User-centric Recommendation Model for AAC based on Multi-criteria Planning

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Abstract—**Recommendation algorithms are useful to fast decision-making in complex scenarios. They are based in grasping knowledge from the user and his environment to personalize applications according to a specific domain. However, the complexity of each domain and the dynamic relations between different items and criteria can be challenging. In Alternative and Augmentative Communication (AAC), assistive technologies have been envisaged to help people with neuro-linguistic disorders in stories construction. Nevertheless, there are still many problems to overcome, related to the algorithms and their application. In this work, we present an original approach based on knowledge domain modelling, user archetypes, learning strategies and multi-criteria planning to assist the user in managing a set of decisions. The proposed algorithm was applied in the context of AAC systems, aimed to help aphasic persons in the construction of coherent and semantically correct stories about their daily activities. The system was validated by an aphasic person and several healthy individuals, in terms of the precision and efficiency of the method, compared with other approaches. The results demonstrate that the presented method has a good precision in the recommendation, allows faster decisions and is well adapted to AAC and can be extended to similar applications.**

Keywords*–*Personalized recommendation; AAC; Multi-criteria; Planning; Hybrid recommender; Phrase Prediction.

I. INTRODUCTION

Communication is an indispensable factor of social behavior. Many people are not able to communicate easily because of different limitations in their intellectual and/or physical abilities. Some disorders, like aphasia, limit the comprehension, production and use of conventional human communication (oral and/or written language) [1].

Augmentative and Alternative Communication (AAC) is a field of assistive technologies which focuses on tools to help people to communicate better. Commonly, computer-based AAC systems are limited to communication boards, with set of symbols or pictograms through navigation menus, for composing messages and synthesizing them [2]. However, computers can in principle do more than this. In fact, current challenges of AAC systems are: first, improving time to generate a message; second, help in keeping a logical semantic and syntactic order, given that people with neurolinguistic disorders can not follow a syntactically correct word order, neither select an exact number and arrangement of symbols [3]; and third, providing support for applications in social environments such as social networks, instant messaging, emails and conversations person to person [4][5][6][7]. Some projects have developed prototypes that attempt to address these challenges. For example, Wiegand and Patel [8], in the SymbolPath project, aimed to enhance the message formulation ease and communication rate by selecting a set of icons, without any specific order, following a path with continuous motion. This system determines the most likely subset of desired icons on the path and rearranges them to form a meaningful sentence. Reiter et al. [9] built a system to support social interaction, which uses external data, knowledge sources, and domain and conversational models, to suggest possible appropriate messages to conversations. Moreover, Ma et al. [10] present a platform for aphasics to find and share information called W2ANE project. It uses an adaptive and adaptable lexical structure, multimodal vocabulary, multimedia content, concepts association and web interfaces.

Particularly, prediction models and recommender systems have been proposed to enhance time generation of messages. Thereby, Wiegand and Patel [11] describe an approach to phrase prediction using semantic grams, which provides relations between message components regardless its word order. Vertanen and Kristensson [12] create a large corpus of fictional AAC messages to suggest phrases by using crowdsourcing and training of language models. Also, Trinh et al. [13] develop a phoneme-based predictive communication system which uses a word auto-completion feature, predicting the word being entered, based on the phoneme prefix and prior words. Finally, Mitchell and Sproat [14] propose a method to predict a whole response given features of previous utterance using an entropy-based measure to find possible phrases on a large corpus of scripted dialogs.

Furthermore, phrase prediction and query expansion methods have been proposed for applications different from AAC. For example, Nandi and Jagadish [15] use a FussyTree structure within a probabilistically driven completion choice model to predict a multi-word phrase. Also, Dong et al. [16] propose an ontology graph based query expansion scheme for biomedical information retrieval, which allows to expand search queries using related specialized concepts. According to Carpintero and Romano [17] those approaches are mainly used in search engines to help users to complete and refine the search queries in order to get better results. Nevertheless, these approaches, regardless of whether or not they are conceived to AAC, are not suitable to withstand the three challenges presented by Wiegand [3] mentioned at the beginning of this introduction. For example, in [11], although there is not an order preferred in input words to guess a sentence, the prediction depends on the size of the training set. In [8], the user does not depend on the selected

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symbols, but the suggested sentences are incoherent. Word and phone-based prediction models [13][15][16] guess terms by assembling letters. This approach requires skills that people with neurolinguistic disorders do not preserve. In addition to the before mentioned, there are requirements of special interest, such as: (1) flexibility in the selection order of different criteria, without affecting the message consistency; (2) richness in the message specificity, (3) focus on social applications and (4) phrase prediction and coherent messages composition.

