When FrameNet meets a Controlled Natural Language

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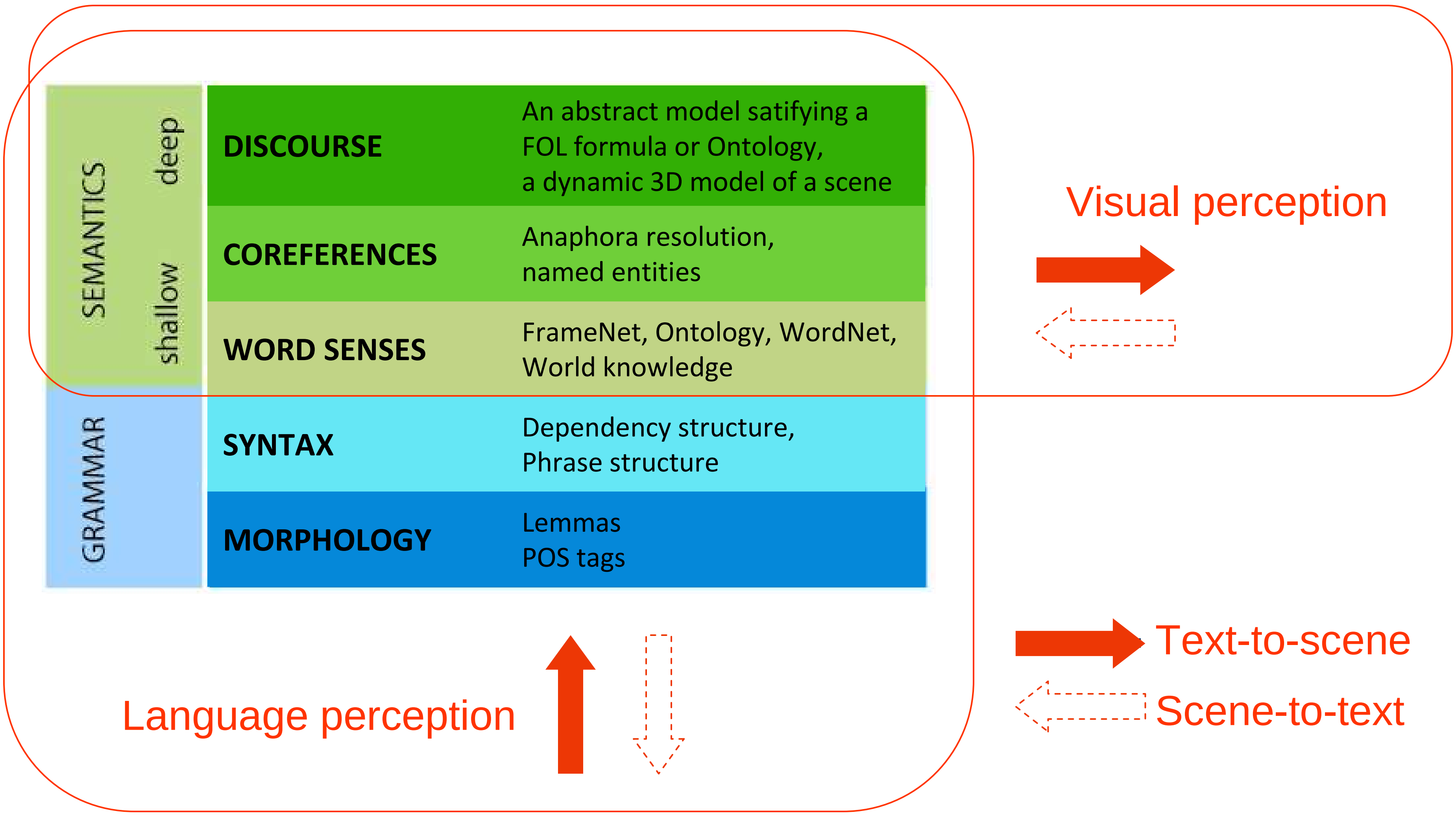
NODALIDA 2011, 12 May 2011, Riga, Latvia

