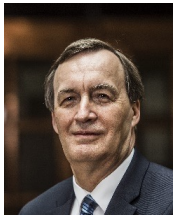
Representation Roadmap

Meaning Representations for Natural Languages Tutorial Part 2

Common Meaning Representations



Jan Hajič
Charles Univ., Prague

- Format & Basics
- Some Details & Design Decisions
- Practice - Walking through a few AMRs
- Multi-sentence AMRs
- **Relation to Other Formalisms**
- UMRs
- Open Questions in Representation

Comparison to Other Frameworks

- Meaning representations vary along many dimensions
  - How meaning is connected to text
    - Anchoring, alignment, multi-layer vs. text-span only
  - Relationship to logical and/or executable form
  - Mapping to Lexicons/Ontologies
    - General, task-oriented
  - Relationship to discourse and discourse-like phenomena
- We'll overview these now

Compositionality, Alignment to Text (1)

- Historical approach to meaning representations
  - Represent “context-free semantics”, as defined by a particular grammar model
- AMR at other extreme
  - AMR graph annotated for a single sentence, but no individual mapping from tokens to nodes

Type 0: Bilexical	Type 1: Anchored	Type 2: Unanchored
Nodes each correspond to one token (Dependency parsing)	Nodes are aligned to text (can be subtoken or multi-token)	No mapping from graph to surface form
Universal Dependencies	UCCA	AMR
MRS-connected frameworks (DM, EDS)	DRS-based frameworks (PMB / GMB)	Some executable/task-specific semantic parsing frameworks
Prague Dependency Treebanks Analytical (Surface Dependency) Layer	Prague Tectogrammatical (Semantic) Layer	

Oepen & Kuhlmann (2016) “flavors” of meaning representations

Compositionality, Alignment to Text (2)

- Less thoroughly defined: adherence to grammar/compositionally
  - *Emily M. Bender, Dan Flickinger, Stephan Oepen, Woodley Packard, and Ann Copestake. 2015. Layers of Interpretation: On Grammar and Compositionality. In Proceedings of the 11th International Conference on Computational Semantics, pages 239–249, London, UK. Association for Computational Linguistics.*
- Some frameworks (MRS/ DRS below) have particular assertions about how a given meaning representation was derived
  - tied to a particular grammar
- AMR encodes many useful things that are often ***not*** considered compositional — named entity typing, cross-sentence coreference, word senses, etc.

<- "Sentence meaning"		Extragrammatical inference ->
Only encode "compositional" meanings predicted by a particular theory of grammar	some useful pragmatic inference (e.g. sense distinctions, named entity types)	Any wild inferences needed for task

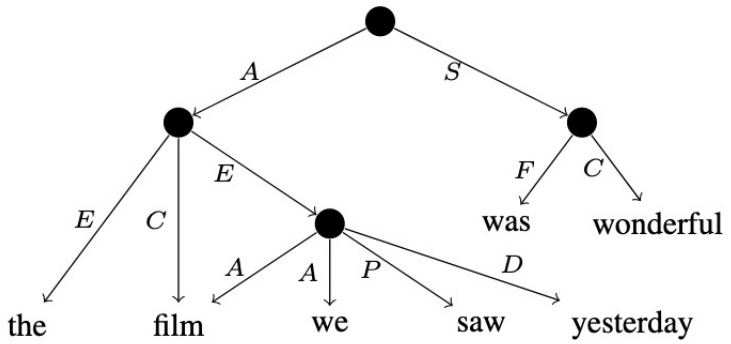
Compositionality, Alignment to Text – UCCA (1)

- Universal Conceptual Cognitive Annotation: based on a typological theory (Dixon's BLT*) of how to do **coarse-grained semantics** across languages
  - Core notions:
    - „Scene" – corresponds to BLT's "semantic clause", or a predicate-argument structure (complete with its adjuncts)
    - "Unit" – abstract concept (an [unlabelled] node in the representation graph)
    - (Coarse-grained) labelled relations between the Units (labelled edges in the representation graph)
      - Single capitalized letters (a signature property of UCCA)
- Similar to a cross between dependency and constituency parses (labeled edges) - sometimes very syntactic
- Introduced in 2013 by
  - *Omri Abend and Ari Rappoport. 2013. Universal Conceptual Cognitive Annotation (UCCA). In Proceedings of the 51st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers), pages 228–238, Sofia, Bulgaria. Association for Computational Linguistics.*

