Semantic frames

Ahmed ElShinawi

Outline

- Structure of Semantic frames
- ATIS system
- Technical challenges of SLU
- Knowledge based approach
- Data driven approach System
- Drawbacks

Semantic Frame

- Semantic frame comes from frame semantics (a theory that relates linguistic semantics to encyclopedic knowledge developed by Charles J. Fillmore)
- A semantic frame is defined as a coherent structure of concepts that are related such that without knowledge of all of them, one does not have complete knowledge of one of the either.
- Idea is that one cannot understand the meaning of a single word without access to all the essential knowledge that relates to that word. For example observe the connection presented in this *commercial transaction frame:*

VERB	BUYER	GOODS	SELLER	MONEY	PLACE
buy	subject	object	from	for	at
sell	to				
cost	indirect object	subject		object	at
spend	subject	on		object	at

Continue: semantic frame

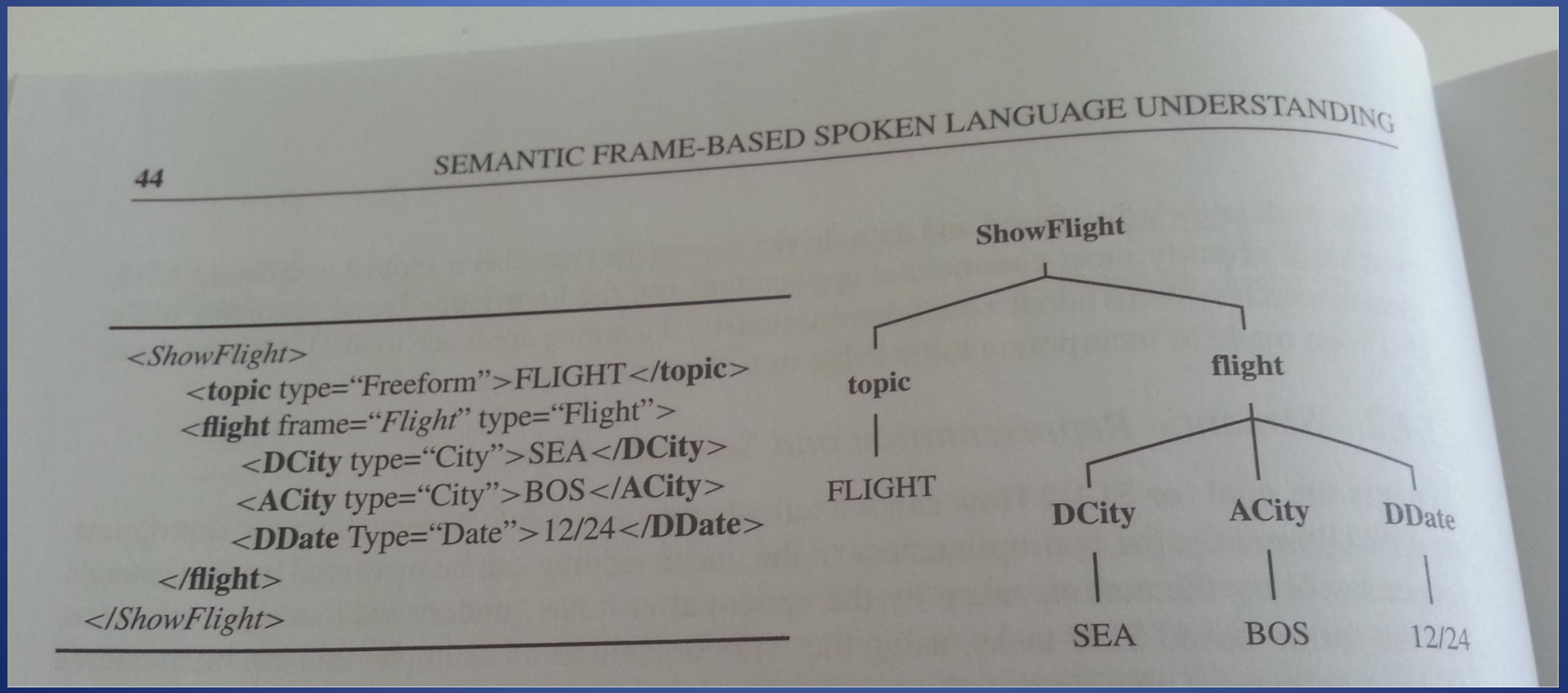
- We observe that a word activates, or evokes, a semantic frame of encyclopedic meaning relating to the specific concept it refers to.
- Words specify a certain perspective in which the frame is viewed.
- Take a minute to come up with words frame relations yourself (Group Work)

Characteristics of frame based SLU

- Limited to specific domain
- Structure of semantic space can be represented by semantic frames
- Semantic frames elements are called slots
- Ultimate goal of frame based slu is to choose the correct semantic frame for an utterance

