Using Context History and Location in Context-aware AAC Systems for Speech-language Impairments

Md. Sazzad Hossain, Masato Takanokura, Hiromi Sakai and Hideki Katagiri

Abstract— **People with speech and language disabilities typically use picture-based communication tools to accomplish their daily duties. Traditionally, augmentative and alternative communication (AAC) methods (e.g., gestures and communication boards) have been utilized for communication. Traditional systems, however, are inconvenient for impaired users, because it is difficult to find specific items from a huge symbol dictionary. Thus, most systems only allow users to produce a few words or phrases. Users cannot express a large variety of statements to achieve a desired goal. However, with these systems, vocabularies can conveniently be seeded from large database by context-aware mechanisms. Additionally, most context-aware AAC systems use location as a context. In this paper, we present a context-aware AAC system that uses not only location context, but also context history, with a dynamic user interface. We include vocabulary as a factor of the context history by leveraging time, week, and frequency to prioritize AAC categories and items. Moreover, we attach a variety of complete sentences to each AAC item to assist impaired users during their daily interactions.**

Index Terms—**Augmentative and Alternative Communication, Context history, Context-aware, Global Positioning System**

I. Introduction

Working with people having speech and language disorders can be a great challenge for researchers. AAC communication tools are among the best solutions for assisting communications with speech-impaired individuals. AAC systems include pictures and symbols, leveraging electronic devices to adapt voice output communication aids, methods and techniques. AAC systems can help users communicate by providing audio or visual prompts to support transmitting words or phrases. The device may also speak the word or phrase via synthesized speech [1]. Current technologies provide excellent means of communication and interaction for people with speech difficulties. Several computer applications and many portable devices are available for such communication support.

Many electronic AAC systems permit a user to pre-defined words and phrases that would otherwise be difficult for the user to produce instantly. Usually, electronic AAC systems have a high initial setup cost, because of the specialized hardware, software, and time required. However, the growing ubiquity of recent mobile devices and applications has led to widespread adoption of AAC software on readily available mobile devices, tablets, and PCs [2]. Proloquo2Go is a common AAC system based on a folder structure, each displaying a box with images and symbols, or providing a text typing input box [3]. A selected symbol can be spoken with natural sounds or via a machine voice. The main problem of traditional AAC systems is the difficulty finding specific items from the huge symbol dictionary. This problem can be solved by using a context-aware mechanism in the AAC system.

Context-awareness, as a study, was first introduced by Schilit and Theimer, who enabled mobile applications to discover and react to changes in users' environments [4]. For context, they included user location, identities of nearby people, and objects. Brown et al. added time-of-day, season, and temperature to the dictionary [5]. Dey and Abowd simplified and generalized the definition of context and context-awareness as any information that can be used to characterize the situation of an entity. An entity can be a person, place, or object considered relevant to the interaction between a user and an application, including the user and applications themselves [6]. If a piece of information can be used to characterize the user's situation during an interaction, then it is considered context. The researchers proposed that the context can be categorized into four categories: identity, location, status, and time. Identity includes the unique identifier of each entity. Location includes the entity's position. Status includes the intrinsic properties of the entity, such as room temperature, brightness in the car, etc. Status refers to the activity. Finally, time is used to define the situation temporally. Moreover, context-aware technology has the capability to sense, detect, and ascertain the environment around users [7]. Context-aware technology plays an important role in the latest mobile devices, which are equipped with a rich set of powerful small, built-in sensors, such as cameras, accelerometers, GPS receivers, magnetic compasses, gyroscopes, ambient light sensors, proximity sensors, multitouch panels, microphones and WiFi radios [8]. These sensors are capable measuring various aspects of the physical world surrounding the mobile device and user. Human beings are engaged in a vast variety of activities

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within very diverse contexts, incorporating the use of mobile phones. Relevant contextual data is acquired through built-in sensors and can be extracted with a smartphone application.

