JADE Semantics Add-on

tutorial

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what is the JSA?

- a JADE extension to automate the interpretation of the meaning of messages exchanged by agents (according to the semantics of the FIPA-ACL standard)

- a framework to build more flexible agents

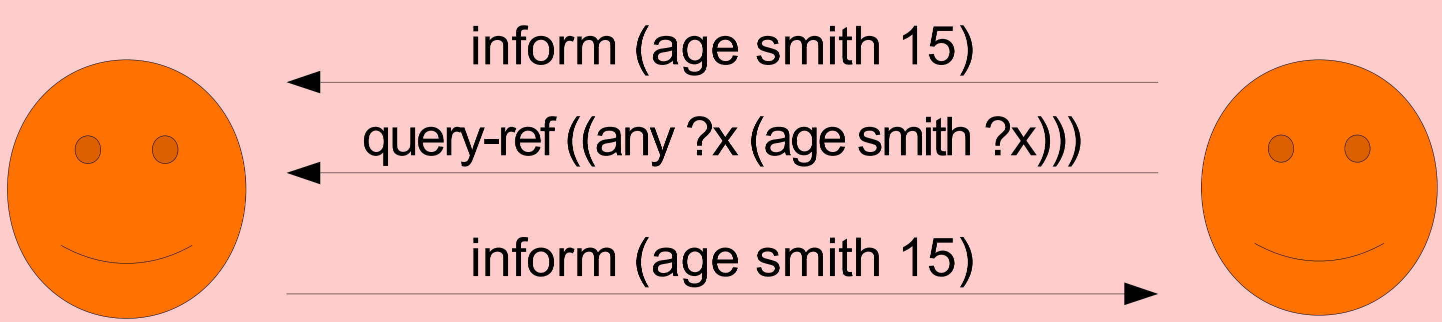
- a set of classes, which makes simpler the coding of JADE agents

- agents built on top of JSA = semantic agents

the most simple semantic agent

- the class SemanticAgentBase provides a default implementation for semantic agents
- it makes it possible to interpret all FIPA-ACL messages (but proxy)

java jade.Boot mySemanticAgent:SemanticAgentBase



FIPA-ACL: a language for understanding each other

- logical formalization of the philosophical theory of speech acts [Austin, Searle, Vandervecken, Sadek]
- "communication is action"
  An utterance involves 3 levels
  - locution: (physical) act of saying
  - illocution: act performed by saying
  - perlocution: act performed by the fact of saying

on the physical environment

on the mental states

of participants

"I ask you to close the door"

performative

propositional content

communicative acts

- syntax

syntax		example
(performative*		INFORM
:sender	sending agent*	(agent-identifier :name me)
:receiver	receiving agents*	(set ...)
:content	propositional content* (action, proposition or IRE)	"((sunny))"
:content-language	content language	fipa-sl
:ontology	content vocabulary	weather-forecast
…other parameters…		
)		

- semantics: formal definition (in a logical framework) of
  - FP : feasibility precondition
  - RE : rational effect or perlocutionary effect

example: query-if

```
(query-if
    :sender s
    :receiver r
    :content "((age smith 10))"
)
```

the agent s *asks*
the agent r
whether the proposition
(age smith 10) *holds*

- **precondition**: s does not know the truth of (age smith 10)
- **rational effect**: r performs the action
  (inform-if :sender r :receiver s :content "((age smith 10))")

- the JSA interpretation engine entails the reaction to a message from its formal features

FIPA-ACL: about 20 performatives

- see http://www.fipa.org/specs/fipa00037
  - information transmission
    inform, inform-if, inform-ref, confirm, disconfirm
  - request on information
    query-if, query-ref, subscribe,
    on actions
    request, request-when(ever)
  - negotiation
    cfp, propose, accept-proposal, reject-proposal
  - action management
    cancel, agree, refuse
  - task delegation
    propagate, proxy
  - error management
    failure, not-understood

FIPA-SL

- logical language, including
  - a first order predicate logic (FOL)
  - a modal logic, with modalities that represent
    - agents' mental states: believes (B, U) and intentions (I)
    - action occurrences: past (done) and future (feasible) ones
- prefixed syntax like in LISP: (and sunny cold)
- 2 main types of expressions
  - terms: represent domain objects
    instances, actions, object descriptions (IRE), ...
  - formulas: represent facts, which can be true or false
- see http://www.fipa.org/specs/fipa00008

FIPA-SL terms (1/2)

- constants

  numbers: 1, -6.5E1 strings: "this is a \"FIPA-SL\" string"

  dates: *YYYYMMDD*T*HHMMSSmmm*z, 20060331T093000000z

  binary constants: #*N*"*byte-sequence*

- sets and sequences

  (set *elem1 elem2 ...*) not significant duplicates and order

  (sequence *elem1 elem2 ...*) significant duplicates and order

- functional terms (e.g. class instances)

  (*funct-symbol* :*param_name param_value ...*)

  (person :name john :age 20)

FIPA-SL terms (2/2)

- actions (including communicative acts)

  (action *actor act*) *act* is usually given as a functional term

  (action s (inform :sender s :content "((sunny))" :receiver (set r)))

  - action composition

    (; *a1 a2*) sequence: do *a1*, then do *a2*

    (| *a1 a2*) indeterministic choice: do either *a1* or *a2*

- identifying reference expressions (IRE)

  (*quant term formula*) where *quant* ∈ {*any*, *iota*, *some*, *all*}

  (iota ?x (age john ?x)) the only value related to john by age (i.e. *the* age of john)

  (some (sequence ?x ?y) (age ?x ?y)) a set of pairs (person, age)

FIPA-SL formulas (1/2)

- atomic formulas

  (*pred-name param1 param2 ...*) all *paramN* are terms

  (age (person :name john :age 20) 20)

  predefined predicates and constants: =, result, true, false

- FOL logical connectors

  not (unary), and, or, implies, equiv (binaries)

  (and sunny cold), (equiv (not cold) hot)

- FOL quantifiers

  (exists *var formula*) there is at least one object *var* satisfying *formula*

  (forall *var formula*) all objects *var* satisfy *formula*

  (forall ?x (implies (person ?x)
  (exists ?y (age ?x ?y)))) all persons have an age

FIPA-SL formulas (2/2)

- mental state modalities

  (*modal-op agent formula*) where *agent* is a term, modal-op ∈ {B, U, I}

  (B (agent-identifier :name john) sunny)
  (B (agent-identifier :name john) (not sunny))
  (not (B (agent-identifier :name john) sunny))

  3 different kinds of belief

- action occurrence modalities

  (*modal-op action formula*) where *action* is a term of kind action, modal-op ∈ {done, feasible}

  (done (| a1 a2) sunny) either a1 or a2 has just occurred, and sunny was true just before

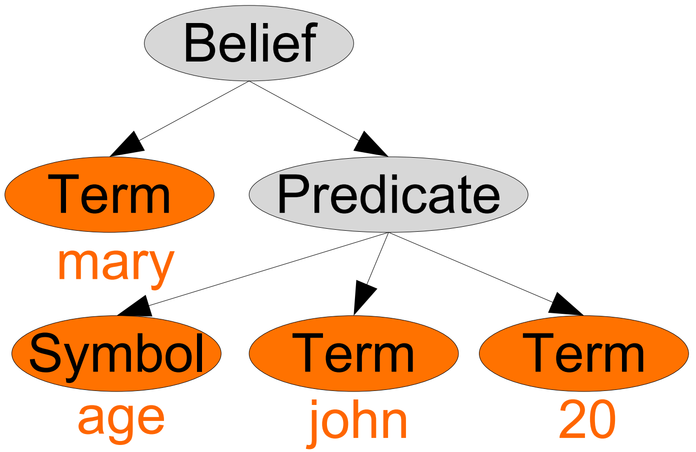
  (feasible (action s (inform :receiver (set r) :content "(sunny)")) (B r sunny))
  it is possible to perform the inform act, and if so, r will believe its content just after its performance

handling SL expressions with the JSA

- SL expressions are represented by Directed Acyclic Graphs of Node objects (counterparts of JADE AbsXXX objects)

(B mary (age john 20))

see package
jade.semantics.lang.sl.grammar



- Some Node objects have specific computation methods
  - e.g. getSimplifiedFormula() on Formula instances
- The main class to handle Node objects is jade.semantics.lang.sl.tools.SL

parsing/unparsing SL expressions

- methods fromTerm(String) and fromFormula(String)
  - parse a string expressed in SL syntax (into a Node object)
- method toString()
  - unparse a Node object into a string expressed in SL syntax

```
Term john = SL.fromTerm("(agent-identifier :name john)");
Formula f = SL.fromFormula("(age " + john + " 20)");

System.out.println("f = " + f);
System.out.println("agent = " +
        ((FunctionalTermParamNode)john).getParameter("name"));

prints          f = (age (agent-identifier :name john) 20)
                agent = john
```

