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# Design and Effect of AR Sign Language Teaching Software Based on Natural Interaction

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**Abstract:** Sign language is an important way for deaf people to communicate and learn knowledge. In the process of the promotion and standardization of national common sign language, sign language teaching is becoming more and more important. However, the current sign language teaching is mainly based on multimedia courseware, sign language videos, and sign language action decomposition diagrams, which lack dynamic and all-round display. Therefore, this study focuses on the teaching of alphabetic sign language for young children. Based on platforms and devices such as Unity 3D and Leap Motion, two functions of this sign language teaching software were designed and developed, namely learning function and practice function, and feedback from students, parents and teachers were collected. It enables deaf children and other sign language learners to learn, practice and communicate sign language through Android devices. Finally, the software implements learning function and practice function. Among them, the sign language learning function is intuitive, three-dimensional and interactive, while the practice function has the characteristics of natural interaction and real-time feedback. The average judgment accuracy of the practice function is 90%, calculated through the use effect of eight children, which is relatively high. The interview results show that students, parents and teachers have good feedback on it. They said that although the software needed to be improved, the three-dimensional display of its learning function was very interesting, and the practice function could help students correct their mistakes.

**Keywords:** Sign language teaching, Natural interaction, Augmented Reality

## 1. Introduction

According to the World Federation of the Deaf, there are over 70 million deaf people in the world (Murray, 2018). Therefore, sign language is an important means of communication and learning knowledge for deaf people. However, the school does not have enough sign language teachers to provide one-on-one instruction, and deaf children's sign language learning efficiency is low because of the limitation of traditional special education methods (Rastgoo, Kiani, & Escalera, 2021). In addition, parents of deaf children are also faced with the challenge of learning sign language and need suitable resources for learning sign language. Currently available tools to assist sign language learning are mostly based on online courses and mobile devices (Martins, Rodrigues, Rocha, Francisco, & Morgado, 2015). The former are mostly frontal displays and recordings, lacking all-round display. While the latter can facilitate users to learn sign language anytime and anywhere, but they are mostly static pictures of sign language, lacking dynamic and comprehensive display, which is undoubtedly a challenge for deaf children whose comprehension is not fully developed. The technical features of Natural interaction and Augmented Reality (AR) can compensate for the deficiency to a certain extent.

Natural interaction is more intelligent and natural than traditional human-computer interaction that requires the use of external hardware devices (e.g., mouse, keyboard, etc.) (Valli, 2008). AR is a technology that applies virtual information to the real world to achieve a sensory experience beyond reality (Azuma, 1996). The combination of the two enables students to conduct natural three-dimensional sign language learning with the machine, resulting in a more realistic learning experience.

Even through Natural interaction and AR have been initially applied in sign language learning, there are still some issues to be improved. User-friendliness as well as accuracy of Natural interaction in sign language learning still need to be improved. The interaction applications are mostly based on wearable devices and visual capture. The former such like gloves and other wearable somatosensory devices make users feel bulky and inflexible (Jiang, Kang, Song, Lo, & Shull, 2022), while the latter such like Kinect can recognize body movements, but the accuracy of gesture recognition is not high (Nguyen, Falk, & Ebling, 2014). The application of AR technology in sign language teaching lacks natural interactivity. Existing AR teaching software is limited to recognizing the static model of the card, lacking the transformation from hand movements to texts.

Based on the above analysis, we focus on two main objectives, developing an AR sign language teaching software and implementing an empirical study of the AR sign language teaching software. Design and develop an AR sign language teaching software. The AR sign language teaching software has two main functions of sign language learning and sign language practice, combining the advantages of AR and Natural interaction. The sign language learning function is intuitive and three-dimensional, while the sign language practice function is with natural interaction and real-time feedback. Implement an empirical study of the AR sign language teaching software. After the development of AR sign language teaching software, the accuracy of the practice function was tested, and users were interviewed. The data were collected to analyze the advantages and disadvantages of the teaching software.