*http://www.glottopedia.org/index.php/Basic_Linguistic_Theory

Compositionality, Alignment to Text – UCCA (2)

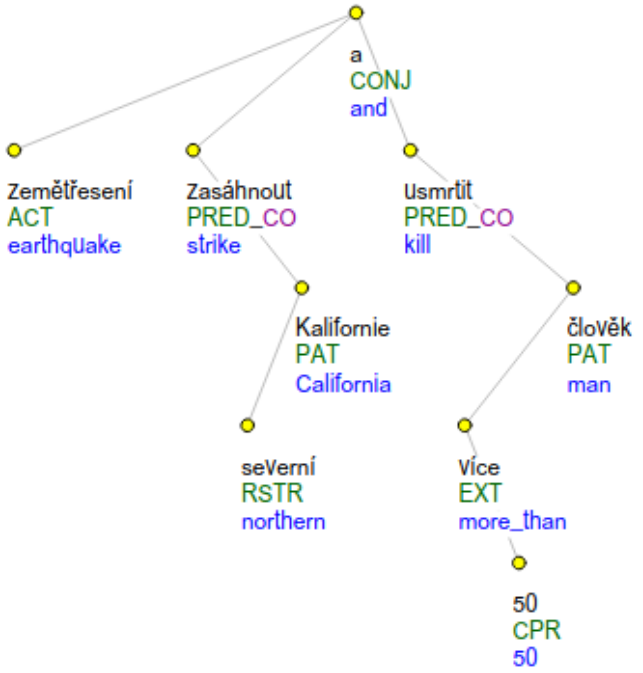
- Coarse-grained roles (only 17 labels), e.g.:
  - P: Process
  - S: State
  - A: participant
  - C: Center
  - D: Adverbial
  - E: Elaborator
  - F: Function
- "Anchored" graphs (Type 1), in the Open & Kuhlman taxonomy (somewhat compositional, but no formal rules for how a given node is derived)



Compositionality, Alignment to Text – Prague PDT (1)

Principles – Prague Dependency Treebanks

- Based on Functional Generative Description (dependency theory)
  - *Petr Sgall, Eva Hajičová and Jarmila Panevová. The Meaning of the Sentence in its Semantic and Pragmatic Aspects. Dordrecht: Reidel. 1986. Pp. xi + 353.*
- Used in the Prague Dependency Treebank family of corpora
  - Czech, English, Arabic, published/extended 2001-2022
- 3 layers of annotation:
  - **Tectogrammatical**, or "meaning" (example →)
    - syntactic-semantic annotation
      - Somewhat similar to F-layer of LFG
  - **Analytical**
    - Surface syntactic (dependency syntax)
  - **Morphology, lemmatization, tokenization**
- For spoken corpora, also audio
- Fully **aligned** between layers (Type 1)

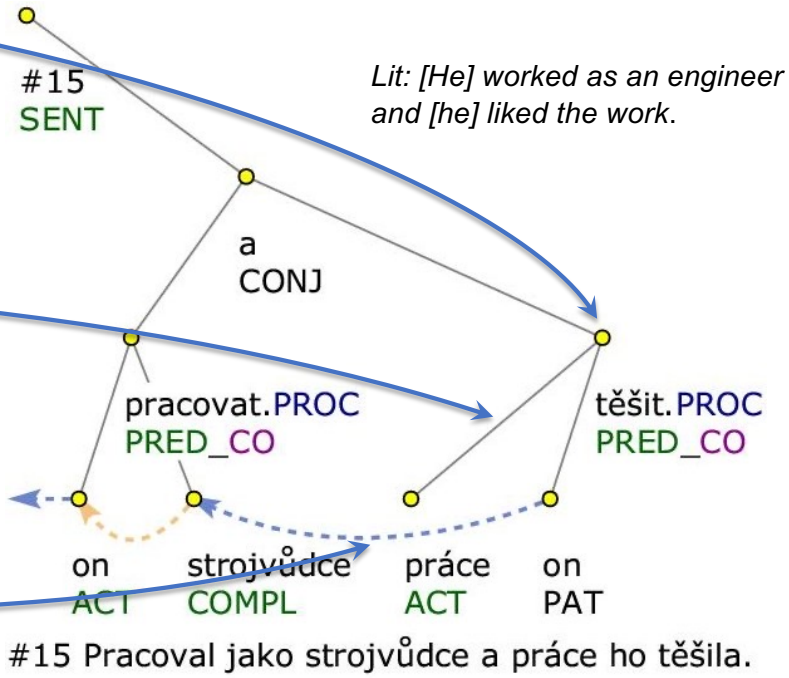


For the Czech version of "An earthquake struck Northern California, killing more than 50 people." (Čmejrek et al. 2004)