SL expression patterns

- the Node hierarchy extends FIPA-SL with “meta-references”
  - it is possible to build “patterns” of expressions
  - meta-references (MR) within a pattern are prefixed by “??”
  - MR may be replaced with expressions of the proper type
  - 2 occurrences of the same MR denote the same expression
  - example (I ??agent (B ??agent ??formula))

??agent may be replaced with a term

??formula may be replaced with a formula

(I john (B john sunny))

- 2 fundamental operations on patterns
  - instantiation replace each occurrence of a MR within a pattern with the same expression
  - matching check whether an expression may result from the instantiation of a pattern

creating and instantiating patterns

- **creating patterns:** SL.fromXXX
  as for creating regular expressions

```
Formula pattern = SL.fromFormula
                    ("(I ??agent (B ??agent ??formula))");
```

- **instantiating patterns:** aNode.instantiate(aString,anotherNode)
  or SL.instantiate(aNode, [aString, anotherNode]*)

```
Term john = SL.fromTerm("(agent-identifier :name john)");
Formula f = SL.fromFormula("sunny");

Formula myFormula = (Formula)SL.instantiate(pattern,
                              "agent", john, "formula", f);
```

very useful to create expressions

matching patterns

- aNode.match(Node)
  returns a MatchResult if a matching is possible
  or null if no matching is possible
- aMatchResult.getXXX(String) and aMatchResult.XXX(String)
  get the value of a given MR satisfying the matching

```
MatchResult result = pattern.match(myFormula);
if (result != null) {
		System.out.println("agent = " + result.term("agent"));
		System.out.println("formula = " + result.formula("formula"));
}
else System.out.println("no match");
```

fundamental to recognize or filter expressions

practical exercises developing an album application

- 4 progressive exercises

- under the tutorials directory
  - exercises/
    - img*.jpg: predefined images for the album application
    - src/album/tools: predefined GUI classes
    - src/album/versionX/Album.java: album class to develop
    - src/album/versionX/Viewer.java : viewer class to develop

    within build.xml, set variable "tuto-home" to the tutorial directory

    compile with ant X jar (X = 1, 2, 3 or 4)

    run with ant X album

    ant X viewer

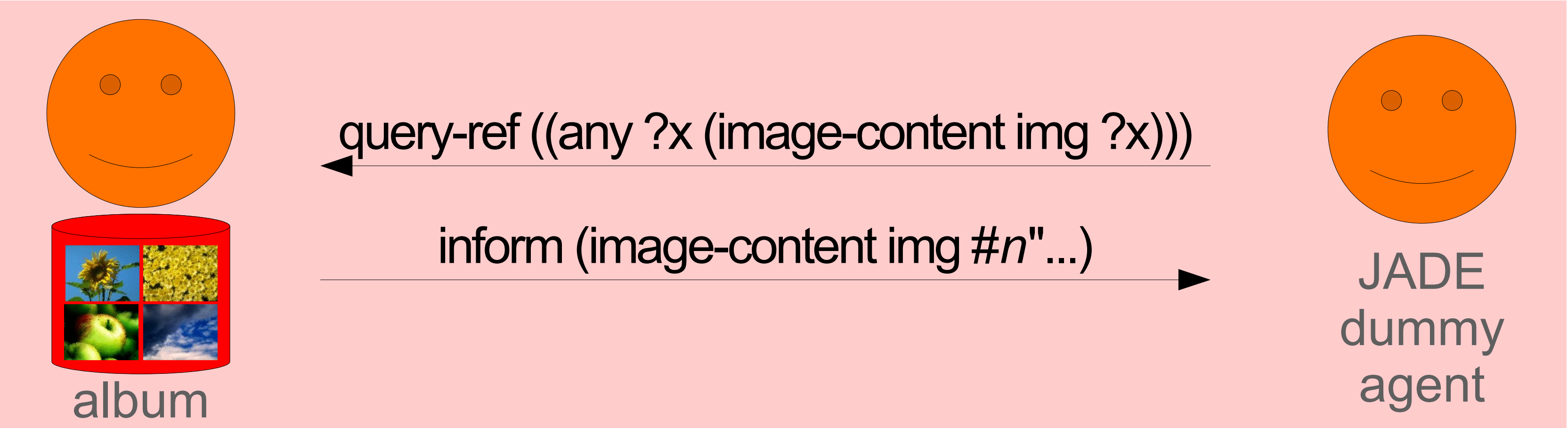
    develop all yourself or start from the *.java.sqel templates
  - solutions/

    same structure, with completed *.java files

album application – exercise 1
handling SL expressions

- register a picture within the album agent
  - use the application-specific predicate (image-content *id byte-content*)
  - read the byte content from the file given as an agent's argument
  - use SemanticCapabilities.interpret(Formula) within the setup() method of the agent

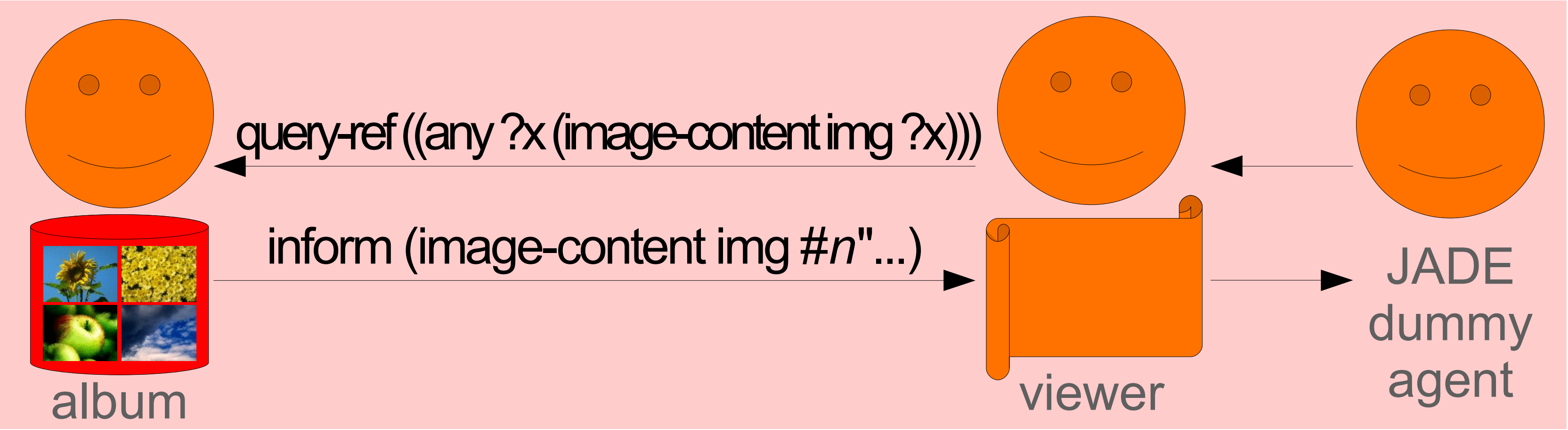
- get the picture (as a byte content) with a JADE dummy agent



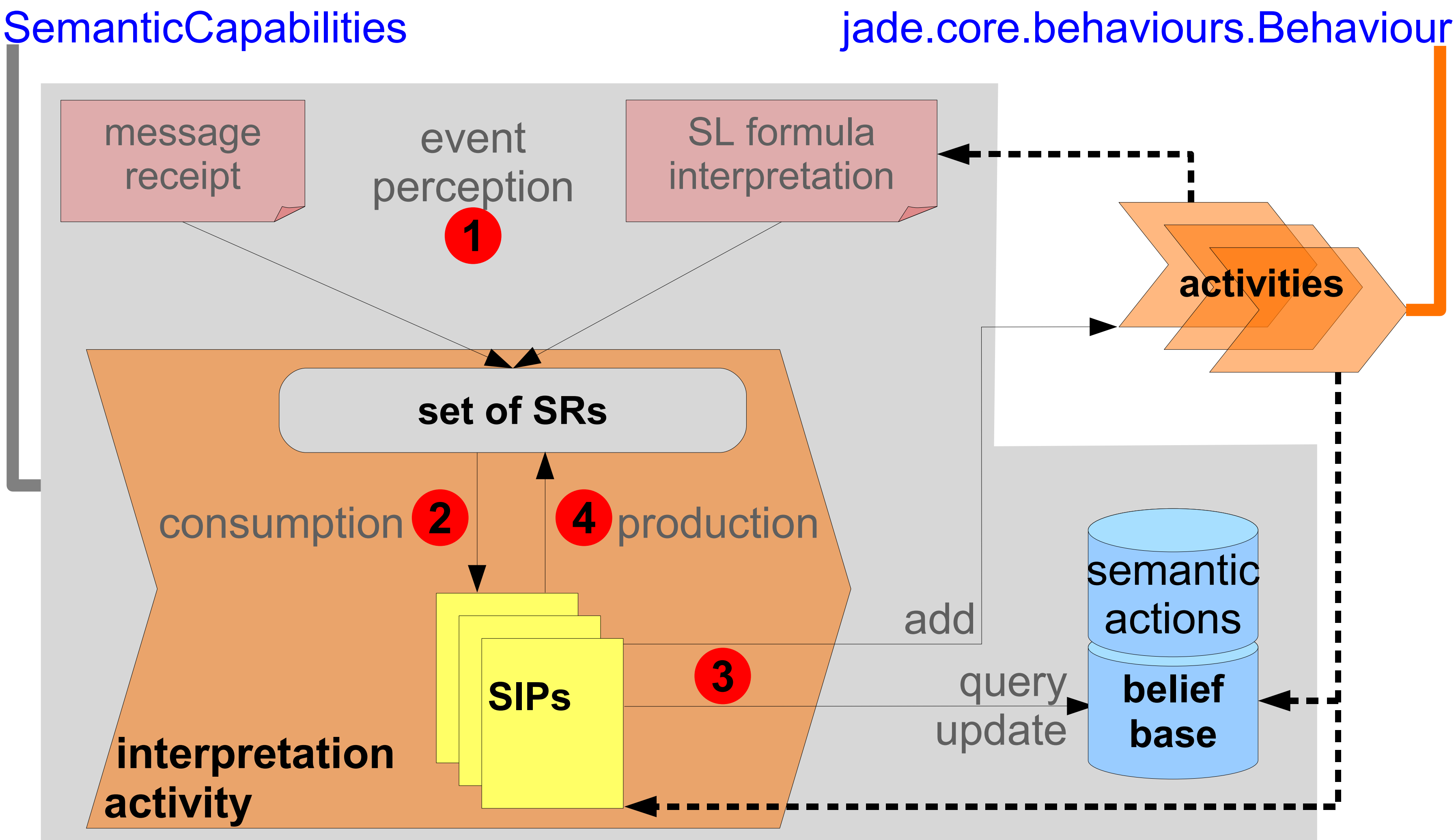
album application – exercise 1 handling SL expressions

