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HOSPISIGN: AN INTERACTIVE SIGN LANGUAGE PLATFORM FOR HEARING IMPAIRED

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Abstract

Sign language is the natural medium of communication for the Deaf community. In this study, we have developed an interactive communication interface for hospitals, HospiSign, using computer vision based sign language recognition methods. The objective of this paper is to review sign language based Human-Computer Interaction applications and to introduce HospiSign in this context. HospiSign is designed to meet deaf people at the information desk of a hospital and to assist them in their visit. The interface guides the deaf visitors to answer certain questions and express intention of their visit, in sign language, without the need of a translator. The system consists of a computer, a touch display to visualize the interface, and Microsoft Kinect v2 sensor to capture the users' sign responses. HospiSign recognizes isolated signs in a structured activity diagram using Dynamic Time Warping based classifiers. In order to evaluate the developed interface, we performed usability tests and deduced that the system was able to assist its users in real time with high accuracy.

***Keywords**: Sign Language Recognition (SLR), Turkish Sign Language (TID), Multimodal User Interface, Microsoft Kinect v2, Assistive Technology, Hospital.*

1. INTRODUCTION

Many hearing-impaired people cannot express themselves clearly in public since they are unable to use speech as a medium of communication, yet a large part of the hearing population cannot communicate with the deaf because they do not know sign language. In some cases, this challenge may be solved either with the use of an interpreter or through written material. However, many hearing-impaired people do not know how to read and write. In case of emergencies where the time is extremely valuable, such as when a Deaf person visiting a hospital with an urgent issue, the inability to communicate becomes a more pressing problem. In this paper, we present the HospiSign system, an interactive sign language platform that is designed to assist hearing-impaired in a hospital environment, which recognizes hand gestures in real-time to interpret Turkish Sign Language (TID) by using Dynamic Time Warping (DTW) based classifiers.

HospiSign solves the communication problem between a Deaf patient and a doctor using an interactive platform. By asking questions as sign videos and suggesting possible answers in a screen, the system helps Deaf users to explain their problems. With a guided interaction tree scheme, the system only looks for the possible answers in each level (step), instead of trying to recognize from all the signs in the dataset.At the end of the interaction, the system prints out a summary of the interaction and the users are guided to take this print out with their ID to the information desk, where they can be assisted according to their needs.

The rest of the paper is structured as following: In Section II sign language based Human-Computer Interaction (HCI) systems are reviewed. Then the HospiSign system is introduced in Section III. The results and the analysis of usability tests and classification experiments are shared in Section IV. Finally, the performance of the system and future work are discussed in Section V.

2. RELATED WORKS

With the development of machine learning and computer visionalgorithms and the availability of different sign languagedatabases, there has been an increasing number of studies in Sign Language Recognition (SLR). A fundamental problem in sign language research is that many signs are multi-modal: many signals are sent simultaneously to express something through hand and body movements, and therefore it is hard to spot and model these modalities in consecutive frames [1].

Among many methods, Hidden Markov Models (HMMs) [2] and Dynamic Time Warping (DTW) [3] based methods are still the most popular machine learning techniques to solve the modeling problem.

Both of these methods are widely used in applications ranging from speech recognition to robot tracking. Starner and Pentland [4] introduced a real-time HMM-based system that can recognize American Sign Language phrases in sentence-level without any explicit model of the fingers. In a signer-dependent platform, Grobel and Assan [5] achieved a recognition rate of 94% on an isolated sign database that included 262 signs of the Sign Language of the Netherlands.Other approaches, such as Parallel Hidden Markov Models (PaHMMs) [6] and HMM-based threshold model [7], are also used in gesture and sign language recognition systems. Chai et al. [8] used DTW based classifiers to develop a translation system similar to the HospiSign, as it interprets Chinese Sign Language to spoken language and vice versa. In more recent studies, Pitsikalis and Theodorakis et al. [9], [10] used DTWto match subunits in Greek Sign Language for recognition purposes.

