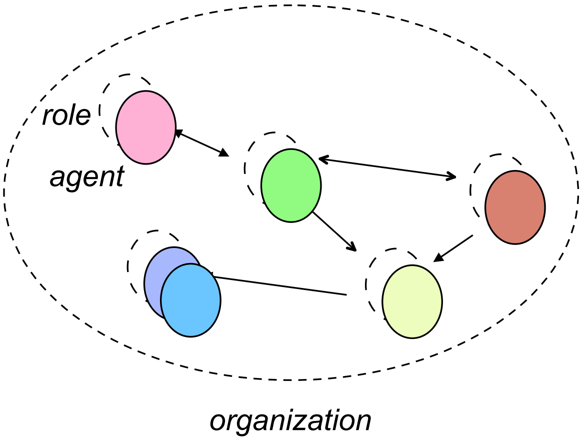
agent

System level architecture

- Software architectures (and components)
  - explicit
  - rational
  - explicit coupling
    - data-level (interfaces, typing)
    - communication-level (connectors)
- Agent organizations (cognitive)
  - explicit
  - rational
  - semantic/knowledge coupling
  - reified
  - evolutive (reorganization)
- Agent organizations (reactive)
  - bottom up / emergent (e.g., ant societies)
  - *and* conformant / top-down ([Cardon 99])

Conformance of an agent to a role

How can we make sure (or estimate) that an agent may (or will be able to) fulfill a role ?



Checking the conformance of an agent to a role

- Role
  - place holder
  - requirements / capabilities
    - » structure
      - procedures
      - knowledge
      - coordination
      - physical (e.g., for locomotion)
    - » activity
      - behavior
      - coordination
      - regulation
      -
- Conformance problem
  - static
    - » procedures signatures / typing
    - » contracts
    - » compatibility with other roles already acquired (MOISE+ [Hübner et al. 02])
  - dynamic
    - » *possible dynamic acquisition (procedures, knowledge, protocols)*
    - » integration test [Rodrigues 05]
    - » deontic specification (MOISE+ [Hübner et al. 02])
    - » monitoring/evaluation mechanims

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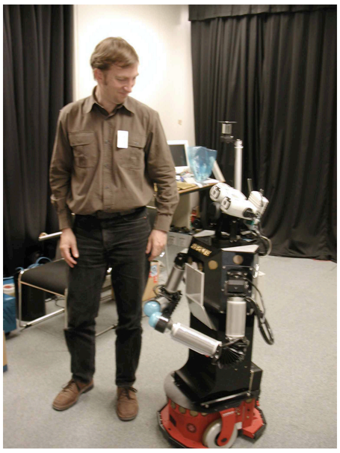
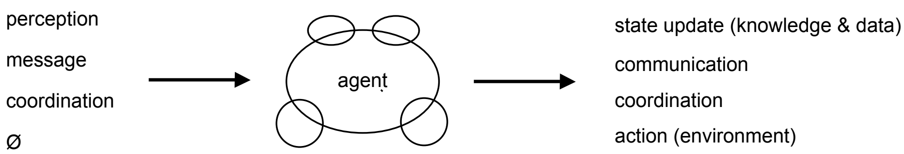
Architectural support for an agent (agent level)



- Central issue: action selection (as for robots)
- More complex than for objects/components:
  - not just procedural (e.g., reasoning)
  - various inputs (environnement, communication...)
  - pro-activity (vs simple reactivity)
  - various levels (self, agents, organization)
  - knowledge (vs data)



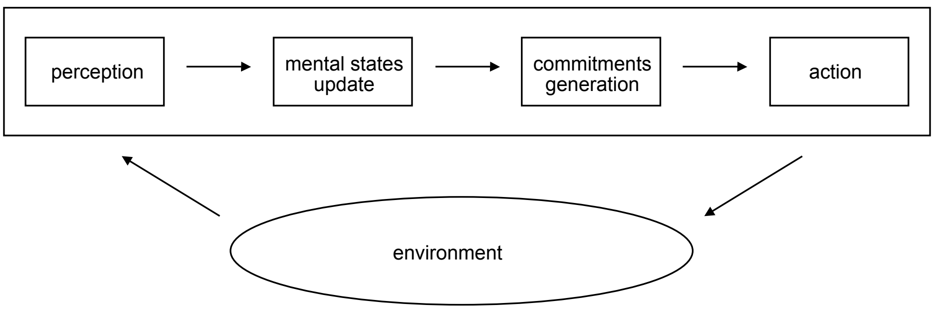
- **Architecture of an agent:**
-
  - **the software structure in charge of that action selection**
  -
  - **functions of the agent and their interactions**

Rationale (tentative typology) for (one) agent architectural decomposition

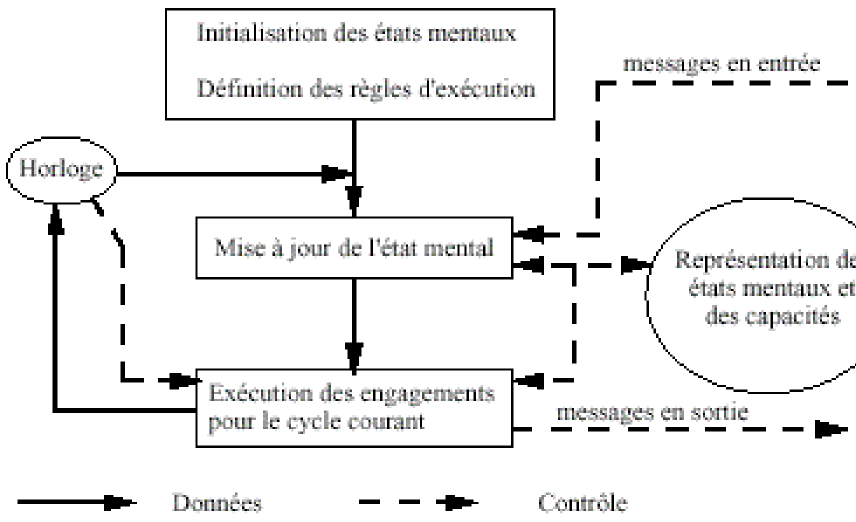
- *Analog to software achitectural styles (layers, pipes&filters...)*
- (computational) Cycle
  - e.g., perception, mental state update, generating commitments, action
    - » e.g., AOP architecture
- Viewpoints and types of processing
  - e.g., interaction, organization, environment
    - » e.g., Volcano architecture
- Levels
  - e.g., world level, individual level, social level
    - » e.g., InteRRaP architecture
- Behaviors
  - e.g., gradient following, obstacle avoidance, random move...
    - » e.g., subsumption architecture

