



Verteilte Künstliche Intelligenz – Kommunikation & Ontologien

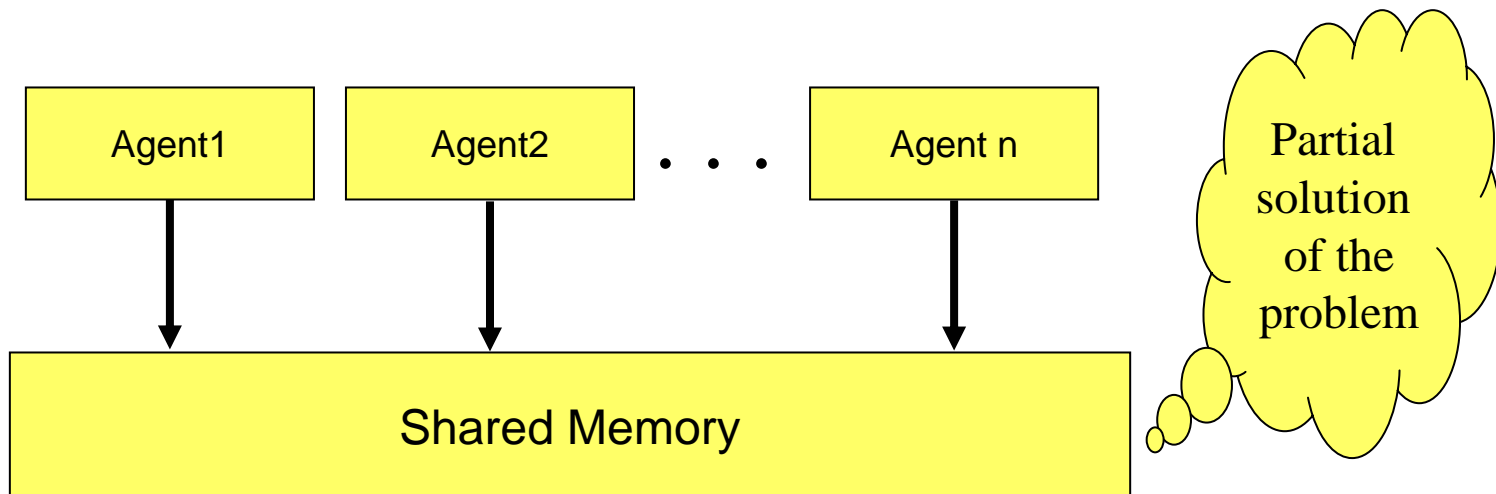
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Shared Memory

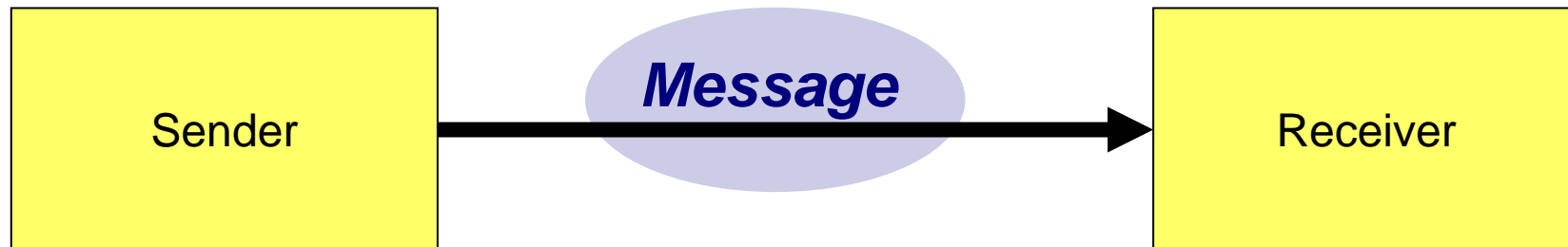
= Blackboard Metaphor [A. Newell, 1962]

Metaphorically we can think of a set of workers, all looking at the same blackboard: each is able to read everything that is on it, and to judge when he has something worthwhile to add to it. This conception is just that of Selfridges Pandemoneums' a set of demons, each independently looking at the total situation and shrieking in proportion to what they see that fits their nature.



Message Passing

- Messages are send from the sender to the receiver
- Messages are based on Speech-Act Theory
- Messages are encoded in an agent communication language
- Series of messages produces a dialog – and are often following predefined structured (protocols)





Process of Agent Communication

■ Speaker

- | | |
|-------------------------------------|--|
| <input type="checkbox"/> Intention | S wants H to believe φ (S believes φ) |
| <input type="checkbox"/> Generation | S chooses the words W (they express φ) |
| <input type="checkbox"/> Synthesis | S utters the words W (addressing them to H) |

■ Hearer

- | | |
|---|--|
| <input type="checkbox"/> Perception | H perceives W' ($W'=W$ ideally!) |
| <input type="checkbox"/> Analysis | H infers tht W' has possible meanings $\varphi_1, \varphi_2, \dots, \varphi_n$ |
| <input type="checkbox"/> Disambiguation | H infers that S intended to convey φ_i (ideally $\varphi_i=\varphi$) |
| <input type="checkbox"/> Incorporation | H decides to believe φ_i (or reject if inconsistent?!) |



Speech-Act Theory

- Communication as a sequence of actions
- *Example: „I sentence you to 6 month imprisonment !”*

- Speech-acts consist of three parts
 - *Locutionary act*: saying something that makes sense in a language
 - *Illocutionary act*: action intended by the speaker (intention)
 - *Perlocutionary act*: effect or 'take-up' of an illocutionary act

- Classification (J.R. Searle, 1976)
 1. Repräsentativa (Representatives)
 2. Direktiva (Directives)
 3. Kommissiva (Commissives)
 4. Expressiva (Expressives)
 5. Deklarationen (Declarations)



Beispiele

■ Repräsentativa (Representatives)

- ☐ behaupten, mitteilen, berichten, informieren
- ☐ „Draußen scheint die Sonne.“

■ Direktiva (Directives)

- ☐ bitten, befehlen, anordnen, verbieten
- ☐ „Die Lösungen zu den Übungsaufgaben sind nächste Woche in unserem Fach abzugeben.“

■ Kommissiva (Commissives)

- ☐ versprechen, geloben, garantieren, schwören, vereinbaren
- ☐ „Ich werde mich bemühen, die Folien vor der Vorlesung ins Netz zu stellen.“

