Formal approaches for Complementary Competence Management and Discovery

(Gestion formelle de Compétences et de leurs Complémentarités)

Université A. Mira,
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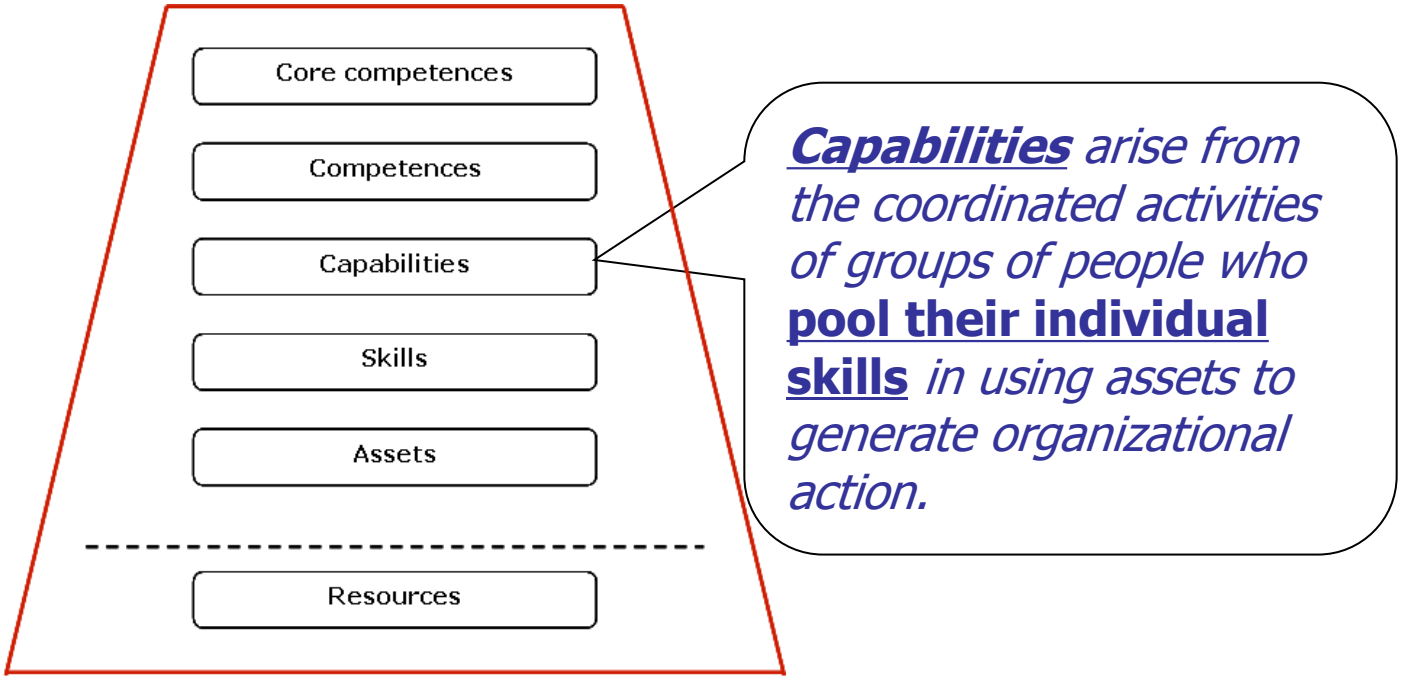
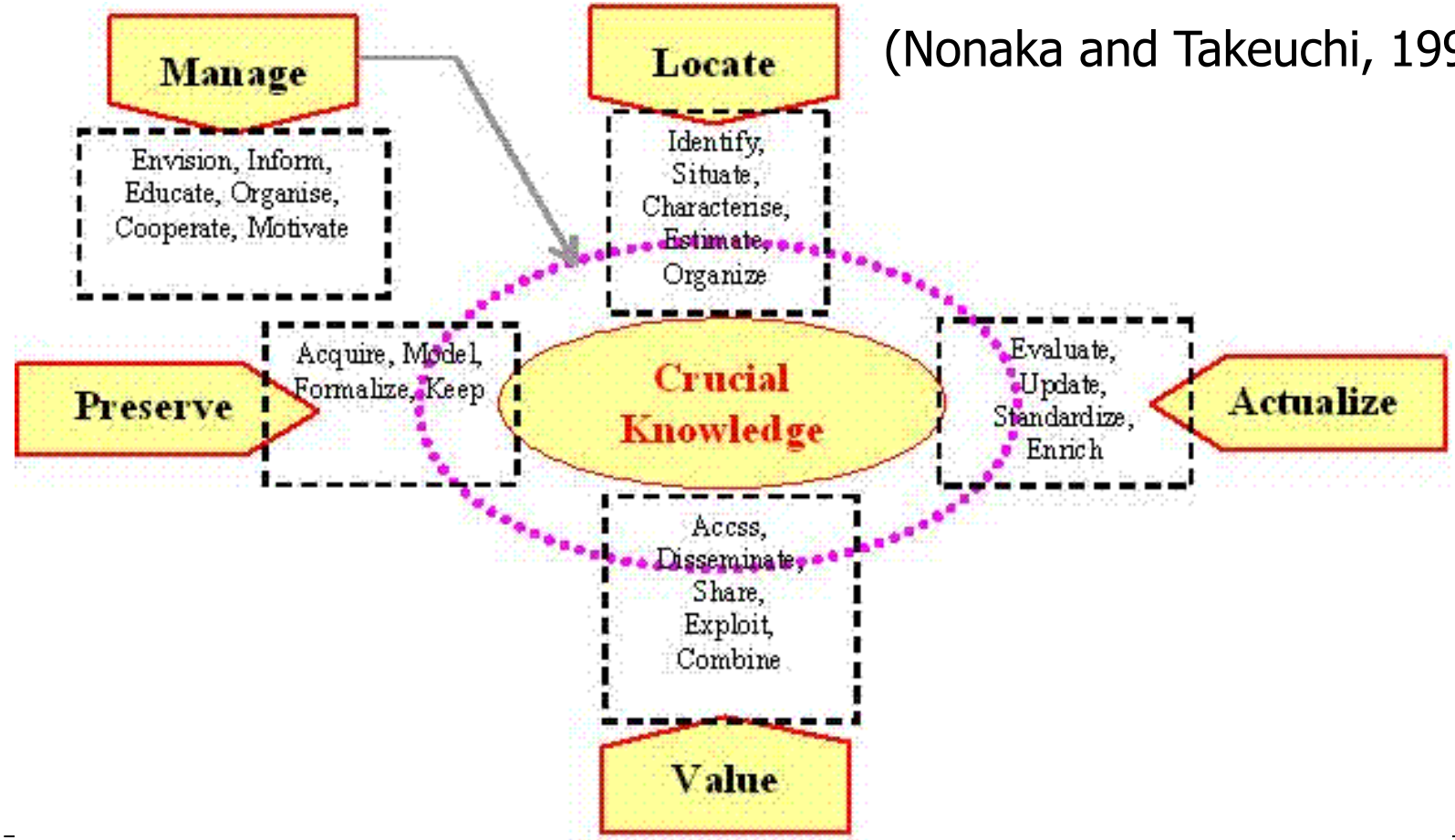
"Competence" vs. "Capability"

- Competence management
- Enterprise knowledge management

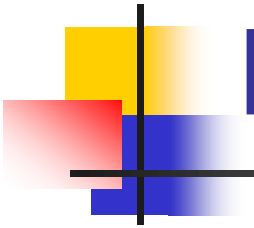


Entreprise Knowledge



(Nonaka and Takeuchi, 1995)

