Broad Coverage Spatial Language Understanding

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Outline

- Context and Disclaimers
- The TRIPS Language Understanding System
- Scales
- Spatial Ontology
- Examples of use

Context and Disclaimers

What is Deep understanding?

Students develop **deep** understanding when they grasp the relatively complex relationships between the central concepts of a topic or discipline. Instead of being able to recite only fragmented pieces of information, they understand the topic in a relatively systematic, integrated or holistic way. As a result of their deep understanding, they can produce new knowledge by discovering relationships, solving problems, constructing explanations and drawing conclusions.

Students have only **shallow** understanding when they do not or cannot use knowledge to make clear distinctions, present arguments, solve problems or develop more complex understanding of other related phenomena.

DEPT. OF EDUCATION, QUEENSLAND

IN OTHER WORDS,
CONNECTING LANGUAGE TO OTHER COGNITIVE ABILITIES:
KNOWLEDGE, REASONING, ACTION, LEARNING, ...

SAME WITH MACHINES - DEEP UNDERSTANDING PRODUCES MEANING THAT IS USABLE FOR MULTIPLE TASKS, INCLUDING REASONING & EXPLANATION

The Goal of The TRIPS Parser

- Broad-coverage parsers are inevitably shallow
  - essentially syntax (possibly with superficial predicate-argument structure)
- Deep semantic parsers are inevitably narrow
  - produce "deep" semantics for the domain they are trained on
  - but little transfer to new domains

	Broad Coverage	Narrow Coverage
Shallow Representation	structural parsers	
Deep Representation	?	semantic parsers

Can we achieve broad AND deep semantic parsing?

Understanding Requires Context

At a grocery store ...

Customer: *black beans?*

clerk: *aisle 3.*

TO UNDERSTAND AN UTTERANCE, WE NEED TO UNDERSTAND ***WHY*** SOMEONE IS SPEAKING TO US, I.E.,

INTENTION RECOGNITION

BUT IN A HOME ENVIRONMENT...

When arriving home ...

Spouse: *black beans?*

You: *Oh, sorry, I forget to get them.*

When cooking ...

Spouse: *black beans?*

You: *in the cupboard.*

When exploring nutrition options ...

Spouse: *black beans?*

You: *227 calories in a cup*

When cooking (adding black beans to a pot) ...

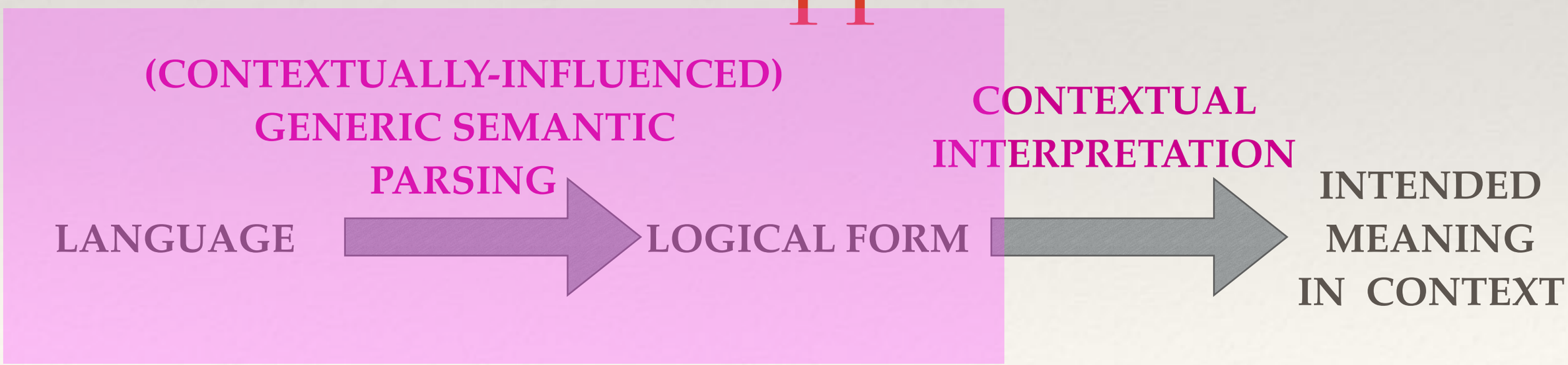
Spouse: *black beans?*

You: *don't you like them.*

The Dilemma

- Language technology is heavily based on interpreting structure
- But full understanding requires reasoning in context

Our Approach



A PRACTICAL MIDDLE GROUND

Requirements for the Logical Form

- *"universal vocabulary"*
  - there is one set of words and senses drawn from a generic ontology for all domains (except domain-specific technical vocabulary)
- *"no word left behind"*
  - we don't know what may be critical in contextual interpretation later
- *"meaning for everyone"*
  - all words should map into an ontology used for reasoning
- *"preserve all detail and subtleties of phrasing"*
- *"retain ambiguity whenever possible"*
  - quantifier scoping
  - abstract word senses
- *"prefer compositional structures over idiosyncratic meanings"*
  - especially with multi-words

How are spatial concepts used in language?

MIGHT BE EASIER TO ANSWER

"WHAT IN LANGUAGE IS NOT COUCHED IN SPATIAL CONCEPTS!"

ENGLISH IS STRUCTURED AROUND WORDS
THAT HAVE SPATIAL INTERPRETATIONS:

Space invades every part of speech

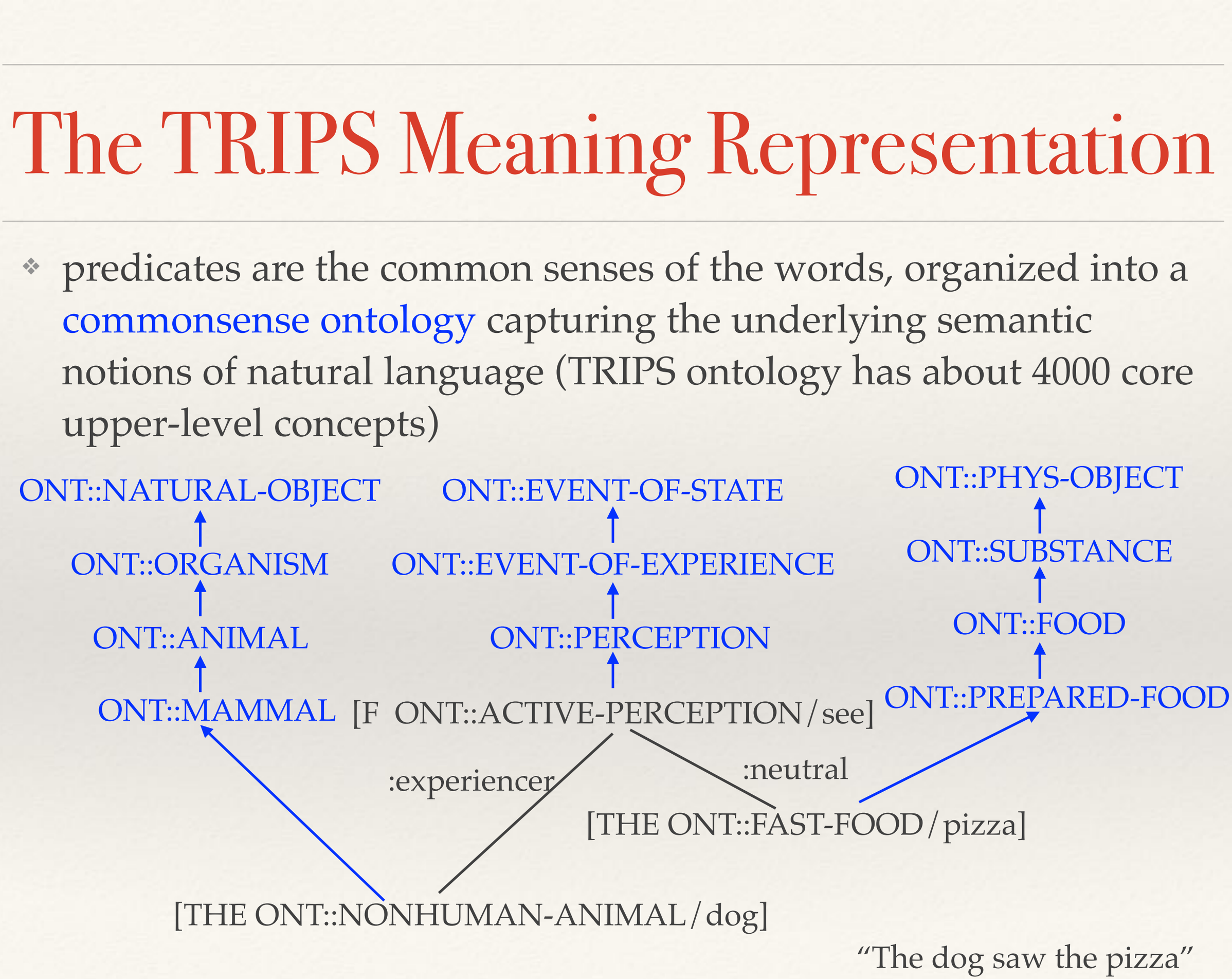
- PREPOSITIONS: in, on, out, by, beside, …
- ADJECTIVES: near, close, adjacent, high, tall, …
- VERBS: touching, supporting, covering, …
- NOUNS: height, width, size, area, …

How are all these related to each other?

The TRIPS Logical Form

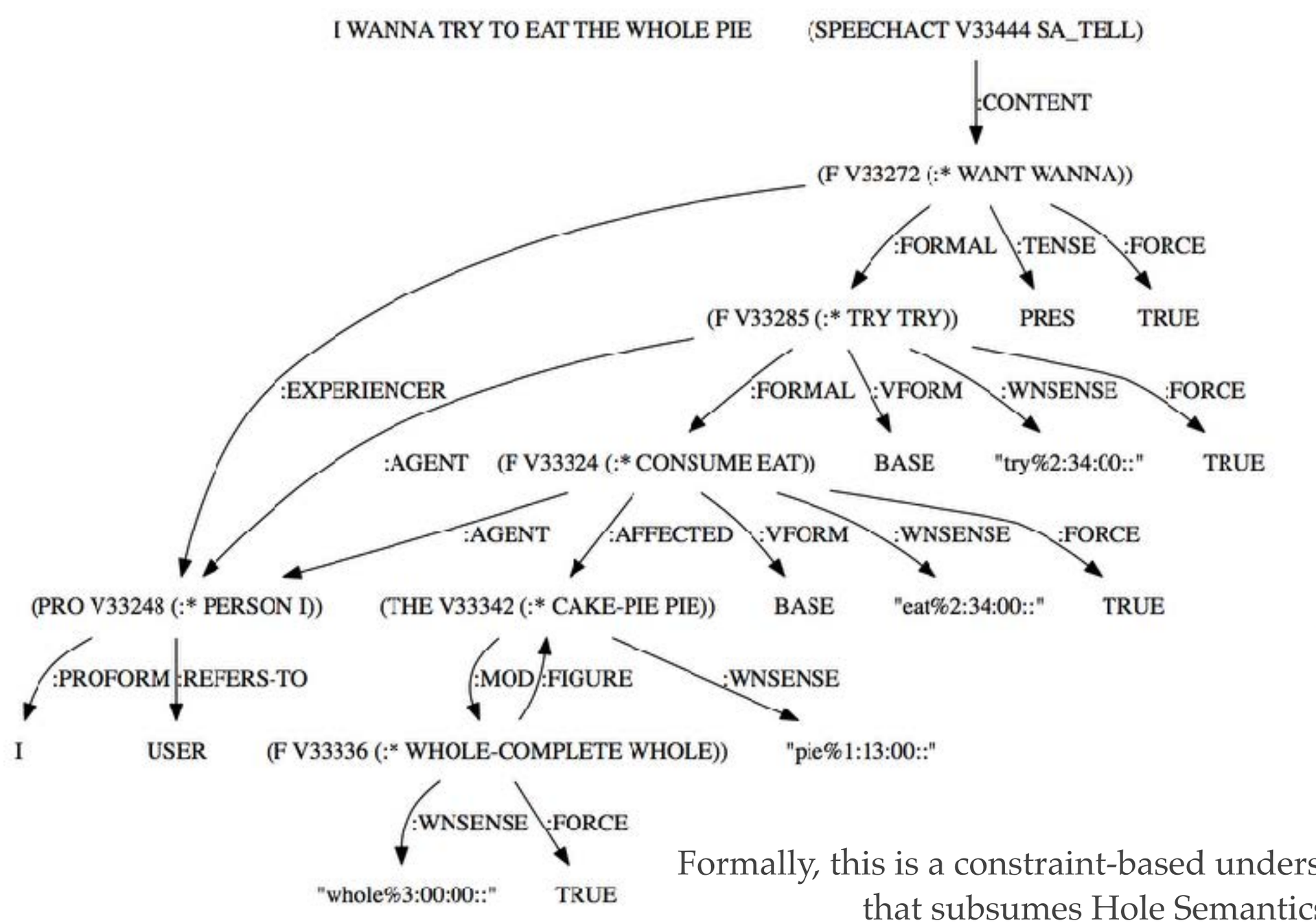
The TRIPS Meaning Representation

- predicates are the common senses of the words, organized into a commonsense ontology capturing the underlying semantic notions of natural language (TRIPS ontology has about 4000 core upper-level concepts)