Compositionality, Alignment to Text– Prague PDT (2)

The Meaning (Tectogrammatical) layer

- Nodes: **lexically based** (and aligned to surface text)
  - Only **content** nodes (and some structural ones holding the graph together), no function words, null nodes
  - Many semantic attributes (tense, number, modalities, …)
  - **Information structure** by topic/focus labels and node order
- Edges:
  - Primary: dependency, labeled by (mostly) **semantic relations** and/or **valency lexicon arguments**
  - Secondary:
    - **Co-reference** (including cross-sentence), bridging
    - **Discourse** relations between clauses (incl. cross-sentence)
- Many aspects similar to AMR/UMR
  - AMR annotation for Czech exists, in parallel to PDT style

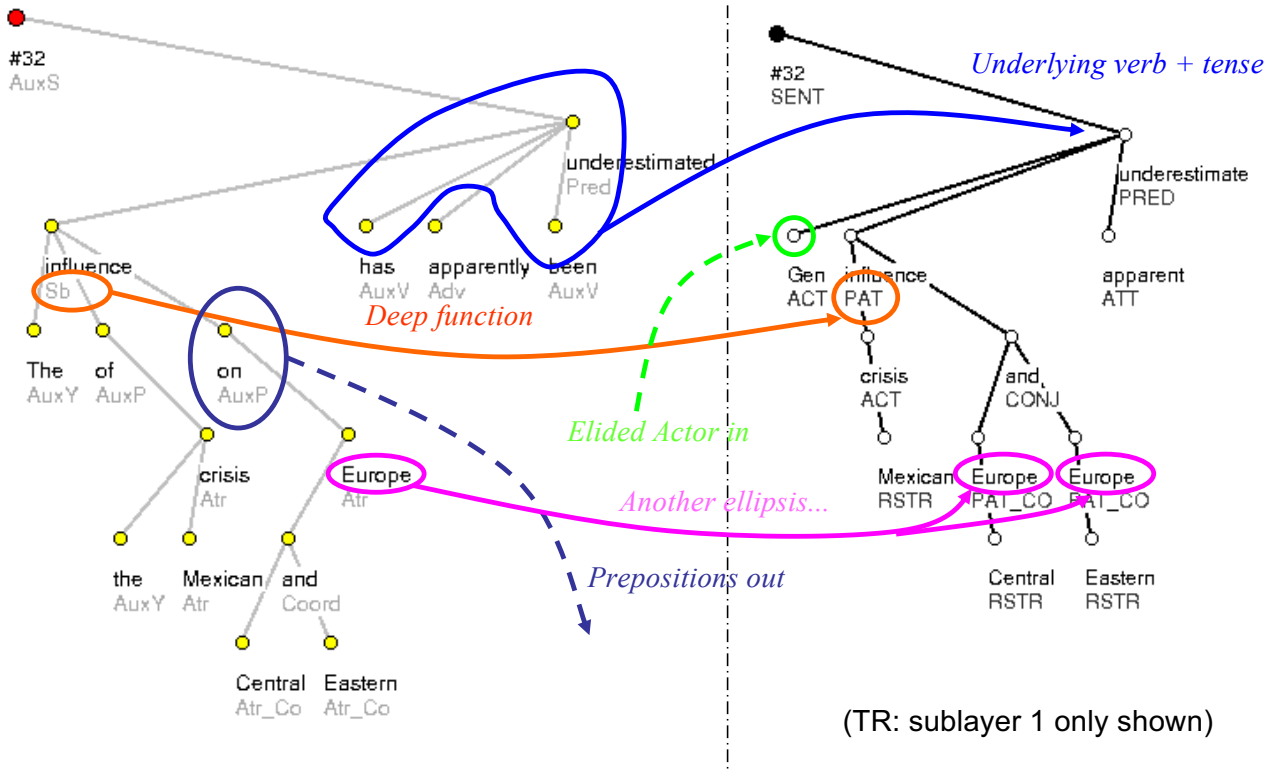


Lit: [He] worked as an engineer and [he] liked the work.

