Subregular toolkit implemented in Python

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Subregular toolkit: general information

`kist`: **k**ist **i**mplementing **s**ubregular **t**oolkit

Motivation: to collect in one place the functionality for subregular languages and subsequential transducers.

- **For researchers:** to avoid manual burden of extracting grammars and designing transducers, creating data samples, or scanning strings;
- **For practitioners:** to start using tools in practice that are currently available only in the literature.

- Python 3 (will be available via `pip`)
- Open source
- Available on GitHub
  # `https://github.com/loisetoil/slp`

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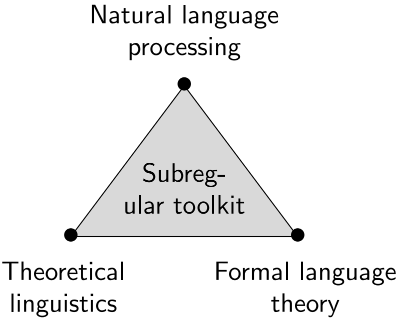


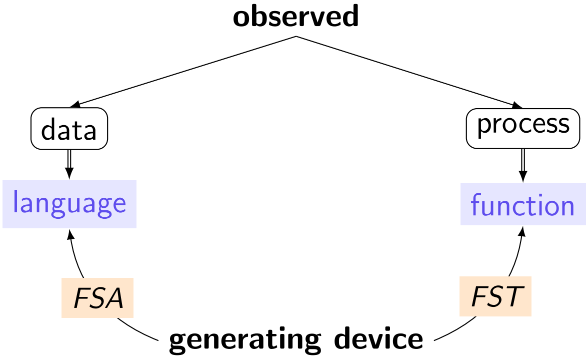
The importance of formalization

- In order to abstract away from details and look at the big picture, we need to *formalize:*
  - Languages → sets of strings of a particular type;
  - Functions → descriptions of processes.

- KIST toolkit provides functionality that allows one to work with (sub)regular languages and functions.

- Such a toolkit is useful for NLP, and not only.

Languages vs. Functions



Here, I only work with (sub)regular – requiring a finite amount of memory – languages and functions.

What is done and what is left

Last year:

- ☑ FSA implementation:
  - ☑ architecture;
  - ☑ optimization.
- ☑ Languages (SL, TSL, SP):
  - ☑ learners;
  - ☑ scanners;
  - ☑ sample generators;
  - ☑ neg↔pos switch;
  - ☑ corresponding FSA.

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- ☐ Transduction learners:
  - ☐ OSTIA;
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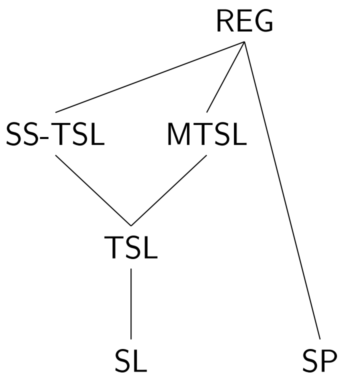
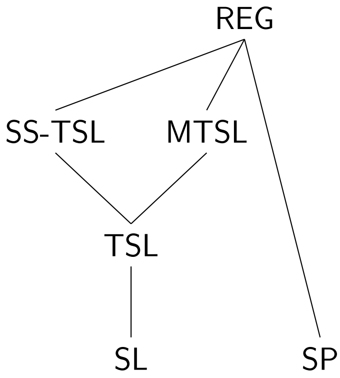
Languages and FSMs



Subregular hierarchy (simplified)

- The class of regular languages consists of smaller sub-classes. (McNaughton&Papert 1971)
- For every (sub)regular language, it is possible to construct a corresponding finite state automaton.
- Most subregular classes are learnable in polynomial time with positive data only.
- There is a variety of applications for subregular languages!

