Intelligent Word-Prediction to Enhance Text Input Rate

(A Syntactic Analysis-Based Word-Prediction Aid for People with Severe Motor and Speech Disability)

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ABSTRACT
Word-prediction is a technique commonly used to reduce the amount of keystrokes needed to input text by people with severe physical disabilities. Several methods based on word frequencies have been developed so far. Many of them do not take advantage of the information inherent to the syntactic sentence structure. This paper puts forth a word-prediction method based on the syntactical analysis of a sentence, carried out using the "chart" parsing method proposed by Allen. This method also adapts its behaviour to the user's lexicon. The obtained results are compared to others obtained from a pure statistical predictor.

Keywords
Motor disabilities, input speed enhancement, word-prediction, syntax analysis, chart technique, adaptation.

INTRODUCTION
People with severe motor and speech disabilities experiment difficulties when using keyboard/mouse and screen-based standard interfaces. To avoid this problem alternative input systems have been developed. For instance, methods based on the scanning of the possible options with selection by a single key. Nevertheless, alternative input methods result far less quickly than standard ones. Since many of these people use computers for personal communication, they experiment frustration because their word/phrase composition rate is too low to maintain a normal conversation. ·

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When these people point to a board containing letters and some special words to communicate with other people, the interlocutors is used to anticipating many of the words before they are completely spelled. That means that in many cases a human interlocutor can predict the next word (or even the next sentence) to be produced, possibly using his/her language knowledge and the context. From the observation of this situation, it is advisable that computers with "intelligent behaviour" should be able to emulate the capability of anticipation shown by humans.

STATE OF THE ART
Several works related to prediction have been published during the last years. While some of them have tried to anticipate n-grams (strings of n characters) [3], most of them are focused on predicting the next word uttered by the user.

There are interesting approaches that are able to propose longer units than just a word. Frequently they are more related to key expansion than to prediction. For expansion, the user types concrete abbreviations that are automatically expanded by the system. Other approaches of this type of prediction model the conversation (possibly using automata of states) and try to offer sentences appropriate to the current state of the conversation [2] [5].

Let us focus on word-prediction. Different approaches have been developed to try to guess the intention of the user. Some of them take into account pure statistical language data: mostly word frequencies [4]. These methods can be enhanced with different additions, for instance, in [7] the "recency of use" is also treated. Even if this statistical approach allows reasonably high hit rates, the absence of context analysis loses valuable information. As it is known, natural language has inherent redundancy that could be interesting for prediction purposes. if it is

conveniently extracted. In this way, the information obtained from the word's syntactic function into the sentence can be used to restrict the set of possible words to be proposed to the user.

Semantic analysis can also be very useful to orientate the search for possible words to a well defined semantic context [6]. Nevertheless, this approach has not given good results so far, due to the difficulty in associating semantic content to every word, and to process it in a reasonably short time.

In this work, an approach based on the syntactic analysis of the sentence that tries to enhance previous statistical prediction methods is described.

WORD-PREDICTION AID DEVELOPMENT

A special feature of syntactic word anticipation is that it is not necessary a complete syntactic analysis that covers all cases, that is, we do not have to take into account all the possible rules that can appear in a given natural language. Since a predictor is not a syntax corrector, you don't have to include all the possible rules to correct all the possible mistakes a user can make. All you need is to include the most probable rules, in order to give good proposals to the user (there is no need to always offer the word the user wants to write: the only need is that the results have to be good enough to enhance the communication rate). Anyway, it is possible that the user would reject all of them, because he/she wasn't using any rule of the predetermined set. In this case, the predictor does not save any time but in the remaining cases it could reduce the number of keystrokes.

The word-predictor we have developed is based on the chart parsing method proposed by [1]. This method is a bottom-up technique to analyse sentences in natural language which work with a set of rules having a left part and a right part. The meaning of these rules is: the component of the left part of the rule can be decomposed into one or several constituents that appear on the right-part of the rule in the order they appear. Normally, the component and the constituents are syntactic categories.

