Context-Aware Communicator for All

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Abstract. We describe the design of a communicator for people with speech impairments of several ages, but that can also be used by everybody. The design is based on the accurate definition of user models and profiles from which we extracted technical goals and requirements. The current design shows the factors to consider to provide a successful communication between users. The system is prepared to be used with children and elderly people with some kind of speech impairment. Moreover, the communicator is able to spontaneously adapt to each user profile and be aware of the situation, summarized in: location, time of the day and interlocutor. Therefore, the vocabulary to be used relates to a particular situation with the possibility to be broadened by the user if needed. This "vocabulary" is not restricted only to the word or syntactic domain but to pictograms and concepts. Several machine learning tools are employed for this purpose, such as word prediction, context-aware communication and non-syntactic modeling. We present a prototype scenario that includes examples of the usage of our target users.

Keywords: Communicator · Augmentative and alternative communication · Pictograms · Word prediction · Context-aware communication · Non-syntactic modeling · Speech impairment

1 Introduction

Communication is an essential part of the social and *Personal* development of an individual. It is a two way process in which individuals share their understanding of the world [9]. People with speech impairments may have limitations that affect this process. One of the main issues is the difficulty they experience to convey a successful communication with others. In this respect, the research community has shown great advances producing algorithms, applications and devices that facilitate their interaction [5,7,9,14].

One of the areas that has acquired popularity is the augmentative and alternative communication (AAC) mainly based on visual aids [5]. Its success relies on the real improvement of the *Quality of Life* of the users. However, there is still much to do to adequate applications and systems to support *Persona*lized

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settings considering a particular context[1]. For example, the system must automatically adequate the vocabulary needed for a particular activity, at a specific time of the day, with the usual people interaction (for example, the children's vocabulary needed for breakfast, in the morning, with mom and dad).

We describe the design of a *Persona*lized communicator that covers the necessities of a wide range of people with impairments that go from a child with autism to an elderly lady that was diagnosed with dementia. We address the system characteristics as immersed in specific environments and contexts that give solution to the user needs. To accomplish the effective operation of the system, we create a model of use centered in the interaction between the user and the desired service in the system, according to the ETSI technical document ETSI EG 202 848 [4] and TR 108 849 [3].

In the next sections, we will give an overview of our communicator design that can lead the reader to a comprehensive summary of the system. Section 2 shows how the user was modeled and the characteristics that the communicator must accomplish. Section 3 details the context-aware adaptability of the system. Section 4 defines the functional communication specifications for the communicator. Section 5 shows the way the communicator will transform a message from one domain to another. Section 6 details a complete example of the usage. Section 7 opens discussion for further research. Finally, Sect. 8 gives the conclusion to this approach.

2 User Modeling

The user model gives an explicit representation of the abilities, intentions and attributes of an individual user who is interacting with the system. We used Persona *mechanism* [8] to obtain a clear idea of our target users. *Persona* modeling design suggests representing the users with as real characteristics as possible to extract their goals and requirements.

For the purpose of this research and to contextualize our research, we defined a six-member family. The Ramos-Castro family is composed of two children, the parents, a grandparent, an uncle and a dog. They are living in a neighborhood on the suburbs of a big city, with all kind of educational and health facilities. The house is fully connected with fixed and mobile telephones as well as high-speed Internet connection in all the rooms (so the communicator can easily connect to a server and perform updates). The two children are Luis and María. Luis is a 14 years old boy. He suffers from Autism Syndrome Disorder (ASD). He is one of the main actors (*Primary Persona*) of the scenario as his communication greatly depends on the technological tools. María (*secondary Persona*) is 12 years old girl with a normal development. She is interested in technology to communicate with family and friends. The parents are Inés and Manuel (*secondary Personas*). Inés, the mother, is 36 years old and she is a teacher in a special education school. She is learning how to use the ICT tools to help her students and Luis. Manuel,

[1] Most of the applications are fixed to general profiles that try to cover all possibilities for a specific group of people and impairment.

