Natural Language Generation for Spoken Dialogue

Thomas Portele

Philips Research Laboratories
Weisshausstr. 2, D-52066 Aachen, Germany
Thomas.Portele@philips.com

ABSTRACT

A natural language generation module for spoken dialogue systems has been developed that performs three steps: generating multiple versions of an utterance, choosing the best version by a set of criteria, and annotating the text using structural information accumulated during the generation process. The requirements of spoken output is catered for by several design decisions.

1. MOTIVATION

In many dialogue systems output is generated using sentence templates and prerecorded phrases. This leads to very high quality output but only for very limited and fixed domains. This restriction can be overcome by using natural language generation techniques.

Language generation modules used in state–of–the–art spoken dialogue systems are a compromise between flexible rule–based systems (e.g. [2]) and template systems (e.g. [1]). A hybrid approach [3, 4, 13] maintains the possibility to hard-code output while allowing for rule-based generation of date and time expressions.

Generation for spoken output has to take into account not only supplying a textually correct result but also prosodic annotations [8, 13]. While purely statistic approaches (e.g. [9, 11]) are attractive by allowing automatic training of the generation process, they fail to deliver prosodic information due to missing information about structure.

A hybrid natural language generation module for the Philips research dialogue system architecture [1, 6] has been developed. It should provide

- separation of dialogue-specific and language-specific properties,
- modeling of certain linguistic phenomena (e.g. referencing),
- reusability of basic elements like date or time expressions,
- adaptability to different output channels (text, speech from templates, speech by synthesis from prosodically annotated text).

2. SYSTEM OVERVIEW

The system involves three steps: a generator which constructs a set of possible results, a chooser which determines the best version from that set, and an annotator which transforms the chosen version from its representation as tree of feature structures into the desired output format, using the attached information to supply adequate annotations (Figure 1).

The input of the system is a hierarchical feature structure (Figure 2 displays an example) generated by the dialogue module. Within this feature structure, a feature can appear multiple times (e.g. if a database query returned multiple results). The NLG module can omit redundant information but output planning (i.e. grouping/sorting) or dialogue strategy (i.e. constraining/relaxing) is not part of its capabilities.

The output of the NLG system can be used as input for a speech synthesizer. The annotator is able to supply a SABLE-compliant annotation [12] (Figure 3). Other implemented formats include plain text and HTML/XML.

3. GENERATOR

The generator transforms an input feature structure into a set of possible generation results. This is done by means of a tree–adjoining grammar. Generation is controlled by constraining features at the root nodes. A system state consisting of a set of variables can be changed by actions associated with a rule. Mechanisms to allow sequential processing of multiple input features and to convert input feature values into rule terminals are implemented.
3.1. Rule Structure

Grammar rules resemble syntactic trees in the TAG formalism [5, 10, 13]. Possible operations on trees are substitution and adjoining [5]. The tree structure is later exploited to obtain prosodic annotations, but flat trees are also allowed. The labeling of the nodes is arbitrary (with one exception: the name of the start node must be “Utterance”). Thus, no linguistically motivated restrictions are imposed on the grammar writer; the grammar writer does not have to be a trained linguist.

Each node can have an associated feature structure that contains conditions for its applicability (root node, Figure 5) or information about the node’s status (leaf type etc., Figure 6). If the root node feature structure can be unified with the current system state and with optional extra constraints represented as a feature structure at a nonterminal leaf, then the pertinent leaf is substituted by the tree starting at the root node. The system state is represented by a set of system variables and input features. For example, in Figure 5 the current system state may not have a feature with attribute “hastime” and value not “true” if the rule should be applied. Thus, a flexible and dynamic derivation process is possible.

3.2. “Target” Features

As a set of features with identical attribute names can be part of the input (e.g. for the results of a database query, Figure 2) these features have to be accessed one after another. Special rules, “target” rules that have the feature target:”true” attached to their root node, take the first feature with an attribute name equal to the root node name and move all internal features up one feature level. The original feature is discarded. Thus, subsequent instances of features with identical attribute names can be processed sequentially (Figure 4).