■ Expressiva (Expressives)

- ☐ danken, Beileid aussprechen, gratulieren, klagen
- ☐ „Danke für Eure Aufmerksamkeit.“

■ Deklarationen (Declarations)

- ☐ ernennen, entlassen, abdanken, taufen, verurteilen
- ☐ „Ich gebe Dir für Deine Prüfungsleistung die Note XY.“



Agent Communication Languages (ACL)

- ACLs define

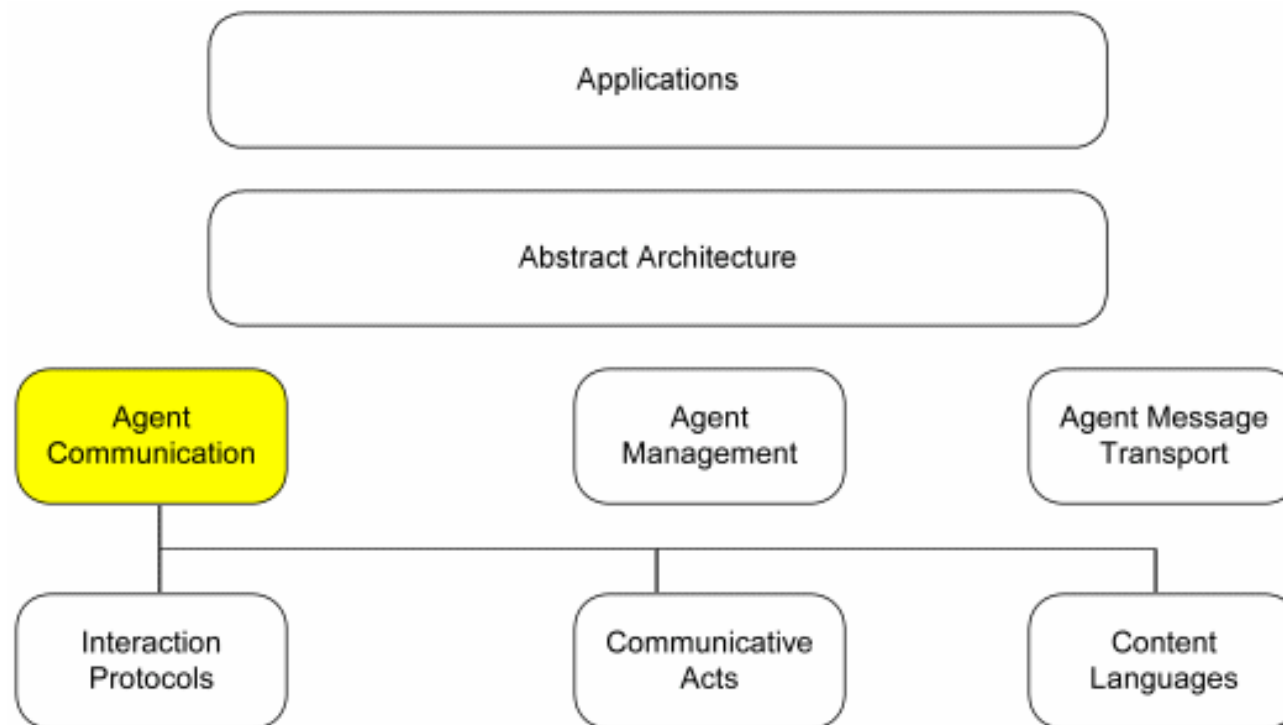
- ☐ High-level communication languages
- ☐ Message (action) classes
- ☐ Protocols
- ☐ But no content, syntax or ontology

- And they are independent from

- ☐ Transport mechanism (TCP/IP, SMTP...),
- ☐ Language for content encoding (KIF, SQL, Prolog...)
- ☐ Ontologies defining context of content

FIPA Agent Communication Language

- <http://www.fipa.org>





FIPA-ACL

■ FIPA-ACL

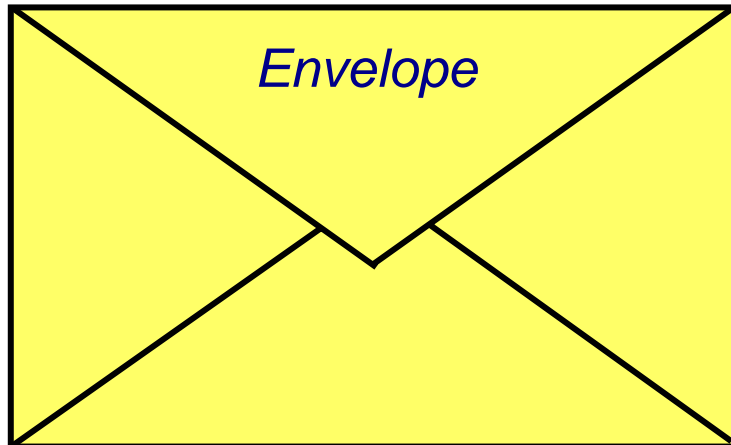
- Refinement of KQML
- Separation of internal and external language
- External language defines intended meaning of message
- Internal language (content language) determines proposition for counter part

■ Semantic Language

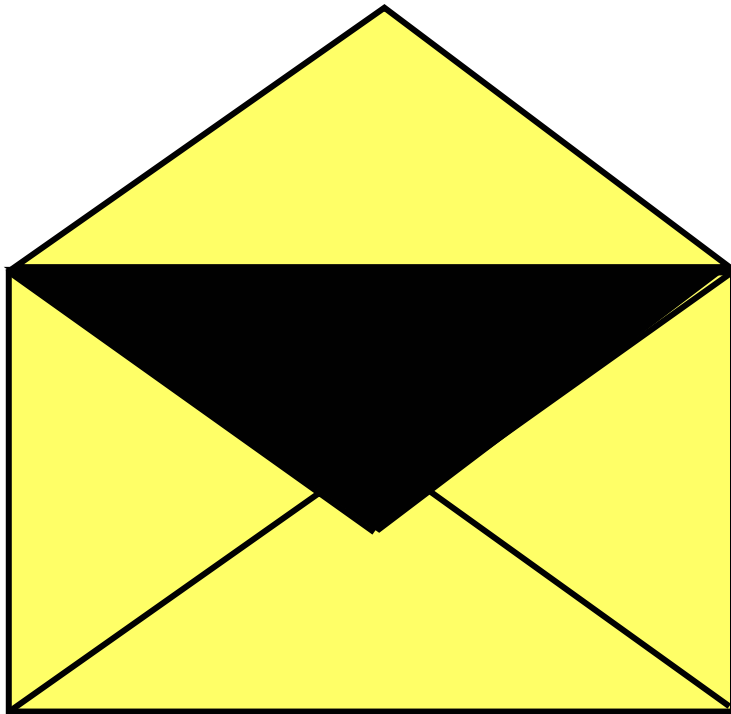
- Formal language for semantics (M.D. Sadek, 1992)
- First-order multi-modal logic (modalities for belief, desires, intentions, uncertain beliefs and persistent goals)
- Concepts for propositions, objects, and actions



