12 - Logic Representation of Text, Semantic Calculus, Textual Entailment

CS 6320

Logic Representation of Text & Textual Entailment

- **Outline**
  - Davidsonian Logic Forms
  - Semantic Relations
  - Examples
  - Hierarchical Representation
  - Introduction to Semantic Calculus
  - Representation of Negation
  - Implicatures
  - Grice Maxims of Communication
  - Application: Textual Entailment

Scenario

The train stood at the Amtrak station in Washington DC at 10:00 AM on March 15, 2005.
The name of the station was Union Station.
The train was an Acela Express, number 176.
The number 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
John arrived by taxi at Union Station at 10:15 AM.
John boarded the Acela at 10:20 AM and handed the train ticket to the conductor.
The conductor punched the ticket.
John sat by the window.
The train left the station on time.

Motivating Example

- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."
- Question:
  "What time did the train depart?"
- **How do we represent and reason over this?**

General Approach

Keyword based approach is not good enough for many applications

Possible approach

- Knowledge representation of a text corpus KT1
- Knowledge representation of questions, or other smaller texts KT2
- Build ontologies for the domains of interest
- Reason by performing semantic similarity between KT1 and KT2. Use domain ontologies and methods from AI such as logic provers, subsumption, textual entailment, etc.

Davidsonian logic forms

Logic form representation

- Intermediate form between syntactic parse and deeper semantic meaning
- Preserves syntactic links between words in the sentence
  - subject and object
  - prepositional attachment
  - complex nominals
  - adjective and adverb connections

Logic Form Transformation

Logic form of a sentence is an intermediary step between syntactic parse and the deep semantic form.

Advantages of LFT over parsed format:

- LF codification acknowledges syntax based relationships such as:
  - syntactic subjects
  - syntactic objects
  - prepositional attachments
  - complex nominals
  - adjectival/adverbial adjuncts
- LF is preferred when it comes to reasoning and other logic manipulations in knowledge bases.

Approach to Implement LFT

Criteria:

- Notation be as close as possible to English.
- Notation should be syntactically simple.

Approach:

- Derive LFT directly from the output of the syntactic parser. Parser resolves the structural and syntactic ambiguities.
- Ignore:
  - plurals and sets,
  - verb tenses
  - auxiliary verbs
  - quantifiers and modal operators
  - comparatives.
- By relaxing the logic formation we can have an effective representation closer to English.

LFT Definitions

Predicates:

- A predicate is generated for every noun, verb, adjective or adverb in the sentence. The name of a predicate includes the base form, and part-of-speech.

  Example:

  A learner is enrolled in an educational institution.

  has predicates: (learner:n, enroll:v, educational_institution:n)
- All verb predicates, as well as the nominalizations representing actions, events or states have three arguments:
- Action/static/event_predicate (e_i, x_1^i, x_2^i), where:
  - e_i represents the eventuality of the action, state or event i
  - x_1^i represents the syntactic subject of the action, event or state
  - x_2^i represents the syntactic direct object of the action, event or state.

LFT Definitions

A person who backs a politician.
person:n(x_1) & back:v(e_1,x_1,x_2) & politician:n(x_2)

When the predicate is a bi-transitive verb:

- verb(e_i,x_1^i,x_2^i,x_3^i)

Professor gives student the grades.
professor:n(x1)& give:v(e_1,x_1,x_2,x_3) & grade:n(x_2) & student:n(x_3)

- $\mathbf{x_3^i}$ represents the syntactic indirect object of the action, event, or state.

Slot allocation representation:

- The arguments of the verb predicates are always in the order: subject, direct object, indirect object.
- The position of the arguments is fixed - for the purpose of simpler notation.
- The arguments for the subject and direct objects are always present even when verb does not have these syntactic roles.
- Argument for indirect object occurs only if necessary.

LFT Definitions

Modifiers:

- Predicates generated from modifiers share the same arguments with the predicates corresponding to the phrase heads.
  - adjectives have same predicates as nouns

    a manmade object

    object:n(x_1)& man-made:a(x_1)

  - adverbial predicate is the eventuality of the verb it modifies.

    run quickly

    run:v(e_1,x_1,x_2)& quickly:r(e_1)

LFT Definitions

Conjunctions:

- Conjunctions are transformed in predicates.
- Conjunction predicates have a variable number of arguments.

An achievement demonstrating great skill or mastery

achievement:n(x_1)*& demonstrate: v*(e_1,x_1,x_2)*& or*(x_2,x_3,x_4)*& skill:n*(x_3)*& great:a*(x_3)*& mastery:n*(x_4)

Roll and turn skillfully

and(e_1,e_2,e_3)*& roll:v*(e_2,x_1,x_2)*& turn:v*(e_3,x_1,x_2)*& skillfully:r*(e_1)

An unintentional but embarrassing blunder

blunder:n(x_1)*& but*(x_1,x_2,x_3)*& unintentional:a*(x_2)*& embarrasing:a*(x_3)

LFT Definitions

Prepositions:

- Every preposition is a predicate with two arguments: the first argument corresponding to the predicate of the head of the phrase, to which PP attaches, and the second argument corresponds to prepositional object.

  Deprive of value for payment

  deprive:v(e_1,x_1,x_2)& *of*(e_1,x_3)& *value:n*(x_3)& *for*(x_3,x_4)& *payment:n*(x_4)

  Playing the position of pitcher on a baseball team

  playing:v(e_1,x_1,x_2)& *position:n*(x_2)& *of*(x_2,x_3)& *pitcher:n*(x_3)& *on*(e_1,x_4) &*baseball_team: n*(x_4)

LFT Definitions

- **Complex nominals**:
  - A new predicate nn is introduced to link together the collocating nouns.
  - nn has a variable number of arguments, the first representing the result of aggregation of the nouns, the rest one for each noun.

An organization created for business ventures.

$organization{:}n(x_2) \& \ create(e_1,x_1,x_2) \& \ for(e_1,x_3) \& \ nn(x_3,x_4,x_5) \& \ business{:}n(x_4) \& \ venture{:}n(x_5)$

Government income credited to taxation.

$nn(x_2,x_3,x_4) \& \ government{:}n(x_3) \& \ income{:}n(x_4) \& \ credit{:}v(e_1,x_1,x_2) \& \ to(e_1,x_5) \& \ taxation{:}n(x_5)$

LFT Inter-Phrase Rulers

Implementation is done with transformation rules that take the parser output into a LF. Every parser rule translates into a LFT rule. IntraPhrase transformation rules generate predicates for every noun, verb, adjective or adverb. They assign the variables that describe the local dependencies.

$ART\ N \rightarrow n(x_1)$
a human being
$human\_being{:}n(x_1)$

$ART\ ADJ_1 ADJ_2\ N \rightarrow n(x_1)\ \&\ adj1(x_1)\ \&\ adj2(x_1)$
A hard straight return
$return{:}n(x_1)\ \&\ hard{:}a(x_1)\ \&\ straight{:}a(x_1)$

$ART\ ADJ1\ AND\ ADJ2N \rightarrow n(x_1)\ \&\ adj_1(x_1)\ \&\ adj_2(x_1)$
A week and tremulous light
$Light{:}n(x_1)\ \&\ weak{:}a(x_1)\ \&\ tremulous{:}a(x_1)$

$V\ ADV \rightarrow v(e_1,x_1,x_2)\ \&\ adv(e_1)$
Cut open
$cut{:}v(e_1,x_1,x_2)\ \&\ open{:}r(e_1)$

$ART\ N_1\text{'}sN_2 \rightarrow n_2(x_1)\ \&\ n_1(x_2)\ \&\ pos(x_1,x_2)$
A person's body
$body{:}n(x_1)\ \&\ person{:}n(x_2)\ \&\ pos(x_1,x_2)$

An Example

A game played with rackets by two or four players who hit a ball back and forth over a net that divides a tennis court