Context-aware applications have become potentially capable of using environmental information to provide real-time and autonomous adaptation for the user and his context [9]. Yan and Selkar implemented an office assistant, in which an agent interacts with visitors at an office door and manages the office manager's schedule [10]. They combined the user's activity, light level, pressure, and proximity of other people as the active context. ComMotion is a reminder application that takes advantage of both location and time context. Reminder messages are created and tagged with a location. When the intended recipient arrives, a message is delivered via voice synthesis without requiring the user to handle the device or read the message on the screen [11].

Only a few research projects have explored the potential of context-aware computing for language impairment. One such system is TalkAbout, which runs on a mobile device and provides context-aware prompting [12]. Converser is an AAC tool that recognized speech produced with a conversation partner, propagating an AAC menu with contextually appropriate responses [13]. Friend Forecaster used location information to generate a list of friends' names and conversation topics [14]. Unfortunately, the above systems mainly leveraged the location context. Recently, Park et al. developed a context-aware AAC application for smartphones that used location, date, and time as active contexts [15]. However, they rearranged items found near the device into a single category. From the above examples, we note that few contexts, other than location, have been used in actual applications. Thus, the history context is generally believed to be useful, but it is rarely used. Furthermore, the above systems provide limited general expressions, regardless of the user's personal needs. To address these limitations, studies have been conducted in the field of psychology and linguistics [1]. However, a context-aware smartphone application is not yet available to assist language and speech-impaired individuals for practical use. Therefore, it is necessary to manage the history context in the AAC application and to provide more general expressions with each AAC item, so that the user can use them for communication.

In light of the above AAC application problems, this paper presents a context-aware AAC system with a simple dynamic user interface, providing more expression for each AAC item to enhance communication. Context-aware personalized services are achieved by taking advantage of the sensing and wireless communication capabilities of the smartphone. In the proposed context-aware method, we not only leverage location as a context, but we also use the history context to accurately express the user's situation. The changing location context is used to filter and update AAC categories. Context history is used to rearrange AAC categories and items. We consider time information, week information, and frequency as context history. We also include a type of vocabulary and context history for prioritizing AAC categories and items.

II. Proposed Design Consideration

Consider the following communication setting. An individual with a speech impairment (e.g., aphasia) uses a smartphone-based AAC application, but cannot find a symbol representing a specific information need. To address the problems of existing systems and to provide the relevant picture or symbol, we propose a smartphone-based AAC application that uses context-aware computing technology. In this paper, we cover the following design issues, which differentiate the proposed AAC system from existing systems.

1) We use context history and vocabulary type to rearrange usage data.

2) We include a variety of complete sentences, used in daily conversation, with each AAC item.

3) The dynamic suggestion capability instantly notifies the impaired person about rearranged AAC items.

A. Reasons to choose context history and vocabulary type

Context-aware systems store data, information, and knowledge that have different relationships, formats, and abstraction levels of contextual bases. The stored histories of user activities constitute the history context. It includes the storage of existing contextual data at different points of time. Furthermore, context-aware systems collect history context data via sensors over time to offer dynamic services. History context is comprised of huge amounts of data about location, time-of-day, season, temperature, lighting level, nearby objects, etc. To quickly provide appropriate service to users, context-aware systems should manage a variety and numerous amounts of context.

Existing context-aware AAC systems on mobile devices and PCs can determine the user's current location, task, or conversational partner, and highlight conversational options relevant to the user's context, such as ordering coffee at a café, or discussing tennis with a fellow sports fan [12-15]. To support context-awareness, a user is presented with conversational options per their current situation. Then, when they select a topic, they are offered relevant discussion points [12]. However, we do not account for persons selecting incorrect topics. This should be an automatic process. Furthermore, the user should get only relevant information about topics per the current context without personally considering previous situations or past contexts. Consider a situation where a person with a language disability is no longer able to communicate with other people. In this case, the history contexts can be an essential tool in communicating with others about needs, particularly when paramedics may be required. Past contextual information can assist users in making correct decisions during an emergency. Based on the contexts and its changes, the context-aware system can trigger designated services to provide appropriate adaptations that serve user needs. Moreover, the history context can be a useful tool for monitoring AAC users, which is ignored by extant systems. Therefore, it is appropriate for the impaired person to get relevant information automatically per their current location and history context.

