Lecture 14
Lexical Semantics

CS 6320

Outline

- Lexical Semantics
- WordNet
- Thematic roles
- Semantic relations
- PropBank
- Metaphor
- Metonymy
- Problem of Knowledge Discovery

Lexical Semantics

- **Lexical Semantics -** is the study of word meanings and relations between word meanings.
- **Lexeme -** is an entry in a vocabulary or lexicon.
- **Lexicon -** has a finite list of lexemes. It includes individual words, compound nouns, idioms, and others.
- **Lexeme (word) sense -** refers to the meaning of that particular lexeme.

Lexical and Semantic Relations

- **Homonymy** – relation between two words that have the same form but unrelated meanings.

- **Homographs** – words with the same orthographic form, but unrelated words.

  bank – financial institution
  bank – river bank

- **Homophones** – are distinct words that have the same pronunciation.

  would & *wood*
  be & *bee*
  weather & *whether*

Lexical and Semantic Relations

- **Polysemy –** when one word has multiple meanings.
  table has 6 noun senses in WordNet
  1 verb sense

- **Word Sense Disambiguation** – is the NLP task that when given a lexicon with word meanings it finds the correct meaning of a word in a context.

- **Synonymy** – two words are synonymous if the substitution of one for the other does not change the truth value of a sentence in which the substitution is made.
  In WordNet these are called **synsets**.
  { telephone, phone, telephone set}

Semantic Relations in WordNet

Category	Unique Forms	Number of Senses
Noun	94474	116317
Verb	10319	22066
Adjective	20170	29881
Adverb	4546	5677

Scope of the current WordNet 1.6 release in terms of unique entries and total number of senses for the four databases.

Semantic Relations in WordNet

Relation	Definition	Example
Hypernym	From concepts to superordinates	*breakfast –> meal*
Hyponym	From concepts to subtypes	*meal -> lunch*
Has-Member	From groups to their members	*faculty -> professor*
Member-Of	From members to their groups	*copilot -> crew*
Has-Part	From wholes to parts	*table -> leg*
Part-Of	From parts to wholes	*course -> meal*
Antonym	Opposites	*leader -> follower*

Noun relations in WordNet

Semantic Relations in WordNet

Relation	Definition	Example
Hypernym	From events to superordinates	*fly -> travel*
Troponym	From events to their subtypes	*walk -> stroll*
Entails	From events to the events they entail	*snore -> sleep*
Antonym	Opposites	*increase ⇔ decrease*

Verb relations in WordNet.

Relation	Definition	Example
Antonym	Opposite	*heavy ⇔ light*
Antonym	Opposite	*quickly ⇔ slowly*

Adjective and Adverb relations in WordNet

Semantic Relations in WordNet

- **Relations between Verbs:** The dominant relation between verbs is **lexical entailment**. In logic, entailment or strict implication is written as

  P |=> Q

  - Proposition P entails proposition Q.
  - Lexical entailment is similar, although has many forms and complications.

    snore sleep

    $verb_1$ $verb_2$

    Bidirectional entailment means that V_1 and V_2 are **synonyms**.

    beat and *defeat*

Semantic Relations in WordNet

- **Troponomy** is a particular kind of entailment, in that every troponym V_1 of a more general verb V_2 also entails V_2.

  limp – walk

  lisp – talk

- **Causative relation** between one causative verb (give) and one resultative verb (have).