$game{:}n(x_2)$ & $play{:}v(e_1,x_1,x_2)$ & $with(e_1,x_3)$ &

$racket{:}n(x_3)$ & $by(e_1,x_1)$ & $or(x_1,x_4,x_5)$ & $two{:}n(x_4)$ &

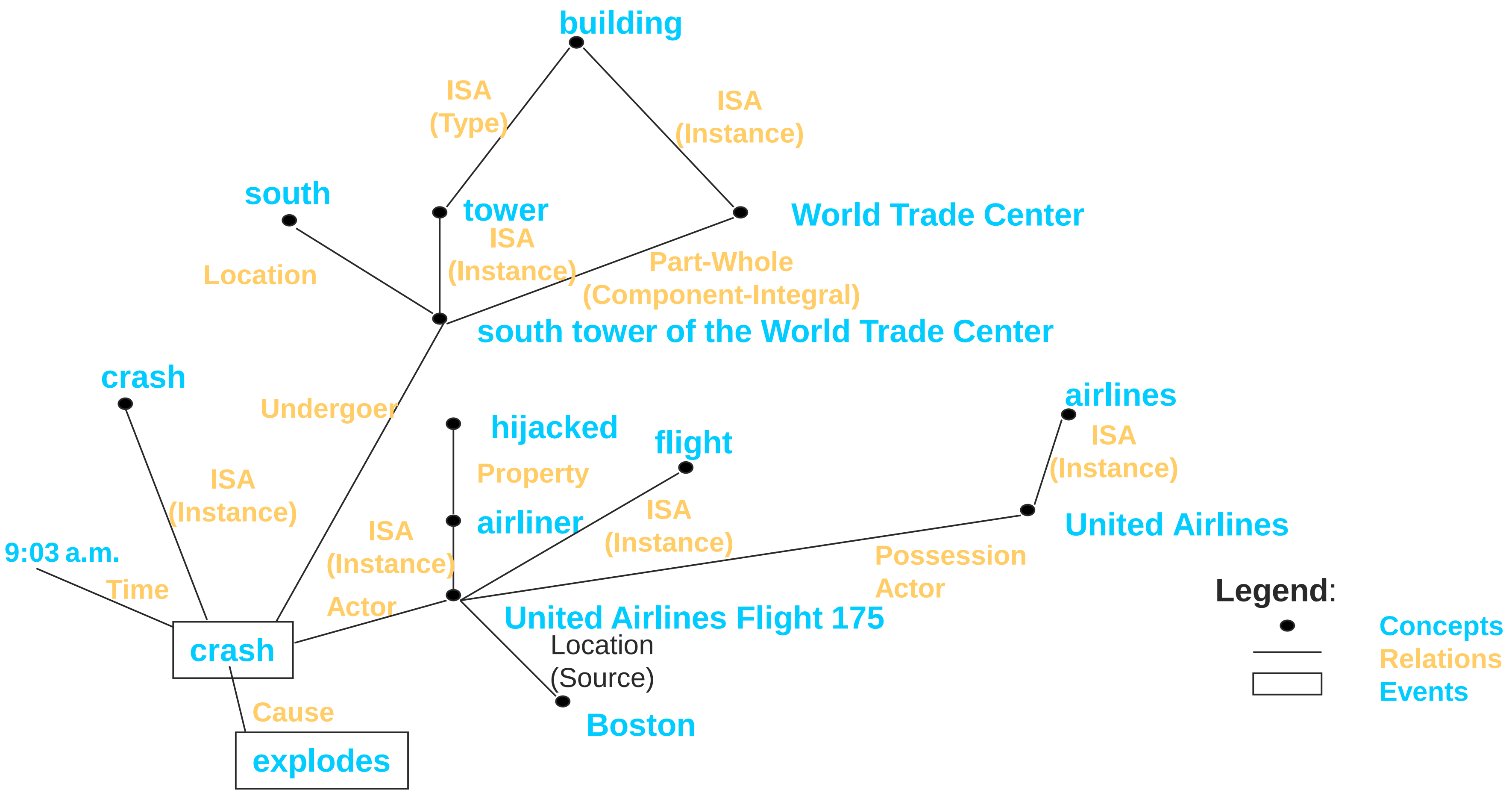
$four{:}n(x_5)$ & $player{:}n(x_1)$ & $hit{:}v(e_2,x_1,x_6)$ &

$ball{:}n(x_6)$ & $back\_and\_forth{:}r(e_2)$ & $over(e_2,x_7)$ &

$net{:}n(x_7)$ & $divide{:}v(e_3,x_7,x_8)$ & $tennis\_court{:}n(x_8)$

Knowledge Representation - Example of a Flat Representation

9:03 a.m.: A second hijacked airliner, United Airlines Flight 175 from Boston, crashes into the south tower of the World Trade Center and explodes



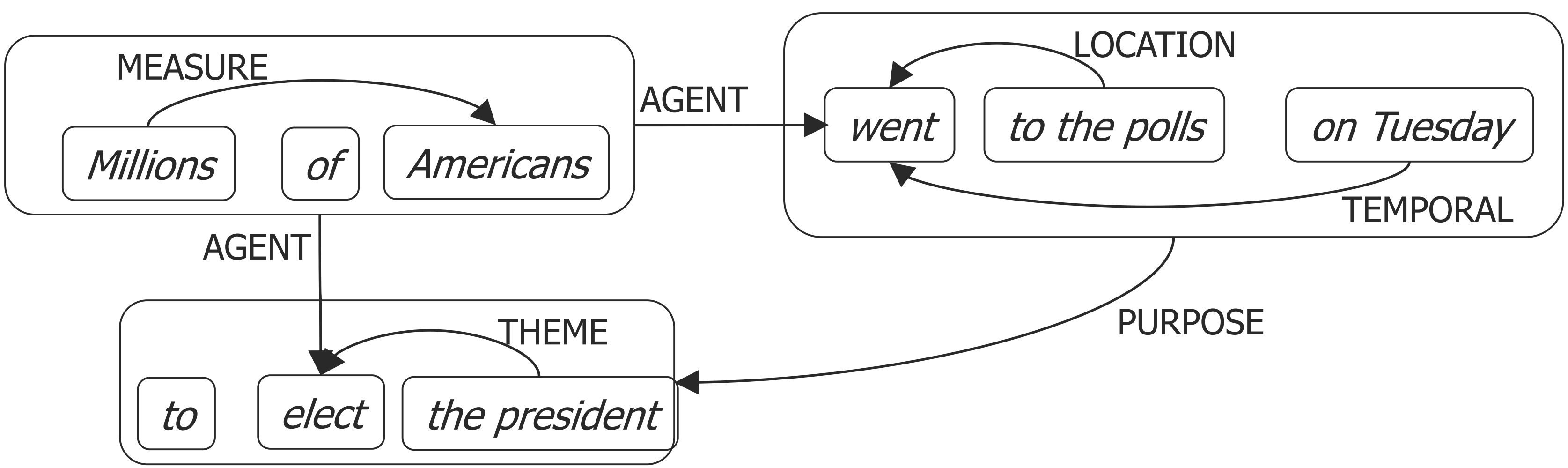
Four-Layered Representation

Hierarchical knowledge representation allows abstraction of details and reasoning

- Syntax Representation
  - Syntactically link words in sentences
- Semantic Relations
  - Provide deeper semantic understanding of relations between concepts ; Word Sense Disambiguation
- Context Representation
  - Place boundaries around knowledge that is not universal
- Event Representation
  - Detect Events; Extract their properties; Use Event Relations

Semantic Relations

- **Overview**
  - "Semantic parser" that automatically detects *semantic relations* (connections with particular types of *meaning*) between concepts in text
- **Example**



Transform Text into RDF Store

1) OWL compliant ontology built from text is transformed into RDF triples
2) Semantic Relations from Text are transformed into RDF triples

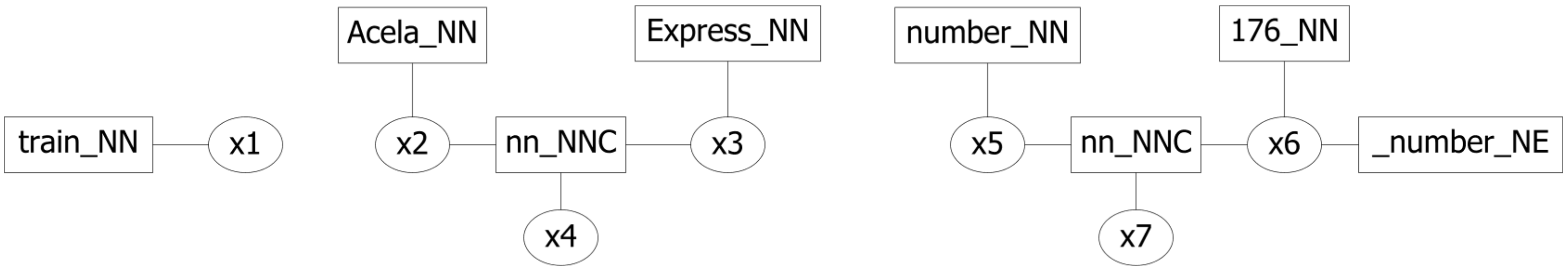
Millions of Americans went to the polls on Tuesday to elect a president.

- MEASURE(Millions, American)
- AGENT(American, go)
- LOCATION(go, poll)
- TEMPORAL(go, Tuesday)
- PURPOSE(go, elect)
- THEME(elect, president)
- AGENT(American, elect)

Logic form + semantics: Example 1

- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."