Languages and FSMs



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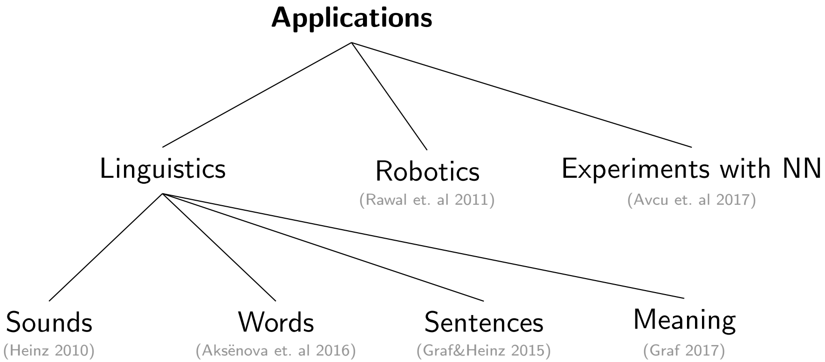
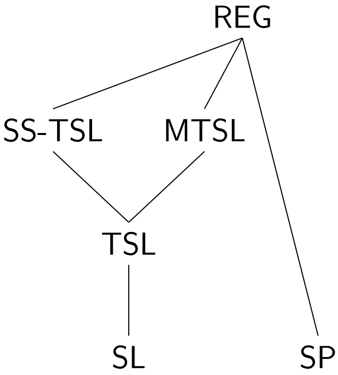


Subregular languages in KIST



Implemented functionality:

- learners;
- scanners;
- sample generators;
- negative ↔ positive grammar translators;
- constructing corresponding FSA;
- trimming FSA.

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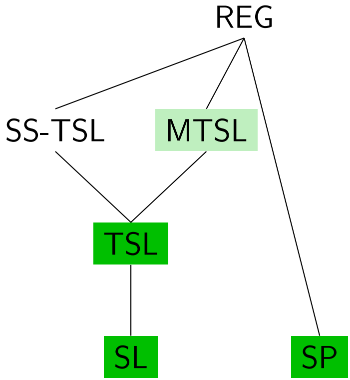

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Language example

- *Language:* BUKUSU (Kenya)
- *Construction:* **V + el/er/il/ir** 'use something to V'
- *Rule:* "match the sounds of the suffix with the sounds of the verb"
- tleex-el 'use smth to cook'
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Simple formal version of the pattern:
$(\mathtt{l},\mathtt{e})^+ \cup (\mathtt{l},\mathtt{i})^+ \cup (\mathtt{r},\mathtt{e})^+ \cup (\mathtt{r},\mathtt{i})^+$

- ^{ok}llliiiillliiii
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Intuition is that [e] and [i] need to agree with each other, as well as [l] and [r]. Among themselves, these two agreements do not interact.

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$$\texttt{(l,e)}^+ \cup \texttt{(l,i)}^+ \cup \texttt{(r,e)}^+ \cup \texttt{(r,i)}^+$$

- *Complexity:* MTSL (multiple tier-based strictly local)
- *Meaning:* there are several sets of items involved in long-distance dependency.
- $T_1 = \{l, r\}$, and $G_{1_{pos}} = \langle ll, rr \rangle$
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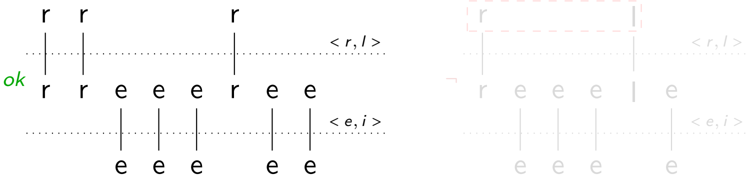

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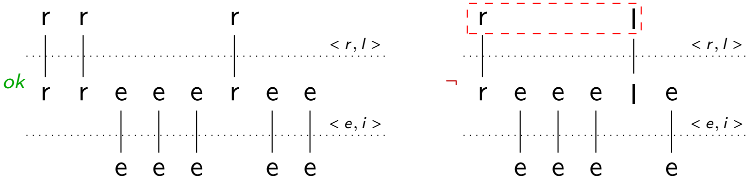