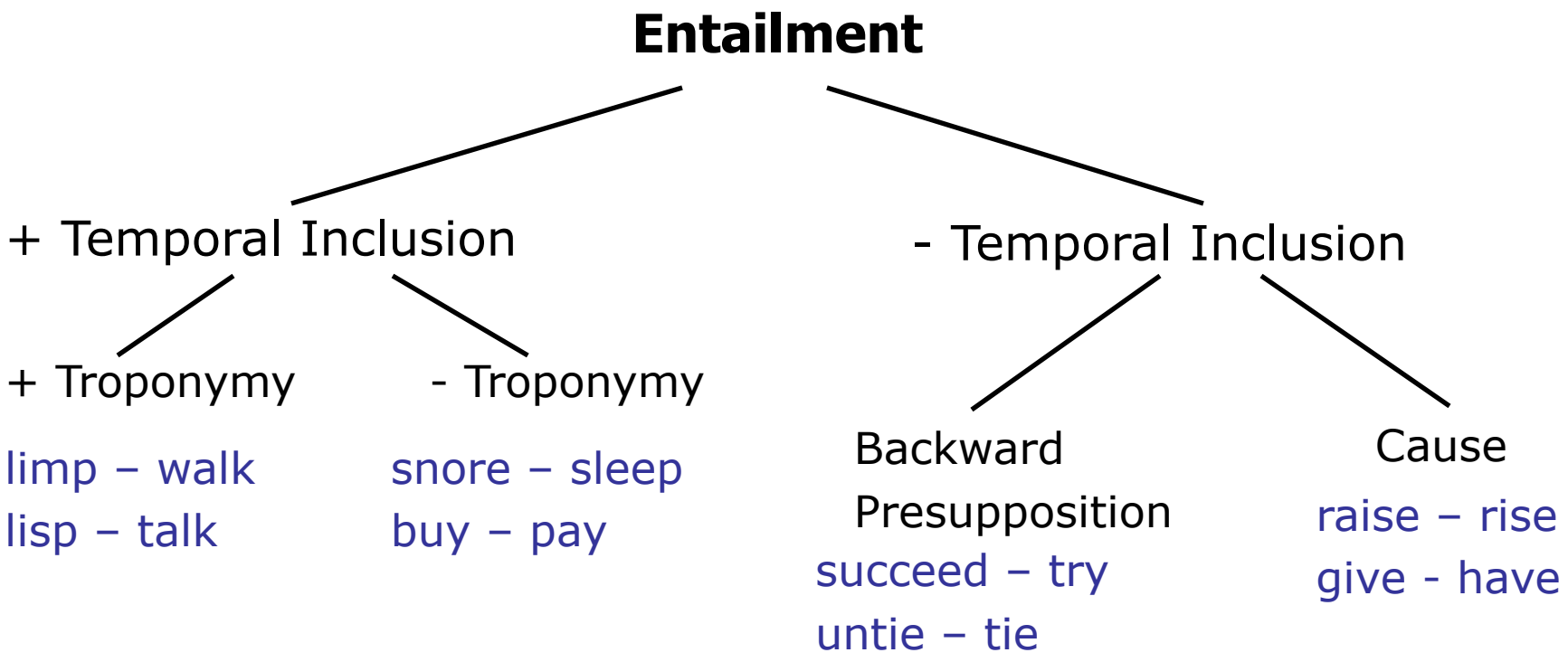
  {teach, instruct, educate} -> {learn, acquire, knowledge}

  If V_1 necessarily causes V_2, then V_1 also entails V_2.

  expel - leave

  bequeath - own

Verb Taxonomy



There are also relations between different parts of speech.

Thematic Roles

Thematic Role	**Definition** **Example**
Agent	The volitional causer of an event *The waiter* spilled the soup.
Experiencer	The experiencer of and event *John* has a headache.
Force	The non-volitional causer of the event *The wind* blows debris from the mall into our yards.
Theme	The participant most directly affected by an event Only after Benjamin Franklin broke *the ice…*
Result	The end product of an event The French government has built a *regular-size baseball diamond…*
Content	The proposition or content of a propositional event Mona asked *"You met Mary Ann at a super market?"*
Instrument	An instrument used in an event He turned to poaching catfish, stunning them *with a shocking device…*
Beneficiary	The beneficiary of an event Whenever Ann Callahan makes hotel reservations *for her boss…*
Source	The origin of the object of a transfer event I flew in *from Boston.*
Goal	The destination of an object of a transfer event I drove *to Portland.*

More Case Examples

John believed that it was raining.
experiencer

I gave the book to Jack for Susan.
beneficiary

I used some flour to make a cake.
instrument

Jack used the sun to dry the apples.
instrument

The ice melted.
theme

Jack enjoyed the play.
Jack – experiencer
the play – theme

Jack ran with a crutch for Susan.
John – agent
with a crutch – instrument
for Susan – beneficiary

Common Realizations of the Major Roles

Role	Realization
AGENT	as subject in active sentences preposition *by* in passive sentences
THEME	as object of transitive verbs as subject of nonaction verbs
INSTR	as subject in active sentences with no agent preposition *with*
EXPERIENCER	as animate subject in active sentences with no agent
BENEFICIARY	as indirect object with transitive verbs preposition *for*
AT-LOC	prepositions *in, on, beyond,* etc.
TO-LOC	prepositions *to, into*
FROM-LOC	prepositions *from, out, of,* etc.