Problem Statement



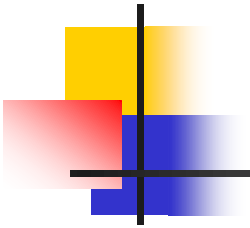
- Aim: “Object’s” capability management
- “Object’s” capability examples:
  - Software components: functions, services, …
  - Industrial Partners: domain(s) of expertise
  - Individuals: skills
- (Possible) Application Domains
  - Component-based Programming
  - E-business (Dynamic service discovery, **Partnership** and **Alliances**, …)
  - **…**

Problem statement

1. (Formally) Represent:
   - Capability representation language(s)?
2. Structure: Explicit the relationships between capabilities
   - More general/More specific/Composable
3. Exploit: Store, Update, Discover and Retrieve
   - Capabilities
   - Complementary capabilities

Problem statement (end)

- **1 & 2**: Represent and Structure:
  - Natural Language (Not formal)
  - **K**nowledge **R**epresentation Languages like **D**escription **L**ogic, **C**onceptual Graphs, etc.
  - Subsumption Hierarchies, **C**lassification techniques
- **3**: Exploit: Retrieve, Discover, Compose
  - Classification techniques
  - Complement Identification/Calculation
  - Cooperation, Distributed Architecture



Presentation Outline

I. Problem Statement
II. Competence Model(s) and Language(s)
III. A Model for Competence Discovery
IV. DL as a Competence Representation Language
V. Capability Management and Discovery
VI. Mediators Federation
VII. Concluding Remarks

Some Competence Models

- **Interoperability Knowledge Map**
  - ✓ **Competence**: Knowledge, Expertise
  - ✓ **Actor**: individual, group of individuals or organizations

- **CRAI Model (Competence-Resource-Aspect-Individual)**
  - ✓ **Competence:** mobilization of resources
  - ✓ **Resource:** Know, Know-How
  - ✓ **Actor**: individual

F. Bouchaib, N. Boudjlida and H-N. Talantikite. *A Generic Model of Knowledge and Competence of Domains*. In E-H. Abdelwahed and H. Mountassir Eds, proceedings of the 3rd International Conference on Web and Information Technologies, p. 209--220, Marrakech, Morocco, June 2010

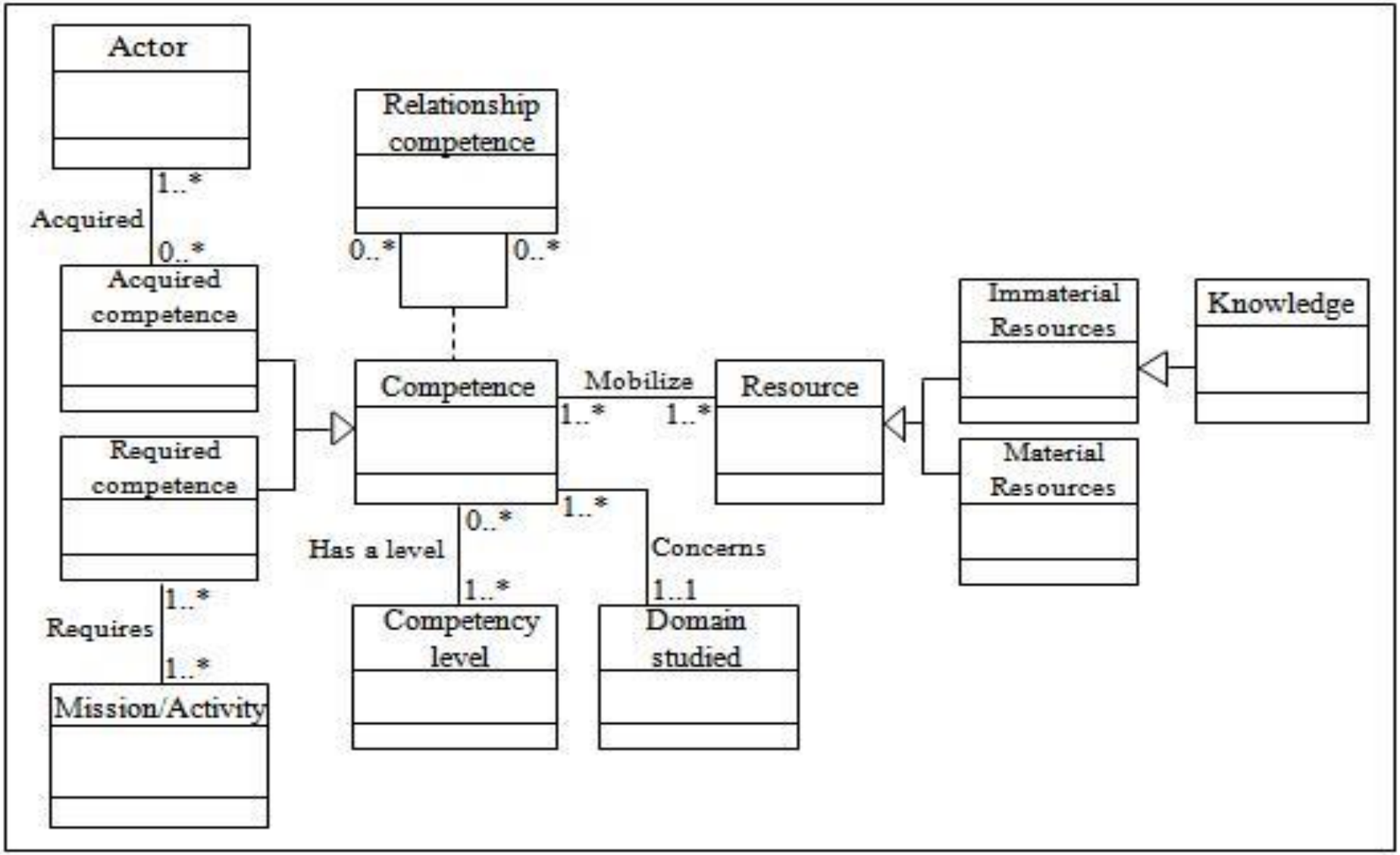
Systemic Model of competences

- **Competence** :
  - Mobilization of resources (personal + environment)
  - Interaction actor/Working Context
- **Actor** : individual

S-A-R-C Model (Situation-Actor-Resource-Competence)