Table 1. User goals and requirements for people with impariments

	Child with autism	Elderly people	Hearing impaired
Technical key goal	– To communicate efficiently with people (express feelings, desires, pain, etc.)	– To communicate efficiently	– To communicate efficiently
	– To organize daily activities	– To organize activities	
		– To reinforce memory	
Requirement	– Pictogram application	– Pictogram application	– Sign language
	– Agenda	– Agenda	– Pictograms
	– Synthesized voice application	– Voice recognition and synthesis	– Synthesized voice
		– Memory reinforcement applications	

the father, is 37 years old and he is CEO of a medical electronic devices company. He would like to have a tool that can organize his activities and that can give flexibility to communicate with his family. The grandparent is Beatriz (*Primary Persona*). Beatriz is 70 years old and she has some memory and cognitive problems due to a stroke she suffered when she was 68 years old. She would like a tool that can facilitate the communication with others. The uncle is Jorge (*Primary Persona*) and he is Inés brother. Jorge is 30 years old and he was diagnosed with sensory-neural deafness at the age of 7. He is interested in technology for hearing impaired people.

From these context, we obtained relevant information of what the family might need in terms of a communicator.

2.1 Target User Model

The communicator can be used by all people, but it is mainly focused on people with speech impairments. From the *Persona* information, we extracted the target user goals and requirements, see Table 1. This information is a step for the final design and prototype. Although refinement may be needed, it shows a general view of the expected attributes that the system must fulfill.

To ensure that the system covers people with no-impairments, we included the secondary *Persona* characteristics. The secondary *Persona* for our communicator are: business man, professional, teacher and teenager. The secondary *Persona* information gives an extra degree of freedom to the final design: the system should include an easy way to switch between communication domains

Table 2. User goals and requirements for people with no impairments

	People with no impairment
Technical Key goal	– To communicate efficiently with people with impairment and no impairment.
	– To organize daily activities and help people with impairments to organize theirs
Requirement	– A translator: a two way system that allows communication from two different domains (for example: spoken speech to pictograms, pictograms to synthetic speech, spoken language to subtitles or pictograms, etc.).
	– Agenda

Table 3. User model design

User Model			
*Persona*l information	Type of impairment	Level of communication	Computer skills
Experience level		Device type and familiarity	
Form of interaction (speech, pictogram, etc.)		Socioeconomic inferred characteristics	

(pictograms, speech, text, etc.). Although the secondary *Persona* interests are very broad, we selected the following (Table 2):

According to Table 1 and 2, the user model must include attributes that can ensure that the goals and requirements are covered. Table 3 summarizes these attributes.

Therefore, special care was given to these characteristics while deciding the methods to employ in the design and to ensure the adaptability to different type of people and impairment.

3 User and Context Adaptability

The communicator performance is strongly related to the context in which it is being used [15]. This information is contained in the profile and considers the age, level of speech impairments and the context in which the communicator is being used. Three context directives are then defined: time, space and person.

1. Person: The type of language that people use depends on who the interlocutor is. Then, the probability of a word to appear in a phrase is a function of the interlocutor.
2. Time: The time of the day is also a variable the system should be consider. It defines the topics to address. For example, if it is morning 7:00 AM, it is probable that the user might be having breakfast. Then, the language to be used is related to food.
3. Space: The location also defines the language to be used.

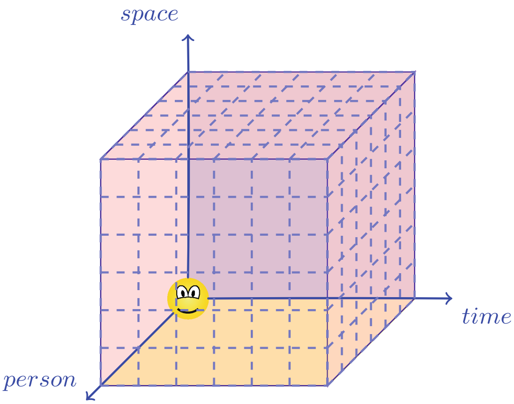

Fig. 1. Context-aware cube

The idea can be viewed in Fig. 1.

In principle it is hard to cover the wide range of characteristics that conform each cube. However, if we define a fine set of elements on the axis, it is possible to create a probabilistic model for each sub-region. For example, in our context, each sub-region will contain a language model adapted to that specific situation (for example, from 7 to 7:30, talking to Mom, at home).

In the next section, we can define how this notion of prediction takes place.