Assigning the subject

- Thematic hierarchy for assigning the **subject**

- AGENT > INSTRUMENT > THEME

John opened the door.
AGENT THEME

John opened the door with a key.
AGENT THEME INSTRUMENT

The key opened the door.
INSTRUMENT THEME

The door was opened by John.
THEME AGENT

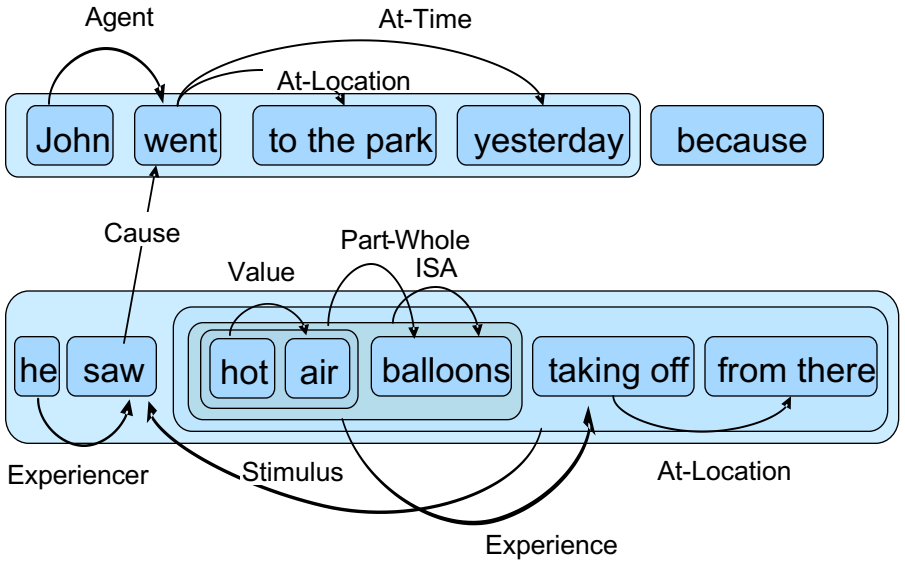
Examples of Semantic Relations in text

Semantic Relations are the interconnections between words or concepts that define the meaning of text. They are used as elements of knowledge bases.

Example:

John went to the park yesterday because he saw hot air balloons taking off from there

Agent(John, went)
At-Location(went, to the park)
At-Time(went, yesterday)
Cause(saw, went)
Experiencer(He, saw)
Stimulus(hot air balloons taking off from there, saw)
Value(hot, air)
Part-Whole(hot air, balloons)
Is-A(hot air balloons, balloons)
Experiencer(hot air balloons, taking off)
At-Loc(taking off, from there)



A Comprehensive list of Semantic Relations

Code	Relation	Definition	Example
POS	**Possession**	X is a possession of Y, Y owns/has X	*[YX] [John] owns [a Porsche];* *[YX] [John] has [4 acres]*
PW	**Part-Whole/ Meronymy**	X is a part of Y	*[XY] [The engine] is the most important part of [the car];* *[XY] [steel][cage];* *[YX] [faculty] [professor];* *[XY] [door] of the [car]*
KIN	**Kinship**	X is a kinship of Y; X is related to Y by blood or by marriage	*[XY] [John]'s [uncle]*
ASO	**Association**	X is associated with Y; X and Y can be people or groups	*[XY] [John] and [Mary] are friends for 20 years.* *[XY] [John] talked to [Mary] about her catering service.*
SRC	**Source/Origin**	X is the origin or previous location of Y	*[XY] [Chilean] [Sea Bass];* *[YX] [Student] from [Russia]*
ISA	**ISA**	X is a (kind of) Y	*[XY] [John] is a [person].*
SYN	**Synonymy/Name**	X is a synonym/name/equal for/to Y	*[XY] [FBI] ([Federal Bureau of Investigation])* *[YX] [This car] is called ["Johann"]*
PRO	**Property Type**	X is a property type of Y	*[XY] [The color] of [the car] is blue.*
VAL	**Property/ Attribute/ Value**	X is a property/attribute/value of Y	*[YX] [The car] is [blue]* *[YX] [The color] of the car is [blue].*
QNT	**Quantification/ Extent**	X is a quantification of Y; Y can be an entity or event	*[XY] [XY] John saw [three] [hurricanes] in the last [two] [years].* *[Y X]The budget [increased] with [10%]*

A Comprehensive list of Semantic Relations Cont.