History & Application

- Started in the 1970s in DARPA speech understanding research (SUR)
- In 1990s outcome of DARPA research programmes, AT&T, MIT, CMU was the ATIS (air travel information system)
- Example：Show me the flights from Seattle to Boston on Christmas Eve



Technical Challenges

- SLU is focused only on specific application domain thus the semantics are defined accordingly, although it might make a problem easier to solve, there are challenges：
  - Extra-grammaticality
  - Disfluencies
  - Speech Recognition errors
  - Out of domain utterances
- Robustness is an important feature in SLU for (spontaneous conversations)

Evaluation Metrics

- A variety of Metrics are used in the evaluation of frame based SLU, some of the commonly used Metrics are:
- Slot Error Rate (SER) :
  - SER = $\frac{\text{\#of inserted/deleted/substituted slots}}{\text{\# of slots in the reference semantic representations}}$
- Sentence/Utterance Level Semantic Accuracy (SLSA):
  - SLSA = $\frac{\text{\#Sentence assigned to correct semantic representation}}{\text{\# of Sentences}}$

Knowledge-based approach

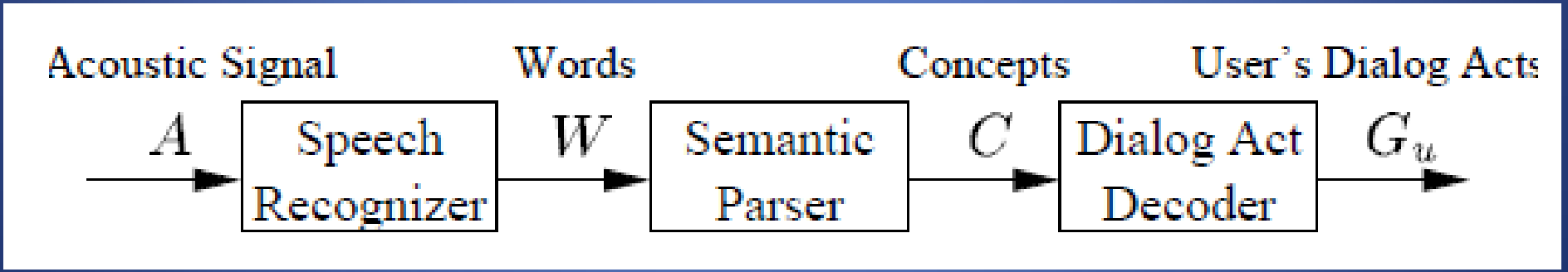
- Knowledge based approaches are helpful in modeling domain-specific language e.g. MIT TINA, SRI Gemini
- CMU Phoenix slu system (developed in 1991) models the domain dependent semantics with a semantic grammar
  - Slots are filled by RTN (Recursive Transition Networks) that specifies a pattern for filling (template matching)
  - Phoenix performs a search process on all active frames & return the single best parse that covered most slots discovered by the slot-nets
- Knowledge-based approaches often requires the exact matching of input sentences to the grammar rules
  - Grammar complexity, for example Phoenix grammar was very complicated, it contained 13k grammar rules
  - Problem with such approach that it becomes not robust to ASR errors

Drawbacks of knowledge based system

- Grammar development is error prone because its highly domain specific
- Grammar needs to evolve over time – new features and scenarios
- Maintaining such systems require expert's involvement
- Grammar is difficult to scale up in sense of allowing users to volunteer multiple pieces of information in a single utterance.

Data Driven Approaches

- The statistical frame-based approach is often previewed as a pattern recognition problem
  - Yulan He and S. Young, "A data-driven spoken language understanding system," *Automatic Speech Recognition and Understanding, 2003. ASRU '03. 2003 IEEE Workshop on*, 2003, pp. 583-588. doi: 10.1109/ASRU.2003.1318505
  - speech recognizer, a semantic parser, and a dialog act decoder



System Architecture

Traditionally, the SLU problem is solved in three stages. First recognize the underlying word string W from each input acoustic signal A, i.e.

$$\hat{W} = \underset{W}{\text{argmax}}\, P(W|A) = \underset{W}{\text{argmax}}\, P(A|W)P(W) \qquad (1)$$

then map the recognized word string $\hat{W}$ into a set of semantic concepts C

$$\hat{C} = \underset{C}{\text{argmax}}\, P(C|\hat{W}) \qquad (2)$$

and finally determine the user's dialog acts or goals by solving

$$\hat{G}_u = \underset{G_u}{\text{argmax}}\, P(G_u|\hat{C}) \qquad (3)$$

Advantages & Drawbacks

- Advantages :
  - Robust to noise
- Drawbacks :
  - Data sparsity
  - Requirements of large amount of labeled data

Summary

- Semantic frame
- Knowledge based approach
- Data driven approach
- Drawbacks

Refrences

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