Semantic Roles

How the arguments of a predicate map to functional elements of the event the predicate is about

▶ The idea goes all the way back to Panini (Pāṇini circa 350BC)

▶ Donald Davidson's event representation for logical form

    ▶ Postulate an event, e

    ▶ Assert the type of e via a unary predicate

        ▶ crossing(e)

    ▶ Assert e's attribute values via binary predicate named after the attribute with its second argument being the value

        ▶ agent(e, *John*), patient(e, *EnglishChannel*)

▶ Thematic roles $\neq$ semantic roles

    ▶ Express important arguments of a predicate

    ▶ As a potential terminological confusion, *theme* is just one of many *thematic* roles

Major Thematic Roles in the Literature
Not a fixed set

Th. Role	Definition	Sample Words
Agent	Volitional causer (includes accidents)	Kick
Experiencer	One who experiences it	Has (a feeling)
Force	Nonvolitional causer	Tsunami
Theme	One (most) directly affected	Shut (the door)
Result	Outcome	Wrote (a book)
Content	Proposition of a propositional event	Asked
Instrument		With a screwdriver
Beneficiary		For his son
Source	Origin of the object in a transfer event	Shipped
Goal	Destination of the object in a transfer event	Delivered

Thematic Roles Exercise

For each thematic role, state an example sentence that illustrates it

Thematic Grid or Case Frame or θ-Grid of a Verb
The set of thematic roles that the verb takes on

▶ Constraints on how a verb's thematic roles are presented and ordered

John	broke	the window		
AGENT		THEME		
John	broke	the window	with	a rock
AGENT		THEME		INSTRUMENT
The rock	broke	the window		
INSTRUMENT		THEME		
The window	broke			
THEME				
The window	was broken by	John		
THEME		AGENT		

Diathesis Alternation or Verb Alternation

Multiple alternative mappings from arguments to syntactic positions

▶ For *break* (previous page)

Subject	Object	Preposition (With) Phrase
AGENT	THEME	
AGENT	THEME	INSTRUMENT
INSTRUMENT	THEME	
THEME		

▶ For *give*, dative alternation

Doris	gave	the book	to	Edward
AGENT		THEME		GOAL
Doris	gave	Edward	the book	
AGENT		GOAL	THEME	

VerbNet
Gathers knowledge about verbs

- ▶ Class hierarchy of verbs that maps out what alternations each verb participates in
- ▶ Verbs that support the dative alternation
  - ▶ Verbs of future having: advance, allocate, offer, owe
  - ▶ Verbs of sending: forward, hand, mail
  - ▶ Verbs of throwing: kick, pass, throw
- ▶ Levin's classification
  - ▶ 47 high-level classes
  - ▶ 193 low-level classes
  - ▶ 3,100 verbs

Problems with Thematic Roles
Despite their intuitive appeal, . . .

- ▶ Difficult to standardize on set of thematic roles
- ▶ Difficult to formally specify
- ▶ Frequent need to refine (fragment) the roles
- ▶ Example: INSTRUMENT seems to be two subroles
    - ▶ This alternation works for INTERMEDIATE INSTRUMENT

      The cook opened the jar with the new gadget

      The new gadget opened the jar
    - ▶ But not for ENABLING INSTRUMENT

      The cook ate noodles with a fork

      *A fork ate the noodles
- ▶ How about this?

  The cook whisked the eggs with a fork

  A fork whisked the eggs

PropBank: Proposition Bank

Labels of (English and Chinese) sentences in Penn Treebank with semantic roles

- ▶ Semantic roles are defined specific to verb senses, not universally
- ▶ Not given meaningful names (helps avoid unnecessary controversy, I assume)
- ▶ Some generalizations
    - ▶ Arg0: PROTO-AGENT
    - ▶ Arg1: PROTO-PATIENT
    - ▶ Arg2: often BENEFACTIVE, INSTRUMENT, ATTRIBUTE, or END STATE
    - ▶ Arg3: often BENEFACTIVE, INSTRUMENT, ATTRIBUTE, or STARTING POINT
    - ▶ Arg4: often END POINT
- ▶ Helps recover shallow semantic information from arguments of verbs

PropBank Frame File Example: Agree.01

- ▶ Arg0: Agreer ≈ Agent
- ▶ Arg1: Proposition being agreed to ≈ Content
- ▶ Arg2: With whom (if any) ≈ Beneficiary

[Arg0 The group] agreed [Arg1 it wouldn't make an offer]
[ArgM-TMP Usually] [Arg0 John] agrees [Arg2 with Mary] [Arg1 on everything]

PropBank Frame File Example: Fall.01

▶ Arg0: Not defined since the normal subject of *fall* is PROTO-PATIENT
▶ Arg1: Thing falling, which is the logical subject and patient
▶ Arg2: Extent, amount fallen
▶ Arg3: Start point
▶ Arg4: End point, end state of Arg1

