Analysis of natural spoken phrases with recurrent neural networks

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1. Goals

- Analysis of natural spoken phrases and determining the meaning without dependencies to the formulation.
- Algorithmic generation of appropriate learn- and validation sets with generative grammar.

2. Specification of phrase-meaning

- Allocation of so-called “semantic roles” for selected phrase parts
  - Max (Agent) loves (Verb) Lisa (Patient)
  - Lisa (Patient) is loved (Verb) by Max (Agent)
- Semantic roles are not grammatical phrase-parts !
  - Remember: “Subject”, “Predicate”, “Object”,...
- Allocation of semantic roles keep the same, although a changed phrase formulation.
- Semantic roles can be defined at one's own descretion

Word	sem. Role
Max	Agent
loves	Verb
Lisa	Patient

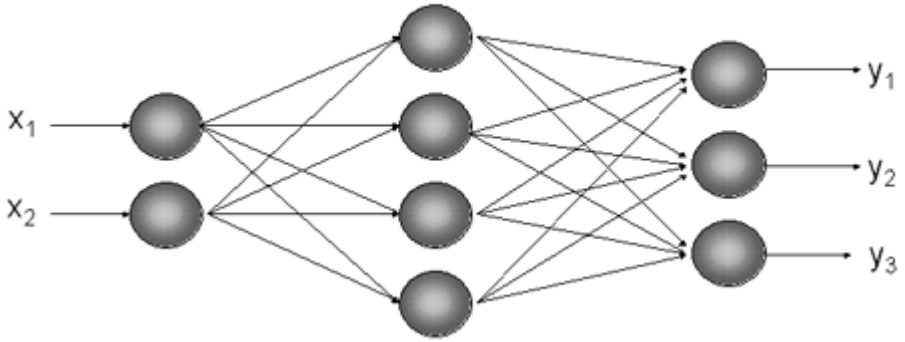
3. Ambiguity

- Problem: Too often natural language is formulated ambiguous.
- Example: "Time flies like an arrow"
  - Time flies as fast as arrows flying away.
  - To time flies like an arrow is doing that.
  - To time flies that look like arrows.
  - "Timeflies" () like (to care for) arrows.
- To determine the meaning of a phrase, syntactical knowledge is not enough
- We need contextual knowledge.
- Problem: A parser isn't able to store or compute the complete sense of the world !

4. Neural Network

- Idea: Use neurobiological concepts to recognize natural language.
- Teach a small amount of example phrases with correct allocated semantic roles.
- Supervised learning analog to the children's speech acquirement.
- Ability to analyse not known phrases by abstracting and generalization.
- Correct allocation of semantic roles for not known phrases.

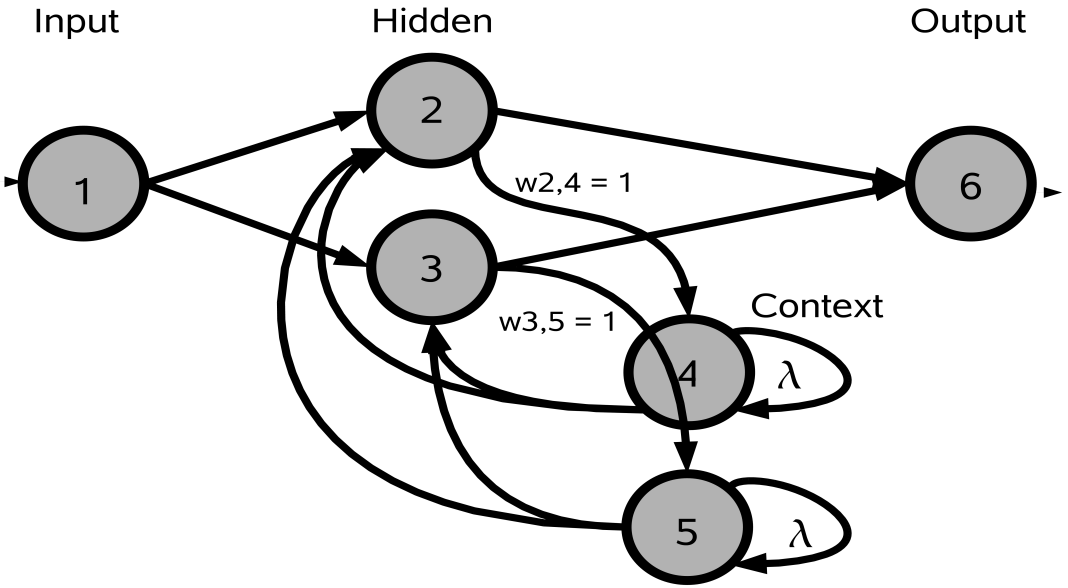
5. Feed-Forward-Net



Limitations:

- Input-Layer has a fixed size (amount of input neurons).
- Cannot accept phrases of different length (word count).
- It Has no “internal memory”, so we cannot propagate the phrases word by word.
- It has no simularities to the human language understanding.