Compositionality, Alignment to Text– Prague PDT (3)

Alignment to surface dependencies and words

- Aligned to syntactic dependency graph layer (“type 1”)
  - m:n, incl. m=0 or n=0
- Each node aligned to surface syntactic graph nodes corresponding to
  - Lexical (content) word
  - Auxiliary (function) words (if any)
  - Graphical symbols (if any and if relevant)



(TR: sublayer 1 only shown)

Compositionality, Alignment to Text– Prague PDT (4)

Information structure (Topic-focus annotation)

- Example:
  - Baker bakes rolls. vs. *Baker*^{IC} bakes rolls.

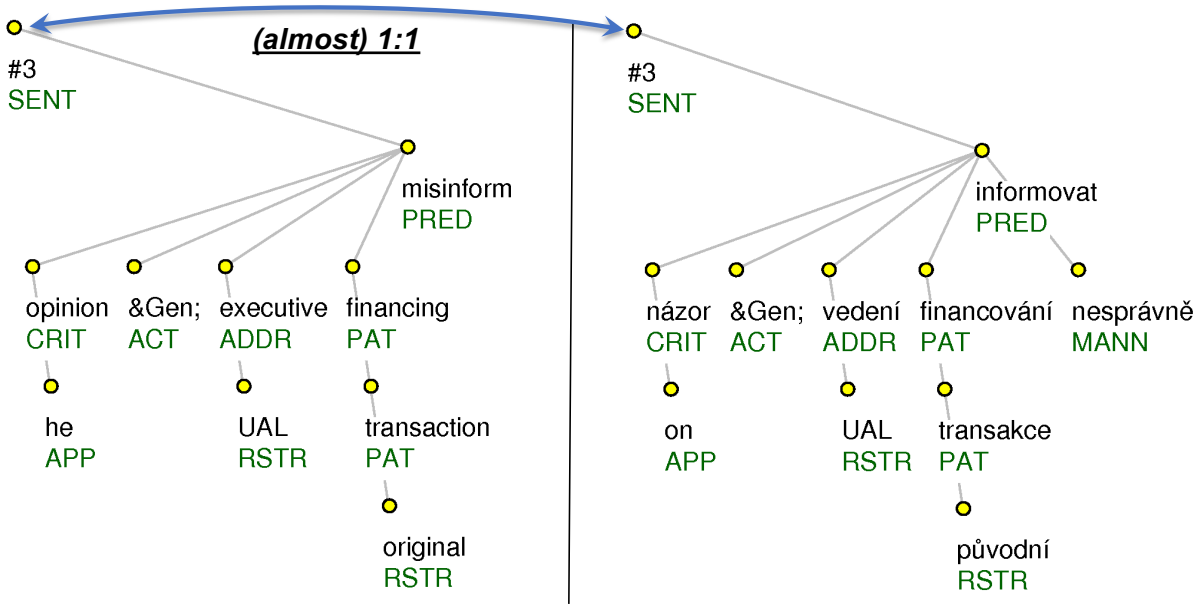
Context: talking about bakers, adding that it is **rolls** they bake

Context: talking about rolls, adding that it is **bakers** who make them

Compositionality, Alignment to Text – Prague PDT (5)

Multilingual PDT style annotation

- Prague Czech-English Dependency Treebank
  - Parallel Czech-English treebank to compare differences (Czech translation of English text, 1 mil. words)
  - Simplified annotation on the Tectogrammatical layer
  - Aligned with the (manual) Penn Treebank annotation



According to his opinion UAL's executives were misinformed about the financing of the original transaction.

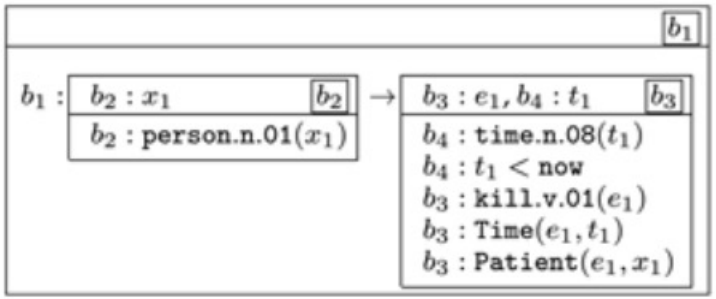
Podle jeho názoru bylo vedení UAL o financování původní transakce nesprávně informováno.