"The dog saw the pizza"

The TRIPS Meaning Representation



CONTENT WORDS)

ORD SENSE

ES

AL/SCOPING LINKS

Formally, this is a constraint-based underspecified representation that subsumes Hole Semantics and MRS,

Manshadi, Gildea & Allen, Computational Linguistics

A fragment of the event ontology

ONTOLOGY TYPE	ROLES (INHERITED, NEW)	EXAMPLE VERBS
SITUATION-ROOT		
EVENT-OF-CHANGE		
EVENT-OF-ACTION	AGENT	
EVENT-OF-AGENT-INTERACTION	AGENT, AGENT1	meet, collaborate,...
AGREEMENT	AGENT, AGENT1, FORMAL	agree, confirm, ..
EVENT-OF-CREATION	AGENT, AFFECTED	bake, establish, ...
EVENT-OF-CAUSATION	AGENT, AFFECTED	push, control, ...
MOTION	AGENT, AFFECTED, RESULT	go, disperse, ...
ACQUIRE	AGENT, AFFECTED, SOURCE	adopt, buy, ...
EVENT-OF-UNDERGOING-ACTION	AFFECTED	die, inherit, ...
EVENT-OF-STATE	NEUTRAL	
POSITION	NEUTRAL, NEUTRAL1	contain, surround, …
EVENT-OF-EXPERIENCE	NEUTRAL, EXPERIENCER	see, like, …
AWARENESS	NEUTRAL, EXPERIENCER, FORMAL	believe, suspect, …

Ontology Types, Roles & Restrictions

ONT::CONSUME
  SEM: [Situation aspect=dynamic, time-span=extended, …]
  ROLES:
    AGENT {required} [Phys-obj origin=living, …]
    AFFECTED {required} [Phys-obj comestible=+, …]
  WordNet: consume%2:34:00, have%2:34:00, …

ONT::ANIMAL
  SEM: [Phys-obj origin=living, …]

ONT::DEVICE
  SEM: [Phys-obj origin=artifact, …]

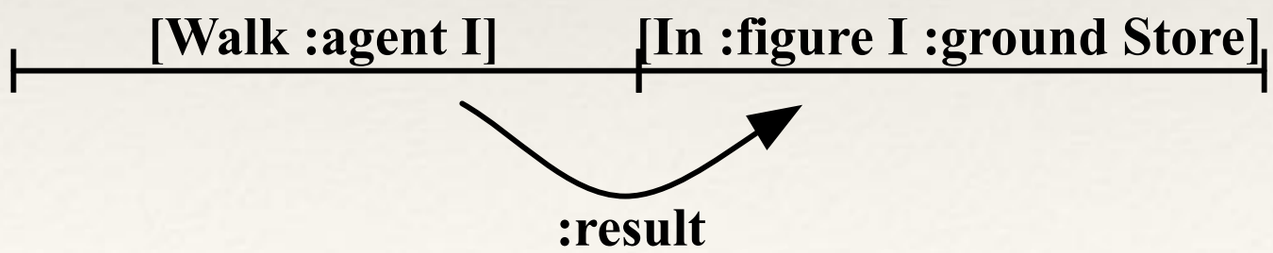
Arguments vs Relational Roles

- Argument roles identify arguments in a a predicate:
  - e.g., *PUSH(e) &* ***agent****(e,ag) &* ***affected****(e, aff)* in a Davidsonian-style representation
- Relational roles are causal/temporal relations between predicates

Ev(e) & agent(e, ag) & ***result****(e, p) & Occurs(e,t) =>*

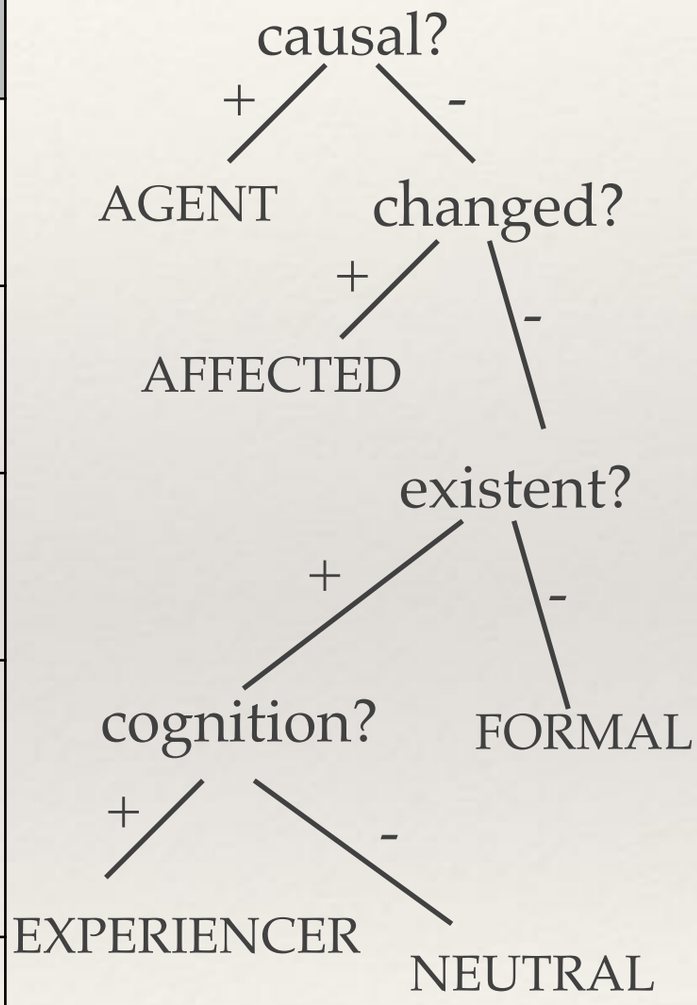
Meets(t, t') & Holds(p,t') & figure(p, ag)

- e.g., "I walked into the store" in a picture ….



TRIPS CORE SEMANTIC ROLES

Role	*Distinguishing Properties*	*Definition*	*Examples*
AGENT	+CAUSAL	Entity that plays a causal or initiating role as part of the event meaning	The boy told a story The hammer broke the window The storm destroyed the house
AFFECTED	-CAUSAL +CHANGED	(non-causing) Entity that is changed as part of the meaning the event	He carried the package The ice melted The ball hit the wall
NEUTRAL	-CAUSAL -CHANGED +EXISTENT	Acausal argument, neither causing nor changed by the event, but which has existence	I saw him I want a pizza I told him a story
EXPERIENCER	- CAUSAL - CHANGED +COGNITION +EXISTENT	An entity undergoing a cognitive or perceptual state	The man knows the plan The dog saw the cat
FORMAL	-CAUSAL -CHANGED -EXISTENT	Acausal argument with no temporal existence	He believes that the money's gone I want to go He seems crazy



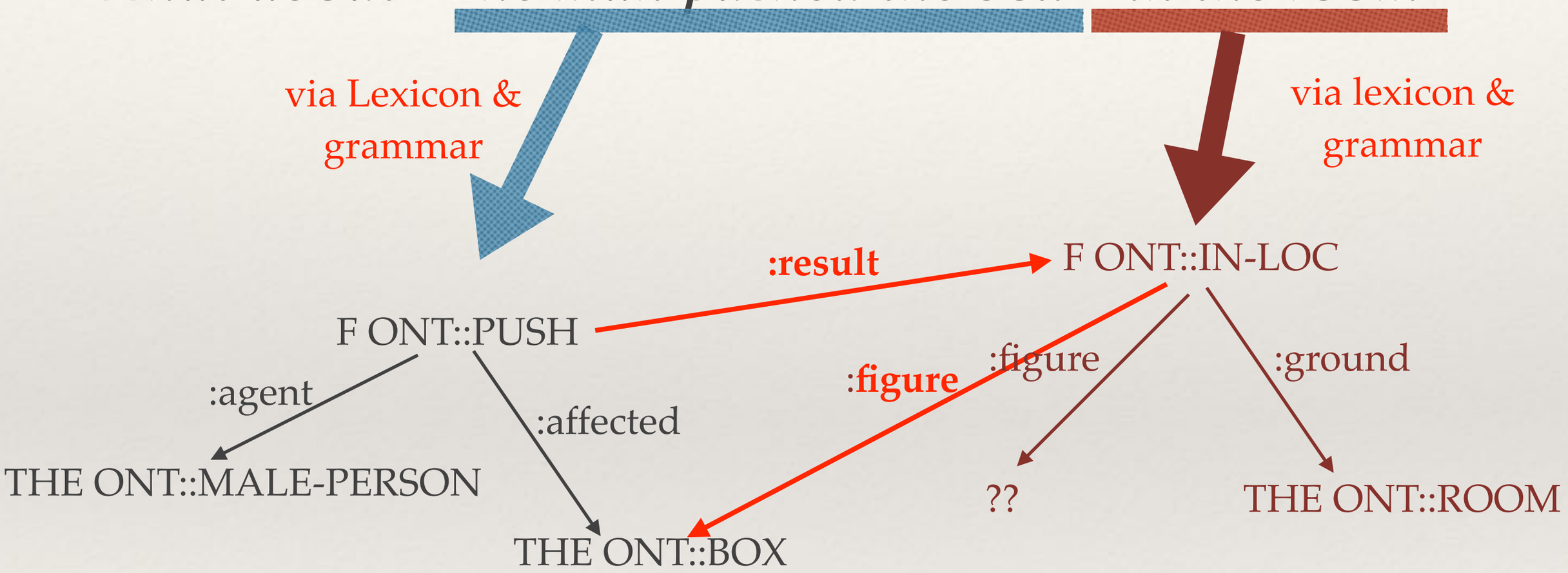
Semantic properties of some relational roles

Relational Role	Verb arguments	Figure of role prop'n	Temp. Relation between e & r	Example
RESULT	agent only	agent	t_e meets t_{result}	I walked into the store
RESULT	agent + affected	affected	t_e meets t_{result}	I pushed the box in the corner
SOURCE*	agent + affected	affected	t_{source} overlaps t_e	I pushed the box from the shelf
TRANSIENT -RESULT*	agent	agent	$t_{tresult}$ during t_e	I walked by the tree
METHOD	agent (+ others)	agent	t_e equals t_{method}	I moved the box by pushing it
LOCATION	any	event	n/a	I ran at the gym
MANNER	any	event	n/a	I ran quickly

** also has the second variant as with RESULT*

The Resultative Construction(s)

What about "The man pushed the box in the room"



Complex Logical Forms built by Constructions

Lexical Approach: *the lexical entry contains the entire set of subcategorization frames*

e.g., VerbNet entries for "push"

CARRY-11.4 (11 frames)

FORCE-59 (4 frames)

FUNNEL-9.3 (4 frames)

HOLD-15-1 (2 frames)

PUSH-12 (4 frames)

SPLIT-23.2 (6 frames)

TRIPS: two senses + a few templates

ONT::PUSH

agent-affected-templ

- "We pushed the cat"