Accordingly, Mancilla et al. [18] presented a domain ontology focused on AAC systems to manage knowledge related to daily activities. Further, Sastoque et al. [19] proposed an architecture to allow the development of user-centered applications by relating domain representations, intelligent processes and multimedia content. As suggested on [18][19][20] those works are intended to develop a computer-based AAC system to assist the creation of semantic coherent stories about routine activities. To do so, it is fundamental to propose a user-centered recommender model that improves message generation time. Thus, this work presents a novel user-centric recommendation model, for an AAC system, which relates a specific domain knowledge with recommendation techniques, to enhance the communication by allowing the composition of coherent sentences, regardless of the word order and the syntactic structure of the message. The main contribution of this work is the proposal of a recommendation model that improves the time of message generation, by suggesting and predicting the main components of a phrase, based on the user behavior over the time, helping aphasic people to enhance their communication process. Tests were performed with 20 healthy people, measuring user experience and particularly, efficiency in the message composition, compared with traditional communication boards and the word prediction approach, Assistive Express Spanish (AES) [21]. Also, the model was validated through a case study with an aphasic person.

This paper is organized as follows: the next section presents a background for this work. Section III describes the recommendation model with each of its components. Section IV focuses on the case study, including the AAC framework and its modules. Section V explains the tests performed and their results. Finally, the last section corresponds to the conclusion and the proposal for further studies to extend the current work.

II. BACKGROUND

A. Recommender Systems

Recommender Systems (RSs) are software tools and techniques that aim to guide users by providing suggestions in a personalized way to their *"items"* of interest in a large space of possible options. *Items* is the general term used to denote what the system recommends to users [22]. The suggestions are related to various decision-making processes. User preferences can be derived from implicit feedback, i.e., user behavior analysis over time, or explicit feedback, i.e., item rating and supplied information. So, RSs take advantage of this, to calculate recommendations by comparing with predefined rules and previous items rates, (Content-based RSs), or to other users preferences (Collaborative-based RSs) [23]. RSs have been classified in the literature according to the way they perform the recommendation process as follows [22][23]: **Demographic RSs** are based on the idea that people with given demographic characteristics (age, sex, level of education, residence) have similar preferences. **Collaborative RSs** exploit collective intelligence by predicting the user ratings to an item, based in those users with similar preferences. **Content-based RSs** recommend based on the past ratings from the same user to similar items. **Knowledge-based RSs** suggest items based on specific knowledge domain, about how certain item features meet user needs and preferences and how the item is useful for the user. **Community-based RSs** follows the aphorism "Tell me who your friends are, and I will tell you who you are" to suggest items based on the preferences of the user friends. **Utility-based RSs** model the user preferences and items using a utility function to predict the user behavior by matching similar utilities values. **Memory-based RSs** continuously analyze changes over time of the user preferences in past item selections. **Critiquing RSs** act like an artificial salesperson which guide the user in the selection, by asking and recommending specific item features. **Conversational RSs** engage the user in an extended dialog, making suggestions based on the users initial query and refining them based on their feedback. **Hybrid RSs** are based on the combination of the RSs listed above, using their advantages to perform a robust recommendation.

Finally, the techniques and algorithms used by RSs depend on the specific recommendation need. They vary from statistical data analytics to complex artificial intelligence processes. In their survey, Ricci et al. [22] mention different applications and methods, such as: modelling user patterns in tree structures for predicting navigation criteria in the web; representation of web page contents on a cellular automaton using their information and structure to provide recommendations; use of the Longest Common Subsequence algorithm (LCS) in clustering web content to model web pages as a graph; application of the nearest neighbors methodology in collaborative filtering techniques; and construction of two clustering-based models using K-means algorithm and the Term Frequency - Inverse Document Frequency (TF-IDF) representation to calculate weights and domain knowledge to each item of a recommendation model. These methods have been widely used in recommendation apps for movies and music, text classification, prediction of the users web surfing and for improvement of search engines, among others. However, they are not suitable to solve the challenges mentioned above in the introduction. That means, they lack a strategy for item recommendation that consider multidimensional criteria, to provide a good support on scalability and adaptability over the time.

