An Adaptive and Predictive Environment to Support Augmentative and Alternative Communication

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Abstract. In this paper we describe Bliss2003, an Information and Communication Technology (ICT) aid for verbal impaired people supporting the use of Augmentative and Alternative Communication (AAC) languages. Bliss2003 allows to compose messages in Bliss and other AAC languages (i.e. PCS, PIC, etc.), to translate them in natural language, to send and receive them via email, or to vocally synthetize them. Bliss2003 is characterized by a predictive module that allows for a more efficient selection of graphical symbols and more natural sessions of communication by adapting a model of the user language behavior.

1 Introduction

Communication represents the main way in which man can live his sociality; in fact, only by communication, man can express thought, emotions, and ideas. Communication plays an important role in everyday life; by communicating man can express necessities, feelings, request for information and aid. Nowadays, millions of verbal impaired people live currently in the world [1]; their communication capabilities are permanently or temporarily corrupted and, for this reason, most of them suffer a condition of social exclusion.

To help verbal impaired people, ad-hoc alternative languages have been developed by the International Society for Augmentative and Alternative Communication (ISAAC) established in 1983 in USA [2]. Among the currently most adopted AAC languages [3] we can cite: Bliss, PCS, PIC, PICSYMB, CORE, Rebus. Each of them is based on a peculiar dictionary of words represented by pictures or symbols, and specific composition rules simple enough to be learnt and used by disabled people [4].

ICT, especially in cases of verbal impaired people, has been widely used to develop effective tools for rehabilitation. Bliss2003, developed from APBliss [5], is an adaptive and predictive environment for AAC developed to provide people during the communicative process with a personal table of Bliss symbols and a set of intelligent tools. Bliss2003 can translate the composed messages to natural language making use of a syntactic/semantic analyzer, vocally synthetize them, and exchange them via email. With respect to traditional AAC software aids, Bliss2003 addresses a set of novel features: an innovative predictive composition assistant based on a discrete implementation of auto-regressive hidden Markov model [6] called DAR-HMM, the simultaneous support of several AAC languages, and the adoption of a graphical interface designed on purpose for impaired users. Bliss2003 has been registered by the Blissymbolics Communication International (BCI) center of Toronto and has been adopted for hundreds hours of experimental validation by several Italian clinics for verbal impaired people. In the following section we introduce the Bliss2003 environment and in Section 3 we describe its the main novelty: the predictive composition assistant. A case study, taken from the validation activity of the tool, is presented in Section 4.

2 The Bliss2003 Graphical Environment

The collaboration of a psychologist expert on graphic trace helped us to design a specific graphical interface that improves usability in order to reduce the difficulties a verbal impaired person can undertake interacting with graphical applications [7]. The main issues we have taken into account regard the iconographic style, the graphical structure of the windows, their place, the number of buttons and their function as well. The whole iconographic collection has been drawn by a web-designer with the requirements of a simple and clear interface, intuitive and unambiguous, with well-blended colors and uniform strokes to assist visual difficulties while supporting content decoding (see Figure 1).

Bliss2003 is organized in seven environments to facilitate the user concentration by reducing buttons, functions and information that the user can simultaneously find on the screen. This environment-based structure has been designed to facilitate users since they express an higher concentration in specific environments than in a general environment that requires to discriminate among many choices. Environments are also related to the capabilities of the user and the adoption of a specific one should be accomplished in collaboration with a therapist.

Since the universality of Bliss language, Bliss messages can be synthesized in any natural language. The user can set more speech features such as male or female voice, tonality, volume, emphasis and so on. The vocal synthesis makes easier the interaction with other people. In addition the verbal impaired user can operate a syntactic concordance, using a syntactic/semantic analyzer, of a Bliss message into natural language according to grammar rules for verb, personal ending using gender concordance and prepositions in order to achieve a sentence syntactically correct. The transposition of messages makes more comprehensible a sentence for people that do not know Bliss language.