Code	Relation	Definition	Example
AGT	**Agent**	X is the agent for Y; X is prototypically a person.	*[XY] [John] [eats] eggs and ham*
EXP	**Experiencer**	X is an experiencer of Y; involves cognition and senses; X is a person	*[XY] [John] [feels] bad*
INS	**Instrument**	X is an instrument in Y	*[YX] John [broke] the window with [a hammer].* *[XY] [The hammer] [broke] the window.* *[YX] John [played] the Brandenburg Concerto on [the harmonica]*
THM	**Theme/Patient/ Result/ Consumed**	X is the theme/patient/result/consumed in/from/of Y	*[YX] John [painted] [his truck].* *[YX] John [baked] [a cake].*
RCP	**Recipient/ Receiver**	X is the recipient of Y; X is an animated entity. The theme of received can be both positive and negative.	*[YX] John [gave] [Mary] roses.* *[YX] John [stole] [Mary]'s car.*
TPC	**Topic/ Content**	X is the topic/focus of cognitive communication Y	*[YX] John [talked] about [politics] with Mary.* *[YX] John [said] [he likes the other party].*
INT	**Intent**	X is the intent/goal/reason of Y	*[YX][YX] [John] wants to [finish the paper] so [he] can [go on vacation].*
STI	**Stimulus**	X is the stimulus of Y; Perceived thorough senses	*[YX] [YX] Mary [heard] [the train] while [smelling] [the roses].*

A Comprehensive list of Semantic Relations Cont.

Code	Relation	Definition	Example
MNR	**Manner**	X is the manner in which Y happens	*[YX] John [read] [carefully]; [ran] [quickly]; [spoke] [hastily]*
LOC	**At-Location/ Space/ Direction/ Source/ Path/ Goal**	X is at location y	*[XY] There is [a cat] on [the roof]* *[XY] The hurricane [passes] through [Galveston].*
TMP	**At-Time**	X is at time Y	*[XY] John [woke up] at [noon]*
CAU	**Cause**	X causes Y; X and Y are events, states	*[XY] [Drinking] causes [accidents].*
MAK	**Make-Produce**	X is a product of Y	*[YX] [GM] manufactures [cars].*
JST	**Reason/ Justification**	X is the reason/motive/justification for Y	*[XY] [The severity of the crime] justifies [the harsh sentence]; [YX] [He is innocent] by reason of [insanity]*
PRP	**Purpose**	X is the purpose for Y; Y did something because this person wanted X	*[YX] John [swims] for [fun]; Mary [works] part-time [to earn some extra money]*
IFL	**Influence**	X caused something to happen to Y	*[XY] [The war] had an impact on [the Economy]*

