The application of fuzzy set theory to the storage and retrieval of conversational texts in an augmentative communication system. N.Alm, M.Nicol and J.L.Arnott. In: *Proceedings of the RESNA '93 Annual Conference,* Las Vegas, USA, 12-17 June 1993, pp. 127-129.

The application of fuzzy set theory to the storage and retrieval of conversational texts in an augmentative communication system

Norman ALM, Mark NICOL and John L. ARNOTT

University of Dundee, Dundee DD1 4HN, Scotland, U.K.

{nalm / jarnott} at *computing.dundee.ac.uk*

The research reported here was published in:

Proceedings of the RESNA '93 Annual Conference, Las Vegas, Nevada, USA, 12-17 June 1993, pp. 127-129.
ISSN 0883-4741. ISBN 0-932101-33-X. Pub: *RESNAPRESS,* Washington, D.C. 20036, USA.

RESNA (Rehabilitation Engineering and Assistive Technology Society of North America): http://www.resna.org/

ABSTRACT

Current augmentative communication systems for severely physically impaired non-speaking people operate primarily on a word-by-word or letter-by-letter basis. Systems based on storage and retrieval of entire sentences and longer texts have thus far proved impractical, given the difficulty of remembering what is stored and how to access it. A number of research systems are under investigation which provide the user with predictive assistance to incorporate pre-stored text appropriately into conversations. The system described in this paper is based on fuzzy set theory, which allows it to continuously provide the user with a predicted set of appropriate next texts, and thus assist the user to move naturally and easily within and across topics. The system was tested in conversational situations by an able-bodied user. It provided an improved performance over a version without the fuzzy retrieval method by always offering appropriate items and requiring less effort from the user.

BACKGROUND

One method for assisting severely physically impaired non-speakers to communicate at a faster rate, and with more impact, would be for a system to offer them whole phrases, sentences, or longer texts to say at once. It is well known that the difficulties with this approach include remembering that a particular text is stored, recalling how to access it, and carrying out the accessing procedure. Users have thus far not made much use of stored text, preferring to create what they wish to say anew each time [1].

It is an open research question how much of everyday conversation is in fact re-usable. Given the large amount of time conversationalists spend recounting stories of all kinds to each other, many of which are told to a number of different people, this would in any case be a useful capability for an AAC system [9]. Certainly, given the difficulties in creating text faced by physically impaired non-speakers, it would seem sensible at least that a system be able to store all new utterances created, and ensure that the user did not have to re-create any of the stored items anew, the next time they had need of them.

A number of research prototypes have demonstrated the effectiveness of modelling conversation patterns in an AAC system, to assist the user in communicating more naturally and easily [3,4,9].

One characteristic of conversation is moving in a coherent way from topic to topic. This is normally handled in a step-wise fashion by conversationalists [6]. In this way, the coherence of the conversation is cooperatively maintained, while each speaker is able to take part in controlling the conversational content. For the non-speaking person using an AAC system, this is a particularly problematic part of communicating. It has been shown that a great deal of AAC communication consists of single word or short phrase responses, where the topic has been set by the unaided speaker [7]. Where the AAC user might like to introduce a new direction in the conversation, the time it takes to create and output a suitable contribution usually means the conversation has moved on.

The Floorgrabber research system has demonstrated a method which, in trials, gave an AAC user increased conversational control by providing them large amounts of their own pre-stored text, to hold the floor when appropriate [4]. The problem of topic change, however, still remains a difficult one. In the Floorgrabber prototype this was handled by having the user search for the next topic with a set of on-screen buttons. A predictive feature would be an effective way to assist the user to move more easily to another topic area, where related texts from other topics could appear in prediction windows for possible selection.

This would only be effective, of course, if the predictions were appropriate ones. A definition of 'appropriate' here might be contributions which the user specifically wanted to say next, but might also include items which the user had perhaps forgotten that they had stored, and which were suitable follow-ons to the last thing said. In this way, such a system could act as a 'prompt' for the user as well as a storage and retrieval system.

A FUZZY RETRIEVAL SYSTEM

With conventional database storage methods, each item is tagged with a set of descriptors, and a search for related items involves comparing these descriptors. In the TOPIC prototype, an experimental text database system for conversational data, the conversational items were given descriptors according to content (semantics) and potential use (pragmatics) [2,5]. Retrieval of the next conversational item was done from a menu of possibilities which were produced by searching on relevant semantic or pragmatic descriptors. Searching was also possible by looking for any string of characters in the store. A *soundex* algorithm reduced keying-in effort by allowing the key words which specified a search to be drastically abbreviated.

