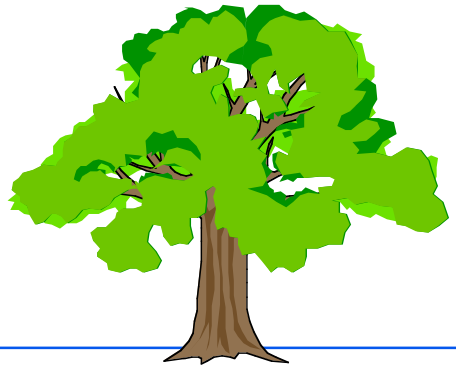
KAOS

Tokens, Classes and Metaclasses
Entities and Relationships
Actions and Time
Agents, Goals and Constraints
The KAOS Methodology

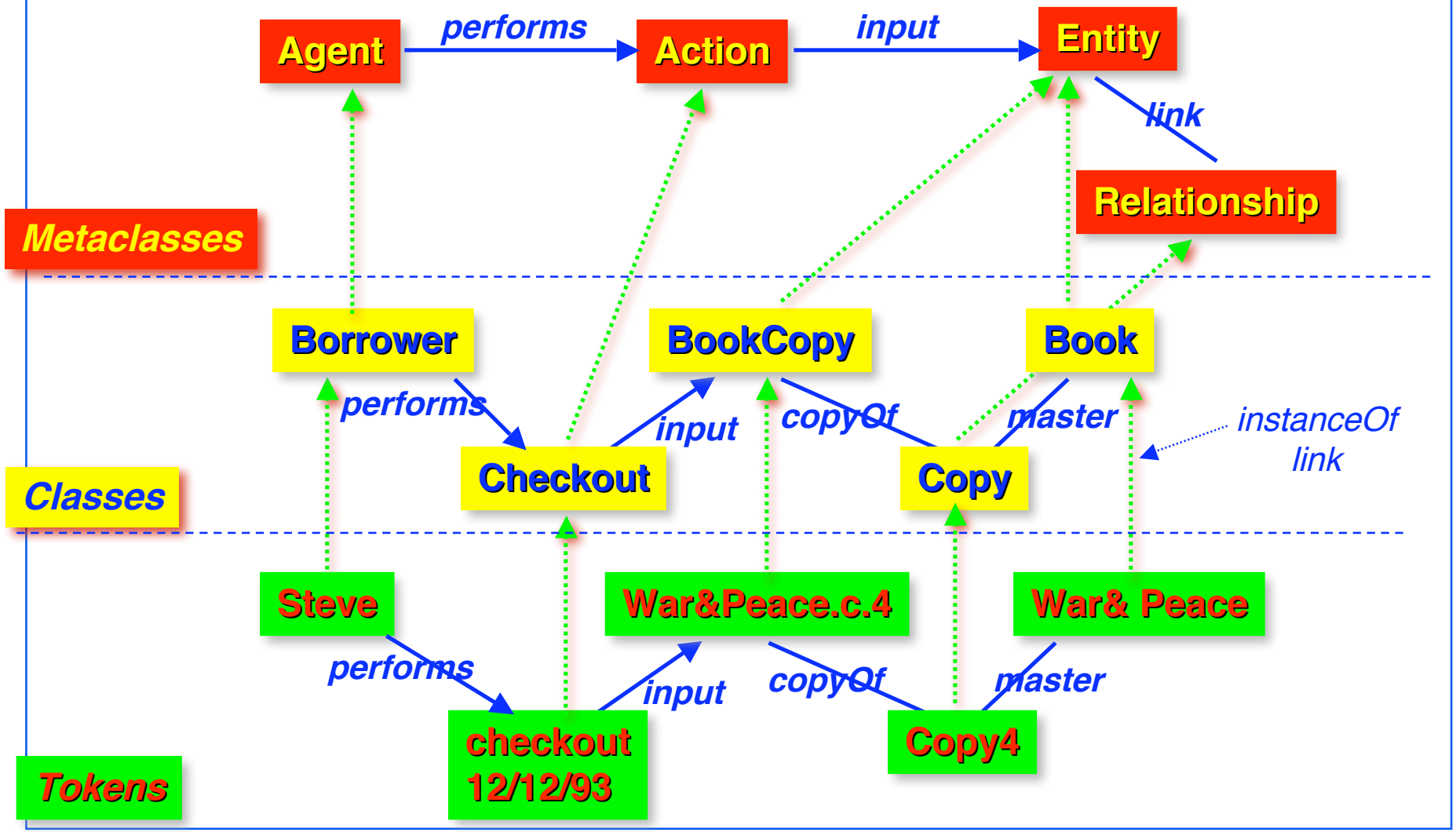
Goal-Directed Requirements Acquisition (KAOS)