- make the request performed by the viewer agent
  - read the name of the album agent from the agent's arguments
  - use SemanticCapabilities.queryRef(IdentifyingExpression) within the setup() method of the agent

- check the exchanged messages thanks to the JADE sniffer
- request the viewer with a dummy agent



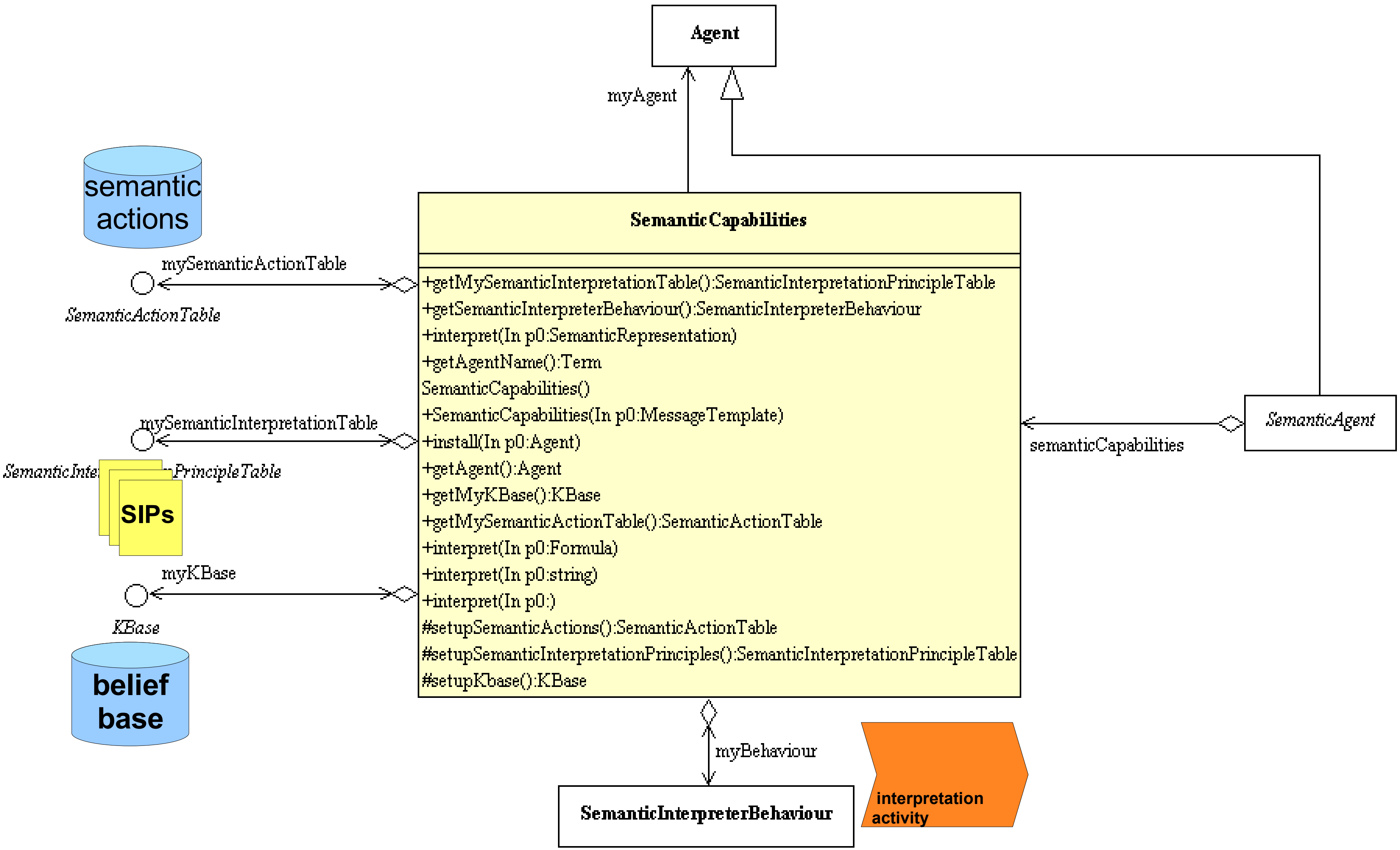
JSA interpretation engine



interpretation algorithm

- event perception: produce an initial SR
  - receipt of a message *m* → (B agent (done (action *sender m*)))
  - interpretation of a formula → *f*
- **while** the list of SRs is not empty, **do**
  remove a SR from the list;
  if the SR is logically equivalent to false, then exit;
  apply all possible SIPs to the SR;
  add all produced SRs to the list;
  end while
- the interpretation finishes when
  - the list of SRs is empty → “normal” case
  - a SR equivalent to false is produced → sending of a not-understood
  - no SIP is applicable → assertion of remaining SRs into the belief base

software architecture



semantic agent skeleton

- semantic agent = JADE agent + SemanticCapabilities

    this attribute specifies the interpretation engine functioning

```
public class MyJSA extends SemanticAgent {
   class MySematicCapabilities extends SemanticCapabilities {
         protected SemanticInterpretationPrincipleTable
                             setupSemanticInterpretationPrinciples() {...}
         protected KBase setupKbase() {...}
         protected SemanticActionTable setupSemanticAction() {...} ...
   }
   public MyJSA() {
         setSemanticCapabilities(new MySematicCapabilities());
   }
   public void setup() {
         super.setup();    ...
   }
}
```

main SemanticCapabilities operations

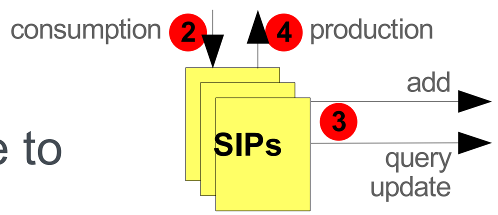
- general operations
  - getAgent()
    returns the JADE agent instance wrapping the semantic agent
  - getAgentName()
    returns a SL term representing the semantic agent AID
  - getSemanticInterpreterBehaviour()
    returns the Behaviour running the semantic interpretation engine
  - interpret(Formula/String/SR)
    runs the semantic interpretation engine on a given formula
- operations to perform communicative acts
  - *performative*(*propositional_content_params*,...,*receiver*)

Formula, ActionExpression or IdentifyingExpression   Term or Term[]

  - example: inform(Formula,Term), request(ActionExpression,Term), ...