Furthermore, an impaired person uses limited vocabulary and expressions in their daily conversations. A communication aid can be anything that makes communicating quicker and easier, depending on individual needs. In any case, we need new ideas to bring alternative methods of communicating into everyday situations. However, existing AAC applications do not rearrange the AAC items. Our proposed design rearranges categories, as well as AAC

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items.

The type of vocabulary is another attribute used to rearrange the user's past data and context history. Vocabulary can be sorted by the expected usage frequency during daily conversation. According to the usage frequency, the vocabulary type can be classified as frequently visited, occasionally visited and storage. Frequently visited words are, by definition, used frequently and occasionally visited words are used occasionally in the daily conversation. Storage words are rarely used. Using the vocabulary type, impaired users can easily identify which items are most frequently used.

B. *Reason to include complete sentences*

Most existing AAC systems do not ensure sentence completeness. Therefore, we include a variety of complete sentences with each AAC item to be used for daily conversation. In this paper, we include three types of sentences: positive, negative, and question, which can be easily used by someone with speech impairement. Sample data is shown in Table I.

TABLE I
SAMPLE DATA FOR SENTENCES AND AAC ITEMS

Item_name	**Exp_type**	**Expression**
Burger	Positive	I would like to eat burger.
	Negative	I would not like to eat burger.
	Question	Would you like to eat burger?
Pizza	Positive	I would like to eat pizza.
	Negative	I would not like to eat pizza.
	Question	Would you like to eat pizza?

C. *Reason to choose dynamic suggestion for AAC items*

People with speech impairments go everywhere with their smartphone. Thus, a new user interface is offered to dynamically rearrange AAC items per the user's situation. This is called "dynamic suggestion" for AAC items. Using dynamic suggestion, searching will be reduced, potentially reducing the need for direct user instructions and actions. A screenshot of a sample dynamic user interface is shown in Fig. 1.

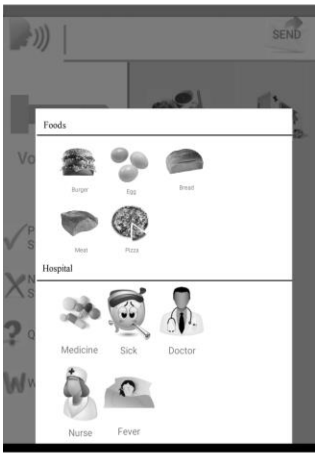

Fig. 1. Proposed context-aware item suggestion

III. PROPOSED CONTEXT-AWARE SYSTEM

Our goal is to design a context-aware smartphone application using location and context history to intelligently manage usage data. We access usage data via smartphone sensors, such as a clock for time, a calendar for the date, and usage frequency for multi-touch.

A. *Location acquisition*

The starting point of the context-aware mechanism is finding points of interest (POI) based on the current device location using GPS. To acquire desired POIs, we determine the current device location and consider only AAC categories found within a set radius from the current device. A location tracking system view is shown in Fig. 2. In this figure, the device tracks four POIs related to the current location.