Semantic Relations – Extended Definition

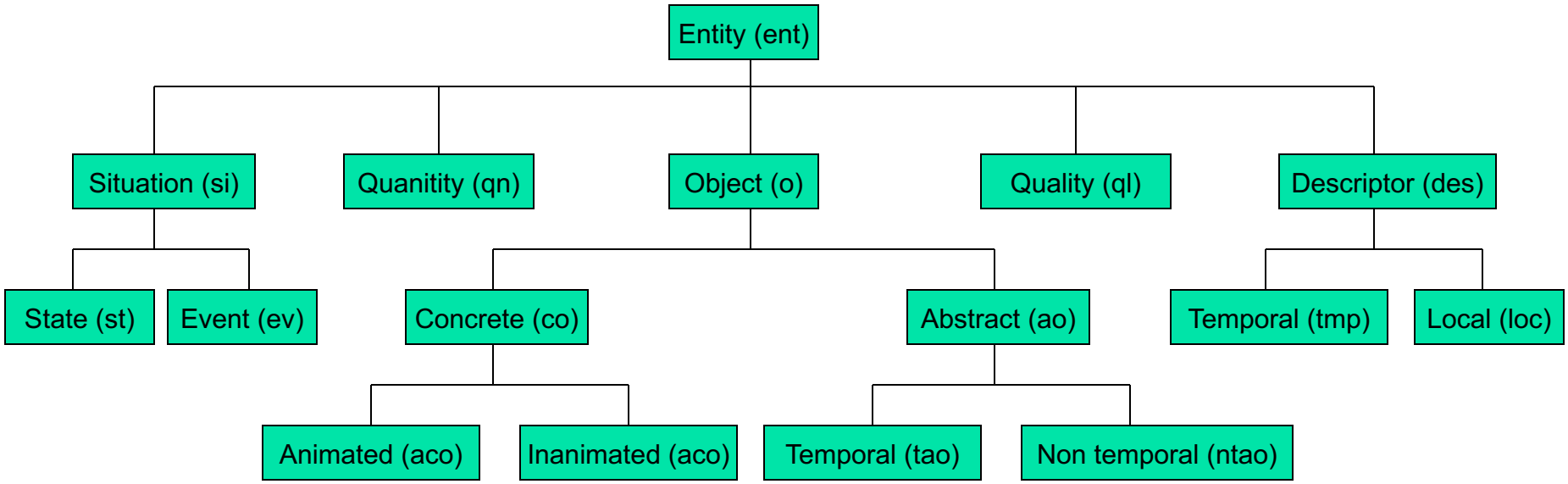
- Given R(x, y), we define:
  - R : relation type
  - x : first argument
  - y: second argument

  - Domain(R): set of sorts of concepts that can be part of the first argument
  - Range(R): set of sorts of concepts that can be part of the second argument

- A semantic relation R(x,y) is defined by stating:
  - R
  - Domain(R)
  - Range(R)

- Advantages:
  - Difference between relations is more clear
  - Can discard potential relations that don't hold
  - Helps combining relations
- Relations can be:
  - Transitive: cat isa feline isa mammal; R(x,y) & R(y,z) = R(x,z)
  - Symmetric: R(x,y) = R(y,x)
  - Reflexive: R(x,y) is reflexive if x is related to itself R(x,x)

High Level Ontology of Sorts



High Level Ontology of Sorts

- Entities: all things about which something can be said.
  - Objects
    - Concrete: occupy space, are touchable, tangible
      - Animated: have life, vigor, spirit
        - *John, the girl*
      - Inanimated: dull, without life
        - *Table, computer*
    - Abstract: intangible, they are somehow product of human reasoning
      - Temporal: *last week, July*
      - Non-temporal: *justice, pain, odor*
  - Situations: anything that happens at a time and place
    - Events: imply a change in the status of other entities
      - *Mix, grow, conference, hurricane*
    - States: do not imply a change
      - *Standing next to the door, account for 10% of the sales*

High Level Ontology of Sorts

- Descriptors:
  - They complement Entities by stating properties about their spatial or temporal context
    - Local: *on the roof, near the Stadium*
    - Temporal: *by the end of the day, on July 15th*
- Quantities:
  - *a few, two, 22*
- Qualities:
  - *heavy, difficult*

Semantic Relations - Clustered

Cluster	Relation Type	Abr	Properties			
			r	*s*	*t*	DOMAIN x RANGE
Reason	CAUSE	CAU	-	-	√	[si] x [si]
	JUSTIFICATION	JST	-	-	√	[si u ntao] x [si]
	INFLUENCE	IFL	-	-	√	[si] x [si]
Goal	INTENT	INT	-	-	-	[si] x [aco]
	PURPOSE	PRP	-	-	√	[si u ntao] x [si u co u ntao]
Object modifiers	VALUE	VAL	-	-	-	[ql] x [o u si]
	SOURCE	SRC	-	-	√	[loc u ql u ntao u ico] x [o]
Syntactic subjects	AGENT	AGT	-	-	-	[aco] x [si]
	EXPERIENCER	EXP	-	-	-	[o] x [si]
	INSTRUMENT	INS	-	-	-	[co u ntao] x [si]
Direct objects	THEME	THM	-	-	-	[o] x [ev]
	TOPIC	TPC	-	-	-	[o u si] x [ev]
	STIMULUS	STI	-	-	-	[o] x [ev]
Association	ASSOCIATION	ASO	√	√	√	[ent] x [ent]
	KINSHIP	KIN	√	√	√	[aco] x [aco]
None	IS-A	ISA	-	-	√	[o] x [o]
	PART-WHOLE	PW	-	-	*	[o] x [o] u [l] x [l] u [t] x [t]
	MAKE	MAK	-	-	-	[co u ntao] x [co u ntao]
	POSSESSION	POS	-	-	√	[co] x [co]
	MANNER	MNR	-	-	-	[ql u st u ntao] x [si]
	RECIPIENT	RCP	-	-	-	[co] x [ev]
	SYNONUMY	SYN	√	√	√	[ent] x [ent]
	AT-LOCATION	AT-L	√	-	*	[o u si] x [loc]
	AT-TIME	AT-T	√	-	*	[o u si] x [tmp]
	PROPERTY	PRO	-	-	-	[ntao] x [o u si]
	QUATIFICATION	QNT	-	-	-	[qn] x [si u o]