ONT::PROVOKE

agent-formal-objectcontrol

- "We pushed him to do it"

All the other VerbNet senses correspond to one of these two + a spatial result

Other Resultative Constructions

- Resultative with Transitive Verbs
  - They wiped the desk clean
  - Sweep the dust into the bin
  - He pushed it flat
- Resultative is intransitive
  - The water froze solid
  - I walked in the store
- Resultative with particles
  - Lay the box down
  - Lay down the box in the corner (2 results)
  - Lay the box down in the corner (2 results)
  - Lay the box in the corner down (1 result)
- Intransitive to transitive+result (our favorite!)
  - The dog barked the cat up the tree

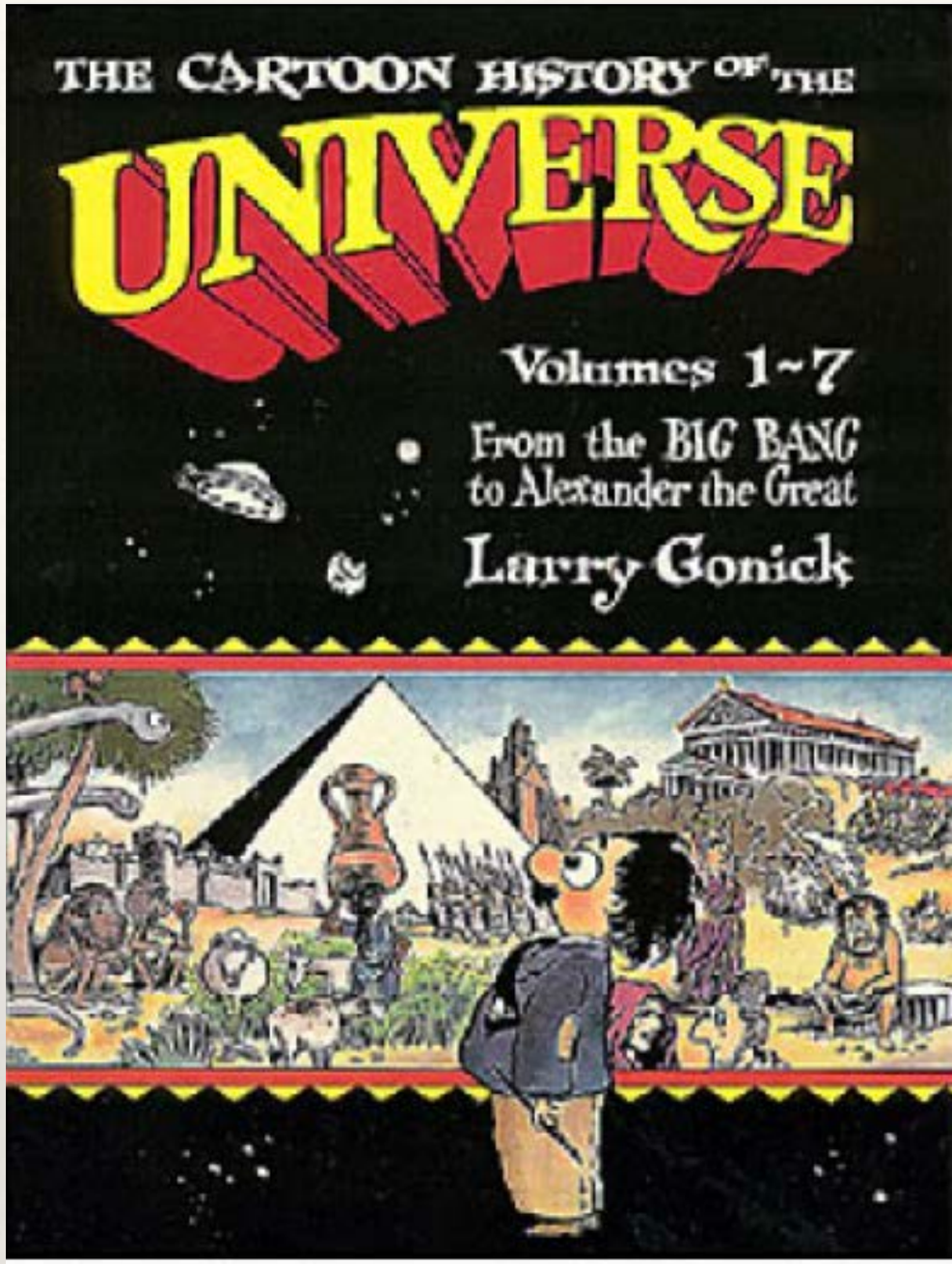
NOTE: Selecting of these rules over other interpretations requires commonsense knowledge about what states events typically cause:

e.g., ***They wiped the table clean***

vs

They wiped the table happy

Scales
(the cartoon version)



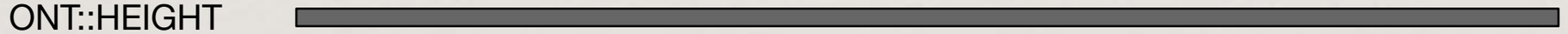
How do the different spatial concepts conveyed by
the different parts of speech relate to each other?

for formulas, see

Allen, J. and C. M. Teng (2013). Becoming Different: A Language-driven formalism for commonsense knowledge. CommonSense: 11th Intl Symp on Logical Formalization on Commonsense Reasoning, Cypress

Scales

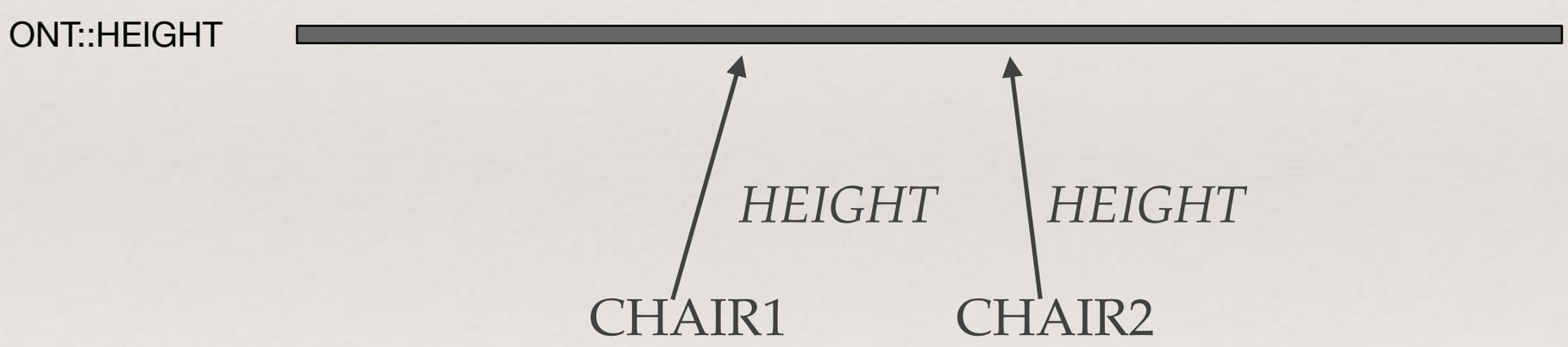
In the beginning, there was a scale ….



Scales are a conceptual organization of a set of values
that can be compared (e.g., taller)
sometimes quantifiable (e.g., 5 feet high)

Scales

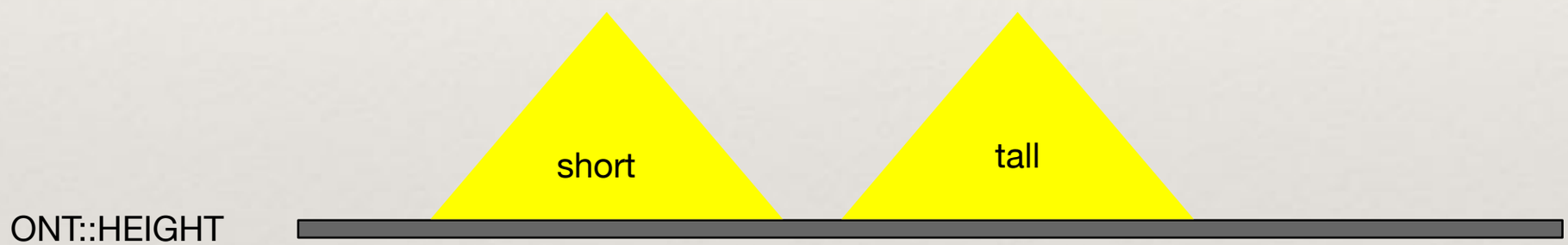
Scales have a characteristic function that maps objects to the scale



CHAIR2 is taller than CHAIR1

Scales

properties (i.e., adjectives) are associated with a range of values ….



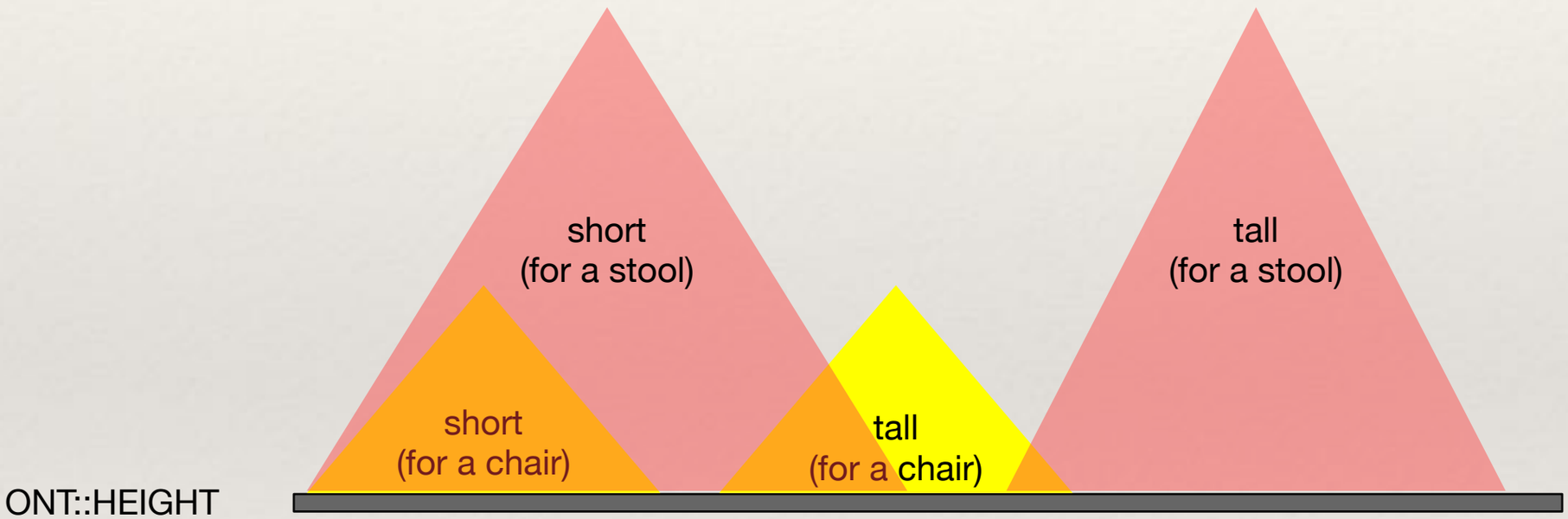
Scales

properties may overlap …

consider “short but not tiny”

Scales

properties may be relative to a reference class of objects …



consider “tall for a chair but not for a stool”