Cycle decomposition: "Horizontal" modular architectures

- one layer
- decision/action cycle



Ex. of Cycle decomposition:
AOP (Agent Oriented Programming) Architecture

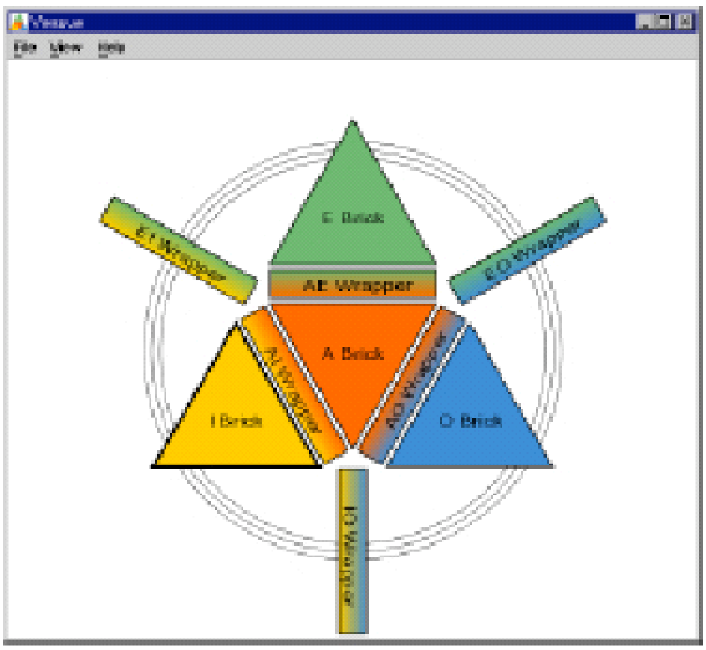


[Shoham 93]

data-driven

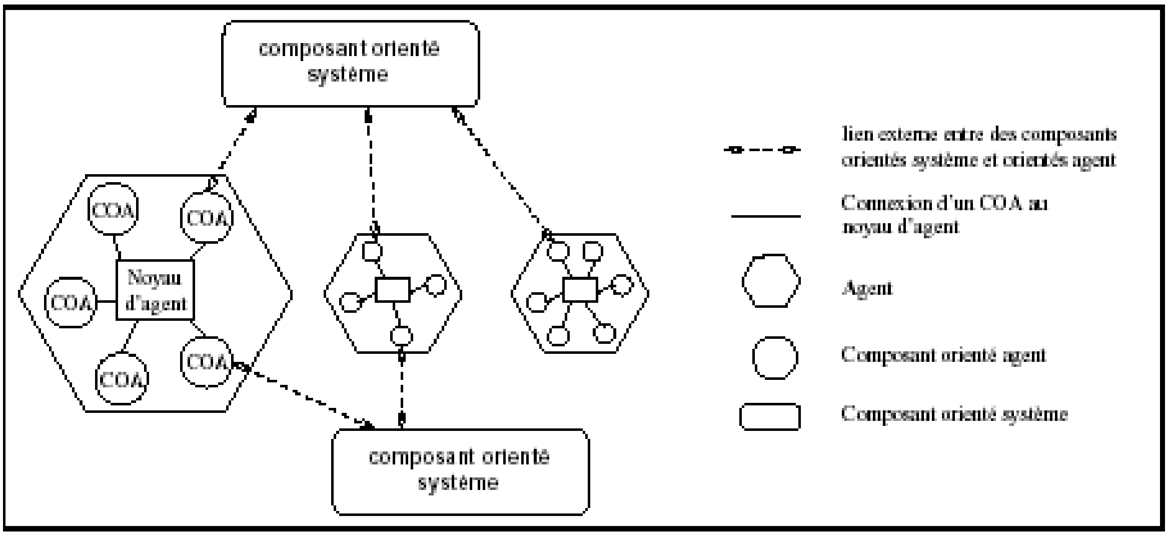
Ex. of Viewpoint decomposition: Vulcano [Ricordel 02]

- Vowels decomposition model [Demazeau 01]:
- A(gent)
- E(nvironnement)
- I(nteraction)
- O(rganization)
-
- Interfacing wrappers/adapters *(ad-hoc)*



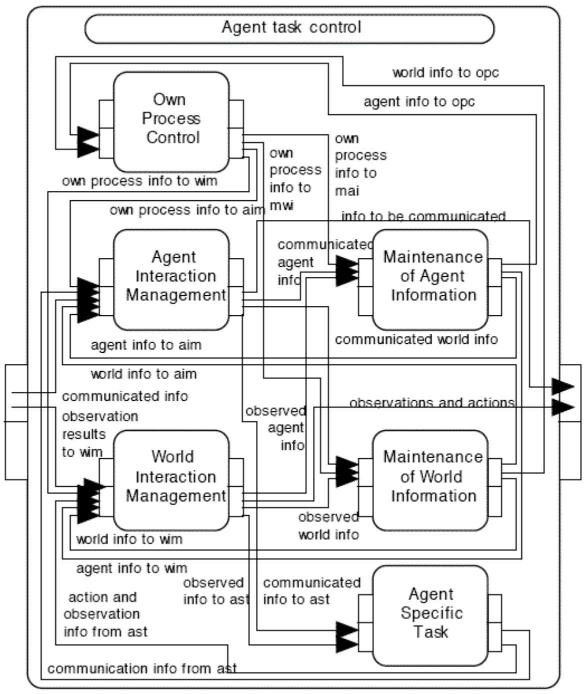
MAST [Vercouter 04]

- provided roles and required roles
- sent events and handled events
- delegation
- priority



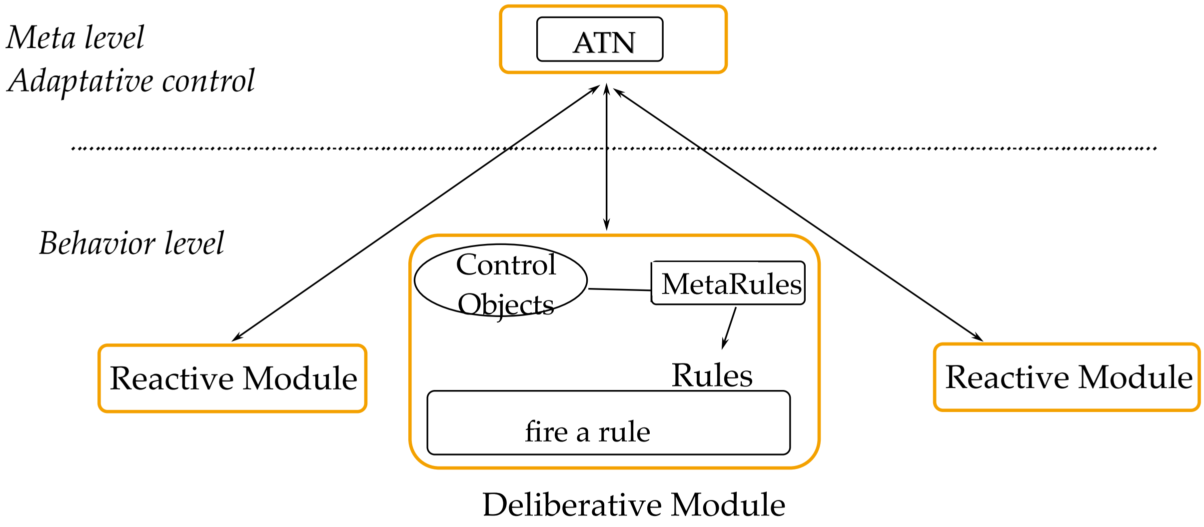
DESIRE [Brazier et al. 95-01]