[$_{Arg1}$ Sales] fell [$_{Arg4}$ to \$25 million] [$_{Arg3}$ from \$27 million]
[$_{Arg1}$ The average junk bond] fell [$_{Arg2}$ by 4.2%]

PropBank Frame File Example: Increase.01

Extracting shallow semantic information from verb arguments

- ▶ Arg0: Causer of increase
- ▶ Arg1: Thing increasing
- ▶ Arg2: Amount increased by; or, manner
- ▶ Arg3: Start point
- ▶ Arg4: End point

Below, *Dole* is the AGENT and *the price of Bananas* is the THEME

[$_{Arg0}$ Dole] increased [$_{Arg1}$ the price of Bananas]

[$_{Arg1}$ The price of Bananas] was increased by [$_{Arg0}$ Dole]

[$_{Arg1}$ The price of Bananas] increased [$_{Arg2}$ 5%]

PropBank Modifiers and Adjuncts, Named ArgM-X

https://verbs.colorado.edu/~mpalmer/projects/ace/PBguidelines.pdf

Name	Definition	Example
DIR: Directional	To or from	He smiled at her
LOC: Locative	Where	He added an amount to the penalty
MNR: Manner	How	She sang happily
TMP: Temporal	When	Now, recently
EXT: Extent	How much	AA raised fares as much as UA did
REC: Reciprocal	Reflexives	themselves, each other
PRD: Secondary predication	Resultative, depictive	ate the fish raw
PNC: Purpose	Because	I left early to catch my flight
CAU: Causative	Why, because	Delayed because of weather
DIS: Discourse	However, and (at beginning)	And, that's how it ends
ADV: Adverbial	On sentence	Happily, she sang (cf. above)
MOD: Modal		
NEG: Negation	n't, no longer	

NomBank

Project for annotations on nouns

▶ When different parties have distinct views of the concept referenced in the noun
▶ Example: *Apple's agreement with IBM*
  ▶ Arg0: Apple
  ▶ Arg2: IBM

FrameNet
Semantic role labeling based on commonsense (background) knowledge

- ▶ Distinct sentences, with different verbs and nouns, may map to the same meaning
    - ▶ The price of oil increased 7%
    - ▶ Oil went up 7%
    - ▶ We saw an escalation of 7% in the price of oil
- ▶ The idea is to represent the meaning of a sentence in a normalized form
- ▶ Frame ≈ model ≈ script
    - ▶ Representation of background knowledge that lends meaning to language
    - ▶ Each word produces one or more frames
    - ▶ Frame elements: frame-specific semantic roles
    - ▶ Frame predicates: those applicable to these roles

Example Frame: Change Position on a Scale

FrameNet labelers guide
https://framenet2.icsi.berkeley.edu/fnReports/data/frameIndex.xml?frame=Change_position_on_a_scale

	Core Roles
ITEM	The entity that has a position on the scale
ATTRIBUTE	A scalar property of the ITEM whose value is changing
DIFFERENCE	The displacement of the ITEM on the scale
INITIAL VALUE	Position on the scale from which the ITEM moves
INITIAL STATE	ITEM's state before change: independent predication
FINAL VALUE	Position on the scale where the ITEM ends up
FINAL STATE	ITEM's state after change: independent predication
VALUE RANGE	Part of the scale over which the ATTRIBUTE varies
	Selected Noncore Roles
DURATION	Over which the change takes place
SPEED	The rate of change of the ATTRIBUTE's value
GROUP	The GROUP in which an ITEM changes the value of an ATTRIBUTE in a specified way

Exercise: Identify the Roles in Each Sentence

▶ Oil prices have risen by 7%

▶ The price of oil has gone up by $2 since last Thursday

Words in the *Change Position on a Scale* Frame
The complete frame

Verbs					
advance	climb	decline	decrease	diminish	dip
double	drop	dwindle	edge	explode	fall
fluctuate	gain	grow	increase	jump	move
mushroom	plummet	reach	rise	rocket	shift
skyrocket	slide	soar	swell	swing	triple
tumble					

Nouns					
decline	decrease	escalation	explosion	fall	fluctuation
gain	growth	hike	increase	rise	shift
tumble					

Adverbs

increasingly

Frames Build on Other Frames

▶ Cause Change of Position on a Scale: composes
  ▶ Change of Position on a Scale
  ▶ Cause relation
  ▶ AGENT role

Selectional Restrictions

Constraints on a word's arguments that reflect its meaning

Consider | I ate tofu today   I ate nearby today |

- ▶ Typical reading of eat in the "nearby" sentence
  - ▶ Intransitive
  - ▶ Nearby indicates location of the eating event
- ▶ Funny reading of eat in the "nearby" sentence
  - ▶ Transitive
  - ▶ Nearby indicates its direct object
- ▶ Selectional restriction: THEME of eat is (usually) edible
  - ▶ Associated with a word sense, not an entire lexeme
  - ▶ Two senses for *serves*:

    | Emirates <u>serves</u> breakfast and lunch | THEME is food |
    | Emirates <u>serves</u> Dubai and Mumbai | THEME is location |

