Subregular toolkit implemented in Python

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A mysterious puzzle

**Russian**

1a. zavtra  
   tomorrow

1b. posle-zavtra  
   the day after tomorrow
A mysterious puzzle

Russian

1a. zavtra
   tomorrow

1b. posle-zavtra
   the day after tomorrow

1c. posle-posle-zavtra
   the day after the day after tomorrow
A mysterious puzzle

**Russian**

1a. *zavtra*
   tomorrow

1b. *posle-zavtra*
   the day after tomorrow

1c. *posle-posle-zavtra*
   the day after the day after tomorrow

**Ilocano**

2a. *bigat*
   morning

2b. *ka-bigat-an*
   the next morning
## A mysterious puzzle

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| 1a. **zavtra**  
   tomorrow | 2a. **bigat**  
   morning |
| 1b. **posle-zavtra**  
   the day after tomorrow | 2b. **ka-bigat-an**  
   the next morning |
| 1c. **posle-posle-zavtra**  
   the day after the day after tomorrow | 2c. *ka*<sup>n</sup>-**bigat-an</sup><sub>n</sub>  
   *the morning after the next one* |
## A mysterious puzzle

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Why is (2c) impossible?
Human language and its complexity

Why does the complexity of human language matter?
Human language and its complexity

Why does the complexity of human language matter?

Science  Industry
Human language and its complexity

Why does the complexity of human language matter?

Science

Classifying an object in terms of its complexity helps to study and predict its properties.

Industry

Knowing types of dependencies, we can design better processing techniques and learners.
The Chomsky Hierarchy of String Languages

- recursively enumerable
- context-sensitive
- mildly context-sensitive
- context-free
- regular
- (finite)
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- recursively enumerable
- context-sensitive
- mildly context-sensitive
- context-free
- regular
  - (finite)

- Sound structure (Kaplan&Kay 1994)
- Sentence structure (Joshi 1985)
- Word structure (Beesley&Karttunen 2003)
Regular languages

Regular languages = FSA recognized = MSO definable
Regular languages

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\[a^+b^+\]
Regular languages

Regular languages = FSA recognized = MSO definable

\[ a^+ b^+ \]

\[ 1 \xrightarrow{a} 2 \xrightarrow{b} 3 \]
Regular languages

Regular languages = FSA recognized = MSO definable

\[a^+ b^+\]

\[a^n b^n\]
Regular languages

Regular languages = FSA recognized = MSO definable

\[ a^+ b^+ \]

\[ a^n b^n \]

Regular
Regular languages

Regular languages = FSA recognized = MSO definable

![Diagram of regular languages](image)

**Regular**

Regular languages $= FSA$ recognized $= MSO$ definable
Regular languages

Regular languages = FSA recognized = MSO definable

Regular

\[a^+ b^+\]

Context-Free

\[a^n b^n\]
The class of regular languages can be decomposed into **subregular hierarchy**

- Introduced by McNaughton & Papert (1971)
- Expanded by numerous researchers
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The most fruitful class for the NL is **tier-based strictly local languages (TSL)**.
TSL intuitions

**Intuition:** TSL is a $n$-gram model on steroids.
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\( n \)-gram model or SL grammar lists the (im)possible sequences of elements.

*ab constraint:

\[
\begin{align*}
\text{ok} & \quad a \ a \ c \ c \ b \ a \\
\end{align*}
\]
**Intuition:** TSL is a \( n \)-gram model on steroids.

\( n \)-gram model or SL grammar lists the (im)possible sequences of elements.

TSL grammar is a SL grammar of a certain subset of the alphabet (*tier alphabet*). Other elements are ignored.

\*ab constraint:

\* a a c \( \overline{a b} \) a c

\( \text{ok} \) a a c c b a

\* a a c c b a
TSL example: (im)possible iteration

**Russian**

1a. zavtra
   tomorrow

1b. posle-zavtra
   the day after tomorrow

1c. posle-posle-zavtra
   the day after the day after tomorrow

Russian & Ilocano: radically different, both TSL

2c pattern: not TSL, unattested
TSL example: (im)possible iteration

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\[
G = \langle \times-\times, \times-posle, posle-\times, 
    posle-posle \rangle
\]
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G = \langle \times-\times, \times\text{-posle}, \text{posle}-\times, \text{posle-posle} \rangle
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G = \langle \times-\times, \times\text{-ka}, \text{an}-\times, \text{ka-an} \rangle
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- Russian & Ilocano: radically different, both TSL
- 2c pattern: not TSL, unattested
TSL example: (im)possible iteration [cont.]

\( \text{\textit{ok}} \) \text{ka-bigat-an}

\[ \times \text{ka} \quad \times \text{an} \quad \times \]

\[ \text{tier} \]

\[ \times \text{ka} \quad \text{bigat} \quad \times \text{an} \quad \times \]
TSL example: (im)possible iteration [cont.]

\[
\begin{align*}
\text{\textit{ok} } & \text{ka-bigat-an} \\
\times & \text{ka} \quad \text{an} \times \\
\times & \text{ka} \quad \text{bigat} \quad \text{an} \times \\
\end{align*}
\]

\[
\begin{align*}
\text{\textit{*ka- ka- ka- bigat -an -an -an}} \\
\end{align*}
\]

\[
a^n b^n \text{ pattern } \rightarrow \text{ CFG!}
\]
Applications of TSL

- Linguistics
  - Sounds (Heinz 2010)
  - Words (Aksénova et al. 2016)
  - Sentences (Graf & Heinz 2015)
  - Meaning (Graf 2017)

- Robotics (Rawal et al. 2011)
Motivations:

- A tool to avoid the pen-and-paper way to create subregular grammars and generate data samples of a particular type in order to test certain hypothesis.
Subregular toolkit: motivations

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- A possibility to use subregular tools in “real life” for language processing problems.
Motivations:

- A tool to avoid the pen-and-paper way to create subregular grammars and generate data samples of a particular type in order to test certain hypothesis.
- A band to connect explorations of human “software” and its possible implementation.
- A way to implement learners for subregular languages and measure their performance.
- A possibility to use subregular tools in “real life” for language processing problems.
- An instrument to explore learnability of certain types of NL patterns.
Subregular toolkit: what’s in it?

**Tools:**

- Sample generators
- Scanners
- Learners
Subregular toolkit: what’s in it?

Tools:
- Sample generators
- Scanners
- Learners

Language classes (minimum):
- Strictly local
- Tier-based strictly local
  - “standard” definition
  - with structural projection mechanism
  - with multiple tiers
- Strictly piecewise
- ... and other subregular classes
Subregular toolkit: details

- Python 3 (available via pip)
  # Python is widely used in scientific community
- Open source
  # to make it available for further enhancement
- With GUI
  # to simplify the use

- Available on GitHub
  # https://github.com/loisetoil/slp
Summary

Subregular toolkit allows:

- test ideas currently available in literature;
- explore new methods to model NL;
- seek out new ways to improve the results.
Thank you!

[Science] is a system for testing your thoughts against the universe and seeing whether they match.

Isaac Asimov
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