6. Elman-Net



- "Internal" memory is enabled by context neurons (Nr. 4 and 5)
  - stores the output of the hidden neurons of the timestep before.
  - depends on the memory-factor $\lambda \in [0,1]$.
- Is able to determine chronological dependencies in the input sequence.

Idea:

- Phrase is propagated sequentially (word by word), also during training.
- Output of the words with its allocated semantic role(s).

7. Learning set / Validation set

- Definition of a generative grammar to produce a large set for learning and validating (example phrases)
  - Non-terminals are substituted with the concrete word-assignment
- It produces a large language-amount (Example: 12x3x3x3x3x3 = 2916 Phrases)
- Only a small fraction of this amount has to be put in the learn- and validation set. Learndensity $\rho \in [0,1]$
  - Neural-Network has to generalize. Only a small amount of learning phrases must be enough.
- $Validationset \subseteq Total\ Amount \setminus Learningset$

8. Encoding the Net-Input

- Example: Active phrase "**`Max(Agent) loves (Verb) Lisa (Patient)`**"
  - Learn pattern
  - AND
  - Word- and Rolebook

	Timeindex		t_0	t_1	t_2
Input	Word		*Max*	*loves*	*Lisa*
Output	Word		*Max*	*loves*	*Lisa*
(Ref-Value)	sem. Role		Agent	Verb	Patient

Word	**Code**
Max	001
loves	010
Lisa	100

Role	**Code**
Agent	001
Patient	010
Verb	100

- Input and Output for the neural net (Timeindex)

Input (Word) **Output** (Word+Role)	0 0 1 0 0 1 0 0 1
Input (Word) **Output** (Word+Role)	0 1 0 0 1 0 1 0 0
Input (Word) **Output** (Word+Role)	1 0 0 1 0 0 0 1 0

t_0

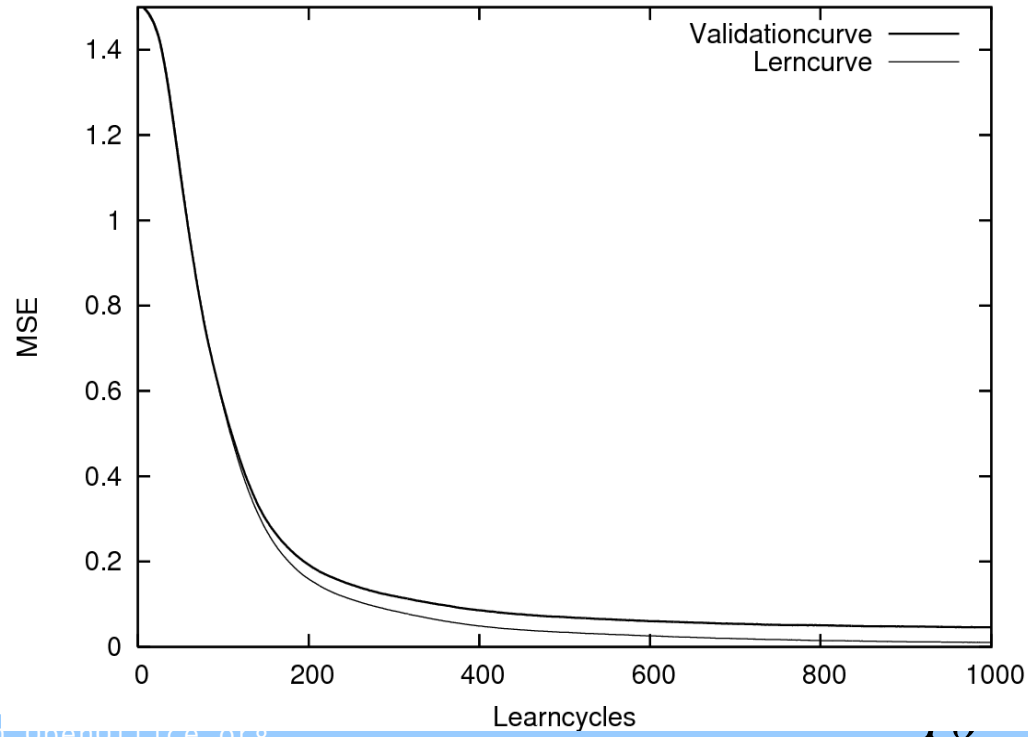
t_1

t_2

9. Learning-process for active- and passivephrases

Example active- and passivephrases

- Total amount of 7488 phrases.
- Learndensity $\rho = 0.01$ results 75 phrases in the learning set and 64 phrases in the validation set (1% of the total phrase amount).
- $Memoryfactor\ \lambda = 0.2, Learningrate\ \eta = 0.01, Cycles\ n = 1000.$
- Elman-Net
  - 2 hidden layer
  - 50 neurons per layer