SIPs in the heart of interpretation

- a "Semantic Representation" (SR)
  - represents a part of the meaning of an event
  - conveys a subjective meaning with respect to the agent
    - of the form (B *myself* ??phi) or (B *myself* (I *myself* ??phi))
- a "Semantic Interpretation Principle" (SIP)
  - elaborates a part of the meaning of an event by
    - consuming a SR (the SIP is said to be applied to the SR)
    - possibly modifying the agent's internal state
    - possibly producing new SRs
  - has an application index, which makes it possible to
    - order the application of SIPs
    - apply SIPs only to relevant SRs (such that *SR index* ≥ *SIP index*)



- the interpretation algorithm is an ad-hoc rule engine

standard SIPs (1/2)

- standard SIPs implement the **generic principles** of the rational agent theory, which FIPA relies on

- **ActionFeature** (B myself (done *??message* true))

  upon receipt of a *message*, produces SRs representing the formal FP and RE of the corresponding communicative act
  (uses the table of SemanticAction, which includes all FIPA acts)

- **BeliefTransfer** (B myself (I *??agent* (B myself *??belief*)))

  decides to adopt a *belief* suggested by another *agent*
  (e.g. upon interpretation of an inform)

- **IntentionTransfer** (B myself (I *??agent ??goal*))

  decides to adopt the intention of another *agent*'s *goal*
  (elementary form of cooperation, e.g. upon interpretation of a request)

standard SIPs (2/2)

- **Planning** (I myself *??goal*)

  creates (and adds to the agent) an activity to reach an intended *goal*
  the JSA is provided with no default planning SIP, however, the PlanningSIPAdapter is intended to plug external planers if needed

- **ActionPerformance** (I myself (done *??action* true))

  creates (and adds to the agent) an activity to perform an intended *action* (uses the table of SemanticAction)

- **RationalityPrinciple** (I myself *??goal*)

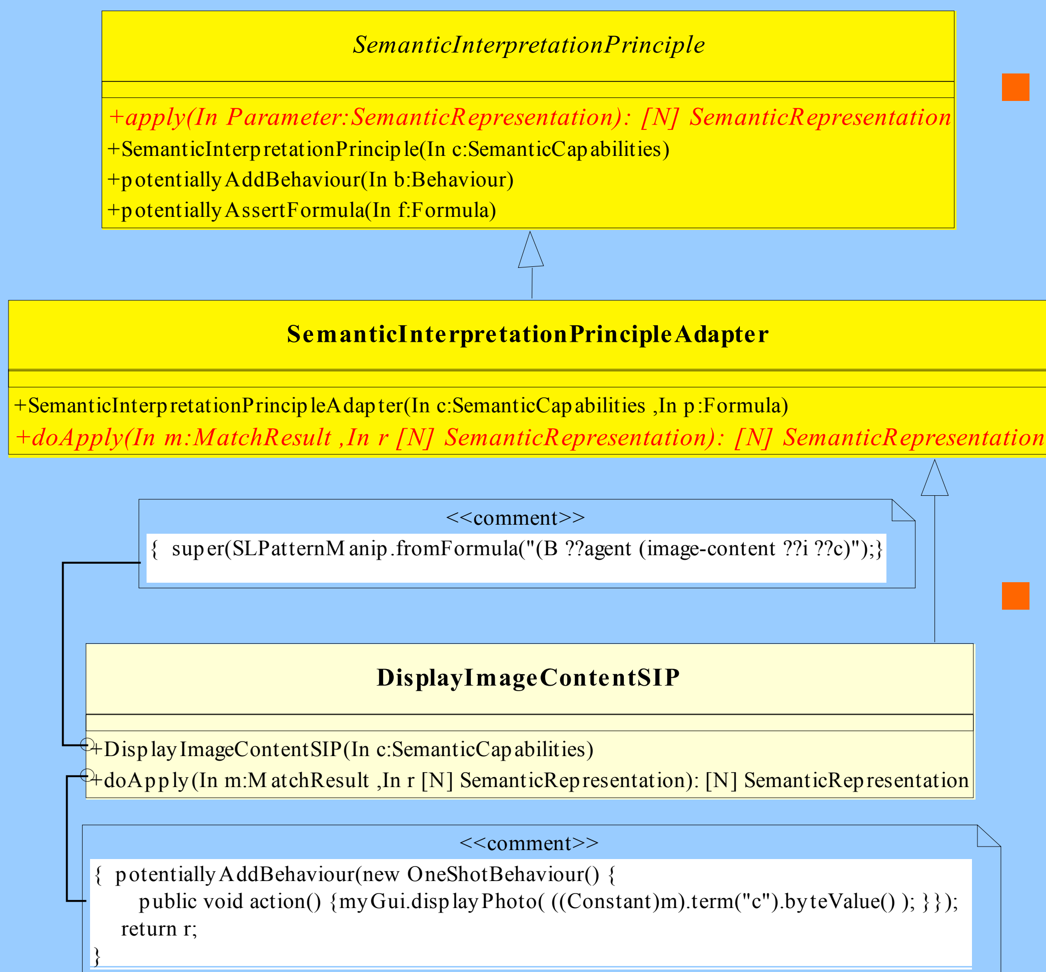
  creates (and adds to the agent) an activity to perform an action, whose effect matches an intended *goal* (uses the table of SemanticAction)

application-specific SIPs

- customize the semantic agents' behaviour with specific SIPs 3 main cases
  - reactive production of an applicative “piece of meaning” (resulting from the interpretation of SL formulas): e.g. production of an intention
  - triggering of applicative “notifications”, e.g. to control a GUI
  - specialization of standard SIPs (e.g. BeliefTransfer, see part XXX)

```
class MySematicCapabilities extends SemanticCapabilities {
   protected SemanticInterpretationPrincipleTable
                                  setupSemanticInterpretationPrinciples() {
         table = super.setupSemanticInterpretationPinciples();
         table.addSemanticInterpretationPrinciple(mySIP);
         ...
         return table;
   }    ...
}
```

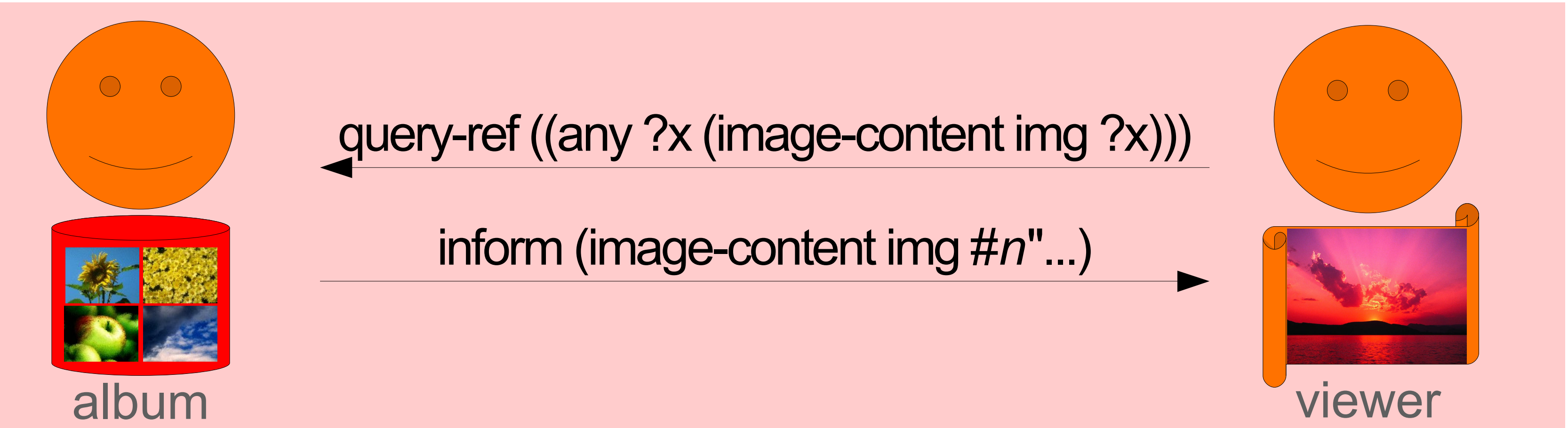
defining an application-specific SIP



- method apply
  - consumes / produces SRs
  - returns null if not applicable
  - add activities with method potentiallyAddBehaviour
  - update the belief base with potentiallyAssertFormula
- method apply first matches the input SR with a pattern
  - the SIP application is specified in method doApply
  - if not applicable, return null
  - if no SR to produce, return result

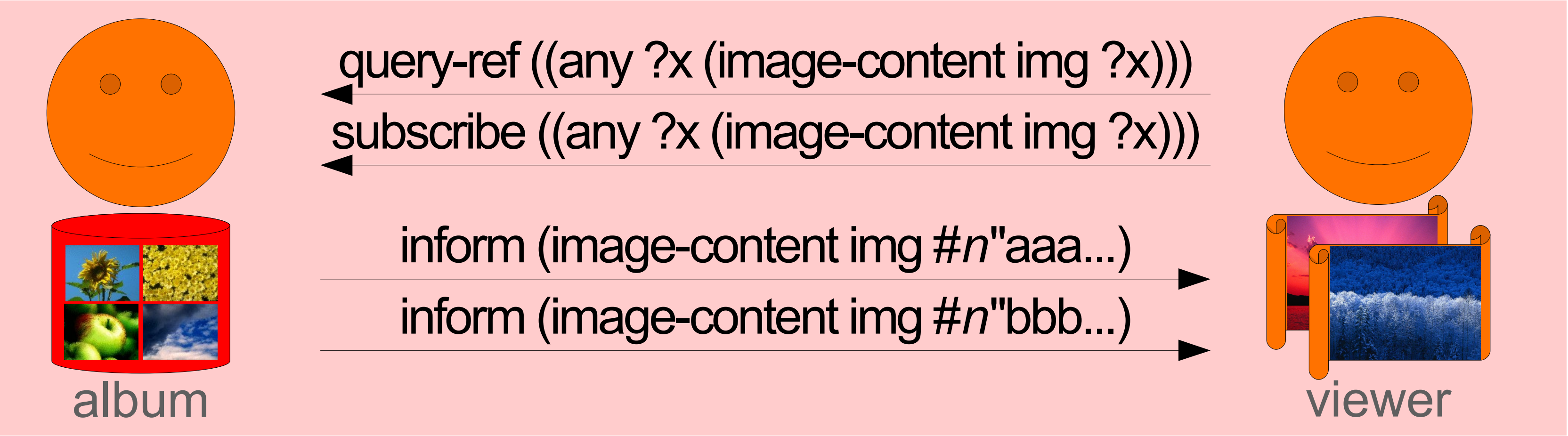
album application – exercise 2 implementing an applicative SIP