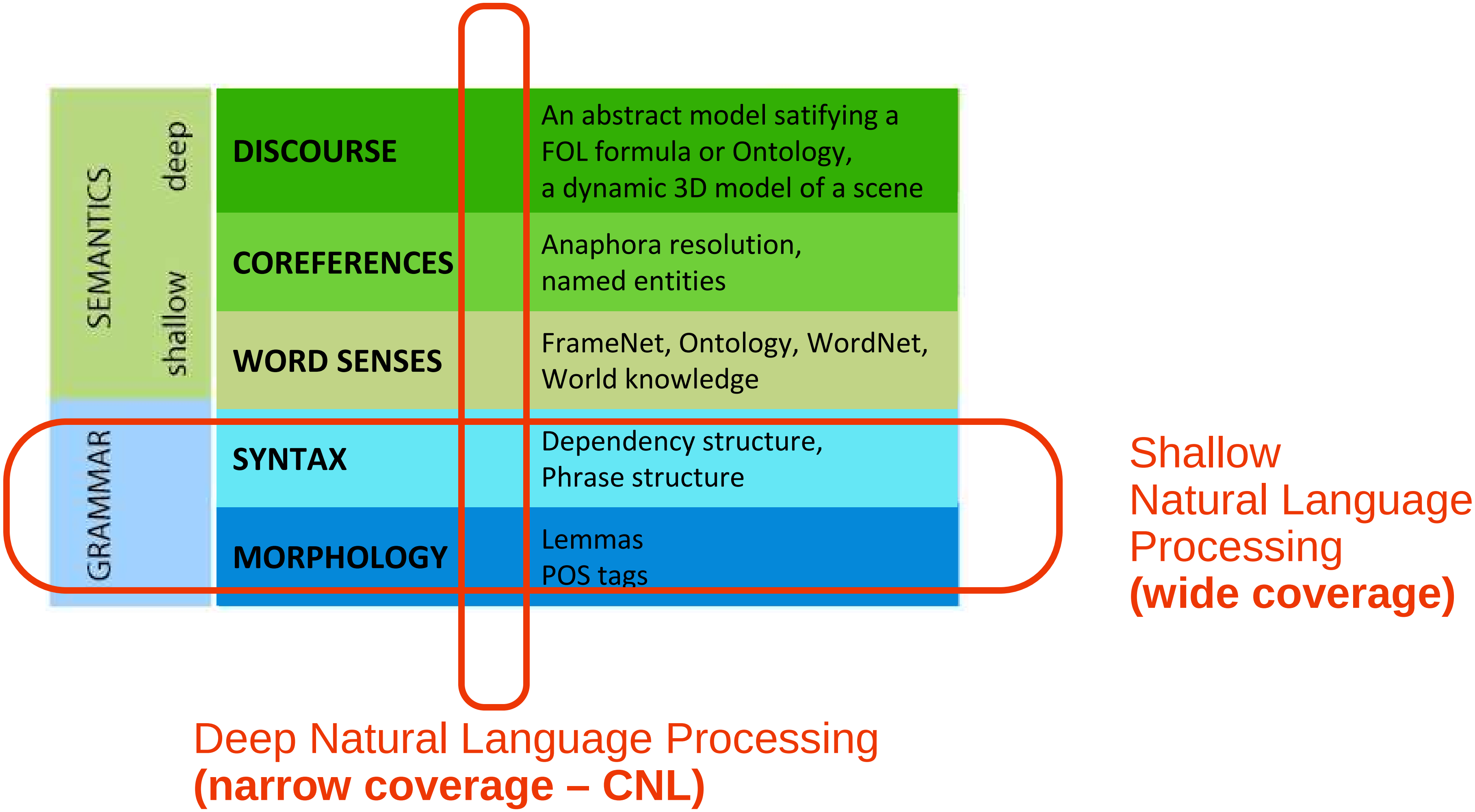
Natural Language Processing

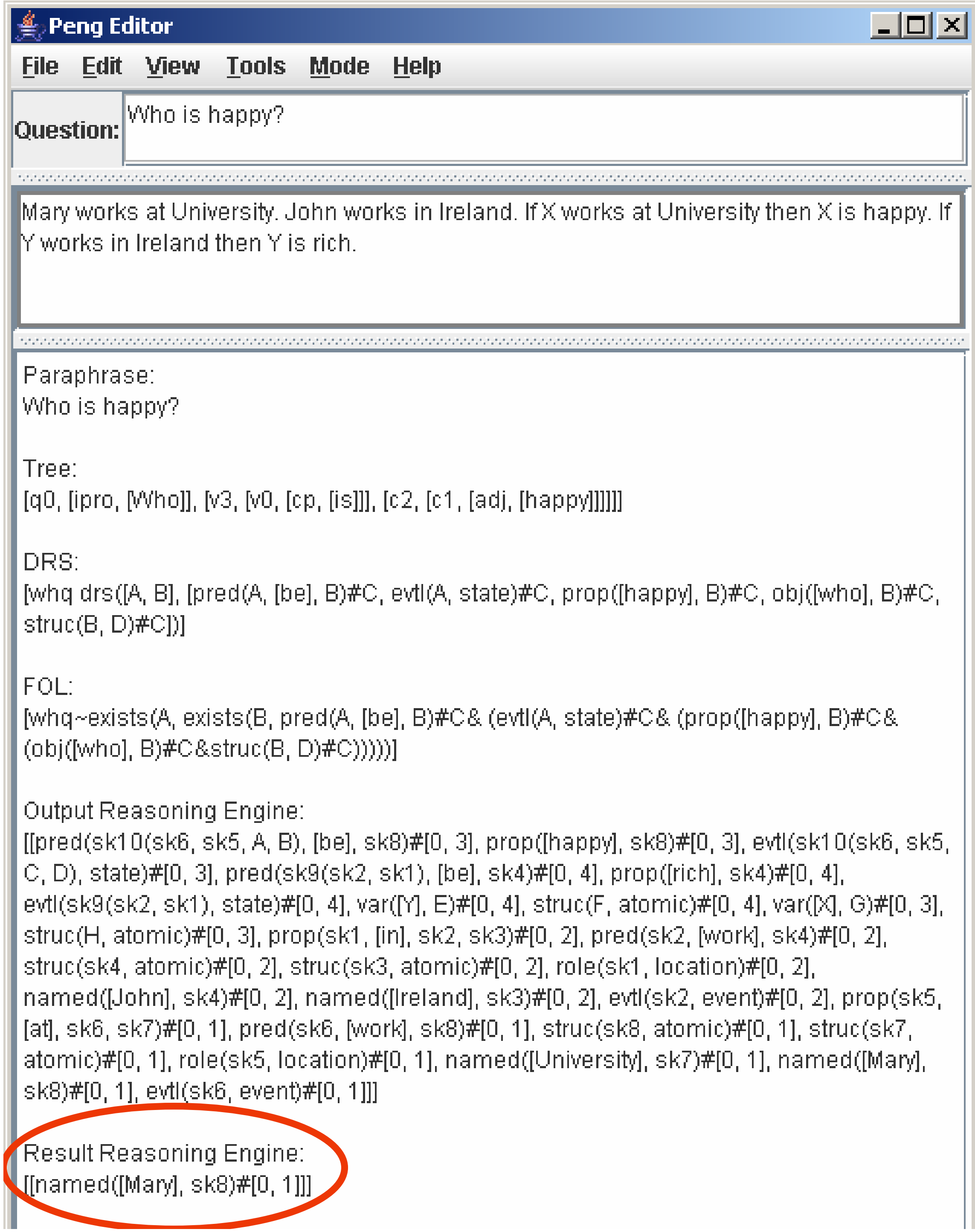
SEMANTICS	deep	**DISCOURSE**	An abstract model satifying a FOL formula or Ontology, a dynamic 3D model of a scene
		COREFERENCES	Anaphora resolution, named entities
	shallow	**WORD SENSES**	FrameNet, Ontology, WordNet, World knowledge
GRAMMAR		**SYNTAX**	Dependency structure, Phrase structure
		MORPHOLOGY	Lemmas POS tags

Natural Language Processing



Two Approaches to Natural Language Processing





Logic based CNL

- Formalize discourse through logic and resoning (FOL or OWL subset)
- Uses a monosemous lexicon and strict syntax interpretation rules to avoid ambiguity
- CNLs are easy to read, but difficult to write (narrow coverage, strict rules)

3D Scene Construction CNL WordsEye

The ground has a grass texture. The ground is pale green. It is partly cloudy. The girl is in front of the house. The girl has red top hat. The woman is facing the girl. The white picket fence is behind the house. The fence is 40 feet wide. Two trees is on left side of house.

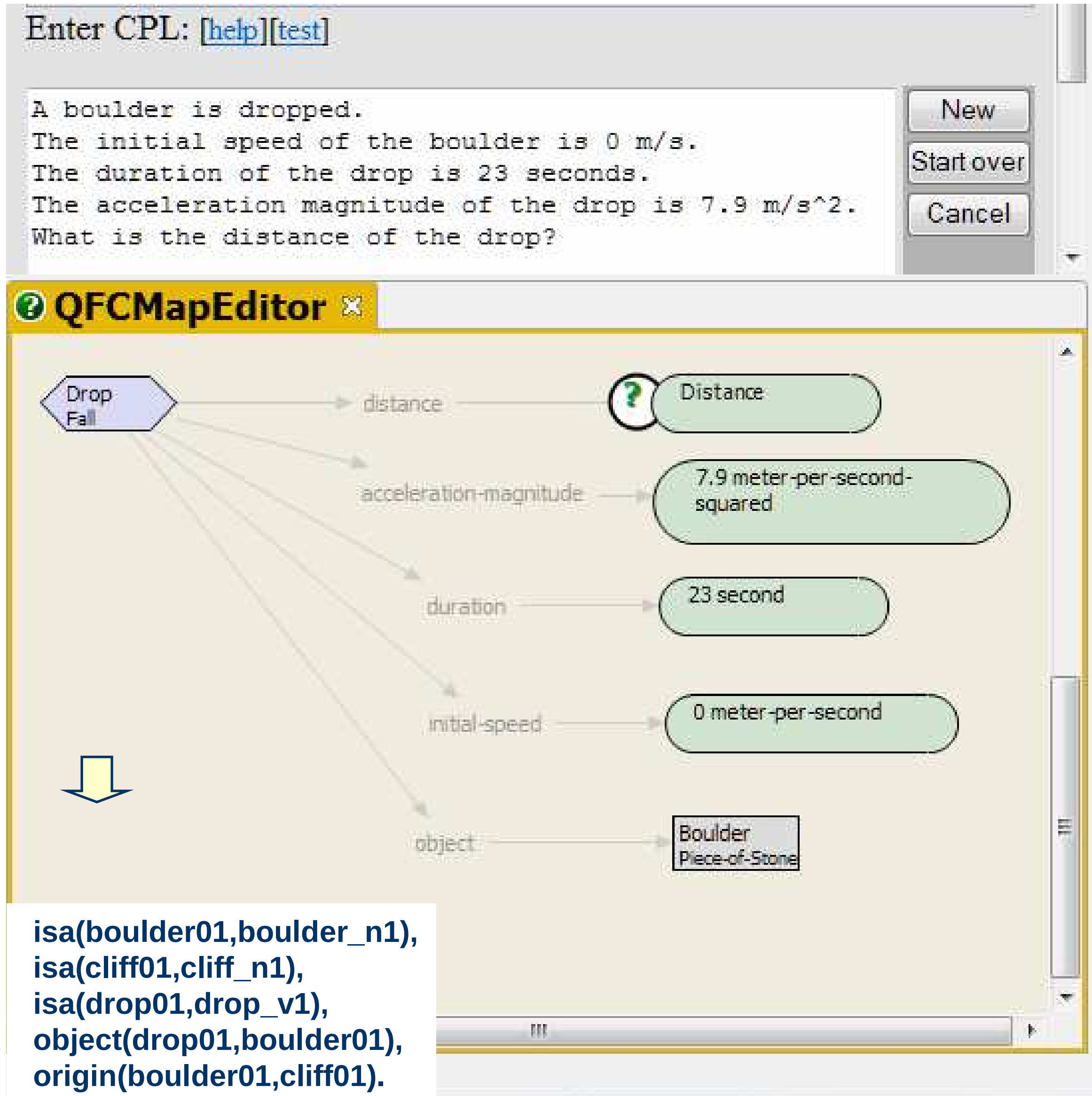
Halo Project CPL CNL (Digital Aristotle)

A question from the Advanced Placement Exam in physics:

An alien measures the height of a cliff by dropping a boulder from rest and measuring the time it takes to hit the ground below. The boulder fell for 23 seconds on a planet with an acceleration of gravity of 7.9 m/s2. Assuming constant acceleration and ignoring air resistance, how high was the cliff?