4 Functional Communication Specifications

To establish a functional communication between the system and the user, the communicator needs the information of the user skills to handle the applications. Therefore, the system must adapt for each user abilities to communicate: pre-communicative, communicative, linguistic and conversational. In this paper, we explored mainly from the communicative to the conversational levels, but an extension can be performed to the rest[2]. The user profile will be updated every time the user logs in the system to provide better responses.

The purpose of this research is to establish a functional communication, meaning that the user can clearly share his/her ideas with others via speech or some other aid device is the final goal of this research. In the next subsections, we will detail the methods explored to accomplish this goal considering the broad range of people and that in some cases the users cannot convey a pure functional communication.

4.1 Concept and Prediction

One of the first questions, we may ask is if it is possible to go from non-functional communication to functional communication. A considerable range of

[2] The user skills should cover, at least, to be able to respond to requests with words and be able to understand and focus on pictograms.

children with autism (around 50 %) have a functionally non-verbal communication [12,13]. From this set a huge number uses pictograms or signs.

We are used to establish a structured and linear communication, meaning that for example if we utter the group of words:

I soup ate.

is meaningless. We have to put them in the correct order for others to understand what we really mean. However, for the wide range of impaired people it is difficult to produce a semantically and syntactically correct sentence of this type and even more difficult to organize complex sentences.

As exemplified by Avaz [1] it may be possible to start from every element from the desired phrase and then continue building up the complete sentence. This approach can be used with words, but also with pictograms. Our purpose is then that given any meaningful word, predict the possible words that are related to that word.

For a clear explanation and to exemplify (see Fig. 2), lets consider that the user points the verb "eat". The system suggests the category food with its options: "soup", "juice", "snack". The user selects soups. The missing element is the subject; then, the options might be: "mom", "dad","I".

The communicator outcome is:

I ate soup.

The user finally gets a complete meaningful sentence that others can understand. Although this is a very simple example, the approach can be extended to complex phrases by just suggesting the most probable concept that follows.

To achieve this goal the system uses machine learning tools to train a concept network. The system trains a generic concept network with all the possibilities based on concept net database. The system adapts this model to each of the users, at first using the profile information and then, by adapting along the usage.

Although we are just referring to concepts in their word form, the method can be extended to the pictogram domain.

4.2 Word-Prediction

As in the concept prediction, the system will include a word predictor[3]. The word predictor suggests the most probable word following syntax rules. Although, this might be thought as a linear sequence of words derived from the *part of speech* POS, it is also possible to use the same approach as in concept prediction to give robustness to the system.

The success of this part of the system relies on the *Language Model* and the correct training and *Persona*lization for each situation. We have to keep in mind

[3] Every word has a match or matches within a set of pictograms.

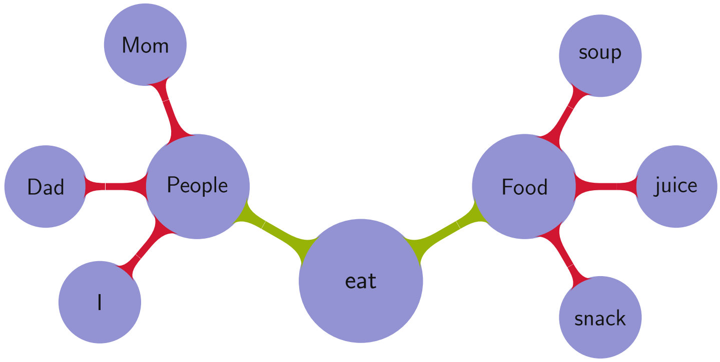

Fig. 2. Conceptual map

that although we can generate a general model that includes all possible situations, a special adaptation must be performed for the given context restrictions (time of the day, person with whom the user is talking to, location).

4.3 Pictogram Prediction

It is known that from the children with some degree of autism [10], more than 50 % are functionally non-verbal [12,13]. Depending on their ability level to communicate, a big set of them prefers pictograms. These children, among other groups, such as elderly people [6,11] with difficulty to understand spoken and written language, rely on *augmentative and alternative communication*, AAC. These methods frequently use pictograms, pictures, sketches, drawings, sign language and videos as their core part.

