The Aims of Linguistic Theory

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Natural Language Processing
Outline

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- Structural Analysis
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- Transformational Rules
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In contrast with programming language we have no
- *clear understanding* of expressions’ structure,
- *explicit statement of the rules of syntax* – we have no direct access to them, they are concealed in our cognitive makeup in natural languages.
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Natural Language Processing

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in natural languages.

Outline

- Introducing of some basic linguistic terminology.
- We show diagnostics and techniques used by linguists for the examination of the structure of natural language utterances.
- Some general goals of a theory of language.
Main Linguistic Goals

Main Goal

- Generalizations about the **structure** and **meaning** of sentence.
**Major Linguistic Goals**

**MAIN GOAL**
- Generalizations about the **STRUCTURE** and **MEANING** of sentence.

These five perspectives contribute to this goal:
- **Syntax** – structure
**Main Goal**

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- **Semantics** – meaning
- **Pragmatics** – meaning in spoken context
- **Morphology** – structure of the word
- **Phonology** – structure of sounds

- **Others** – structure of discourse, study of brain mechanisms
Patterns

Certain structural regularities.

Example

1. John left the party earlier.
2. The man with the coat left the party earlier.
3. Every guest left the party earlier.
4. He left the party earlier.
Syntax of the Sentence

Patterns
 Certain structural regularities.

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Highlighted words in each sentence appear in the same structural context and all perform the same grammatical function – subject.
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Highlighted words in each sentence appear in the same structural context and all perform the same grammatical function – *subject*.

- Each highlighted word can be replaced by any of the others and it is still grammatically correct.
- This part is called **DISTRIBUTINAL ANALYSIS**.
- Important unit – *noun phrase*. 
Example

Prepositional Phrase

1. *The man with the coat* walked in.
2. *The book on the shelf* is mine.
Examples: Distributional Analysis

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Adjectival Phrase

1. *The young and happy* couple just got married.
2. *My children are young and happy.*
### Examples: Distributional Analysis

#### Example

**Prepositional Phrase**

1. *The man* with the coat walked in.
2. *The book* on the shelf *is* mine.
3. John put the book *on* the shelf.

#### Example

**Adjectival Phrase**

1. *The young and happy* couple just got married.
2. My children are *young and happy*.

#### Example

**Verb Phrase**

1. Bill ate the cake and Mary ate the pie.
2. Mary *likes to go swimming* and Bill *does too*.
3. John made Mary *pack her bags*.
- Natural Language Processing
- Structural Analysis
- Transformational Rules
Structural Differences

- Some structural differences or similarities in sentences are not so obvious and they may be more elaborate.

Example 1
I expected John to leave.

Example 2
I persuaded John to leave.

Considering two sentences above we know:
- There is a relation between John and to leave.
- John performs the role of the object in 2, but not in 1.
- In 1, what is being expected is the entire proposition (John’s leaving).
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How do we do structural analysis?

- **syntactic (also diagnostic) tests**

  - Selectional properties of verbs:
    - In case of verb *persuade*, the noun phrase must be animate (one cannot persuade the book to do something).
    - Selectional restriction = dependency between verb and its object

  - Examining the meaning of sentences

    - Difference between object of the verb
      - *expect* – object is whole sentence
      - *persuade* – has two objects – noun phrase and embedded sentence
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Tree structures are the key to the analysis of natural language syntax.
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Example

```
S
 NP   VP
   Det N V Adj
     The man is tired
```

- S – sentence
- NP – noun phrase
- Det – determiner
- V – verb
- Adj – adjective
- N – noun
- VP – verb phrase
Tree Structures

- Tree structures are the key to the analysis of natural language syntax.