Logical & Executable Forms

- Lots of logical desiderata:
  - Modeling whether events happen and/or are **believed** (and other modality questions):
    - Sam believes that Bill didn't eat the plums.
  - Understanding **quantifications**: reference to **one song or many**?
    - Every child has a favorite song.
- PDT (Prague tectogrammatical layer):
  - **Scoping negation** within Information structure annotation (schematically only):
    - We did not visit grandma[topic] **Neg.RHEM** on Friday[f] (but on Thursday) vs.
    - We did not visit **Neg.RHEM** grandma[focus] on Friday[f] (but our aunt on Saturday)
- AMR: (with certain assumptions), PENMAN is a bracketed tree that can be treated like a logical form
  - Default assumption for AMR:
    - `":polarity -"` is a feature of a single node; no semantics for quantifiers like "every" – assumption is Neo-Davidsonian: bag of triples like ("instance-of(b, believe-01)", "instance-of(h, he), "ARG0(b, h)"
    - One cannot modify more than one node in the graph
- Competing frameworks like DRS and MRS more specialized for this

Logical & Executable Forms – DRS (1)

- Grounded in long theoretical DRS tradition (Heim & Kamp) for handling **discourse referents, presuppositions, discourse connectives, temporal relations across sentences**, etc.
  - *Kamp, H., 1981, "A theory of truth and semantic representation", in J.A.G. Groenendijk, T.M.V. Janssen, and M.B.J. Stokhof (eds), Formal methods in the Study of Language, Mathematical Centre Tracts 135, Amsterdam: Mathematisch Centrum, pp. 277–322.*
- DRS for "everyone was killed" (Liu et al. 2021)



Logical & Executable Forms – DRS (2)

- DRS frameworks
  - Scoped meaning representation
  - Outputs originally modified from CCG parser LF outputs -> DRS
  - DRS uses “boxes” which can be negated, asserted, believed in, …
  - ***Not*** natively a graph representation!
    - “box variables”(bottom): one way of thinking about these
      - a triple like “agent(e1, x1)” is part of b3
      - Box b3 is modified (e.g. b2 POS b3)
  - Annotations in Groeningen Meaning Bank and Parallel Meaning Bank
    - *Lasha Abzianidze, Johannes Bjerva, Kilian Evang, Hessel Haagsma, Rik van Noord, Pierre Ludmann, Duc-Duy Nguyen, Johan Bos (2017): The Parallel Meaning Bank: Towards a Multilingual Corpus of Translations Annotated with Compositional Meaning Representations. Proceedings of the 15th EACL, pp. 242–247, Valencia, Spain.*

24/3221: No one can resist.

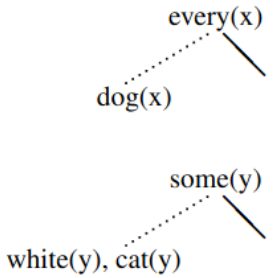

```
k0 NOT b2
b2 REF x1
b2 person n.01 x1
b2 POS b3
b3 Agent e1 x1
b3 REF e1
b3 resist v.02 e1
```

Logical & Executable Forms – MRS (1)

