A Flexible Rule Compiler for Speech Synthesis

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Abstract. We present a flexible rule compiler developed for a text-to-speech (TTS) system. The compiler converts a set of rules into a finite-state transducer (FST). The input and output of the FST are subject to parameterization, so that the system can be applied to strings and sequences of feature-structures. The resulting transducer is guaranteed to realize a function (as opposed to a relation), and therefore can be implemented as a deterministic device (either a deterministic FST or a bimachine).

1 Motivation

Implementations of TTS systems are often based on operations transforming one sequence of symbols or objects into another. Starting from the input string, the system creates a sequence of tokens which are subject to part-of-speech tagging, homograph disambiguation rules, lexical lookup and grapheme-to-phoneme conversion. The resulting phonetic transcriptions are also transformed by syllabification rules, post-lexical reductions, etc.

The character of the above transformations suggests finite-state transducers (FSTs) as a modelling framework [Sproat, 1996; Mohri, 1997]. However, this is not always straightforward for two reasons.

Firstly, the transformations are more often expressed by rules than encoded directly in finite-state networks. In order to overcome this difficulty, we need an adequate compiler converting the rules into an FST.

Secondly, finite-state machines require a finite alphabet of symbols while it is often more adequate to encode linguistic information using structured representations (e.g. feature structures) the inventory of which might be potentially infinite. Thus, the compilation method must be able to reduce the infinite set of feature structures to a finite FST input alphabet.

In this paper, we show how these two problems have been solved in rVoice, a speech synthesis system developed at Rhetorical Systems.

2 Definitions and Notation

A deterministic finite-state automaton (acceptor, DFSA) over a finite alphabet \( \Sigma \) is a quintuple \( A = (\Sigma, Q, q_0, \delta, F) \) such that:

- \( Q \) is a finite set of states, and \( q_0 \in Q \) is the initial state of \( A \);
- \( \delta : Q \times \Sigma \to Q \) is the transition function of \( A \);
- \( F \subset Q \) is a non-empty set of final states.
A (non-deterministic) finite-state transducer (FST) over an input alphabet $\Sigma$ and an output alphabet $\Delta$ is a 6-tuple $T = (\Sigma, \Delta, Q, I, E, F)$ such that:

- $Q$ is a finite set of states;
- $I \subset Q$ is the set of initial and $F \subset Q$ that of final states;
- $E \subset Q \times Q \times \Sigma \cup \{\epsilon\} \times \Delta^*$ is the set of transitions of $T$. We call a quadruple $(q, q', a, o) \in E$ a transition from $q$ to $q'$ with input $a$ and output $o$.

Each transducer $T$ defines a relation $R_T$ on $\Sigma^* \times \Delta^*$ such that $(s, o) \in R_T$ iff there exists a decomposition of $s$ and $o$ into substrings $s_1, \ldots, s_t, o_1, \ldots, o_t$ such that $s_1 \cdot \ldots \cdot s_t = s$, $o_1 \cdot \ldots \cdot o_t = o$ and there exist states $q_0 \ldots q_t \in Q$, $q_0 \in I, q_t \in F$, such that $(q_{i-1}, q_i, s_i, o_i) \in E$ for $i = 1 \ldots t$.

If $R_T$ is a (partial) function from $\Sigma^*$ to $\Delta^*$, the FST is called functional.

A deterministic finite-state transducer (DFST) is a DFSA whose transitions are associated with sequences of symbols from an output alphabet $\Delta$. It is defined as $T = (\Sigma, \Delta, Q, q_0, \delta, \sigma, F)$ such that $(\Sigma, Q, q_0, \delta, F)$ is a DFSA and $\sigma(q, a)$ is the output associated with the transition leaving $q$ and consuming the input symbol $a$.

In addition to the concepts introduced above, we will use the following notation. If $T, T_1, T_2$ are finite-state transducers, then $T^{-1}$ denotes the result of reversing $T$. $T_1 \cdot T_2$ is the concatenation of transducers $T_1$ and $T_2$. $T_1 \circ T_2$ denotes the composition of $T_1$ and $T_2$.

## 3 Requirements

In this section, we review the state of the art in finite-state technology from the angle of applicability to the symbolic part of a TTS system.