The TOPIC system produced coherent conversation, but further development of the storage and retrieval method was needed in order to minimise the effort in using it, and to provide a structure which could be used to predict text items. The TOPIC system had more structure in the storage of items than Floorgrabber, but a problem remained with the efficient and effective use of descriptors.

With a conventional database, it is difficult to decide how many descriptors would be needed for a large database, and even with a large number there will be frequent problems of deciding whether or not to assign a particular item to a given descriptor. If too few descriptors are used, there will be too many candidates after any search and further searching will be needed to identify suitable ones. If too many descriptors are used, then the possibilities increase of getting a null result from a search.

Also deciding on a list of descriptors requires knowledge in advance of the material to be stored in the database, and the purpose for which it is required. This is not appropriate for a conversational database, which will grow with each individual and will need to be used by them flexibly in a large number of different situations.

Fuzzy set theory is an extension to conventional set theory which is particularly appropriate for modelling complex systems where it is not possible to classify the components of the system into discrete sets [10]. The theory is mathematically rigorous, but takes as its starting point the central concept that membership of any set, instead of being a binary property (yes or no, 1 or 0), is describable as a real number between 0 (definitely not in the set) and 1 (definitely in the set). Thus, instead of 'x belongs to set Y', we have 'The membership value of x for the set Y is 0.146', which gives a relative value to how strongly x belongs to set Y.

This theory has been applied successfully in control systems of various sorts [8]. If applied to an information retrieval system, the theory allows for more flexible storage and retrieval methods. The similarities between items in the database can be captured without the need for similar items to share a number of descriptors from a given set. From the point of view of a conversational database, a fuzzy set retrieval system has the advantage that, given one item, it will always produce a set of the most similar items in the database. It will never return from a search with no items found.

A PROTOTYPE COMMUNICATION SYSTEM BASED ON FUZZY SETS

In order to test out the feasibility of using fuzzy set retrieval methods in a conversation aid, a prototype system was developed. The conversational content of the system was taken from the Floorgrabber system. For the Floorgrabber project, a non-speaking person, with the help of volunteers to interpret his word board, has been creating a database of conversational material over a period of one year. This contains stories, jokes, autobiographical material, current news, and a wide variety of characteristic speech acts for use in giving feedback to another speaker.

The fuzzy set system prototype was written in C++. For labelling the stored items, two types of descriptor were used. Based on previous work with a text database, the descriptors either represented the semantics of an item (its subject) or the pragmatics (its purpose in a dialogue, i.e. speech act) [2,5]. The system used eight subject descriptors (travel, music, sport, driving, communication, work, family, friends) and five purpose descriptors (opening, elaboration, question, joke, conclusion). Each item in the fuzzy set database had a vector associated with it which described its degree of belonging to these thirteen categories.

A number of experiments were carried out to determine an efficient and accurate way to assign these values. The optimum design was an analogue display on the computer screen (a sliding control) with which values could be set for each item. For the purposes of this feasibility test the values were set by one of the authors. It is expected that the values set will always have a certain degree of subjectivity. This is acceptable, however, and is even a desirable characteristic, in a system which should model the conversational style of the user.

The control interface for the fuzzy set conversation system is shown in Figure 1. The CURRENT TEXT window contained the text being spoken at the moment. The OPTION windows contained texts predicted by fuzzy matching to be good candidates for the next text. To control the system, the user only needed to perform three actions. Using a mouse, if the user clicked on the CURRENT TEXT window, that text was spoken by a speech synthesiser. If the user clicked on any of the OPTION windows, the text displayed was spoken, that text was moved to the CURRENT TEXT window, and the three OPTION windows were updated with three text items from the entire store which were most closely related to the new current choice. By clicking the mouse on MORE OPTIONS, the OPTION windows were filled with three more choices of text, which were the next three closest matches to the item in the CURRENT TEXT window. Repeated choices of MORE OPTIONS would in effect continually widen the search criteria, each time producing a full set of candidate texts.

PRELIMINARY EVALUATION

To evaluate the performance of the system against an equivalent system based on Boolean search database retrieval methods, a version of the system was created which used the same stored text items, but which depended on conventional database searching to compare stored items. As expected, the conventional system often produced no texts which matched a given text, whereas the fuzzy set system always produced a full set of candidate texts.

