

Lexical knowledge representation and natural language processing

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aims of the semantic lexicon

- create a lexical model which
 - can do disambiguation and complement selection without using word sense enumeration
 - can account for new word contexts and creative use of language
- overall goal: significant improvement of natural language processing systems in **computational lexical semantics**

semantic lexicon

methods and basic formalisms

- lexical formalism makes use of a knowledge representation framework
- disambiguation becomes part of the *semantic analysis* procedure
- different word senses result directly from interaction of mutual compatible roles in the lexical entry - *compositional approach*

lexical ambiguity

word sense enumeration

- 1) a fast car
- 2) a fast typist
- 3) a fast book
- 4) a fast game

lexical ambiguity - a semantical approach

- consider the following examples:
 - a fast car
 - a fast typist
 - a fast book
 - a fast motorway
- the lexical sign of the noun contains semantic information which can be modified by the adjective
- more powerful mechanism than word sense enumeration

ambiguity and compositionality

new lexical entries

- lexical entry encodes a range of representative aspects of lexical meaning
- mutual compatible roles force a special interpretation of a word in a specific context
 - more complex process than matching of features
 - mechanisms for composition on phrasal level
- compositional approach revises the more conventional view which treats verbs as functions and nouns as arguments

lexical signs

four levels of representations

- Argument structure:
 - mapping from a word to a function
 - number and type of arguments
- Event structure:
 - event type for a verb or a phrase
 - state (S), process (P) and transition (T)
 - information about the event and event composition

lexical signs

four levels of representations

- Qualia structure
 - defines essential attributes of objects, events, and relations
 - specifies an argument structure for nouns and nominal phrases
- Lexical inheritance structure
 - defines relations to other words in the lexicon
 - provides a link to general world knowledge

Qualia structure

- system of relations that characterizes the semantics of nominals
- specifies four aspects of word meaning:
 - *Constitutive role* - the relation between an object and its constituent parts
 - *Formal role* - that which distinguishes it within a larger domain
 - *Telic role* - its purpose and function
 - *Agentive role* - factors involved in its origin or „bringing it about“

Qualia structure – an example from the lexicon

door (x,y)

CONST = **aperture(y)**

FORMAL = **physobj(x)**

TELIC = **walk_through(P,w,y)**

AGENTIVE = **artifact(x)**

Qualia structure the role approach

- roles determine a minimal semantic description of a word
- approach enriches the semantics of nominal types to „spread the semantic load“ more evenly through the lexicon
- possibility to create an account for new word senses arising in syntactic composition
- motivated by linguistic phenomena

some examples

- They walked through the **door**.
She will paint the **door** red.
- Black smoke filled the **fireplace**.
The **fireplace** is covered with soot.
→ relation between the *Formal* and the *Constitutive qualia*

some examples

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door (x,y)