Restated in Computer-Processable Language (CPL):

A boulder is dropped. The initial speed of the boulder is 0 m/s. The duration of the drop is 23 seconds.The acceleration of the drop is 7.9 m/s^2. What is the distance of the drop?



isa(boulder01,boulder_n1),
isa(cliff01,cliff_n1),
isa(drop01,drop_v1),
object(drop01,boulder01),
origin(boulder01,cliff01).

Controlled Natural Languages

Logic based CNLs

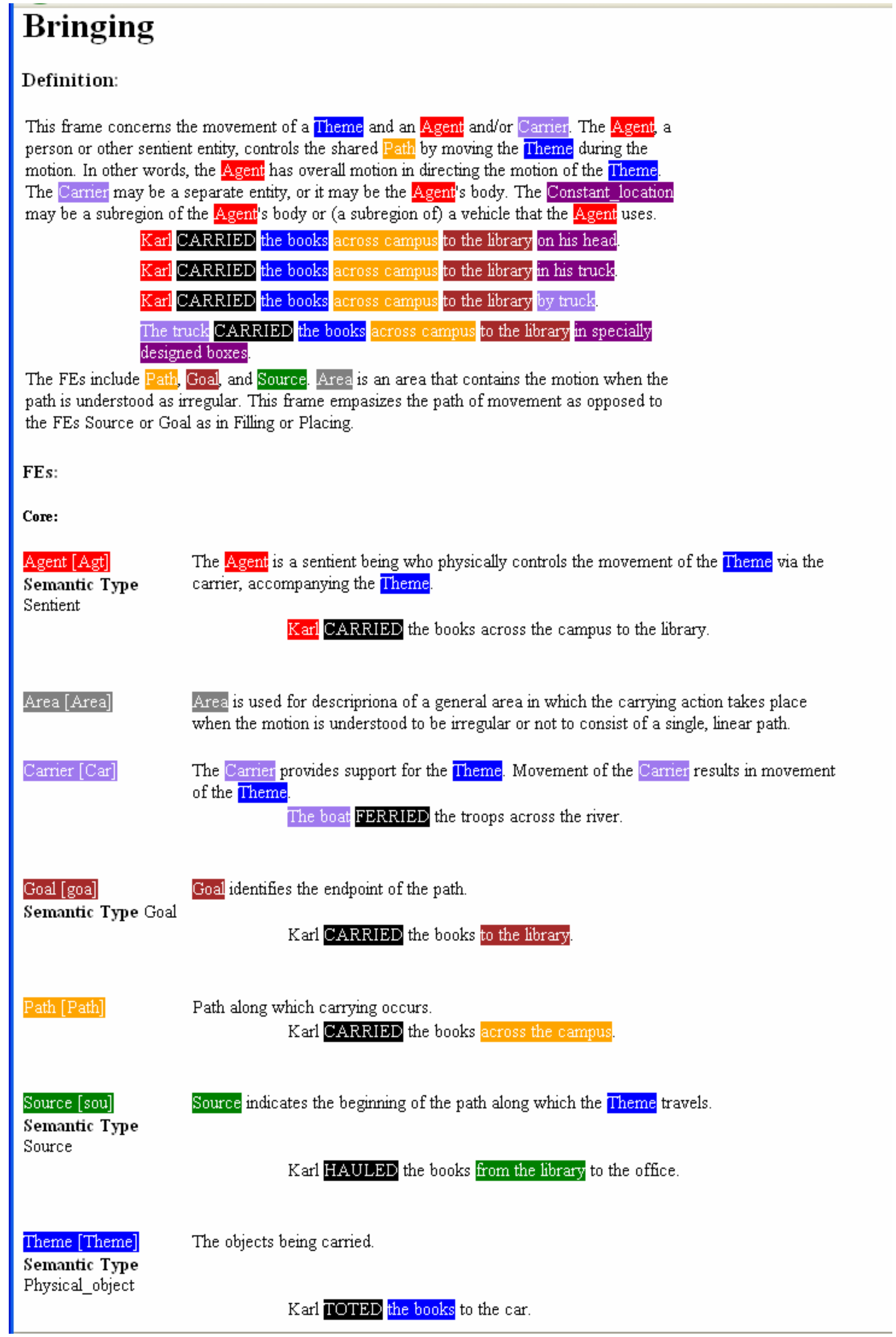
- Processable ENGlish (PENG)
- CPL
- Attempto Controlled English (ACE)
- RABBIT
- Common Logic Controlled English (CLCE)
- ...

Other CNLs

- Boeing Simplified English
- Simplified Technical English (ASD)
- Caterpillar English
- Air Traffic Control (aviation)
- OPORD
- Molto (SPARQL, Grammar Framework)
- ...

FrameNet

- Developed in ISCI, Berkley by C.Fillmore et.al.
- Consists of ~800 *frames* (generic <u>situations</u> and <u>objects</u>) and their arguments – *frame elements*
- Derived from extensive text corpus evidence – new frames caused only by unique *argument structure*
- Frames organized in *inheritance* hierarchies
- Largely language independent
  - LexicalUnits assigned to frames
    - back.n (Observable_bodyparts)
    - back.n (Part_orientational)
    - back.v (Self_motion)
    - back.a (Part_orientational)



Bringing

Definition:

This frame concerns the movement of a Theme and an Agent and/or Carrier. The Agent, a person or other sentient entity, controls the shared Path by moving the Theme during the motion. In other words, the Agent has overall motion in directing the motion of the Theme. The Carrier may be a separate entity, or it may be the Agent's body. The Constant_location may be a subregion of the Agent's body or (a subregion of) a vehicle that the Agent uses.

Karl CARRIED the books across campus to the library on his head.

Karl CARRIED the books across campus to the library in his truck.

Karl CARRIED the books across campus to the library by truck.

The truck CARRIED the books across campus to the library in specially designed boxes.

The FEs include Path, Goal, and Source. Area is an area that contains the motion when the path is understood as irregular. This frame empasizes the path of movement as opposed to the FEs Source or Goal as in Filling or Placing.

FEs:

Core:

Agent [Agt]
Semantic Type
Sentient

The Agent is a sentient being who physically controls the movement of the Theme via the carrier, accompanying the Theme.

Karl CARRIED the books across the campus to the library.

Area [Area]

Area is used for descripriona of a general area in which the carrying action takes place when the motion is understood to be irregular or not to consist of a single, linear path.

Carrier [Car]

The Carrier provides support for the Theme. Movement of the Carrier results in movement of the Theme.

The boat FERRIED the troops across the river.

Goal [goa]
Semantic Type Goal

Goal identifies the endpoint of the path.

Karl CARRIED the books to the library.

Path [Path]

Path along which carrying occurs.

Karl CARRIED the books across the campus.

Source [sou]
Semantic Type
Source

Source indicates the beginning of the path along which the Theme travels.