- formal specification
-
- Generic Agent Model (GAM)
-
- retro-engineering of some architectures
- (e.g., BDI) and applications (e.g., ARCHON)



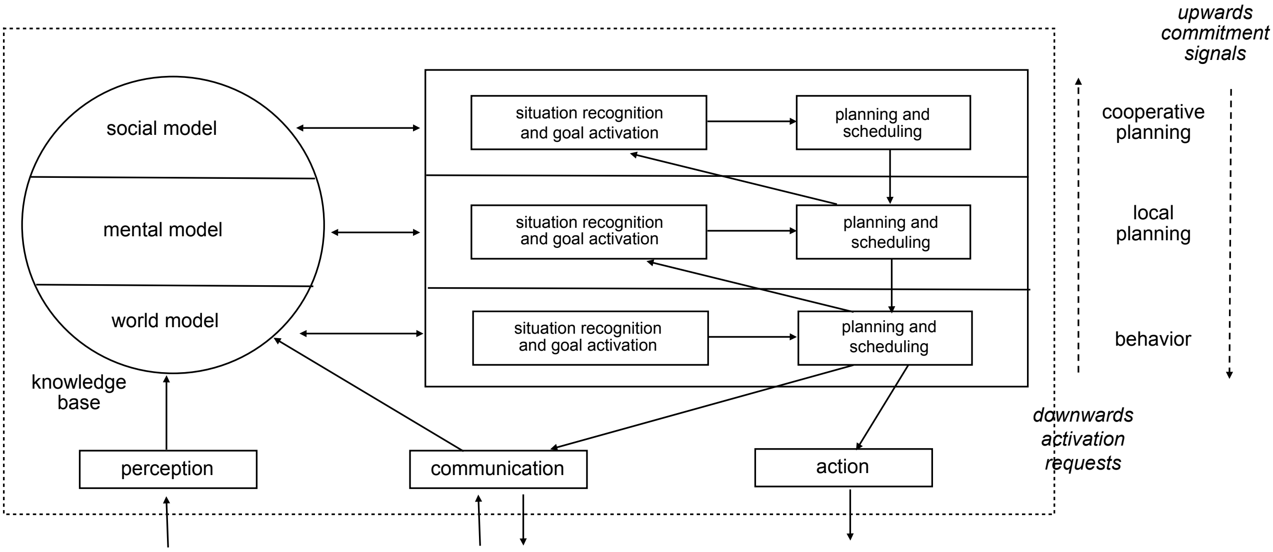
Modules decomposition, Ex: DIMA architecture [Guessoum 99])

ATN = Augmented Transition Network (automata)



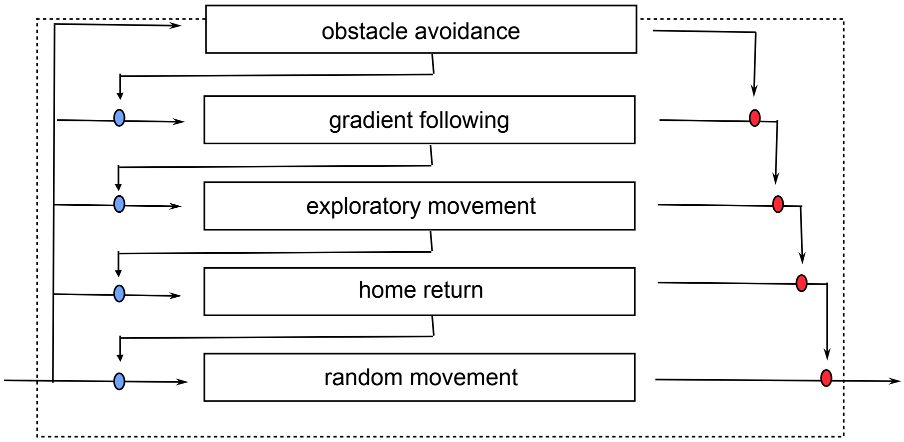
Ex. of Level decomposition: InteRRap [Müller 94]

- 3 levels/layers activated in //
  - behavior - beliefs about the state of the environment
  - local planning - beliefs about oneself
  - cooperative planning - beliefs about and commitments with other agents



Ex. of Behavior decomposition: Subsumption architecture [Brooks 86]

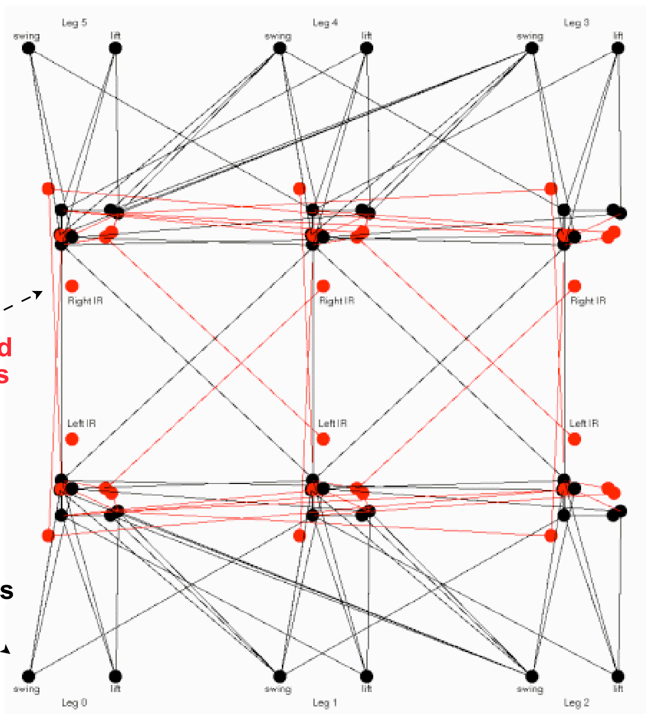
- components activated in parallel
- competitive *and* hierarchical
- priorities and inhibitions:
  - taking over input of lower component
  - inhibiting output of lower component
- hard-wired



Other: Evolvable architectures [Meyer et al. 98]

infra-red sensors

leg actuators



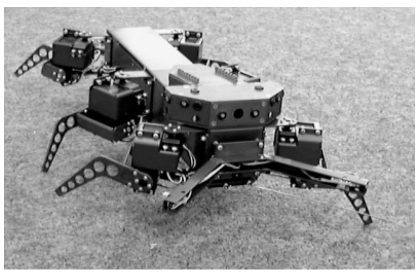
Genetic programming

Evolution of the development program

instructions:
DIVIDE, GROW, DRAW...