Prior to the release of consumer depth cameras, such as the Microsoft Kinect sensor [11], many computer vision researches had used gloves (such as DataGlove, CyberGlove), embedded accelerometers, multiple sensors, and web/stereo-cameras to capture a user’s hand and body movements for sign language recognition [12]. However, the Kinect sensor provides color image, depth map, and real-time human pose information [13], by which it

diminishes the dependency to such variety of sensors.

Table 1. A Survey of Sign Language Recognition Applications. ML: Multi-Lingual, CA: Community-Aid, TR: Translation & Recognition, E: Education, WS: Wearable Sensors, CC: Color Camera, CG: Color Gloves.

Study	Year	Language	Goal	Sensor(s)	Method
TESSA [14], [15]	2002	BSL	CA	WS	FSN
SignTutor [16]	2009	ASL	E	CG& CC	HMM
CopyCat [17]	2010	ASL	E	WS	HMM
SMARTSign [18]	2011	ASL	E	N/A	N/A
Hrùz et al. [19]	2011	ML	TR	CC	k-NN, HMM
CopyCat [20]	2011	ASL	E	WS& Kinect	HMM
Dicta-Sign [21]	2012	ML	TR	Kinect	N/A
Karpov et al. [22]	2013	ML	TR	N/A	N/A
VisualComm [23]	2013	CSL	TR	Kinect	DTW
Kinect-Sign [8]	2014	LGP	E	Kinect	N/A
LSESpeak [24]	2014	LSE	CA	Kinect	N/A
HospiSign (Ours)	2015	TID	CA	Kinect v2	DTW

In the rest of this section, we are going to discuss the methods and applications in sign language research in three categories: educational tools, translation and recognition systems, and community-aid applications. A summary of these sign language recognition applications can be seen in Table 1.

2.1. Educational Tools

Recently there have been studies on teaching sign language to non-native signers, including non-hearing-impaired people. Aran et al. have developed a sign language tutoring platform, SignTutor [16], which aims to teach sign language through practice. Using an interactive 3D animated avatar, the SignTutor enables its users to learn sign language by watching new signs and validate their performances through visual feedback. The system uses a left-to-right continuous HMM classifier for verification, and

gives feedback on user's performance in terms of manual (handshape, motion and location, etc.), and non-manual (facial expressions and body movements) features for a selected sign. The performance of the SignTutoris evaluated on a dataset of 19 signs from American SignLanguage (ASL) and reports the results for signer-depended and signer-independent scenarios in a real-life setting.

On a database of 1,204 signed phrase samples collected from 11 deaf children playing the CopyCat, which is a gesture-based educational game for deaf children, Zafrulla et al. [17] have performed real-time ASL phrase verification using HMMs with a rejection threshold. During the game, a child is required to wear two different-colored gloves with embedded accelerometers on both hands. The child signs a particular phrase displayed on the screen to a (hero) avatar selected at each game and then the system determines whether (s)he has signed it correctly. If the child sign phrases correctly, (s)he gains points and progresses through the game. The authors achieved a phrase verification accuracy of 83% in their study even though many non-manual features were not included to reduce the complexity of their system.

Zafrulla et al. [20] made further improvements in their existing CopyCat system with a new approach to the automatic sign language recognition and verification tasks by using the Microsoft Kinect sensor. A total of 1000 ASL phrases were collected from two different platforms: CopyCat Adult and Kinect. For each of the 19 signs in their vocabulary, the samples in the classes were trained with HMMs. Using their previous work [25] as a baseline, the authors compared the performance of the Kinect based system on two phases, recognition and verification. The Kinect-based system eliminates the need for color gloves and accelerometers, and gives comparable results to the CopyCat system. Similarly, Gameiro et al. [24] have developed a system that aims to help users to learn Portuguese Sign Language (LGP) through a game using the Kinect sensor. The system has two modes: the school-mode and the competition-mode. In the school mode, users learn new signs in classroom-like environment, whereas in the

competition-mode, users experiment their sign language knowledge in a competitive game scenario (such as Quiz and Lingo).