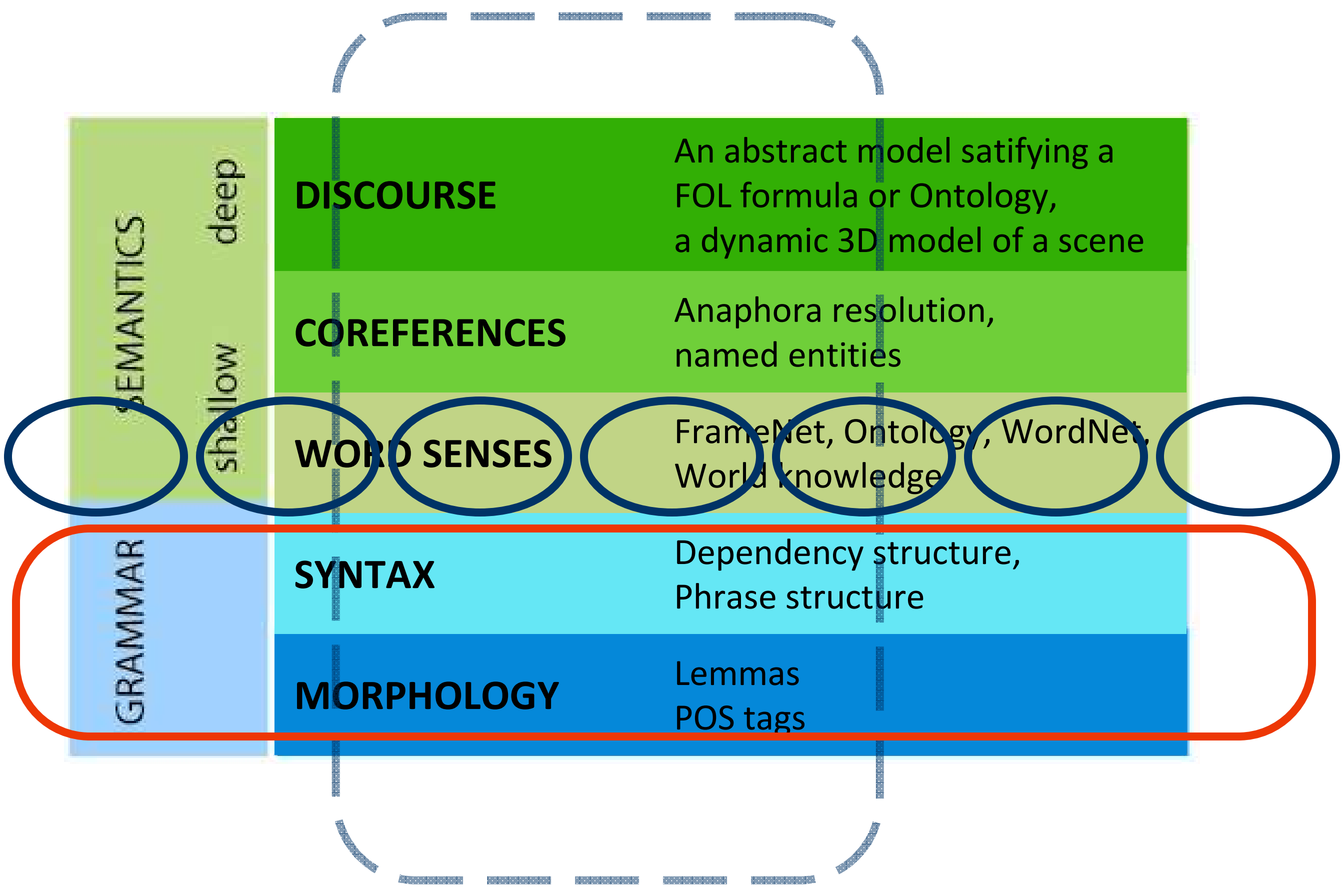
Karl HAULED the books from the library to the office.

Theme [Theme]
Semantic Type
Physical_object

The objects being carried.

Karl TOTED the books to the car.

When FrameNet meets a Controlled Natural Language



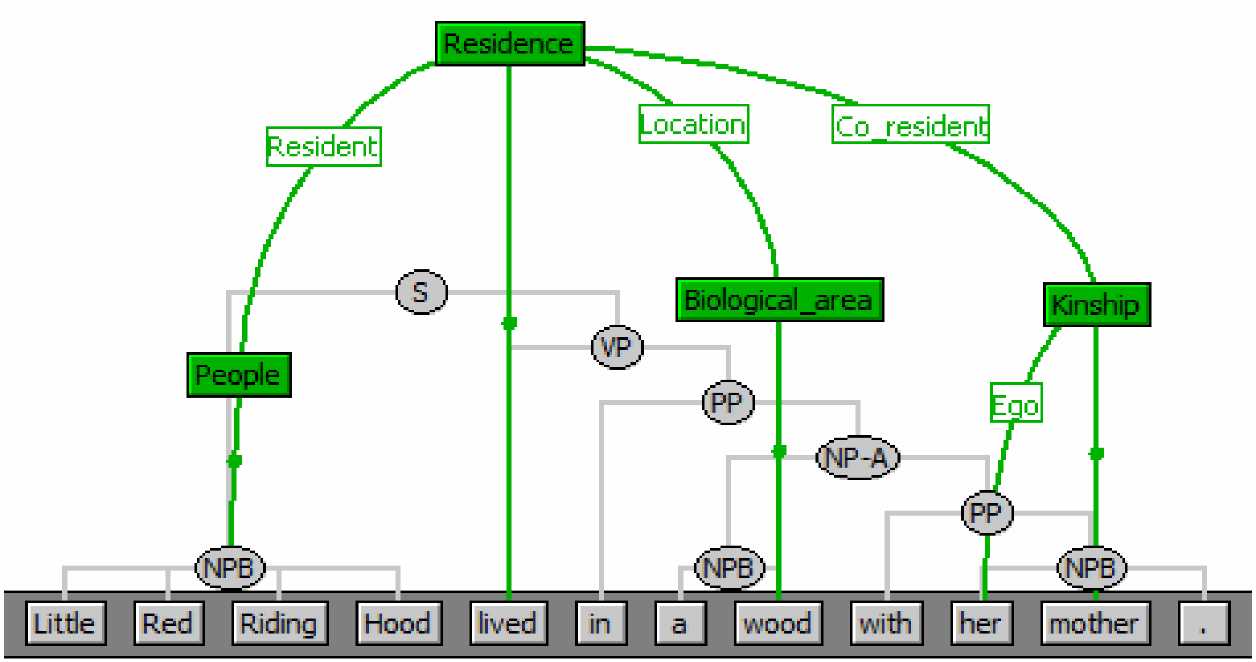
FrameNet defines **wide coverage** coarse-grained word-senses **(focus no verbs)**

Shallow Natural Language Processing **(wide coverage)**

A CNL based on FrameNet would be coarse-grained, but could enable wide coverage deep processing

FrameNet CNL (informal definition)

- **FrameNet CNL:** text that 100% maps into **sequential** FrameNet SITUATION frames (and OBJECT frames)



- **No ambiguity**: fixed terminology lexemes enable **anaphora** resolution and 3D visualisation
- **No temporal/intensional/modal/conditional** operators: *could, if, thus...*
- **No terminology definitions**, assumptions: *apple is a fruit,...*
- **No plural, quantification**