- (Organizational) goals lead to requirements.
- Goals justify and explain requirements which are not necessarily comprehensible by stakeholders.
- Goals can be used to assign responsibilities to agents so that prescribed constraints can be met.
- Goals provide basic information for detecting and resolving conflicts that arise from multiple viewpoints

[Dardenne93]



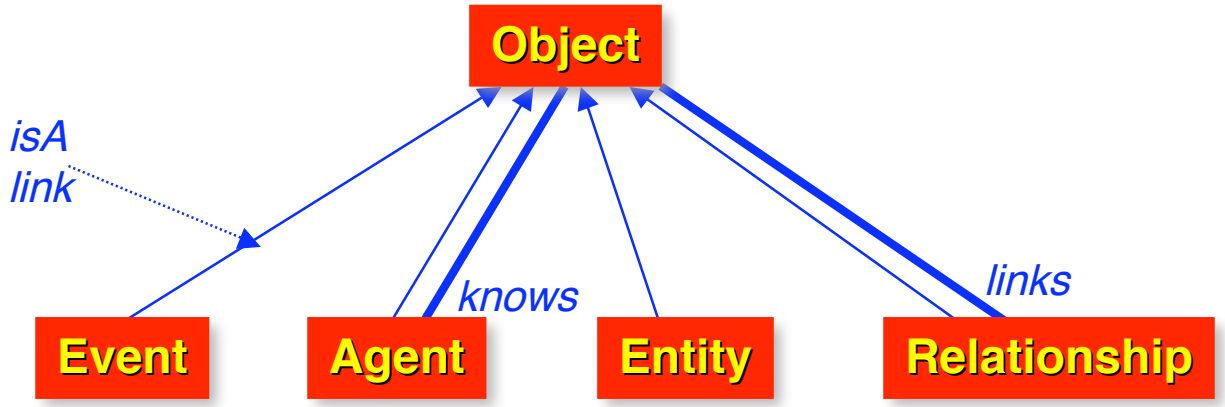
The Meta, Domain and Token Level



Entities and Relationships

Entity Library
Has collection, available, checkedOut, lost: setOf[BookCopy]
coverageArea: setOf[Subject]
Invariant collection = available ∪ checkedOut ∪ lost
∧ available ∩ checkedOut = ∅ ∧ available ∩ lost = ∅
∧ checkedOut ∩ lost = ∅)
...
end Library
Relationship Borrowing
Links Borrower [Role Borrows, Card 0::N]
BookCopy [Role Borrowed, Card 0::1]
Invariant (∀lib: Library, bor: Borrower, b:Book, bc: BookCopy)
[Borrowing(bor,bc) ∧ bc ∈ lib.collection ⇒
bc ∈ lib.checkedOut ∧ ◆ Requesting(bor,b) ∧ Copy(bc,b)]
... **end** Borrowing

Entities and Relationships at the Metalevel



Object has meta-attributes name, informalDef, also:

exists -- is either true or false at the instance level,

invariant -- its values are assertions at the domain level

More Entities and Relationships

Entity Meeting
Has when: TimeInterval, where: Location, feasible, scheduled: Boolean
Invariant (∀m: Meeting) (feasible(m) ⇒ ... ∧
scheduled(m) ⇒ when ≠ none ∧ where ≠ none)
end Meeting