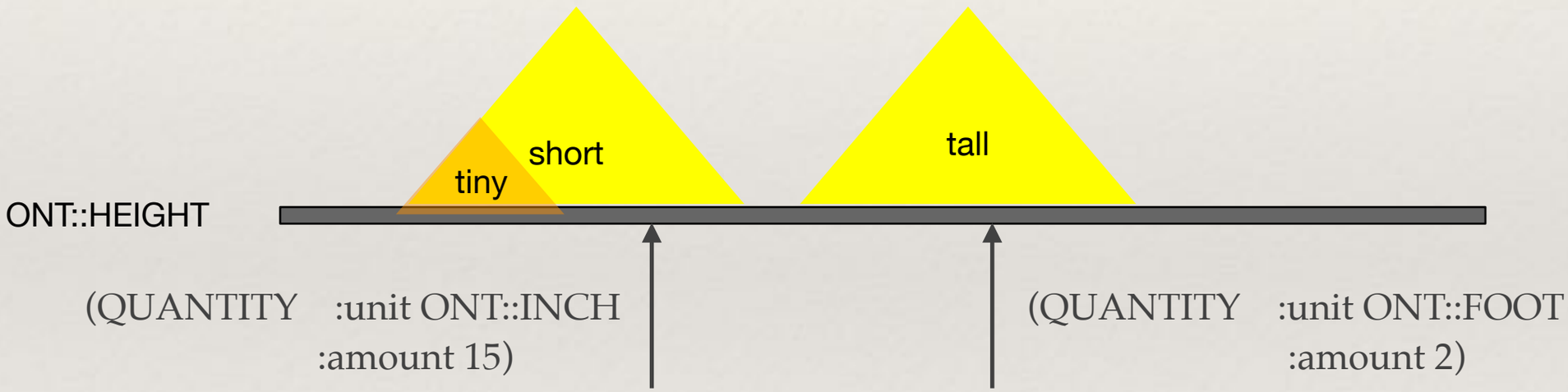
Scales

scales may also be defined in terms of another object (GROUND)

e.g., “the chair is close to the door”

Scales

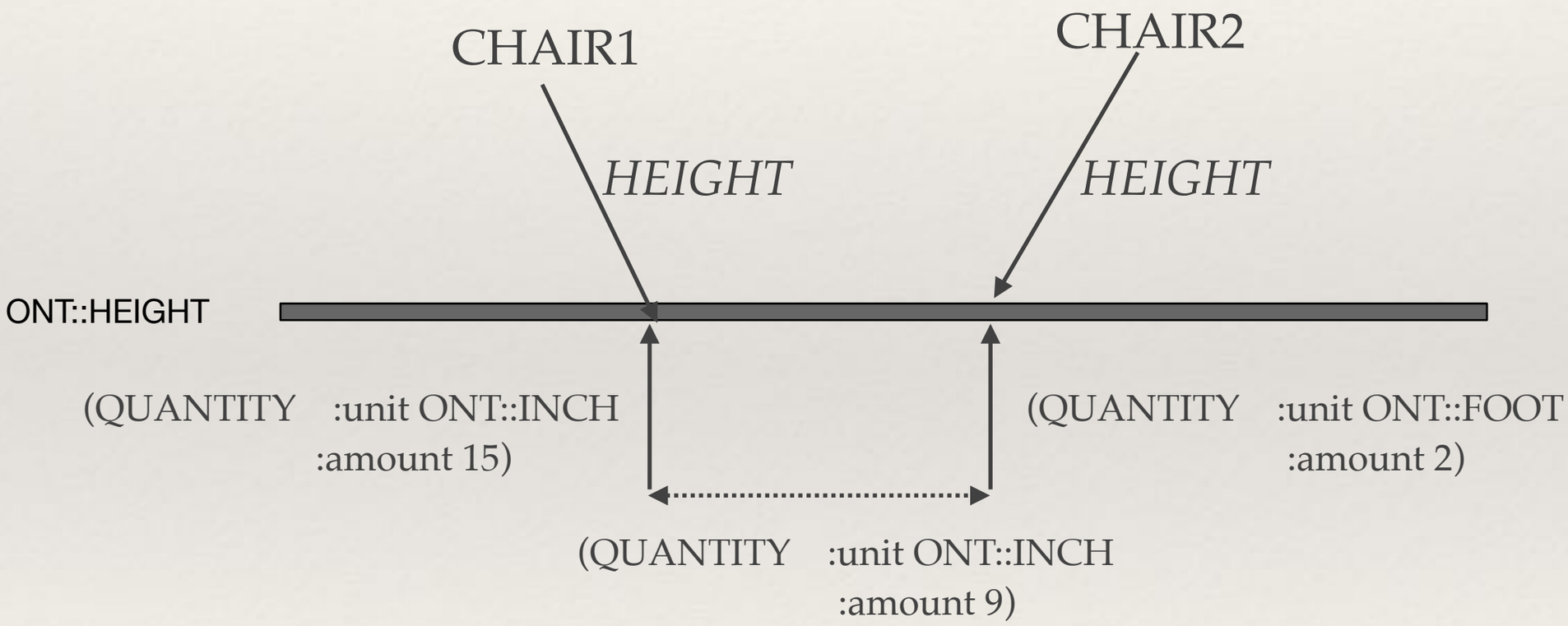
scales may be quantifiable using measure phrases



e.g., “the chair is 15 inches tall”

Scales

scales support comparison operators: a objected is compared with with another (the COMPAR object)

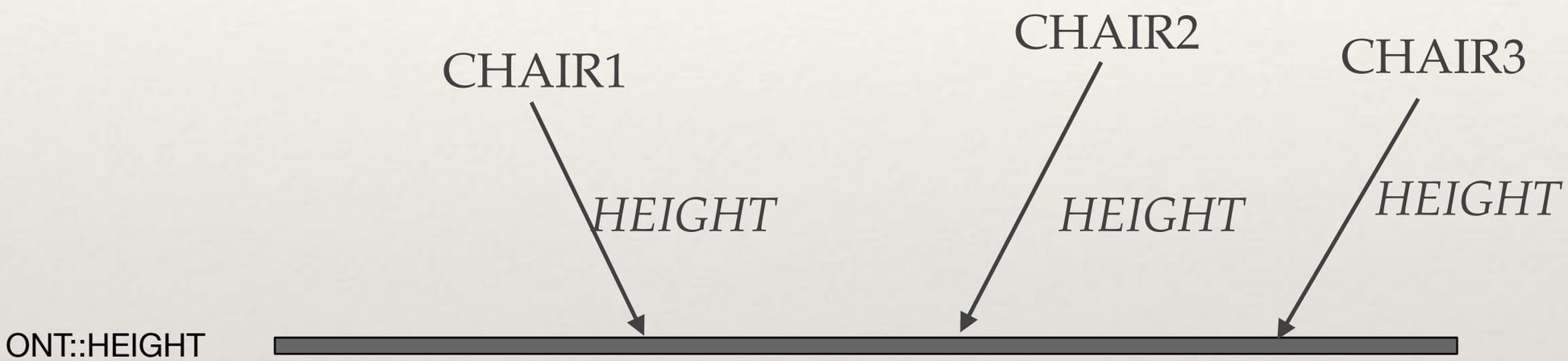


e.g., “CHAIR2 is **taller** than CHAIR1 by 9 inches”

COMPAR = CHAIR1

Scales

Scales also enable selection of a object from a set (the REFSET)



e.g., “the tallest chair”
“The tallest of the chairs”

REFSET ={CHAIR1. CHAIR2, CHAIR3}

Summary: Roles associated with scale-based properties

Table 7: The Semantic Roles for Scalar Predicates

Role	Definition	Example (argument is underlined)
FIGURE	**the argument that is being characterized with respect to other objects (the GROUND), a scale, or an relative sub scale (the STANDARD),**	**The red block** **The block is red.** **The larger dog** **The tallest building**
GROUND	**the argument related to the FIGURE**	**The building closer to the river**
COMPAR	**An explicit object with which the FIGURE is being compared**	**My dog is larger than your dog** **The building closer to the river than that**
REFSET	**A explicit set of objects of which the FIGURE belongs**	**She is the tallest of the girls in the class** **The larger of the animals died.**
SCALE	**The scale on which a predication is based (typically implicit in the predicate)**	**It is hotter in temperature** **It is hot spice-wise**
STANDARD	**a relative subscale defined by a predicate, ranging from fairly simple (e.g., tall for a dog, the standard is the height subscale associated with dogs) to complex (e.g., short to reach the shelf defined a standard that is a subscale of heights where someone could reach the shelf.**	**It is hot enough for taking a walk** **The shelf is too high to reach** **The ladder is a bit short to reach the shelf** **He is large for a dog** **He is old to be in third grade**
EXTENT	**The amount by which the figure differs from the ground in a comparison operation**	**It is 6 inches longer than the shelf**
DEGREE	**A qualitative measure of value on a scale**	**He is very tall**

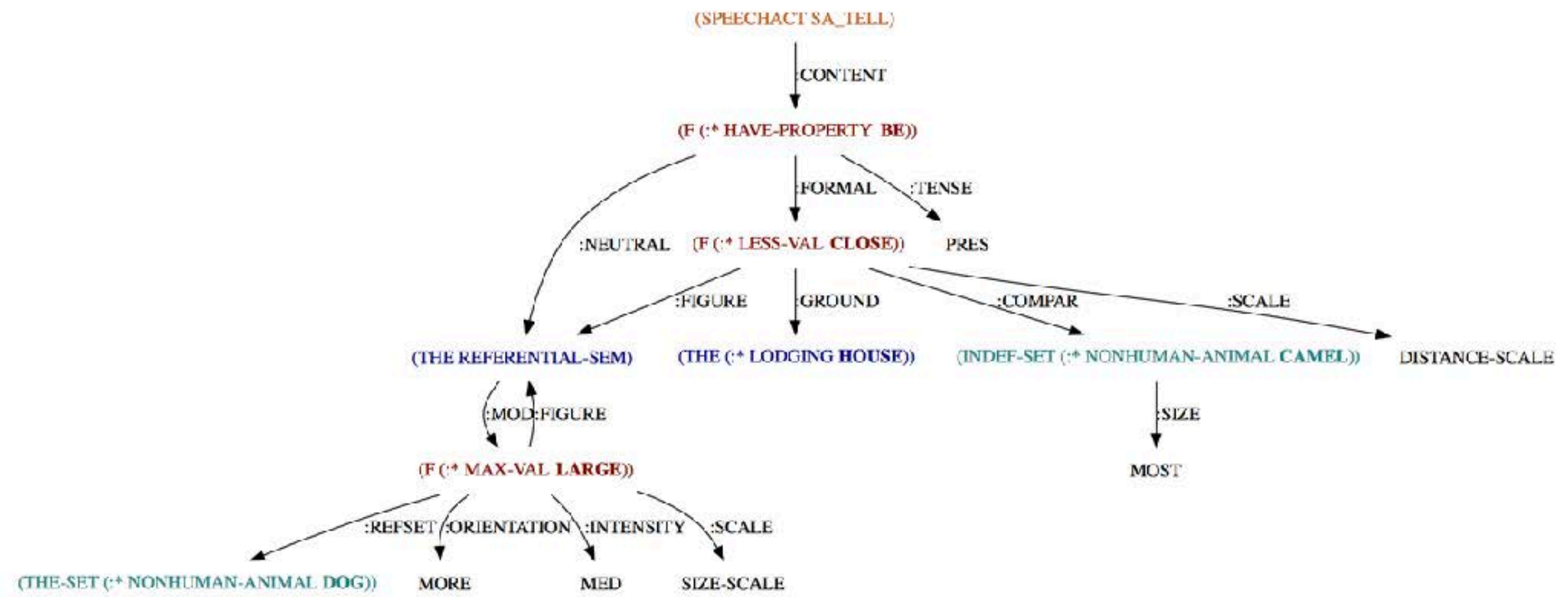
Sample parse involving most of the roles ...