Modular design/construction:

Black network : walk
Red network : obstacle avoidance



Reuse of architectural components

- Cycle
  - e.g., AOP
  - only little decomposition
  - often only conceptual, no implementation decoupling
- Viewpoints
  - e.g., Volcano
  - replacing a brick -> replace the adaptors
- Levels
  - e.g., InteRRaP
  - often only conceptual, no implementation decoupling
- Behaviors
  - e.g., Subsumption architecture
  - hard-wired
  - very difficult to evolve

Architectural model versus Component model

- Existence of an architecture restrains the possible combination of components
  - cons: **constraints**
  - pros: **constraints** ! (structure)
    - » Reuse of (stable) architecture is more easy
    - » Cf. Frameworks - “Is reusable only what has already been reused” [Johnson]
- But difficult to evolve the architecture itself (e.g., add a component)

Radical option:

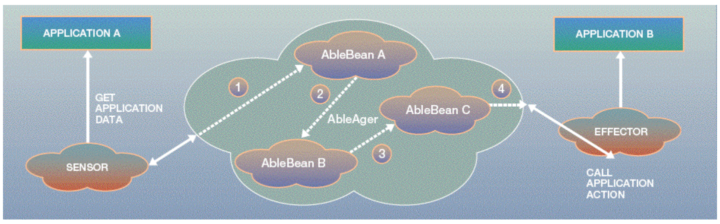
- No more architecture
- Just a component model (like ex: JavaBeans)

Rationale for agent architectural decomposition (2)

- Tools/techniques
  - e.g., backpropagation, bayesian, time series, rules...
    - » e.g., ABLE architecture
- Protocol components
  - e.g., Agentalk, SCD
- Behaviors
  - e.g., gradient following, obstacle avoidance, random move...
    - » e.g., MALEVA component architecture

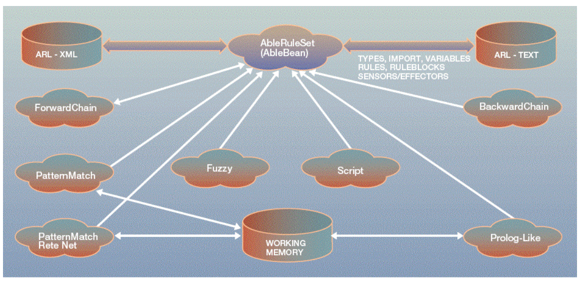
Tools (tool box) decomposition, ex: ABLE architecture [Bigus et al. 02]

IBM Autonomic computing programme

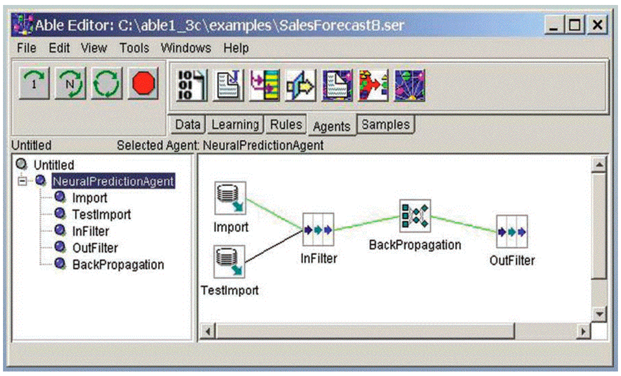


- **Data beans**
  e.g., TimesSeriesFilter
- **Learning beans**
  e.g., BackPropagation
- **Rule beans**
  e.g., FuzzyForwardChaining
- **Specific beans**
  e.g., GenericSearch

Java Beans-based implementation

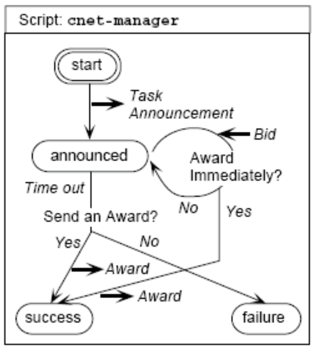


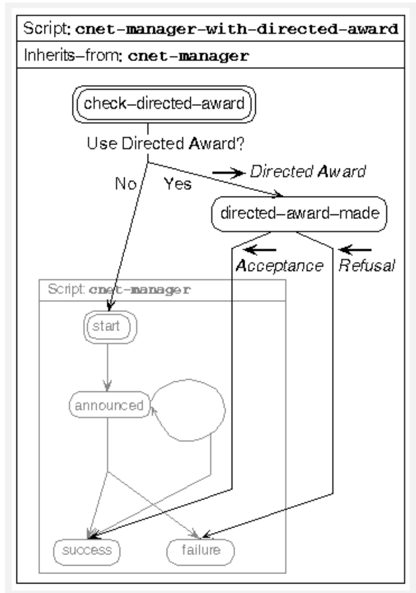
E.g., rule beans



Reusing protocol components

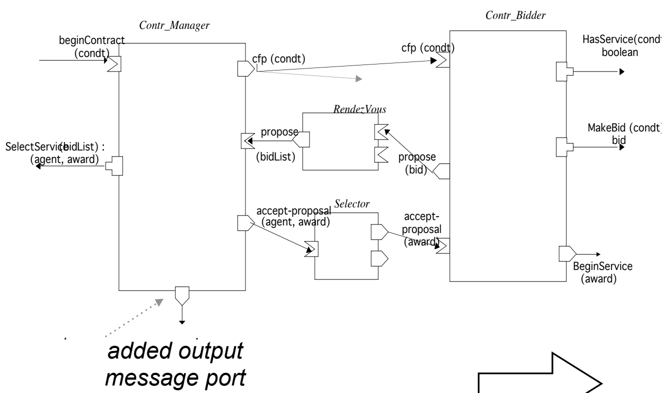
- Extensions of the Contract Net Protocol (CNP)
- Agentalk [Kuwabara et al. 95]
  - inheritance (e.g., directed-award-CNP)
  - customization interface

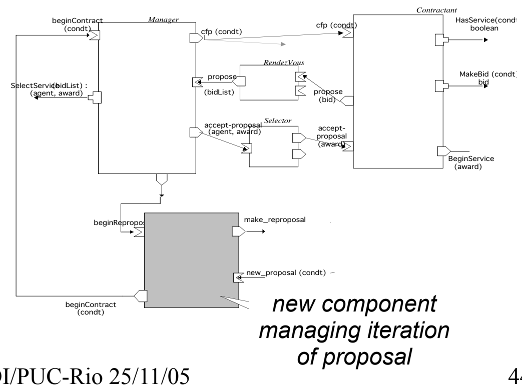




Reusing protocol components

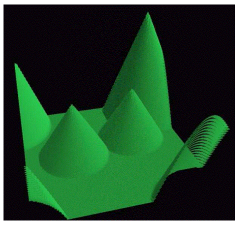
- SCD [Yoo et al. 98]
  - inheritance (e.g., time-out-CNP)
  - composition (e.g., iterated-CNP)



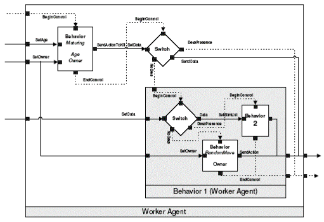


• also XMLaw [Carvalho et al. 04]

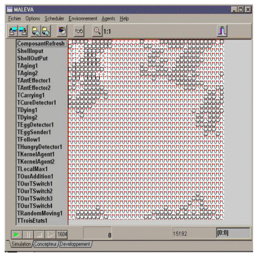
The MALEVA agent component model [Lhuillier et al. 98]