## 2. Related Work

### *2.1 Sign Language Teaching*

The World Health Organization reports that 466 million people in the world need rehabilitation to address their "disabling" hearing loss, including 34 million children (WHO, 2021). And Smith's research shows that about 1 in 1,000 children in developed countries is born with a bilateral hearing loss of at least 40 decibels. More serious is deafness. The World Federation of the Deaf reports that there are about 70 million deaf people in the world. Among them, there are more than 20 million deaf people in China, including nearly 800 thousand children under the age of seven. Therefore, attention needs to be paid to issues such as treatment, education, and employment of hearing loss or deaf groups (Smith, Bale, & White, 2005).

In education, the main channel for learning sign language is still in the form of class teaching in special schools. Sign language teachers teach according to the outline requirements of sign language textbooks. This teaching method is difficult for deaf people, especially beginners, to interact with the teacher during the learning process, and the learning efficiency is very low (Rastgoo, Kiani, & Escalera, 2021).

Therefore, with the development of information technology, various technologies are gradually applied in the teaching of deaf children. For example, using information technology to learn through storytelling (Alsumait & Al-Musawi, 2013; Flórez-Aristizábal et al., 2019), developing serious games for gamified sign language learning (Economou et al., 2020) and developing the sign language teaching and translation software or hardware (Alrabiah, AlMuneef, AlMarri, AlShammari, & Alsunaid, 2020). These applications basically use gesture recognition technology for sign language action matching and natural interaction for sign language dialogue (Rastgoo, Kiani, & Escalera, 2021). What's more, the addition of AR enhances the sense of experience and immersion.

### *2.2 Augmented Reality in Sign Language*

AR has the characteristics of virtual and real combination, real-time interaction and three-dimensional registration (Azuma, 1996), which is a bridge connecting the real world and the virtual world (Cai, Wang, Ynag, & Liu, 2016). Based on AR, users can see the real world and virtual objects integrated in the real world and interact with them naturally. At present, AR has been widely used in scientific practice teaching, and has gradually entered the field of special education (Kose & Guner-Yildiz, 2021; Yenioglu, Ergulec, & Yenioglu, 2021).

As shown in Table 1., the current researchers mainly use three kinds of devices such as data gloves, Kinect, and Leap Motion combined with AR to assist in sign language learning. Some studies have shown that this system can effectively improve the sign language learning of deaf students (Deb, Suraksha, & Bhattacharya, 2018).

Table 1. *Applications of natural interaction technologies in learning sign language*

| Device | Applications | Conclusions |
|---|---|---|
| Data gloves (Amin, Rizvi, & Hossain, 2022) | Chinese Sign Language Thesaurus | Data gloves are required for interaction. High device requirements and inconvenient interaction. |
| Kinect (Baldeon, Oñate, & Caiza, 2022) | Self-directed learning and practice | Strong interaction support for students, but more limited in the use of equipment (e.g., the distance limited, etc.) |
| Leap Motion (Chuan, Regina, & Guardino, 2014) | Sign language practice | Higher accuracy, relatively low cost of equipment, but high system requirements for computers. |

This study adopts Leap Motion, a lightweight gesture recognition device based on visual capture, which can capture hand movements more accurately and does not rely on a wearable device. There have been many studies applying Leap Motion to special education, training children with autism spectrum disorder or other developmental disabilities (Cai, Zhu, Wu, Liu, & Hu, 2018; Hu, Lee, Tsai, Yang, & Cai, 2020). The development in Leap Motion needs to be more integrated with practical teaching and Chinese sign language. Currently, Leap Motion is developed with high accuracy in sign language (Vaitkevičius et al., 2019). The development of both static (Rakesh, Kovács, Mokayed, Saini, & Pal, 2021) and dynamic (Hisham & Hamouda, 2021) sign language mostly focuses on feature combinations or 30 letters, lacking of the integration with pictorial Chinese sign language. This study starts from the actual needs of Chinese sign language teaching.