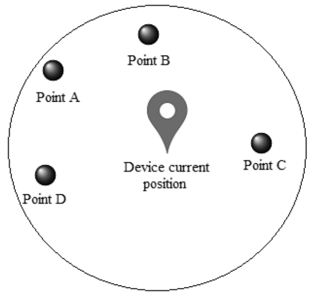

Fig. 2. Proposed location tracking system

B. *Proposed AAC categories and items rearranging method*

The impaired user will benefit from receiving a sequence of AAC categories as well as AAC items, per the usage during daily conversation. The flow diagram of the rearranging mechanism is shown in Fig. 3. The shaded part is responsible for rearranging the filtered AAC categories and corresponding AAC items per the context history. We utilize the context history in an efficient way by separating the present-day time into four timeslots. Morning spans from 9:01 to 12:00; afternoon spans from 12:01 to 17:00; evening spans from 17:01 to 21:00; and night spans from 21:01 to 24:00. Per the frequency of the timeslot, AAC categories and items are rearranged by context history, as shown in Table II.

TABLE II
DIFFERENT TYPES OF CONTEXT HISTORY FOR REARRANGING USAGE DATA

Context history	**Rearrange categories and items**
Frequencies of present *timeslot*	According to the frequency of *timeslot*
Frequencies of present timeslot of current *week*	According to the frequency of *current week timeslot*
Frequencies of current *day*	According to the frequency of *current day*
Frequencies of current *week*	According to the frequency of *current week*

Consider an impaired person situated near a restaurant in the morning. It will be more helpful to him if he found the AAC symbols of categories and items arranged by his current location and previous usage. In this case, the sequence of morning food items is ordered by morning frequency. Considering the above scenario, we need to discuss how to properly rearranging the AAC items. In this case, we consider the total week's frequency of current time slot. If the frequencies consist of the same priorities, then we consider the total frequency of the current day. If the total frequencies of a time slot are same, we consider the total frequency of the current week. A sample data table for AAC item frequency per time and week is shown in Table III. M_Time, A_Time, E_Time, and N_Time represent frequencies of different time slots during the current day. M_Week, A_Week, E_Week, and N_Week represent frequencies of different time slots during the current week (see Table IV).

Finally, if the context history fails to rearrange the usage data, then the categories and corresponding AAC items are rearranged by vocabulary type and total frequencies. During the insertion of a new AAC item, we set the vocabulary type as frequently visited, occasionally visited or storage according to the expected usage of that item in daily conversation.

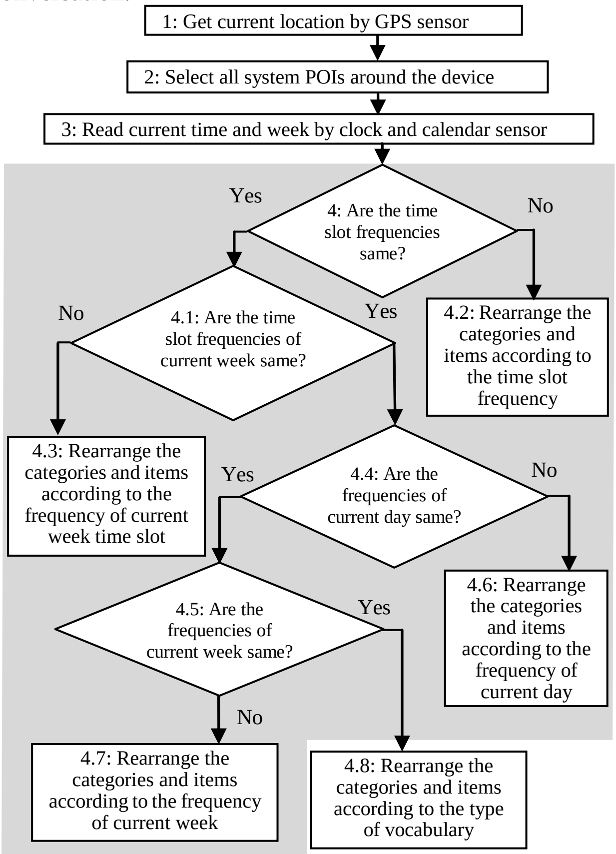

Fig. 3. Proposed flow diagram to rearrange usage data by context history and vocabulary type