### 3.1 Finite-State Rule Compilers

Many solutions have been proposed for compiling rewrite rules into FSTs, cf. [Kaplan and Kay, 1994], [Roche and Schabes, 1995], [Mohri and Sproat, 1996]. Typically, a rewrite rule $\phi \rightarrow \psi/\lambda, \rho$ states that a string matching a regular expression $\phi$ is rewritten as $\psi$ if it is preceded by a left context $\lambda$ and followed by a right context $\rho$, where both $\lambda$ and $\rho$ are stated as regular expressions over either the input alphabet $\Sigma$ or the output alphabet $\Delta$. The compiler compiles the rule by converting $\phi$, $\lambda$ and $\rho$ into a number of separate transducers and then composing them into an FST that performs the rewrite operation.

Since a rule may overlap or conflict with other rules, a disambiguation strategy is required. There are several possibilities. Firstly, if the rules are associated with probabilities or scores, these numeric values may be added to transitions in the form of weights, thus defining a weighted finite-state transducer (WFST). Such a WFST is not determinizable in general, but the weights may be used to guide the search for the best solution and constrain the search space.
Secondly, a deterministic longest-match strategy may be pursued. Finally, we may regard the order of the rules as meaningful in the sense of priorities: if a rule $R_k$ rewrites a string $s$ that matches its focus $\phi_k$, it blocks the application of all rules $R_i$ such that $i \geq k$ to any string overlapping with $s$.

In our research, we have focused on the third strategy as the most appropriate one in the context of our TTS system and the available resources. This choice makes determinizability a particularly desirable feature of the rule FSTs as it guarantees linear-time processing of input. Although a transducer implementing rules with unlimited regular expressions in the left and the right context is not determinizable in general [Poibeau, 2001], deterministic processing is still possible by means of a *bimachine*, i.e., an aggregate of a left-to-right and a right-to-left DFSA [Berstel, 1979]. For this, the resulting rule FST must realize a function.

Unfortunately, the compilers described by [Kaplan and Kay, 1994] and [Mohri and Sproat, 1996] are not guaranteed to produce a functional transducer in the general case. Thus, we have had to develop a new, more appropriate compilation method. The new method is described in detail in section 4.

### 3.2 Complex Input Types

In rVoice, linguistic information is internally represented by lists of feature structures. If $o$ is an item and $f$ a feature, $f(o)$ denotes the value of $f$ on $o$.

Rewrite operations can be applied to different levels of this model, the input sequences being either strings of atomic symbols (characters, phonemes, etc.) or sequences of items characterized by feature-value pairs. While the former case is straightforward, the latter requires a translation step from feature structures to a finite alphabet of symbols.

This issue has been addressed in a wide range of publications. The solutions proposed mostly guarantee a high degree of expressivity, including feature unification. The price for the expressive power of the formalism is non-determinism [Zajac, 1998] and/or the use of rather expensive unification operations [Becker et al., 2002, Constant, 2003].

For efficiency reasons, we have decided to pursue a more modest approach in the current implementation. The approach is based on the observation that only a finite number of feature-value pairs are used in the actual rules. Since distinctions between unseen feature-value pairs cannot affect the mechanism of rule matching, unseen features can be ignored and the unseen values of the seen features can be merged into a special symbol #.

If $f_1 \ldots f_K$ are the seen features and $\Sigma_1 \ldots \Sigma_K$ the respective sets of values appearing in the rules, then a complex input item $o$ can be represented by the $K$-tuple $(v_1 \ldots v_K)$ such that $v_i \in \Sigma_i \cup \{\#\}$ is defined as

\[
    v_i = \begin{cases} 
        f_i(o) : & f_i(o) \in \Sigma_i \\
        \# : & f_i(o) \text{ undefined or } f_i(o) \notin \Sigma_i 
    \end{cases}
\]
The context rules are formulated as regular expressions whose leaves are *item descriptions*. An *item description*, e.g., \[ \text{pos} = \text{nn}|\text{nnp} \text{ case} = \text{u} \], consists of a set of *feature-value descriptions* (here: \( \text{pos} = \text{nn}|\text{nnp} \) and \( \text{case} = \text{u} \)), determining a set \( U_j \) of values for the respective feature \( f_j \). If no feature-value description is specified for a feature \( f_j \), we set \( U_j = \Sigma_j \cup \{\#\} \). Clearly, an item \( (v_1 \ldots v_K) \) matches an item description \( [U_1 \ldots U_K] \) iff \( v_1 \in U_1 \ldots v_K \in U_K \).