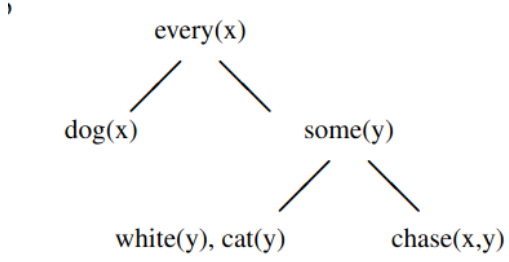
- **Minimal Recursion Semantics** (and related frameworks)
    - *Copestake, A., Flickinger, D. P., Sag, I. A., & Pollard, C. (2005). Minimal Recursion Semantics. An introduction. In Research on Language and Computation. 3:281–332*
- Define set of **constraints** over which variables outscope other variables
- Copestake (1997) model proposed for semantics of HPSG - this is connected to other **underspecification** solutions (Glue semantics / hole semantics / etc.)
    - *Asudeh, Ash & Crouch, Richard. (2002). Glue semantics for HPSG. Proceedings of the International Conference on Head-Driven Phrase Structure Grammar. 10.21248/hpsg.2001.1.*
- HPSG grammars like the English Resource Grammar
    - *Ann Copestake and Dan Flickinger. 2000. An Open Source Grammar Development Environment and Broad-coverage English Grammar Using HPSG. In Proceedings of the Second International Conference on Language Resources and Evaluation (LREC'00), Athens, Greece. European Language Resources Association (ELRA).*
    - produce ERS (English Resource Semantics) outputs (which are roughly MRS)
    - Also modified into a simplified DM format ("type 0" bilexical dependency)

Logical & Executable Forms – MRS (2)

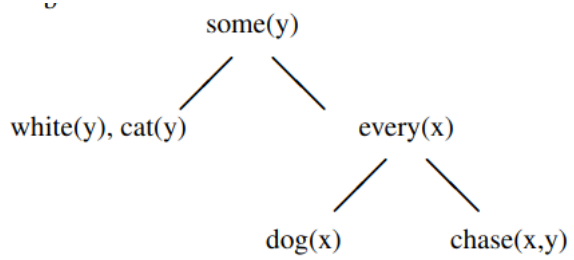
- Underspecification in practice:
  - MRS can the thought of as many fragments with constraints on how they scope together
  - Those define a set of MANY possible combinations into a fully scoped output, e.g.:



Every dog barks and chases a white cat (as interpreted in Manshadi et al. 2017)



$h1$: every$(x, h3, h5)$, $h3$: dog(x), $h7$: white(y), $h7$: cat(y),
$h5$: some$(y, h7, h4)$, $h4$: chase(x, y)



$h1$: every$(x, h3, h4)$, $h3$: dog(x), $h7$: white(y), $h7$: cat(y),
$h5$: some$(y, h7, h1)$, $h4$: chase(x, y)

Logical & Executable Forms – MRS (3)

- Variables starting with ***h*** are "handle" variables used to define constraints on scope.
  - h19 = things under scope of negation
  - h21 = leave_v_1 head
  - h19 =q h21 : equality modulo quantifiers
  - (neg outscopes leave)
- "forest" of possible readings
- **Takeaway:** Constraints on which variables "outscope" others can add flexible amounts of scope info

Sandy knows that Kim probably didn't leave.

$$\langle h_1, e_3,$$
$$\left| \begin{array}{l} h_4{:}\text{proper\_q}(x_6, h_5, h_7), \\ h_8{:}\text{named}(x_6, \textit{Sandy}), \\ h_2{:}\text{\_know\_v\_1}(e_3, x_6, h_9), \\ h_{10}{:}\text{proper\_q}(x_{12}, h_{11}, h_{13}), \\ h_{14}{:}\text{named}(x_{12}, \textit{Kim}), \\ h_{15}{:}\text{\_probable\_a\_1}(e_{16}, h_{17}), \\ h_{18}{:}\text{neg}(e_{20}, h_{19}), \\ h_{21}{:}\text{\_leave\_v\_1}(e_{22}, x_{12}, p_{23}) \end{array} \right|$$
$$\{ h_{19} =_q h_{21},\ h_{17} =_q h_{18},\ h_{11} =_q h_{14},\ h_9 =_q h_{15},\ h_5 =_q h_8,\ h_1 =_q h_2 \} \rangle$$

Lexicon/Ontology Differences

- Predicates can use different ontologies – e.g. more grounded in grammar/valency, or more tied to taxonomies like WordNet, or a combination (SynSemClass)
- Semantic Roles can be encoded differently, e.g. with non-lexicalized semantic roles (discussed for UMR later)
- Some additional proposals: "BabelNet Meaning Representation" propose using VerbAtlas (clusters over wordnet senses with VerbNet semantic role templates);
  - *R. Navigli, M. Bevilacqua, S. Conia, D. Montagnini and F. Cecconi. Ten Years of BabelNet: A Survey. Proc. of IJCAI 2021, pp. 4559-4567*
- SynSemClass: An event-type multilingual ontology
  - *Z. Urešová, E. Fučíková, E. Hajičová, J. Hajič (2020): SynSemClass Linked Lexicon: Mapping Synonymy between Languages. In: Proceedings of the 2020 Globalex Workshop on Linked Lexicography (LREC 2020), pp. 10-19, Marseille, France, ISBN 979-10-95546-46-7*