Relationship Requesting
Links Initiator [**Role** Requests, Card 0::N]
Meeting [**Role** RequestedBy, Card 1::N]
Has dateRange: TimeInterval, participantList: setOf[Participant]
Invariant (∀m: Meeting, p: Participant, i:Initiator)
(Requesting(m,i) ∧ m.when≠none ∧ p ∈ Requesting(m,i).participantList
⇒ available(p,m.when)
...
end Requesting

Events

- An event is an instantaneous object.
- `Occurs(e) == e.exists = true`
- Here is an example of an event:

```
Event ReminderIssued
    Has toWhom:Bor, what:BookCopy, mes: text;
    Invariant  (∀rs: ReminderIssued)
      (Occurs(rs(toWhom,what,mes)) ⇒
            (∃p: Staff)(Performs(p,IssueReminder(what,toWhom)))
...
end ReminderIssued
```

- Event classes have a frequency meta-attribute which indicates how frequently their instances occur; its value is a time interval.

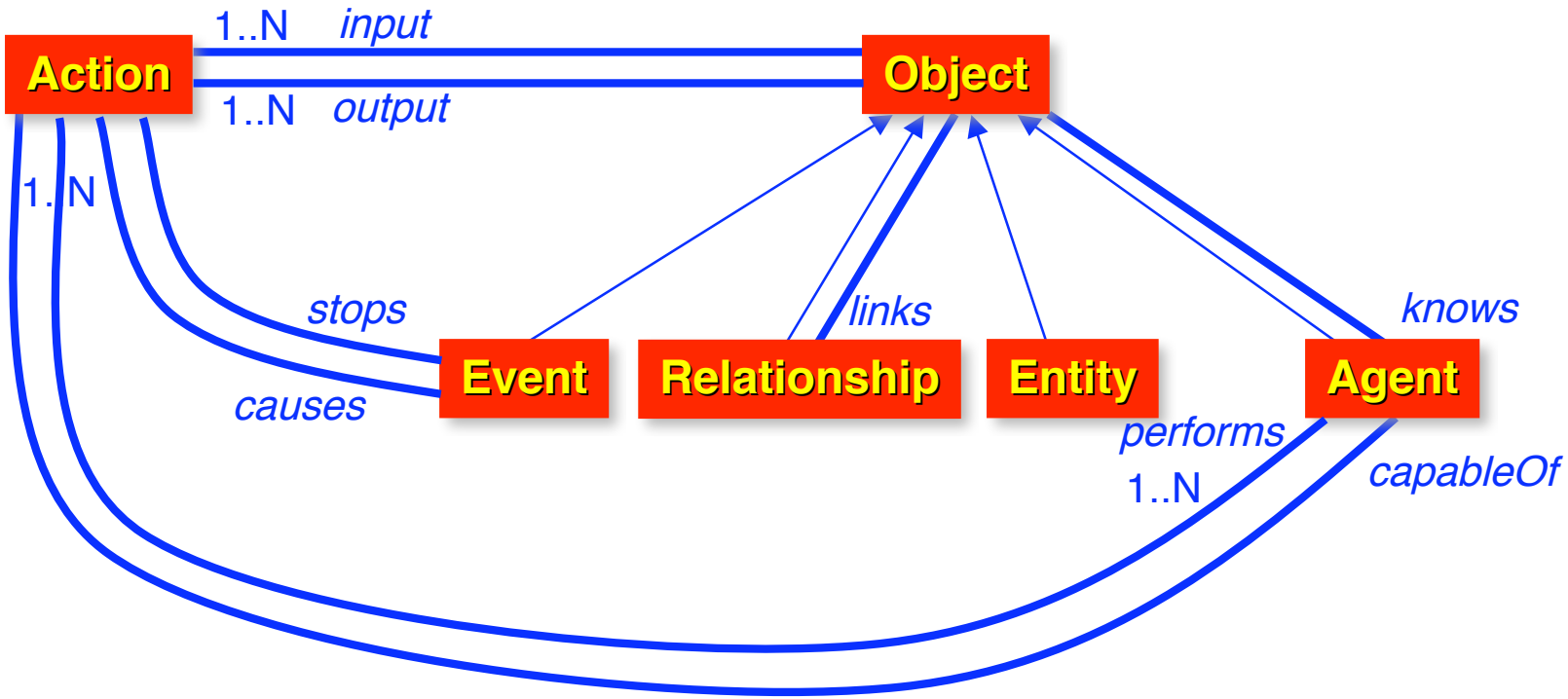
Actions

Action CheckOut
Input BookCopy [**Arg**: bc], Library [**Arg**: lib], Borrower [**Arg**: bor]
Output Library [**Res**: lib], Borrowing
Precondition bc ∈ lib.available
Postcondition ¬(bc ∈ lib.available) ∧ bc ∈ lib.checkedOut ∧
Borrowing(bor,bc)

...

Action IssueReminder
Input BookCopy [**Arg**: bc], Borrower [**Arg**: bor]
Output Reminder
Triggercondition
$\blacklozenge_{>2wks}$ Borrowing(bor,bc) ∧
¬($\blacklozenge_{\leq 1wk}$ ∃r: IssueReminder Occurs(r(bc,bor)))
/* bc has been borrowed by bor for at least 2wks and there hasn't been a reminder to bor regarding bc within the last week */

The Action Metamodel



More on Actions

- The meta-attributes of Action include:
  - ✓ Precondition -- must be true before execution;
  - ✓ Postcondition -- will be true after execution;
  - ✓ TriggerCondition -- triggers execution.
- In addition, actions participate in four meta-relationships:
  - ✓ Input(act,obj) -- obj is in the domain of act;
  - ✓ Output(act,obj) -- obj is in the codomain of act;