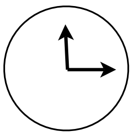
- Domain: multi-agent simulation
  - e.g., trafic simulation, eco-systems, population micro-simulation...
- Unit of decomposition: agent behavior
- Assembling behaviors into more complex behaviors
  - concept of composite component (behavior)

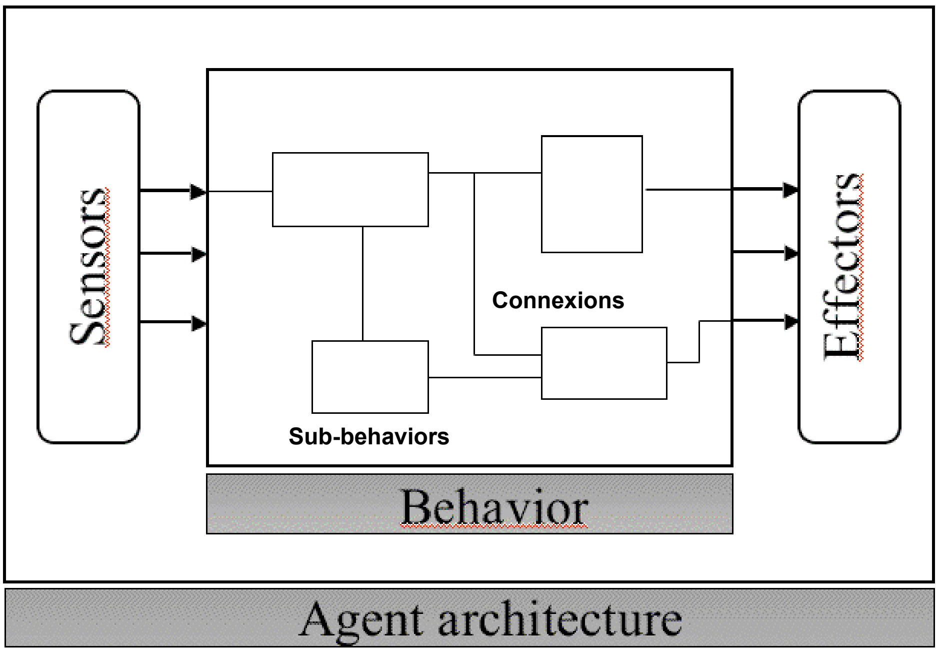


- Supports behavior dynamic change
  - e.g., from an egg, to a larva, to a worker ant
- Distinction between
  - data flow
  - control flow
- JavaBeans-based (re)implementation

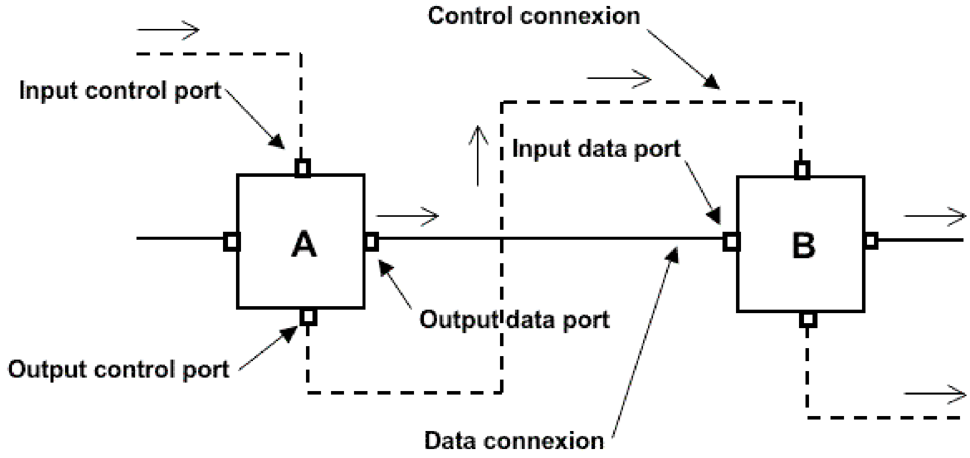


General agent architecture



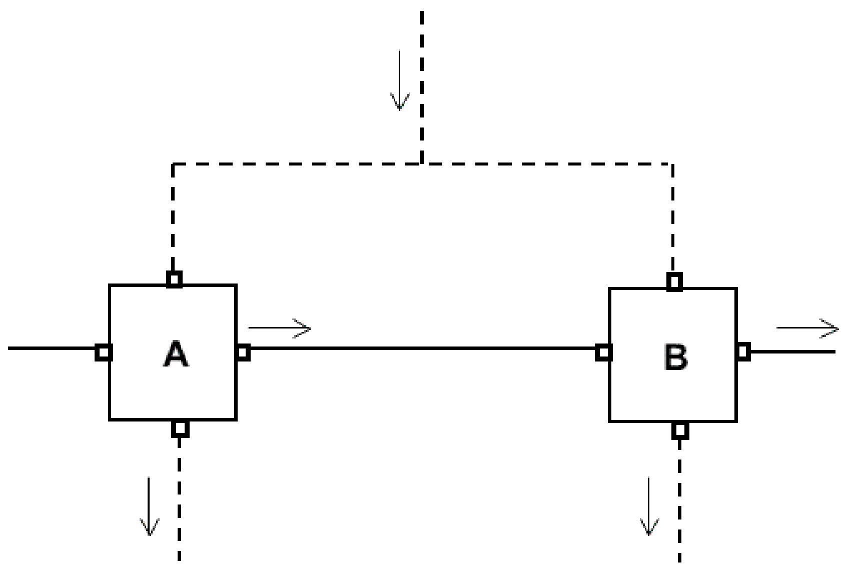


Data flow and control flow: ports and connexions



Sequence

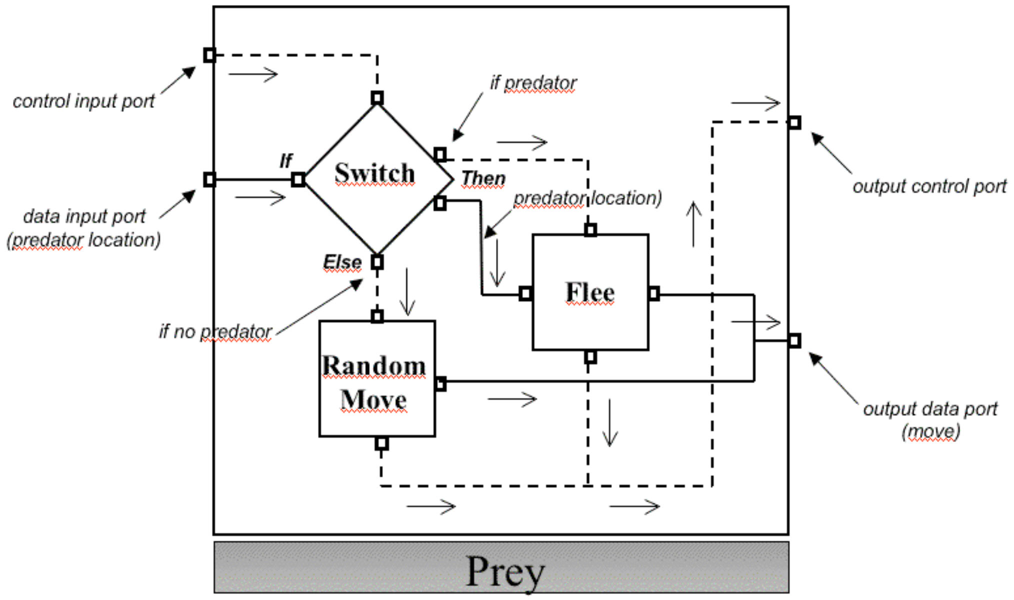
Data flow and control flow: ports and connexions