This technique takes the syntactic category of the current word (in the running sentence) and compares it with those that appear on the right-part of the rules.

When the category of the current word matches the first category of a rule, this becomes "active". Including these categories in the recognised part of the rule, this becomes partially completed and it is called an "active arc". If the category of the next word is the one needed by an active rule at the present state of the current sentence, the partially completed rule should increase its size, adding the recognised category to it. If a rule still remains incomplete, it will require some other word, of a determined syntactic category, to be the next one. And, if it is completed, it can recursively start some other rules.

Since each rule has a weight depending on the frequency of use of the rule, some syntactic categories are going to be more probable than others in the current position of the sentence. As it can be seen in figure 1, words belonging to categories with active arcs are more probable than the others. In this way the set of candidates is restricted, as noted before.

So, the syntactic information is used in addition to the statistical information, to emphasise the most probable categories and also the most probable words. In addition, within a rule some concordances, relative to the gender and number of the components of the right-part, are defined. This can be used in addition to morphological information to properly adapt the gender and the number of the proposals, if it is necessary.

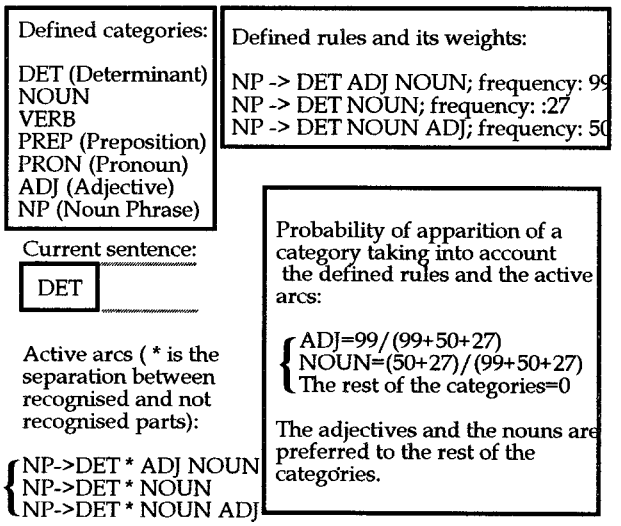

Fig. 1. A graphical interpretation of the chart, and its application to extract the most feasible categories.

All this information related to the words (statistical, syntactic and morphological) is stored in a dictionary. In the beginning, this dictionary is the same for all users but, according to the use, it changes to adapt itself to the user's vocabulary. The rules are stored apart from the dictionary, but their weights are also adapted to the user frequencies. In summary, the entire system is adaptable to the user's vocabulary and syntactic particularities.

An exception to this way of operation are the first words of sentences. In this particular case, there are no partially completed rules. To be able to give proposals the system will work with the words and the syntactic categories that have higher probability to be at the beginning of a sentence.

When a new word appears, not present in the dictionary, a special situation occurs. This new word must be included in the dictionary to adapt the system to the user. The system has only a hint of the syntactic category associated to the word, obtained from the current active arcs. An automatic addition to the lexicon will produce the lack of definition of syntactic information, because the system can not guarantee whether the estimation it makes (with the defined rules it has) is correct. In our approach, these words are categorised as "not-categorised". In a special interactive session the system asks the user about the syntactic information associated with these new words in order to complete the needed information.

RESULTS AND EVALUATION

Prediction Measurement

Anticipation ability is usually measured in terms of hits. But, if the length of the predicted word is small and/or the amount of actions needed to accept the proposal is large, the effort-saving is not significant for the user.

We measure our results in terms of keystroke savings, **s**:

$$s = \frac{i + a}{n}$$

where **n** is the number of characters (or keystrokes[1]) needed to write the complete text in a standard keyboard, **i** is the number of characters effectively typed by the user and **a** is the number of keystrokes needed to select or accept the proposal, if necessary.

To make comparisons, the method of prediction by frequencies is taken as a model. This method gives low results, but the needed computational effort is minimal. The results using syntactic prediction are better but the needed computational effort is greater too.