Therefore, this study is based on Leap Motion and AR to realize the natural interaction of sign language movements, develop learning and practice functions, and collect feedback from students, parents and teachers.

## 3. Design and Development

We apply 3D modeling, Natural interaction and AR as the core technology and Android application development technology. The AR sign language teaching software can demonstrate sign language models on Android mobile devices and precisely realize Leap Motion preset functions on PC respectively.

### *3.1 Application Technological Foundation*

#### *3.1.1 3D Modeling*

Considering the demand of hand model establishment, we implement Maya as the modeling tool and applied techniques such as bone binding, skinning as well as animation to realize 3D modeling. The modeling progress can be divided into procedures as the establishment of hand models, the adjustment of the joint position and angle parameters, and the animation. To make the model more vivid, we replace the static model with partly dynamic model, which enhances the interactivity, fidelity, accuracy and interestingness of the application.

#### *3.1.2 Natural Interaction*

Leap Motion is utilized to accurately capture sign language and realize natural interaction. The sign language learning scenario is established and developed on the Unity 3D platform.

Gesture capture based on Leap Motion: To customize the interactive gestures in real time and define the sign language, we apply Leap Motion controller to obtain the raw data of gestures in the camera’s field of view, including the number and the names of fingers and the 3D co-ordinates and the vectors of the palm and joints.

Gesture definition based on Unity 3D: Using the 2018.2.15f1 version of Unity 3D development tool that supports Leap Motion, we compile the script to realize the definition of gestures and the interaction of the context and sign language.

### 3.1.3 *Augmented Reality*

This study is based on Unity 3D platform, combined with Vuforia AR Toolkit, overlaying virtual information in real scenes to achieve AR effect.

Unity 3D technological route: Based on Unity 3D platform, the application is developed in Windows system and operates in Android system. In Unity 3D platform, we build scenes according to the requirements, add components, write corresponding scripts and keep debugging and running, and finally realize different functions required for various scenes.

Vuforia technological route: We design the target images of corresponding sign language course, add the 3D static and dynamic model of sign language, and determine the best display position by adjusting the parameters such as model position, angle, size, etc.

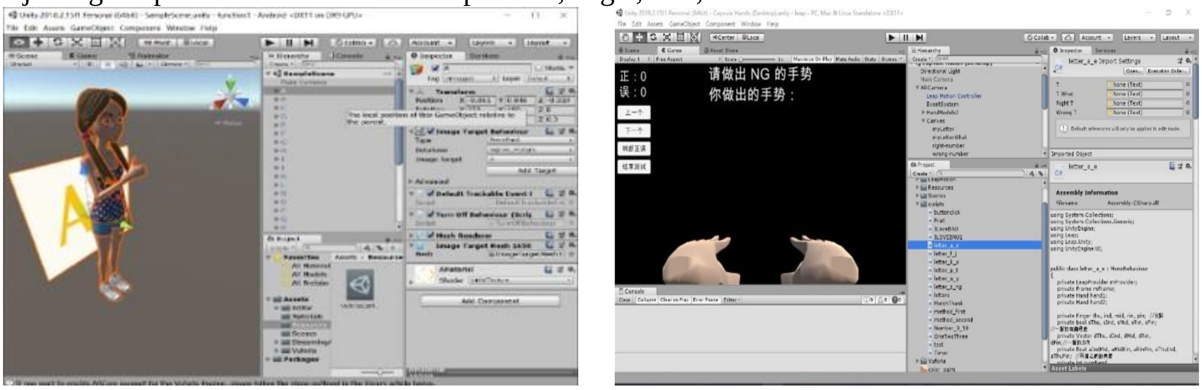


*Figure 1.* Application development in Unity 3D

### 3.1.4 *Android Application Development*

The hardware device of the teaching software is selected as a lower cost Android phone or tablet, so we add Android SDK to realize the design and development in Android platform and finally realize the AR effect in Android devices.