Words

THE LARGEST OF THE DOGS IS CLOSER TO THE HOUSE THAN MOST CAMELS

Tags

Logical Form

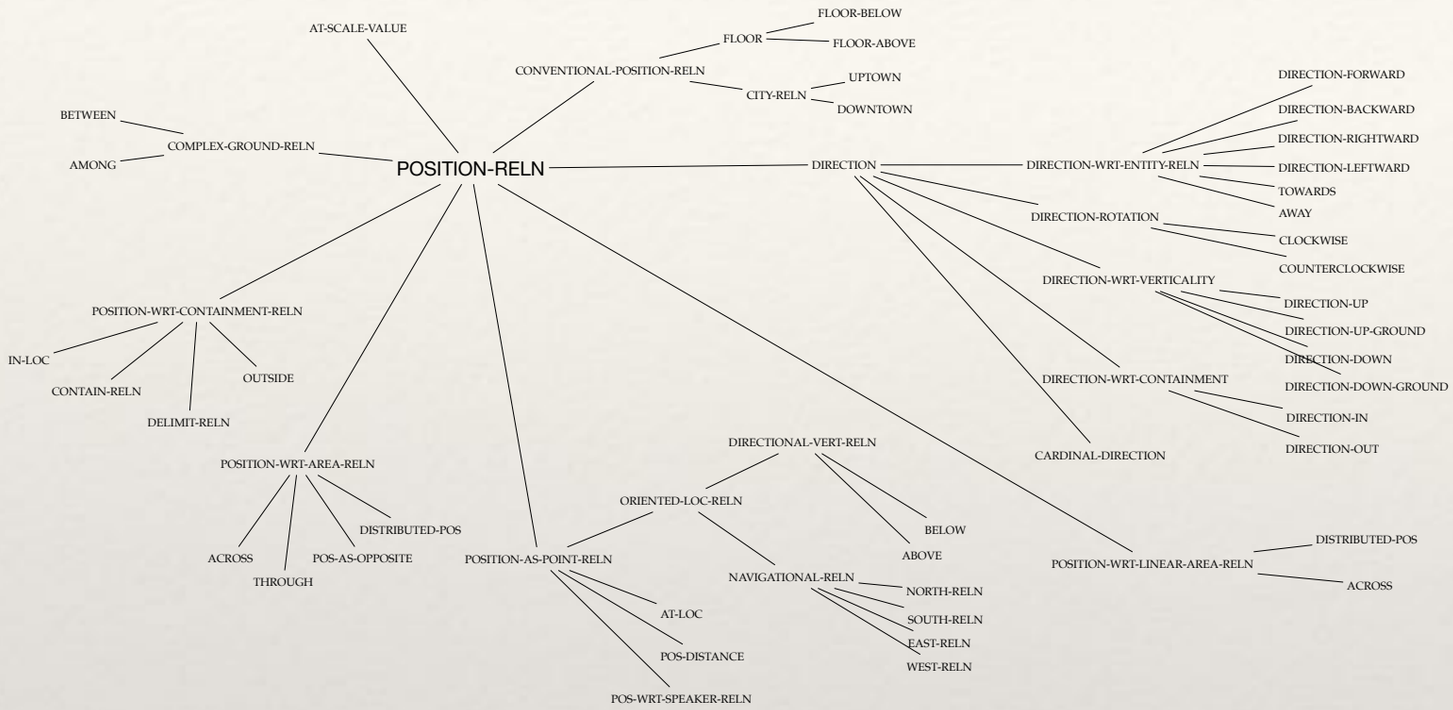


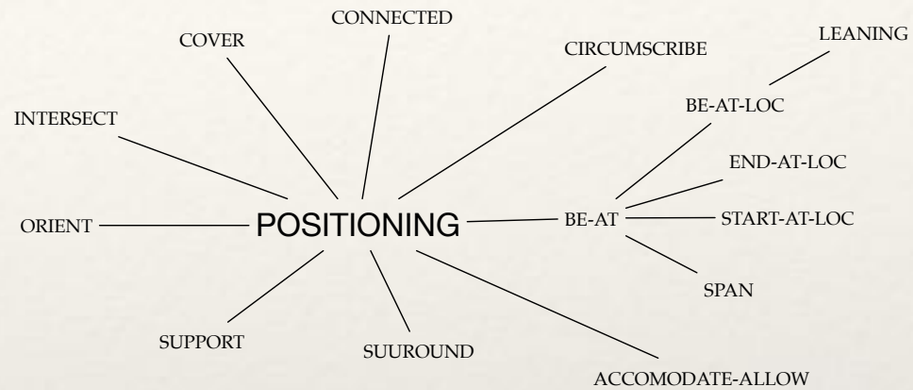
Spatial Content

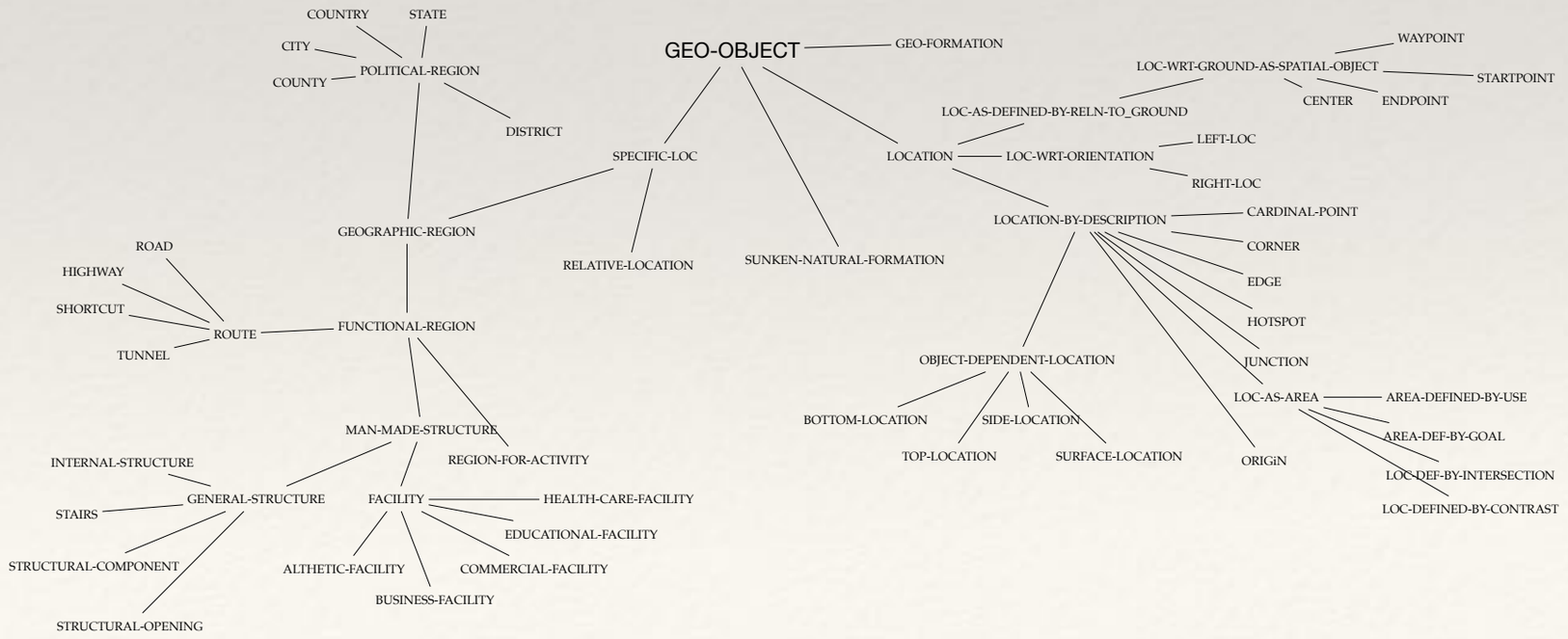
SO FAR I'VE FOCUSED ON STRUCTURAL ASPECTS OF SPATIAL RELATIONS

NOW I TRY TO CLASSIFY THEM BY THEIR CONTENT

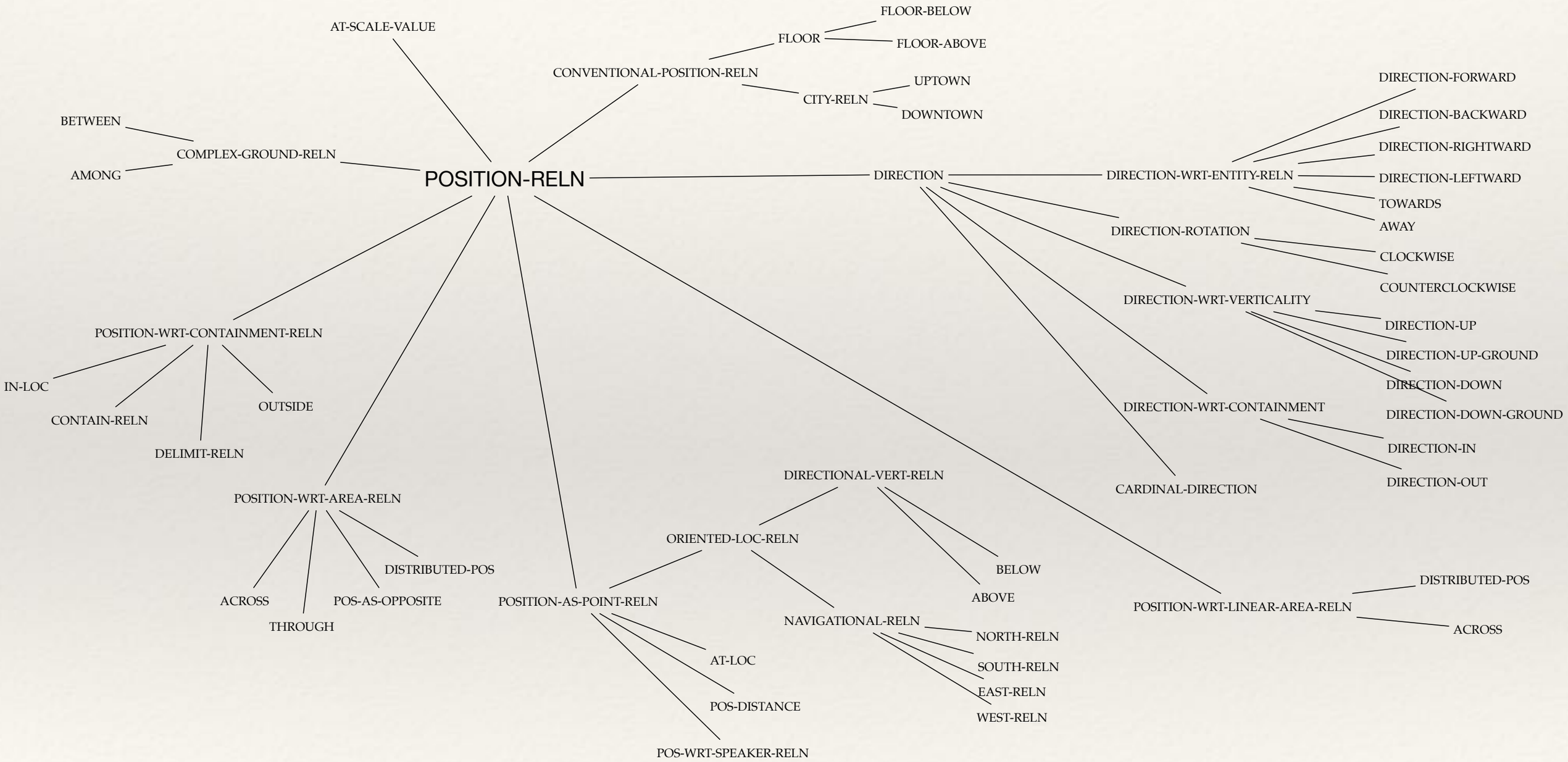
The Spatial Concepts in TRIPS





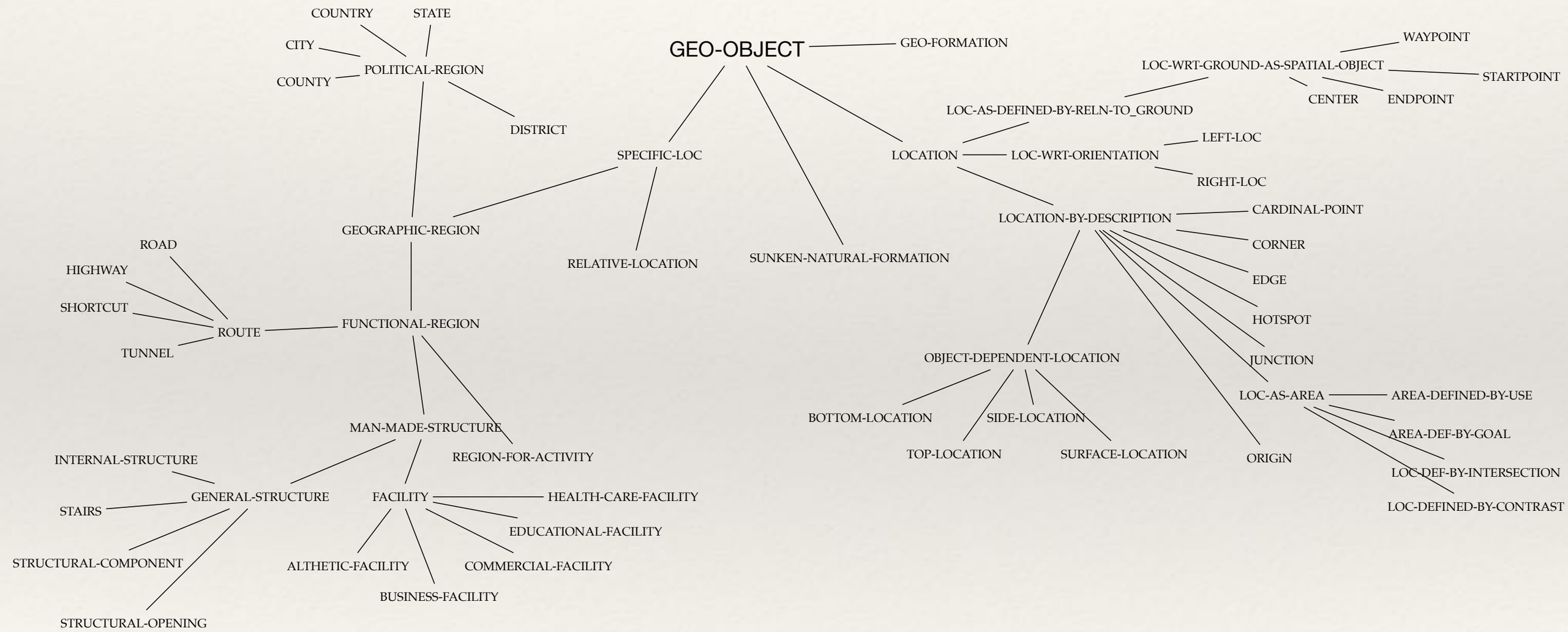


The Spatial Relations



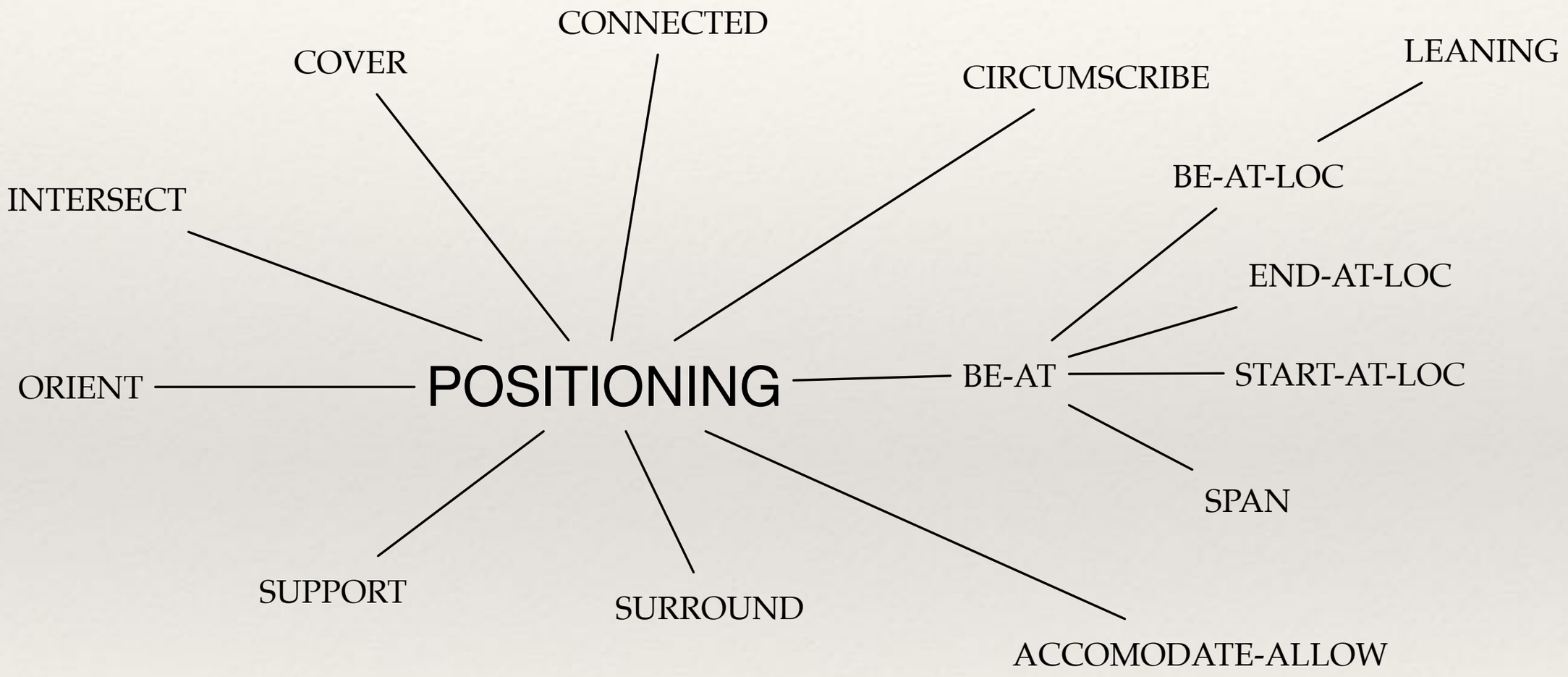