  - ▶ Adjectives can have arguments too: odorless applies naturally to objects that can have an odor

Silence of the Lambs: I am having an old friend for dinner

Representing Selectional Restrictions

- ▶ Words vary in the restrictiveness of their restrictions
    - ▶ Imagine's THEME can be any entity
    - ▶ Lift's THEME can be any physical entity
    - ▶ Diagonalize's THEME must be a matrix
- ▶ Represent as unary predicate capturing the restriction on the specified argument
    - ▶ Accurate but cumbersome
- ▶ Identify which WordNet synset is acceptable
    - ▶ A filler is acceptable if it is a hyponym of this synset
    - ▶ That is, one sense of the filler word satisfies the restriction

Selectional Preferences

Generalizing beyond hard restrictions

- ▶ Strict restrictions are often violated in language
  - ▶ With negation: can't eat gold
  - ▶ With anomalous or surprising occurrences: eat glass
- ▶ Selectional preference strength—how selective a verb is
  - ▶ Eat is informative about its direct objects
  - ▶ Be is not too informative about its direct objects
- ▶ Compare probability distributions of object class c with object class c given verb v
  - ▶ $P(c|v)$: actual distribution of c given v
  - ▶ $P(c)$: approximation of above not knowing v
  - ▶ KL divergence from $P(c|v)$ to $P(c)$: How much information verb v carries about its arguments

$$S(v) = \sum_c P(c|v) \log \frac{P(c|v)}{P(c)}$$

Selectional Association with WordNet Classes

- Selectional association of a WordNet class c and v

$$A(c, v) = \frac{1}{S(v)} P(c|v) \log \frac{P(c|v)}{P(c)}$$

  - Positive when v prefers c; negative when v repels c
- For n, let $c_{\max} = \underset{n \text{ belongs to } c}{\arg\max} \; A(c, v)$, from the Brown corpus
- $S(v)$ is summed over all classes (previous page)
- $P(c|v)$ and $P(c)$ refer to this class

Examples of Selectional Association with WordNet Classes
Shown for direct objects

▶ $A(c_{\max}, v)$ figures are scaled up $100\times$

▶ Plausibility below of object-verb pairs: judged by humans in a prior study

Verb v	**Plausible direct objects**			**Implausible direct objects**		
	Object	Class $c_{\max}$	$A(c_{\max}, v)$	Object	Class $c_{\max}$	$A(c_{\max}, v)$
Read	article	writing	6.80	fashion	activity	−0.20
Write	letter	writing	7.26	market	commerce	0.00
See	friend	entity	5.79	method	method	−0.01
Judge	contest	contest	1.30	climate	state	0.28
Answer	request	speech act	4.49	tragedy	communication	3.88

▶ Some mistakes, apparently due to word sense confusions
  ▶ For Answer, *tragedy* is treated as a dramatic play (hence, placed in communication)

Simplified Selectional Preferences
Avoids use of WordNet

▶ Simply calculate co-occurrence for specific pairs of words
▶ For verb v, noun n, relation r, estimate one of these from the counts
  ▶ $P(n|v, r)$
  ▶ $P(v|n, r)$
  ▶ $\log \text{count}(v, n, r)$

Evaluating Selectional Preferences
How well a verb matches a noun in a role

▶ Human judgments
  ▶ About plausibility of verb-argument pairs
  ▶ Use as basis for correlation with a model
▶ Pseudowords: for each verb
  ▶ Take a legitimate argument
  ▶ Generate a *confounder* as the nearest neighbor in the sense of having a frequency closest to but greater than the legitimate argument
  ▶ Evaluate how often a model chooses the legitimate word or the confounder
  ▶ Variations on how to generate the confounders

Decomposition into Predicates

Conceptual dependencies: relate to frames and scripts
Seek to capture the core meaning of a sentence, i.e., a verb

Primitive	Definition
ATRANS	The abstract transfer of possession or control from one entity to another
PTRANS	The physical transfer of an object from one location to another
MTRANS	The transfer of mental concepts between entities or within an entity
MBUILD	The creation of new information within an entity
PROPEL	The application of physical force to move an object
MOVE	The integral movement of a body part by an animal
INGEST	The taking in of a substance by an animal
EXPEL	The expulsion of something from an animal
SPEAK	The action of producing a sound
ATTEND	The action of focusing a sense organ

Conceptual Dependency Example
Maps each primitive to a fixed set of roles

The waiter brought Mary the check

- ▶ Physical transfer of the check: PTRANS, *p*
  - ▶ Actor of *p*: the waiter
  - ▶ Object of *p*: the check
  - ▶ Destination of *p*: Mary
- ▶ Abstract transfer of the check: ATRANS, *a*
  - ▶ Actor of *a*: the waiter
  - ▶ Object of *a*: the check
  - ▶ Destination of *a*: Mary