## 3.2 *Application Function*

In the learning function part, 30 sign language models and corresponding target images were designed and developed. The learning function of the APP is running on Android system. The target images are recognized by the phone or tablet camera and the 3D static or dynamic models are presented in the form of AR. Users can zoom in and out of the models through the screen and observe the models in 360 degrees for vocabulary learning and review.


*Figure 2.* Screenshot of learning function

As shown in Figure 3, in the practice function part, the sign language teaching software captures sign language movements in real scenes through a computer camera and matches them with virtual 3D hand model through Leap Motion device, which judges the gesture of the virtual hand and returns the result of correctness or incorrectness. Learners are enabled to practice various sign languages in a customized way according to their learning progress. The practice data is collected so that teachers and students can be aware of the practice status in real time.

*Figure 3.* Screenshot of practice function

## 4. Experiment and Results

### *4.1 Experiment Procedure*

To ensure the accuracy of the sign language teaching software and collect participants' using experience, 8 children aged 8-10 (4 deaf children and 4 normal children) with similar sign language learning levels would use the sign language teaching software to learn and practice 30 alphabetic sign language actions.

The experimental procedure is mainly divided into three parts: learning, practicing and interviewing (Figure 4.).

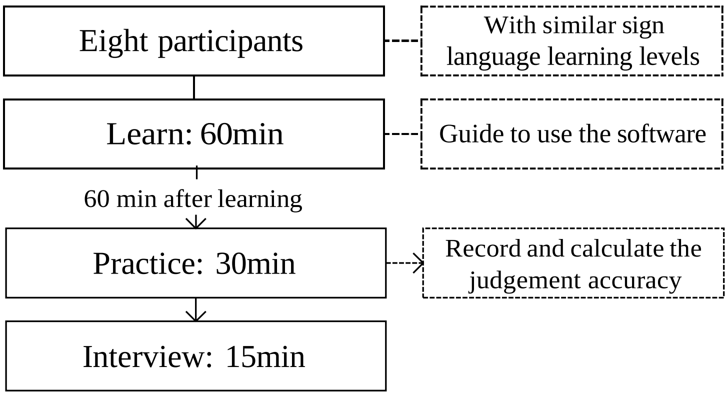


*Figure 4.* The experimental procedure

Before the experiment, parents of participants were asked to read and sign an informed consent form. In the formal experiment, a sign language teacher from deaf school and a researcher guided the whole experiment. Participants first used the learning function of this software to learn the 30 alphabetic sign language actions. They could observe the sign language action from multiple angles by rotating and zooming, and then, imitate the sign language action. One hour after learning, they used the practice function of this software to review and consolidate sign language actions. When a letter appeared on the screen, the participants made the corresponding sign language action within the range that the camera could capture. Then, the software judged it right or wrong. At this time, the researcher would record whether the software judged correctly, so as to calculate the judgement accuracy of this software. After the practice, participants and their parents would be interviewed about their experience and views of the sign language teaching software.

Calculate the judgment accuracy of the software's practice function through the accuracy formula (1).

$$ACC = (CC+IC)/(CC+IC+CI+II) \quad (1)$$

Among them, CC/IC refer to the number of times that correct/incorrect sign language is correctly recognized, while CI/II refer to the number of times that correct/incorrect sign language is incorrectly recognized. So ACC refers to the proportion of software correctly judged

### *4.2 Experiment Results*

#### *4.2.1 Accuracy*

The 30 letters are divided into 5 groups in turn. The average accuracy of the software during the review process of the eight subjects was calculated, as shown in Table 2. The software is 90.0% accurate in judging a certain letter. Among them, the judgment accuracy of the second and fifth groups is low, indicating that the judging scripts of the two still need to be improved.