  - ✓ Causes(ev,act) -- ev causes act;
  - ✓ Stops(ev,act) -- ev stops act;
- Modify and Inspect are two specializations of Action. Modify changes the state of one or more objects, while Inspect does not.

Representing Time in KAOS

$\bigcirc\phi$	- ϕ is true in the next state
$\bullet\phi$	- ϕ is true in the previous state
$\Diamond_{\leq x}\phi$	- ϕ will be true sometime (within x)
$\blacklozenge_{\leq x}\phi$	- ϕ was true sometime (within x)
$\Box_{\leq x}\phi$	- ϕ will be always true (after some time)
$\blacksquare_{\leq x}\phi$	- ϕ was always true (until some time)
$\phi \mathrm{U} \psi$	- ϕ is true until ψ becomes true
$\phi \mathrm{S} \psi$	- ϕ has been true since ψ became true

Notation:

- circle - previous/next state
- star - sometime in the past/future
- square - always in the past/future

Agents

Agent Staff
Has competenceAreas: setof[Competence]
Invariant ("st:Staff)
InstanceOf(st,LibrarianStaff) ∨ InstanceOf(st, ClerkStaff)
Load …. /* describes the agent's work load */
CapableOf CheckIn, CheckOut, IssueReminder, Reference, Cataloguing
Performs assigned: Action
Knows Borrowing [Interface: BorrowingSheet]

- Agents may be humans, organizational units, or software.
- Agents may be composed from other agents through a Cartesian product construction.
- An agent performs only actions she is capable of.
- Knows(ag,obj) means that ag can observe the state of obj through some interface.

Goals

SystemGoal Achieve[BookRequestSatisfied]
InstanceOf SatisfactionGoal
Concerns Borrower, Book, Borrowing,...
Definition (∀bor: Borrower, b: Book, lib: Library)
(Requesting(bor,b) ∧ b.subject ∈ lib.coverageArea
⇒ ◇ (∃bc: BookCopy) (Copy(bc,b) ∧ Borrowing(bor,bc)))
ReducedTo EnoughCopies, RegularAvailability, AvailabilityNotified
ReducedTo AsManyCopiesAsNeeded

SystemGoal Maintain[SafeTrasportation]
InstanceOf SafetyGoal
Concerns Passenger
InformalDef ...