Communicative Acts in FIPA



Communicative Acts in FIPA



(inform *Message*

:sender

(agent-identifier :name i)

:receiver

(set (agent-identifier :name j))

:content

"weather (today, raining)"

:language Prolog

)



XML-Example of an Envelope

```
<envelope> <params index="1">
  <to>
    <agent-identifier>
      <name>receiver@foo.com</name>
      <addresses> <url>http://foo.com/acc</url> </addresses>
    </agent-identifier>
  </to>
  <from> ... </from>
  <acl-representation>fipa.acl.rep.xml.std</acl-representation>
  <date>20000508T042651481</date>
  <encrypted>no encryption</encrypted>
  <received >
    <received-by value="http://foo.com/acc" />
    <received-date value="20000508T042651481" />
    <received-id value="123456789" />
  </received>
</params> </envelope>
```



ACL Message Structure

Element	Category of Elements
performative	Type of communicative acts
sender	Participant in communication
receiver	Participant in communication
reply-to	Participant in communication
content	Content of message
language	Description of content
encoding	Description of content
ontology	Description of content
protocol	Control of conversation
conversation-id	Control of conversation
reply-with	Control of conversation
in-reply-to	Control of conversation
reply-by	Control of conversation

Classification of communicative acts by performatives denoting the initiating agent's intention of this action.



The Semantic Language (SL) (1)

- First-order modal logic with identity
- Concepts (propositions, objects, actions)
- Modalities:
 - Belief: (**B** <agent> <expression>)
Agent believes that expression is true (KD45 semantic structure).
 - Uncertainty : (**U** <agent> <expression>)
Agent believes that expression is more likely true than false.
 - Intention: (**I** <agent> <expression>)
Agent intends that expression will becomes true and will plan to bring it about.
 - Persistent Goal: (**PG** <agent> <expression>)
Agents holds a persistent goal that expression becomes true, but will not necessarily plan to it about.



The Semantic Language (SL) (2)

■ Action Operators

- (**feasible** <Actionexpression> <Wff>)
Actionexpression can take place and just afterwards Wff will be true.
- (**done** <Actionexpression> <Wff>)
Actionexpression has taken place and has just before that Wff was true.

■ Referential Operators

- (**iota** <term> <formula>)
Variable binding: (iota x (P x)): "The x such that P [is true] of x"
- (**any** <term> <formula>), (**all** <term> <formula>)

■ Further Operators

- Quantification (forall, exists)
- Logical connectives (not, and, or, implies, equiv)
- Relational operators (=, \=, >, <, <=, >=, member, contains)



Communicative Acts

- Defined for each speech-act type (performative):
 - Summary
 - Message Content
 - Description
 - Formal Model
 - Example

- Formal Model is using SL (including mental attitudes)
 - Expression
 - Feasibility precondition (FE)
 - Rational effect (RE)

 - Abbreviations:
 - $B_i\phi \equiv B_i\phi \vee B_i\neg\phi$
 - $U_i\phi \equiv U_i\phi \vee U_i\neg\phi$



Performative: inform

- The sender informs the receiver that a given proposition is true.
- Sender's point of view:
 - The sender holds that some proposition is true,
 - intends that the receiving agent also comes to believe that the proposition is true, and,
 - does not already believe that the receiver has any knowledge of the truth of the proposition.
- Receiver's point of view:
 - The sender believes the proposition that is the content of the message, and,
 - the sender wishes the receiver to believe that proposition also.



Performative: inform

- The sender informs the receiver that a given proposition is true.

Formal Model

$\langle i, \text{inform } (j, \phi) \rangle$

FP: $B\ i\ \phi \wedge \neg B\ i\ (B\ i\ j\ \phi \vee U\ i\ j\ \phi)$

RE: $B\ j\ \phi$



Performative: inform

- The sender informs the receiver that a given proposition is true.

Example

```
(inform  
  :sender (agent-identifier :name i)  
  :receiver (set (agent-identifier :name j))  
  :content "weather (today, raining)"  
  :language Prolog)
```



Performative: confirm

- The sender informs the receiver that a given proposition is true, where the receiver is known to be uncertain about the proposition.
- Sender's point of view:
 - The sender believes that some proposition is true,
 - intends that the receiving agent also comes to believe that the proposition is true, and,
 - believes that the receiver is *uncertain* of the truth of the proposition.
- Receiver's point of view:
 - The sender believes the proposition that is the content of the message, and,
 - the sender wishes the receiver to believe that proposition also.



Performative: confirm

- The sender informs the receiver that a given proposition is true, where the receiver is known to be uncertain about the proposition.

Formal Model

$\langle i, \text{confirm } (j, \phi) \rangle$

FP: $B_i \phi \wedge B_i U_j \phi$

RE: $B_j \phi$



Performative: confirm

- The sender informs the receiver that a given proposition is true, where the receiver is known to be uncertain about the proposition.

Example

```
(confirm  
  :sender (agent-identifier :name i)  
  :receiver (set (agent-identifier :name j))  
  :content "weather (today, raining)"  
  :language Prolog)
```



Performative: disconfirm

- The sender informs the receiver that a given proposition is true, where the receiver is known to be uncertain about the proposition.
- Sender's point of view:
 - The sender believes that some proposition is false,
 - intends that the receiving agent also comes to believe that the proposition is false, and,
 - believes that the receiver either believes the proposition, or is *uncertain* of the proposition.
- Receiver's point of view:
 - The sender believes that the proposition that is the content of the message is false, and,
 - the sender wishes the receiver to believe the negated proposition also.



Performative: disconfirm

- The sender informs the receiver that a given proposition is true, where the receiver is known to be uncertain about the proposition.