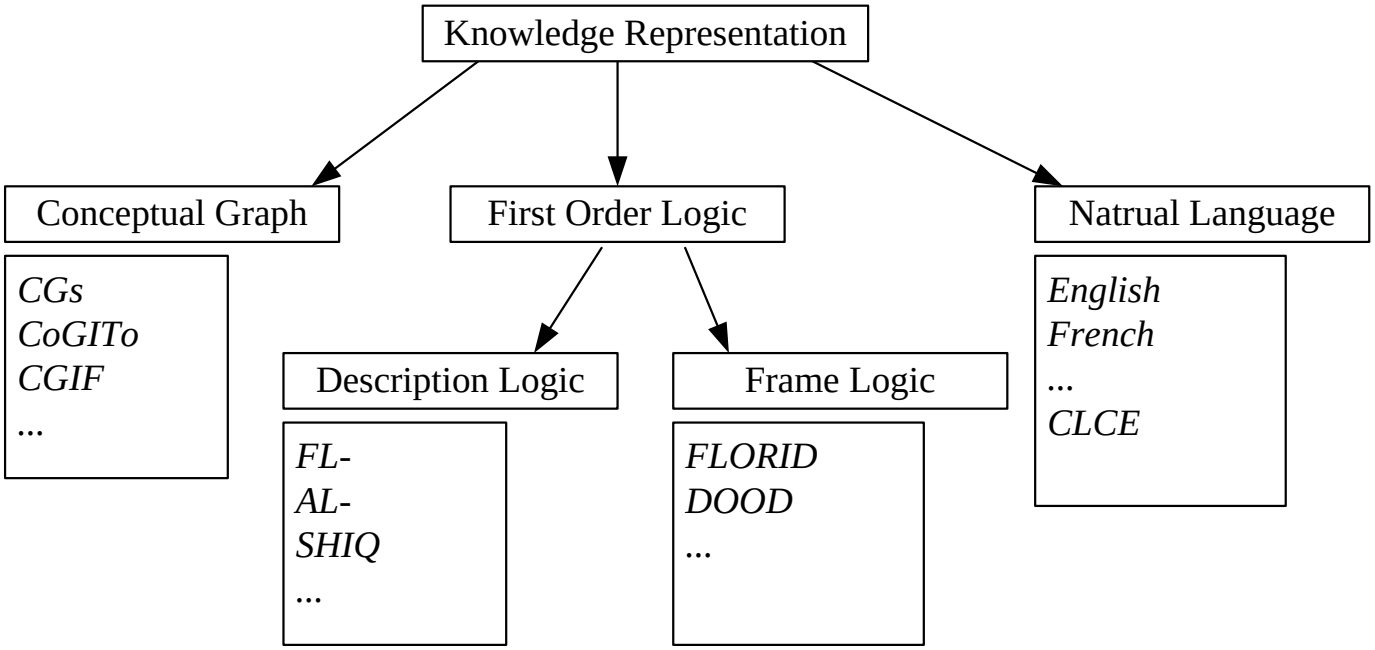
- **Competence** : - Resource mobilisation (personal + envrnmt)
  - Interaction Actor - Situation – Resource
- **Actor** : individual or group of individual
- **Resource**: Material Resources
- **Situation**: Task to be done or Problem to be solved

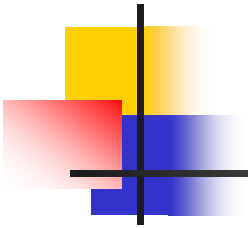
What a Competence Model



What a Representation/Description Language?

- Formal, ½ Formal, Unformal?
- What an exploitation process?





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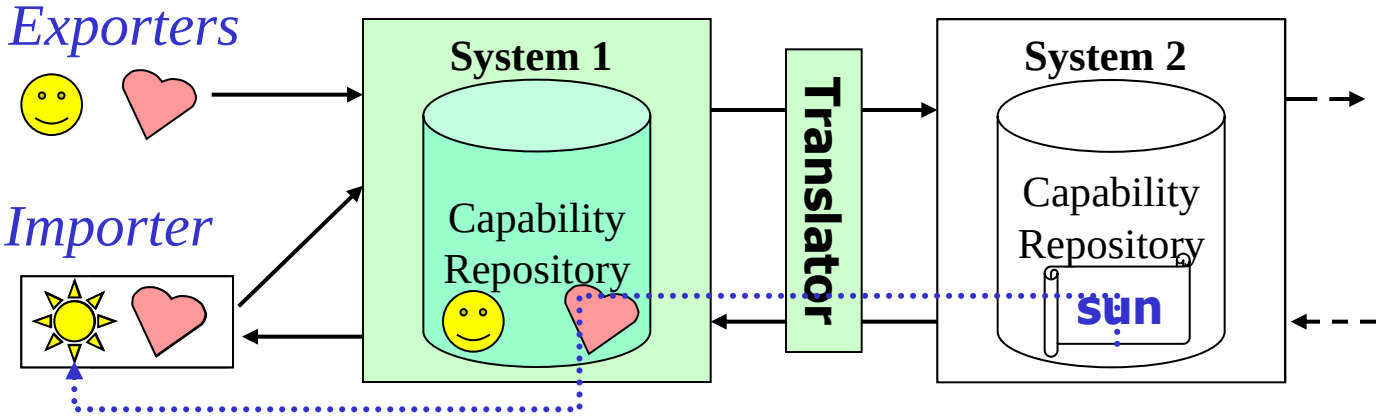
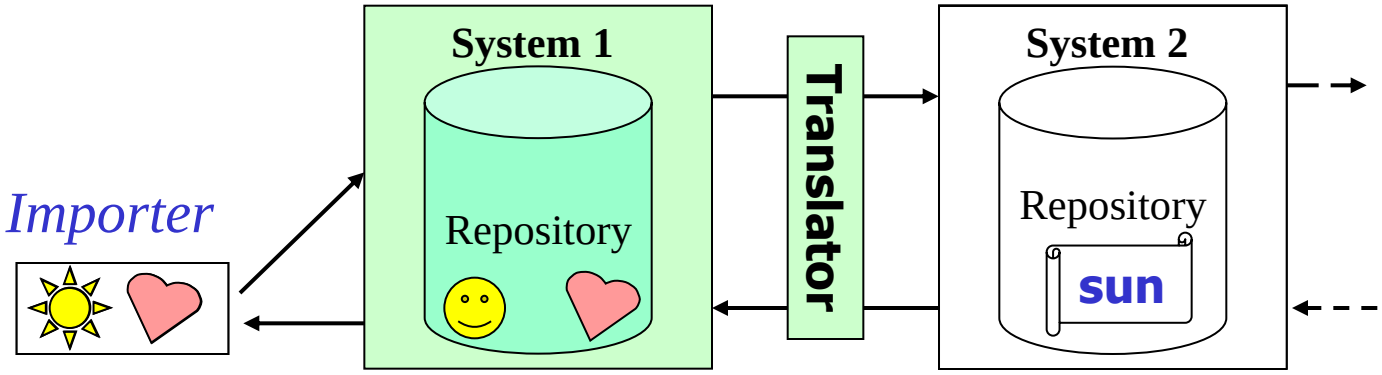
III. A Model for Competence Discovery

- *exporters* publish their capabilities at one or more repositories
- *importers* send requests to a repository, asking for exporters fitted with a given set of capabilities.
- (heterogeneous) repositories are explored and may compose their capabilities to try to satisfy the request



III. A Model for Competence Discovery

1. Single individual satisfaction
2. Composing multiple individuals' capabilities
3. Composing multiple individuals in multiple homogeneous capability repositories
4. Composing multiple individuals from multiple heterogeneous capability repositories