User Interface Dependency

Results strongly depend on the number of proposals issued by the predictor. For instance, if a predictor issues ten proposals at once it has more hit probability than if the same predictor offers only one. So if we only consider the hit rate, the system should offer as many proposals as possible.

On the contrary, when the number of proposals offered by the predictor increases, it is more difficult for the user to select the one he/she likes. That is, it takes more time to read the proposals and he/she has to perform more actions to choose one of them.

So, a balance must be reached between the number of proposals and the effort to select one (or none) of them. Putting this problem aside, the integration of the proposals in an interface based on scanning and single key selection is not difficult. The proposals can be added to the other options the user can select from the display. But, user testing and evaluation of our prediction systems, demonstrate that when the disabled user is able to type on a standard keyboard, he/she frequently concentrates their sight on the keys and he/she forgets the aids appearing in the screen. So, more adequate user interfaces should be designed for this category of users.

In our study, four cases have been tested: predictors which offer one, five and ten proposals with implicit rejection (that is, there is no need to explicitly reject the given proposals: if a new character is added to the word all the proposals are rejected), and one proposal with explicit rejection (in this case there is a need to explicitly accept or reject the proposal).

Adaptation to the User

One of the features that can be highlighted is the user adaptability. Even if natural languages are very complex and many different syntactic structures are possible, people only use a subset of them, with a significant frequency. Similarly, the lexicon used by people is restricted in comparison with the total set of possible words for a language. In addition, some words, like names, are closely related to the vital context of the person. For this reason, the structures and word frequencies, taken from standard corpora are not well adapted to the real user's tongue.

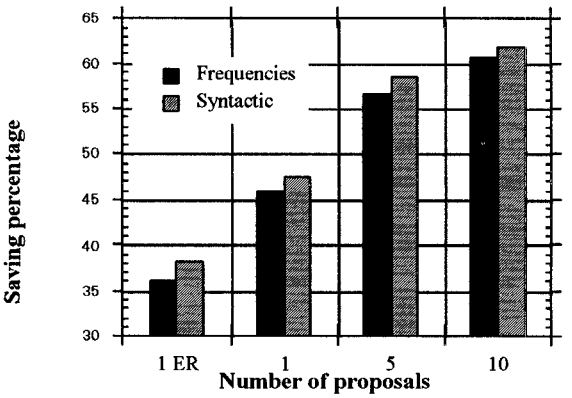

Fig. 2. Results comparing frequencies and syntactic-based word-prediction systems

To avoid this inadequacy, the lexicon used by our method is continuously updated by use. So, some time after one starts to use it, the content of the lexicon of two concrete

[1] We consider that one keystroke produces a character. Multiple keystroke characters have not been taken into account so far.

users can become quite different. In this sense, the system is adapted to the user, and the ability to predict is enhanced with use.

Influence on the Overall Interface

The use of Artificial Intelligence techniques for natural language processing enhances the acceptance by the user of the overall interface, due to its ability to cope with the user's own language.

We have implemented this word-prediction system in different portable personal computers used for personal communication by people with disabilities. The usability test shows that the syntactic analysis-based word-predictor is better accepted than the previous frequency-based one due to its higher hit rate, but also because of its capacity to adapt the accepted word to match the syntactic structure.

CONCLUSIONS

As shown before, the proposed method for word-prediction obtains better results than the purely statistical one, mainly due to the addition of the kind of underlying intelligent behaviour in terms of the syntactic analysis of natural language. Although the required computational effort is higher, the presented system adapts itself to the user's vocabulary while it is being used in both the lexicon and the rules. However, there are some problems as the new words added to the lexicon which can require some human participation in order to maintain the system in an correct way.

There are also some possible dysfunctions if a user does not look at the proposals offered by the predictor and types all that he/she wants to write. We propose to design this aid within an overall interface which may minimise these dysfunctions. For instance, the use of touch-screens, where all the information related to the input and the output are placed one beside the other, as a part of the interface can be helpful for this purpose.

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