- add a SIP to the viewer agent to display received pictures
  - use the provided implementation of the ViewerGUI interface
  - define the inner class ViewerSemanticCapabilities, instantiate it within the viewer constructor
  - overload the setupSemanticInterpretationPrinciples() method
  - create an ApplicationSpecificSIPAdapter, which adds a OneShotBehaviour that calls ViewerGUI.displayPhoto(byte[])



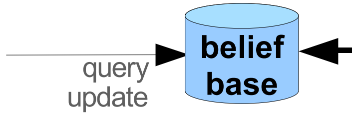
album application – exercise 2.bis implementing a subscribe

- within the setup() method of the album agent
  - add a TickerBehaviour, which periodically changes the image content (the agent's arguments give the available pictures)
    - 1st implementation: use retractFormula, then interpret
    - 2nd implementation: use interpret on (= (iota ?x (image-content img ?x)) *value*)
- within the setup() method of the viewer agent
  - send a subscribe message, identical to the previously sent query-ref



belief base (BB)

- representation of a semantic agent's **internal state**
  - **update** of the internal state
  - **information retrieval** on the internal state
  - **notification of changes** on the internal state



- **subjective** internal state
  - all stored facts are believed by the agent
    (B myself (age john 20)), (I myself (B mary (age john 20)))
  - any fact that is not stored is not believed
    (not (B myself sunny)), (not (B myself (not sunny)))
- **logically consistent** internal state
  - e.g., cannot store both (B myself cold) and (B myself (not cold))
- **jade.semantics.kbase.KBase interface**

updating beliefs

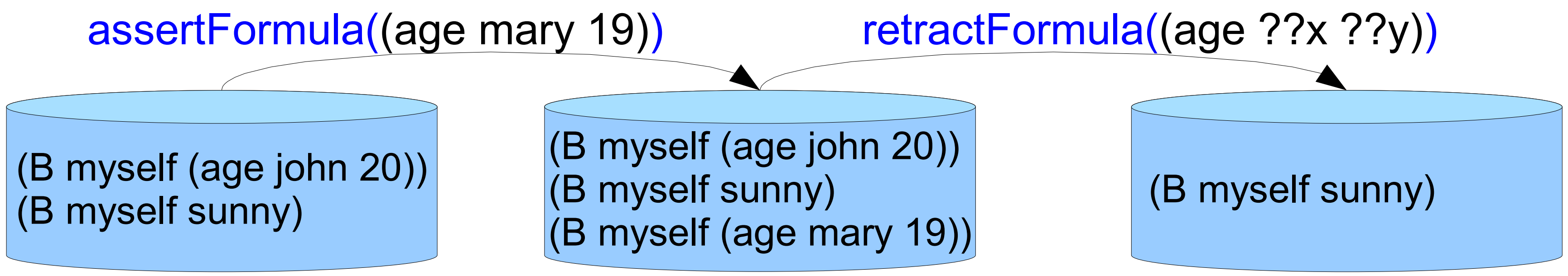
- assertFormula(Formula f)

  consistently assert (B myself f)

- retractFormula(Formula f)

  consistently assert (not (B myself f))

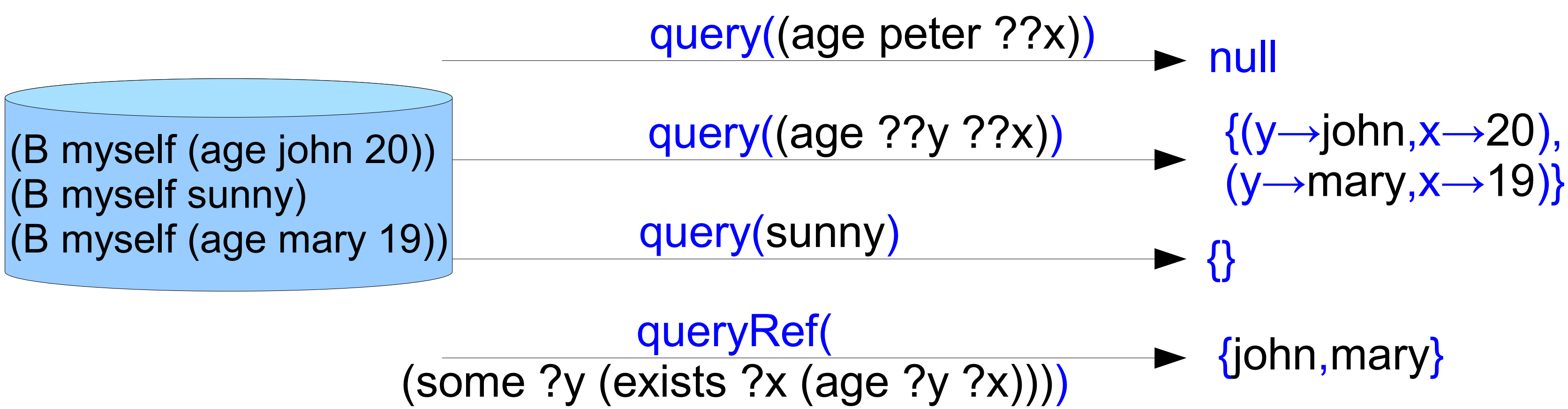
  f may include meta-references



- such asserted formulas are **not interpreted by the SIPs**
  use rather aSemanticCapabilities.interpret(Formula)

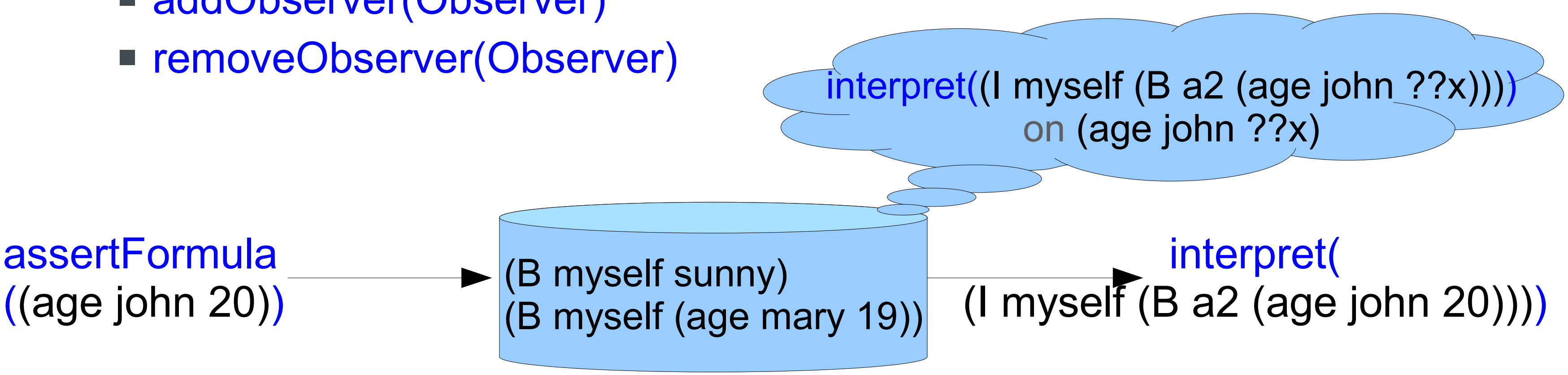
querying beliefs

- query(Formula f): ListOfMatchResults, returns
  - null if (B myself f) is false
  - a list of MatchResult objects, which provides the values of the meta-references such that (B myself f) is true
- queryRef(IdentifyingExpression ire): ListOfTerm, returns
  - null if no object o satisfies (B myself (= o ire))
  - the list of objects o satisfying (B myself (= o ire))



notification of belief changes

- the Observer interface defines
  - a pattern of formula to monitor
  - a Java code to execute as soon as this pattern becomes believed
- EventCreationObserver implementation
  - the code to execute calls interpret on a given formula (“event”)
  - the observer may be permanent or “one shot”
- useful methods of the KBase interface
  - addObserver(Observer)
  - removeObserver(Observer)



implementing a belief base

- developers may implement their own BB (according to the KBase interface)

  hard task!