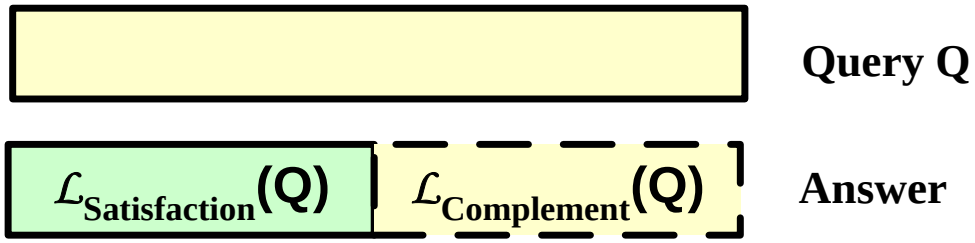
Notion of Composite Answers - 1

- "Usual" Answers

$$\mathcal{L}_{Answer} = \{Yes, No, Unknown\}$$

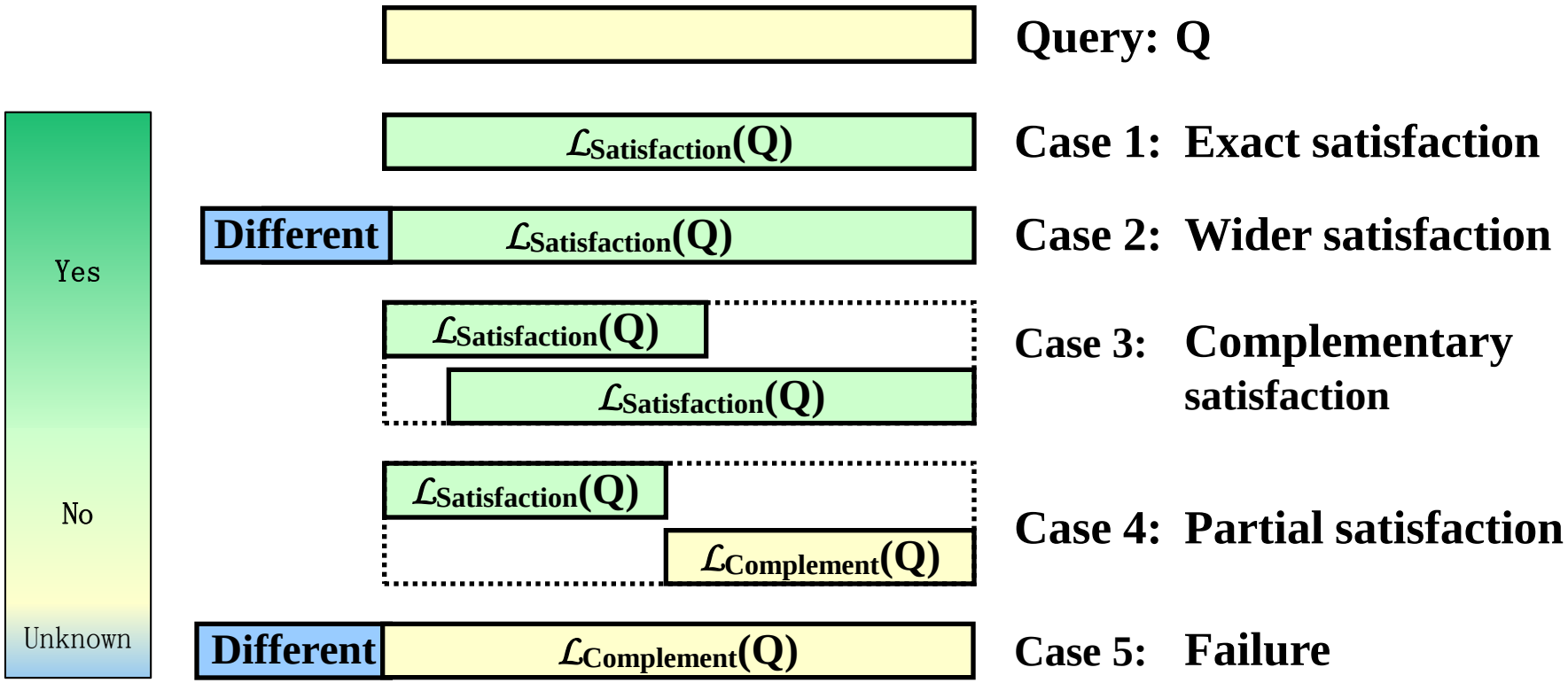
- Composite answer for individuals' capabilities composition
- Complement and Composite Answers

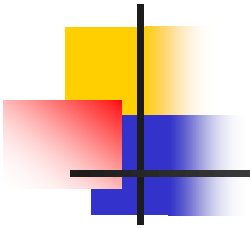
$$\mathcal{L}_{Answer} = \mathcal{L}_{Satisfaction} + \mathcal{L}_{Complement}$$



Notion of Composite Answers - 2

- Query satisfaction situations





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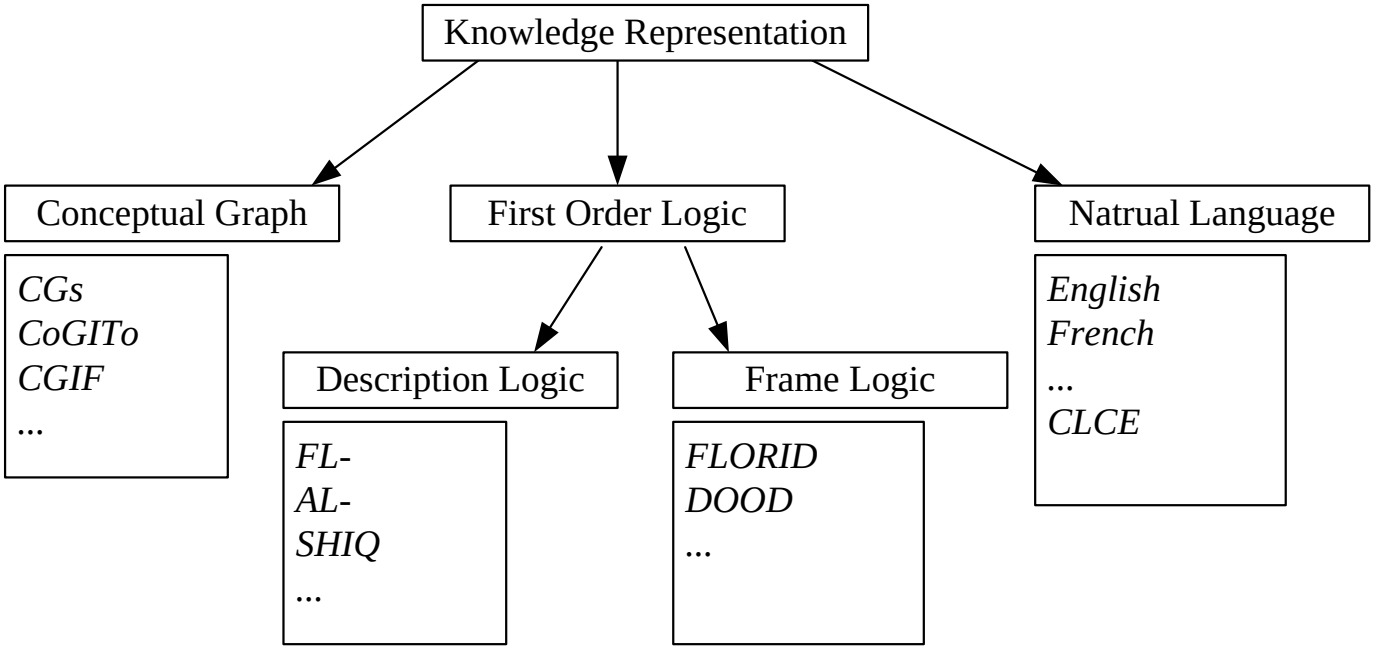
IV. DL as a Competence Representation Language

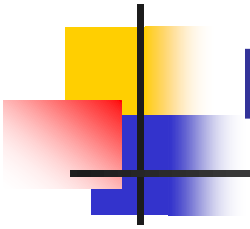
(Some) Candidate Representation Languages



DL as a Competence Representation Language

(Some) Candidate Representation Languages

	DLs	**F-logics**	**CGs**
Concept Description	Concept	Class	Concept,
Capability Description	Role	Class : :Method	Relation
Individual Description	assertion	object	individual
Knowledge Organization	subsumption hierarchy	IS-A hierarchy	directed graph
Reasoning method	structural comparison, tableau method	sorted F-logic, multiset-valued method	inverting resolution,



DL as a Representation Language

- Concept: Set (class) of "individuals"
- Role: Modality (properties, relationship) of Concepts
- A concept C subsumes a concept D if and only if C's extension necessarily contains D's extension
- Subsumption relationship: organization of concepts and roles into hierarchies and according to generalization levels