TABLE III
SAMPLE DATA FOR TIME AND AAC ITEMS

Item_name	M_Time	A_Time	E_Time	N_Time
Bread	2	1	1	1
Burger	1	2	1	1
Egg	2	1	1	1
Meat	0	2	1	1
Pizza	0	2	0	1
Doctor	2	0	4	0
Nurse	1	0	4	0
Sick	2	1	3	1
Medicine	3	3	0	3
Fever	2	0	0	2

TABLE IV
SAMPLE DATA FOR WEEK AND AAC ITEMS

Item_name	M_Week	A_Week	E_Week	N_Week
Bread	14	6	1	4
Burger	12	8	3	1
Egg	5	4	1	4
Meat	1	11	3	3
Pizza	9	12	6	1
Doctor	2	3	4	0
Nurse	4	4	4	0
Sick	2	1	1	1
Medicine	15	3	2	3
Fever	2	0	1	2

C. *Proposed dynamic interface for categories and dynamic suggestions for items*

The dynamic interface is redrawn with AAC categories, which are rearranged by our proposed context-aware mechanism. The proposed design filters and rearranges a few AAC categories from the huge symbol dictionary using current location and usage contexts. Therefore, the impaired user can easily identify previously used AAC items. Moreover, the dynamic suggestion of the rearranged AAC items with their corresponding categories, are drawn on a new screen. This reduces extra instructions and manual actions. Assume the device locates two POIs near the current location, such as a hospital and a restaurant. After rearranging categories, the dynamic interface redraws the new category list, as shown in Fig. 4. Alternatively, the dynamic suggestion and rearranged AAC items of each category are drawn in another interface shown in Fig. 2. Impaired users easily notice their used AAC items via dynamic suggestion.

Fig. 4. Proposed context-aware layout of categories

D. *Comparison with existing systems*

We designed this system with a simple user interface so that the user can easily operate and navigate the system. The hierarchy levels to access an item from categories are not more than two levels. Therefore, the user can easily locate desired items. It is possible to save and modify different types of expressions which will help the user to communicate with others. The existing systems work only on a single category that is found near the device, whereas we consider more categories. Moreover, we did not use an online POI database for location attributes or Map application to obtain the location. Instead, we used the Google Place API which directly works on categories. Furthermore, the existing system used an online POI database for a specific area, whereas the proposed system uses global GPS so that it can be used anywhere. A comparison of context information is shown in Table V and a technical comparison for communication with existing systems is shown in Table VI.

TABLE V
CONTEXT INFORMATION OF PROPOSED VS, EXISTING SYSTEMS

AAC systems	Context History					Others	
	Location	Frequency	Time	Day	Week	Vocabulary Type	Conversation partner
TalkAbout [12]	✓						✓
TryTalk [15]	✓	✓	✓		✓		
Proposed AAC system	✓	✓	✓	✓	✓	✓	

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TABLE VI
TECHNICAL AND CONVERSATIONAL COMPARISON WITH OTHER SYSTEMS

AAC systems	Location retrieval technique	Is location information retrieval simple?	Is POI database required?	How many categories are considered in adaptable interface?	Possible to get context-aware suggestion for communication?	Which data is saved for communication?
TalkAbout [12]	Switch Map application to get location			1		Conversation scenario can be saved for each AAC item
TryTalk [15]	POI database to retrieve location attributes		✓	1		Only one expression can be saved for each AAC item
Proposed AAC system	Google Place API to get location information	✓		1 or more	✓	Different expressions can be saved for each AAC item

IV. USABILITY TESTING

This paper demonstrates communication methods that help impaired individuals. Users may adapt the system to their specific need or impairment, based on their communication goals. Users can benefit from concrete and visual information regarding daily events. Context-based adaptation can reduce the amount of search needed to find commonly used words and phrases.