- the JSA comes with a default BB, which provides a good trade-off between efficiency and expressiveness

```
class MySematicCapabilities extends SemanticCapabilities {
   protected KBase setupKbase() {
         KBase base;                    |  KBase base;
         base = new MyKBase(...);       |  base = super.setupKbase();
         ...                            |  ...
         return base;                   |  return base;
   }
   ...
}
```

default belief base (1/2)

- the jade.semantics.kbase.FilterKBase interface is based on a filter mechanism to manage
  - the storage and consistency of beliefs (assertion operations)
  - the retrieval of beliefs (query operations)
- a set of standard filters handles the generic FIPA-SL predicates and logical operators
- specific filters must be added to manage the storage, the consistency and the retrieval of applicative predicates

```
protected KBase setupKbase() {
        FilterKBase base = (FilterKBase)super.setupKbase();
        base.addKBAssertFilter(myAssertFilter);
        base.addKBQueryFilter(myQueryFilter);
        ...
        return base;
}
```

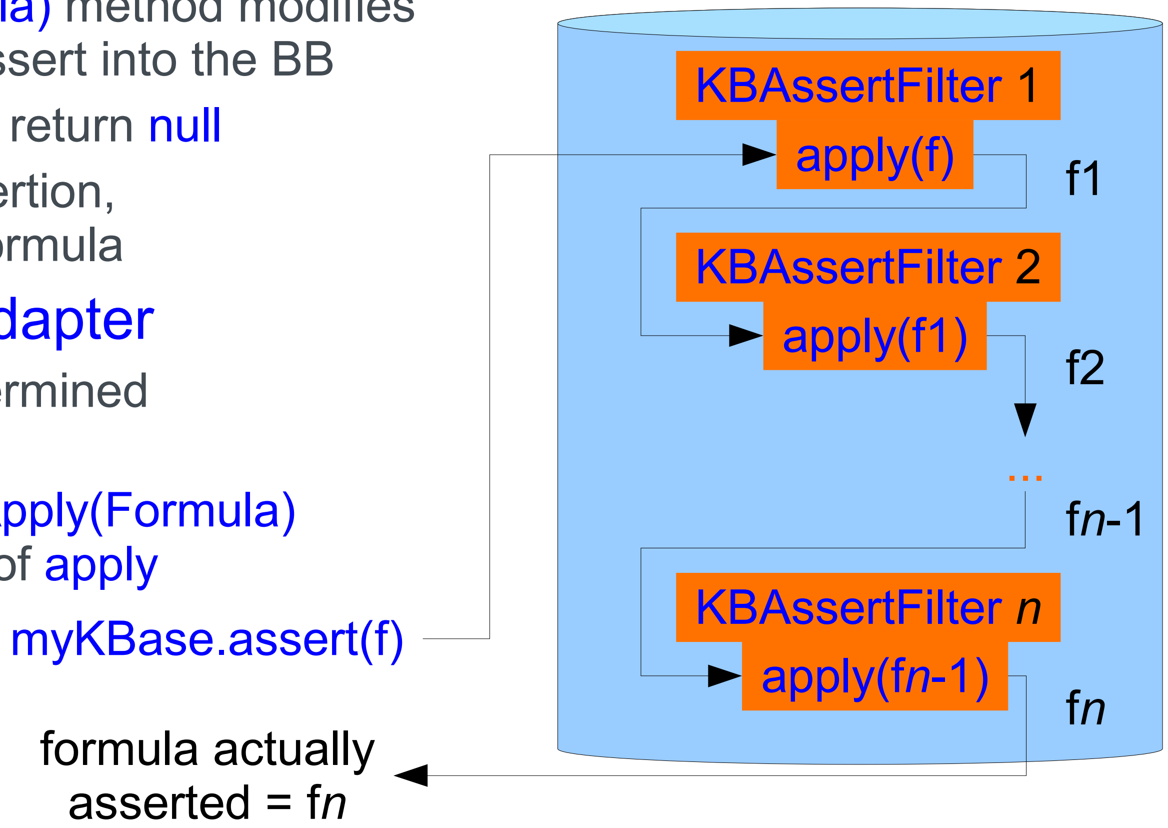
default belief base (2/2)

- use class jade.semantics.kbase.FiltersDefinition to add a set of filters (assertion filters, query filters or both)
- share filters between several semantic agents

```
class MyFilters extends FiltersDefinition {
   MyFilters() {
         defineFilter(myAssertFilter);
         defineFilter(myQueryFilter);
         ...
   }
}
protected KBase setupKbase() {
         FilterKBase base = (FilterKBase)super.setupKbase();
         base.addFiltersDefinition(new MyFilters());
         return base;
}
```

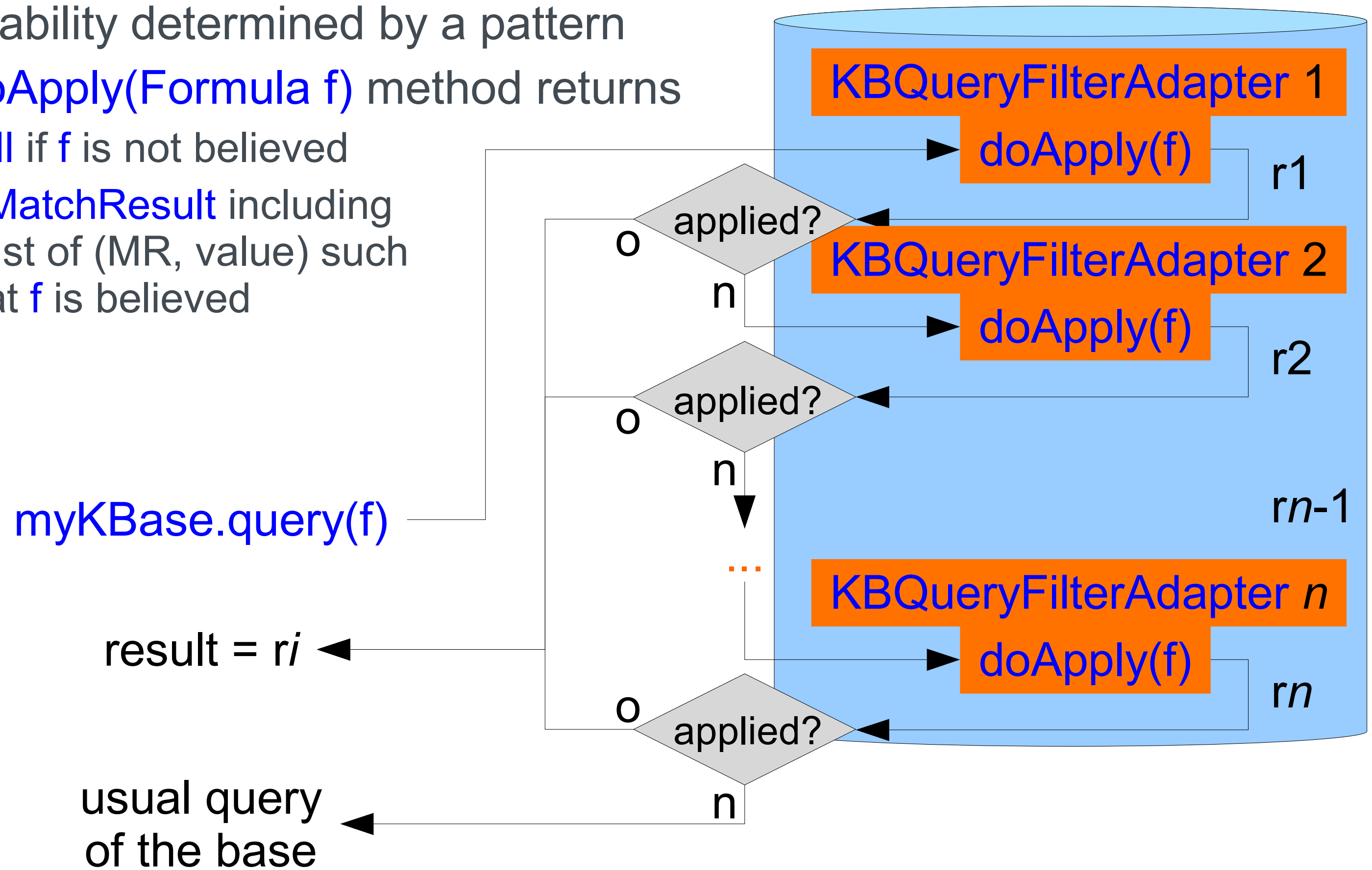
assertion filters

- jade.semantics.kbase.filter.KBAssertFilter
  - the apply(Formula) method modifies the formula to assert into the BB
  - if not applicable, return null
  - to block the assertion, return the true formula
- KBAssertFilterAdapter
  - applicability determined by a pattern
  - override the doApply(Formula) method instead of apply



query filters

- jade.semantics.kbase.filter.KBQueryFilterAdapter
  - applicability determined by a pattern
  - the doApply(Formula f) method returns
    - null if f is not believed
    - a MatchResult including a list of (MR, value) such that f is believed