Goal Patterns

- A goal is a *non-operational objective* in that there is no single action that an agent can perform to achieve it.
- Patterns identify what is to be done with a goal:
  - ✓ *Achieve* -- achieve the goal at some point in the future
    $P \Rightarrow \Diamond Q$
  - ✓ *Cease* -- undo a goal at some point in the future
    $P \Rightarrow \Diamond \neg Q$
  - ✓ *Maintain* -- maintain a goal for some time
    $P \Rightarrow \Box Q$
  - ✓ *Prevent* -- prevent a goal from becoming true
    $P \Rightarrow \Box \neg Q$
  - ✓ *Optimize* -- maximize or minimize some measure
    max(fcn) or min(fcn)

Goal Categories

Goals also have associated categories (these are specializations of the `Goal` metaclass), such as:

- *SatisfactionGoal* -- satisfying agent requests
- *InformationGoal* -- informing agents
- *RobustnessGoal* -- recovering from failures
- *ConsistencyGoal* -- maintaining consistency
- *SafetyGoal*, *PrivacyGoal*, maintain agents in states that are safe and observable under restricted conditions.

These categories are useful because each one has its heuristics for decomposition and operationalization (satisfaction).

Subgoals

SystemGoal Maintain[RegularAvailability]
InstanceOf SatisfactionGoal
Concerns Library
Definition (∀bor: Borrower, b: Book, bc: BookCopy, lib: Library)
(bc ∈ lib ⇒ □[¬(bc ∈ lib.available) ⇒ (◇≤Nwks bc ∈ lib.available)])
/* N is a parameter */

SystemGoal Achieve[AvailabilityNotified]
InstanceOf InformationGoal
Concerns Borrower, Library
Definition (∀bor: Borrower, b: Book, bc: BookCopy, lib: Library)
(Requesting(bor,b) ∧ ●(¬∃bc:BookCopy (Copy(bc,b) ∧ bc ∈ lib.available)) ∧ (∃bc:BookCopy (Copy(bc,b) ∧ bc ∈ lib.available)) ⇒ ◇ Knows(bor,lib.available))
/* If a borrower requests a book, and the book just became available, the borrower will be informed */

Conflicting Goals

PrivateGoal Maintain[LongBorrowingPeriod]
InstanceOf SatisfactionGoal
Concerns Borrower, Borrowing
Definition (∀bor: Borrower, b: Book, bc: BookCopy)
[Borrowing(bor, bc) ∧ Copy(bc, b) ∧ ❍Need(bor, b)
⇒ ❍Borrowing(bor, bc)]
/* If a borrower has borrowed a book and she still needs it, she can continue to borrow it */
Conflicts with RegularAvailability

This goal is in conflict with `RegularAvailability` and can be declared so explicitly.

Constraints

- Constraints are *operational objectives* in that there are particular actions that agents can perform to achieve them. Constraints may be *hard* or *soft*.

  SoftConstraint Maintain[LimitedBorrowingPeriod]

  Definition (∀bor: Borrower, bc: BookCopy)

  (Borrowing(bor, bc) ⇒ ◇¬ Borrowing(bor, bc)

- Constraints operationalize goals

  SystemGoal Maintain[RegularAvailability]