Syntax of ALN_{r+}

Name	Abstract syntax	Concrete syntax
primitive concept	C, D → A	A
universal concept	⊤	TOP
bottom concept	⊥	BOTTOM
primitive negation	¬A	(not A)
at-least restriction	(≥ n r)	(atleast n r)
at-most restriction	(≤ n r)	(atmost n r)
concept conjunction	C ⊓ D	(and C D)
value restriction on roles	∀R.C	(all R C)
role name	R, S → r	r
universal role	$\top_{role}$	TOProle
bottom role	$\bot_{role}$	BOTTOMrole
role disjunction	R ∪ S	(or R S)
symmetric closure	R^{-}	(R^{-})
transitive closure	R^{+}	(R^{+})
reflexive-transitive closure	R^{*}	(R^{*})
role functional restriction	RfS	(RfS)

DL as a Representation Language

- Concept/Role description in $\mathcal{ALN}_{\mathrm{r}+}$
  - Primitive Concept/Role

$$\texttt{CITY} \;\dot{\sqsubseteq}\; \top \qquad\qquad \texttt{has-flight} \;\dot{\sqsubseteq}\; \texttt{has-way}$$

  - Defined Concept/Role

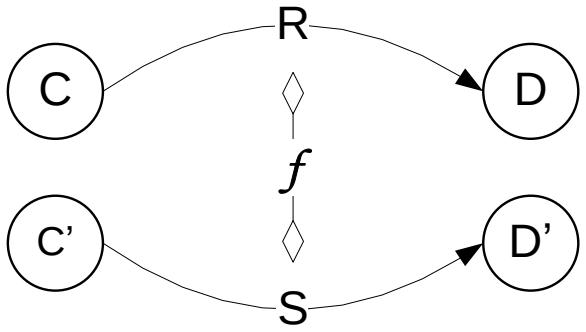
$$\begin{aligned}\texttt{CITY-AIRPORT} \;\doteq\; (\,&\texttt{and CITY}\\ &(\texttt{all has-flight}^{*}\ \texttt{CITY})\\ &(\texttt{at-least 1 has-flight}^{-}))\end{aligned}$$

- Capability Description Form:

  $\forall R.\mathrm{T}$: where ***R*** is a role and **T** is the top concept

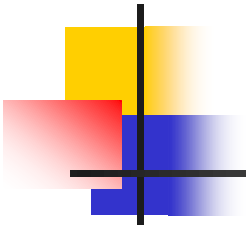
DL as a Representation Language

- The role functional restriction
  - 4 concepts
  - 2 roles
  - 1 predicate logical form



$$R \equiv S \Leftrightarrow RfS,\ where\ f = \{a \in \Delta^{\mathcal{I}} \mid \forall b.(a,b) \in R^{\mathcal{I}} \leftrightarrow (a,b) \in S^{\mathcal{I}}\}$$
$$R \subseteq S \Leftrightarrow RfS,\ where\ f = \{a \in \Delta^{\mathcal{I}} \mid \forall b.(a,b) \in R^{\mathcal{I}} \rightarrow (a,b) \in S^{\mathcal{I}}\}$$

$$R \circ S := \{(a,c) \in \Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}} \mid \exists b\ \forall R\ \forall S.(a,b) \in R^{\mathcal{I}} \wedge (b,c) \in S^{\mathcal{I}}\}$$



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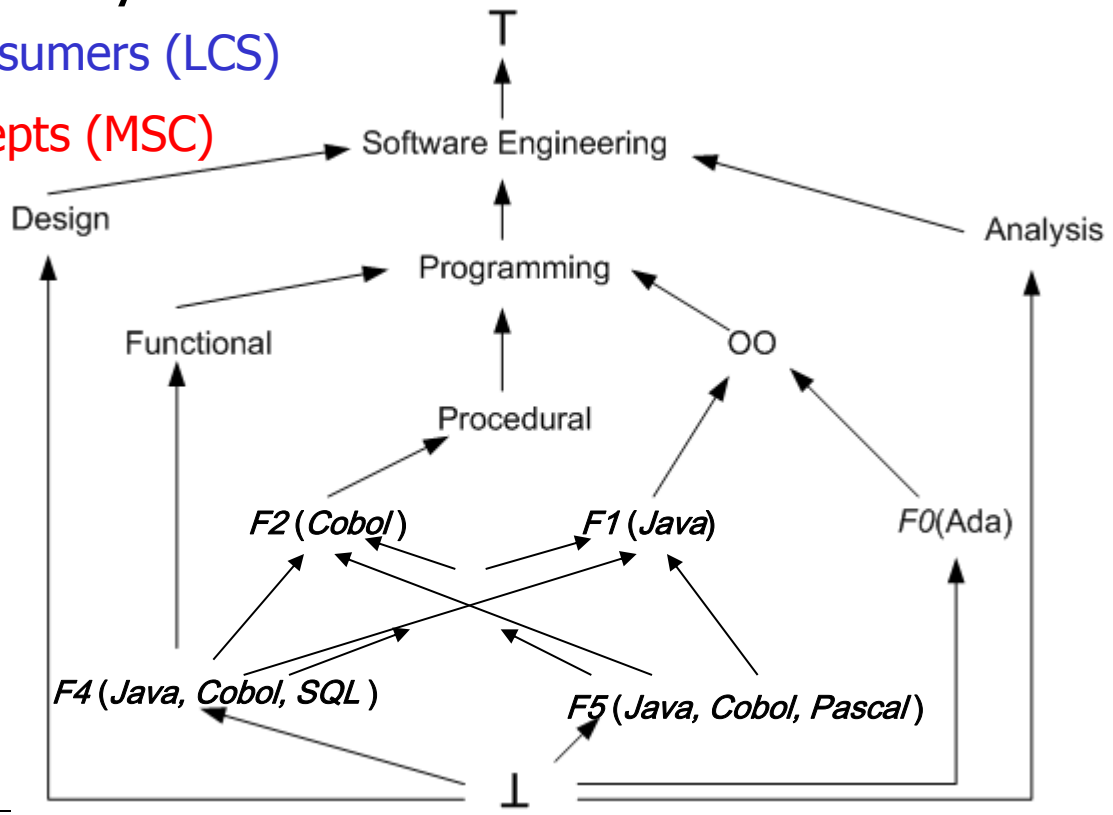
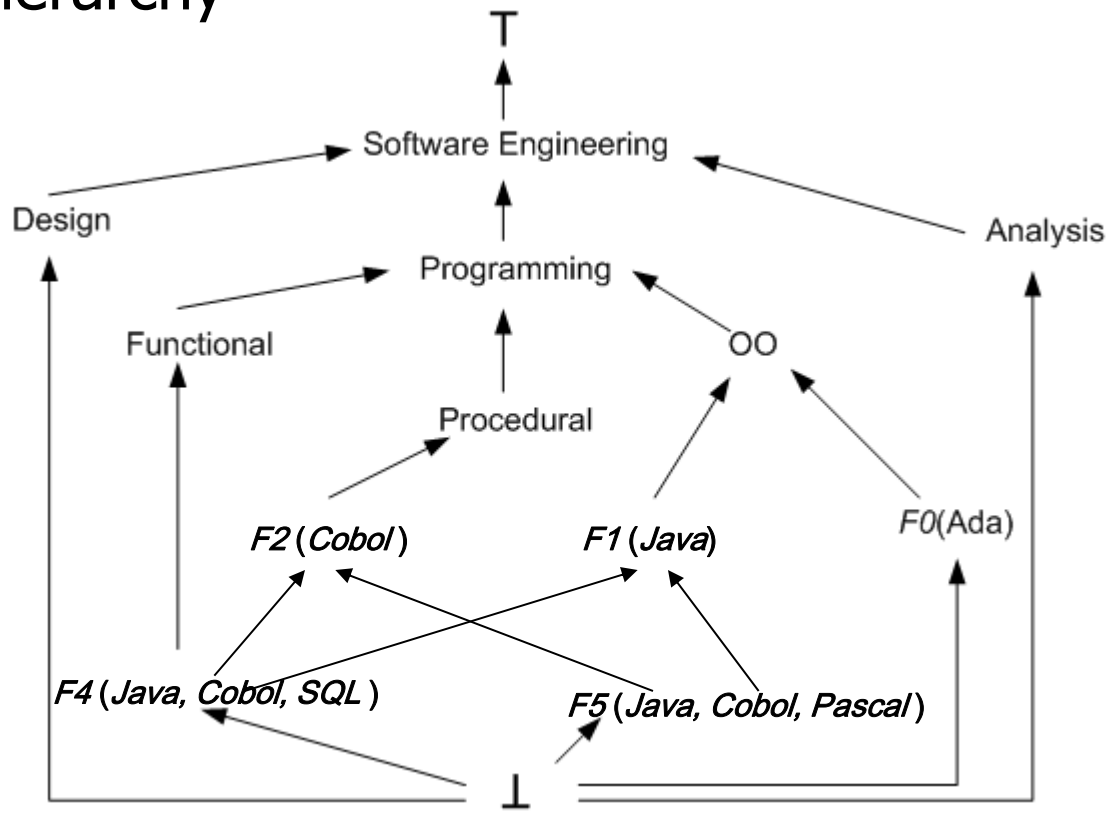
V-1. Classification -1