Formal Model

$\langle i, \text{disconfirm } (j, \phi) \rangle$

FP: $B_i \neg \phi \wedge B_i (U_j \phi \vee B_j \phi)$

RE: $B_j \neg \phi$



Performative: disconfirm

- The sender informs the receiver that a given proposition is true, where the receiver is known to be uncertain about the proposition.

Example

```
(disconfirm
  :sender (agent-identifier :name i)
  :receiver (set (agent-identifier :name j))
  :content ((mammal shark))
  :language FIPA-SL)
```



Performative: request

- The sender requests the receiver to perform some action. One important class of uses of the request act is to request the receiver to perform another communicative act.



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- The sender requests the receiver to perform some action. One important class of uses of the request act is to request the receiver to perform another communicative act.

Formal Model

$\langle i, \text{request}(j, \alpha) \rangle$

FP: $\text{FP}(\alpha) [i \setminus j] \wedge B i \text{ Agent}(j, \alpha) \wedge \neg B i I j \text{ Done}(\alpha)$

RE: $\text{Done}(\alpha)$

$\text{FP}(\alpha) [i \setminus j]$ denotes the part of the FPs of α
which are mental attitudes of i



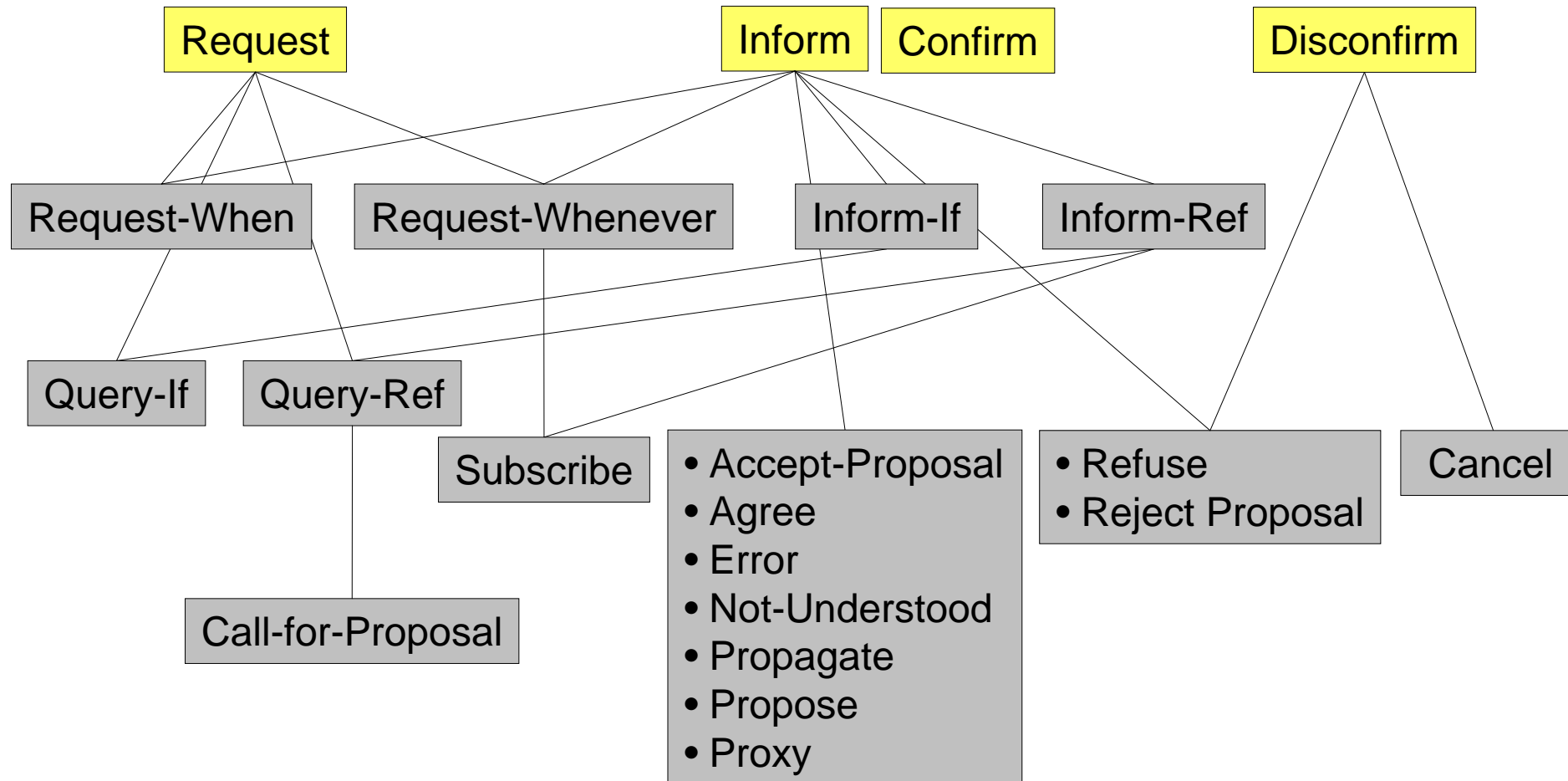
Performative: request

- The sender requests the receiver to perform some action. One important class of uses of the request act is to request the receiver to perform another communicative act.