Children at ~3 years generally do not use these unsupported features

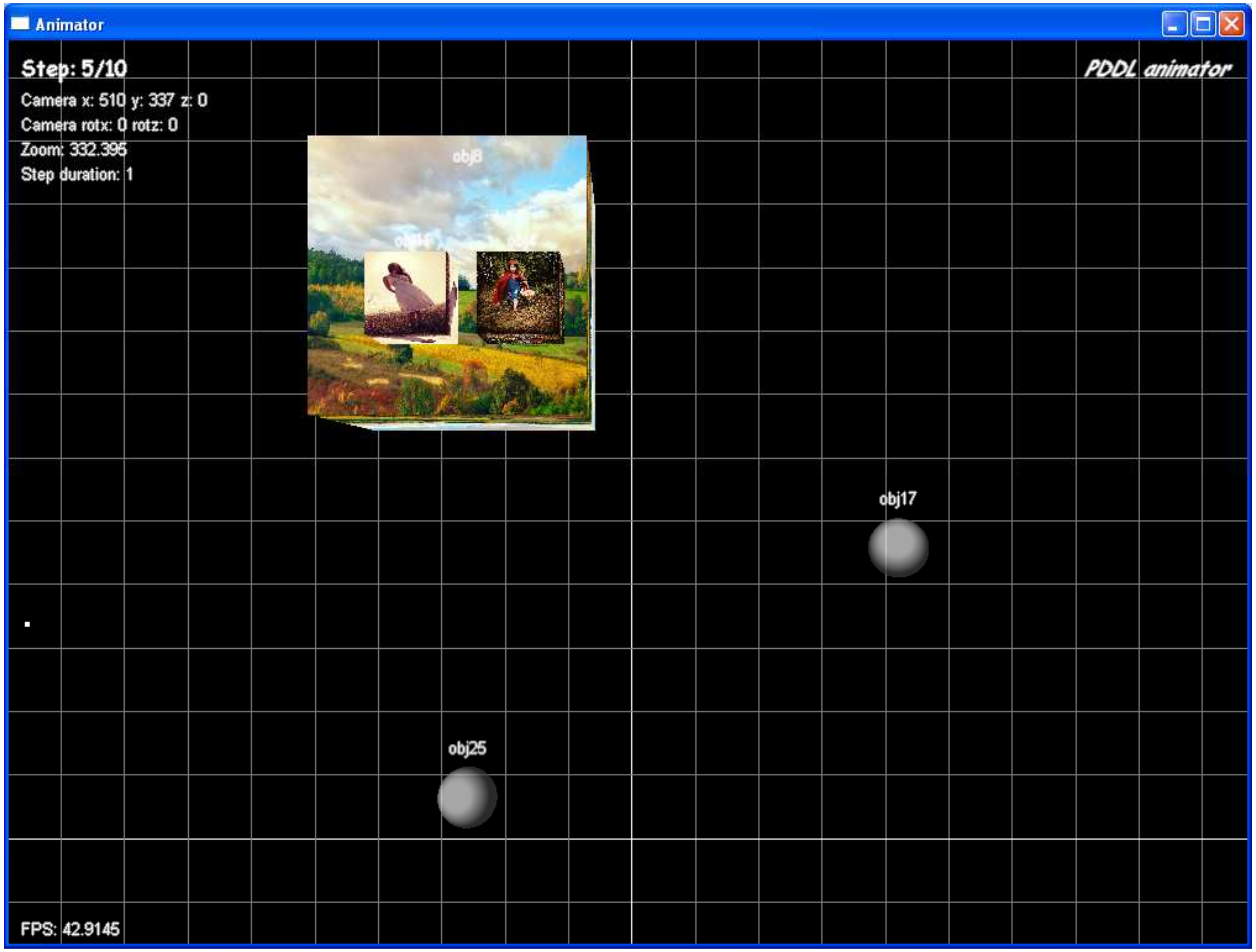
Example of FrameNet CNL text

FrameNet annotation
+ anaphora resolution

1. Little Red Riding Hood
2. lived
3. in a wood
4. with her mother.
5. She baked
6. tasty
7. bread
8. and brought it
9. to her grandmother.

1. **people**
   person=obj4 icon="*littleredridinghood.m3d*"
2. **residence**
   co-resident=obj11 location=obj8 resident=obj4
3. **biological_area**
   locale=obj8 icon="*wood.m3d*"
4. **kinship**
   alter=obj11 ego=obj4 icon="*mother.m3d*"
5. **cooking_creation**
   cook=obj4 food=obj15
6. **chemical_sense_description**
   perception_source=obj15 icon="*tasty.label*"
7. **food**
   food=obj15 icon="*bread.m3d*"
8. **bringing**
   agent=obj4 goal=obj25 theme=obj15
9. **kinship**
   alter=obj25 ego=obj4 icon="*grandmother.m3d*"

Discourse: a Dynamic 3D Scene

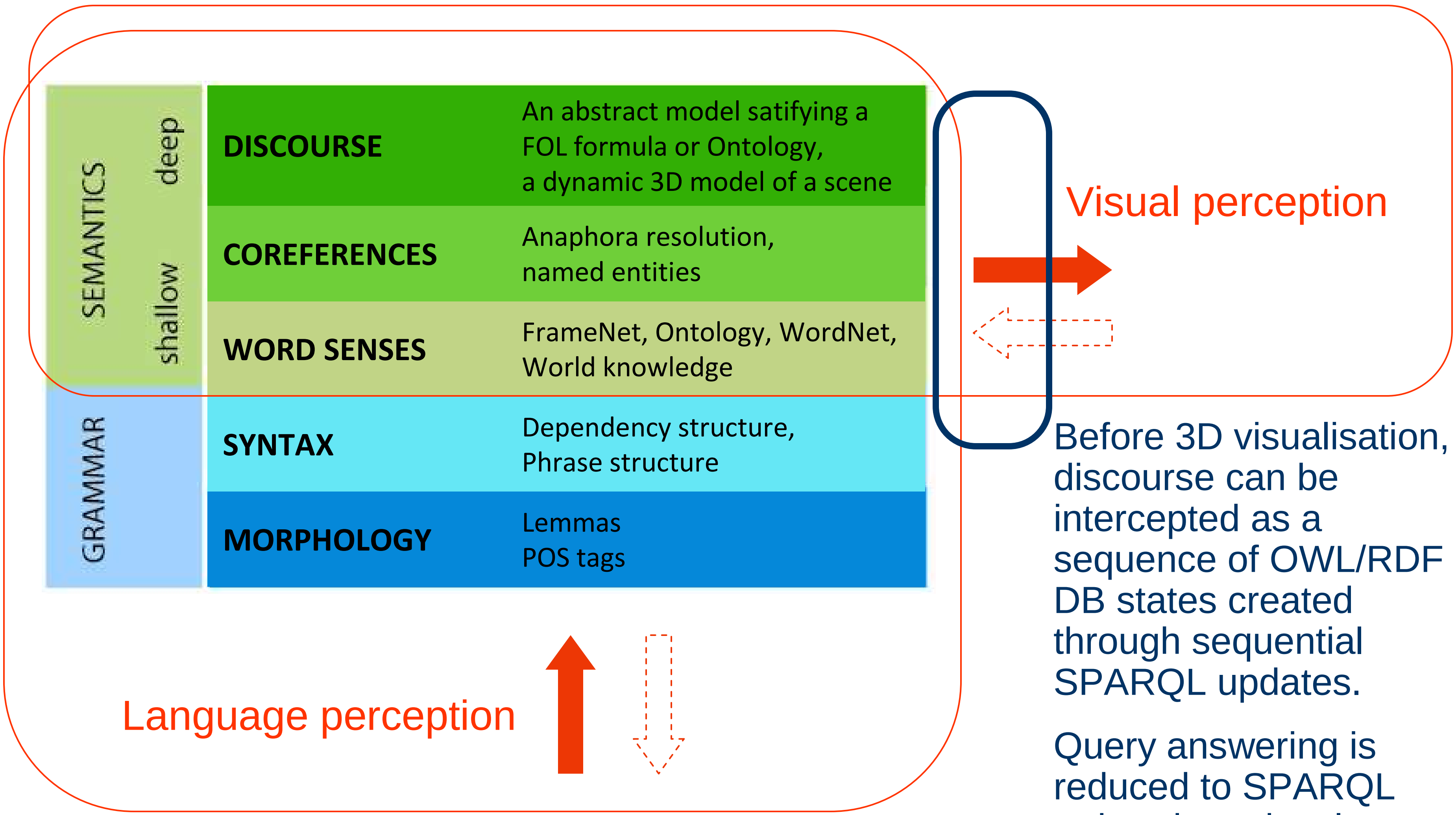


- **Incremental semantic interpretation word-by-word**

Query Answering in FrameNet CNL

- Who delivered bread to a granny?
- Did LittleRedRidingHood visit her granny?
- Where did bread was initially?
- When did the granny got bread?