Concurrency

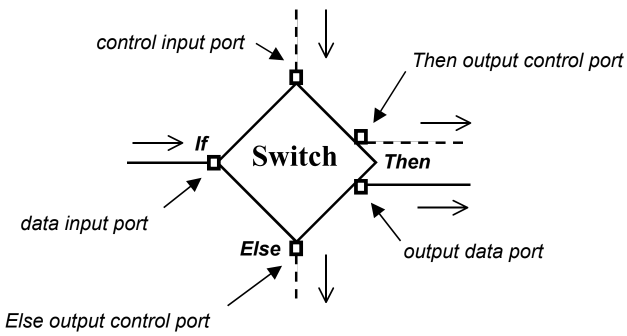
A first example: Prey

- if the Prey detects a Predator, it flees away
- otherwise, it moves randomly



Control components

- dispatch of control flow
- Switch
  - reifies in a component
  - traditional conditional control structure
  - *(if then else)*
  -
-
-
-
- *other control components:*
-
  - control structures
    - » e.g., Repeat
  - synchronization
    - » e.g., Sync *(synchronization barrier)*



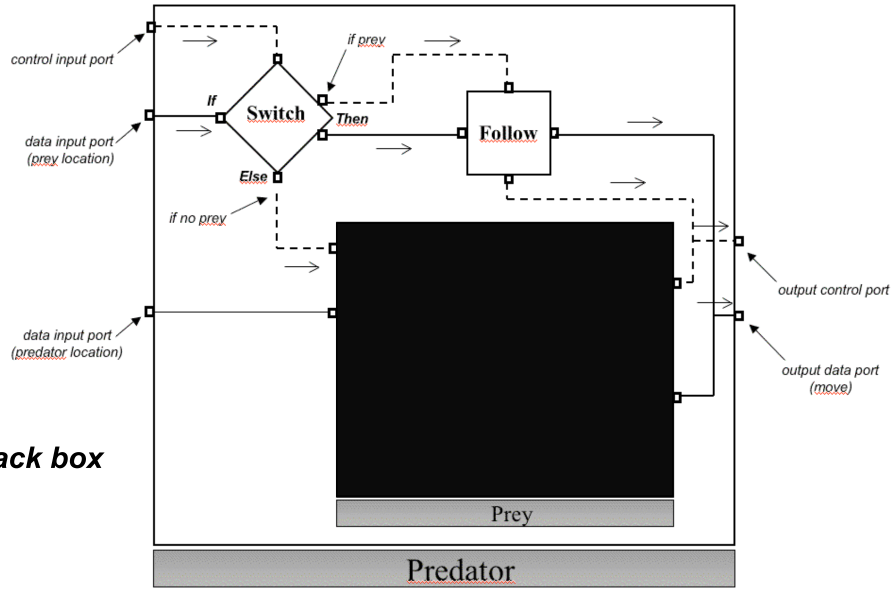
if *input data*

then *transfer control to Then control port and transmit data to Then data port*

else *transfer control to Else control port*

Reuse of a Prey: Predator

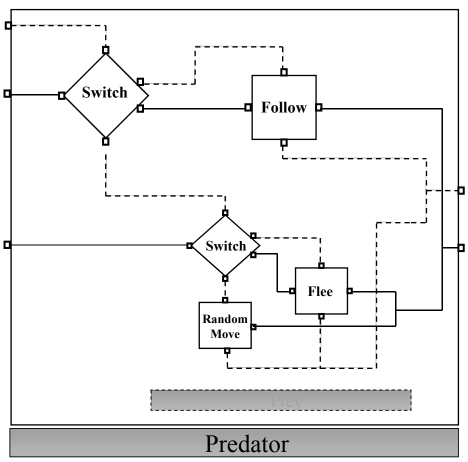
- if the Predator detects a prey, it follows the prey
- otherwise, it acts as a Prey (cannibalism among Predators)



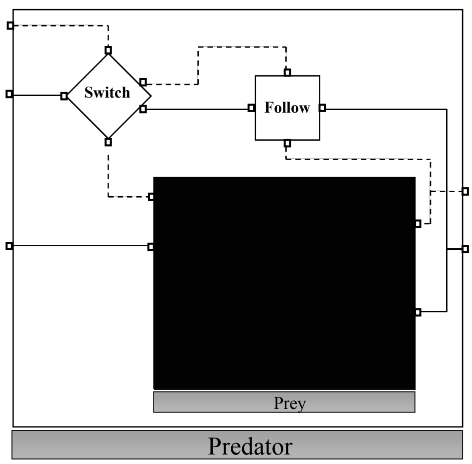
Prey is reused as a black box

Importance of composite component

- Two kinds of composition:



functional composition
(assemblage)



structural composition
(composite component,
information hiding, black box)