The system offers a big set of pictograms that covers mainly children necessities, and a combination of both, pictograms and pictures that are useful for elderly people. However, one of the main issues, is how to enhance the fluency of the communication. It is difficult and time consuming to be searching for a particular pictogram among thousand of pictograms. The system uses a prediction algorithm in three domains: the word, the concept domain and the word domain. The word prediction approach follow the POS rules (linear). In the pictogram approach, the initial condition is a random selection of an element of a phrase. Then, the next probable pictogram will also convey the rules of the concept prediction or word domain (time, space and location).

5 Translator

The translator converts the language from one domain to another as shown in Table 4.

The transformation from one domain to the other is not an easy task. The straightforward conversion is speech to written words and vice versa. There is

Table 4. Domain conversion

Input	Output
speech	pictograms
pictograms	synthetic speech
written words and phrases	pictograms
speech	written words and phrases

an exact correspondence between a spoken word and its written representation. However, one of the main challenges is that there is not a one to one match between words and pictograms. Pictograms tend to have several meanings, so the system selects the closest depending on the situation. In here, the system ensures that the words are context dependent and uses synonyms as part of the choices to ensure an efficient communication.

Moreover, to allow a functional communication, the most challenging part is how to deal with POS, verb tenses, conjugation and articles, without increasing the complexity of the system[4]. In this sense, the system flexibility and adaptation are the key points. The system models for each approach (pictograms, speech, concept) are context dependent and are updated and readapted continuously to give the user a set of expected answers. However, it must also give the possibility to select from a huge set of unexpected answers the desired pictogram or word.

6 A Full Example

Figures 3 and 4 include a full example of the capabilities and usage of the communicator.[5] The communicator architecture consists of mainly two parts: a main unit (server) and a mobile device (iPad, tablet, smartphone). All the intensive computation the acoustic, concept and language models are trained and updated in the server. Every profile and sensitive information is stored in the server as well and sends updates to the end users devices. The mobile devices employ a user friendly interface which updates the interface output at every system request.

The first part (Fig. 3) includes a usage scenario for a child with autism with medium level of communication. The system uses concept prediction. The profile is already downloaded in the device and the next step is to wait for a user request. The user, selects the communicator, although some other applications are possible (gallery, agenda, chat, etc.), see Fig. 3(a). The communicator shows a first screen with a set of preferred categories, see Fig. 3(b). Luis selects a

[4] Although there are languages with no gender articles, in Spanish every noun has its corresponding article. Moreover, in languages like English, the verb tenses include extra words or minimum changes, in Spanish the endings change for every tense but also for every person.

[5] The used symbols are work of Sergio Palao for CATEDU (http://catedu.es/arasaac/) that publishes under Creative Common's License [2].

Fig. 3. Luis example of usage (concept prediction approach, the sequence is from left to right and from top to bottom). Luis shows "I finished my homework", starting from the element "homework" and selecting the suggested categories or pictograms until he terminates the phrase.

random pictogram. The system reconfigures the screen choices according to the first selection, see Fig. 3(c). For the concept prediction, the phrase can start at any element and the completion is performed according to the suggested categories. Luis chooses a second pictogram and the screen reconfigures again, see Fig. 3(d). The second selection is a verb which may need conjugation, see Fig. 3(e). The system is prepared to construct correct conjugations and missing words. Finally, the screen reconfigures again to add a subject to the sentence, see Fig. 3(f). The final output could be: pictograms, text or synthetic speech.

Figure 4 includes a usage scenario for an elderly person with a medium level of communication based on word and pictograms. The user employs correct syntactic phrases. The first screen shows the available options. Beatriz selects the communicator application, see Fig. 4(a). The categories are then located at