B. Planning

The definition of planning varies according to the context. Commonly is defined as the process of thinking about and organizing the activities required to achieve a desired goal, or as an abstract, explicit deliberation process that chooses and organizes actions by anticipating their expected outcomes [24]. The basic elements of planning are [25]: a **State** that is the current condition of the environment and captures all possible situations that could arise; a **Time** which is the sequence of decisions that must be applied over a temporal length to achieve the goal; an **Action** that is the way to manipulate the

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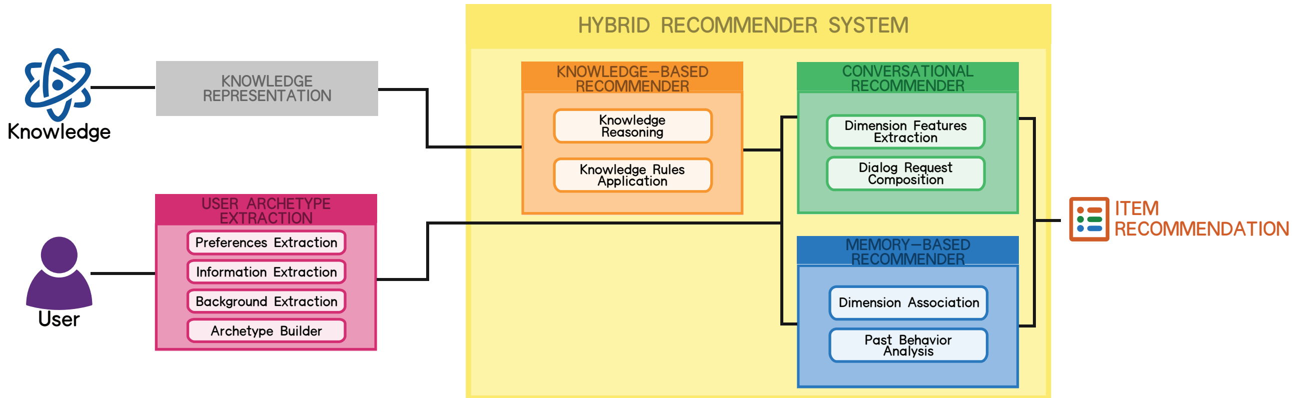

Figure 1. User-centric hybrid recommendation model for AAC based on multi-criteria planning

current state to change it; an **Initial and Target State** which is the starting point and the arriving point to accomplish a goal; a **Plan criterion** which encodes the desired outcome of a plan in terms of the state and actions that are executed; and a **Plan** that imposes a specific strategy or behavior on a decision maker, i.e., the sequence of action to be taken. Planning algorithms have been applied to many problems as pathfinding, motion planning, game solving, biological modelling, robotics and scheduling. A clear example of planning in recommender systems are the popular navigation systems which offer near real-time traffic information and routing. These systems use different features like traffic, user alerts, path planning and time to reach a place in order to recommend and guide a user to its destination.

C. Ontologies

In computer science, ontologies are the formal (machine readable) modelling of knowledge, through the hierarchical representation of relevant entities and their relations. In this sense, an entity refers to anything that can be represented (objects, ideas, processes, etc.) [26]. Gruber [27] defined an ontology as “an explicit specification of a conceptualization”, understanding by conceptualization a consensus of knowledge and not a particular view. Thanks to this, an ontology is meant to be reused, independently of its initial purpose, by keeping some design criteria such as clarity, coherence, extendibility, minimal encoding bias and minimal ontological commitment [27]. Ontology engineering focuses on capturing significant information of a domain and seizing it to a higher abstraction level, keeping clarity and expressiveness. As a result, ontologies need to be formalized maintaining the predicate logic that encloses semantic richness [26].

III. User-Centric Hybrid Recommendation Model

The proposed recommendation model was designed and evaluated for AAC applications where users are assisted to accomplish efficient and effective communication processes by the composition of coherent messages. However, it could be extensible to several contexts with similar conditions. Thus, the proposed recommendation model is based on: (1) knowledge representation of a specific domain, (2) user depiction through an archetype and (3) a hybrid recommendation system made up of knowledge-based, memory-based and conversational RSs, as shown in Figure 1. In contrast to previous works, this model overcomes different issues, such as: support to multiple criteria recommendation; adaptive training over time; coherent relations between criteria of choice, regardless the selection order; and, uses a knowledge representation to add contextual information to the recommendation.

A. User Archetype Extraction

The archetype represents behavior patterns, goals and user needs by obtaining implicit and explicit information. The purpose of the archetype extraction process is to obtain user data related with her preferences, background and information. The *Preferences extraction* component is related to get user particular desires, as for example, displaying modes, font sizes or colors and media settings. The *background extraction* process retrieves information about the behaviour and records of the user, which is used to help in prediction and recommendation processes. *Information extraction* consists in gathering user personal and environmental data, such as relatives names, home address, etc. All this data could be extracted by interviews or surveys and stored in specially designed data structures, through an *archetype builder* process, allowing user representation, tracking his evolution and forecasting his behaviour.

B. Hybrid Recommender System

The *Hybrid Recommender System* consists of three approaches based on Knowledge, Memory and Conversation RSs, which allow: use of a domain knowledge (which in most cases is multi-criteria), bidirectional dialogue with the user, monitoring user behavior, and item suggestion. Each of the recommender systems are described below.