A. *Testing Scenario*

To test and demonstrate the usability and effectiveness of our system, we create a common sample scenario. See Table VII. In this scenario, a user and another person discuss lunch near a restaurant. The user sees only few categories, including food and context-aware suggestions, on the smartphone screen. The user only needs to learn how to navigate the desired item and choose the desired expression from the AAC system.

TABLE VII
CONVERSATION BETWEEN A USER AND ANOTHER PERSON

Users	**Expression**
Other	What do you want to eat?
User	Burger
User	Would you like to eat burger?
Other	No
Other	I would like to eat pizza.
User	I would not like to eat pizza.
User	Thank you

B. *Testing with real participants*

Usability testing is a method of testing a product while considering the target users to find existing usability problems. A usability study aid in the removal of design issues should improve the product's end user experience. For usability testing, users are given tasks to perform while using the product, and are observed to detect if they have any issue performing a task. Depending on the observations, the usability team suggests designing solutions. The application should be tested by real users, because they tend to ignore the internal details of the system. Thus, we test this system on four adult research participants with aphasia (3 male, 1 female). The participants have motor impairment because of their strokes. This fact makes it difficult for them to navigate using a touch screen. Participants attend therapy session once per week for approximately 4h/day. The session is taught by trained facilitators, covering such topics as reading, news, music, weather, cooking, maps, travel, etc. They also meet with a professional speech language therapist. During these meetings, they practice different daily conversations. We divide the participants into two groups, based on their condition. The first group can speak, but cannot pronounce precise words. The other group can speak, and can write words. Therefore, we focus on the second group for evaluation. One participant is a 52 years old male. He presents with right-sided hemiparesis and severe expressive aphasia because of a stroke. He can understand conversations and can express himself by writing a note. We demonstrated to him how to choose items via category and voice. He operates and navigates the AAC application properly, which is judged acceptable.

C. *Accuracy of the proposed system*

The accuracy result of the proposed context-aware AAC system is shown in Fig. 5. Voice control and text-to-speech services have the highest accuracy. The automatic suggestion by the system has lowest accuracy. The location accuracy of this system is approximately 95 %. Sometimes the weak GPS signal unwanted location information. The navigation rate of participant is approximately 80 %. To improve the accuracy on navigation, we need to improve categories, so that the participant can quickly navigate and identify their desired category and get a proper suggestion. To provide proper suggestions, we need further considerations. For example, we need to enrich the image vocabulary. This is a user-centric application. Thus, we should consider all the suggestions that come from impaired users, family members, and speech therapists.

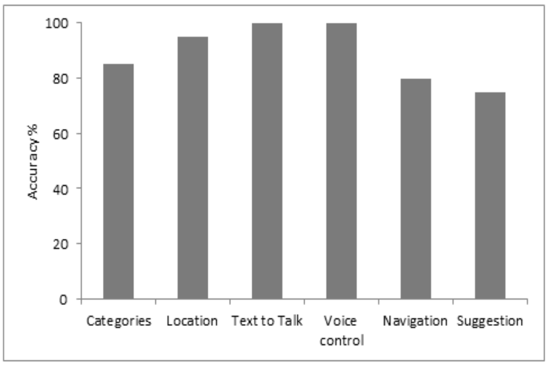

Fig. 5. Accuracy of proposed context-aware AAC system

V. CONCLUSION

This paper presented a context-aware AAC system that provides automatic suggestions to help people with speech-language disabilities. Location and context history was used to make this system context-aware. Location context was used to filter AAC categories. Moreover, context history and type of vocabulary were used for rearranging AAC categories and AAC items. Each AAC item contains expressions that can be used during daily conversation. People with speech disabilities currently use traditional AAC devices and mobile applications to enhance their communication. They will benefit more when they use the proposed context-aware based AAC system. However, the current version is tested with only a few aphasic people. In the future, we will test this application with more participants who have language difficulties. The current version of this system considers only two contextual factors: the user's location and context history. Future versions may incorporate additional contextual factors, such as physical activities and facial expressions to further improve the adaptability of the user interface.

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