CONST = **aperture(y)**

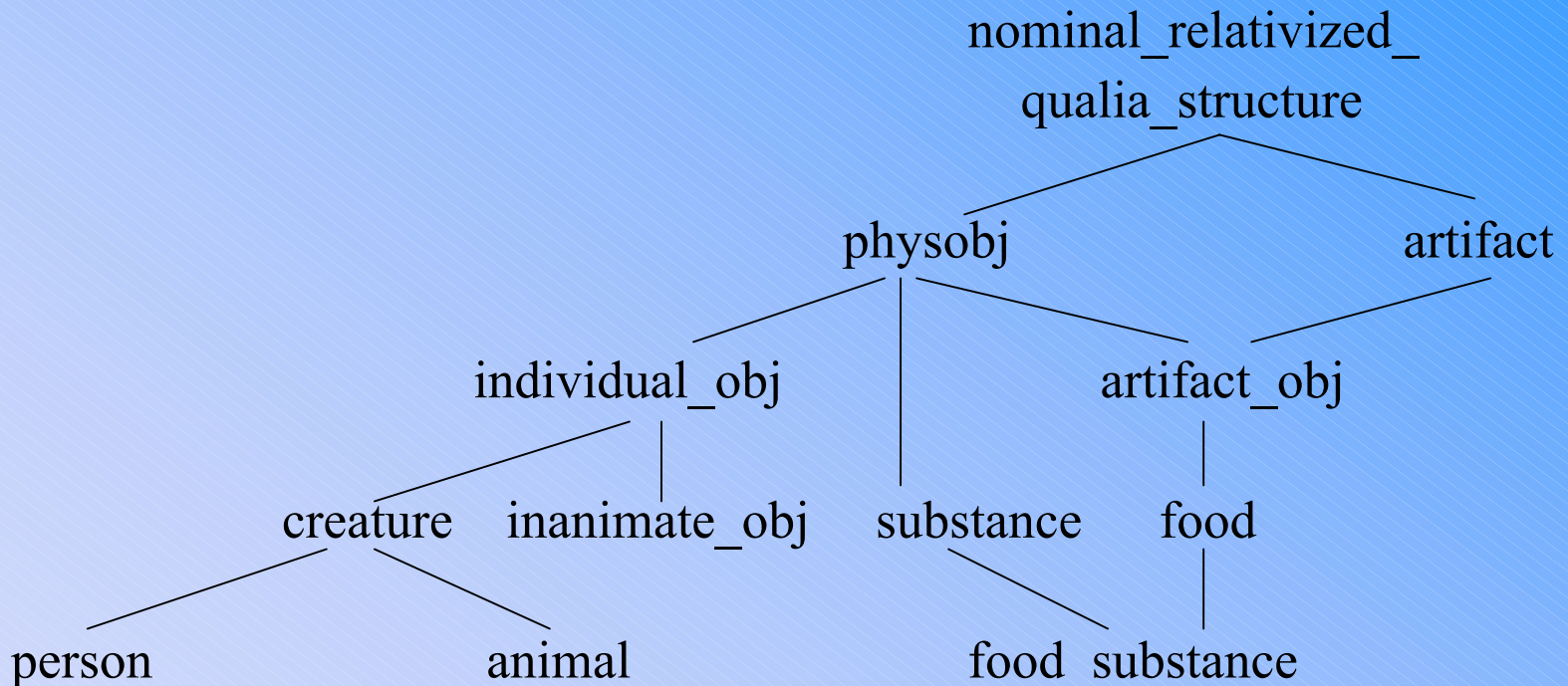
FORMAL = **physobj(x)**

TELIC = **walk_through(P,w,y)**

AGENTIVE = **artifact(x)**

qualia structure

an example type hierachy



inheritance in the type hierarchy

artifact (x)
TELIC = Pred(E,y,x)

physobj(x)
FORMAL = physform(x)
PHYSICAL-STATE = solid(x)

artifact_obj(x)
FORMAL = physform(x)
PHYSICAL-STATE = solid(x)
TELIC = Pred(E,y,x)

formal aspects of the type hierarchy

- constraints as restrictions on PATR-II-type feature structures
- well formedness conditions:
 - completeness
 - well typedness
 - uniqueness

Lexical ambiguity and compositionality

- a fast car
- a fast typist
- a fast book
- a fast motorway

„fast“ modifies the
Telic role of the noun
which is of type *event*

Lexical ambiguity and compositionality

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car (x)
CONST = {body,engine,...}
FORMAL = physobj(x)
TELIC = drive(P,y,x)
AGENTIVE = artifact(x)

Lexical ambiguity and compositionality

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„fast“ modifies the
Telic role of the noun
which is of type *event*

car (x)
CONST = {body,engine,...}
FORMAL = physobj(x)
TELIC = drive(P,y,x)
 & fast (P)
AGENTIVE = artifact(x)

Lexical ambiguity

- different meanings of „fast“ can be derived from only one lexical entry
- no word sense enumeration
- new word meaning can be created eg. „a fast motorway“:

[TELIC: travel (P,cars) & on (P,x) & fast (P)]

→ fast selects a complement of type TELIC

example: advantages of the type hierarchy

sentence „Mary finished her sandwich.“

sandwich(x)
CONST = {bread,...}
FORMAL = physobj(x)
TELIC = eat(P,w,x)
AGENTIVE = artifact(x)

- process is an event which is part of the Telic role value
 - each artifact has a Telic role
- compositional combination is possible

Qualia structure – complement selection

- Mary woke John up.
 - The cup of coffee woke John up.
 - John's drinking the cup of coffee woke him up.
 - Mary enjoyed the movie.
 - Mary enjoyed watching the movie.
- syntactic differences, but complements are all events of some sort
 - word sense enumeration is unintuitive
- complement selection by *type coercion*

Qualia structure – type coercion

Type coercion: Convert the argument to the type which is expected by the function.