In [18], Weaver and Starner introduced SMARTSign, which aims to help the hearing parents of deaf children with learning and practicing ASL via a mobile phone application. The authors share the feedback they received from the parents on the usability and accessibility of the SMARTSign system.

Furthermore, they interviewed the parents in order to determine whether the SMARTSign can alleviate their problems and discuss the ways they can improve their system.

2.2. Translation and Recognition Systems

Hrùz et al. [19] have implemented an automatic translation system, which converts finger spelled phrases to speech and vice versa, in a client-server architecture. The goal of the study is not only to help a hearing-impaired person but also to assist a visually impaired person to interact with others. The system supports many spoken and sign languages, including Czech, English, Turkish and Russian, and the translation between these spoken languages are handled using the Google Translate API. The recognition of multilingual finger spelling and speech was done using k-Nearest Neighbor Algorithm (k-NN) and HMMs, respectively. In the finger spelling synthesis model, a 3D animated avatar is used to express both manual and non manual features of a given sign.

The Dicta-Sign [21] is a multilingual sign language research project that aims to make Web 2.0 applications accessible to Deaf people so that they can interact with each other. In their Sign Wiki prototype, the authors demonstrate how their system enables sign language users to get information from the Web. Like Wikipedia, in which users are asked to enter text as an input from their keyboard, sign language users can search and edit any page they want, and interact with the system via a Kinect sensor in the Dicta-Sign Wiki. The Dicta-Sign is currently available in four languages: British Sign Language (BSL), German Sign Language (DGS),

Greek Sign Language (GSL) and French Sign Language (LSF).

In a similar way, Karpov et al. [22] present their universal multimodal synthesizer system for Russian (RSL) and Czech (CSE) sign languages and speech synthesis that uses a 3D animated avatar. VisualComm [23], [8], a Chinese Sign Language (CSL) recognition and translation tool, aims to help the Deaf community to communicate with hearing people via the Kinect sensor in real-time. The system can translate a deaf person's sign phrases to text or speech and a hearing person's text or speech to sign language using a 3D animated avatar. Based on 370 daily phrases, VisualComm achieves a recognition rate of94.2% and demonstrates that 3D sign language recognition can be done in real-time by using the depth and color images obtained from the Kinect sensor.

2.3. Community-Aid Applications

Community-aid applications are mainly designed to be used to help the deaf community in their daily life. One of the earliest tools was the TESSA (Text and Sign Support Assistant) [14, 15], which was developed for the UK Post Office to assist a post office clerk in communicating with a Deaf person. The TESSA system translates a postal officer's (listener) speech into British Sign Language (BSL) and thendisplays the signs to the screen with an avatar to a Deaf customer at the post office. The authors used the entropic speech recognizer and performed semantic mapping on a best match basis to recognize the most phonetically close phrase. Using a subset of 155 out of the 370 phrases, the system achieved a 13.2% error in its best performance, whereas the language processor achieved an error rate of 2.8% on its semantic mapping to choose the most likely phrase on a given utterance.

Lopez-Ludena et al. [26] have also designed an automatic translation system for bus information that translates speech to Spanish Sign Language (LSE) and sign language to speech. The system works in real-time and achieves a sign error rate of 9.4%.

3. HOSPISIGN

When classified as one of the previously discussed categories, the HospiSign platform can be defined as a community-aid application, for the system aims to assist hearing-impaired people in their daily lives. The HospiSign platform consists of a personal computer (PC), a touch display to visualize the sign questions and answers to the user, and a Microsoft Kinect v2 sensor. Since it is necessary to track the users' hand motions in order to recognize the performed signs, Kinect sensor plays an essential role as it provides accurate real-time human body pose information.

3.1. Interaction Design

While designing the interface, we focused on two criteria: functionality and usability. The scenarios, therefore, wereprepared based on the advice of the family medicine clinicdoctors and a Turkish Sign Language instructor, who is also anative hearing-impaired person. A sign language database wascollected using Microsoft Kinect v2 sensor for the possible hospital scenarios that consists of 33 sign classes with 8 samples per class. The Turkish Sign Language database which also contains the database created for the HospiSign platform will be publicly available on the BosphorusSign website[1]. In the future, the number of signers and repetitions of each sign will be increased to boost the recognition rate of the existing system.