Primarily adverbs (aka prepositions) and adjectives

The Spatial Objects



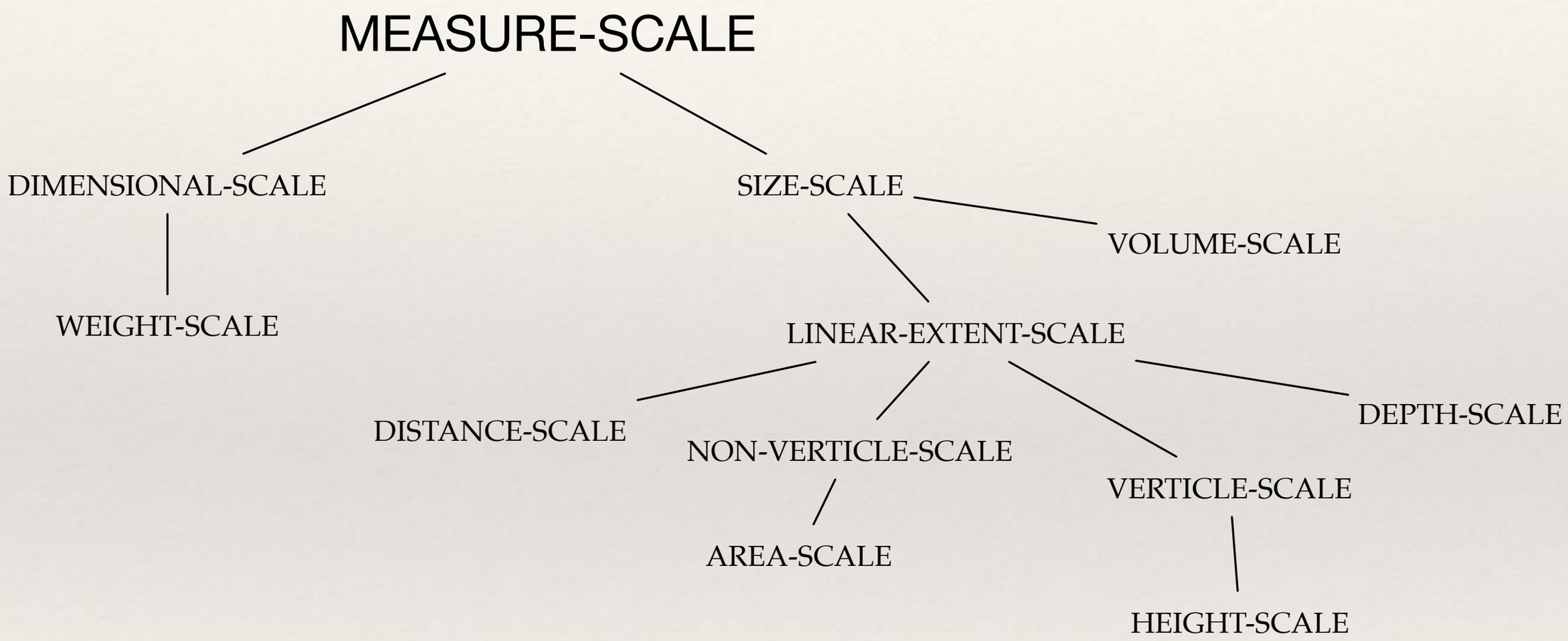
Primarily concrete nouns (types of locations)

The Spatial Verbs



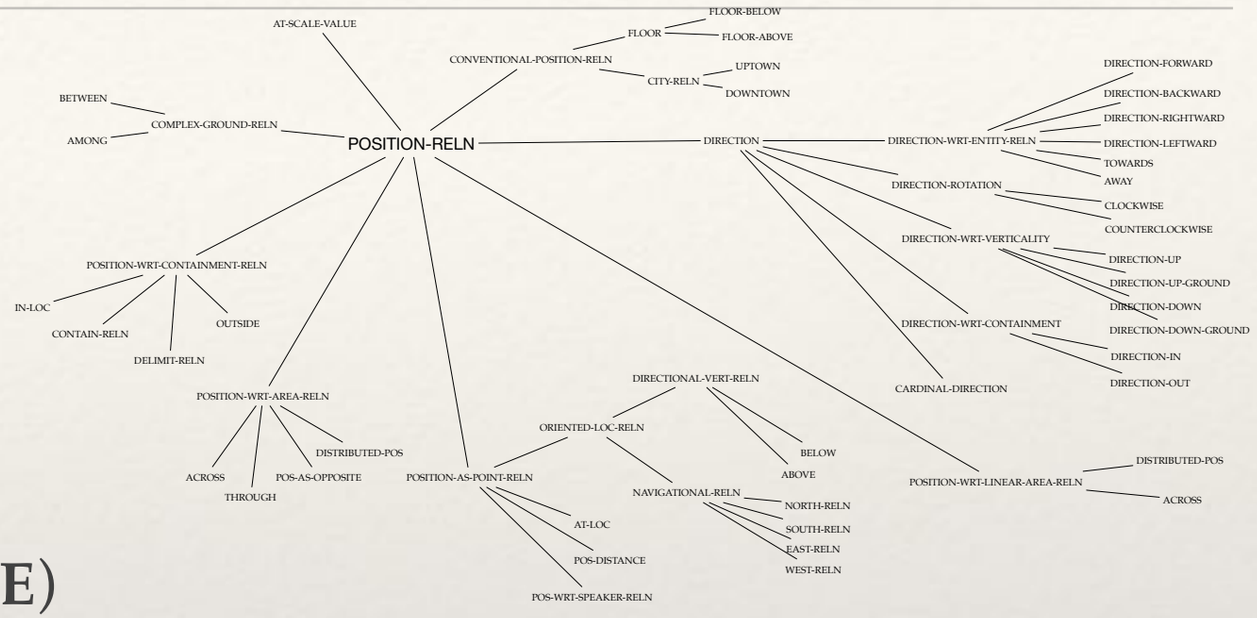
Primarily stative verbs

The Spatial Scales



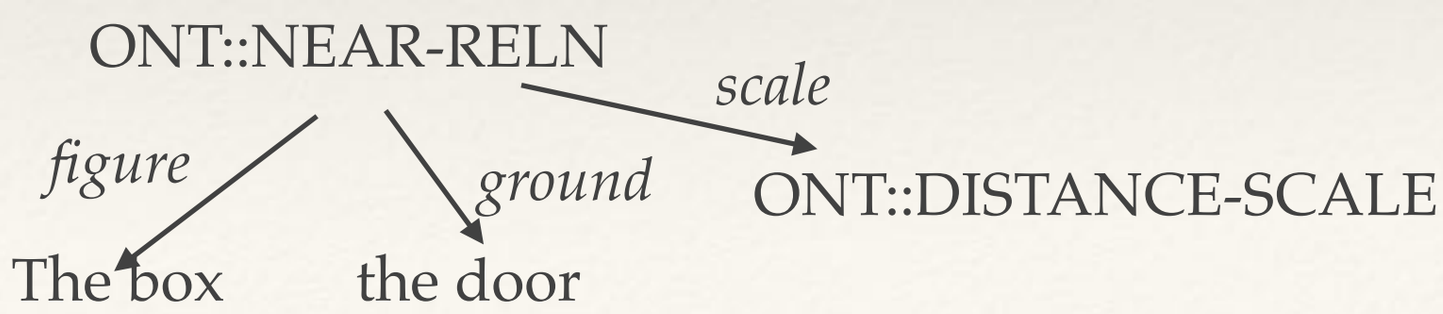
Primarily abstract nouns

The Spatial Relations



Spatial Relations relate an object (the **FIGURE**)
to a reference object (the **GROUND**), sometimes implicit,
with respect to some measure function (the **SCALE**), typically implicit