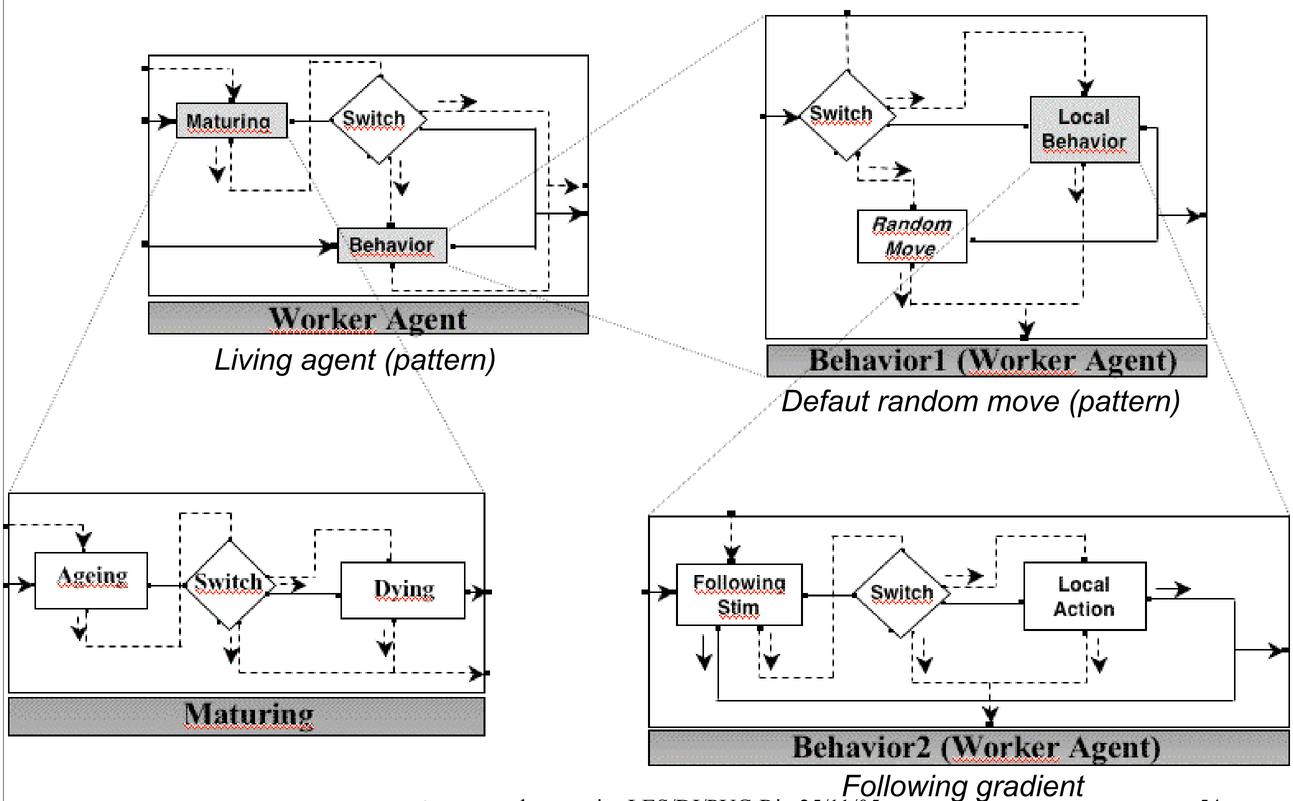
2nd Example: Ant Nests Simulation

- Reingineering of MANTA simulation testbed [Drogoul 93]

ants (workers)
larvae
eggs
queen

- Redesign/construction of ant behaviors using MALEVA [Guillemet et al. 98]

Ex. of hierarchical behavior: Ant Worker

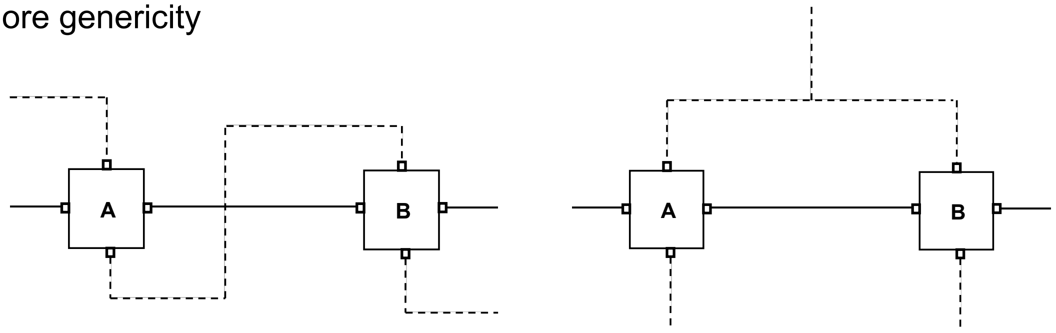


Dynamicity (dynamic change of behavior)

- e.g., egg -> larva -> ant
- behavior server meta-component
  - set up future behavior
  - check what components to keep, to add, to remove
  - install connexions

Advantages of explicit control flow

- decoupling activation logic from functionality
- more genericity



- fine grain control of intra-agent scheduling
  (specification of temporal depencies)
  see next example/slides

3rd Example: population reproduction/evolution

Simplification of demography
micro-simulation model Destinie [INS 99]

Mating * *

Birth

Divorce *

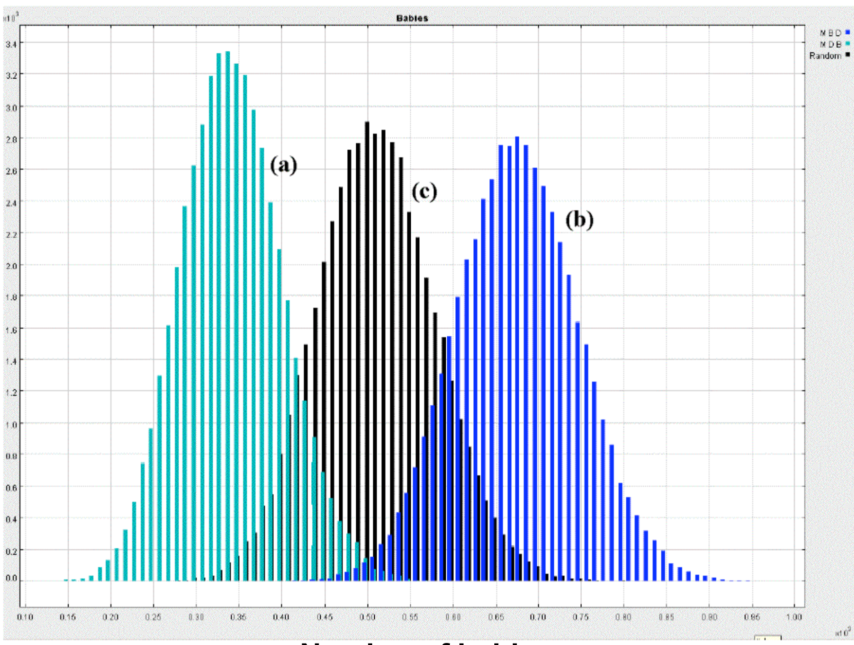
3 behaviors/components
(probabilistic state change):

getMarried	newBaby	divorce

Issue for the designer of the model/simulation:
(Note: often not an expert programmer)

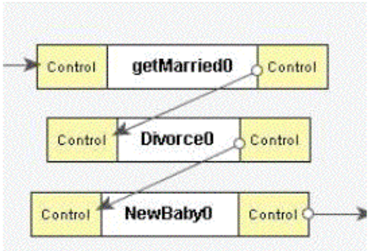
in what order should we activate these behaviors ?

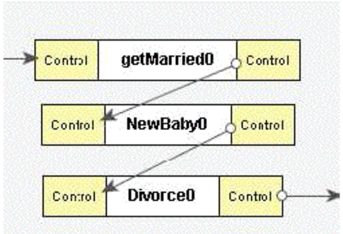
Impact: Scheduling bias

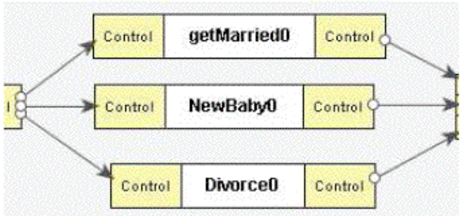


Number of babies

Specification of intra-agent temporal dependencies [Meurisse 04]

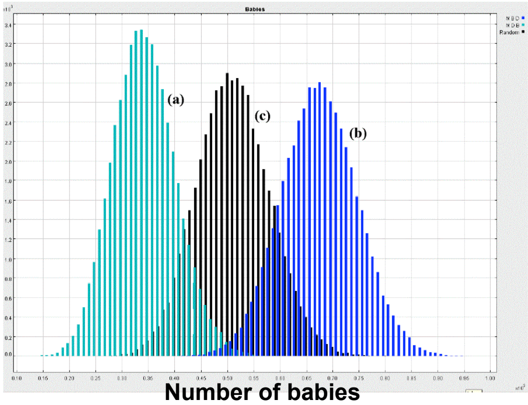






getMarried ; Divorce ; NewBaby **getMarried ; NewBaby ; Divorce** **getMarried || Divorce || NewBaby**