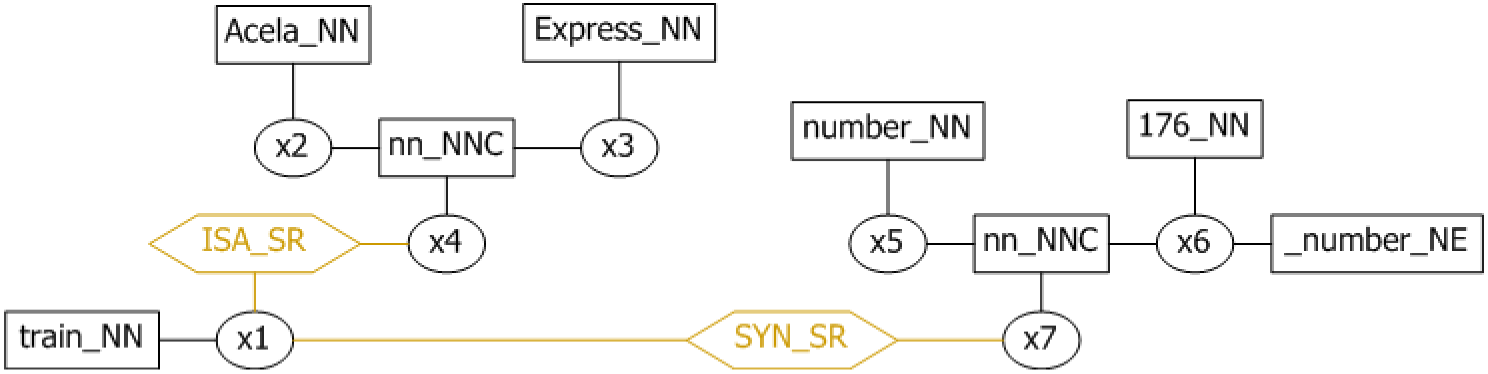
- Logic Form Representation:
  train_NN(x1) & Acela_NN(x2) & Express_NN(x3) & nn_NNC(x4,x2,x3) & number_NN(x5) & 176_NN(x6) & _number_NE(x6) & nn_NNC(x7,x5,x6)



Logic form + semantics: Example 1

- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."

- Logic Form + Semantic Relations:
  train_NN(x1) & Acela_NN(x2) & Express_NN(x3) & nn_NNC(x4,x2,x3) & number_NN(x5) & 176_NN(x6) & _number_NE(x6) & nn_NNC(x7,x5,x6) & ISA_SR(x1,x4) & SYN_SR(x7,x4)



Logic form + semantics: Example 2

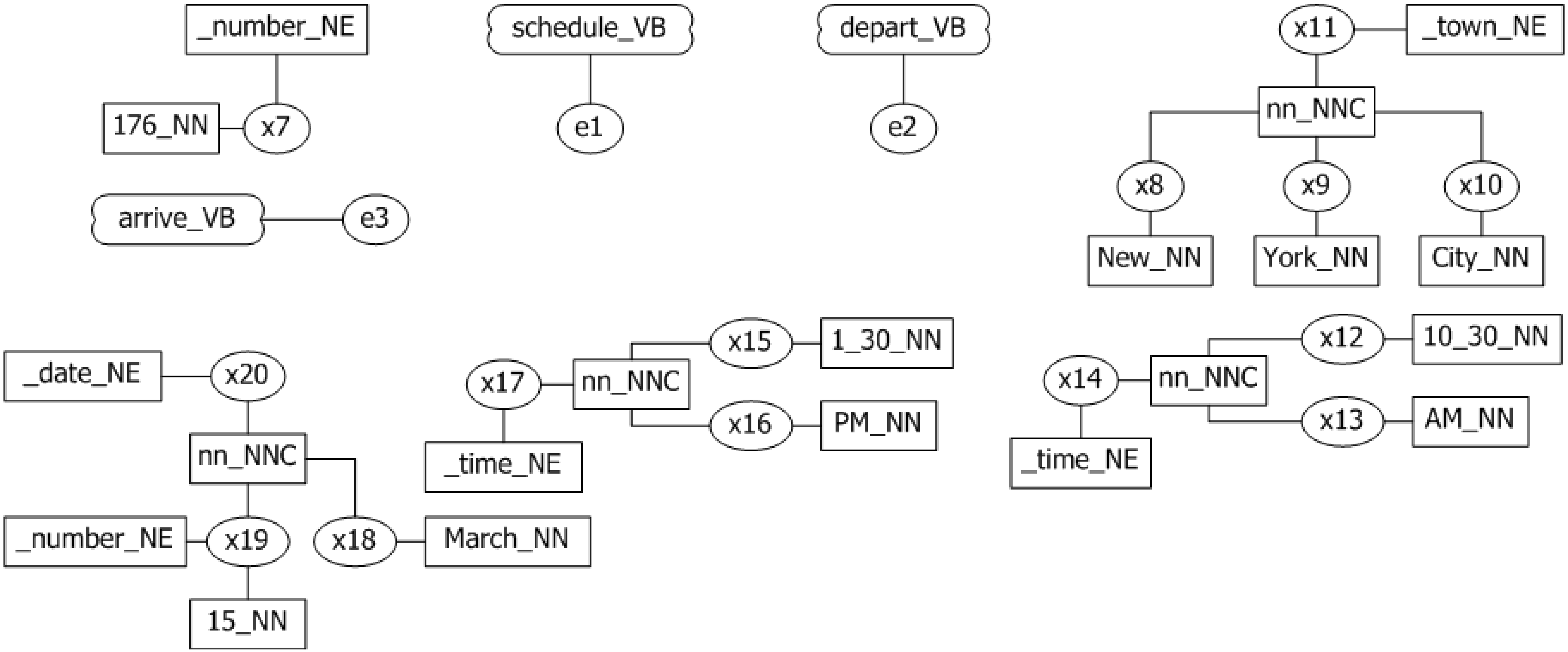
- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."

- Logic Form Representation

176_NN(x7) & _number_NE(x7) & schedule_VB(e1) & depart_VB(e2) & New_NN(x8) & York_NN(x9) & City_NN(x10) & nn_NNC(x11,x8,x9,x10) & _town_NE(x11) & 10_30_NN(x12) & AM_NN(x13) & nn_NNC(x14,x12,x13) & _time_NE(x14) & arrive_VB(e3) & 1_30_NN(x15) & PM_NN(x16) & nn_NNC(x17,x15,x16) & _time_NE(x17) & march_NN(x18) & 15_NN(x19) & _number_NE(x19) & nn_NNC(x20,x18,x19) & _date_NE(x20)

Logic form + semantics: Example 2

The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.



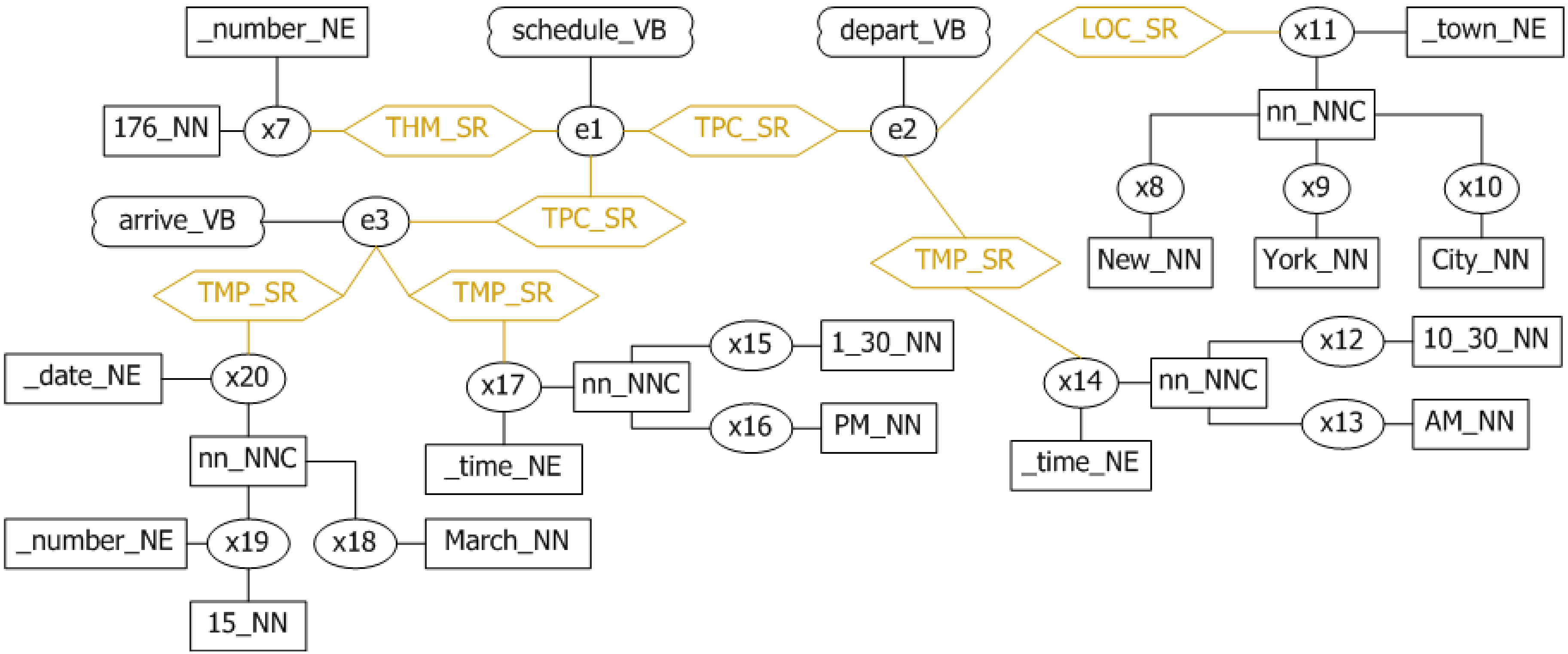
Logic form + semantics: Example 2

- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."