Relation Discovery:
An approach for lexico-syntactic pattern discovery

- Pick one Semantic Relation at a time
- Find lexico-syntactic patterns that express that SR
- Create a corpus with positive and negative examples
- Learn constraints that discover the SR
- Evaluate performance: precision and recall.

Relation Discovery

IS-A Relations

Relation	Lexico-syntactic Patterns	Examples
IS-A	NP1 such as NP2	These capabilities are vital in the study of *infectious diseases* such as *AIDS* ..
	NP1 and other NP2	Its local links connect major telecommunications users, such as *brokerages* and other *financial institutions* ..
	NP1, including NP2	An abandoned compound in the heart of Afganistan's capital city used by Osama bin Laden's Al Qaeda network appears to have been a makeshift for studying *unconventional arms,* including *nuclear weapons* ..

Relation Discovery

Cause relations

Relation	Lexico-syntactic Patterns	Examples
CAUSE	NP2 consequence of NP1	*Grief* was just the first consequence of the *World Trade Center attacks* .
	NP1 lead to NP2	Interferon is the first treatment to relieve and even cure lingering *hepatitis B infections* that lead to *cirrhosis* and *liver cancer* ..
	NP1 produce NP2	The *economic dislocations* produced by the *Sept. 11 attacks* are so unprecedented that it is impossible for anyone to forecast their duration or eventual magnitude.

Relation Discovery

Influence Relation

INFLUENCE	NP1 impact on NP2	Listeriosis is usually manifested as *meningitis* or *meningoencephalitis*, which have impact on the *brain tissues.*
	effect of NP1 on NP2	The effect of new *issues* on the *market* was seen on April 5, when the Bank of England announced the issue Pounds 800m 9 percent Treasury bonds.
	inverse relation between NP1 and NP2	Moreover, the inverse relationship between *blood cholesterol level* and *risk* was limited to only one type of stroke.

Relation Discovery

"Learning Semantic Constraints for the Automatic Discovery of Part-Whole Relations" (Girju, Badulescu and Moldovan 2003)

- Automatic procedure for the discovery of semantic constraints for the disambiguation of meronymic lexico-syntactic patterns;

"The car's main messenger is busy at work in the *mail car* as the *train* moves along. Through the open *slide door* of the car, moving scenery can be seen.. He peeks through the *door*'s *keyhole* leading to the tender and *locomotive cab*.."

Relation Discovery: Lexico-syntactic patterns expressing meronymy

- Variety of meronymy expressions:
  - Explicit part-whole constructions. E.g.,

    The substance *consists of* two ingredients.

    Iceland is a *member of* NATO.

    He is *part of* the game. (*not part-whole)
  - Implicit part-whole constructions:

    "girl's mouth", "eyes of the baby", "high heel shoes";
  - Manual inspection of pattern types:
    - Phrase-level patterns;
    - Sentence-level pattern;
  - Get pattern statistics and select the most frequent ones:

    "NP1 of NP2"; "NP1's NP2"; "NP1 have NP2";

Relation Discovery: Learning Semantic Constraints

- Machine Learning approach (decision trees);
- Training corpus:
  - SemCor 1.7 (19,000 sentences) and TREC9 (100,000 sentences) text collections => Corpus A;
  - Each sentence was parsed (Charniak 2000);
  - Focusing only on the three patterns, all NPs in the 53,944 relationships matched by the patterns were manually annotated with their corresponding WordNet glosses;
  - Positive examples: 34,609;
  - Negative examples: 46,971;