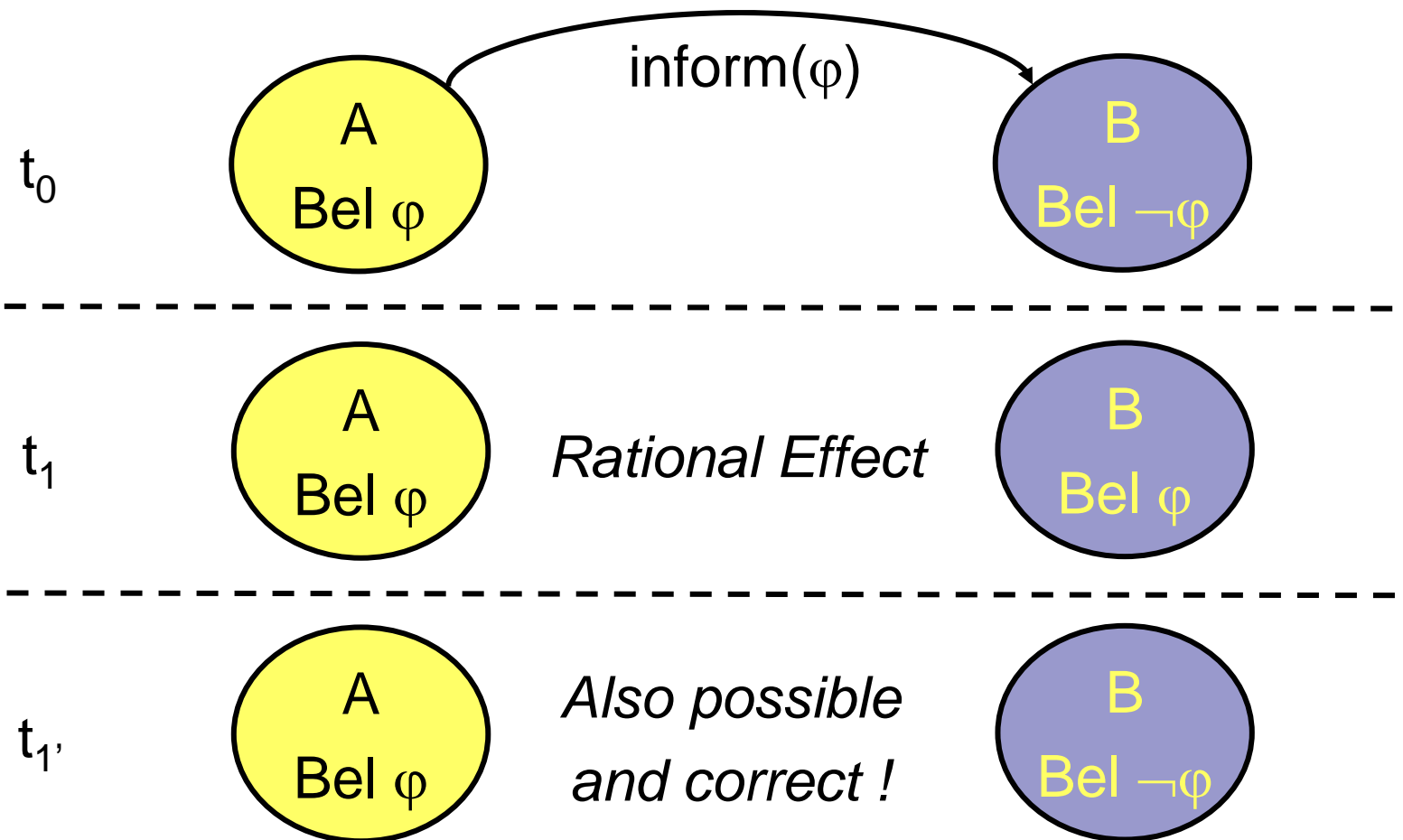
Example

```
(request  
  :sender (agent-identifier :name i)  
  :receiver (set (agent-identifier :name j))  
  :content "open \"db.txt\" for input"  
  :language vb)
```

Derived Performatives



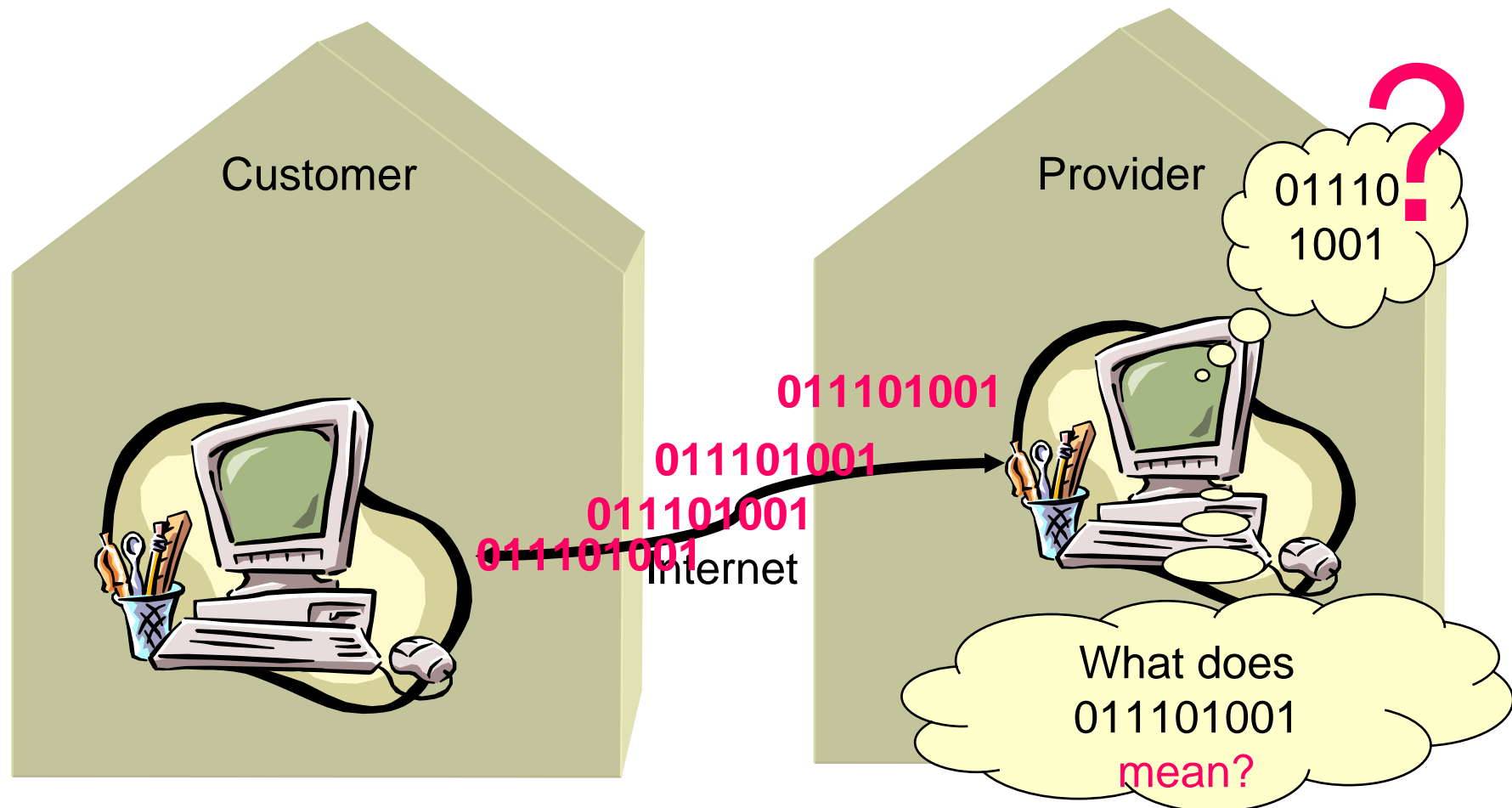
Remark on Semantics in FIPA





Ontologien

Das Problem der Kommunikation



Beispiel: Datenstrukturen

hotel	
	name
	location
	category
	price



Name	Location	Category	Price
Radisson	Copenhagen, Denmark	Congress-Hotel	580
Mercure	Hamburg, Germany	Congress-Hotel	190
Ritz	London, England	Congress-Hotel	130
...