- Classification : Locate a concept description in the subsumption hierarchy
  - Least Common Subsumers (LCS)
  - Most Specific Concepts (MSC)

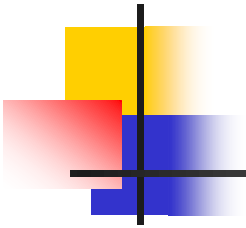


V-1. Classification -2

- Classification as a mean to satisfy a query description in the subsumption hierarchy
  - LCS partly satisfy Q.
  - MSC fully satisfy Q.



Q (*Java, Cobol*)



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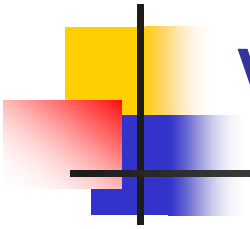
V-2. Complement Concept

- As a basis for composite answers
- Formally: A, B, C being concepts: A U $B \equiv C$
- Intuitively: B is a complement for A "to be" C
  - $\mathcal{L}_{\text{Answer}}(Q) \equiv \mathcal{L}_{\text{Query}}(Q)$
  - $\mathcal{L}_{\text{Answer}}(Q) \equiv \mathcal{L}_{\text{Satisfaction}}(Q)$ U $\mathcal{L}_{\text{Complement}}(Q)$
- The complement of a concept A relatively to another concept C is the smallest subsuming common concept B of the two concepts

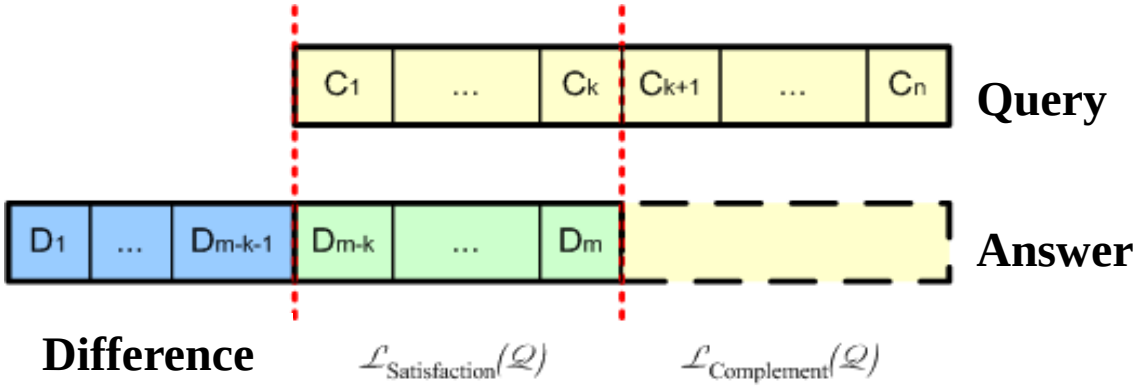


V-3. Capability Discovery Process

1. Normalization/Comparison algorithm
2. Satisfying candidate(s) selection & Complement calculation algorithm
3. Capability discovery in a repository
4. Capability discovery in multiple directories

V-3.1. NC algorithm

- Normalization-Comparison Algorithm
  - Normalized formula is composed by conjunctive atomic concepts.
  - Compare (for subsumption) each atomic concept in a Query and concepts in possible candidates



V-3.1. NC algorithm (end)

- Comparison process
  - CITY-AIRPORT subsumes CITY-AIR-TRAIN

(C) CITY-AIRPORT $\doteq$ (and CITY

$C:$ $(\sqcap$ CITY $(C_1)^{\text{ITY}})$

$(\geq \infty$ 1 has-flight$^-$.CITY)) $(C_2)^{\text{light}^-}))$

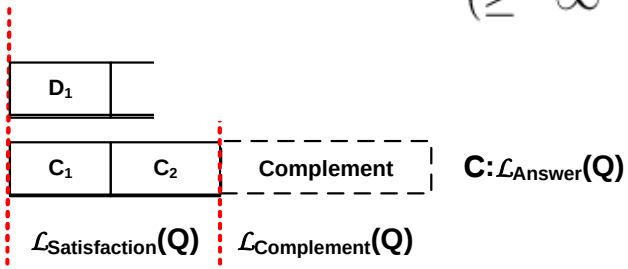
(D) $D:$ $(\sqcap$ CITY (D_1)

$(\geq \infty$ 1 has-flight$^-$.CITY) $(D_2)^{\text{ITY}})$

$(\geq \infty$ 1 has-train$^-$.CITY)) $(D_3)^{\text{light}^-})$

(all has-train CITY)

(at-least 1 has-train$^-$))



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V-3.2. Satisfaction Calculation

- **m** ***Exporters*** entities (**Ds**) has relative with the query **C**.
- **C** contains **n** atomic concepts.
- "Satisfaction Table"

$$ST[D_j, C_i] = true \leftrightarrow D_j^i \sqsubseteq C_i$$

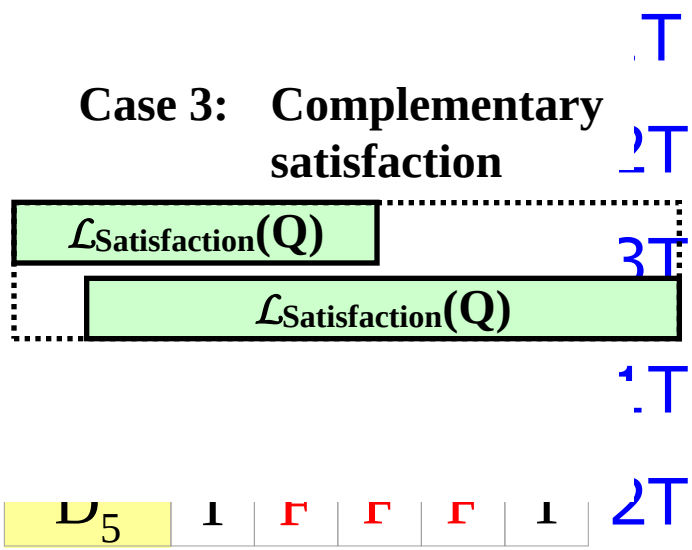
- An observed list of values

$$ORoD[i] = \bigvee_{j=1}^{m} ST[D_j^i, C_i], \forall i \in [1..n]$$

	C_1	C_2	C_3	…	C_n
D_1	T	F	F	…	F
D_2	F	F	T	…	F
…					
D_m	T	F	T	…	F
ORoD	T	F	T	…	F

V-3.2. Satisfaction Calculation (cont'd)