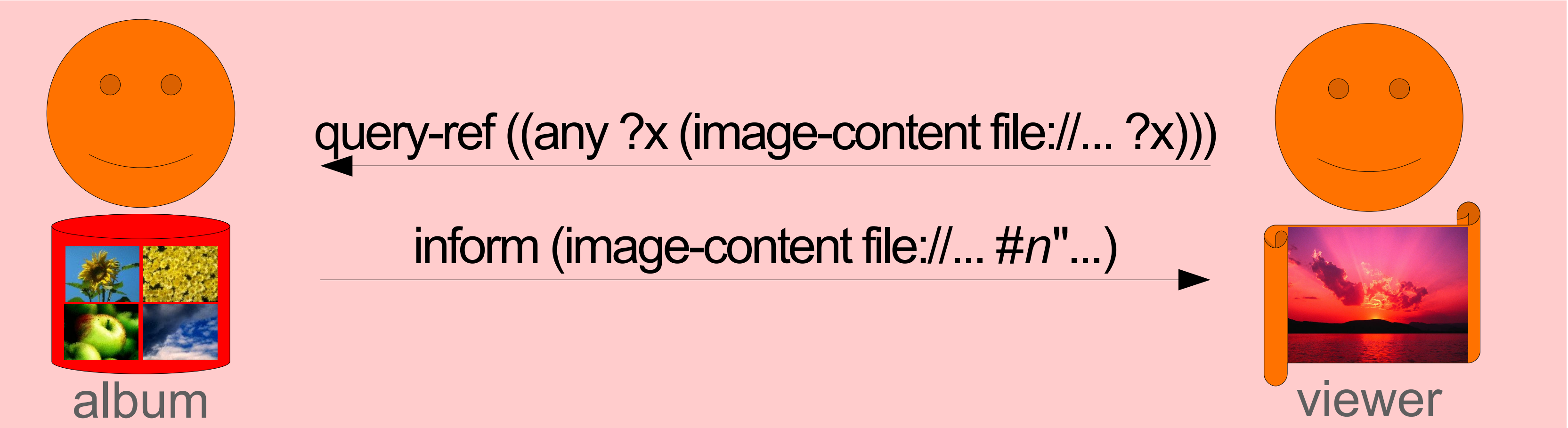


query filters: a step further

- the KBQueryFilterAdapter class has limits
  - cannot control the filter applicability (entirely determined by the pattern)
  - cannot return more than one solution (only one MatchResult object returned by the doApply method)
- the KBQueryFilter is more general
  - method apply(Formula f) instead of doApply(Formula f)
  - returns a QueryResult object
    - filterApplied field — true if the filter is applicable, false otherwise
    - result field — null if f is not believed
otherwise, list of MatchResult that make f believed
  - method getObserverTriggerPatterns(Formula,Set)
in order to optimize the notification mechanism of the BB
- improvements of KBQueryFilter expected in future versions

album application – exercise 3 coding a query filter

- within the album agent
  - remove the TickerBehaviour and the content of the setup() method
  - create a KBQueryFilterAdapter, which reads the content of queried pictures from their URL and not from the BB
- within the viewer agent
  - remove the subscribe sending
  - fill the query-ref content from the URL given by the agent's argument

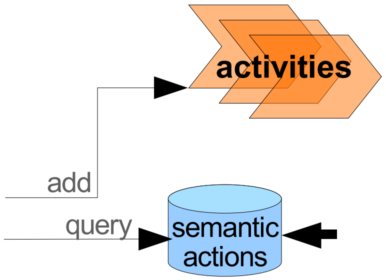


album application – exercise 3.bis coding an assertion filter

- within the viewer agent
  - create a KBAssertFilterAdapter, which prevents actual assertion of image contents into the BB
- request the viewer agent with a dummy agent
  to check the former knows no image content any longer

semantic actions

- formal representations of a semantic agent's elementary “know-how”
  - feasibility precondition (SL formula): must be true **just before** the action performance
    if not true, the action is considered not feasible and any attempt to perform it fails
  - postcondition (SL formula): will be true **just after** the action performance
    if the action is successfully performed, the postcondition is asserted into the BB
  - body (JADE behaviour): “concrete” code to perform the action



- stored in the SemanticActionTable of each semantic agent
  - includes all FIPA-ACL communicative acts (by default)
  - plus application-specific actions (to be defined by developers)

application-specific semantic actions

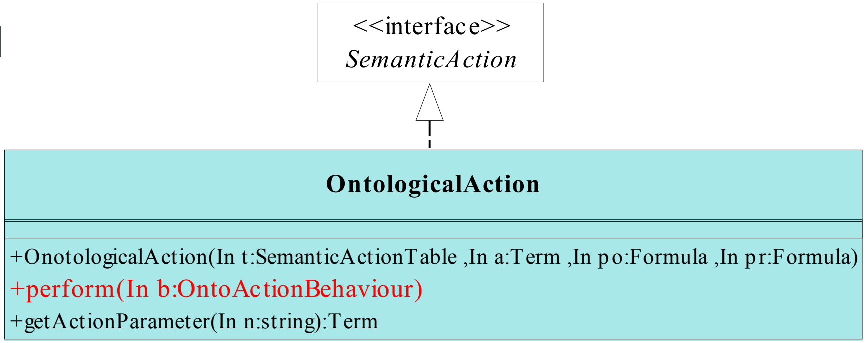
- extend semantic agents' “know-how”
- used by planning-related SIPs
  - standard ones: ActionPerformance, RationalityPrinciple
  - applicative ones: subclasses of PlanningSIPAdapter
- coding

```
class MySematicCapabilities extends SemanticCapabilities {
    protected SemanticActionTable setupSemanticAction() {
            SemanticActionTable table=super.setupSemanticAction();
            table.addSemanticAction(myAction);
            ...
            return table;
    }
    ...
}
```

defining applicative semantic actions

- OntologicalAction constructors expect
  - an action expression, which
    - specifies the **pattern** of functional term that represents the action
    - may include MRs

    (lock :what ??o (::? :delay ??d))



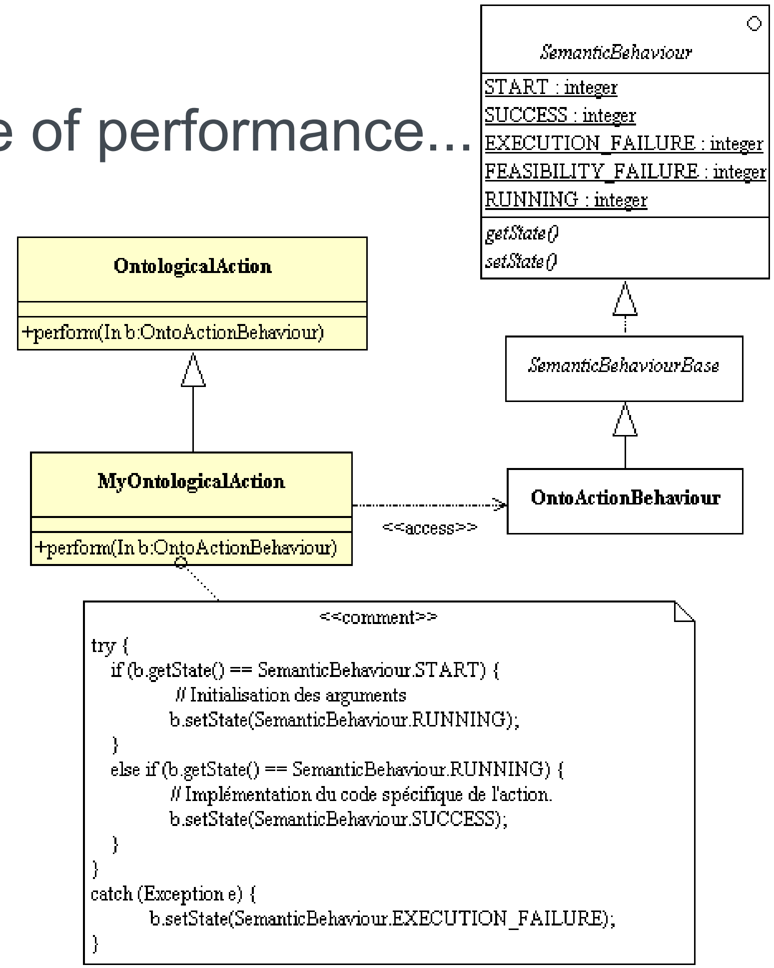
  - two SL formulas, which
    - specify a precondition and a postcondition
    - may include the MRs occurring in the action expression (if needed, ??sender represents the actor of the action)

    (owns-a-key ??sender ??o), (locked ??o)

- when an action is performed (scheduled in a JADE behaviour)
  - the BB is queried **before** performance to check the **precondition**
  - the **postcondition** is asserted into the BB **after** performance

defining the body of a semantic action

- SemanticBehaviour maintain a state of performance...
  - when the performance fails
    - FEASIBILITY_FAILURE
      unsatisfied precondition
    - EXECUTION_FAILURE
      failure during execution
  - when it succeeds: SUCCESS
- ...to manage the execution of semantic actions (inc. comm. acts)
- Case of applicative actions
  - the action() method of OntoActionBehaviour is defined upon the perform() method of the corresponding OntologicalAction