- Logic Form + Semantic Relations:
  176_NN(x7) & _number_NE(x7) & schedule_VB(e1) & depart_VB(e2) & New_NN(x8) & York_NN(x9) & City_NN(x10) & nn_NNC(x11,x8,x9,x10) & _town_NE(x11) & 10_30_NN(x12) & AM_NN(x13) & nn_NNC(x14,x12,x13) & _time_NE(x14) & arrive_VB(e3) & 1_30_NN(x15) & PM_NN(x16) & nn_NNC(x17,x15,x16) & _time_NE(x17) & march_NN(x18) & 15_NN(x19) & nn_NNC(x20,x18,x19) & _date_NE(x20) & THM_SR(x7,e1) & TPC_SR(e2,e1) & LOC_SR(x11,e2) & TMP_SR(x14,e2) & TPC_SR(e3,e1) & TMP_SR(x17,e3) & TMP_SR(x20,e3)

Logic form + semantics: Example 2

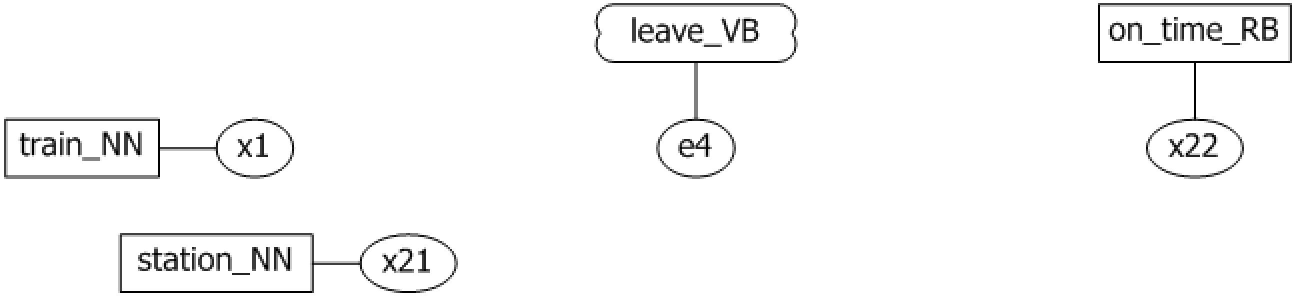
The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.



Logic form + semantics: Example 3

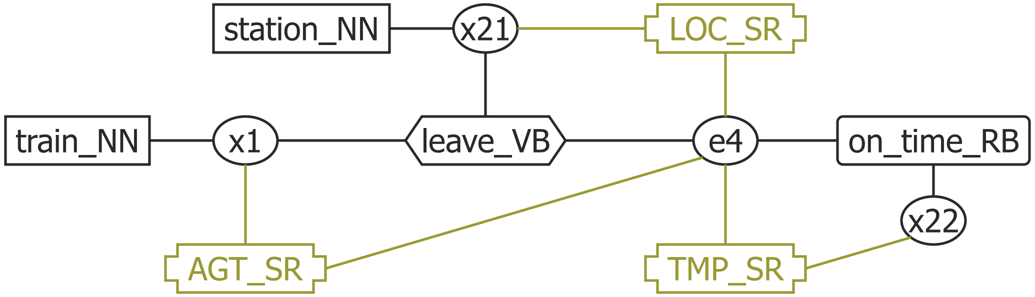
- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."

- Logic Form Representation:
  train_NN(x1) & leave_VB(e4) & station_NN(x21) & on_time_RB(x22)



Semantic Relations Example

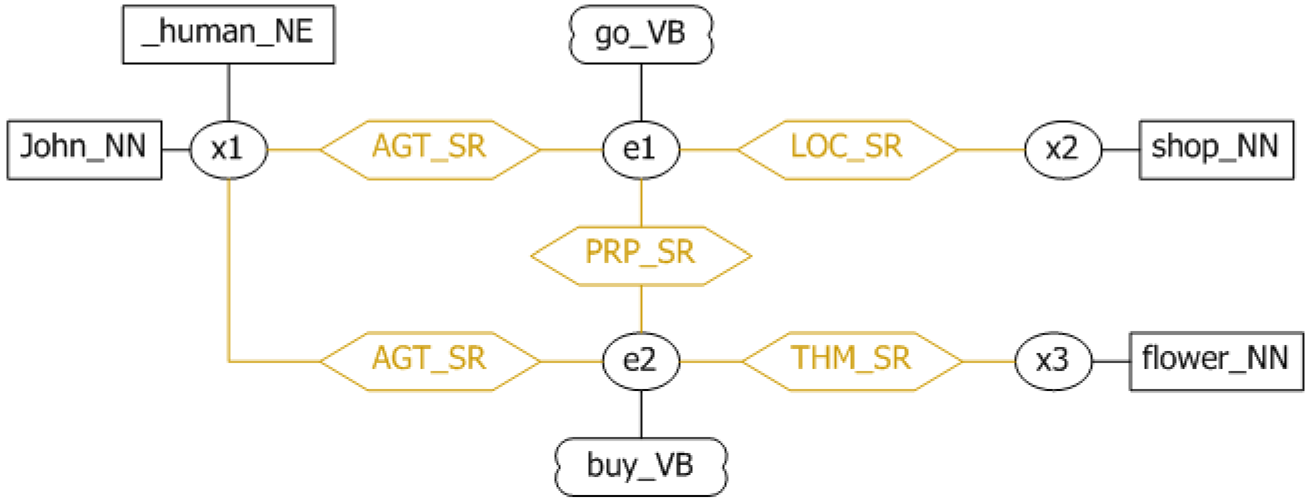
- Scenario:
  "…
  The train was an Acela Express, number 176.
  The 176 was scheduled to depart for New York City at 10:30 AM and arrive at 1:30 PM on March 15.
  …
  The train left the station on time."
- Logic Form + Semantic Relations:
  train_NN(x1) & leave_VB(e4) & station_NN(x21) & on_time_RB(x22) & AGT_SR(x1,e4) & LOC_SR(x21,e4) & TMP_SR(x22).



Logic form + semantics: Example 4

- John went to the shop to buy flowers.

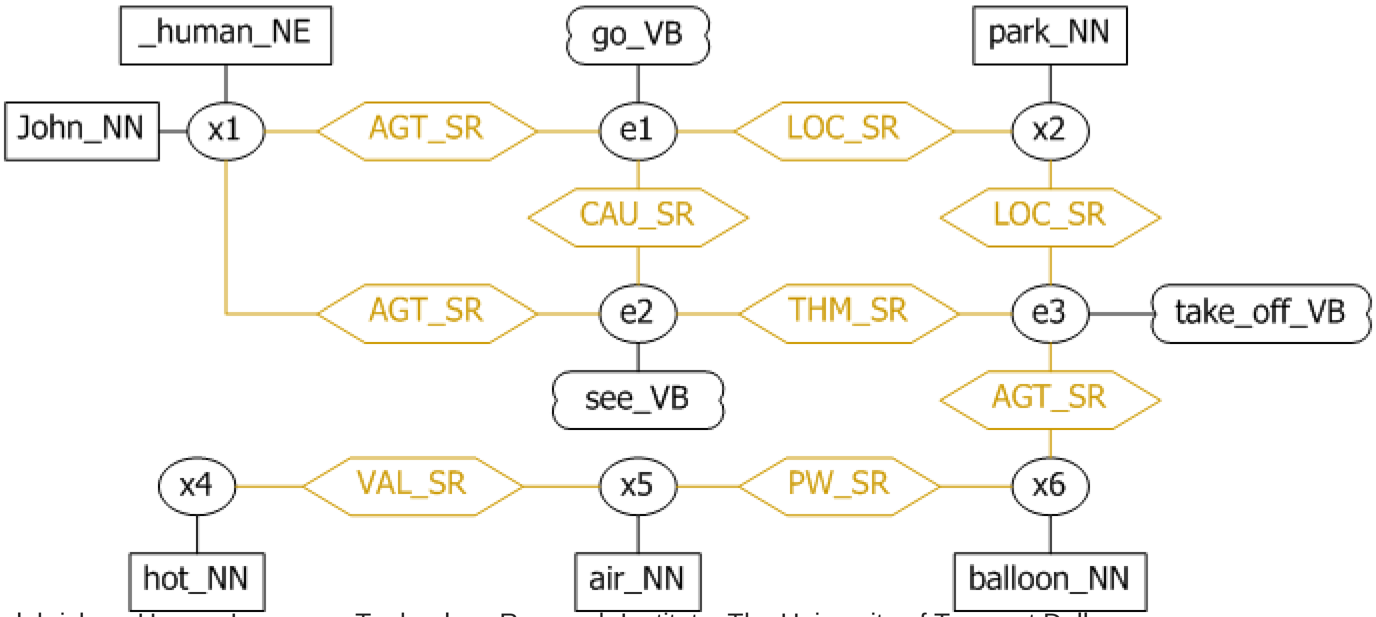
➡ Logic Form + Semantic Relations
John_NN(x1) & _human_NE(x1) & go_VB(e1) & shop_NN(x2) & buy_VB(e2) & flower_NN(x3) & AGT_SR(x1,e1) & LOC_SR(x2,e1) & AGT_SR(x1,e2) & PRP_SR(e2,e1) & THM_SR(x3,e2)