Similarly to other AAC communication software application, Bliss2003 is focused on the symbols table. In particular, Bliss2003 provides a *master table* composed of all Bliss symbols – about 2000 – and a *personal table* composed of just the symbols used by the user. Through the symbol editor environment

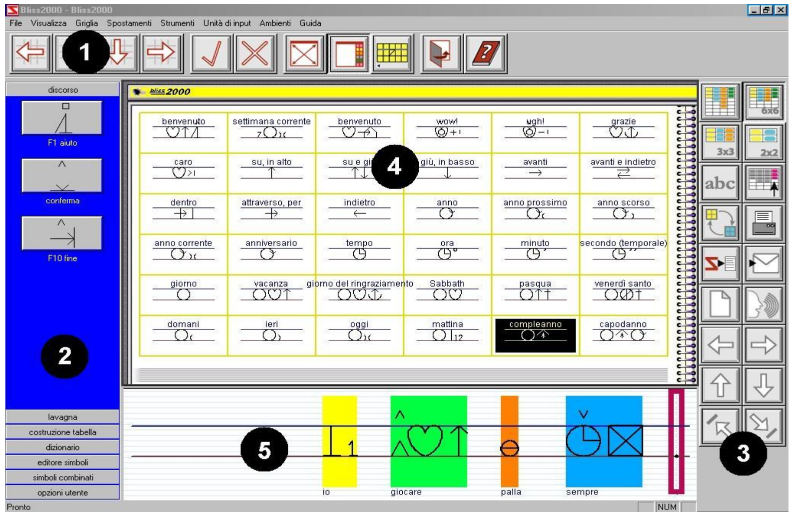

Fig. 1. Bliss2003 graphical user interface. The underlined spots refer to the *Main Command Bar* (1), the *Environment Option Bar* (2), the *Environment Command Bar* (3), the *Data Zone* (4), and the *Temporary Processing Zone* (5).

therapists can load PCS, PIC, or Rebus collection, so that Bliss2003 could be employed as a generic software for alternative communication and could be used as a multiuser system (in clinic, with people who communicate using different alternative codes). The provision of multi-language support evidenced extreme utility in rehabilitative processes. Furthermore Bliss2003 interface supports devices other then classical mouse and keyboard, in order to overcome motor disabilities in the user (e.g., joystick, touch sensor, switch buttons, graphic tables, etc.).

3 Predictive composition assistant

The Bliss2003 environment provides a predictive composition assistant, named caba^{2}l [8], which supports disables in composing sentences, by speeding up the symbols selection process, reducing the strain and the composition time, while increasing their self esteem. Literature about AAC languages application is rich of works concerning alphabetical prediction systems [9], but it is almost completely lack of systems performing symbols prediction [10]. To overcome this issue we have designed an innovative prediction system for Bliss language. Caba^{2}l is a prediction system able to suggest the user a set of Bliss symbols as next probable choice for his/her sentence according to the last symbol selected and the history of sentences previously composed. In other word, when a symbol is selected from the table, caba^{2}l shows a list of symbols that it considers as most probable ones – with respect to its model of the user language behavior – to continue his/her text. For instance, in the sentence "I want to eat" the next symbol will probably be some kind of food, so the assistant should suggest "pizza", "pasta", "bread", "cake", on the basis of last selected symbol and user characteristics. CABA^{2}L proposes a limited number of symbols defined by the therapist depending disable capabilities and operates a scansion of them by adopting an adaptive rate similarly to [11].

The composition assistant is based on a novel auto-regressive Hidden Markov Model implementation, called Discrete Auto-Regressive Hidden Markov Model (DAR-HMM) that we have developed specifically for symbolic prediction. Bliss symbols have been divided in six grammatic categories (adverbs, verbs, adjectives, substantives, persons, punctuation), and each one of them has been divided in sub-categories using semantic network formalism [12] (about 30 subcategories). In the following, we give a brief formal description of DAR-HMM according to the notation adopted by Rabiner in [6] to specify hidden Markov models:

- $S \triangleq \{s_i\}$, (sub)categories set with $N = |S|$;
- $V \triangleq \{v_j\}$, predictable symbols set with $M = |V|$;
- $V^{(i)} = \{v_k^{(i)}\}$, set of symbols predictable in (sub)category i
- $O(t) \in V$, observed symbol at time t;
- $Q(t) \in S$, (sub)category at time t;
- $\pi_i(t) = P(Q(t) = s_i)$, probability of s_i being (sub)category at time t;
- $a_{ii'} = P(Q(t+1) = s_i | Q(t) = s_{i'})$, transition probability $s_{i'} \rightarrow s_i$;
- $b_k^i = P(O(0) = v_k^{(i)} | Q(0) = s_i)$, probability of observing $v_k^{(i)}$ from (sub)category s_i at $t = 0$;
- $b_{kk'}^{ii'} = P(O(t) = v_k^{(i)} | Q(t) = s_i, O(t-1) = v_{k'}^{(i')})$, probability of observing $v_k^{(i)}$ from the subcategory s_i having just observed $v_{k'}^{(i')}$.

Given $\lambda =< \Pi^0 = \{\pi_i(0)\}, A = \{a_{ii'}\}, B = \{b_{kk'}^{ii'}\} >$ the vector of parameters describing a specific language behavior model, we can predict the first observed symbol as the most probable one at time $t = 0$:

$$\begin{aligned}
\hat{O}(0) &= \arg\max_{v_k^{(i)}} \left(P(O(0) = v_k^{(i)} | \lambda) \right) \\
&= \arg\max_{v_k^{(i)}} \left(P(O(0) | Q(0), \lambda) P(Q(0)) \right) \\
&= \arg\max_{v_k^{(i)}} \left(b_k^i \cdot \pi_i(0) \right) .
\end{aligned}$$

Then, using the DAR-HMM generative model described in Figure 2, to predict the t^{th} symbol of a sentence we want to maximize the symbol probability in the present (hidden) state given the last observed symbol:

$$P(O(t) = v_k^{(i)}, Q(t) = s_i | O(t-1) = v_{k'}^{(i')}, \lambda).$$

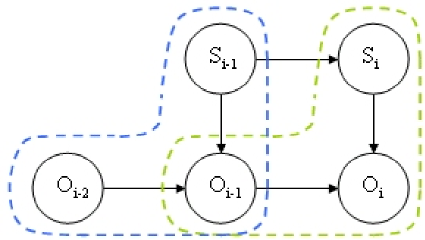

Fig. 2. Symbols emission in DAR-HMM; S_i is the i^{th} state (Bliss subcategory), O_j is the j^{th} observed symbol

Recalling that we can compute the probability of the current (hidden) state as

$$P(Q(t)) = \sum^{N} P(Q(t)|Q(t-1))P(Q(t-1)) =$$
$$= \sum_{i'=1}^{N} \pi_{i'}(t-1)a_{ii'} = \pi_i(t),$$

we obtain the a recursive form for symbol prediction at time t :

$$\hat{O}(t) = \arg\max_{v_k^{(i)}} \left(b_{kk'}^{ii'} \cdot \sum_{i'=1}^{N} \pi_{i'}(t-1)a_{ii'} \right).$$

In CABA^{2}L, the probability tables on λ vector are computer using a data set of Bliss sentences from the user and can adapt their values according to the evolution of the composition capabilities of the disable. In doing this, we have adopted a variation of the Baum-Welch algorithm, an iterative algorithm based on the Expectation-Maximization method [6], adapting this technique to the specific case of DAR-HMM. This feature is particularly relevant in the rehabilitation cases where, during the rehabilitation, the dictionary of the disable increases and his/her linguistic capabilities improve (an interested reader can retrieved a deeper analysis of CABA^{2}L in [8]).

4 Tool Validation

According to recent studies [13], 37% of impaired people dismiss to use the rehabilitation tool mainly because of lack of a real match to their needs. For this reason, in the development of Bliss2003, we have collaborated with two Italian clinical centers operating on verbal impairment – PoloH and SNPI of Crema (Italy) – to focus on an extensive experimentation of the new tool. Among the users who collaborated with us we have chosen to report the case study we consider as the most significant: “Elisa” an eighteen-year-old girl, who has been communicating with Bliss language for ten years.