On the design of the interface, the question sign-video is placed at the top-center of the screen to attract the user's attention. Then, the answer sign-videos are displayed at the bottom of the screen with a smaller size than the size of the question sign-video. A sample from the user interface of the HospiSign platform is shown in the Figure 1. Since there some questions which have more thanthree answers, the timing is given to each question

[1] www.BosphorusSign.com

accordingly so that users can be able to view all the answers.

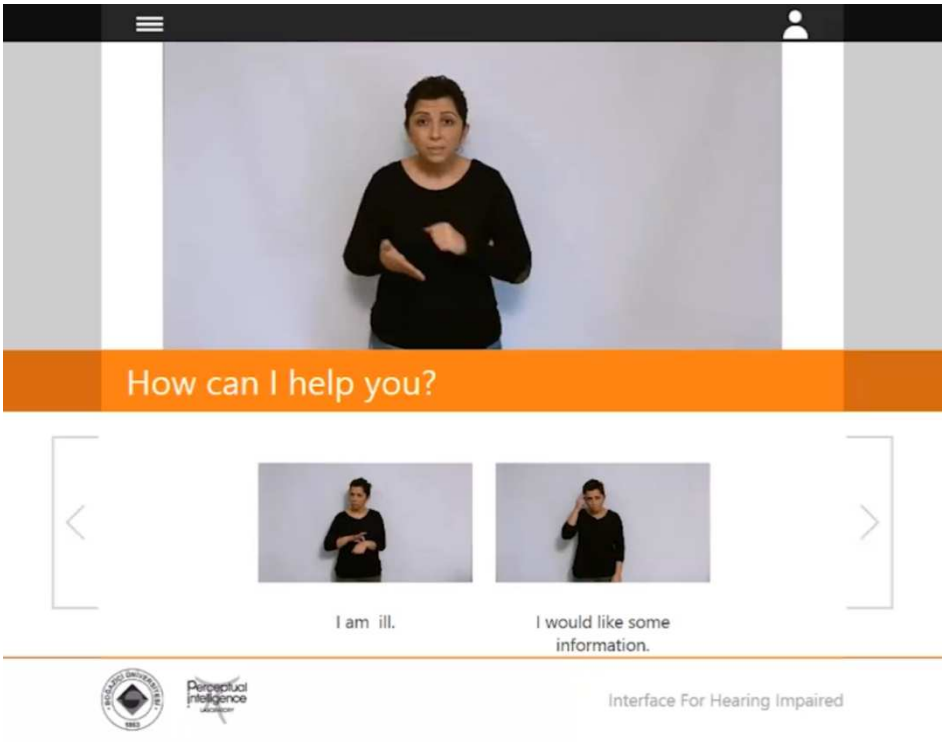

Figure 1. The HospiSign Interface

The HospiSign system follows three stages to move to the next question in the tree scheme: (1) display of the question; (2) display of the possible answers to that question; and (3) the recognition of the answer (sign). The user first watches the question displayed on the top-center of the screen; then performs a sign from the list of possible answers displayed at the bottom of the screen (See Figure 1); and then moves to the next question. This process is repeated until the system gathers all the necessary information from the user. After the user answers all the related questions, the system prints out a summary report to be given to the information desk

or the doctor at the hospital. This summary contains the details of user's interaction with the HospiSign.

To make classification task easier, the questions are placed into an activity diagram in such a way that each question will lead to another sub-question via the answer selected by the user. With categorization of possible answers to each question, it is intended to help the users to easily describe their illness or intention of their visit. The configuration of the activity diagram can be seen in Figure 2.

One of the most important advantages of using such a tree scheme is that it makes the system more user-friendly and easy-to-interact. The guided tree scheme also boosts the recognition performance of the system, as the interface does not have to recognize the sign displayed by the user from all the signs in the dataset, but rather searches among only the possible signs in each step. Experiment results show that even in a small dataset of 33 signs, HospiSign with its guided tree scheme shows drastically improved performance by reducing the number of classes to be matched.