1) Knowledge-based RS: The use of *knowledge representation* enables personalized and tailor made prediction processes. This brings to recommendation the possibility of applying rules and particular information of a specific domain. Thus, the knowledge-based RS uses information and rules of a domain, to relate different items, that will be recommended in a logical and coherent way according to real scenarios. Items with similar features are clustered in groups (known as criteria or dimensions) and connected by relations

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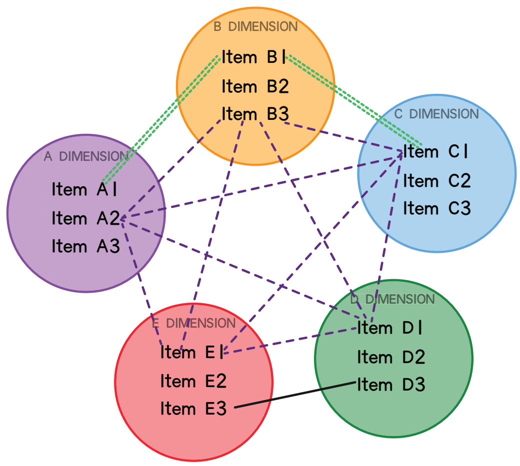

Figure 2. Example of set of rules to manage dimensionality

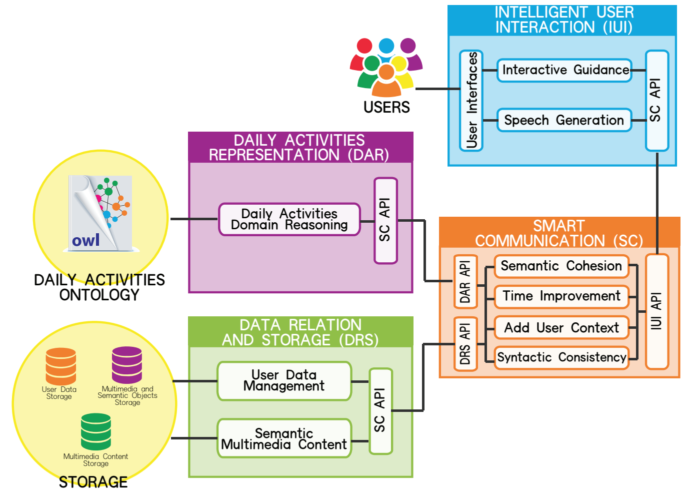

Figure 3. Components of an Augmentative and Alternative Communication System for generating syntactically and semantically coherent messages.

between different dimensions. The features and dimensions extraction depends on the way knowledge is represented, e.g., using formal techniques for ontologies conceptualization to model a specific domain. For example, in [18] the domain is divided into several dimensions (aka classes) representing the daily activities and their associated information, e.g., Place, Activity, Feeling and Person, etc., using its own features, i.e., the criteria of Place has features like address, city and country, among others.

This system consists of two main processes, *knowledge reasoning* which draws inferences and generates new information from relations between criteria; and *knowledge rules application* that organizes this information through a set of predefined steps and guidelines.

2) Conversational RS: In many cases, people have no clarity about which item they want to select from a set of possibilities, needing to be guided in the selection of the items features that satisfy their desires. To allow this, conversational RS uses a dialogue flow with the user, employing the ask and answer method, to guide through the selection process. This system uses domain knowledge to extract the main features of each dimension (*Dimension Features Extraction*) and use them to pose specific questions for refining those items to be recommended (*Dialog Request Composition*).

3) Memory-Based RS: User behavior is essential to establish personalized recommendation processes. For this, memory-based RS tracks users over time and thus suggest the items that best meet their preferences. In this way, the processes, *Dimension Association* and *Past Behaviour Analysis*, use user archetypes in conjunction with artificial intelligence and statistical methods, specifically a decision tree and a probabilistic model, to predict and suggest items. To overcome the problem raised by multi-dimensional criteria, in this work it is proposed a set of rules (exemplified in Figure 2) that permits efficiently manage dimensionality.

1) The final product of a recommendation consist of a set of items, each from a different criterion (dimension).
2) A ***Connection*** is the relation between two items of different dimensions. (Black straight line in Figure 2 - Items E3 and D3)
3) Two items of the same dimension are not connected.
4) A connection defines a statistical weight to mean the strength of a relation.
5) A new connection could be created with the user intervention.
6) A ***Path*** is a set of connections (Pointed double green line in Figure 2 - Items A1, B1 and C1).
7) A Valid Path is one which has all of its items interconnected (Dashed purple line in Fig 2. - Items A2, B3, C1, D1 and E1).
8) ***Valid paths*** are scored by an optimization criteria based on the statistical weight of all their connections.
9) The recommendation is performed by ordering valid paths according with their strength, i.e., global scores.