Relation Discovery

Number of Relations	Y verb X	Y's X	X of Y	All Patterns
Number of patterns	280	225	962	1467
Number of correct relations	18	23	78	119
Number of relations retrieved	25	24	91	140
Number of correctly retrieved relations	18	22	77	117
Precision	72%	91.16%	84.61%	**83.57%**
Recall for pattern(s)	100%	95.65%	89.71%	**98.31%**

Selectional Restrictions and Semantic Constraints

- Lexemes place semantic restrictions on other lexemes and phrases that can accompany them.

- Different senses of *kill* dictated by the THEME.

  John killed the wolf.

  John killed the project.

  John killed that bottle of wine.

- Selectional constraints imposed by causation.

  Greenspan makes a recession

  Greenspan makes a mistake

Metaphor

- **Metaphor** is a lexical model in which words and phrases with completely different meanings are used but which are easily understood by the listener.

- Metaphor is pervasive and is responsible for the large degree of polysemy in language.

  That does not scare Microsoft.

  He snored like a horse.

  The stock market reached the bottom last week.

  The father of my friend has deep pockets.

Metonymy

- **Metonymy** - refers to situations where we denote a concept by naming some other concept closely related to it.

  White House held a press conference.

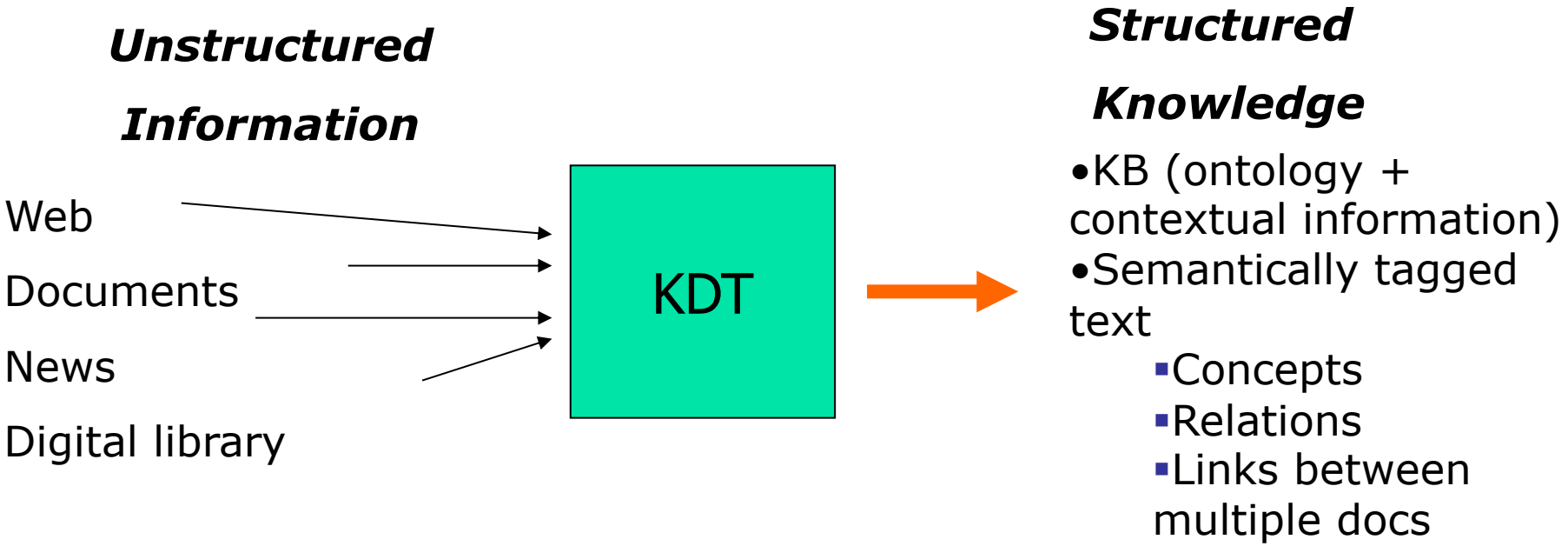
  The flight serves dinner.