	DRS (GMB/PMB)	MRS	Prague (PDT, PCEDT, PDTSC, …)	AMR	UCCA
Semantic Roles	VerbNet (general roles)	General roles	General roles + valency lexicon [SynSemClass – upcoming]	Lexicalized numbered arguments	Fixed general roles
Predicates	WordNet	grammatical entries	PDT-Vallex valency lexicon (Propbank-like) + [SynSemClass – upcoming]	Propbank Predicates	A few types (State vs process …)
non-predicates	wordnet	Lemmas	Lemmas	Named entity types	Lemmas

Task-specific Representations (1)

- Many use “Semantic Parsing” to refer to **task-specific, executable representations**
  - Text-to-SQL (long history, since 1990s)
    - Air traffic information system (ATIS – IBM and others’)
  - interaction with robots, text to code/commands
    - From T. Winograd block system (1970s)
  - interaction with deterministic systems like calendars/travel planners
- Similar distinctions to a general-purpose meaning representation, BUT
  - May need to map into **specific task taxonomies** and ignore content not relevant to task
    - Good and bad
  - Can require more detail or **implicit inference** (vs. “context-free” representations)
    - Good and bad
  - Often can be thought of as **first-order logic** forms — simple predicates + scope

Task-specific Representations (2)

- Classic datasets (Table from Dong & Lapata 2016) regard household commands or querying KBs

Dataset	Length	Example
JOBS	9.80	*what microsoft jobs do not require a bscs?*
	22.90	answer(company(J,'microsoft'),job(J),not((req_deg(J,'bscs'))))
GEO	7.60	*what is the population of the state with the largest area?*
	19.10	(population:i (argmax $0 (state:t $0) (area:i $0)))
ATIS	11.10	*dallas to san francisco leaving after 4 in the afternoon please*
	28.10	(lambda $0 e (and (>(departure_time $0) 1600:ti) (from $0 dallas:ci) (to $0 san_francisco:ci)))
IFTTT	6.95	*Turn on heater when temperature drops below 58 degree*
	21.80	TRIGGER: Weather - Current_temperature_drops_below - ((Temperature (58)) (Degrees_in (f))) ACTION: WeMo_Insight_Switch - Turn_on - ((Which_switch? ("")))

- Recent tasks for text-to-SQL

Complex question

What are the name and budget of the departments with average instructor salary greater than the overall average?

Complex SQL

```
SELECT T2.name, T2.budget
FROM instructor as T1 JOIN department as
T2 ON T1.department_id = T2.id
GROUP BY T1.department_id
HAVING avg(T1.salary) >
    (SELECT avg(salary) FROM instructor)
```

Discourse-Level Annotation

- Do you do multi-sentence coreference?
  - Partial coreference (set-subset, implicit roles, etc.)?
- Discourse connectives?
- Treatment of multi-sentence tense, modality, etc.?
- Prague Tectogrammatical annotations & AMR only general-purpose representations with extensive **multi-sentence** annotations

Overviewing Frameworks vs. AMR

	Alignment	Logical Scoping & Interpretation	Ontologies and Task-Specifc	Discourse-Level
DRS (Groeningen / Parallel)	Compositional /Anchored	Scoped representation (boxes)	Rich predicates (WordNet), general roles	Can handle referents, connectives
MRS	Compositional /Anchored	Underspecified scoped representation	Simple predicates, general roles	n/a
UCCA	Anchored	Not really scoped	Simple predicates, general roles	Some implicit roles
Prague Tectogrammatical Representation Layer	Anchored	Not really scoped with exceptions (negation)	Rich predicates, semi-lexicalizekd roles	Rich multi-sentence conference, discourse
AMR	Unanchored (English); Anchored (Chinese)	Not really scoped yet	Rich predicates, lexicalized roles	Rich multi-sentence conference

End of Meaning Representation Comparison

- What's next: UMR — proposal within AMR-connected scholars on next steps for AMR.
- Questions about how AMR is annotated?
- Questions about how it relates to other meaning representation formalisms?