4) Recommendation Model Operation: The recommendation process follows a planning technique with the next characteristics:

- The goal is to sequentially selecting one or several items among the set of criteria considered. However, it is possible to skip any criteria.
- A state is a situation in which the user has already selected items, from some dimension, and is ready to select a suggested item from an ordered list.
- The initial state occurs when no selection has been made.
- The target state is when all dimensions have been covered.
- An action is the selection of an item by the user.
- The plan criterion is that the user has selected at least one item.

At the initial state, the recommendation system prompts the user for a starting dimension. After this, the following processes are accomplished for each of the remaining dimensions: first, the system asks for the next dimension. Second, the knowledge-based system uses the domain rules

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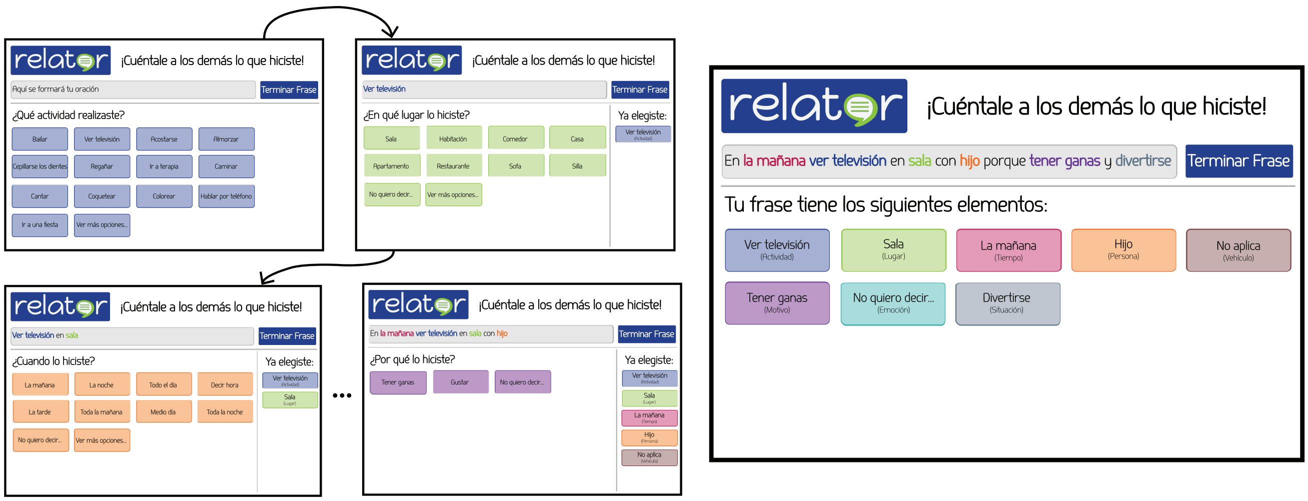

Figure 4. Screenshots of the actions taken to create the sentence *"In the morning to watch T.V. at lounge with son because to have desire and have fun"*.

and inferences to send the items that are related to the other two RSs. Third, the memory-based system carries out the *Dimensional Association* process for retrieving all those items that are in the current valid paths. Fourth, the items that are not in the valid paths, are ordered by using the *Past Behavior Analysis* and the *Knowledge Rules Application*. Fifth, the recommender system suggests a list of items, ordering first those belonging to valid paths and then the remaining ones. Sixth, the user selects an item and the recommender system evolves the archetype by creating or updating user records. The plan is repeated until the goal is achieved. Finally, the system uses all the selected items to perform prediction operations.

IV. Case Study

For the recommendation model validation, a case study based on a previous developed system was carried out, which helps people with language impairments in telling stories related with their daily activities [18]. The system is designed under an ontology-based architecture [19], which consists of the following components (Figure 3): The *Intelligent User Interaction (IUI)* provides interactive assistance for message construction; *Smart Conversation (SC)* drives the creation of semantically coherent messages through recommendation strategies; *Daily Activities Representation (DAR)* focuses on the formalization of daily activities domain through an ontology and its reasoning; and finally, *Data Relation and Storage (DRS)* refers to user data storage related to recommendation process and the management of textual, sound and pictographic representations of concepts.

The recommendation model is related to three components of the proposed AAC system. The *Interactive Guidance* leads the user in the message construction by using questions as ***"What activity did you do?"*** or ***"Who accompanied you to do that activity?"***. Also, the *Daily Activities Domain Reasoning* and *Semantic Cohesion* processes infer information from the ontology, e.g., if the user selects the activity ***watching tv*** the system suggests only ***indoor places***. Finally, *The Time Improvement* process predicts user preferences and suggests the most probable item, i.e., ***every time the user goes to therapy uses a taxi as transportation***.