The box is near the door



The Spatial Relations

ONT::POSITION-AS-POINT-RELN

Both FIGURE and GROUND are viewed as point like objects

ONT::ORIENTED-LOC–RELN

SCALE involves a directional orientation

ONT::DIRECTIONAL-VERT–RELN *above the counter*

SCALE involves a vertical orientation

ONT::NAVIGATIONAL–RELN *north of the barn*

SCALE involves a vertical orientation

ONT::POS-DISTANCE *near the factory*

SCALE is distance between two points

ONT::AT-LOC *at the store*

SCALE is degree of co-location of FIGURE and GROUND

Spatial Relations

ONT::POSITION-WRT-AREA-RELN

GROUND is an extended space

ONT::ACROSS *the path across the field*

FIGURE bisects the GROUND

ONT::THROUGH *the road through the tunnel*

FIGURE bisects the GROUND and is conceptually IN it

ONT::POS-AS-OPPOSITE *the house across the street*

FIGURE is on opposite side of GROUND from a reference object

ONT::DISTRIBUTED-POS *the flowers throughout the field*

FIGURE is a set of objects in or on the GROUND

ONT::AROUND *The path around the city*

FIGURE is a space that surrounds the GROUND, or goes through the GROUND

Spatial Relations

ONT::POSITION-CONTAINMENT-RELN

GROUND is viewed as a container (physical or abstract), and may be an extended space

ONT::IN-LOC *the dog in the box, the idea in my mind*

FIGURE is contained in the GROUND

ONT::CONTAINS *the park contains a fountain*

FIGURE contains the GROUND

ONT::OUTSIDE *the trees outside the park*

FIGURE is nor contained in the GROUND

at

Spatial Relations

ONT::DIRECTION

The prototypical sense of direction relates an object (the FIGURE) to itself at another time along some orientation

the dog moved away from the house

DISTANCE(dog, house, t2) > DISTANCE(dog, house, t1)

i.e., the RESULT of the move event is that the dog is further from the house than when it started (e.g., AWAY(dog, house, t1, t2))

Spatial Relations

ONT::DIRECTION

FIGURE is changing location relative to some GROUND

ONT::DIRECTION-WRT-ENTITY-RELN

Change is relative to some orientation based of an entity

ONT::DIRECTION-FORWARD *the dog moved forward*

ONT::TOWARDS *It rolled towards the house*

ONT::DIRECTION-ROTATION *It turned clockwise*

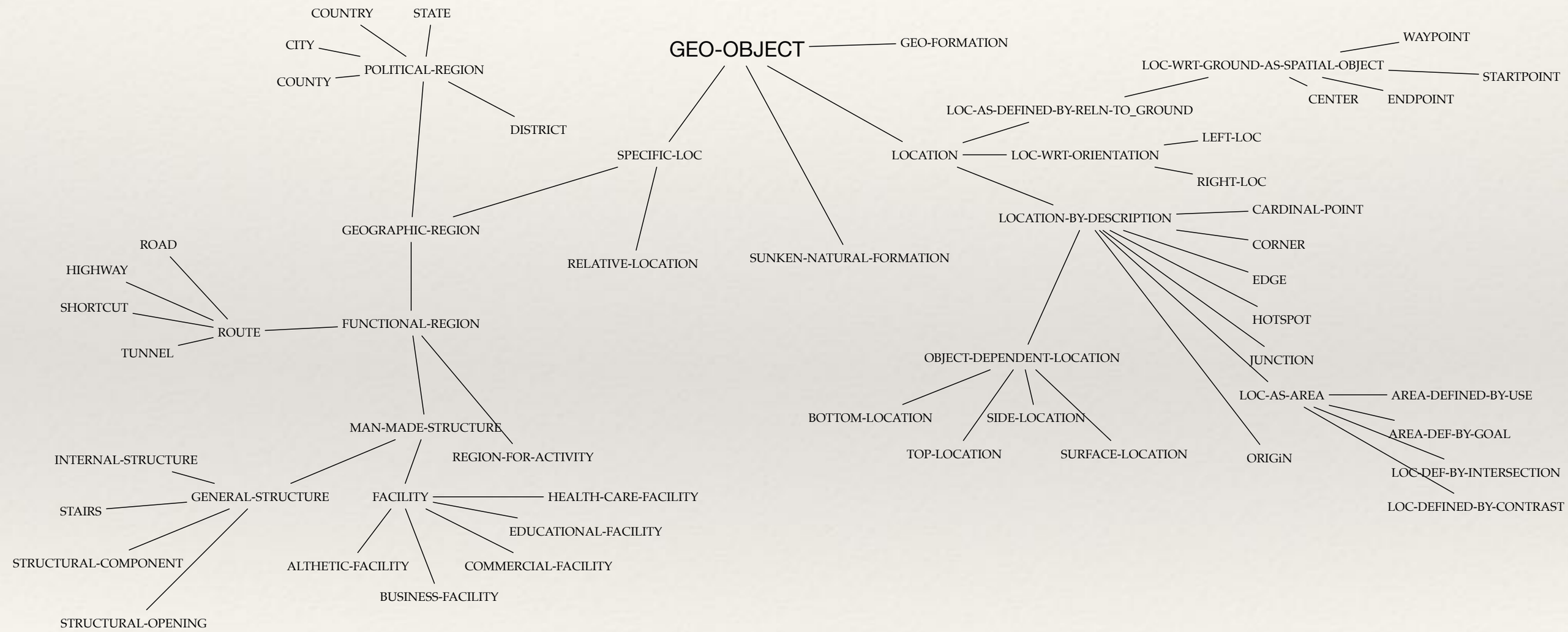
ONT::DIRECTION-WRT-VERTICALITY *We pushed it up, they ran down the mountain*

FIGURE changes in a vertical direction

ONT::CARDINAL-DIRECTION *they moved east/eastward*

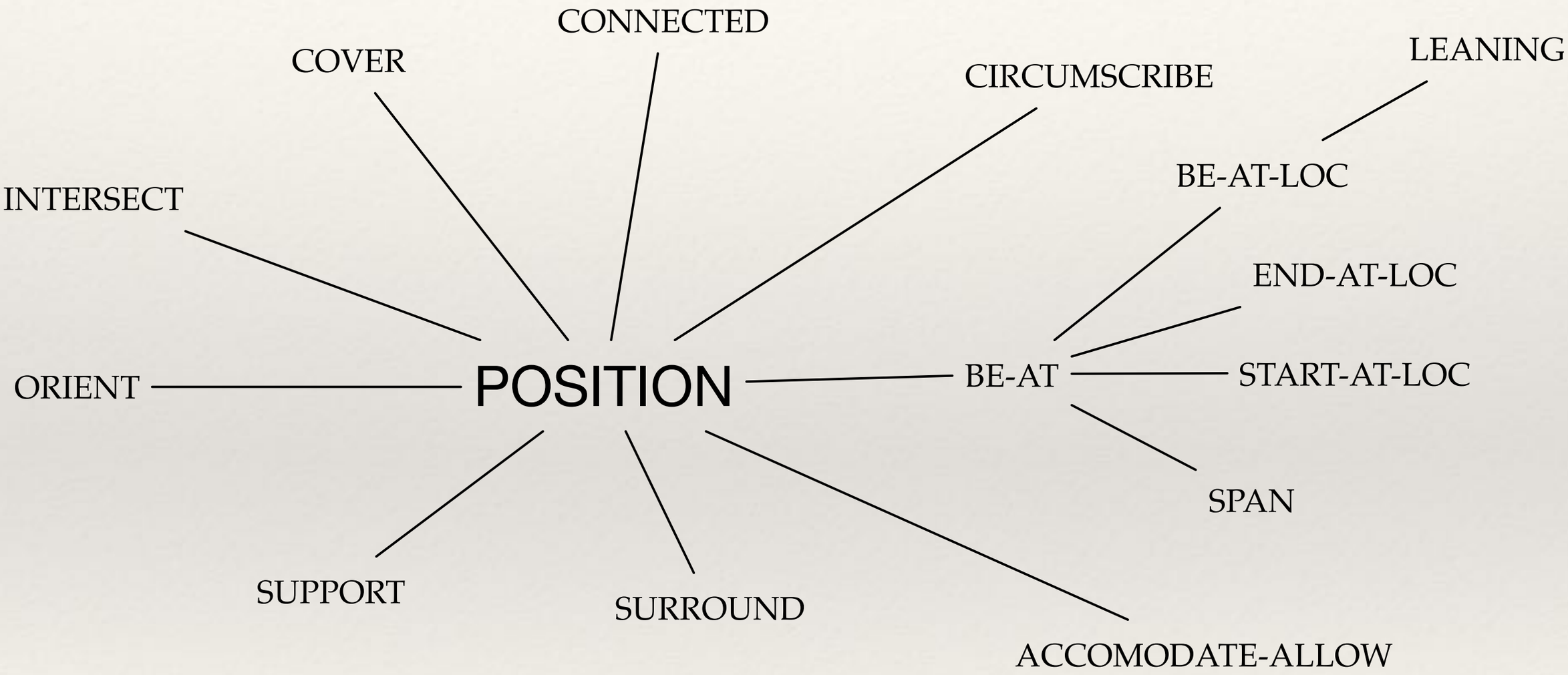
FIGURE changes

The Spatial Objects



Primarily concrete nouns (types of locations)

The Spatial Verbs



Primarily stative verbs

Spatial Relations Realized by Verbs

- while spatial relations are most commonly realized as preposition/adverbs and adjectives
- some spatial relationships can only be described using verbs

the shovel is leaning against the fence

the dog is touching the door

The ball is in the box == *the box contains the ball*

Spatial Relations as Verbs

ONT::POSITION

NEUTRAL is in a spatial relationship with NEUTRAL1

ONT::BE-AT

NEUTRAL is at NEUTRAL in some postural position

The cup is sitting on the table/hanging from the shelf/leaning against the wall

ONT::SURROUND *The sense surrounds the field*

ONT::SUPPORT *The legs can support the table*

ONT::COVER *The blanket covered the bed*

ONT::CONNECTED *The two countries connect at the river.*

ONT::INTERSECT *The roads cross near there*

Pondering

Where do spatial concepts end and non-spatial begin?