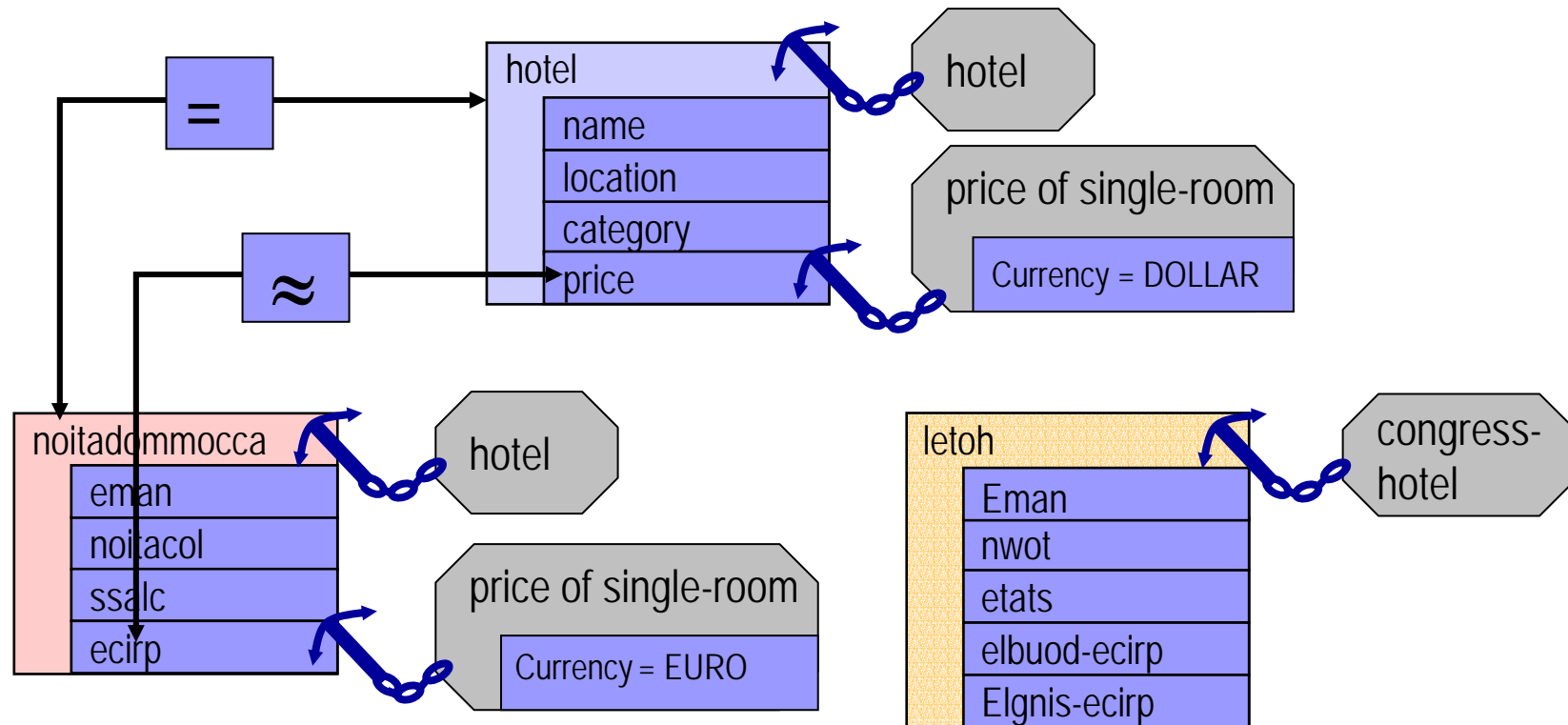
accommodation	
	name
	location
	class
	price



Name	Location	Class	Price
IBIS	Potsdam, Germany	Hotel	65
Meier	Berlin, Germany	Appartment	55
Schulz	Potsdam, Germany	Bungalow	60
...

- Anwendungskontext: Buchung einer Übernachtung
- Unterschiedliche Dienstanbieter für Hotels, Herbergen
- Gegeben: üblicherweise die eigene Definition