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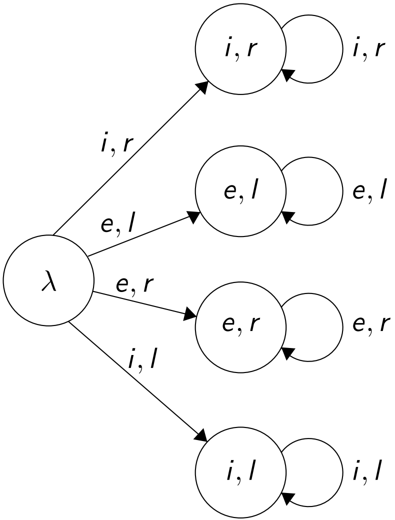
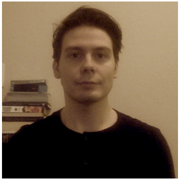
Corresponding FSA:



Languages in kist: outcomes

- Aksënova, Alëna and Sanket Deshmukh (2018)
  Formal Restrictions on Multiple Tiers
  Proceedings of SCiL-2018, ACL anthology, Salt Lake City.
- Aksënova, Alëna (2018)
  The Hitchhiker's Guide to Harmony Interactions
  Poster at GLOW41, Budapest.
- McMullin, Kevin, Alëna Aksënova and Aniello De Santo (submitted)
  Learning Phonotactic Restrictions on Multiple Tiers
- Moradi, Sedigheh, Alëna Aksënova and Thomas Graf (submitted)
  The Computational Cost of Explicit Generalizations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Languages: local summary

- Subregular classes accommodate most linguistic patterns.
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- A **Finite State Automaton** detects whether a given string belongs to a certain class.
- In order to re-write a string, one needs a **Finite State Transducer**.

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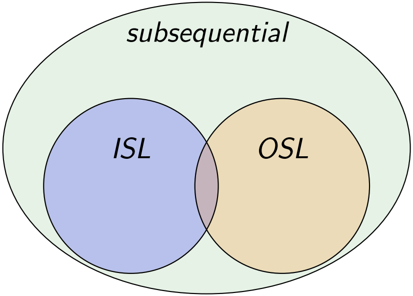
Functions and string FSTs



- String transducers have been used for different tasks since 1960-s. (Schützenberger 1961)
- In linguistics, multiple string extending and rewriting operations are represented via transductions.
  cat + s ↦ cats
  witch + s ↦ witches
- Currently, one of the directions of research is to carve sub-classes of the whole class of subsequential transducers.
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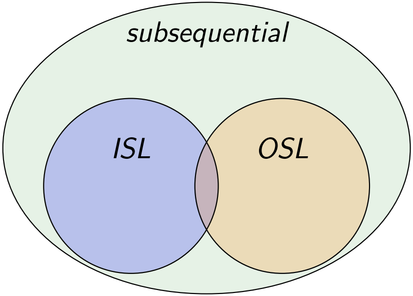

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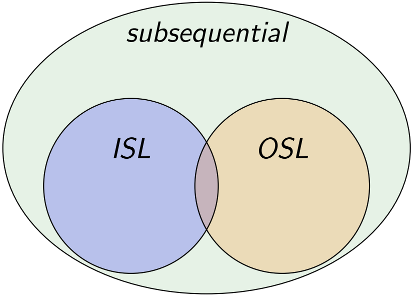

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  - OSTIA: subsequential transductions, cubic time, less data (Oncina, García, and Vidal 1993; de la Higuera 2010)
  - SOSFIA: subsequential transductions, linear time, more data (Jardine et. al 2014)
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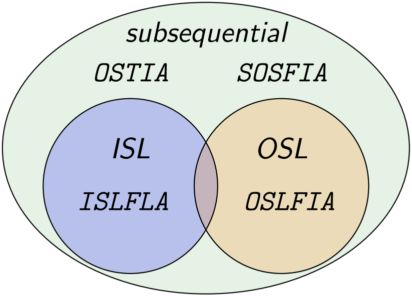