Example

- **S** – sentence
- **NP** – noun phrase
- **Det** – determiner
- **N** – noun
- **VP** – verb phrase
- **Adj** – adjective
- **V** – verb

Linguistic notation (phrase marker):

\[
[S[NP[Det the][N man]][VP[V is][Adj tired]]]
\]
Phrase marker definition

If \( t \) is a tree and \( \{ t \} \) is the phrase marker for that tree, then:

1. The phrase marker for word is the word itself.
2. The phrase marker for \( A \) \( t \) is \( \[ A \{ t \} \] \).
3. The phrase marker for \( B \) \( t_1 \ldots t_n \) is \( \{ B \{ t_1 \} \ldots \{ t_n \} \} \).
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1. phrase marker for word is the word itself

2. the phrase marker for $A$ is $[A\{t\}]$

\[
\begin{array}{c}
A \\
\downarrow \\
t
\end{array}
\]
Phrase marker definition

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is \([A \{ t \}]\)

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\begin{array}{c}
\phantom{t_1 \ldots t_n} \\
B \\
\phantom{t_1 \ldots t_n} \\
\end{array}
\]

is \([B \{ t_1 \} \ldots \{ t_n \}]\)
• persuade

Example

```
S
  NP
    I
  VP
    V
      persuaded
    John.NP
    VP
      to leave
```
• persuade

Example

\[
[S[NP]]_V [V[persuaded]] [NP[John]_VP[to leave]]
\]
- **expect**

**Example**

```
S
  /\ 
/   \/
NP    VP
  /\  /\ 
 /   /   /
John expected to leave
```

Note: As you can notice "John to leave" is marked as sentence S. (Further information can be found in literature.)
• **expect**

Example

```
[S [NP I] [VP [V expected]] [S [NP John] [VP to leave]]]
```

• **Note:** As you can notice *John to leave* is marked as sentence S. (Further information can be found in literature.)
- Natural Language Processing
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Q: How to relate two sentences with the same meaning but different structure?

- active and passive forms in English
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- active and passive forms in English

A: Relatedness between sentences can be captured by deriving the two phrase markers (Chomsky):

- S-structures (surface structure)
- D-structures (deep structure)
According the Chomsky transformational theory, grammar for natural language has the following components:

1. Set of phrase structure rules (all of them in form of context-free rules)
2. A lexicon (dictionary for the language)
3. The transformational rules
4. Rules of phonology
Lexicon contains this type of information:

1. Categorization
2. Subcategorization
3. Selectional Restriction
4. Argument structure
5. Lexical semantics
6. Phonetic representation
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Example

Lexical entry for word hit
hit: V, <NP>, (AGENT, THEME, INSTR)
- (1) represents grammatical type,
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Lexical entry for word *hit*

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- (2) *hit* is a transitive verb, taking an NP object,
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Example

Lexical entry for word *hit*

hit: V, <NP>, (AGENT, THEME, INSTR)

- (1) represents grammatical type,
- (2) *hit* is a transitive verb, taking an NP object,
- (4) argument structure is a list of thematic roles
• Transformational rules establish **generalization** in language.

**Passive Transformation**

• One rule captures the relatedness between the **active** and **passive** forms of sentence.

**Definition:** In a context, NP V NP X:
• transpose two NP,
• add the relevant form of the verb **be**,
• change the verb to its past participle.

**SD** - structural description

**SC** - structural change
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<td>SD: NP V NP X 3 4</td>
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- SD - structural description
- SC - structural change
Passive Transformation

Example

\[ S [ np \ this \ man [ aux ] [ vp [ v \ love ] [ np Mary ] ] ] \]

The result of the passive transformation is the sentence in passive form with the same meaning as the sentence in active form.
Example

\[ [S[NP \textit{this man}[\textit{AUX}][VP[V love][NP Mary]]]] \]

<table>
<thead>
<tr>
<th>SD:</th>
<th>this man</th>
<th>love</th>
<th>Mary</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>⇒</td>
</tr>
<tr>
<td>SC:</td>
<td>3</td>
<td>\textit{be+2(pp)}</td>
<td>4</td>
<td>\textit{by + 1}</td>
</tr>
<tr>
<td>Mary</td>
<td>\textit{is loved}</td>
<td>ε</td>
<td>by \textit{this man}</td>
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Example