4. EXPERIMENTATION AND RESULTS

4.1. User Testing

The user testing procedure has been prepared in order to evaluate usability and functionality of the interface. These tests aimed to answer the following questions:

- Can users navigate to important information from the current prototype's main page?
- Can users be able to understand the flow of the system at first sight?
- Will answers provided in the interface suffice in the real life?
- Can users understand all the signs interpreted in the interface?
- Are there confusing steps in the tree scheme?

- Will users be able to turn back easily if they make a wrong choice?
- Will users easily find the flow menu button at the top-left corner of the interface?

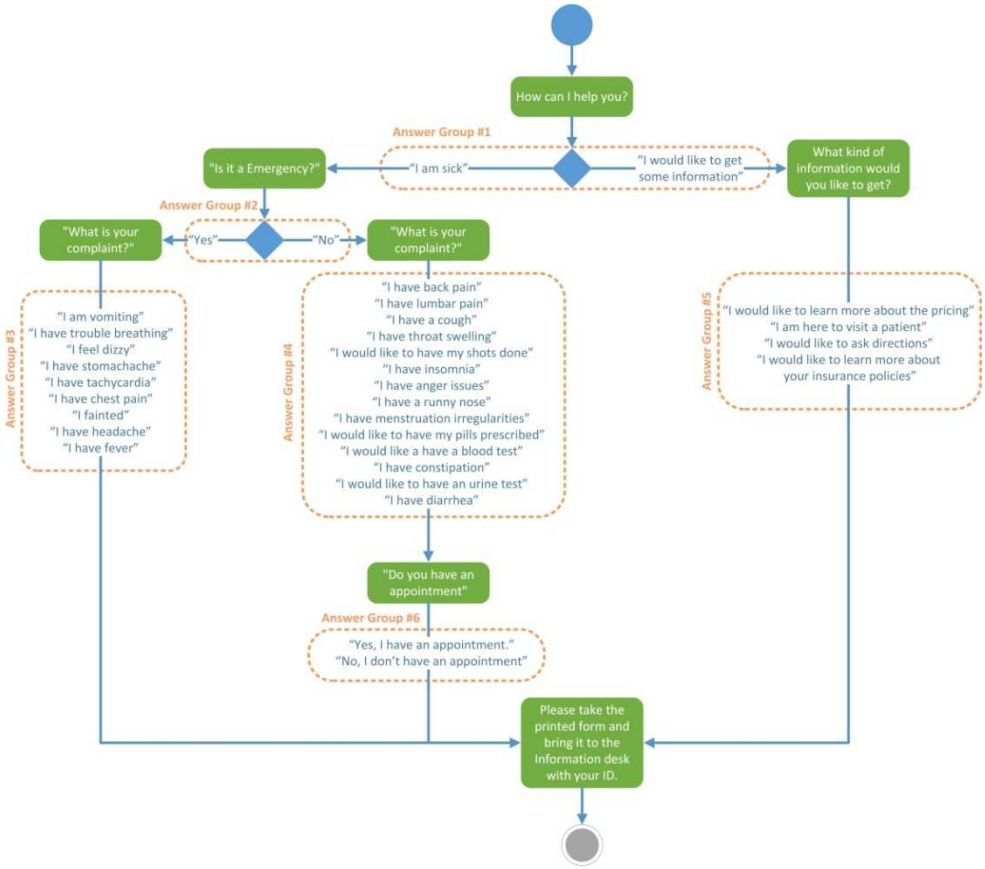

Figure 2. Activity Diagram of the HopiSign Platform

Tests were administered to five different users. Five scenarios were identified and users were asked to use the system under each scenario. Table 2 lists these scenarios. All of the users successfully finished each scenario. The average time to finish a scenario was one minute. However, most of the users spend approximately three minutes in theScenario #3 and made minor

errors. In Scenario #3, users wereasked to take a blood test. As it can be seen in the activitydiagram (See Figure 2) this option can only be reached through giving the answer "I am sick" previously. Nonetheless, one might not be sick to take a blood test. This issue was duly noted and fixed in the updated version.