This leads to the desired regular interpretation of feature-structure matching rules: a concatenation of unions (disjunctions) of atomic values. If \( \text{case}, \text{pos} \) and \( \text{type} \) are the relevant features, the last one taking values from the set \{alpha, digit\}, the item description \( \{\text{pos} = \text{nn}|\text{nnp} \text{ case} = \text{u}\} \) is interpreted as \((\text{nn}|\text{nnp}) \cdot \text{u} \cdot (\text{alpha}|\text{digit}|\#)\). Clearly, this interpretation extends to regular expressions defined over the set of item descriptions. For example, \( ([\text{pos} = \text{nn}|\text{nnp} \text{ case} = \text{u}])^+ \) is interpreted as \( ((\text{nn}|\text{nnp}) \cdot \text{u} \cdot (\text{alpha}|\text{digit}|\#))^+ \).

## 4 Formalisation

### 4.1 The Rule Formalism

For reasons of readability, we decided to replace the traditional rule format \( (\phi \rightarrow \psi/\lambda, \rho) \) by the equivalent notation \( \lambda/\phi/\rho \rightarrow \psi \), which we found much easier to read if \( \lambda \) and \( \rho \) are complex feature structures. Thus, the compiler expects an ordered set of rules in the following format.

\[ \lambda_i/\phi_i/\rho_i \rightarrow \psi_i, i = 1 \ldots n \]

\( \lambda_i \) and \( \rho_i \) are unrestricted regular expressions over the input alphabet \( \Sigma \). The focus \( \phi_i \) is a fixed-length expression over \( \Sigma \). The right-hand side of the rule, \( \psi_i \), is a (possibly empty) sequence of symbols from the output alphabet \( \Delta \).

Compared to [Kaplan and Kay, 1994] and [Mohri and Sproat, 1996], the expressive power of the formalism is subject to two restrictions. Firstly, the length of the focus \( (\phi) \) is fixed for each rule, which is a reasonable assumption in most of the mappings being modelled. Secondly, only input symbols are admitted in the context of a rule, which appears to be a more severe restriction than the first one, but does not complicate the formal description of the considered phenomena too much in practice.

### 4.2 Auxiliary Operations

In this section, we define auxiliary operations for creating a rule FST.

**accept\_ignoring(\( \beta, M \))** This operation extends an acceptor for a pattern \( \beta \) with loops ignoring symbols in a set \( M \) of markers, \( M \cap \Sigma = \emptyset \). In other words, \( \text{accept\_ignoring}(\beta, M) \) accepts \( w \in (\Sigma \cup M)^* \) iff \( w \) can be created from a word \( u \in \Sigma^* \) that matches \( \beta \) by inserting some symbols from \( M \) into \( u \).

The construction of \( \text{accept\_ignoring}(\beta, M) \) is straightforward: after creating a deterministic acceptor \( A = (\Sigma, Q, q_0, \delta, F) \) for \( \beta \), we add the loop \( \delta(q, \mu) = q \) for each \( q \in Q \) and \( \mu \in M \).
accept\_ignoring\_nonfin(\(\beta, M\)) is like accept\_ignoring(\(\beta, M\)) except that it does not accept symbols from \(M\) at the end of the input string. For example, accept\_ignoring\_nonfin(a\(^*\),\{#\}) accepts aaaa and ##a##aa, but not aaa####.

The construction of this FSA is similar to that of accept\_ignoring(\(\beta, M\)). First, we create a deterministic acceptor \(A = (\Sigma, Q, q_0, \delta, F)\) for \(\beta\). Then a loop \(\delta(q, \mu) = q\) is added to \(A\) for each \(\mu \in M, q \not\in F\). Finally for each \(q \in F\):

1. if \(\delta(q, a)\) is defined, its target is replaced with a new non-final state \(q'\);
2. we add the transitions \(\delta(q', \mu) := q'\) for each \(\mu \in M\) and \(\delta(q, \epsilon) := q'\).