Some problems could be in sentences containing idioms. For example:

1. John took advantage of the situation.
2. Advantage was taken of the situation by John.
3. The situation was taken advantage of by John.
Contraction in English

Eg. using verb want in everyday speech:

- *I wanna buy the beer for the party.*
- *want* and *to* become one word phonetically
- (also others – *going to* → *gonna*, *used to* → *useta*)

Questions:

- Can we contract *want* and *to* if they are contiguous?
- Answer: No.
Common Verbs in English – Contraction

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But there is no possibility to contract *want* and *to* in this case:

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- *I want Bill to buy a beer for the party.*

⇒ Q: Can we contract *want* and *to* if they are contiguous?

Answer: **No.**
Example

- Who do you **want to** buy the beer for the party? we can not contract to
- 😞 Who do you **wanna** buy the beer for the party?
Common Verbs in English – Contraction

Example

- Who do you want to buy the beer for the party? we can not contract to
- 😔 Who do you wanna buy the beer for the party?

→ Why we can not do this? It is explained by deep study of the sentence structure.
wh-questions

- One type of generalization that can be captured by transformations involves questions.
- Questions involving who and what are called wh-questions.
Example

TYPE I

1a John drove his car.
2a John thinks Mary drove his car.
3a John thinks Mary wants Bill to drive his car.
wh-questions

Example

TYPE I

1a John drove his car.
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TYPE II

1b What did John drive?
1c Who drove his car?
2b Who does John think drove his car?
2c What does John think Mary drove?
3b Who does John think Mary wants to drive his car?
3c What does John think Mary wants Bill to drive?
wh-movement

- Q: How could we generate sentences in these two classes? (TYPE I. and TYPE II. in previous example)
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**wh-movement**

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<td>SD: X wh Y</td>
</tr>
<tr>
<td>1 2 3</td>
</tr>
<tr>
<td>SC: 2 do+1 e 3</td>
</tr>
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</table>

- e - empty category (trace) marking an interesting concept
Example

Applying this rule to sentence 1b:

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<tr>
<th>SD:</th>
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<th>what</th>
<th>ε</th>
</tr>
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<tbody>
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<td>2</td>
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Result: What does John drive?
wh-questions

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Result: What does John drive e?

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wh-questions

**Example**

Applying this rule to sentence 1b:

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Result: What\(_i\) does John drive \(e_i\)\

- Index \(i\) means that wh-word and trace refer to the same thing.

By comparing two sentences 1a and 1b we get following semantic representation:

1. DRIVE(John, John’s car)
2. ?(For which x) DRIVE (John, x)
wh-questions

Example

- wh-questions explain previous example with contraction of want and to.
- In fact, want and to are not contiguous, because there is a NP-trace between them.

  - You want who to buy the beer for the party?

    and after applying the wh-movement we get:

    - Who_i do you want e_i to buy the beer for the party?
Example

• John is believed to be wanted by police, by everyone in this room.

→ Apply reverse passive transformation to get the sentence in active form:
Example

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- Everyone in this room believes John to be wanted by police.

→ The sentence still contains a passive form → apply passive transformation:
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- Original deep structure:

  - $[S[NP\text{everyone} \ldots ][VP\text{believe}[S[NP\text{the police}][NP\text{want John}]]]]$
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In the original sentence were two passives. How do we know where to apply the rule first?
How do we know where to apply the rule first?

1. Apply the rule to the lowest (most deeply embedded) sentence.
2. Work our way up to the top cycle.

- wh-movement also applies cyclically.
References

James Allen:  
*Natural Language Understanding*,  
The Benjamin/Cummings Publishing Company, Inc., 2005

Robert N. Moll, Michael A. Arbib, A. J. Kfoury:  
*An Introduction to Formal Language Theory*,  
Springer-Verlag, 1988
Thank you for your attention!
End