Aliases Σ_α of an expression α allow polymorphical treatment of α and allow changes of type and denotation

α of type a can be coerced to type b if there is an σ in Σ_α so that $\sigma(a)$ is of type b

Qualia structure – type coercion an example

adjective *fast* wants to modify a noun e.g.
motorway

the adjective needs an argument of type **event**
but the noun is of type **artifact_object**

because *motorway* is an artifact it has an TELIC
value with some event in it

→ type of *motorway* can be coerced to event
using an alias σ in Σ_α

[TELIC: travel (P,cars) & on (P,x) & fast (P)]

type coercion and functional application

functional application: Is α of type $\langle b, a \rangle$, and is β of type b , then $\alpha(\beta)$ is of type a .

functional application with type coercion:

If α is of type $\langle b, a \rangle$, and β is of type c , then

- 1) $\alpha(\beta)$ is of type a , if $c=b$
- 2) $\alpha(\sigma(\beta))$ is of type a , if there is a $\sigma \in \Sigma_\beta$ where $\sigma(\beta)$ is of type b
- 3) type error otherwise

Qualia structure – subtypes und type paths

- ***type path*** in a type hierarchy:
 - If a is a type, then is $[a]$ a type path
 - If a and b are type paths with $b \leq a$, then $[a\ b]$ is a type pathwhere \leq is the order in the type hierarchy
- extended ***type definition***:
 - $[e]$ is a type
 - $[t]$ is a type
 - if $[a]$ and $[b]$ are any types, then $\langle [a],[b] \rangle$ is a typewhere e,t are standard types from Montague

Qualia structure – type coercion an example

- phrase „begin a book“
 - begin expects phrase of type [event]
 - book has type [individual physobj]
 - noun’s alias permits type coercion of „book“ to type [event]
 - existence of the alias is guaranteed by inheritance in the type hierarchy
 - two candidates associated with „book“

Qualia structure – subtype coercion

- *subtype coercion*: conversion of the argument to the subtype which is expected by the function
- *functional application with subtype coercion*:
If α is of type $\langle [b\ c], [a] \rangle$, and β is of type $[b\ d]$, then
 - 1) $\alpha(\beta)$ is of type a , if $c=d$
 - 2) $\alpha(\sigma(\beta))$ is of type a , if there is a $\sigma \in \Sigma'_\beta$ with $\sigma(\beta)$ is of type c
 - 3) type error otherwise