Logic form + semantics: Example 5

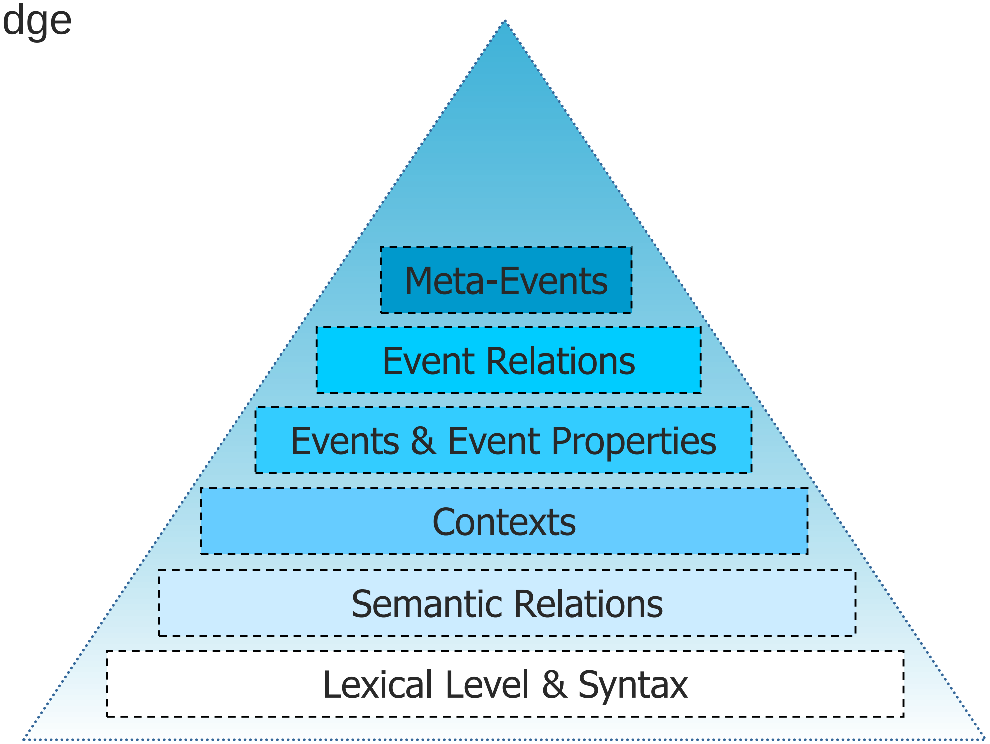
- John went to the park yesterday because he saw hot air balloons taking off from there.

➡ Logic Form + Semantic Relations
John_NN(x1) & _human_NE(x1) & go_VB(e1) & park_NN(x2) & yesterday_NN(x3) & see_VB(e2) & hot_JJ(x4) & air_NN(x5) & balloon_NN(x6) & take_off_VB(e3) & AGT_SR(x1,e1) & LOC_SR(x2,e1) & TMP_SR(x3,e1) & CAU_SR(e2,e1) & AGT_SR(x1,e2) & THM(e3,e2) & PW_SR(x5,x6) & VAL_SR(x4,x5) & AGT_SR(x6,e3) & LOC_SR(x2,e3)



Hierarchical Representation

- Explicit knowledge



- Implicit knowledge: implicatures, humor, sarcasm, deceptions, etc.
- Other textual phenomena: negation, modality, quantification, coreference resolution

Hierarchical Rep Facilitates Reasoning

Meta-Events

REVENGE

Event Relations

CAUSE_EV(e4,e2), earlier_TMP(e4,e2)

Events & Event Properties

event(e2,x2) & THM_EV(x1,e2) & TMP_EV(x4,e2)

event(e4,e3) & AGT_EV(x5,e2) & AGT_EV(x1,e4) & THM_EV(x5,e4) & TMP_SR(x6,e4)

Contexts

during_TMP(e1,x4)

during_TMP(e3,x6)

Semantic Relations

THM_SR(x1,x2) & AGT_SR(x2,e1) & TMP_SR(x4,e1)

AGT_SR(x1,e3) & THM_SR(x5,e3) & TMP_SR(x6,e3)

Lexical Level & Syntax

Gilda_Flores_NN(x1) & _human_NE(x1) & _s_POS(x1,x2) & kidnapping_NN(x2) & occur_VB(e1,x2,x3) & on_IN(e1,x4) & _date_NE(x4) & time_TMP(BeginFn(x4),1990,1,13,0,0,0) & time_TMP(EndFn(x4),1990,1,13,23,59,59)

he_PRP(x1) & fire_VB(e3,x1,x5) & kidnapper_NN(x5) & _date_NE(x6) & time_TMP(BeginFn(x6),1990,1,6,0,0,0) & time_TMP(EndFn(x6),1990,1,6,23,59,59)

Input Text

Gilda Flores' kidnapping occurred on January 13, 1990.

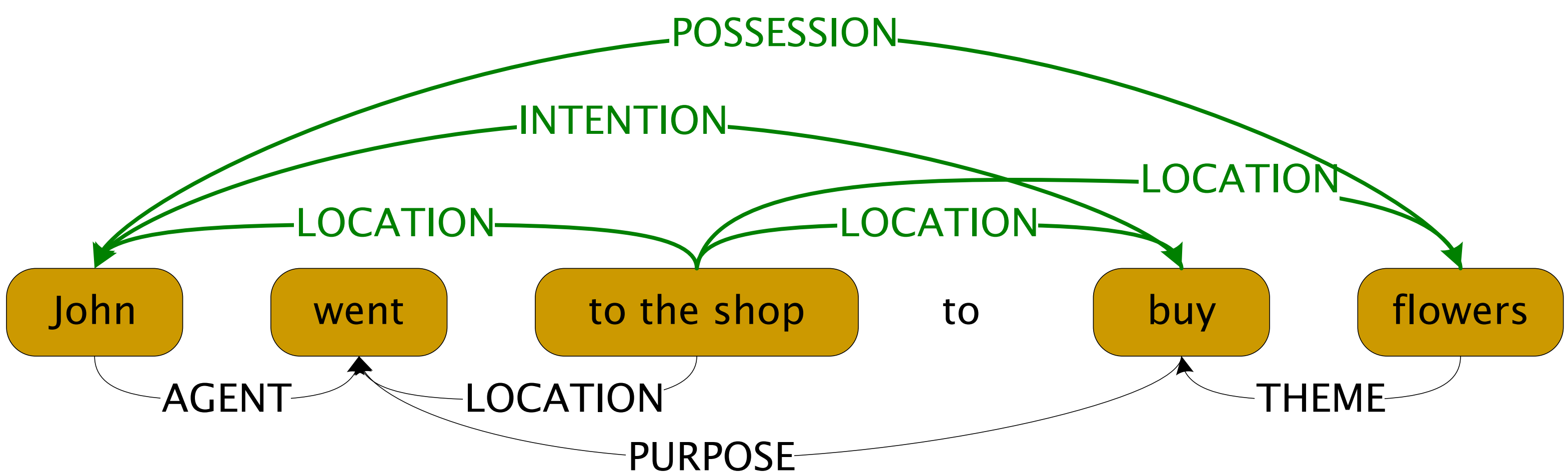
A week before, he had fired the kidnappers.

Semantic Relations – not extracted by SP

John went to the shop to buy flowers,

SP extracts the **elementary** relations indicated with black arrows.

Green arrows indicate missing relations that can be retrieved by **combining** elementary relations using **inference axioms**



$$R_1\,(x, y) \circ\ R_2\,(y, z) \rightarrow\ R_3\,(x, z)$$

Semantic Calculus

Composition of Semantic Relations

- Provides a formal framework for **manipulating semantic relations**

- Aims at **inferring relations** by applying **inference axioms** over already identifies (elementary) relations in text
  - Given some relations as **premises**, an axiom unequivocally yields a semantic relation that holds as **conclusion**

  - Combine two or more semantic relations

- Combine the semantic relations with other sources of semantic information from the context, for example, the verb's frame semantics, to further interpret the text

Applications of Semantic Calculus

- Customization of a set of semantic relations
  - CSR axioms are used to obtain new relations, specific to a particular domain
    - Advantage: no change required to the SP, and yet we obtain more semantic relations
- Recognizing textual entailment
  - CSR reveals new semantic relations, and these new relations have proven useful for detecting entailments
- Common sense knowledge extraction
  - Using manually annotated resources and CSR, commonsense knowledge, such as *one can see thru windows* is extracted

Customization of a set of relations

- Inference axioms:

No.	Axiom	Constraint on y
1	AGT (x,y) $\circ$ THM $^{-1}$ (y,z) $\rightarrow$ ARRESTED (x,z)	arrested concept
2	THM (x,y) $\circ$ AT-L (y,z) $\rightarrow$ ARRESTED–AT (x,z)	arrested concept
3	AGT (x,y) $\circ$ AT-L (y,z) $\rightarrow$ BANKS-AT (x,z)	banking activity
4	POS $^{-1}$ (x,y) $\circ$ AT-L (y,z) $\rightarrow$ BANKS-AT (x,z)	account concept