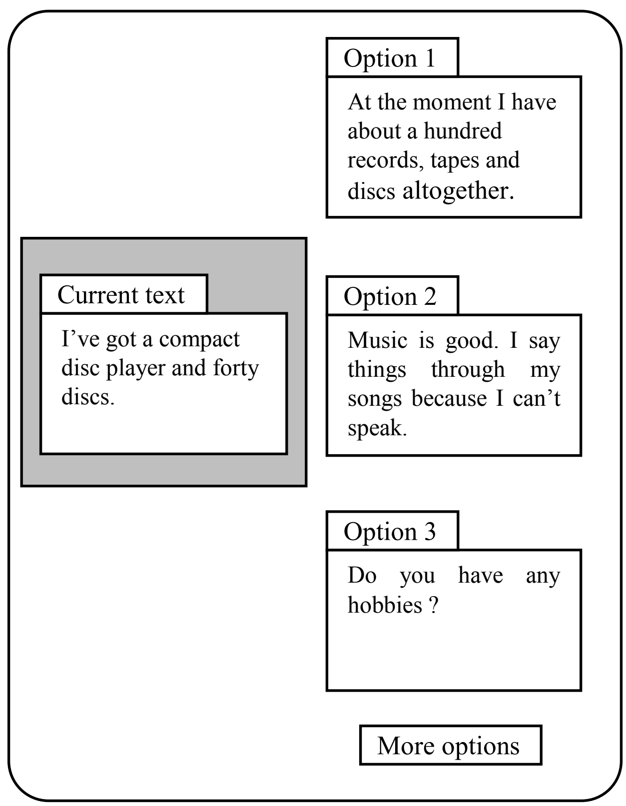

Figure 1: Interface for the fuzzy set communication system

A comparison was done with the Floorgrabber prototype, which had 850 stored text items, retrievable through a hierarchical search method (topic → subtopic → text item). The same text items were loaded into each system. Conversation sequences which had been performed with the fuzzy set system, were then reproduced using the Floorgrabber system. Fewer mouse clicks were needed to produce the conversation using the fuzzy set system (20% to 35% fewer). Occasionally, the Floorgrabber system required a large number of input activations (e.g. mouse clicks) to produce an utterance, whereas the fuzzy set system tended consistently to need only one or two. Also there was a difference in the cognitive task involved. With the Floorgrabber system, the user had to form a search plan and execute it. The fuzzy set system simply presented appropriate material automatically.

It could be objected that the 'prompting' nature of the fuzzy set system was inimical to real conversation, in that one could never know what the user might have said if working with a totally free choice. Against this, it can be argued that with stored re-usable material, the order in which it is said matters less than its successful and appropriate introduction into a conversation. The criterion is thus not a direct comparison with unaided speech, but with successful versus unsuccessful communication, however accomplished.

The next stage in this research will be further experimentation to improve the interface of the system, work on devising an easy-to-use method for labelling new conversational items for storage, and further trials of the system in actual use.

ACKNOWLEDGEMENTS

This work was funded with the assistance of the European Community Social Fund, and a charitable donation from the Digital Equipment Corporation.

Address: University of Dundee, Dundee DD1 4HN, Scotland, U.K.

REFERENCES

1. Alm, N. (1988) Towards a conversation aid for severely physically disabled non-speaking people. *Ph.D. Thesis.* University of Dundee, Scotland, U.K.

2. Alm, N., Arnott, J.L., Newell, A.F. (1989) Database design for storing and accessing personal conversational material. *Proc. of the RESNA 12th Annual Conference (RESNA '89),* New Orleans, Louisiana, USA, 25-30 June, pp. 147-148.

3. Alm, N., Newell, A., Arnott, J.L. (1992) Prediction and conversational momentum in an augmentative communication system. *Communications of the ACM*, Vol.35, No.5, pp. 46-57.

4. Alm, N., Arnott, J.L., Newell, A.F. (1992) Evaluation of a text-based communication system for increasing conversational participation and control. *Proc. of the RESNA International '92 Conference,* Toronto, Canada, 6-11 June, pp. 366-368.

5. Arnott, J.L., Alm, N., Newell, A.F. (1988) A text database as a communication prosthesis. *Proc. of the International Conference of the Association for the Advancement of Rehabilitation Technology (ICAART 88),* Montréal, Canada, 25-30 June, pp. 76-77.

6. Atkinson, J. and Heritage, J. (1984) *Structures of Social Action - Studies in Conversation Analysis.* London. Cambridge University Press.

7. Light, J. (1988) Interaction involving individuals using augmentative and alternative communication systems: state of the art and future directions. *Augmentative and Alternative Communication,* Vol.4, No.2, pp. 66-82.

8. Sutton, R. and Towill, D.R. (1985) An introduction to the use of fuzzy sets in the implementation of control algorithms. *Journal of the Institution of Electronic and Radio Engineers,* Vol.55, No.10, October, pp. 357-367.

9. Waller, A. (1992) Providing narratives in an augmentative communication system. *Ph.D. Thesis.* University of Dundee, Scotland, U.K.

10. Zadeh, L.A. (1973) Outline of a new approach to the analysis of complex systems and decision processes. *IEEE Transactions on Systems, Man, and Cybernetics,* Vol. SMC-3, No.1, pp. 28-44.