- Composing Answers (many strategies)



	C_1	C_2	C_3	C_4	C_5
D_3	T	F	F	T	T
D_2	T	T	F	F	F
D_4	T	F	T	F	T
ORoD	T	T	T	T	T

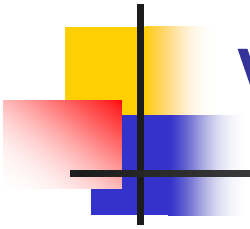
V-3.2. Satisfaction Calculation (end)

- Situation determination

$$ORoS = ORoD_1 \vee ORoD_2 \vee \ldots \vee ORoD_n$$

$$ANDoS = ORoD_1 \wedge ORoD_2 \wedge \ldots \wedge ORoD_n$$

LCS(Q)	MSC(Q)	ORoS	ANDoS	CASE
X	X	True	True	1 : Exact Satisfaction
X	Y	True	True	2 : Wider Satisfaction
X	BOTTOM	True	True	3 : Complementary Satisfaction
X	BOTTOM	True	False	4 : Partial Satisfaction
TOP	BOTTOM	False	False	5 : Failure



V-3. Capability Discovery Process

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V-3.3. Capability discovery in a repository

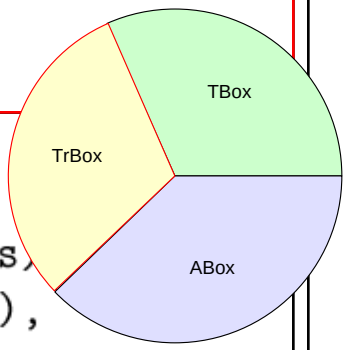
- Capability space (T_rBox)

TBox

```
CITY            ⊑̇  ⊤
VEHICLE         ⊑̇  ⊤
CITY-AIRPORT    ≐  ( and CITY
                       (all has-flight* AIRPLANE)
                       (at-least 1 has-flight⁻))
CITY-TRAIN      ≐  ( and CITY
                       (all has-train TRAIN)
                       (at-least 1 has-train⁻))
AIRPLANE        ⊑̇  VEHICLE
TRAIN           ⊑̇  VEHICLE
CITY-AIR-TRAIN  ≐  ( and CITY
                       (all has-flight* AIRPLANE)
                       (at-least 1 has-flight⁻)
                       (all has-train TRAIN)
                       (at-least 1 has-train⁻))
```

T_rBox

```
has-way     ⊑̇  ⊤
has-flight  ⊑̇  has-way
has-train   ⊑̇  has-way
```



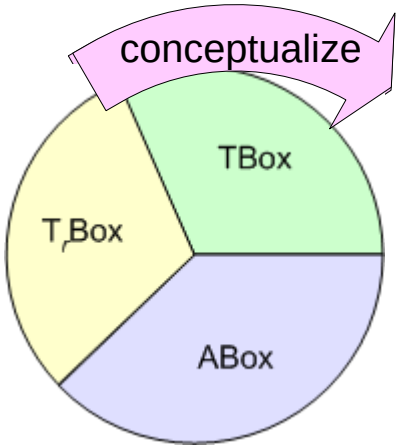
ABox

```
CITY-TRAIN(Beijing), CITY-TRAIN(Nancy),
CITY-AIR-TRAIN(Beijing), CITY-AIR-TRAIN(Paris),
has-train(Nancy, Paris), CITY-AIRPORT(Paris),
CITY-AIRPORT(Beijing), CITY-AIRPORT(Wuhan),
has-flight(Beijing, Wuhan), has-flight(Paris, Beijing)
```

V-3.3. Capability discovery in a repository

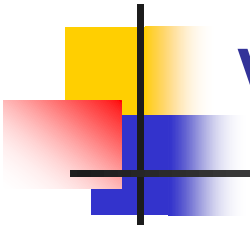
- Capability discovery
- Model discovery
- Individual discovery

has-way (Nancy, Wuhan) is composed by **has-train (Nancy, Paris), has-flight (Paris, Beijing), has-flight (Beijing, Wuhan), CITY-TRAIN(Nancy), CITY-AIR-TRAIN(Paris), CITY-AIRPORT(Beijing), T(Wuhan).**



$$\begin{aligned} \text{has-way} &\dot{\sqsubseteq} \top \\ \text{has-flight} &\dot{\sqsubseteq} \text{has-way} \\ \text{has-train} &\dot{\sqsubseteq} \text{has-way} \end{aligned}$$

CITY-AI
has-trai
CITY-AIRPO
(Wuhan),
has-flight(Beijing, Wuhan), has-flight(Paris, Beijing)



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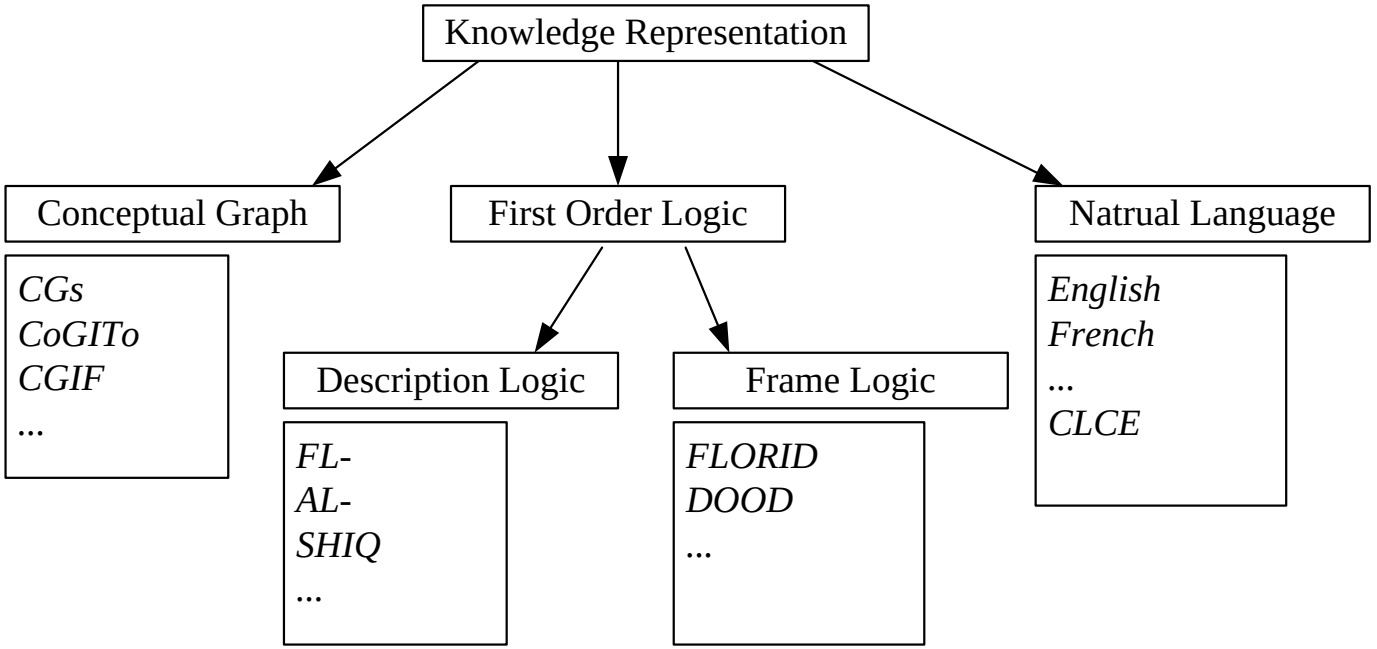
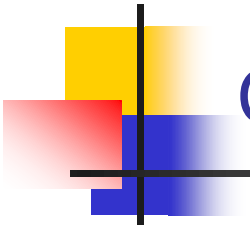
Capability discovery in multiple repositories

Case of Heterogeneous Representation Languages





Capability translation & Term matching

- Query by capability descriptions

"Who knows a computer language?"