- Examples
  - [Police]$_x$ [apprehended]$_y$ 51 [football fans]$_z$

    ARRESTED(Police, football fans)

  - Police [apprehended]$_y$ 51 [fans]$_x$ [near the stadium]$_z$

    ARRESTED-AT(fans, near the stadium)

  - [John]$_x$ [withdrew]$_y$ \$20 [at the nearest Chase branch]$_z$

    BANKS-AT(John, Chase)

Sub-Relations for Association

1. Communication – lexical constraint
   a. COMMUNICATE
      i. WRITE_TO
         1. WRITTEN_COMMUNICATION
         2. ELECTRONIC_COMMUNICATION
      ii. TELEPHONE_TO
      iii. SPEAK_TO
      iv. COMMANDS_OR_CONTROLS(person)
      v. OTHER_COMM
      vi. RECRUITED
2. Meeting – lexical constraint
   a. MEET
3. Joint work – lexical constraint
   a. WORK_WITH
   b. SHARE_TASK_WITH
   c. IS_COWORKER_OF
4. . Economic/trade – usually lexical constraint
   a. SEND_TO
   b. RECEIVE_FROM
   c. SELL_TO
   d. PURCHASE_FROM
   e. TRANSFER
   f. IS_EMPLOYER_OF
5. Teacher/pupil – lexical constraint
   a. TEACH
6. Directly described association – lexical constraint
   a. IS_AFFILIATED_TO
7. Common group membership
   a. MEMBER_OF & MEMBER_OF – no constraint
   b. MEMBER_OF & COMMANDS_OR_CONTROLS(org)
   c. KINSHIP
8. Presence at shared location – no constraint
   a. SHARE_LOCATION
9. Common origin – no constraint
   a. SHARE_ORIGIN
10. Frequent travel to shared location – no constraint
    a. TRAVEL_TO

Association – Example 1

- Composition Axiom:

$AT\text{-}L^{-1}(x,z) \circ THM(z,q) \circ AGT^{-1}(q,y) \rightarrow WRITTEN\_COMMUNICATION(x,y)$ [*z* is a *written_communication* concept; *q* is a *receiving* concept]

- Example text expressing written communication

This letter mentions the fact that two prior letters from Jordan Smith at USC were received by Dr. Chaves.

Association – Example 1

- Semantic Relations:

  AGT(letter, mentions) & THM(fact, mentions) & TPC(fact, received)& THM(letters, received) & AT-L(letters, Jordan Smith) & AT-L(Jordan Smith, USC) & AGT(Dr. Chaves, received) & QNT(two, letters) & VAL(prior, letters)

- Lexical Chains:
  - LETTER: letter/NN/1 text/NN/1 written_communication/NN/1
  - WRITE: write/VB/5 write/VB/4 write/VB/1 write/VB/2
  - RECEIVE: receive/VB/1 receive/VB/3

- Association Relation:

$\text{AT-L}^{-1}(\textit{Jordan Smith, letter}) \circ \text{THM}(\textit{letter, received}) \circ \text{AGT}^{-1}(\textit{received, Dr.Chaves}) \rightarrow$ WRITTEN_COMMUNICATION(*Jordan Smith, Dr. Chaves*)

Association - Example 2

- Composition Axiom:
  - $AGT(x,z) \circ THM|RCP^{-1}(z,y) \rightarrow SPEAK\_TO(x,y)$ [z is a *speaking* concept]

- Example text expressing spoken communication

Jordan ask Dr. Chaves and Professor Lee to tutor outside of office hours.

Association – Example 3

- *Jordan began attending classes by the professor, Dr. Chaves, who remembers Jordan as “smart and respectful to others.“*
- Semantic Relations:
  - AGT(Jordan, began) & THM(attending, began) & TPC(attending, classes) & POS(classes, Dr. Chaves)
- Lexical Chains:
  - SCHOOL: educational_institution/NN/1 school/NN/2 school/NN/3 class/NN/3 educational_activity/NN/1
  - ATTEND: attend/VB/1
  - TEACHER: instructor/NN/1 educator/NN/1 trainer/NN/1
- Composition:
  - AGT(x,z) ° THM^{-1}(q,z) ° POS^{-1}(t,q) → TEACH(x,t) [z is a *attending* concept; q is a *school* concept, x is a human and t is a human]

Semi-Automated Algorithm for Semantic Calculus

1. Run the NLP pipeline through sample text [auto]
2. Determine what kind of concepts *x* and *y* might be [manual]
   - named entities and WordNet hierarchies
3. Extract chains of relations between concepts identified in (2) [auto]
   - Breadth First Search over the output of NLP pipeline
     - nodes are concepts, relations are edges
4. Cluster chains based on frequency, concepts and relations involved [auto]
   - sorted by concepts
   - sorted by relations in the chain
5. Classify chains into [manual]
   - valid: new relation R can be inferred, generate semantic calculus axiom
   - invalid: the new relation cannot be inferred, do not generate semantic calculus axiom

Steps 3 and 4 in Detail

- Steps 3 and 4: extracting and clustering chains of relations
  - Input:
    - Files processed through NLP pipeline
    - Define constraints for the chains (any combination of):
      - maximum length
      - first argument: named entity, wordnet classes and lemma
      - second argument: named entity, wordnet classes and lemma
      - other arguments along the chain: wordnet classes
      - banned relations
  - Output:
    - All chains found in the processed files fulfilling the constraints clustered by:
      - concept (chains starting with argument)
      - relation type (chains starting with relation R)

Generating Axioms for Educational Events

1. Define constraints:
   - LHS: human named entity
   - RHS: One of the following entities or concepts
     - college | university | school | academy
     - Degree | grade | masters | bachelor | bachelors | bachelor's | BA | BS | M.S. | MS | MFA | MA | PhD | doctorate
     - Train | learn | instruct | teach | study | educate
2. Run the Breadth First Search on the X number of documents from the domain
3. Select the axioms to use for inference from the axioms generated
   - 176 (unique axioms)
   - 5,184 (instantiations)
   - Most instantiated axiom: 1440 instances
   - Second most instantiated axiom: 432 instances
   - Second most instantiated axiom: 288 instances
4. 65 good inference vs. 111 bad inferences, but the 65 good axioms account for 68% of instantiations

Examples of Good Axioms

AGT(Fisher, taught) ° LOC(taught, Reynoldsburg High School) → ED_EVENT(Fisher, Reynoldsburg High School)
Fisher formerly taught at Reynoldsburg High School and coached the district's eighth-grade girls' basketball team.

AGT(Hurtt, graduated) ° LOC(graduated, University of Phoenix) → ED_EVENT(Hurtt, University of Phoenix)
Hurtt graduated with a Bachelor of Science degree in Sociology from Arizona State University 1977 and a Master's degree in Organizational Management from the University of Phoenix

AGT(Garcia, left) ° THM(program, left) ° LOC(program, Boston University) → ED_EVT(Garcia, Boston University)
The evidence demonstrates that Garcia left his economics program at Boston University in 1991 without a degree, when his J-1 visa expired.

(Good inference even learned from imperfect relations)
ISA(Zuniga, student) ° TMP(former, student) ° TMP(former, Midland College) → ED_EVT(Zuniga, Midland College)
Subsequent investigation revealed that the USB drive belonged to Zuniga, a former Midland College student who had since transferred to the University of Texas in San Antonio

Examples of Bad Axioms

(arrested is not a education event)

THM(Elias Jacob Muñoz III, arrested) ° LOC(arrested, University of Texas at El Paso) ! → ED_EVT(Elias Jacob Muñoz III, University of Texas at El Paso)

Martha Patricia Muñoz, 47, was arrested at her Westside residence; her son, Elias Jacob Muñoz III, 22, was arrested at the University of Texas at El Paso …

(contains degree, wrong sense)
THM(Carlos Alvarado, convicted) ° CAU(2nd degree, convicted) ! → ED_EVT(Carlos Alvarado, 2nd degree)

Carlos Alvarado, age, 37, was convicted of murder, 2nd degree, in Baltimore County and was initially sentenced to six years of incarceration in 2005. His victim was 11 years old.