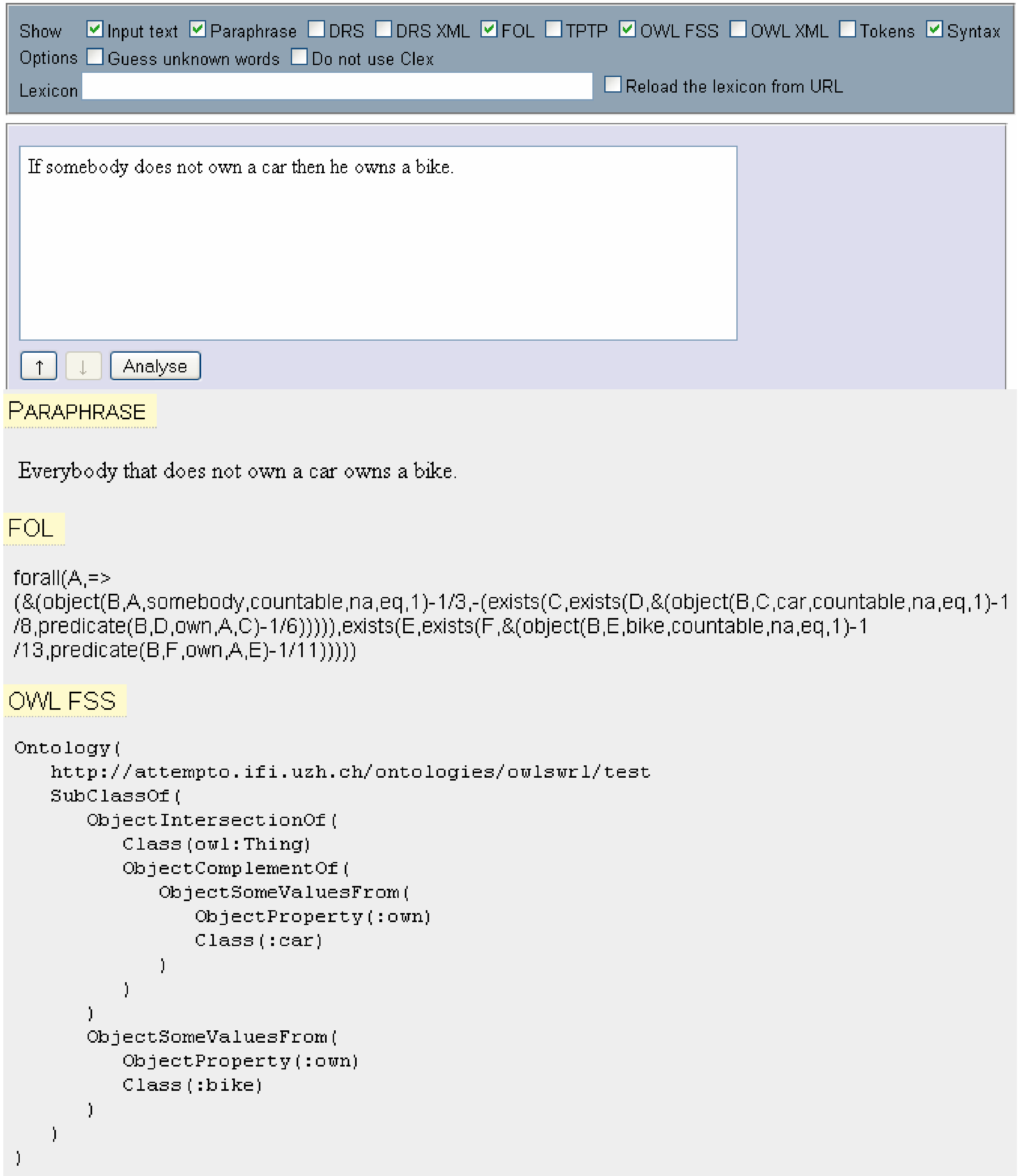
FrameNet CNL → PAO CNL



Before 3D visualisation, discourse can be intercepted as a sequence of OWL/RDF DB states created through sequential SPARQL updates.

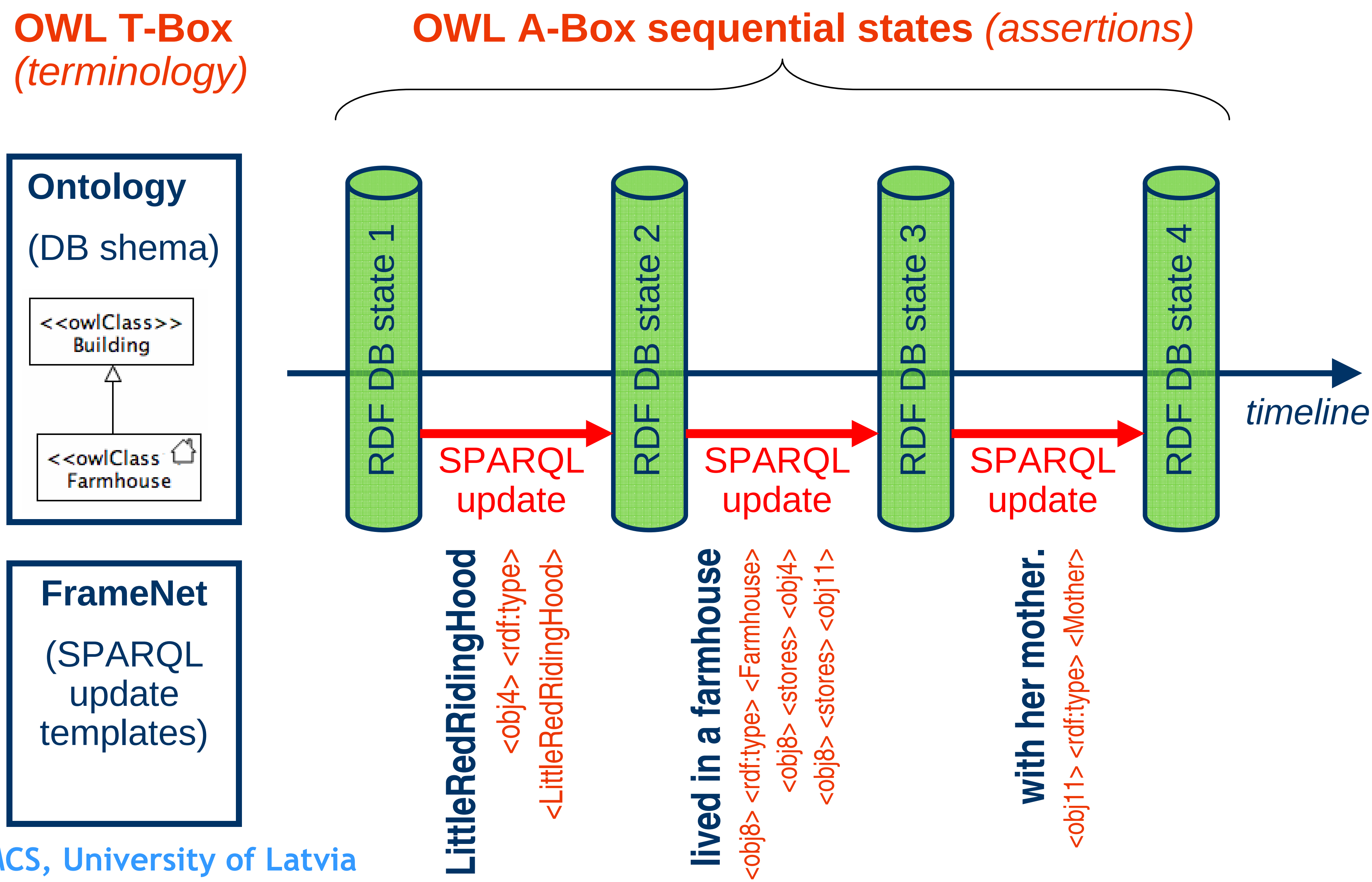
Query answering is reduced to SPARQL rather than visual interpretation

ACE – Attempto Controlled English



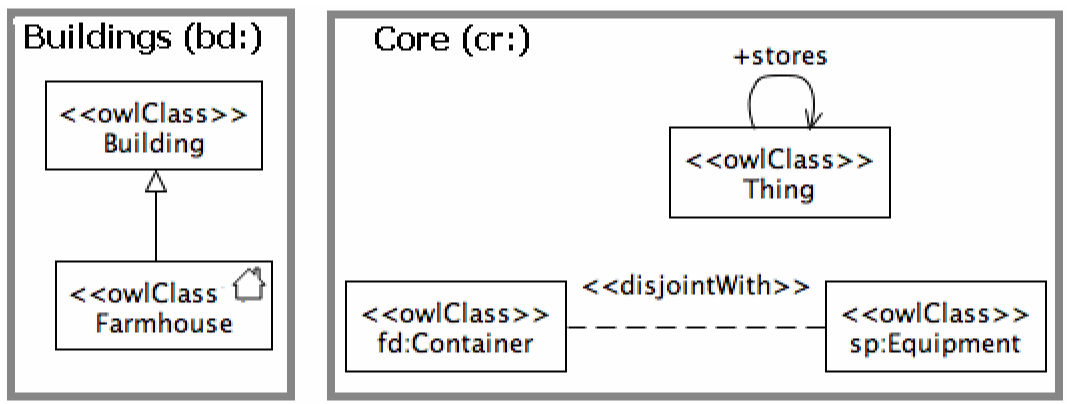
- ACE = logic-based CNL with good tool support for bi-directional translation between CNL and OWL
- PAO = Procedures (FrameNet) + ACE + OWL

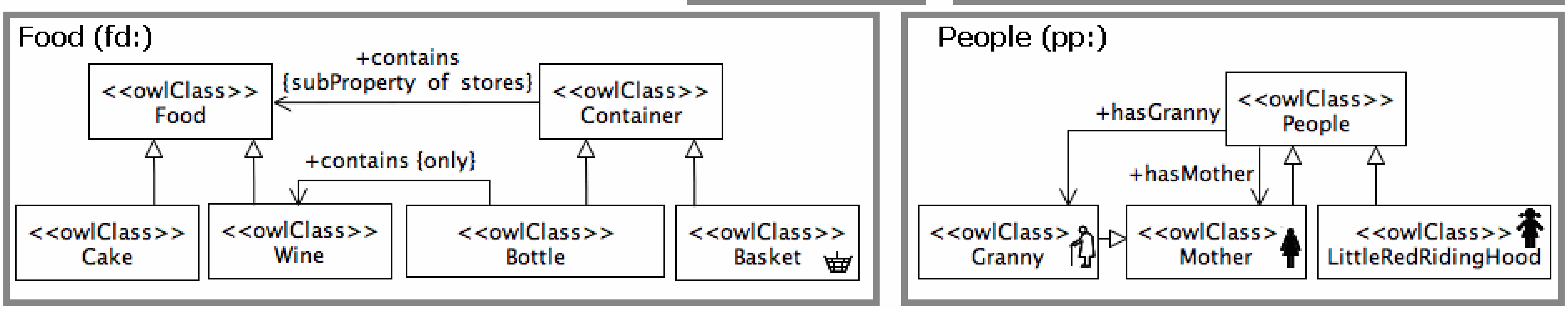
Operational Semantics: PAO CNL



OWL Ontology: terminology classes and properties, their 3D icons

Every Basket is a Container.
Every Bottle is a Container.
Every Cake is a Food.
Every Wine is a Food.
Everything that contains something is a Container.
Everything that is contained by something is a Food.
Everything that is contained by a Bottle is a Wine.
If X contains Y then X stores Y.