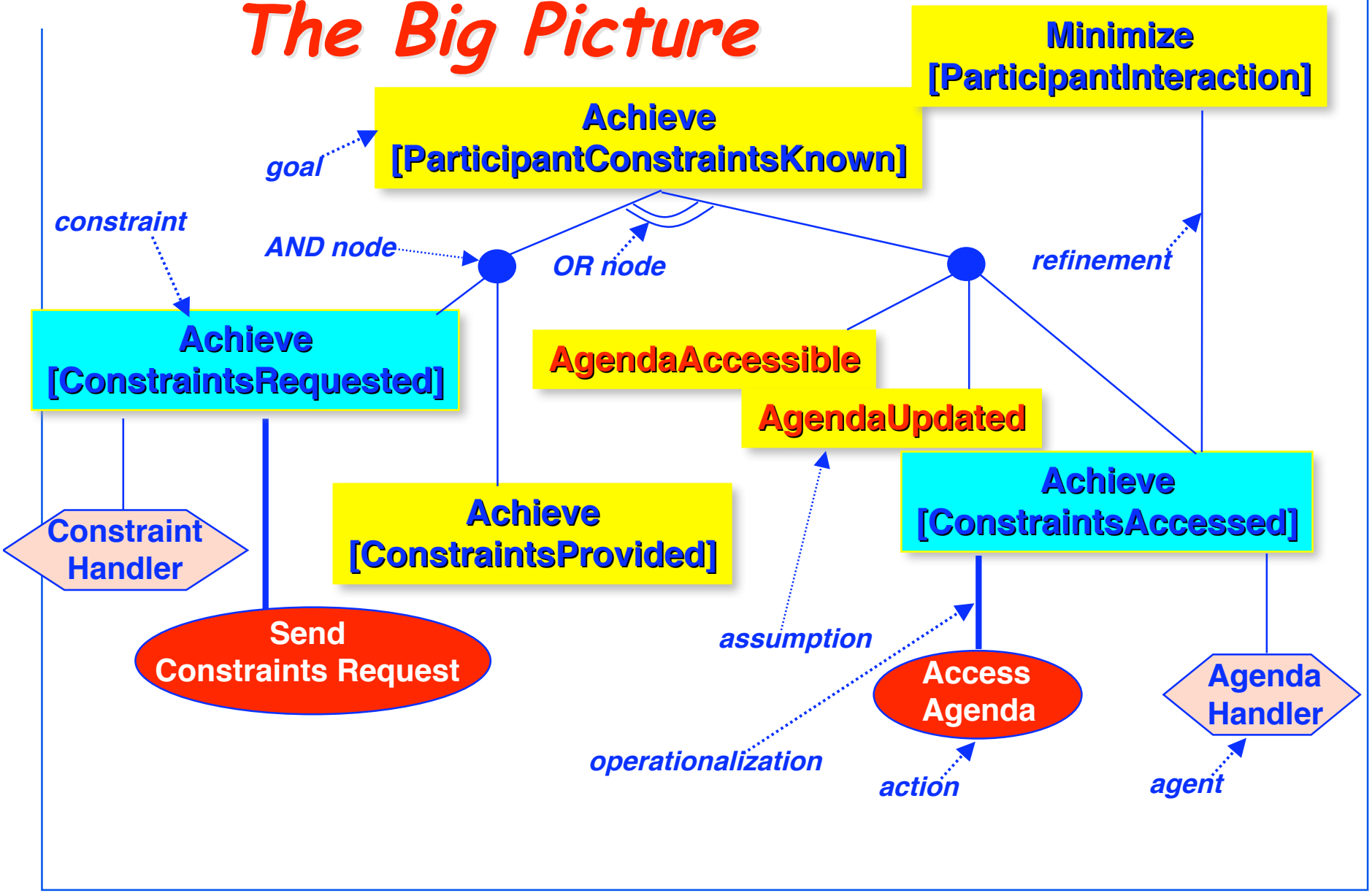
  Concerns ...

  Definition ...