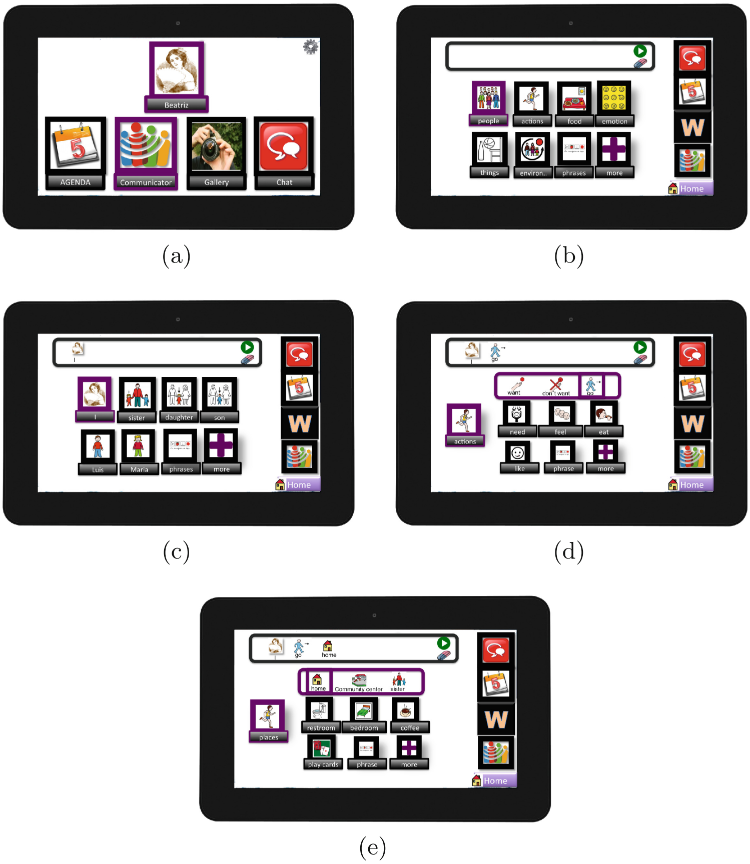

Fig. 4. Beatriz example of usage (word prediction approach, the sequence is from left to right and from top to bottom). In here, Beatriz employs word prediction with pictograms. She writes "I want to go home" with the correct syntax. Note that the categories also exist at word level.

certain positions depending on the most used categories, see Fig. 4(b). She is able to construct syntactically correct phrases. She selects the category: people. The communicator updates the screen choices with the words contained in the people category, see Fig. 4(c). She selects I and the screen reconfigures again with the most probable options. She chooses a verb, which is correctly conjugated by the system, see Fig. 4(d). Finally, she selects the complement of the phrase.

For both systems, the log files are sent to the server; the profiles and models are updated and send back to the device.

7 Discussion

We have detailed the design of a context-aware communicator that will be beneficial for people with impairments of different ages. The accurate definition of the models and the profiles together with the requirements that the system should fulfill impacts the design. Therefore, apart from providing the services as communicator, the system will adapt to each profile and the interface screen will reconfigure according to the user skills and preferences.

Although AAC systems are very popular nowadays, it is still a challenge how to make the systems work not just for a restricted group of people, but for a broader range relying on the performance of the system to specific communication levels. From the technical point of view, the research community has opened branches to find better ways to predict the words and phrases. For example, the simplest prediction is performed with n-grams. However, sophisticated methods such as neural networks might also give more accurate results. Besides, a complementary paradigm for this design is to include the concept modeling and prediction as a tool to enhance the communicator performance. The concept modeling, by itself, or the non-syntactic approaches can also provide flexibility to the system. In this sense, depending on the user skills to communicate the system should adapt the vocabulary. There is still much to do in the adaptation of our methods to work on different contexts.

After this design phase, the next step is to implement all the core algorithms and obtain a prototype of the system operating in a real scenario. The core algorithms, such as model training for all the domains, will perform the computation in a server. The device will connect the server via internet. The interface implementation must run on different platforms (IOS, android, linux, and windows). The server will send the reconfiguration commands to the devices. Although for acquiring the necessary updates a connection to the internet is needed, the last uploaded functionalities will also operate offline.

8 Conclusions

We have shown a design of a multiage system that also covers context-aware requirements. This research shows a communication system as an aid for people with communication impairments. We focused mainly on two target groups: children with autism, and elderly people. However, the system can be used by everybody as an agenda or communicator. It is, then, a context-aware system that offers *Persona*lized services depending on the time of the day, location and interlocutor. Apart from being context-dependent, the communicator transforms the vocabulary elements to different domains that go from simple pictogram structures to complete sentences. Moreover, to facilitate the communication it predicts the next element (word, pictogram or concept) to be selected. We showed examples of how the system would work in a real scenario and made special emphasis on personalized services for people with impairments.

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