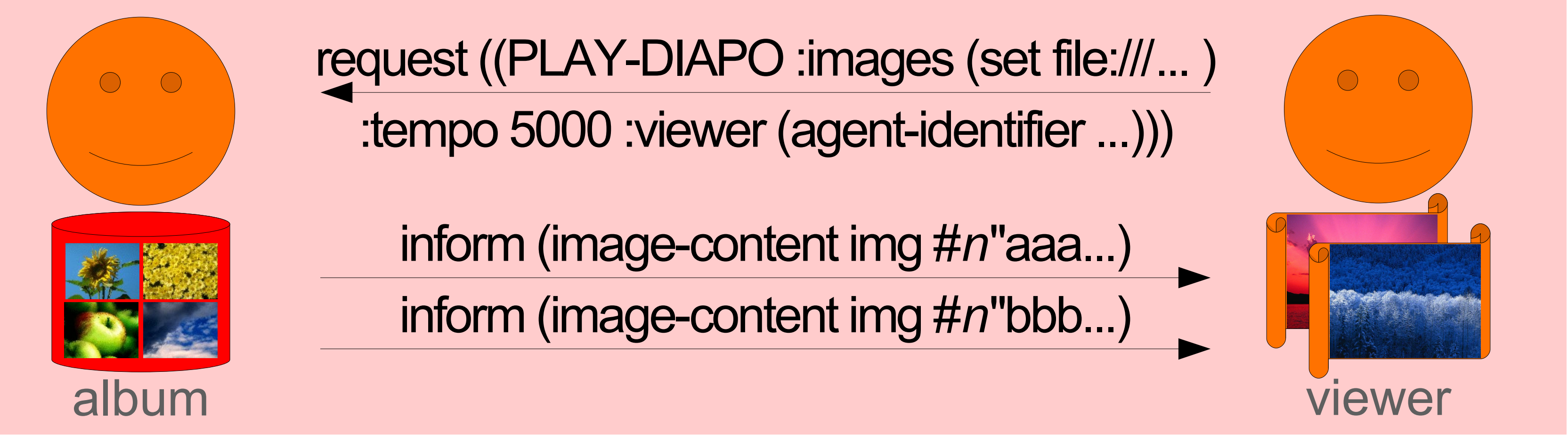
  - same programming style as the action() method of JADE Behaviour

album application – exercise 4 coding a diaporama semantic action

- within the album agent, implement an ontological action

  consisting in sending to another agent (:viewer parameter) a set of pictures to display (:images parameter), with an optional delay (:tempo parameter) between pictures

- within the viewer agent
  - send a request on this action instead of the previous query-ref
  - the list of pictures is read from the agent's arguments



customizing standard SIPs (1/2)

- most of standard SIPs may be customized
  - add an instance of the proper SIP adapter to the agent's SIP table
  - pass proper arguments to the constructor (generally a SL pattern to match) and/or override the proper method (generally doApply())
  - see the jade.semantics.interpreter.sips.adapters package

```
protected SemanticInterpretationPrincipleTable setupSemanticInterpretationPrinciples() {
        table = super.setupSemanticInterpretationPinciples();
        table.addSemanticInterpretationPrinciple(
                new PlanningSIPAdapter(this, "??goal") {
                        public ActionExpression doApply(...) {
                                ...
                        }
                });    ...
        return table;
}
```

customizing standard SIPs (2/2)

- the doApply() method of most of the SIP adapters
  - provides **pre-computed arrays of SR** to return, corresponding to the various possible results of the SIP
  - e.g., the BeliefTransferSIPAdapter provides 2 pre-computed results: one to accept the controlled belief and one to reject it (see below)
- when the result of the SIP cannot be decided at once
  - return an empty array of SR (to “absorb” the input SR)
  - install a proper behaviour, which
    - makes the decision (for example, by interacting with other agents)
    - finally interprets the pre-computed result corresponding to the made decision

```
ArrayList doApply(MatchResult matchFormula, MatchResult matchAgent,
                  ArrayList acceptResult, ArrayList refuseResult,
                  SemanticRepresentation sr) {
        potentiallyAddBehaviour(new MyDecisionBehaviour(...));
        return new ArrayList();
}
```

belief transfer SIP adapter

- controls the adoption of beliefs coming from other agents
- constructor
  - formulaToBelievePattern: the pattern of belief to control
  - originatingAgentPattern: the pattern of agent originating the belief to control (beliefs from other agents will not be controlled by the SIP)

  Optional arguments (set to true by default)
  - notPattern: if true, also controls the adoption of (not *formulaPattern*)
  - allPattern: if true, also controls (= (all ??X *formulaPattern*) (set))
    (pattern used to retract all instances of the belief)
- doApply() method
  - the first 2 arguments give the results of the matching of the belief to control and the originating agent against the specified patterns
  - acceptResult: array of SR to return if the belief can be adopted
  - refuseResult: array of SR to return if the belief must not be adopted

intention transfer SIP adapter

- controls the adoption of intentions of other agents
- constructor
  - goalPattern: the pattern of goal (to intend) to control
  - agentPattern: the pattern of external agent intending the goal to control (intentions of other agents will not be controlled by the SIP)

  Optional argument (set to true by default)
  - feedBackRequired: if true, generates a feedback towards the external agent
    - intention adopted: acknowledges the adoption, then the goal achievement
    - intention not adopted: acknowledges the adoption refusal
- doApply() method
  - the first 2 arguments give the results of the matching of the goal to control and the originating agent against the specified patterns
  - acceptResult: array of SR to return if the goal can be intended
  - refuseResult: array of SR to return if the goal must not be intended

planning SIP adapter

- computes a plan to reach an intended goal
- constructor
  - goalPattern: the pattern of goal, for which the SIP may find a plan
- doApply() method
  - returns an action expression representing the computed plan (instead of an array of SR) – if null, the SIP is considered not applicable
  - matchResult: result of the matching of the intended goal against the specified pattern
- the returned plan is performed
  - if it ends out to be not feasible, the next matching planning SIP in the SIP table is tried (in the order of the SIP table) to find a new plan
- several SIPs can be defined (for different goals as well as for the same goal)

CFP SIP adapter (1/2)

- controls the answer to a CFP
- a CFP expects 2 content elements
  - a requested action (expressed as an action expression)
  - a condition (expressed as an IRE)
- default adapter constructor (with no argument)
  - automatically answers CFPs by evaluating the condition **independently from the action** (this is a simplifying assumption)
- regular constructor, to control specific patterns of CFP
  - ireQuantifierPattern: the pattern of the IRE quantifier (given as a constant, see QueryRefPreparationSIPAdapter.ANY/IOTA/SOME/ALL)
  - ireVariablesPattern: the pattern of the IRE quantified variables
  - conditionPattern: the pattern of the condition formula
  - actPattern: the pattern of action
  - agentPattern: the pattern of agent (AID) originating the CFP

CFP SIP adapter (2/2)

- prepareProposal() method
  - works along the same principle as the doApply() methods
  - the first 4 arguments give the elements defining the CFP to control,
  - the following 3 arguments give the results of the matching of these elements against the specified patterns
  - result: array of SR to return if the SIP is not absorbent (or to interpret later if the SIP is absorbent and delays its processing)
- this method is expected to set up in the belief base proper values of the condition to perform the requested actions
  - use the assertProposals() method to do so
  - the first 4 arguments give the elements defining the condition/action
  - the last argument gives the list of proper values for these condition/action

what about protocols, conversation-id, ...?

- semantic agents **genuinely interpret** received messages
  - such an interpretation is **consistent** with FIPA interaction protocols

    handling complex protocols, such as CFP, consists
    in specializing the proper SIP adapter(s)

  - such an interpretation is **more flexible**, so that agents may naturally engage in intermediate exchanges, without the need of making them explicit in a protocol specification
- no need to make the used protocol explicit
- no need to make the conversation-id explicit

and ontologies?

- there is no explicit support for a specific ontology model
- developers have to define the way of representing classes, properties, instances, ... by SL expressions. For example:
  - SL functional terms may represent frames with slots
    - (Person :name john :age 20)
    - use the setParameter(String,Term) and getParameter(String,Term) methods to handle directly slot values
    - see also the jade.semantics.kbase.FunctionalTable class (experimental)
  - SL predicates generally represent properties
    - (hasFather i1 i2), (is_a i1 Person), (subclass Mother Female), ...
- no ContentManager, because the JSA automatically analyses the content of incoming messages
- under study: a “mapper” between JADE ontologies and SL patterns (for reusing some JADE features with the JSA)

differences between JADE and JSA

- an empty JSA agent is not so empty
  it can react properly to many requests
- SL is the “internal” language to programme JSA agents
  take advantage of the SL pattern mechanisms
- Basic programming advices
  1. **Never use** the receive() method, avoid the send() method
  2. Programme your agent's **observable behaviours** through **SIPs**
  3. Programme your agent's **skills** through **semantic actions**
  4. Reasoning on **facts** and fact storage are managed by the **belief base**