Qualia structure – functional application with subtype coercion – an application

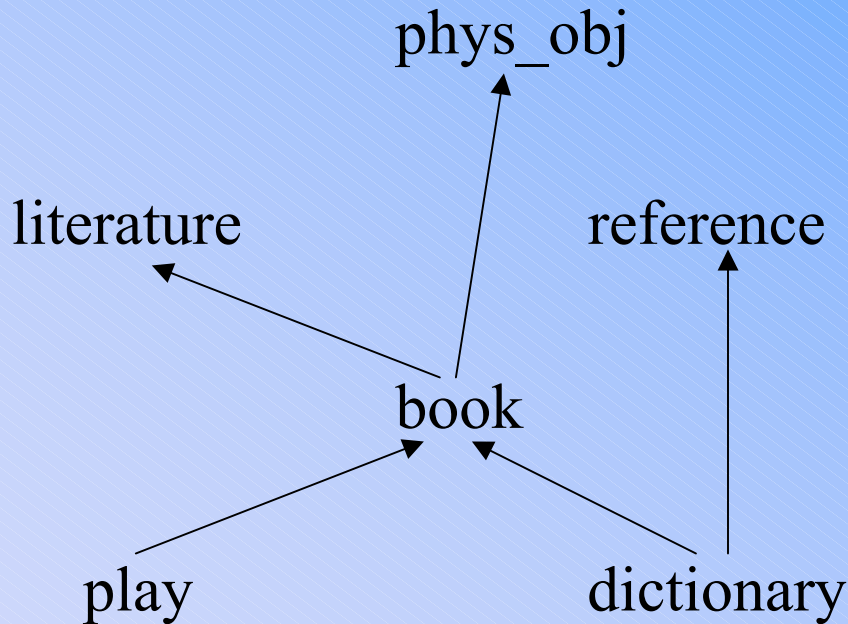
example: a fast car

- generic type of adjectives $\langle [N], [N] \rangle$
- fast can be instantiated with the more specific subtype $\langle [N \text{ Telic}], [N] \rangle$
- car has the type $\langle [N \text{ artifact}] \rangle$
- every artifact has a Telic role \rightarrow existence of an alias σ is guaranteed
- application $\text{fast}'(\sigma(\text{car}'))$ is possible

knowledge representation in the semantic lexicon

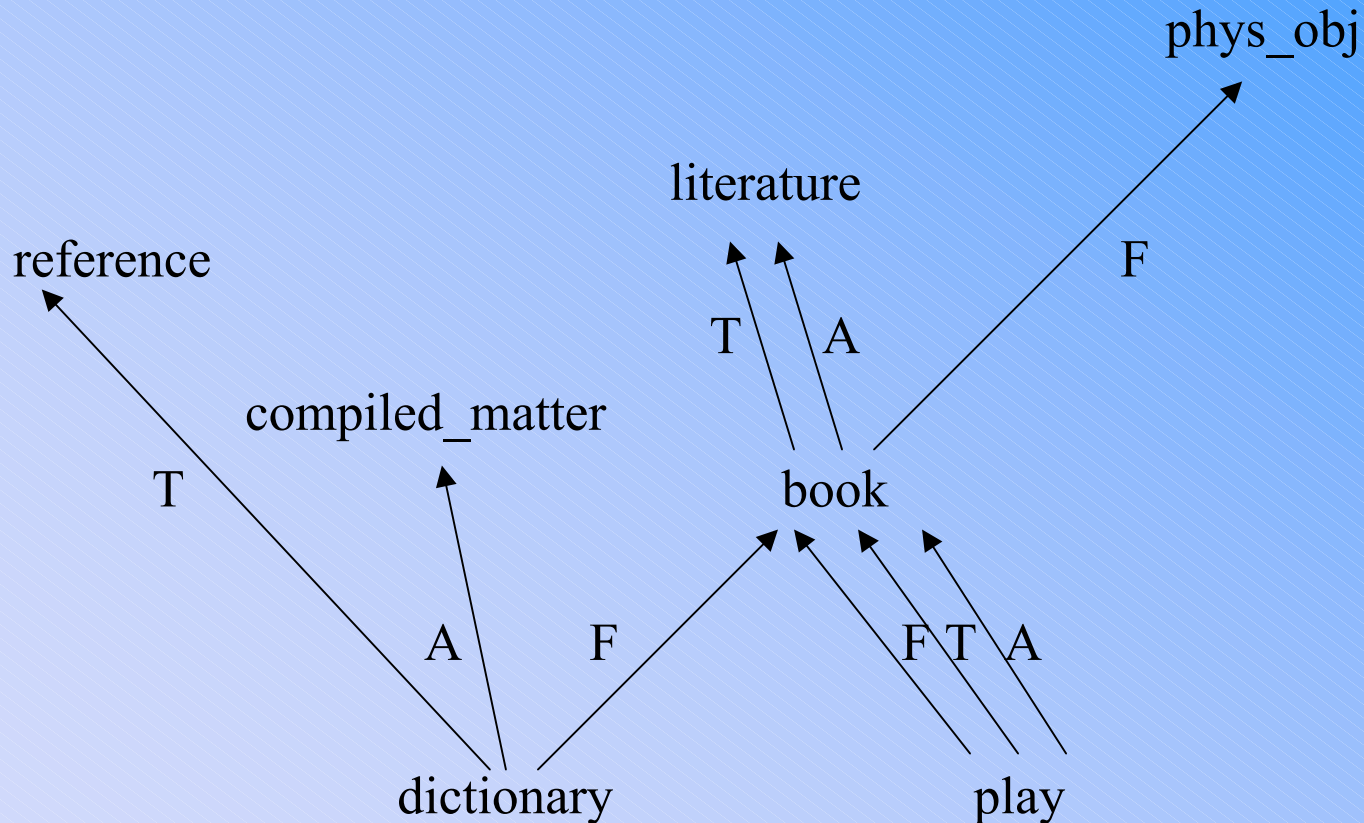
- goal: impose a structure on the lexicon which helps to resolve „hidden“ lexical ambiguity
- simple is_a-hierarchy
- is_a-hierarchy with multiple inheritance to model contextual ambiguities
 - information flow along specification/ generalization edges causes problems
- Qualia structures cause more complex inheritance hierarchies