 Fig. 1. Construction of accept\_ignoring\_nonfin(\(\beta, \{\#\}\)).

replace(\(\beta, \gamma\)) translates a regular expression \(\beta\) into a string \(\gamma\). It is constructed by turning an acceptor \(A = (\Sigma, Q, q_0, \delta, F)\) for \(\beta\) into a transducer \(T = (\Sigma, Q \cup \{q_f\}, q_0, \delta, \sigma, \{q_f\})\) such that \(q_f\) is a new final state, \(\sigma(q, a) := \epsilon\) for each \((q, a) \in \text{Dom}(\delta)\), \(\delta \subseteq \tilde{\delta}\), \(\delta(q, \epsilon) := q_f\) and \(\sigma(q, \epsilon) := \gamma\) for each \(q \in F\).

mark\_regex(\(\Sigma(\beta, \mu)\)) This operation inserts a symbol \(\mu\) after each occurrence of a pattern \(\beta\). It is identical to the type 1 marker transducer defined in [Mohri and Sproat, 1996]. It can be constructed from a deterministic acceptor \(A = (\Sigma, Q, q_0, \delta, F)\) for the pattern \(\Sigma^* \beta\) in the following way: first, an identity transducer \(Id(A) = (\Sigma, \Sigma, Q, q_0, \delta, \sigma, \{q_f\})\) is created such that \(\sigma(q, a) := a\) whenever \(\delta(q, a)\) is defined. By construction, \(Id(A)\) is deterministic.

Then, \(T = (\Sigma, \Sigma \cup \{\mu\}, Q \cup F', q_0, \delta, \tilde{\sigma}, (Q \cup F') \setminus F)\) is created such that

\[
\begin{align*}
F' &:= \{q' : q \in F\} \text{ (a copy of each final state of } Id(A)) \\
\delta(q, a) &= \delta(q, a), \tilde{\sigma}(q, a) = \sigma(q, a) \text{ for } q \not\in F, a \in \Sigma \\
\delta(q', a) &= \delta(q, a), \tilde{\sigma}(q', a) = \sigma(q, a) \text{ for } q \in F, a \in \Sigma \\
\delta(q, \epsilon) &= q', \tilde{\sigma}(q, \epsilon) = \mu \text{ for } q \in F
\end{align*}
\]

Informally, the construction of \(T\) consists in swapping the final and non-final states of \(Id(A)\) and splitting each final state \(q\) of \(A\) in two states \(q\) and \(q'\) such that all transitions \(t\) leaving \(q\) in \(A\) leave \(q'\) in \(T\). The two states are then connected by a transition \((q, q', \epsilon, \mu)\), as shown in figure 2.
left\_context\_filter_L(\beta, \mu) This operation deletes all occurrences of a symbol \mu in a string \(s \in (\Sigma \cup \{\mu\})^*\) that are not preceded by an instance of pattern \beta. A transducer performing this operation can be constructed from a deterministic acceptor \(A = (\Sigma, Q, q_0, \delta, F)\) for the pattern \(\Sigma^*\beta\) by creating an identity transducer \(Id(A) = (\Sigma, \Sigma, q_0, \delta, \sigma, F)\) and then turning it into a transducer \(T = (\Sigma \cup \{\mu\}, \Sigma \cup \{\mu\}, Q, q_0, \bar{\delta}, \bar{\sigma}, F)\) such that:

\[
\begin{align*}
\bar{\delta}(q, a) &= \delta(q, a), \bar{\sigma}(q, a) = \sigma(q, a) \text{ for } q \in \text{Dom}(\delta) \\
\bar{\delta}(q, \mu) &= q \text{ for } q \in Q \\
\bar{\sigma}(q, \mu) &= \mu \text{ for } q \in F \text{ (copying of } \mu \text{ into the output after a match of } \beta) \\
\bar{\sigma}(q, \mu) &= \epsilon \text{ for } q \notin F \text{ (deletion of } \mu \text{ after a string that does not match } \beta)
\end{align*}
\]

4.3 Constructing a Rule FST

Each rule is compiled into a composition of two FSTs. The first one inserts the symbol \(<_i\) before each match of \(\phi_i \cdot \text{accept.ignoring}(\rho_i, \text{Markers}_{<_i})\), where \text{Markers}_{<_i} is the set of all markers \(<_j, j < i\). The second transducer deletes all occurrences of \(<_i\) that are not preceded by an instance of the left context pattern \(\lambda_i\) or possibly interspersed with markers inserted by previous rules \(<_j\). The resulting translation is the original string with the marker \(<_i\) inserted at all positions where rule \(R_i\) fires.