Moreover, the system is aimed for Spanish speakers and it is supported by the Google App Engine (GAE) platform. The graphic user interfaces provide sequential guidance while communicating, through color schemes that represent each dimension. Also, the system predicts and composes telegraphic sentences with the selected words, relating them by specific connectors, as shown in Figure. 4.

V. Tests and Results

The AAC system and the recommendation model were validated, regarding prediction times and user experience factors. Three tests were performed: computational experiments, verification with healthy people and validation with an aphasic person.

A. Computational Experiments

The accuracy of the recommender model was evaluated by cross-validation and measurements of the Mean Reciprocal Rank (MRR). MRR is the average of the reciprocal ranks of results for a sample of queries, as shown in equation 1, where Q is the number of queries and $rank$ is the item position in the order list.

$$MRR = \frac{1}{Q}\sum_{i=1}^{Q}\frac{1}{rank_i} \quad (1)$$

For this experiment, we used the corpus of daily activities obtained by Sastoque et al. [28]. From this corpus, 400 phrases were extracted and translated into ontology concepts. For cross-validation purposes, 300 sentences were randomly selected for training and 100 for testing. For each sentence, the MRR was calculated by querying for each word in a phrase. The Prediction Rate (PR) was assessed by averaging the MRR over the whole set of test sentences. The experiment was conducted 30 times, the results are shown in Figure 5. The main prediction rate of the recommender system is $PR = 0.7687$ with standard deviation, $\sigma = 0.1372$.

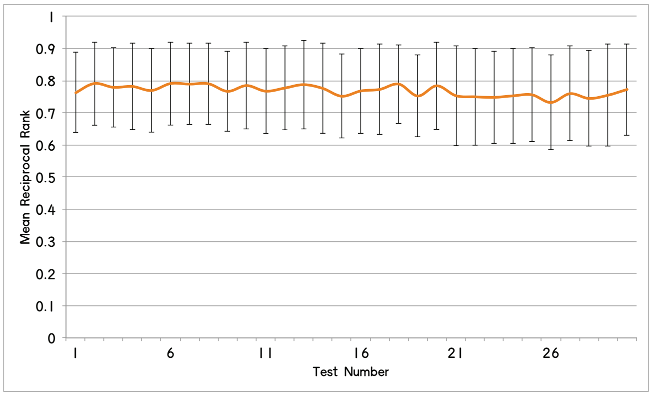

Figure 5. Mean Reciprocal Rank average for each computational experiment.

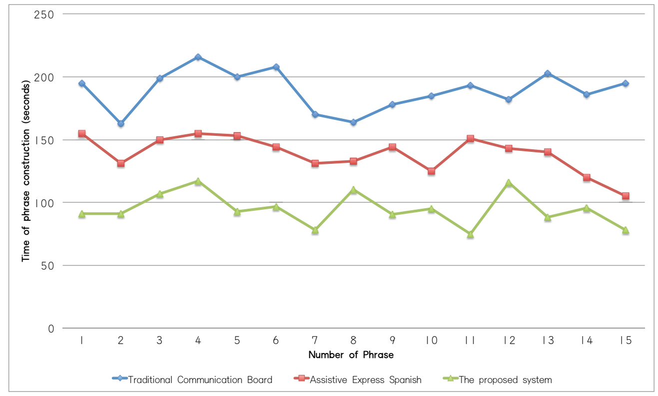

Figure 6. Time taken for healthy people to create phrases with three different AAC systems.

B. Validation with healthy people

Some tests were performed for 20 people with higher education (12 female, 8 male, aged from 21-35, M=27, σ=3.66). All participants were Spanish native speakers without speech, physical, perceptual or intellectual impairments. Also, all participants have standard and similar skills using computers. The study involved the comparison of three different systems to create phrases, using: Traditional Communication Boards (TCB), the AES application [21] (word prediction) and the presented application. Three different tests were performed in which participants were inquired to: (1) transcribe five sentences, (2) create five sentences from a specific set of words and (3) create five sentences freely. The systems order was randomly set. The time spent in creating a sentence was measured, the results are shown in Fig 6. The time averages for each system are: $t_{TCB} = 189s$ - $\sigma = 15.75$, $t_{AES} = 139s$ - $\sigma = 14.43$ and our approach $t = 95s$ with $\sigma = 13.04$.