Problem	**Imp**	**D1**	**D2**
speeding up communication	5	4	2
aiding the symbol selection process	5	4	2
compose Bliss message with much autonomy	5	4	1
performing the social integration making easier communication with non-Bliss interlocutor	5	5	3
exploiting communicative found	5	4	2
increasing user's attention degree	4	4	2
making powerful learning	4	4	3
Total score		**137**	**70**

Table 1. IPPA interviews comparison

From a disable perspective the most significant reason for assessing effectiveness is to assure that his/her problem has been solved. The effectiveness of an assistive technology provision, in its most basic form, can thus be defined as the degree to which the problem is actually solved in relation to its intended aim. We dealt with this by using two international ad-hoc protocols: IPPA [14] and MPT [15]. In the following we report the results we have obtained using IPPA and MPT protocols introducing an overall evaluation of Bliss2003 (we do not describe the evaluation of each single components, such as composition assistant or multi-language adoption).

4.1 IPPA (Individually Prioritized Problem Assessment)

IPPA is a protocol centered on the verbal impaired user, in particular on the evaluation of the difficulties the disable undertakes interacting with the aid. The user is asked to identify a set of problems that he/she experiences in daily life and that he/she hopes to eliminate or decrease. This is done at the very beginning during the service delivery process so that the user is not influenced by service provider. The evaluation consists in the comparison of interviews regarding the use of different aids, and reporting the difficulties that the user undertakes in the accomplishment of the problems previously identified. The identification process is an interactive process and we take care to designate problems on the basis of user's concrete activities. Table 1 reports the problems identified by Elisa.

A first interview has been accomplished before the use of Bliss2003 and refers to an AAC communication software previously adopted by Elisa at SNPI; Elisa with her parents and clinical staff assigned scores (on a five-grades scale) to the tool both with respect to the importance (Imp) of the problem and the level of difficulty of performing the specific activity (D1). During the follow-up interview, a few months after Elisa has started using Bliss2003, she had assigned a new difficulty score for the same activities (D2). The total score for each interview is calculated summing each difficulty score weighted by relative importance factor. The difference between the total IPPA score before and after

Interview	Positive	Indifferent	Negative
1^a	10	12	9
2^a	22	6	3

Table 2. SOTU questionnaire comparison

Area	Scores 1^{st} int.	Scores 2^{nd} int.
Disability	1.214	3.28
Aid	4.3	4.6
Environment	3.571	3.71
Character	4.027	4.25

Table 3. ATD PA questionnaire comparison

the provision of Bliss2003 represents an index of the aid effectiveness. The data reported in Table 1 evidence that the difficulty score is decreased in all identified problems while the total score is almost cut by half. Similarly to the Elisa case of study the interviews obtained from other disables evidence a lower difficulty score in comparison with the previously adopted AAC communication software.

4.2 MPT (Matching Person and Technology)

MPT is a validation protocol founded on active dialogue between the disable and the assistive technology expert. It allows to identify disables needs and their point of view on assistive technology aids so that we can develop a software to prevent assistive technology abandonment. In particular we have used three MPT instruments:

- *MPT working sheet*: to define targets and guidelines with possible information technology solutions;
- *SOTU questionnaire*: to analyze user's personal and social characteristics;
- *ATD PA questionnaire*: to analyze the features of assistive technology aid and its applicative domain.

These instruments are structured as questions with closed answer which have been compiled by Elisa parents, her clinical staff and us as information technology experts, according to two session: before using Bliss2003 and a few months after using it.

Comparing the first interview score with the second one about SOTU questionnaire (shown in Table 2) the negative answers decrease in the light of the progress on the social and communicative integration. Taking into account the ATD PA questionnaire results (shown in Table 3) the score is higher thus indicating that Bliss2003 has improved Elisa's communication capabilities.

5 Conclusions

In this paper we have introduced Bliss2003 an adaptive and predictive environment to support augmentative and alternative communication. In particular we described its overall architecture, its innovative predictive composition assistant and the experimental activity we did to validate the tool.

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