modelling using an is_a-hierarchy



	play	dictionary
read	√	—
buy	√	√
consult	—	√
begin	√	—

modelling with qualia typed inheritance



denotation of a concept

let P and Q be concepts in our model of lexical organization

- $\langle Q_1, P_1, \dots, P_n \rangle$ is called *inheritance path*, which can be read as conjunction of ordered pairs
- *conclusion space* Φ_q is the set of sequences that lie on an inheritance path $\langle Q, \dots, P \rangle$ imposed by the Qualia q
- *complete conclusion space* Φ is the set of all conclusion spaces defined for each quale of a concept

denotation of a concept

- $\text{Inh}(S)$: set of values inheritable from S

ϕ

- $[[\alpha]]$ designates the denotation of α with respect to the conclusion space ϕ

ϕ

- e.g. $[[\text{book}]] =$

$\lambda x [\text{book}(x) \ \& \ \text{Formal}(x) = \text{Inh}(\text{physobj})$

$\ \& \ \text{Telic}(x) = \text{Inh}(\text{literature})$

$\ \& \ \text{Agentive}(x) = \text{Inh}(\text{literature})]$

implications for natural language
processing and knowledge representation

- Conflate different word senses in only one lexical meta-entry

lexical conceptual paradigm (LCP)

- encoding regularities of word behavior depend on context
- reducing the size of the lexicon
- syntactic information is inheritable between two lexical entries

encoding regularities of word
behavior depend on context

example: product/producer paradigm

qualia can differentiate the different aspects

- The coffee cup is on top of the *newspaper*.
- The article is in the *newspaper*.
- The *newspaper* attacked the senator from Massachusetts.
- The *newspaper* is hoping to fire its editor next month.

inheritance of syntactical information

[union (x)
CONST = {entity(y),entity(z)}
FORMAL = entity(x)
AGENTIVE = artifact (x)]

[merger (x)
CONST = {company(y),company(z)}
FORMAL = company(x)
AGENTIVE = artifact (x)]

word – argument realization by syntactic schemas

- pattern to realize word-argument structure: **union**

LCP schema (N=union, X=arg1, Y=arg2)

N of X and Y

X's N with Y

Y's N with X

N between X and Y

N of Z (Z = X + Y)

N between Z

implications for natural language processing and knowledge representation

- shown methods and theories can be adopted by knowledge representation
 - nouns which describe conceptually relations between a physical object and an aperture of some sort:
window, door, room
 - nouns only referring to the physical object:
lid, cap, cover, ...

implications for natural language processing and knowledge representation

- boundary between lexical and commonsense knowledge can be further defined
- generative lexicon with well defined semantic relations
- division of the semantics in different aspects
- semantic information is spread more evenly in the lexicon by a compositional approach with mutual compatible rules
- improved overall robustness of automatic natural language processing concerning lexicon acquisition and language learnability