Implemented functionality:

- transducer's template construction;
- learners;
- string rewriting;
- transducer trimming;
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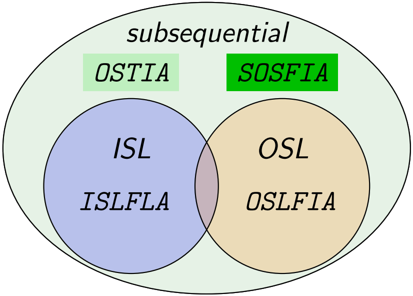

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String FSTs: an example of application

- **Tokenization** – separating words from sentence-level punctuations for further sentence processing.

  "Bob, Sue and Bill didn't buy sugar-free coffee."

  $\mapsto$ " Bob , Sue and Bill didn't buy sugar-free coffee ."
- *Challenges:*
  - Trying to avoid hard-coding the linguistic variety of contexts and punctuations (for example, Spanish '¿')
  - Not all same symbols are treated in the same way:

    "Dogs bark." $\mapsto$ " Dogs bark ."

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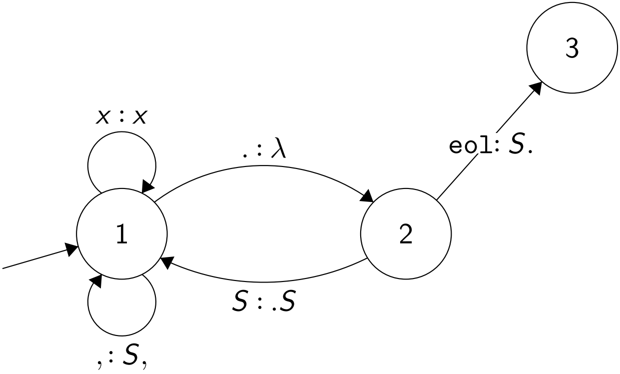
String FSTs: an example of application [cont.]

Simplified FST for tokenization:



Functions in kist: current projects

Kyle Gorman

- with Jeffrey Heinz and Kyle Gorman
  OSTIA-based tokenizer
  developing a low memory resource and high-accuracy tokenizer that avoids hard-coding language-specific information

- with Thomas Graf and Jeffrey Heinz
  Transduction learner for insufficient data
  creating a learning algorithm that allows to learn a class of non-equivalent transducers that can be inferred based on the insufficient input data

String transducers: local summary

- Finite State Transducers read a string as input, and return another string as output.
- Variety of different tasks can be performed via FSTs:
  - tokenization;
  - XML parsing;
  - multiple linguistic processes;
  - even machine translation!
- Current lines of research:
  - tree transducers;
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Timeline

Months	**Goals**
September	OSTIA (general subsequential learner)
October	OSLFIA (OSL transductions learner)
November	ISLFLA (ISL transductions learner)
December	MTSL learners, scanners, sample generators
January	SS-TSL learners, scanners, sample generators
February	Learner for regular languages (RPNI)
March	
April	Testing, documentation and publishing
May	

Conclusion

- `kist` package is a subregular toolkit for linguistics and NLP.
- Last year, I implemented subregular language tools.
  Why? They learn and generate formal languages of a required complexity.
- This year, I am implementing transduction learners.
  Why? They extract different types of maps from input to output forms.
- **For researchers**, this toolkit facilitates the process of data analysis and generation, as well as assists in measuring complexities of already existent datasets.
- **For practitioners**, it opens new ways and perspectives of modeling natural language dependencies, and not only.

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> What I cannot create, I do not understand.
>
> *Richard Feynman*

Thank you!

References I

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