Beispiel: Integration heterogener Quellen

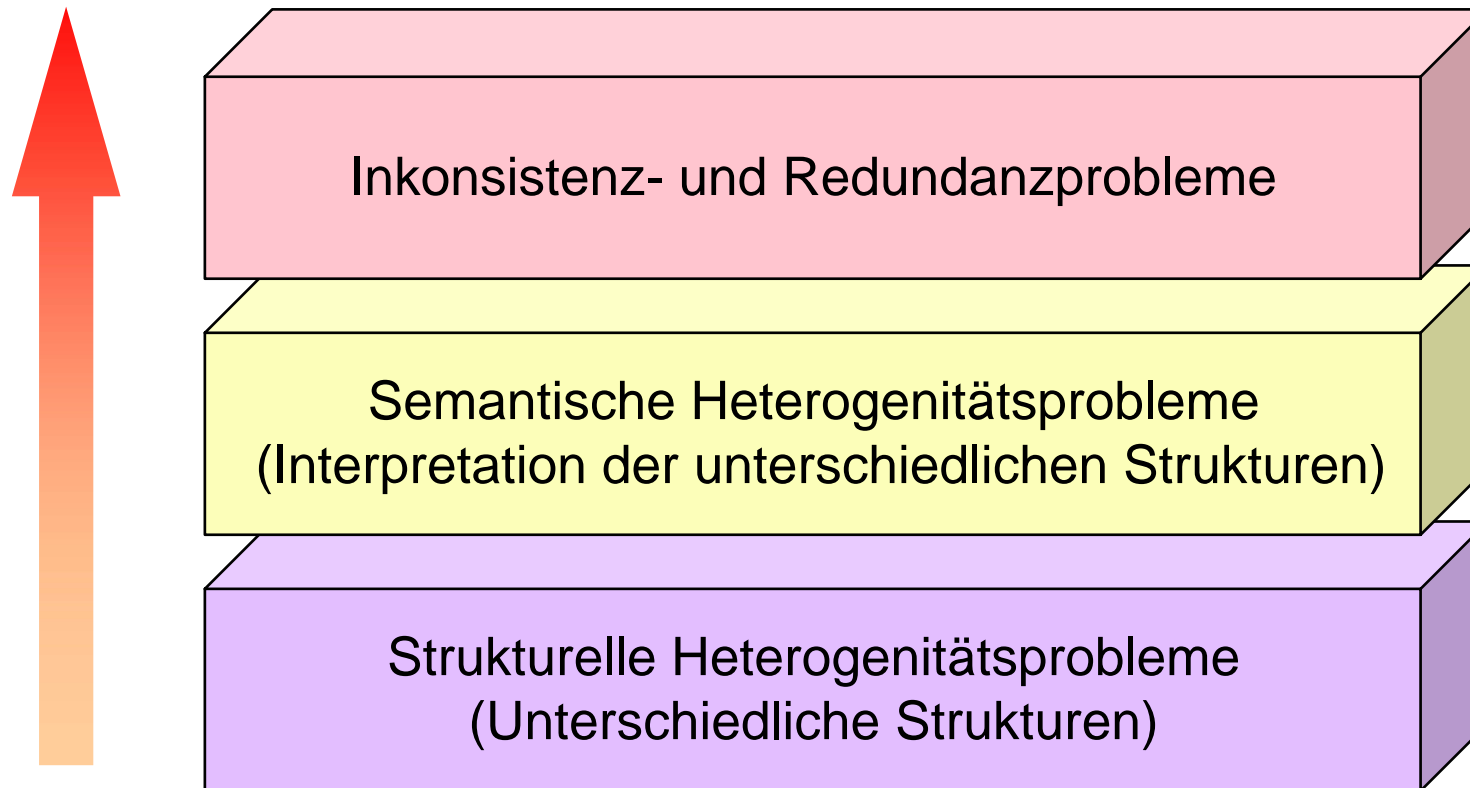


Wichtiger Schritt bei der Kommunikation:
Semantisch äquivalente Informationen

**Problem semantischer
Interoperabilität**



Klassifikation des Integrationsproblems





Formale Definition von Ontologien

- Eine Ontologie ist eine formale Konzeptualisierung einer Welt
- Eine Ontologie spezifiziert eine Menge von **constraints**, die festlegen, was notwendigerweise in jeder möglichen Welt erfüllt sein muss
- Jede mögliche Welt sollte konsistent mit den festgelegten constraints sein
- Bei gegebener Ontologie wird eine zulässige Weltbeschreibung so definiert, dass es eine mögliche Welt ist, die alle constraints erfüllt



Formalisierung von Konzepten

- Grundlage: **Objekte** in der realen Welt: x_1, x_2, \dots
- **Relationen** zwischen Objekten: $r(x_1, x_2)$
- **Konzepte** als Menge von Objekten: $\{x_1, x_2, \dots\}$

- Ontologie als constraint System:
 - Relationen zwischen Konzepten: $=, \supseteq, \subseteq$
 - Bedingung für Klassenmitgliedschaft, z.B.
 - $\{x \mid \exists y: r(x,y)\}$
 - $\{x \mid \forall y: r(x,y) \Rightarrow y \in \{y_1, y_2, \dots\}\}$
 - Beschränkungen von Relationen
 - $r(x,y) \Rightarrow x \in \{x_1, x_2, \dots\} \wedge y \in \{y_1, y_2, \dots\}$



Beschreibungslogiken

- Alternative Bezeichnungen
 - Beschreibungslogik (BL)
 - Description logic (DL)
 - Terminologische Logik (TL)
- Anwendungsgebiet
 - Beschreibungslogiken dienen der Modellierung einer fachsprachlichen Terminologie,
 - insbesondere der begrifflichen Über- und Unterordnungsbeziehungen.
- Deklarativität
 - Modelltheoretische Semantik
 - Vermeidet Mehrdeutigkeiten der Frame-Sprachen
- Effizienz
 - Entscheidbares Erfüllbarkeitsproblem
 - Vermeidet die Problemkomplexität der Prädikatenlogik



Wissen über Sachverhalte

- ☐ Diana ist verheiratet mit Charles.
- ☐ Elizabeth hat Charles, Andrew und Edward als Kinder.
- ☐ Charles, Andrew und Edward sind Männer.
- ☐ Elizabeth und Diana sind Frauen.
- ☐ Diana hat keine Töchter.
- ☐ Elisabeth ist Großmutter.
- ☐ Diana hat William als Kind.



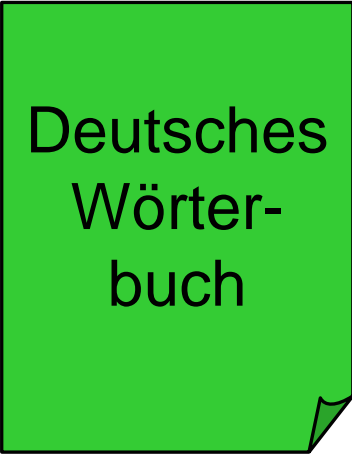
Das
goldene
Blatt

Assertionales Wissen



Wissen über Terminologie

- ☐ Eine Frau ist ein weiblicher Mensch.
- ☐ Ein Mann ist ein männlicher Mensch.
- ☐ Eine Ehefrau ist eine Frau, die mit einem Mann verheiratet ist.
- ☐ Ein Elternteil ist ein Mensch, mit einem Menschen als Kind
- ☐ Eine Mutter ist ein weibliches Elternteil.
- ☐ Eine Frau-ohne-Töchter ist eine Frau, deren Kinder alle nicht weiblich sind.
- ☐ Eine Großmutter ist eine Frau, mit einem Kind, das Elternteil ist.