Representing Negation

- Negation is a process that turns part of a statement into its opposite
- Pinpointing what is negated and what is implicitly positive is challenging
  - I don't have a watch <u>with me</u>
  - They didn't release the UFO files <u>until 2008</u>
  - His new job doesn't require <u>driving</u>
  - His new job doesn't require driving <u>yet</u>
  - His new job doesn't <u>require</u> anything
  - A panic on Wall Street doesn't exactly <u>inspire</u> confidence
- The state of the art only encodes that the verb is negated

Incorporating Negation to Semantic Relations

- Use symbol '-' to indicate that an argument of a relation that must negated
  - R(-x, y); [not x] is R of y
  - R(x, -y); x is R of [not y]

- The cow didn't eat grass <u>with a fork</u>

agent(the cow, -ate) & theme(grass, -ate) & instrument(with a fork, -ate)
agent(-the cow, ate) & theme(grass, ate) & instrument(with a fork, ate)
agent(the cow, ate) & theme(-grass, ate) & instrument(with a fork, ate)
agent(the cow, ate) & theme(grass, ate) & instrument(-with a fork, ate)

Detecting the focus allows us to choose the right interpretation

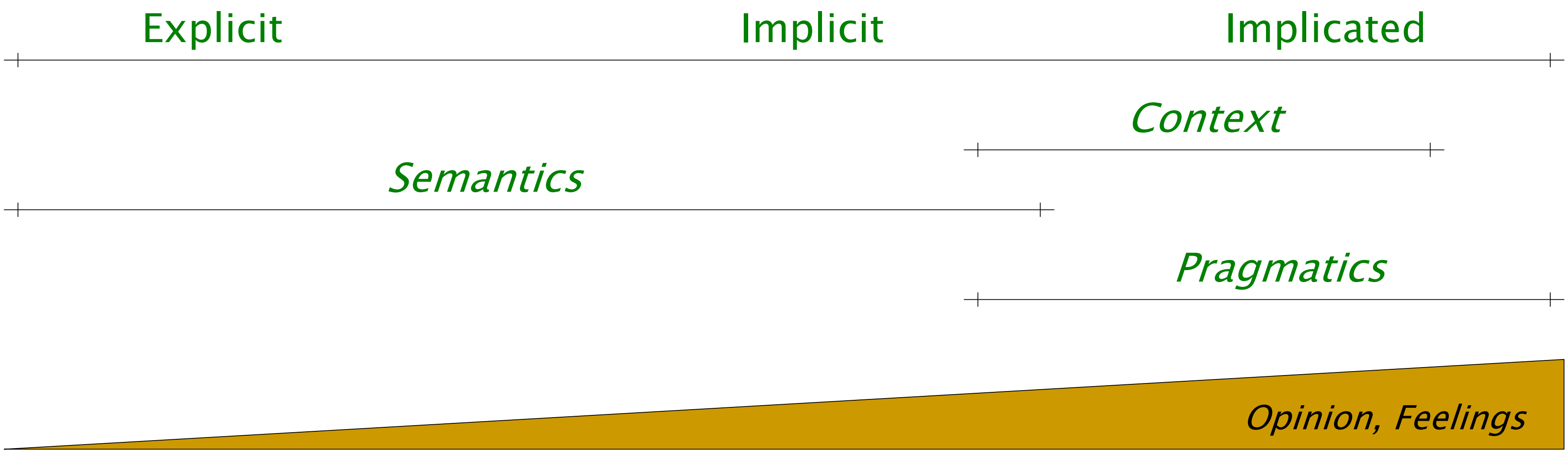
Interpreting negation

- John doesn't know exactly how they met
  - agent(John, know)
  - theme(how they met, know)
  - manner(-exactly, know)   i.e. manner(incompletely, know)
- I don't have a watch with me
  - agent(I, have)
  - theme(a watch, have)
  - at-location(-with me, have)
- The cow didn't eat grass with a fork
  - agent(the cow, ate)
  - theme(grass, ate)
  - instrument(-with a fork, ate)

Perspective: Levels of Text Understanding

- IM chat conversation
  - **A:** *Dinner's ready! prawns, grouper in some sauce, vegetables, rice and shark's fin melon soup! Still waiting for lotus root soup this week!*
  - **B:** *Eeeeeee lotus root?*
  - **A:** *so what you having for dinner?*
- Conversation meaning
  - Explicitly conveyed
    - Dinner is ready. A list of dishes: prawns, grouper with sauce, rice, soup made of shark's fin and melon, lotus root soup for later in the week. A is asking B what B is having for dinner.
  - Inferred logically (implicitures)
    - There exists a meal which includes all the dishes mentioned. The sauce is part of a dish. The soup is a dish. Dish is part of dinner. One or more dishes are ready. B's eeeeeeee points to disgust, a feeling of dislike
  - Contextually implicated (implicatures)
    - A is excited and proud about having prepared a gourmet dinner. B dislikes lotus root and cannot believe A would choose to eat it. A has a poor opinion of B's gastronomic knowledge (B should not question A's choices in dinner dishes).

Perspective: Levels of Text Understanding



Boundary between Implicitures and Implicatures

- A: Are you inviting Mike to the party?
- B: No. I’m inviting nice people.

- Scenario 1 (no context)
  - B thinks Mike is not a nice person.
  - This is an entailment, a presupposition.

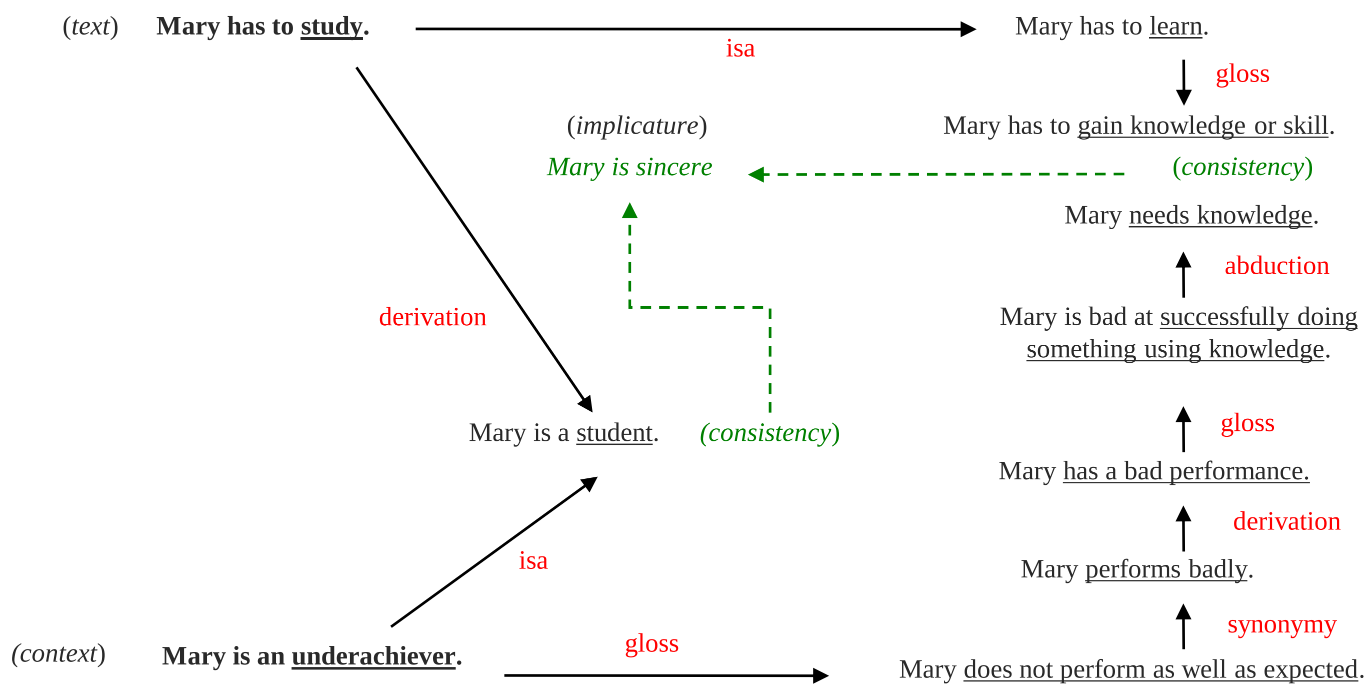
- Scenario 2 (context: B had an argument with Mike, A knows it was B’s fault)
  - Implicature by A +> B is revengeful

Examples of Implicatures

- John: Do you want to play tennis this weekend?
- Mary: I have to study.
  - Scenario 1: Mary is sincere, she is an underachiever student
  - Scenario 2: Mary does not want to see John, refusing him politely

- Paul: Has Bob got a girlfriend?
- George: He’s been playing a lot of tennis lately
  - Scenario 1: No, he does not have a girlfriend, evidenced by spending time plying tennis
  - Scenario 2: Yes, he has a girlfriend, spending time with her playing tennis, reinforced by
    - Paul: He always liked athletic girls.