Both FSTs are obviously functional, and so is their composition.
Marking of the Right Context and Focus Match  The first transducer \( \text{pre\_mark} \) inserts a left focus marker \( (\textless_i) \) before each match of \( \phi_i \cdot \text{accept\_ignoring}(\rho_i, \text{Markers}_{<i}) \). It is right-to-left deterministic and can be created by composing the following operations:

\[
\text{pre\_mark}_i = \text{mark\_regex}_{\Sigma \cup \text{Markers}_{<i}}([\phi_i \cdot \text{accept\_ignoring}(\rho_i, \text{Markers}_{<i})]^{-1}, \textless_i)^{-1}
\]

Note that the \( \text{mark\_regex} \) operation is performed relative to the extended alphabet \( \Sigma \cup \text{Markers}_{<i} \) as the input string may already contain markers inserted by an earlier rule.

Checking the Left Context  The task of the second FST, \( \text{check\_left\_cxt} \), is to remove all occurrences of \( \textless_i \) that are not preceded by an instance of \( \lambda_i \). Note that the substring matching \( \lambda_i \) may contain some of the markers \( \textless_1, ..., \textless_i \), therefore the \( \text{left\_context\_filter} \) operation is performed relative to the extended alphabet \( \Sigma \cup \text{Markers}_{<i} = \Sigma \cup \{\textless_1, ..., \textless_{i-1}\} \).

\[
\text{check\_left\_cxt}_i = \text{left\_cxt\_filter}_{\Sigma \cup \text{Markers}_{<i}}(\text{accept\_ignoring}(\lambda_i, \text{Markers}_{<i}), \textless_i)
\]

Composition of Rule Transducers  The transducer for rule \( R_i \) is the result of the composition: \( r_i := \text{pre\_mark}_i \circ \text{check\_left\_cxt}_i \).

Since both transducers are deterministic (hence functional), the result of their composition is functional, too. The application of the rules \( R_1, ..., R_n \) to a string \( s \) is then modelled by the composition of FST's: \( (r_1 \circ r_2 \circ \ldots \circ r_n \circ \text{rewrite})(s) \). \( \text{rewrite} \) is a simple FST that, having read a marker symbol \( \textless_i \), leaves the initial state and jumps to a subnetwork translating \( \phi_i \) to \( \psi_i \) (ignoring markers). When the translation is finished, \( \text{rewrite} \) returns to its initial state. \( \text{rewrite} \) can be constructed as the closure of the union of transducers \( \text{rewrite\_rule\_focus}_i, i = 1...n \), defined as:

\[
\text{rewrite\_rule\_focus}_i := \text{replace}(\textless_i \cdot \text{accept\_ignoring\_nonfin}(\phi_i, \text{Markers}_{\geq i}), \psi_i)
\]

Note the use of \( \text{accept\_ignoring\_nonfin} \) rather than just \( \text{accept\_ignoring} \). This guarantees that the transducer will not consume any markers following the last character of \( \phi_i \) (these markers indicate the next rule application).

The transducer \( \text{rewrite} \) is then defined as:

\[
\text{rewrite} := (\bigcup_{i=1}^n \text{rewrite\_rule\_focus}_i)^*
\]

Clearly, \( \text{accept\_ignoring\_nonfin} \) is determinizable, and the resulting transducer \( \text{rewrite} \) is deterministic. With \( r_1 \ldots r_n \) being functional, it follows that the

\footnote{We assume that at least one marker will be inserted at each position in the input string. This can be achieved by specifying a default rule \( /\mu/ \rightarrow \gamma \) for each \( \mu \in \Sigma \).}
rational relation $r_1 \circ r_2 \circ \ldots \circ r_n \circ \text{rewrite}$ is functional. Therefore, the result of the compilation is a functional FST that is either determinizable or can be factorized into a bimachine.\footnote{Note that if the focus of a rule contains more than one character, rules with lesser priority may insert markers into the matched string. For example, the rules $R_1 : /ab/ \rightarrow X$ and $R_2 : /b/ \rightarrow Y$ will mark up the string $ab$ as $<1 a <2 b$, but, in accordance with the operational semantics of the compiler, the second marker will be ignored by the \text{rewrite} transducer when the match is rewritten as $X$.}

5 Applications

rVoice is implemented as a pipeline of modules that successively transform the input string into sound. The text processing modules create a sequence of segments (phones and pauses) organized into syllables, words and phrases. The result is passed to the speech modules that generate the actual speech signal. At each level, linguistic information is represented by a heterogeneous relation graph [Taylor et al., 2001], typically a list of feature structures.