C. Validation with an aphasic person

A case study was carried out with a 55-year-old woman, who will be called *"Katherine"*, with a neuro-linguistic disorder characterized by Broca's aphasia. Katherine preserves comprehension skills and her biggest communication difficulties are given by the impairment in the production of oral and written language. For the purpose of this study, we relied on the help of a Katherine's relative, who provided important information related to her common practices and routines and gave us useful feedback about the validation process. For over four years, Katherine has used AAC paper books, mime and point out to tell a story. Currently, she takes between 4 to 6 minutes approximately to pass a message about her routine, in an effective way. Before this study, Katherine was trained, during a week, in the use of the proposed system. Setting up was performed with Katherine's most frequently activities.

Katherine's daily activities were monitored during 15 days. At the end of each day, she was asked to use the system to create five sentences corresponding to the most relevant performed activities. Her relative followed the process and, in a few cases, helped her in the message composition. For the sake of validation, the efficacy of the communication process was measured by validating the message content with the Katherine's relative and by asking to 20 receivers if they could understand the messages. The efficiency was estimated by gauging the time taken by Katherine to create an utterance; and, the user experience was evaluated by asking to Katherine her judgment about the application.

The study showed promising results considering that: (1) the communication process could be established between Katherine and other people through the system, the receivers understood on average the 81% of the 75 sentences analyzed. The main issues for the messages understanding were due to their telegraphic structure. (2) The average time used by Katherine was $t = 3.11min$ - $\sigma = 0.63min$, revealing, a significant reduction in time spent on message composition, achieving an effective and efficient communication process. (3) According to her own perception, confirmed by her relative, Katherine enjoyed the experience of using this technology, considering that she could improved her communication process and she was excited about the possibility to use this system at home or to take it with her everywhere. Actually, according to Katherine's review, she said: ***"I liked how I did it, it is great, I can talk better. Of course it is very useful and very good. I want to use it. It is beautiful. I can use it here or there and tell him or her. Thank you"***. The moments that she required help were due to problems related with understanding words, which are typical limitations of her disorder.

VI. Conclusion and Future Work

This paper proposed a novel approach about a user-centric recommendation model for an AAC system, which improves the message generation time by suggesting and predicting the main components of a phrase. In addition, the proposal can be adapted to other applications as it is considered as a general recommendation model. The model relates specific domain knowledge with recommendation techniques to enhance communication process for people with language disorders. The model supports multiple criteria recommendation, adaptive training, coherent relations between criteria, regardless the selection order; and it uses knowledge representation to add contextual information to the recommendation. Results of the verification and validation test demonstrated that the model led to significant improvements in user performance in terms of efficiency and effectiveness. The prediction rate of 76.87% shows that the system has good performance in recommendation processes. However, the PR can be increased over time as the user uses the system. Also, through the verification with healthy people, it is exposed that the proposed AAC system has the potential to provide an effective mean of generating novel messages in less time. In addition, the validation with the aphasic person lets make evident promising results in the improvement of the communication processes of people with language disorders.

From this work, it can be proposed the following studies as future work: first, the validation and verification process showed that the participants had difficulties at the interpretation of the telegraphic style of the messages. Therefore, further studies aims to create a method for language structuring in order to improve syntactic coherency. Second, messages created are very general and lack of specificity in the user's personal information. Hence, it is required to customize the ontology to add specific information for each user. However, this presents a major challenge in terms of the knowledge domain scalability and information coupling. Finally, to improve system usability, it is necessary to conduct user experience studies to design and develop an adapted Graphical User Interface (GUI) and multimedia content (animations, pictures, videos, texts) to represent concepts of the ontology.

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REFERENCES

[1] P. Watzlawick, J. B. Bavelas, and D. D. Jackson, Pragmatics of human communication: A study of interactional patterns, pathologies, and paradoxes. WW Norton and Company, 2011.

[2] S. Baxter, P. Enderby, P. Evans, and S. Judge, "Barriers and facilitators to the use of high-technology augmentative and alternative communication devices: a systematic review and qualitative synthesis," International Journal of Language and Communication Disorders, vol. 47, no. 2, 2012, pp. 115–129.

[3] K. Wiegand, "Semantic disambiguation of non-syntactic and continuous motion text entry for aac," ACM SIGACCESS Accessibility and Computing, no. 105, 2013, pp. 38–43.

[4] J. Light and D. McNaughton, "The changing face of augmentative and alternative communication: Past, present, and future challenges," Augmentative and Alternative Communication, vol. 28, no. 4, 2012, pp. 197–204.

[5] L. Janice and M. David, "Putting people first: Re-thinking the role of technology in augmentative and alternative communication intervention," Augmentative and Alternative Communication, vol. 29, no. 4, 2013, pp. 299–309.