3.3. Actions

Each rule has a (possibly empty) set of actions assigned to it. An action is a simple assignment statement with an optional condition (Figure 5 and 7). The assignments are made to variables that can contain a string value or a float value. The actions can access variables from the system state and features from the current input feature structure. In actions functions can be called that transform one input value into an output value. Predefined functions can be used as well as user–defined transformations. User–defined functions are simple lists of input–output pairs (e.g. “/1/one, 2/two, ...”). Predefined functions are e.g. wcount, which returns the number of words in a string, or hasfeature, which evaluates whether the current input feature structure has a certain attribute at its top level. The actions of a rule are performed when a rule is applied. The system state, the list of variables, is changed due to these actions.

3.4. Leaves

The leaves of a rule tree can be either terminal, nonterminal or slot leaves. Nonterminal leaves demand substitution with trees that have the same node name as root node name (Figure 5). Terminal leaves are constants. Slot leaves are variables filled by accessing the input feature structure or the variables in the system state (Figure 6).

Slot leaf filling is performed after the pertinent rule has been applied.
The output versions are evaluated to obtain the one with the highest score. Different methods $s_i, i = 1 \ldots n$ can be combined to score the generation results $r_j$: $s_i(r_j) = \sum_{i=1}^{n} w_i s_i(r_j)$. The method weights $w_i$ can be adapted to select e.g. longer or shorter utterances depending on the user preferences. Currently, four methods are implemented:

- random choice,
- a method that favours either the longest or shortest version (measured by the number of words),
- a method that favours the version with the smallest number of words not contained in a given lexicon (e.g. the lexicon of the speech recognizer in order to use as many words as possible on the output side that the system can understand on the input side),
- a method that assesses the quality of referring expressions to entities.

For the last method entities are defined as being associated with those leaves of the output tree that used to be slot leaves (i.e. carry important information). An entity has a class which is the attribute of the pertinent slot feature (e.g. movie), and a value which is the slot value (e.g. Star Wars). Entities are referenced by parts of text. A reference can be either a pronoun ("he,she,he"), a definite description ("this movie"), or an explicit reference. A set of entities is constructed during the generation process of a dialogue. For each entity a list of references with their types and utterance indices (the number of an utterance in the current dialogue) is kept and updated which constitutes a kind of dialogue history. Work is in progress to include user input as well, but currently, only the system output is taken into account for the entity set.

The referring score for a generated result is computed by summing up positive and negative values associated with constraints, e.g.

- the current reference is a pronoun, and the entity was never mentioned before (negative)
- the current reference is a pronoun, and the last mentioned entity of that class is the current entity, and the entity was last mentioned in the same utterance (positive)
- the current reference is a definite reference, and the last mentioned entity of that class is not the current entity (negative)
- the current reference is neither a pronoun nor a definite reference, and the entity has not been mentioned before (positive)

A further scoring method envisaged is using language model scores [7] based on application-dependent large corpora.

5. ANNOTATOR

The output version with the highest score is chosen and annotated with e.g. prosodic information. Several annotation methods exist, and new ones can easily be added. Each annotation method takes
a generation tree and produces a text string. The information in
the tree is employed to perform annotations, e.g. to put accent
markers around references to slot entities, to put boundary mark-
ers between two words if the route in the generation tree from one
word to the next one involves moving up a certain number of lev-
els within the tree, to use phonetic transcriptions from a lexicon
etc. Supported annotations are

NoAnnotation just gets the surface string,
SableAnnotation inserts tags compliant with Sable 0.2 [12], a
markup language for speech synthesizers (Figure 3),
XMLAnnotation provides XML tags,
HTMLAnnotation provides HTML tags.

6. CONCLUSION

The system presented here is a hybrid system that allows for
prosodic annotation derived from the structural information ac-
cumulated during derivation, but the rules do not have to adhere
to any syntactic theory. The same holds for referencing analysis
where non–linguistic criteria derived from the dialogue system
specification are applied. Coherence between input and output
(what the system understands and what it says) is ensured by us-
ing a common lexicon. Thus, performance in spoken dialogues is
supported by the design of the generation system.

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