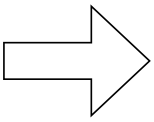
Possible scheduling bias on number of babies



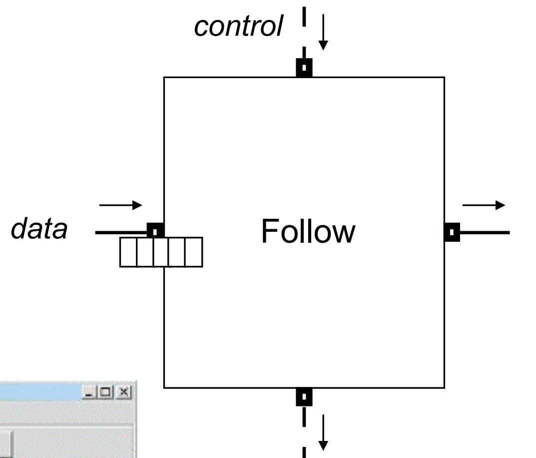
Number of babies

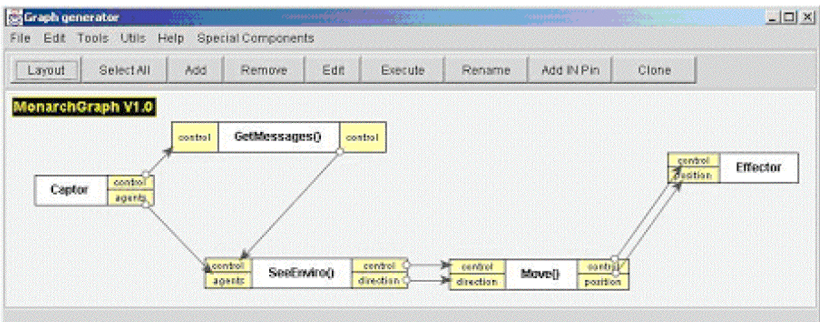
Reingineering of existing behavioral code [Meurisse 04]

- a Java class (name)
- a method (name)
- method signature
  e.g., position Follow(position p)



CGraphGen tool

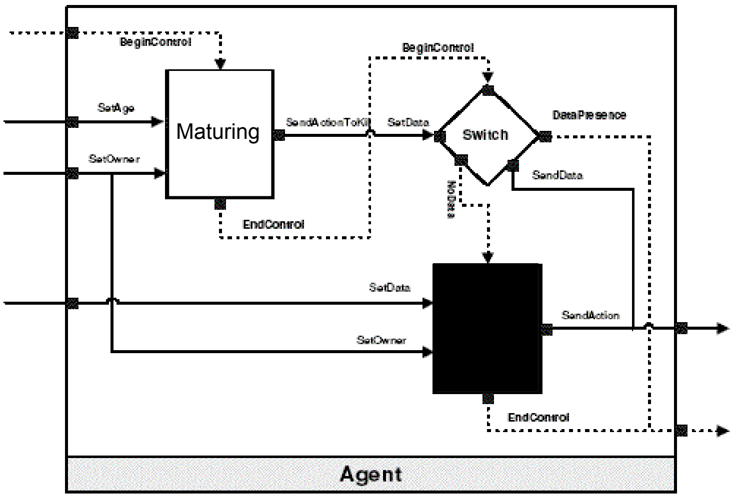




- typed ports
- one FIFO for each data input port

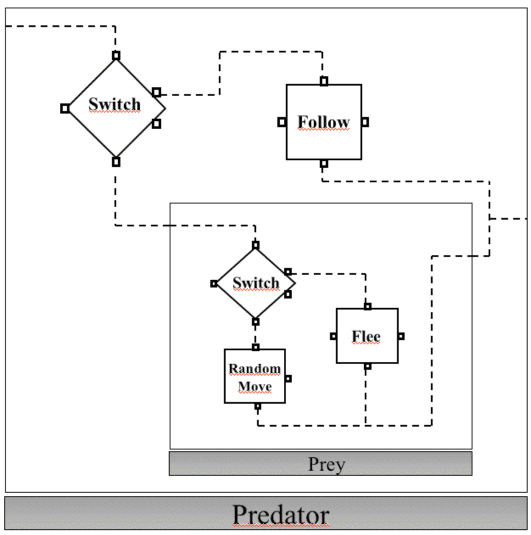
Reuse: Design Patterns [Guillemet et al. 99]

- E.g., "Living Agent" (ageing agent) pattern
  - used for egg,
  - larva,
  - ant worker,
  - queen...



- Actually, we offer more
- than just a design pattern:
- a **black box micro-framework** - *parameterized component*
  - with (in this case) one hot-spot (***Behavior***)

From control flow graph to process algebra term



Even with the hierarchy of components (composite components), which helps at encapsulate some complexity of the control flow graph, specifying it is precise but low level

An alternative direction could then be in using a formalism (coordination language), to specify control coordination language (a very fine grained one)

Process algebra, e.g., CCS

Pi-calculus to handle dynamicity

a compact term

isPrey.Follow || isPredator.Flee || (isNoPrey.RandomMove + isNoPredator.RandomMove)

Outline

- Components
- Agents and Multi-Agent Systems (MAS)
- Evolution of programming
- What agents can bring to components?
  - Autonomy/Evolvability
  - Assistance to Assemblage
    - » Ex: The COGENTS project
- What components can bring to agents?
  - Self-containedeness
  - Architectural support
    - macro-level, ex: role/agent conformance control
    - micro-level: agent architecture
- Component-based agent architectures
  - Various decomposition rationales (levels, modules, behaviors...)
  - Ex: behavior decomposition: the MALEVA agent component model
- Conclusion

Conclusion on MALEVA

- components can be useful to help at decomposing/recomposing agent architectures
- fine grained (behaviors)
  - but optimizations possible
- composite components hierarchy
- dynamic change of behaviors
- data flow and control flow for decoupling activation from functionality
- typed ports
- libraries of
  - behaviors
  - parameterized behaviors (e.g., ageing agent)

General Conclusion (Components & Agents)

- Dual movement:
  - Distributed systems/applications are getting more adaptable/dynamic
    - » dynamic reconfiguration
    - » more semantic support
    - » e.g., GRID and MAS: “Brain meets brawn” [Foster et al. 03]
  - Agents and multi-agent systems have greater software maturity
    - » deployment
    - » configuration
    - » life cycle
- Reuse is difficult (no free lunch)
  - components
  - but also:
    - » inheritance, parameterization, frameworks, delegation
    - » reflective architectures, aspects [Garcia et al. 04], meta-models [Silva et al. 04]...
- Alternative to distributed components: Web services
  - simpler infrastructure (e.g., vs Corba Component Model)
    - » e.g., Web-service-based MAS interoperability [Melliti et al. 04]

Perguntas ?