[6] J. Light and D. McNaughton, "Communicative competence for individuals who require augmentative and alternative communication: A new definition for a new era of communication?" Augmentative and Alternative Communication, vol. 30, no. 1, 2014, pp. 1–18.

[7] A. Stent and S. Bangalore, Natural Language Generation in Interactive Systems. Cambridge University Press, 2014.

[8] K. Wiegand and R. Patel, "Symbolpath: a continuous motion overlay module for icon-based assistive communication," in Proceedings of the 14th international ACM SIGACCESS conference on Computers and accessibility. ACM, 2012, pp. 209–210.

[9] E. Reiter, R. Turner, N. Alm, R. Black, M. Dempster, and A. Waller, "Using nlg to help language-impaired users tell stories and participate in social dialogues," in Proceedings of the 12th European Workshop on Natural Language Generation. Association for Computational Linguistics, 2009, pp. 1–8.

[10] X. Ma, S. Nikolova, and P. R. Cook, "W2ane: when words are not enough: online multimedia language assistant for people with aphasia," in Proceedings of the 17th ACM international conference on Multimedia. ACM, 2009, pp. 749–752.

[11] K. Wiegand and R. Patel, "Non-syntactic word prediction for aac," in Proceedings of the Third Workshop on Speech and Language Processing for Assistive Technologies. Association for Computational Linguistics, 2012, pp. 28–36.

[12] K. Vertanen and P. O. Kristensson, "The imagination of crowds: conversational aac language modeling using crowdsourcing and large data sources," in Proceedings of the Conference on Empirical Methods in Natural Language Processing. Association for Computational Linguistics, 2011, pp. 700–711.

[13] H. Trinh, A. Waller, K. Vertanen, P. O. Kristensson, and V. L. Hanson, "iscan: a phoneme-based predictive communication aid for nonspeaking individuals," in Proceedings of the 14th international ACM SIGACCESS conference on Computers and accessibility. ACM, 2012, pp. 57–64.

[14] M. Mitchell and R. Sproat, "Discourse-based modeling for aac," in Proceedings of the Third Workshop on Speech and Language Processing for Assistive Technologies. Association for Computational Linguistics, 2012, pp. 9–18.

[15] A. Nandi and H. Jagadish, "Effective phrase prediction," in Proceedings of the 33rd international conference on Very large data bases. VLDB Endowment, 2007, pp. 219–230.

[16] L. Dong, P. K. Srimani, and J. Z. Wang, "Ontology graph based query expansion for biomedical information retrieval," in Bioinformatics and Biomedicine (BIBM), 2011 IEEE International Conference on. IEEE, 2011, pp. 488–493.

[17] C. Carpineto and G. Romano, "A survey of automatic query expansion in information retrieval," ACM Computing Surveys (CSUR), vol. 44, no. 1, 2012, p. 1.

[18] D. Mancilla, S. Sastoque, J. Mendoza, and M. Iregui, "Conceptualizing a daily activities ontology for an augmentative and alternative communication system," in 5th Latin American Conference on Networked and Electronic Media (LACNEM-2013). Universidad Nacional de Colombia - Sede Manizales, 2013.

[19] S. Sastoque, C. Narváez, and M. Iregui, "Ontological knowledge based model for personalizing multimedia applications," Ventana Informática, no. 30, 2014, pp. 175–191.

[20] S. Sastoque, D. Mancilla, C. Narváez, and M. Iregui, "Case study to validate the knowledge representation in user-centric web applications through multimedia enriched content," in 8th research meeting. Universidad Militar Nueva Granada, 2013.

[21] "Assistive Express Spanish," https://itunes.apple.com/au/app/assistive-express-spanish/id816122415?mt=8, 2010, [Online; accessed June-2014].

[22] F. Ricci, L. Rokach, and B. Shapira, Introduction to recommender systems handbook. Springer, 2011.

[23] J. Bobadilla, F. Ortega, A. Hernando, and A. Gutiérrez, "Recommender systems survey," Knowledge-Based Systems, vol. 46, 2013, pp. 109–132.

[24] M. Ghallab, D. Nau, and P. Traverso, Automated planning: theory and practice. Elsevier, 2004.

[25] S. M. LaValle, Planning algorithms. Cambridge university press, 2006.

[26] S. Staab and R. Studer, Handbook on ontologies. Springer, 2010.

[27] T. R. Gruber, "Toward principles for the design of ontologies used for knowledge sharing?" International journal of human-computer studies, vol. 43, no. 5, 1995, pp. 907–928.

[28] S. Sastoque, D. Mancilla, and M. Iregui, "A bag of words based method for information extraction in simple texts," in 3rd International Multimedia Congress. Universidad Militar Nueva Granada, 2013.