FrameNet Frames (PDDL notation – SPARQL update templates)

```
Procedure: Residence
  :parameters (?resident ?co-resident ?location)
  :precondition ()
  :effect (and(stores ?location ?resident)
           (stores ?location ?co_resident))
  :lexicalUnits (camp, inhabit, live, lodge, reside, stay)

Procedure: Removing
  :parameters (?agent ?source ?theme)
  :precondition (stores ?source ?theme)
  :effect (and(stores ?agent ?theme)
           (not(stores ?source ?theme)))
  :lexicalUnits (confiscate, remove, snatch, take, withdraw)

Procedure: Bringing
  :parameters (?agent ?goal ?theme)
  :precondition (and(stores ?agent ?theme)
                 (stores ?a ?agent) (not(= ?a ?goal)))
  :effect (and(stores ?goal ?theme)(stores ?goal ?agent)
           (not(stores ?agent ?theme))
           (not(stores ?a ?agent)))
  :lexicalUnits (bring, carry, convey, drive, haul, take)
```

Role of PDDL and Situation Calculus

- Planning Domain Description Language (PDDL), for STRIPS-like planning problems
  - Developed by Drew McDermott for planning competitions
  - Central concepts are OBJECTS and ACTIONS
  - ACTIONS have *precondition* and *effect*
  - Planning problem: given an initial and *goal* states, find a sequence of actions (*plan*) leading from initial to goal state
- PDDL role in PAO CNL
  - Mapping of OBJECTS and sequential FrameNet SITUATIONS into PDDL language
  - Planning in PAO is needed to fill-in missing actions not explicitly mentioned in the text, but asumed implicitly (e.g., “John eats an apple”, implicitly means that John picked an apple before that)
  - FrameNet situation semantics → situation calculus (PDDL)

Bringing

Definition:

This frame concerns the movement of a Theme and an Agent and/or Carrier. The Agent, a person or other sentient entity, controls the shared Path by moving the Theme during the motion. In other words, the Agent has overall motion in directing the motion of the Theme. The Carrier may be a separate entity, or it may be the Agent's body. The Constant_location may be a subregion of the Agent's body or (a subregion of) a vehicle that the Agent uses.

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Area [Area]	Area is used for descripriona of a general area in which the carrying action takes pla when the motion is understood to be irregular or not to consist of a single, linear path.
Carrier [Car]	The Carrier provides support for the Theme. Movement of the Carrier results in mov of the Theme. The boat FERRIED the troops across the river.
Goal [goa] **Semantic Type** Goal	Goal identifies the endpoint of the path. Karl CARRIED the books to the library.
Path [Path]	Path along which carrying occurs. Karl CARRIED the books across the campus.
Source [sou] **Semantic Type** Source	Source indicates the beginning of the path along which the Theme travels. Karl HAULED the books from the library to the office.
Theme [Theme] **Semantic Type** Physical_object	The objects being carried. Karl TOTED the books to the car.

PDDL:

```
(:action bringing
  :parameters (?agent ?goal ?theme)
  :precondition (and(stores ?agent ?theme)
                 (stores ?a ?agent) (not(= ?a ?goal)))
  :effect (and(stores ?goal ?theme)(stores ?goal ?agent)
           (not(stores ?agent ?theme))
           (not(stores ?a ?agent)))
  :lexicalUnits (bring, carry, convey, drive, haul, take)
```

SPARQL:

```
MODIFY
DELETE {<obj4> <stores> <obj15>.
     ?a <stores> <obj4>}
INSERT {<obj25> <stores> <obj15>.
     <obj25> <stores> <obj4>}
WHERE {?a <stores> <obj4>.
  FILTER (?a != <obj25>)}
```

PAO Paraphrase and SPARQL Updates Sequence

LittleRedRidingHood lives in a farmhouse with her mother.
She takes a basket from the farmhouse and carries it to her granny.

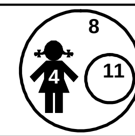
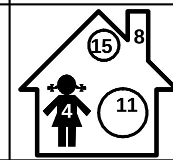
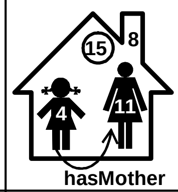
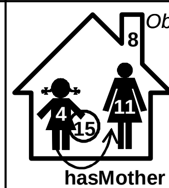
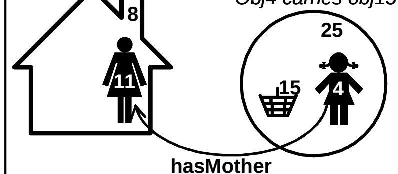
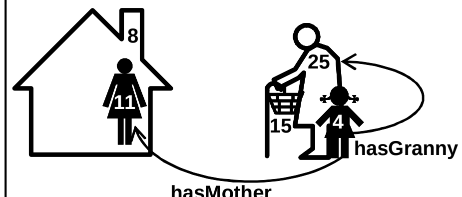
A. Ob4 is a LittleRedRidingHood
B. Obj4 lives in obj8 with obj11.
C. Obj8 is a farmhouse.
D. Obj4 hasMother obj11.
E. Obj4 removing-takes obj15 from obj8.
F. Obj15 is a food-basket.
G. Obj4 carries obj15 to obj25.
H. Obj4 hasGranny obj25.

	EXPLICIT STATEMENTS	IMPLICIT STATEMENTS BY ENTAILMENT AND PLANNING
A	INSERT {<obj4> <rdf:type> <pp:LittleRedRidingHood>}	
B	**INSERT {<obj8> <stores> <obj4>. <obj8> <stores> <obj11>}**	
C	INSERT {<obj8> <rdf:type> <bd:Farmhouse>}	INSERT {<obj8> <stores> <obj15>} *Inserted by planning because of procedural template precondition at step E.*
D	INSERT {<obj4> <pp:hasMother> <obj11>}	INSERT {<obj11> <rdf:type> <pp:Mother>} *Entailed by range of the property pp:hasMother.*
E	**DELETE {<obj8> <stores> obj15}** **INSERT {<obj4> <stores> <obj15>}**	
F	INSERT {<obj15> <rdf:type> <fd:Basket>}	
G	**DELETE {<obj4> <stores> <obj15>. ?a <stores> <obj4>}** **INSERT {<obj25> <stores> <obj15>. <obj25> <stores> <obj4>}** **WHERE {?a <stores> <obj4>. FILTER (?a != <obj25>)}**	
H	INSERT {<obj4> <pp:hasGranny> <obj25>}	INSERT {<obj25> <rdf:type> <pp:Granny>} *Entailed by range of the property pp:hasGranny.*

PAO Discourse: RDF DB states

RDF DB states discourse format can be used in two ways:

- Dynamic 3D visualisation
- Query answering via SPARQL

A	<obj4> <type> <LittleRedRidingHood>.	 Obj4 is a LittleRedRidingHood.
B	<obj4> <type> <LittleRedRidingHood>. <obj8> <stores> <obj4>. <obj8> <stores> <obj11>.	 Obj4 lives in obj8 with obj11.
C	<obj4> <type> <LittleRedRidingHood>. <obj8> <stores> <obj4>. <obj8> <stores> <obj11>. <obj8> <type> <farmhouse. <obj8> <stores> <obj15>	 Obj8 is a farmhouse.
D	<obj4> <type> <LittleRedRidingHood>. <obj8> <stores> <obj4>. <obj8> <stores> <obj11>. <obj8> <type> <farmhouse>. <obj4> <hasMother> <obj11>. <obj11> <type> <mother>. <obj8> <stores> <obj15>	 Obj4 hasMother Obj11.
E	<obj4> <type> <LittleRedRidingHood>. <obj8> <stores> <obj4>. <obj8> <stores> <obj11>. <obj8> <type> <farmhouse>. <obj4> <hasMother> <obj11>. <obj11> <type> <mother>. <obj4> <stores> <obj15>	 Obj4 removing-takes obj15 from obj8.
F	<obj4> <type> <LittleRedRidingHood>. <obj8> <stores> <obj4>. <obj8> <stores> <obj11>. <obj8> <type> <farmhouse>. <obj4> <hasMother> <obj11>. <obj11> <type> <mother>. <obj4> <stores> <obj15> <obj15> <type> <food-basket>	 Obj15 is a food-basket.
G	<obj4> <type> <LittleRedRidingHood>. <obj25> <stores> <obj4>. <obj8> <stores> <obj11>. <obj8> <type> <farmhouse>. <obj4> <hasMother> <obj11>. <obj11> <type> <mother>. <obj25> <stores> <obj15>. <obj15> <type> <food-basket>.	Obj4 carries obj15 to obj25. 
H	<obj4> <type> <LittleRedRidingHood>. <obj25> <stores> <obj4>. <obj8> <stores> <obj11>. <obj8> <type> <farmhouse>. <obj4> <hasMother> <obj11>. <obj11> <type> <mother>. <obj25> <stores> <obj15>. <obj15> <type> <food-basket>. <obj4> <hasGranny> <obj25>. <obj25> <type> <granny>	Obj4 hasGranny Obj25. 

Query Answering in PAO

1. Who delivered a basket to a granny?
2. Did LittleRedRidingHood visit her granny?
3. Where initially was the basket?
4. When did the granny got the basket?

1.
```
SELECT ?x
WHERE-AT-STEP(?n) {?w <stores> ?x. ?x <stores> ?y.}
WHERE-AT-STEP(?n+1) {
  ?z <stores> ?x. ?z <stores> ?y.
  ?y <rdf:type> <fd:Basket>.
  ?z <rdf:type> <pp:Granny>}
```
ANSWER: ?x = obj4

2.
```
SELECT * WHERE-AT-STEP(any) {
  ?z <stores> ?x.
  ?x <rdf:type> <pp:LittleRedRidingHood>.
  ?z <rdf:type> <pp:Granny>}
```
ANSWER: yes

3.
```
SELECT ?x WHERE-AT-STEP(min) {
  ?x <stores> ?y.
  ?y <rdf:type> <fd:Basket>}
```
ANSWER: ?x = obj8

4.
```
SELECT ?n WHERE-AT-STEP(?n) {
  ?y <stores> ?x.
  ?x <rdf:type> <fd:Basket>.
  ?y <rdf:type> <pp:Granny> }
```
ANSWER: ?n = H

Query Answering in PAO

1. Who delivered a basket to a granny?

   LittleRedRidingHood [*delivered a basket to granny*].

   ANSWER: ?x = obj4

2. Did LittleRedRidingHood visit her granny?

   Yes [, *LittleRedRidingHood visited granny*].

   ANSWER: yes

3. Where initially was the basket?

   [*Basket initially was*] *in the farmhouse.*

   ANSWER: ?x = obj8

4. When did the granny got the basket?

   In step H [, *when LittleRedRidingHood brought the basket to granny*].

   ANSWER: ?n = H

Dynamic 3D Visualisation with Physics Simulation

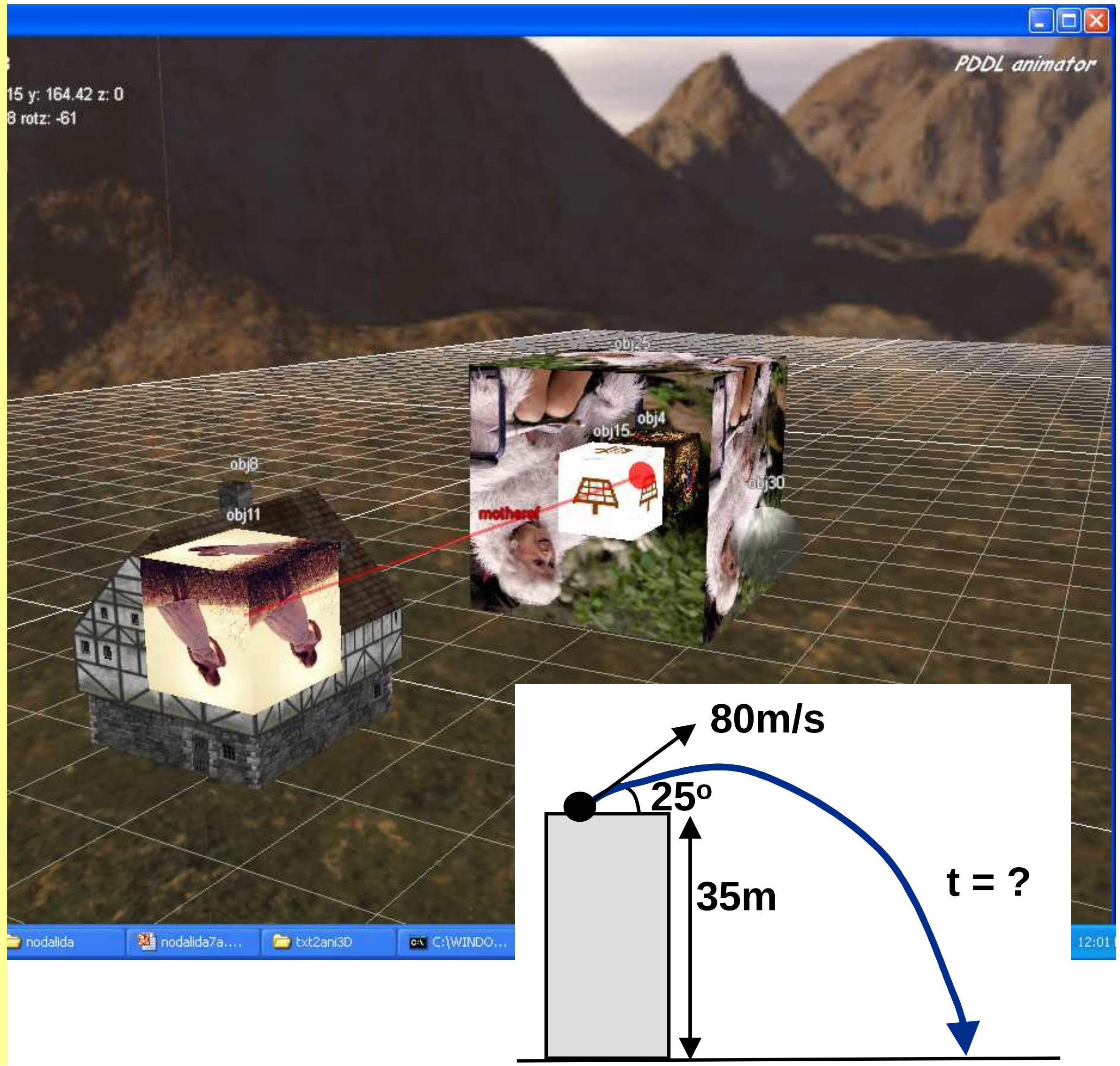
A question from the Advanced Placement Exam in physics:

A ball is thrown upward from the top of a 35m tower with an initial velocity of 80 m/s at an angle of 25 degrees. Find the time the ball is in the air.

Restated in controlled English (CPL):

A ball is thrown. The initial vertical position of the throw is 35 m. The initial velocity of the throw is 80 m/s. The direction of the initial velocity of the throw is 25 degrees. The final vertical position of the throw is 0 m. What is the duration of the throw?

$$d = vt - \left(\frac{1}{2}\right) \cdot gt^2$$



Conclusion

- PAO (FrameNet) CNL is not yet formally defined, nor implemented apart from the informal examples demonstrated
- FrameNet has a great potential for creating a coarse-grained wide coverage CNL for deep semantic processing at discourse level
- Some limitations of the proposed approach are listed on Slide 11.(e.g. only simple sequence of events in the discourse currently supported)

Thank you!