Table 2. Scenarios

#	Scenarios
1	You came to the hospital to visit your sick friend, whose name you have in written form.
2	You are having trouble to sleep for the last month. Yesterday you made an appointment to see the doctor concerning your issue.
3	You just registered to a gym but they require a blood test before letting you use their swimming pool. Therefore you visit your local hospital to get your blood tested.
4	You visit a hospital but before you take any medical care you would like to get more information about their insurance policies.
5	You have a fever and need emergency care.

After completing the scenarios on the interface, the participants were given a questionnaire to acquire their feedback on the system. Questionnaire consists of five statements and the user was expected to give scores between 1 and 5, 1 being the worst and 5 being the best. Also there was a recommendation-section in the questionnaire, in which the users were ableto express themselves with their own words. Questionnaire statements and scores given by the users can be seen in Table 3.

Table 3. User Questionnaire and Its Scores

Questionnaire	**Score (/5)**
I was able to express my situation using HospiSign	4.85
HospiSign is easy to use.	4.85
Most people could learn to use HospiSign quickly.	5.00
Options were sufficiently clear.	4.45
HospiSign would help the hearing impaired.	5.00

4.2. Recognition Tests

A baseline Sign Language Recognition framework is developed using Microsoft Kinect v2 sensor. Users' answers are captured by the sensor and the provided human body pose information is used for recognition. High level HA/TAB/SIG features are also extracted, which are semantic sign language indicators are proposed by Kadir et al. [27].

In order to perform the recognition, spatio-temporal alignment distances between training and test samples are calculated using Dynamic Time Warping algorithm (DTW). These distances are then utilized as a dissimilarity measure and used in a nearest neighbor fashion to obtain a gesture level classification decision.

The experiments were conducted on a database which contains 33 signs from the BosphorusSign database. The gestures corresponding to each sign is recorded 8 times and leave one out cross validation is used to assist recognition performance. To evaluate the performance of the guided tree structure, classification was done on subsets of the dataset and their performance was compared with doing recognition on the whole dataset. As it can be seen from the experiment results in Table 4, using the guided tree structure instead of trying to classify signs from the whole dataset increased the performance drastically.

Table 4. Recognition Performance

Experiment Set	**# of Signs**	**Accuracy**
All Signs	33	**83%**
Answer Group 1	2	**88%**
Answer Group 2	2	**100%**
Answer Group 3	9	**98%**
Answer Group 4	14	**90%**
Answer Group 5	4	**84%**

Answer Group 6	2	**100%**

5. CONCLUSION

In this study, we have presented an interactive communication interface for the Deaf community named HospiSign, which is designed to help the Deaf in their hospital visits. The HospiSign platform guides its users through a tree-based activity diagram by asking specific questions and requiring the users to answer from the given options. This approach alleviates the problem of recognizing the sign displayed by the user among all the signs, since the system only looks for the possible answers to recognize the sign in each step. The preliminary results show that the activity diagram does not only increase the recognition performance rate of the classifier, but also makes our system more user-friendly and accessible to everyone. The system consists of a personal computer, a touch display to visualize the questions and answers, and a Microsoft Kinect v2 sensor, which provides body pose information, to capture the responses of the users. In order to evaluate the performance of our system, we have collected 8 samples from 33 signs. Based on the feedback we have received from the users, we are planning to update our system, HospiSign, by extending our dataset and improving the user-independency of the recognition framework, so that it will be suitable to use in hospitals.

After reviewing the currently available sign language based Human-Computer Interaction applications, we have realized the absence of community-aid system for the Deaf community in hospitals. Our current results show that we can increase the recognition performance of the HospiSign system by recognizing isolated signs in a structured activity diagram rather than using a generalized model. As future work, we are planning to extend the scope of our existing system and to develop another system, FinanSign, which will be used to assist the Deaf in a bank environment.

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