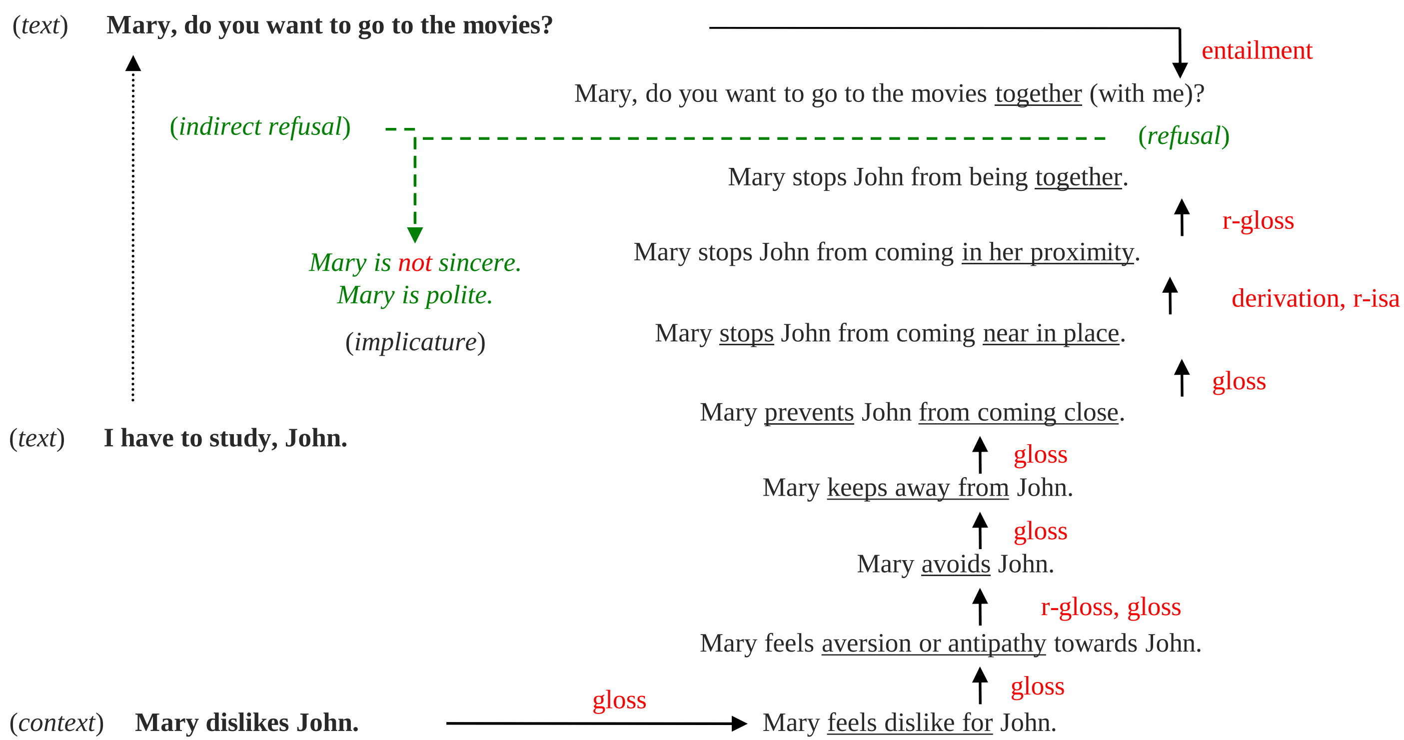
Implicatures (sincerity)



John: *Do you want to go to the movies?*

Mary: *I have to study.*

Implicatures (politeness)



John: *Do you want to go to the movies?*
Mary: *I have to study.*

Mary dislikes John.

Gricean Theory

Grice developed a theory to *explain* and *predict* conversational implicatures

Cooperative Principle: Contribute what is required by the accepted purpose of the conversation

1. **Maxim of Quality**: Say only what you believe to be true and only what you have evidence for (justified)
2. **Maxim of Quantity**: Be as informative as required, no more no less
3. **Maxim of Relation**: Be relevant to the topic at hand
4. **Maxim of Manner**: Be perspicuous, avoid obscurity, ambiguity, be brief, be orderly

Note: These maxims are valid for cooperative activities in general, not only for conversations

Observe the Maxims

- A: *I'm out of gas.*
  B: *There is a garage around the corner.*

Cooperative principle: yes

Maxim of Quality: B knows there is a garage, thinks is open and selling gas.

Maxim of Quantity: is informative, is not saying anything else

Maxim of Relation: garage has gas and this is what A needs

Maxim of Manner: yes

- A: *What on earth has happened to the roast beef?*
  B: *The dog is looking very happy*
  +> The dog has eaten the roast beef

Maxims are respected here too.

Textual Entailment

- T: Toyota Ireland, through its Eurocare program, provides owners of both new and up to 3 year old Toyota models with the peace of mind of a comprehensive roadside assistance service.

  H: Eurocare is a program of roadside assistance service.

- T: Competition between IBM and Oracle is certainly nothing new, and the customer does ultimately benefit.

  H: IBM is a competitor of Oracle.

- T: Canadian Nation Defense has been using virtual reality to train pilots and ground soldiers.

  H: Soldiers have been trained using virtual reality.

Semantic-based Logic Approach

- Textual Entailment
  - Task definition: *T entails H*, denoted by $T \rightarrow H$, if the meaning of *H* can be inferred from the meaning of *T*
  - inferred means logic (theorem prover + natural language axioms)
  - meaning means semantics (semantically enhanced knowledge representation)

A Semantic Approach

- $T \rightarrow_{semantic} H$ or $meaning(T) \rightarrow meaning(H)$
- "$\rightarrow$" logic axioms + logic prover
- meaning() semantic semantic relations
- meaning(*text*) $\leftrightarrow$ {semantic relations encoded in the *text*} = $\mathcal{SR}(text)$

$$T \rightarrow_{semantic} H \leftrightarrow \mathcal{SR}(H) \subseteq \mathcal{SR}(T)$$

RTE Example Proof

T: John and his son George emigrated with Mike, John's uncle to US in 1969.

LFT: John_NN(x1) & _human_NE(x1) & son_NN(x2) & his_PRP(x1,x2) & and_CC(x3,x1,x2) & George_NN(x4) & _human_NE(x4) & emigrate_VB(e1,x3,x5) … & KINSHIP(x1,x2) & ISA(x4,x2) & AGENT(x3,e1) & …

(DEPARTING frame: emigrated)

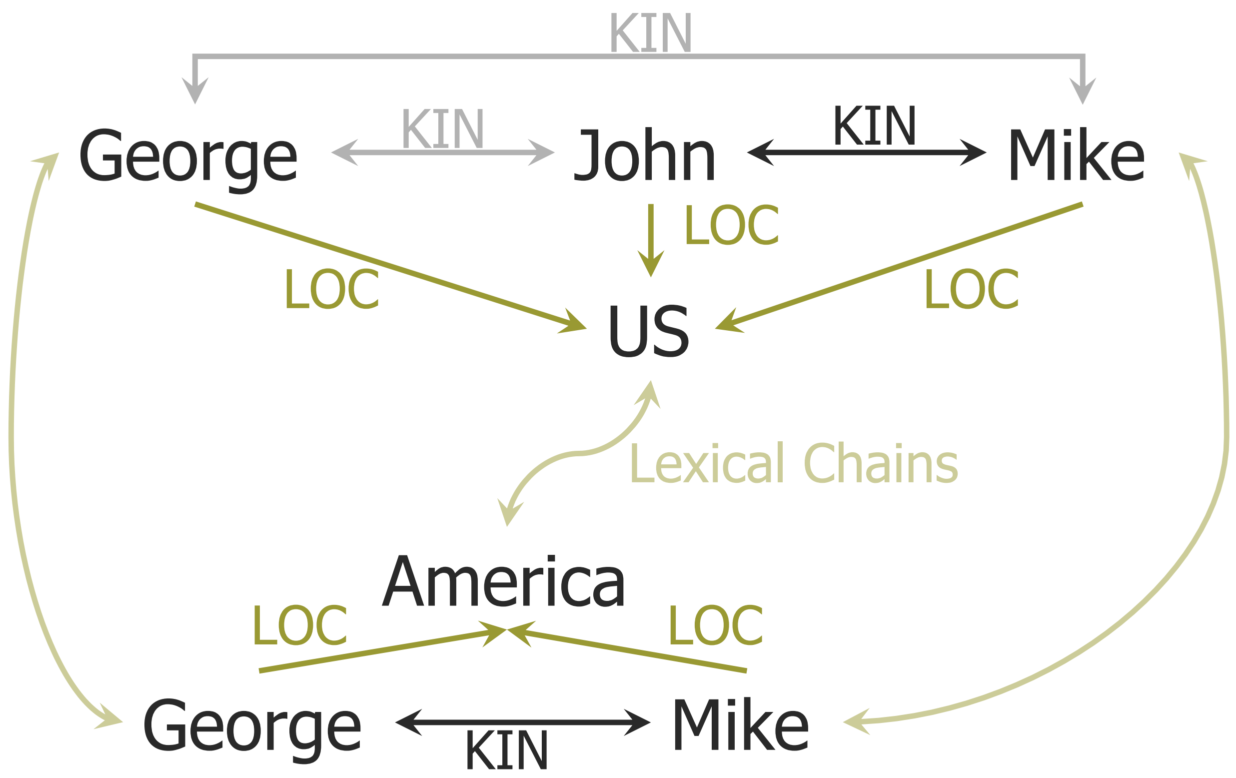
& theme_FE(x3,e1) & cotheme_FE(x6,e1) & goal_FE(x8,e1) & time_FE(x9,e1)

Semantic Axioms for T

- `KIN(x1,x2) ↔ KIN(x2,x1)`
  - KINSHIP(son,John)
- `ISA(x1,x2) & KIN(x2,x3) → KIN(x1,x3)`
  - KINSHIP(George,John)
- `KIN(x1,x2) & KIN(x2,x3) → KIN(x1,x3)`
  - KINSHIP(George,Mike)
- `Departing_F → LOC(Theme_FE,Goal_FE)`
  - LOCATION(John,US) and LOCATION(George,US)
- `Departing_F → LOC(Cotheme_FE,Goal_FE)`
  - LOCATION(Mike,US)

Example Proof

T: John and his son, George, emigrated with Mike, John's uncle, to US in 1969.



H: George and his relative, Mike, came to America.