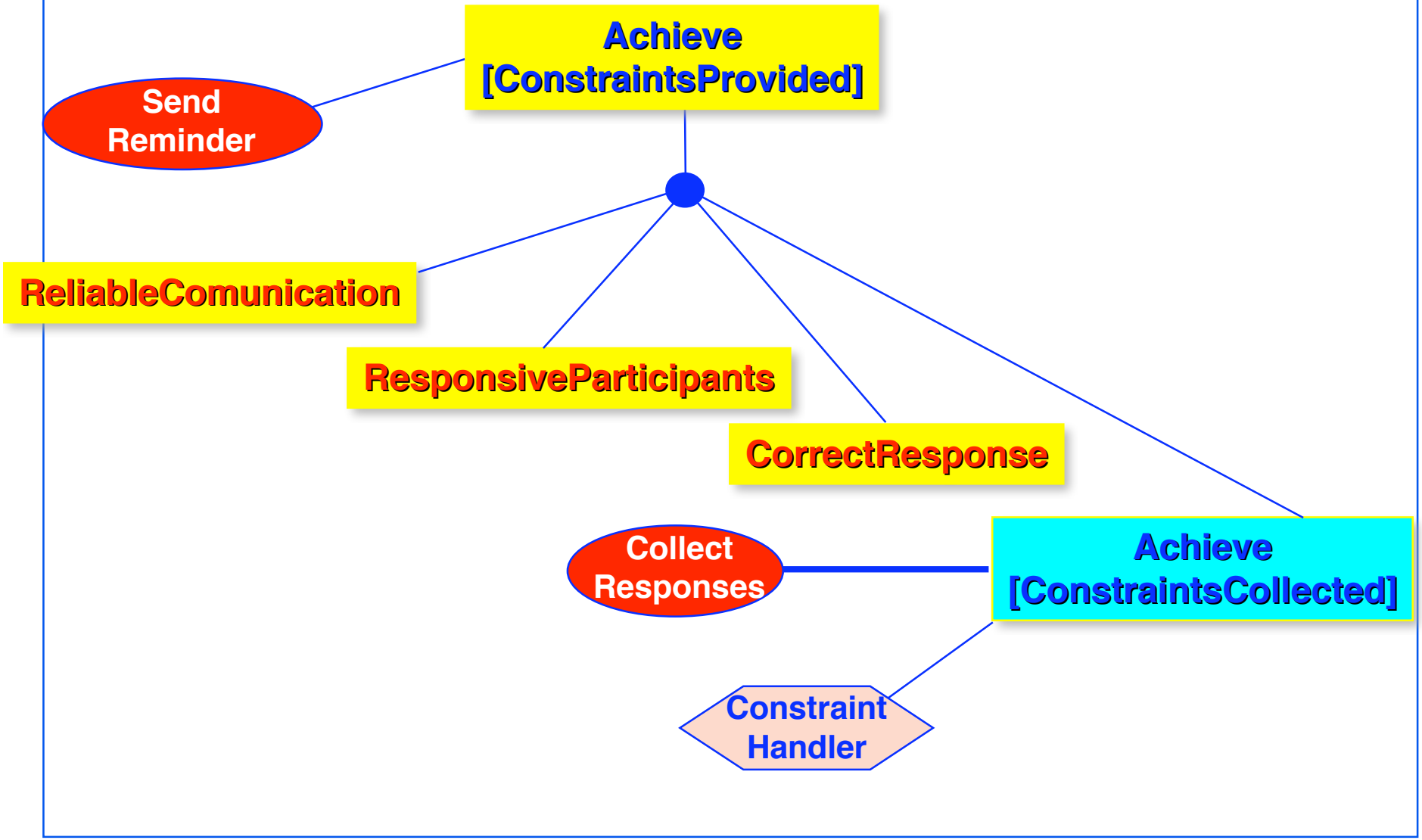
  OperationalizedBy LimitedBorrowingPeriod, NoLostCopies,...

- Constraints are *ensured* by restricting existing actions and objects (through strengthened preconditions, invariants, etc.) or through the introduction of new actions and objects.

The Big Picture



...in Detail...



The KAOS Modeling Philosophy

- Modeling a social setting involves a variety of concepts, including *Goals*, *Agents*, *Concerned Objects*, *Actions*, *Constraints* and *Responsibilities*.
- Goals lead to assignments of responsibilities and designs of actions and artifacts
- Use a metamodel to support reuse of generic domain modeling patterns [Dardenne93]
- For example, the library domain is an instance of the "resource allocation" meta-domain, which also covers car/room/dwelling rental and is similar to airline/hotel reservation, class registration etc.

The KAOS Acquisition Process

- *Identify Goals*, and their *Concerned Objects.*
- *Identify* potential *Agents* and their *Capabilities.*
- *Operationalize Goals* into *Constraints.*
- *Refine Objects* and *Actions.*
- *Derive* strengthened *Objects* and *Actions* to *Ensure Constraints.*
- *Identify* alternative *Responsibilities.*
- *Assign Actions* to responsible *Agents.*

All this could be just as useful to someone doing organizational design, rather than software development!

References

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