10. Practical test for active and passive phrases

- Test for all 64 Phrases of the validation set
  - It is essential: *Validationpattern ⊄ Learningset.*

semantic role	Ref-Allocations	Actual-Allocations	%
Agent	64	58	*90.6 %*
Patient	64	60	*93.8 %*
Verb	64	64	100.0 %
Place	64	64	100.0 %
Time	64	64	100.0 %
Total	320	310	96.9 %

- Variant role-allocations were learned and abstracted “very well” (> 90%)
- Invariant role-allocations were learned “perfect”, because special words only appear with a special semantic role (yesterday, today, tomorrow).

11. Learning-process for ambiguous phrases

- Motivation: Determining the semantic role for the last phrase part.
- We learn only phrases of the following kind
  - AGENT enchains PATIENT with the chain (instrument).
  - AGENT enchains PATIENT with the binoculars (attribute).
  - AGENT observes PATIENT with the chain (attribute).
  - AGENT observes PATIENT with the binoculars (instrument).

  and
  - AGENT looks at PATIENT with the binoculars (instrument).

- Interesting question: How acts the neural net with the not learned phrase
  - AGENT looks at PATIENT with the chain (???)

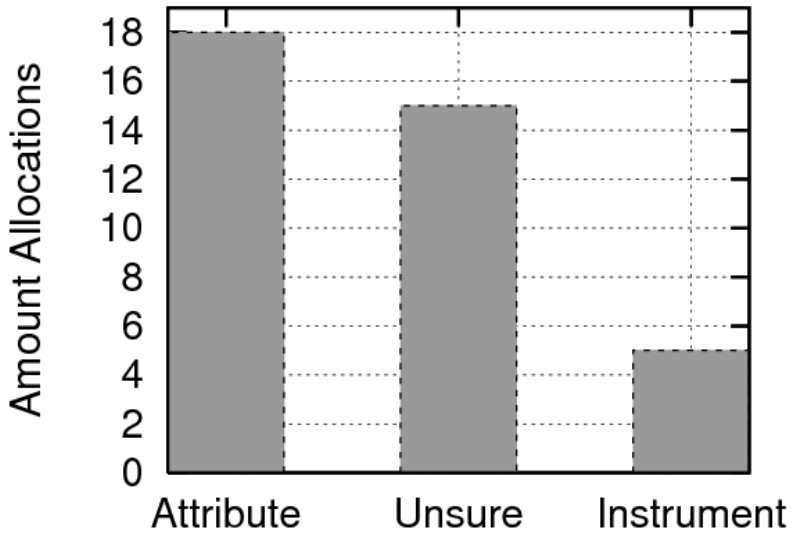
12. Practical test for ambigous phrases

- Test only with phrases of the following kind (37 phrases)
  - AGENT looks at PATIENT with the chain. (not learned)
- What semantic role is allocated to the phrase part “with the chain” ?

  (instrument or attribute ?)
- Result: Attribute: 18 Phrases, Unsure: 14 Phrases, Instrument: 5 Phrases

Conclusion:

- The net has learned the alternating relation between instrument and attribute.
- The words “look at” are never learned in relation with attribute !
- Special words now behave like operands.



12. Practical test for ambigous phrases

- Demonstrative interpretation:
- **IF**
  - Max enchains Lisa with the chain => (instrument).
  - Max enchains Lisa with the binoculars => (attribute).
  - Max observes Lisa with the chain => (attribute).
  - Max observes Lisa with the binoculars => (instrument).

12. Practical test for ambigous phrases

- Demonstrative interpretation:
- **IF**
  - Max enchains Lisa with the chain => (instrument).
  - Max enchains Lisa with the binoculars => (attribute).
  - Max observes Lisa with the chain => (attribute).
  - Max observes Lisa with the binoculars => (instrument).

  AND
  - Max **X** Lisa with the binoculars => (instrument)

12. Practical test for ambigous phrases

- Demonstrative interpretation:
- **IF**
  - Max enchains Lisa with the chain => (instrument).
  - Max enchains Lisa with the binoculars => (attribute).
  - Max observes Lisa with the chain => (attribute).
  - Max observes Lisa with the binoculars => (instrument).

  AND
  - Max **X** Lisa with the binoculars => (instrument)
- **THEN**
  - Max **X** Lisa with the chain => (attribute)

End

Thank you !