  The newspaper printed the story.

  Recently, the President's office called.

- **Computational Approaches to Metaphor and Metonymy**

Problem of Knowledge Discovery



Problem of Knowledge Discovery

- **Example 1**:
  Some domestic US terrorist groups, including Aryan Nation and the Phineas Priesthood, and some militia members are also religiously motivated in addition to being driven by a hatred of the federal government.

  HYPERNYM (terrorist group, US terrorist group)
  HYPERNYM (US terrorist group, Aryan Nation)
  HYPERNYM (US terrorist group, Phineas Priesthood)
  HYPERNYM (terrorist group, Latin American terrorist group)

  LOCATIVE (US terrorist group, US)
  MANNER (religiously motivated, militia members)
  PART-WHOLE (members, militia)

Problem of Knowledge Discovery

- **Example 2:**

  We want to work together to build our new economy, creating jobs by investing in technology so America can continue to lead the world in growth and opportunity.

  (from the Democratic response to the President Bush's 2003 State of the Union Address)

  MANNER (together, work)
  PURPOSE (to build our new economy, work)
  MANNER (creating jobs, build)
  MANNER (by investing in technology, create)
  MANNER (in growth and opportunity, lead)

Problem of Knowledge Discovery

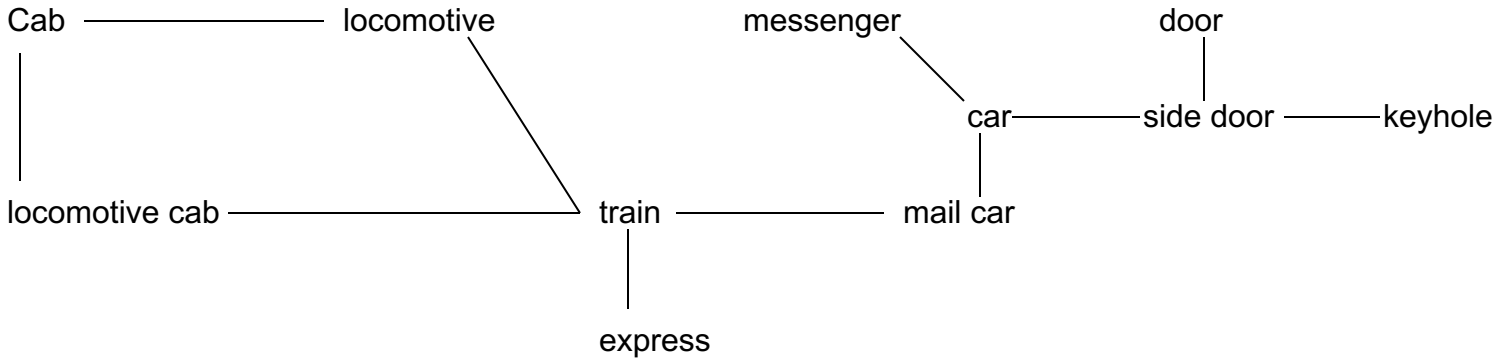
- **Example 3:**

  The car's mail messenger is busy at work in the mail car as the train moves along. Through the open side door of the car, moving scenery can be seen. The worker is alarmed when he hears an unusual sound. He peeks through the door's keyhole leading to the tender and locomotive cab and sees the two bandits trying to break through the express car door.

Problem of Knowledge Discovery

MERONYM (mail car, train)
MERONYM (side door, car)
MERONYM (keyhole, side door)
MERONYM (tender, train)
MERONYM (locomotive cab, train)
MERONYM (locomotive, train)

MERONYM (car, express)
HYPERNYM (door, side door)
SPACIAL (messenger, car)
HYPERNYM (messenger, mail messenger)
MERONYM (cab, locomotive)



Problem of Knowledge Discovery

- **Example 4:**

  Colleagues today recall with some humor how meetings would crawl into the early morning hours as Mr. Dinkins would quietly march his staff out of board meetings and into his private office to discuss, en masse, certain controversial proposals the way he knows best.

  MANNER (with some humor, recall)
  MANNER (how, crawl)
  MANNER (quietly, march)
  MANNER (en masse, discuss)
  MANNER (the way he knows, discuss)
  MANNER (best, knows)