Deutsches
Wörter-
buch

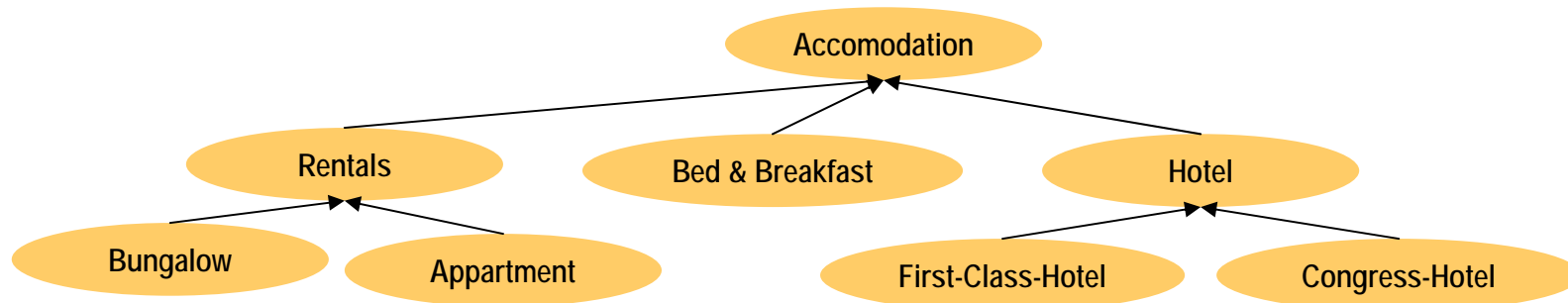
Terminologisches Wissen



Beschreibungslogiken (Description Logics)

- Entscheidbare Teilmenge von Prädikatenlogik 1. Stufe
- Ermöglicht Formulierung von konzeptuellem Wissen durch Primitiva
 - Konzeptausdrücke (Formeln mit 1 freien Variablen) für die Beschreibung von Objekten
 - Bool'sche Operatoren: $C \cap D$, $C \cup D$, $\neg C$
 - Quantifikation: $(\exists R.C)$, $(\forall P.C)$
 - Constraints auf Kardinalitäten: $(= n R)$, $(> n R)$, $(< n R)$, $(\geq n R)$, $(\leq n R)$
 - Axiome definieren Relationen zwischen Konzepten
 - Subsumption: $C \subseteq D$
 - Äquivalenz: $C \equiv D$
 - Disjunktion: $C \cap D \subseteq \perp$

Eine Beispielontologie



$\text{Hotel} \equiv \text{Accommodation} \cap (> 1 \text{ Units}) \cap (\forall \text{Building. Collective})$

$\text{First-Class-Hotel} \equiv \text{Hotel} \cap (\geq 4 \text{ Stars})$

$\text{Congress-Hotel} \equiv \text{Hotel} \cap (\exists \text{Facilities. ConferenceRooms})$

$\text{Rental} \equiv \text{Accommodation} \cap (\forall \text{Building. Private})$

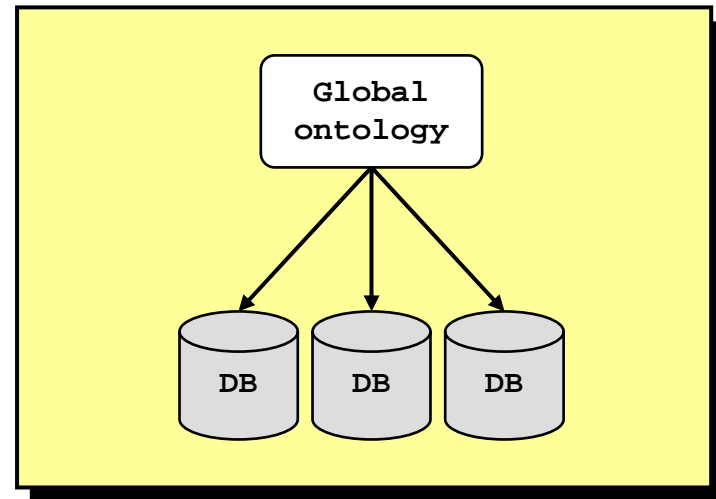
$\text{Bungalow} \equiv \text{Rental} \cap (= 1 \text{ Units})$

$\text{Appartment} \equiv \text{Rental} \cap (> 1 \text{ Units})$

$\text{Bed\&Breakfast} \equiv \text{Accommodation} \cap (\forall \text{Building. Private}) \cap (\exists \text{Meals. Breakfast})$

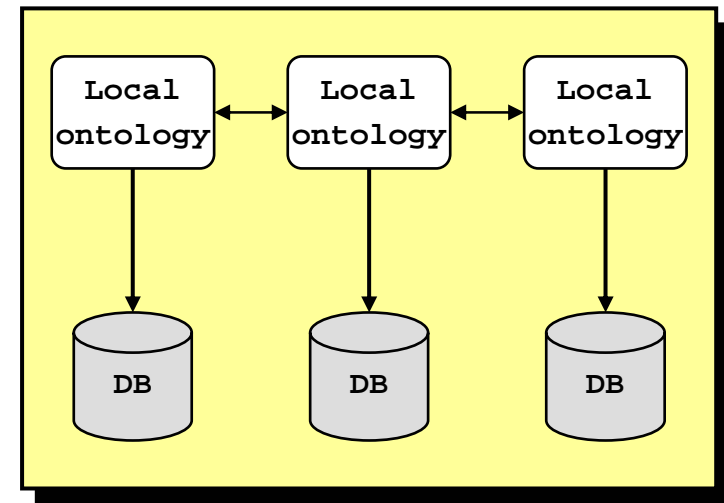
Ontologien in der Kommunikation (I)

- Single ontology approaches
 - Global ontology, shared vocabulary (e.g. SIMS)
 - Can be combination of several ontologies because of modularization
 - Same view on domain necessary, susceptible when information source changes, minimal ontology commitment hard to find



Ontologien in der Kommunikation (II)

- Multiple ontology approaches
 - Information source has own ontology (e.g. OBSERVER)
 - No shared vocabulary
 - No common and minimal ontology commitment needed (about global ontology)
 - Problems with different source ontologies (inter-ontology-mapping needed)
 - Hard to define inter-ontology mappings in reality



Ontologien in der Kommunikation (III)

■ Hybrid approaches

- Information source has own ontology
- Built upon one global shared vocabulary
- Description of local ontologies is interesting
- Advantages
 - New information sources easily added
 - „Comparable“ ontologies due to shared vocabulary
- Disadvantage
 - Reuse of existing ontologies difficult