Each module creates a new relation or adds information to the existing ones. The tokenizer splits the input string into a list of tokens. The text normalisation module expands abbreviations, numbers, dates, etc., creating a list of words, each one annotated with a normalised word form. Further modules (part-of-speech/homograph tagger, reduction module, language identification) set features such as part-of-speech on the words.

The lexicon module tries to find a phonetic transcription for the normalized word form that is consistent with the features set on it. If it fails, the transcription is generated by letter-to-sound rules.

In order to accommodate the requirements of different TTS modules, our rule compiler is parameterizable with respect to input types and emissions. Two specific instantiations have been employed so far. The first one is the conversion the string of atomic symbols from an input alphabet $\Sigma$ into a string of symbols from an output alphabet $\Delta$. The second application is setting features on a list of complex objects (relation items). In the remainder of this section, we illustrate each of the two scenarios with an application.

5.1 Grapheme-To-Phoneme Conversion

The case of grapheme-to-phoneme conversion is straightforward. The input alphabet $\Sigma$ comprises all alphabetic characters, while the output alphabet $\Delta$ is the set of all legal phonetic symbols of the language under consideration. For each character, we need to write rules describing how this character can be pronounced. If more than one pronunciation is possible, each variant is covered by a rule. The ordering of the rules determines how conflicts between rules are resolved and makes it possible to write simple default rules.

The following rules describe the pronunciation of ‘c’ in American Spanish:
Such hand-written rules are used for languages that have a very regular orthography, such as Spanish, which is covered by 110 rules, including stress assignment. The resulting FST has 119 states and 5160 transitions.

5.2 Homograph Disambiguation

In rVoice, homograph disambiguation is the result of an interaction between several modules. First of all, a statistical part-of-speech tagger determines the part-of-speech of each word in an utterance. This information is useful, but not always sufficient for determining the right pronunciation. For instance, both pronunciation variants of lead are compatible with the POS noun, as in the sentences Lakeview took a 14-0 lead in the second quarter and There’s very high lead levels in your water. Furthermore, the POS tagger may be consistently inaccurate in certain contexts, in which case its predictions are overridden by hand-written homograph rules. The rules refer directly to the sense IDs associated with the pronunciation variants of the word in question, as the rules that disambiguate between the different senses of suspects:

\[
\begin{align*}
\text{name=that} & / \text{name=suspects} / \rightarrow \text{[sense=2]}; \\
([\text{pos=dt|cd}] & \text{name=terror}) / \text{name=suspects} / \rightarrow \text{[sense=1]}; \\
\text{name=suspects} & / \text{name=that} \rightarrow \text{[sense=2]}; \\
\text{name=suspects} & / \rightarrow \text{[sense=1]}; \# \text{default rule}
\end{align*}
\]

To explain how the rules interact, we will look at the following example:

\[\text{the}_1 \text{terror}_2 \text{suspects}_3 \text{that}_4 \text{were}_5 \text{in}_6 \text{court}_7\]

We can see that the second and the third rule match the context of word 3. The action associated with the lower rule index is chosen, resulting in the value of sense being set to 1 on the item.

According to the compilation method described in section 3.2, a sequence of items is translated into a sequence of relevant feature values. The compiled rule FST rewrites this sequence as a sequence of features to be set according to the right-hand-side of the rules (in this case, it is the feature sense).

6 Conclusions

By using FSTs, we have achieved a uniform and declarative way of expressing linguistic knowledge in rVoice. The rule compilers are run off-line for each FST-based module, producing a DFST encoding the combined rules used by this particular module. The FST is loaded by the system at runtime. Thus, it has been possible to achieve a clear separation of the language-independent
processing algorithms and the language-, accent- or speaker-specific data (the 
FSTs). The (minimized and determinized) FSTs have contributed to a sig-
nificant speedup and footprint reduction.

The interaction of the rule-based FSTs and the automatically trained text 
modules (POS tagger, language identification) reflects the strengths of both 
approaches. The latter components, trained on newspaper text, guarantee a 
high accuracy baseline on input similar to the available training material. In 
particular, the POS accuracy is over 96% on news text, while the accuracy 
of language identification exceeds 99% (both measured per token). The rule-
based modules are typically used to correct or to complement the predictions 
of the automatically trained modules, for example on untypical text genres, 
or in response to specific customer requirements.

The FST-based rVoice modules comprise homograph disambiguation, post-
lexical reductions, grapheme-to-phoneme conversion and syllabification. In all 
these applications, the compiler has proved to be a flexible and useful com-
ponent of the system.

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