The blanket covered the bed

The car fits five people

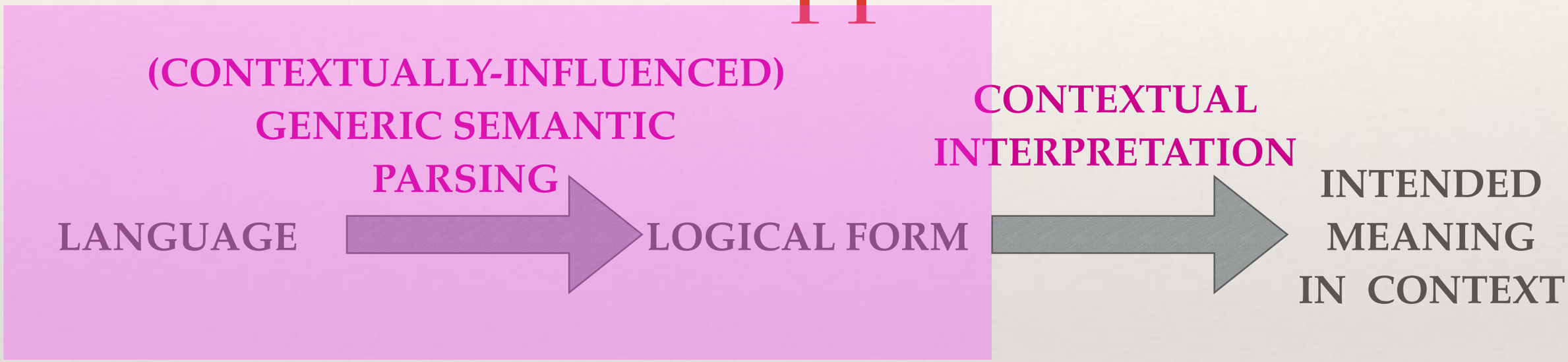
He is holding a pizza!

He carried the backpack

He bought a backpack

does it matter?

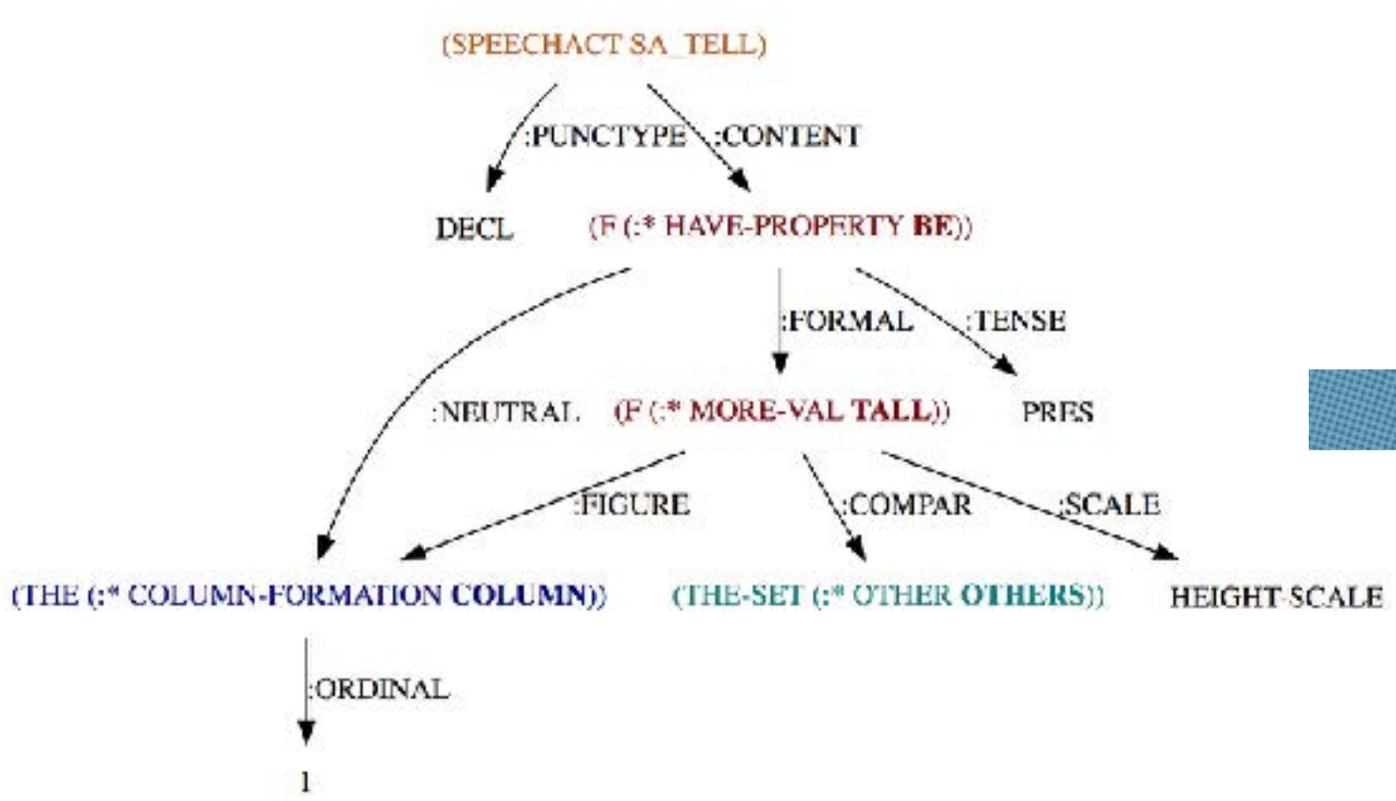
Our Approach

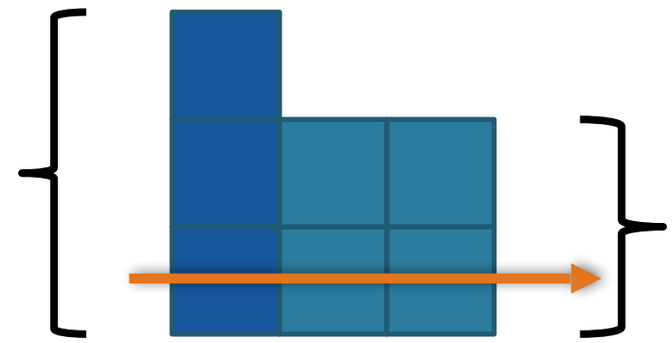


A PRACTICAL MIDDLE GROUND

Examples of Applications

Building and Learning Structures in a Situated Blocks World Through Deep Language Understanding

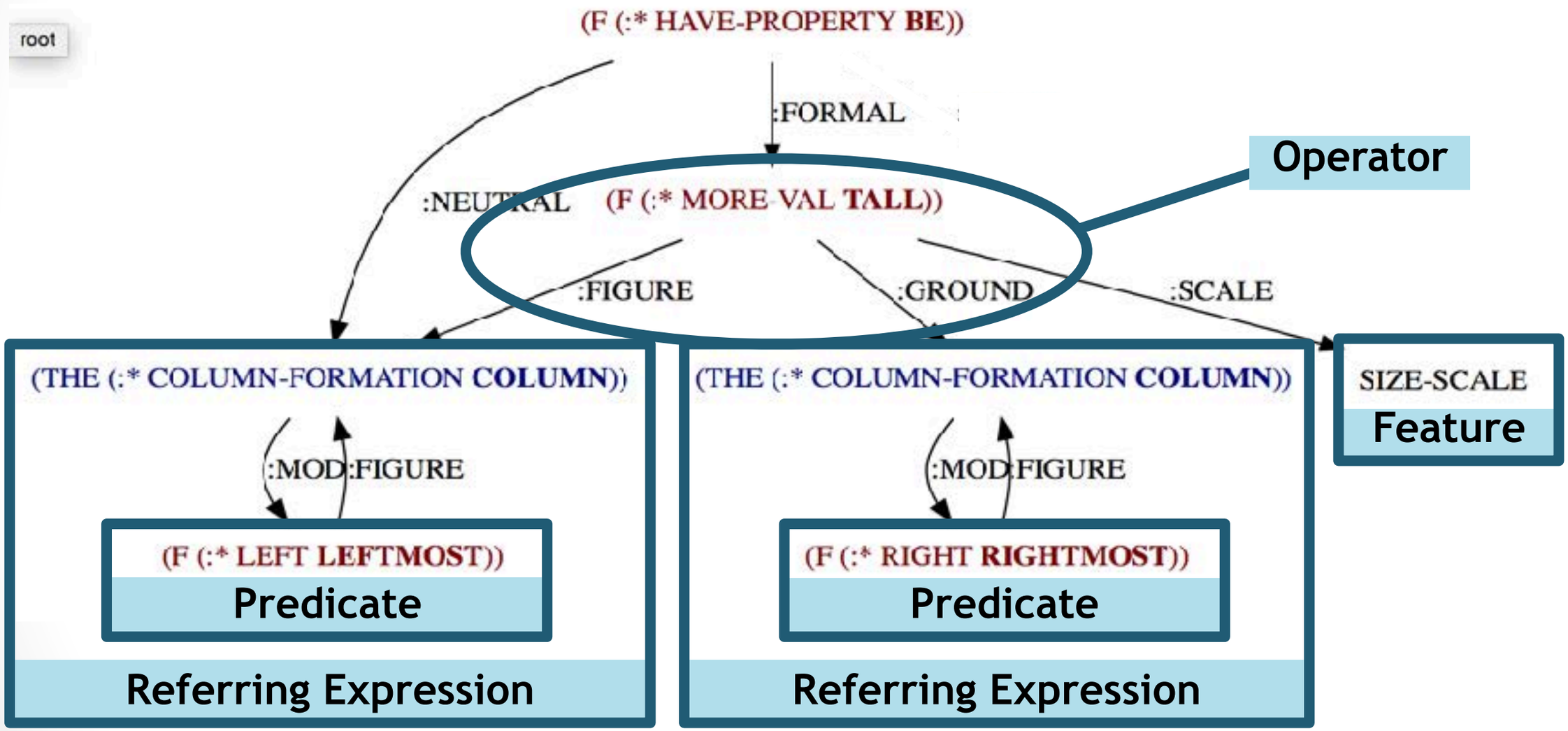




1st 2nd 3rd/ Last

Ian Perera, See paper this workshop

Constraint Interpretation



Extraction of the spatial roles and relations in descriptions of images

Parisa Kordjamshidi, Tulane

About 20 kids in traditional clothing and hats waiting on stairs

Extract the following roles and relations:

- (About 20 Kids) is the **trajector**
- (On) is the **spatial indicator**
- (Stairs) is the **landmark**
- (**About 20 kids, on, Stairs)** is the spatial triplet.

Initial Results

- The results show a significant improvement on spatial relation extractions based on experiments on a subset of CLEF annotated benchmark.

	Without TRIPS			With TRIPS relation labels		
	Precision	Recall	F1	Precision	Recall	F1
Trajector	61.111	64.706	62.857	57.895	64.706	61.111
Landmark	84.615	78.571	81.481	81.250	92.857	**86.667**
Indicator	100.000	85.714	92.308	92.308	85.714	88.889
Triplets	55.556	58.824	57.143	50.000	88.235	**63.830**

- Result 1: The most challenging part is the relation extraction, and previous models have good performance on Roles. It seems TRIPS has a significant impact on relation (triplet extraction). Particularly, the relation labels improve the recall and consequently improve the overall F1.

- Result 2: The TRIPS phrases types still improved the relation extraction but dropped the results of role classification more. We assume the phrase types var a lot and generate sparse features. We have not used TRIPS ontology still to get the more generic types of phrases but we assume by integrating the ontology we can obtain better results.

Domains Using TRIPS Parser

Big Mechanism:reading biology research papers

"We hypothesized that MEK inhibition activates AKT by inhibiting ERK activity, which blocks an inhibitory threonine phosphorylation of EGFR and HER2, thereby increasing ERBB3 phosphorylation."

CWC Blocks World: Collaborative action

"Why don't we place the large blue block behind that wall"

CWC Biocuration: exploring Bio pathways

"Is the amount of MAP2K1-MAPK1 complex sustained at a high level if we increase the total amount of MAPK1 and DUSP6 by 5 fold?"

Crop Modeling: Building causal models from text

"The government promotes high-yielding and drought/flood-tolerant rice varieties with policy to encourage the application of organic fertilizers, decreasing the cost on inorganic fertilizers"

Using the same grammar, lexicon, and ontology for every domain! and no training corpus required!

CWC Story Understanding

"Sandra was walking to the store. She passed a little girl who was crying on her front steps. Sandra asked her what was wrong. The little girl said she was locked out of her house. Sandra sat down and waited with her for her parents to come home"

Music Composition

"Move these notes up a step"

ASMA

(texting with teens)

"K"

Try it out and explore!

- Pointers to a TRIPS parsers customized to different domains at
  - www.trips.ihmc/parser
    - also provides web services for programmatic access
- Browse the Lexicon and Ontology at
  - www.cs.rochester.edu/research/trips/lexicon/browse-ont-lex.html

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