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HFST: Modular Compatibility for Open Source Finite-state Tools

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HFST team

- Krister Lindén, PhD, leader of the team
- Anssi Yli-Jyrä, PhD, researcher providing theory and compilation formulas
- Erik Axelsson, Miikka Silfverberg, Tommi Pirinen, MA/MSc students, programming the HFST interface and tools based on it
- Kimmo Koskenniemi, professor, funding and consulting

Existing finite-state software

- Lots of finite-state packages have been created by different researchers and teams (maybe 50-100), (including NooJ).
- Some are free open source, others commercial or with other restrictions (e.g. shareware).
- Some packages only provide the basic finite-state calculus as a library or as separate programs.
- Some integrate a calculus with an interpreter (or compiler) tailored for a specific rule or lexicon formalism.
- Some are actively maintained and developed, many have neither maintenance nor other activities.

HFST: Helsinki Finite State Toolkit

- Does not implement yet another finite-state calculus, but rather utilizes existing free open source implementations:
  - SFST (Helmut Schmid) transducers without weights,
  - OpenFST (M. Riley, J. Schalkwyk, W. Skut, C. Allauzen and M. Mohri) with weighted transducers, and others such as
  - Vaucanson (Jacques Sakarovitch).
- Intends to provide practical and general purpose free open source finite-state tools.
- Provides HFST, a carefully defined and well documented common interface to several FSM engines.
- Implements useful tools on top of this HFST interface.
- Full scale language modules for testing.

Goals of the HFST

- Create convergence and cooperation within the community which develops finite-state calculus and tools.
- Create a neutral platform where different implementations of the FS calculus can coexist and compete with each other.
- Create a critical mass of research for improving the basic algorithms of the calculus, and compilation algorithms.
- Stimulate the production of free open source software for compiling dictionaries, grammars and rules into FSTs.
- Stimulate the production of language resources (e.g. dictionaries, grammars, rules) to be compiled into FSTs.
- Inspired by CLARIN infrastructure and supports it.

First tools to be implemented with HFST

- Lexicon compilers: HLEXC like Xerox LEXC useful for complex morphological phenomena such as agglutination, derivation and compounding. Derivation and compounding can be cyclic.
- Morphophonemic rule compilers:
  - HTWOLC: Two-level compiler (like Xerox TWOLC)
  - Cascaded replace operations (like SFST and Xerox XFST)
- Challenges: Finnish has lots of word-forms (> 10^{24}) and a lot of morphophonological alternations (consonant gradation, vowel harmony, stem final alternations. Northern Sámi is even more complex.

Lexicon compiler

- Words are composed out of morphemes. Morphemes correspond to entries in the lexicon.
- Morphemes are grouped into classes with similar distribution: morphemes belong to the same class, if they can be interchanged (regarding what precedes). Classes are represented as sublexicons.
- Morphemes may still differ regarding what classes of morphemes may follow, i.e. there is a continuation class (which points to a sublexicon from which the next morpheme can be chosen).
- The lexicon compiler reads in a lexicon and produces a FST out of it.

An example of a lexicon

```
LEXICON Root
talo N;
kaTu N;
LEXICON N;
+N+Sg+Nom:0 #;
+N+Sg+Gen:n #:
+N+Sg+Ine:ssA #
+N+Pl+Gen:jen #;
 Root;
n Root;
END
```

Two-level rule compiler

- Morphemes are considered to have two representations
  - lemma and features to be shown as the result of the analysis
  - a morphophonemic representation of the morpheme
- The task for the rule component is to relate the morphophonemic representation to the surface form, e.g.

  -
    ```
    p e t t ä ä +V +Pss +Pcp2 +Sup +Pl +Ine
    p e t T Ä t T U I m P I s s A
    p e t 0 e t 0 y i m m i s s ä
    ```
- Rules are parallel with no rule ordering, e.g.

  -
    ```
    T:0 <=> t _ Vowel (I:i) Cons (Cons | :#)
    I:j <=> :Vowel _ :Vowel
    A:a <=> (:a | :o | u:) :* _   (elsewhere ä)
    ```