Table 2. *The accuracy of the sign language teaching software*

| Group | Letters | ACC |
|---|---|---|
| 1 | A/B/C/D/E/F | 93.3% |
| 2 | G/H/I/J/K/L | 85.9% |
| 3 | M/N/O/P/Q/R | 90.6% |
| 4 | S/T/U/V/W/X | 93.8% |
| 5 | Y/Z/ZH/CH/SH/NG | 86.6% |
| Average | | 90.0% |

#### *4.2.2 Interview Results*

Finally, interviews were conducted with the participants who were able to communicate, all parents and the sign language teacher about their feelings and feedback during using or viewing process.

Participants said that the way to scan the cards to see the 3D model is very interesting, and the practice function is also very convenient. I can practice many times and get corrections. Compared with the form of video and pictures, AR software can better meet the visual needs of students (Al-Megren & Almutairi, 2019). But participants also raised some questions: "The sensitivity of the 3D model character is too high during the drag and rotation process, and it takes a lot of time to adjust the angle."

Parents said, "Although, it is worth affirming that the effect of teachers' instructing should be better, with this AR method, children can continue to learn sign language without teachers around." Some parents also suggested that this is also a way for them to learn sign language. Indeed, for families with deaf children, family members also need to study sign language. And compared with deaf children who can study sign language at school, other family members can only study sign language through online classes, sign language books or videos in their spare time (Frank, 2017). And this more visual sign language teaching software undoubtedly provides a new way for them to study sign language. Parents are also concerned about the children’s health problems brought about by long-term use of electronic devices for learning.

The sign language teacher believes that the concept of this software is feasible to a certain extent, but if it is to be truly applied in sign language classrooms, more vocabulary and functions are needed, such as learning various related sign languages in different life scenarios. Sign language teachers believe that the concept of this software is feasible to a certain extent, but to really apply it to the sign language classroom, more vocabulary and functions are needed, such as learning various related sign language situations in different lives. Studies have shown that deaf children have difficulty learning sign language out of context (Almutairi & Al-Megren, 2017). And sign language teachers also said that sign language teaching is generally carried out based on a certain story situation or a dialogue scene. In addition, the design of the practice function is very helpful, it would be better if the test method can be more flexible. Regarding the accuracy of the software, the teacher said, “among the 30 alphabetic sign languages in this experiment, individual sign language movements are very similar”. So it is difficult for participants to remember and distinguish, and the software may also make mistakes in judgment.

For example, "H" and "I", "M" and "N", “Z” and “ZH” are only slightly different. This is a good explanation for the lower accuracy of the second and fifth groups. That is, there are sign language movements with similar characteristics in the group, but the script does not distinguish them well. In addition, the sign language teacher also said that if the software is used reasonably, it can reduce the burden of one-on-one guidance for the sign language teacher, guiding students to learn sign language and supervising students to practice sign language through the software.

## 5. Conclusion and Future Work

The purpose of this study is to design and develop alphabetic sign language learning software for deaf children. Then, calculate the accuracy of the software and collect participants' feedback after participants use the software.

The software can assist students in sign language learning without teacher guidance, and also help parents in basic learning of sign language. The learning function of the software enables students to conduct all-round observational learning. Students can act as both "speakers" and "listeners" to observe the characteristics of the front and back of sign language movements. The practice function of the software allows students to get feedback on their practice, so that students can carry out targeted practice according to their weak sign language vocabulary, improving the effect and efficiency of practice.

However, some challenges have also been raised. Accuracy and interface of the software need to be further improved. In the future, it is necessary to develop more sign language vocabulary in combination with life scenarios to realize sign language situational learning. This experiment recruited a small number of participants, and no quasi-experimental research or case study was conducted to explore the learning effect of participants, only the accuracy and experience of use were investigated.

Moreover, sign language expression is not only dependent on the movements of the hands, but also related to the expresser’s expression at that time, the speed of the movement, and the context at that time (Shaffer, 2018). We need to note that technology can reduce the burden on teachers but not replace teachers, especially in the field of special education, which requires more humane care.

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