  - **DL**: ∀know.COMPUTER-LANGUAGE
  - **F-logic**: X←know(Computer-Language)
  - **CGIF**: [Object: *X][Object: Computer-Language]
    [know ?X ?Computer-Language]

Capability translation & Term matching

- Answers use different vocabularies.

"Someone knows a computer language"

- **DL**: (and ENGINEER
  (all skill MACHINE-LANGUAGE))
- **F-logic**: Student [capability⇒⇒ BASIC]
- **CGs**: [WebManager: @every]→ (competence)
  → [Java]

Capability translation & Term matching

- Ontology, Dictionary

  WordNet, EuroWordNet, …

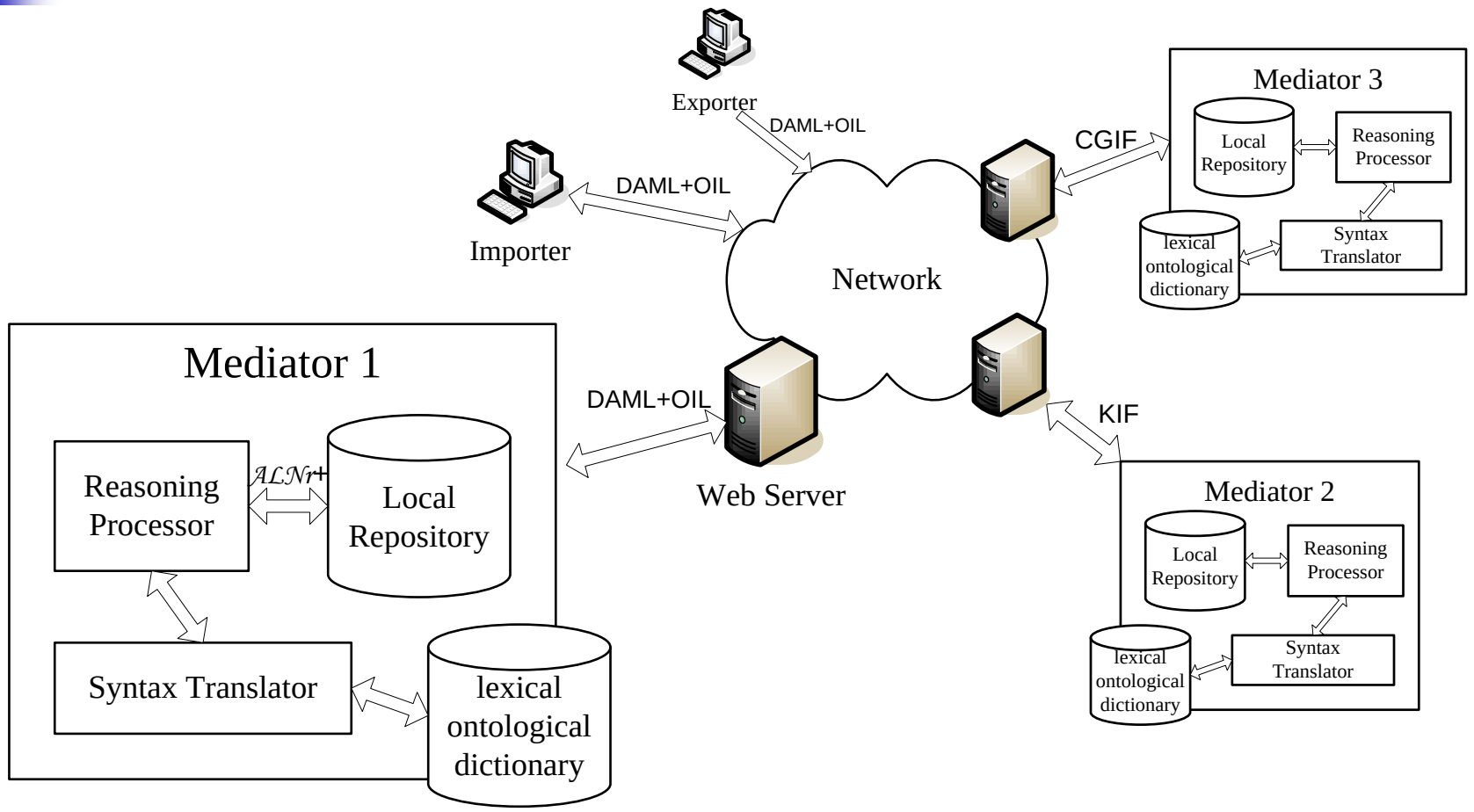
- Matching algorithms
- Similarity Measurement…

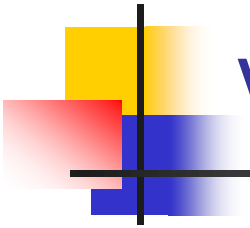
$$Sim(X,Y) = \frac{2 \times |X \cap Y|}{|X| + |Y|}$$

Presentation Outline

I. Competence vs Capability
II. Competence Models
III. A Model for Competence Discovery
IV. DL as a Competence Representation Language
V. Capability Management and Discovery in DL
    1. Classification
    2. Complement Concept
    3. Capability Discovery
VI. Capability Management and Discovery in CGs (?)
VII. Mediators Federation for Composite Answers
VIII. Concluding Remarks

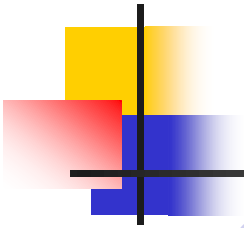
VI. Mediators Federation





VI. Mediators Federation Techniques

- Web service techniques
- Service description in WSDL
- Service cooperation description in OWL-S (i.e. static, pre-defined inter-action flow between the mediators)
- Messages in SOAP
- P2P
- Cloud?



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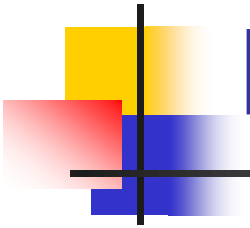
1. Competence description and organization

   (Inference services, capability management,
   role closure, role functional restriction model)

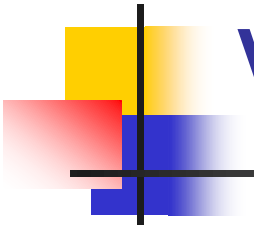
2. Competence discovery and Composition

   (complement concept, capability description,
   conceptualization, individualization)

Discussion: Archi vs P2P



1. Autonomy (YES): every server offers its services to its clients (importer & exporter)
2. Dynamicity :
   - Dynamic and Semantic discovery of the mediators and their services
   - Federation Management: Join/Leave a federation
3. Decentralization : decentralized architecture *per essence*
4. Cooperation : cf. Composite answers



VII. Concluding Remarks: Going further

1. Competence Model and description
   - Enrich syntax, NP complete, other KR languages
2. Capability structure
   - Competence Relationships, modal logic, second-order logic
3. Mediators federation
   - Dynamic federation, enrich the services
4. Application domains
   - UDDI, Dynamic ERPs, Repository integration

That’s all Folks

Thank you for paying attention!

Merci pour votre attention !

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