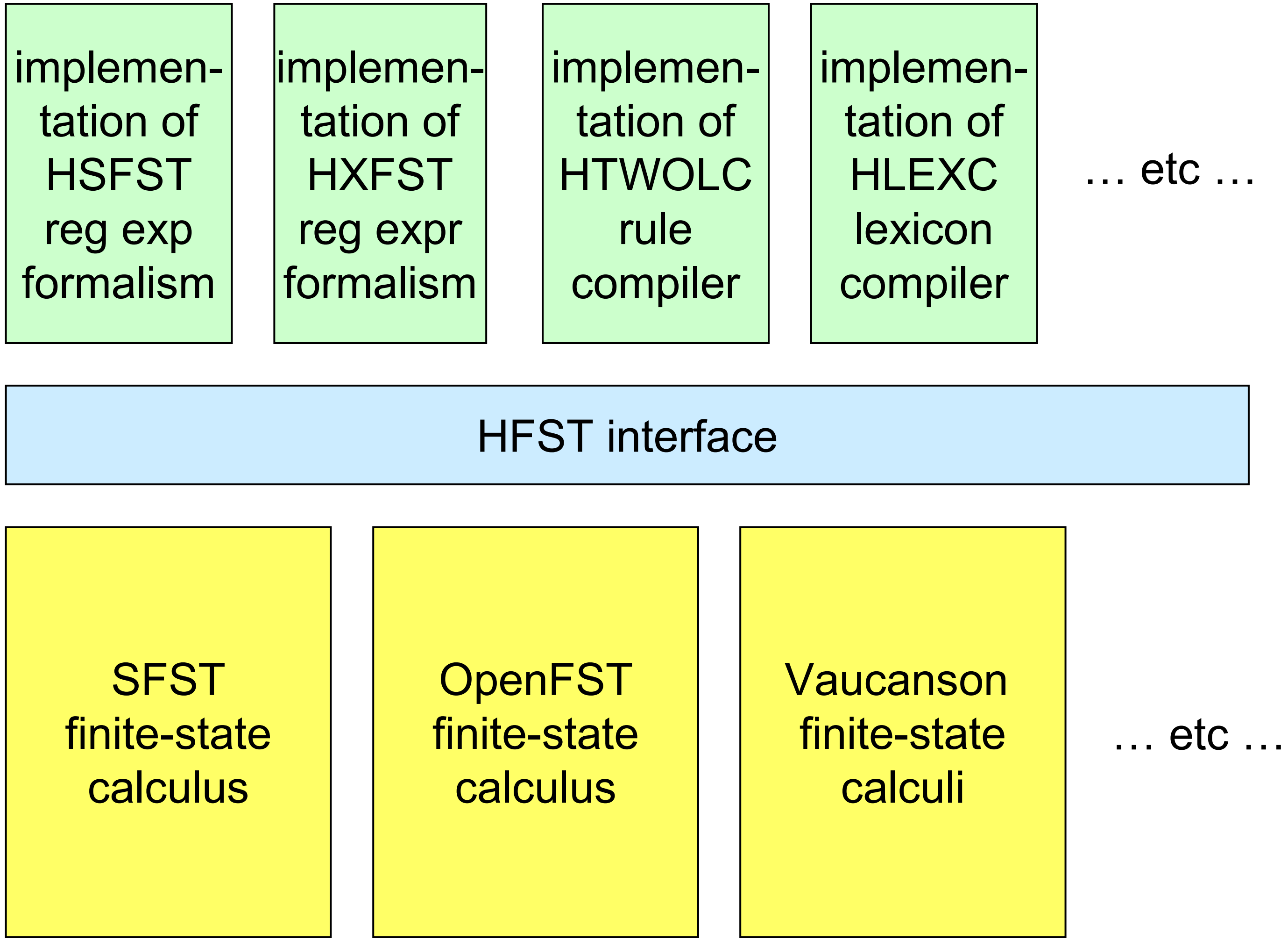
The SFST structure

regular expression formalism

translation into function calls

functions for the finite-state calculus

Design of the HFST



implementation of HSFST reg exp formalism

implementation of HXFST reg expr formalism

implementation of HTWOLC rule compiler

implementation of HLEXC lexicon compiler

… etc …

HFST interface

SFST finite-state calculus

OpenFST finite-state calculus

Vaucanson finite-state calculi

… etc …

HFST interface

- Definitions of underlying concepts and functions.
- Consistent naming of functions and use of parameters.
- C++ code as needed to achieve similar behaviour of different calculus packages.
- DOXYGEN documentation www.ling.helsinki.fi/~eaxelson/hfst/namespaceHFST.html
- TWiki documentation https://kitwiki.csc.fi/twiki/bin/view/KitWiki/HfstHome
- File formats (from AT&T, OpenFST, SFST) for exchanging binary and text mode FSTs.

Rule compilation

- Kaplan and Kay found a way to compile rewrite rules into FSTs. Koskenniemi modified that for two-level rules.
- Anssi Yli-Jyrä discovered a new simpler and more general way to compile rules, so called general restriction.
- With an auxiliary symbol § and alphabet S, one can express various rules as implications, e.g.

  S* § t:d § S* => S* a § S* § a S*

  says that t:d may only occur between two a's. Alternative contexts (the right part) can be expressed as disjunctions of the right-hand side (whereas Kaplan and Kay had a much more complex compilation scheme for that).

HFST and NooJ

- FSTs produced with HFST tools could be reused in NooJ, e.g. morphological analysis of languages with complex alternations and inflection. (A Finnish verb has some 12,000 distinct forms and several distinct stems.)
- Heuristic methods for collecting named entities and new lexemes could be based on HFST tools, and the results used in NooJ.
- NooJ dictionaries could be reused with the HFST tools.
- Some NooJ/INTEX functionalities could be implemented using the HFST API.

OMor: open source morphologies

- For research, we need free open source resources which we can improve and develop as needed. In parallel with HFST, we have a OMor project for creating free morphological analyzers.
- OMorFi is creates a Finnish transducer lexicon based on a list of words of a dictionary with inflectional codes.
- A project in Norway has created two-level morphological analyzers for Northern and Lule Sámi using Xerox tools. These will be reimplemented with HFST tools as open source.
- HFST demos already exist for Finnish (OMorFi), Swedish, English and French.

HFST commercial and open source applications

- HFST is written under GNU LGPL (compatible with GPL), SFST is GPL, OpenFST is under Apache license. These are all free open source licenses.
- Any further tools developed from HFST or combined with it will remain under (L)GPL.
- Any FSTs produced with HFST tools will remain under the same conditions as the input lexicon and rules, i.e. either proprietary commercial or free open source.
- Thus, HFST tools can be used both for open source and proprietary projects.

A note on finite-state patents

- Xerox and AT&T have claimed several patents on finite-state techniques and their applications (maybe 100).
- If they are "software patents", they are not in effect in Europe. (Some may be and others perhaps not.)
- Many patents are invalid because there is previous commercial use of the method or the method is obvious and the only solution. Invalidating patents is expensive. (Patents are a bit like a minefields.)
- Patents do not prevent private or "fair use".
- Most use of HFST (and other finite-state tools) is, thus, safe. The use of FSTs produced this way should also be safe.