

SignMaster: Bridging the Gap, One Sign at a Time



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Abstract

The learning of Hong Kong Sign Language (HKSL) is currently hindered by a lack of accessible and engaging resources. To address this, we developed the first-ever mobile application dedicated to teaching HKSL in an interactive manner. Built using Swift on Xcode, the app focuses on commonly used signs in our everyday life, enhancing the learning experience through user engagement.

A standout feature is the real-time AI-powered assessment, which provides instantaneous feedback on user signing accuracy. This functionality is driven by a custom-trained CoreML model. We created a comprehensive dataset of 1,750 videos demonstrating 35 different HKSL signs. This dataset was used to train a fine-tuned hand action classifier within the CoreML framework. The training process involved iterative training cycles and hyperparameter optimization (e.g. learning rate and batch size) to maximize model accuracy. The model works by analyzing video frames captured by the device's camera, comparing the user's sign execution to the data in the training dataset. Ultimately, enabling rapid and accurate assessment of the user's signing accuracy. The trained model was seamlessly integrated into Xcode using CoreML's framework, ensuring efficient deployment and real-time performance.

SignMaster aims to contribute significantly to the UN's Sustainable Development Goal 10 (Reduced Inequalities) by directly mitigating communication barriers for individuals with hearing or speaking difficulties. Its interactive design, incorporating a reward system and progress tracking, motivates users to achieve HKSL fluency, thereby promoting inclusivity and fostering a more equitable and understanding society.

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Introduction

1.1 Background

1. Prevalence of Hearing or Speaking disabilities in Hong Kong

In Hong Kong, a significant number of individuals experience hearing or speaking impairments. The Census and Statistics Department reports that approximately 246,200 people (3.3% of the population) have hearing difficulties. This substantial figure highlights the considerable need for improved accessibility and support services.

Those with these disabilities encounter significant communication challenges in their daily lives, resulting in feelings of isolation, frustration, and exclusion. A major concern is the inadequate methods for teaching sign language, which can be complex to learn, especially for those without prior exposure. The lack of qualified sign language instructors and resources further restricts access to quality education and training. Moreover, the shortage of sign language interpreters, captioned media, and accessible communication technologies adds to these challenges. Individuals with hearing and speaking impairments often face discrimination in both employment and social settings, limiting their job opportunities and participation in community activities. These communication barriers also place a significant burden on caregivers, impacting family well-being and requiring extensive emotional and practical support.

2. Uniqueness of Hong Kong Sign Language

Hong Kong Sign Language (HKSL) holds a unique position within the global landscape of sign languages. Sign languages are not universally understood; an estimated 300 distinct sign languages are used worldwide, each with its own unique grammatical structures, vocabulary, and cultural nuances. HKSL, therefore, represents a vital component of Hong Kong's linguistic and cultural heritage, distinct from other sign languages used in different regions.

Understanding this unique linguistic diversity is crucial for providing effective communication and educational resources tailored to the specific needs of the Hong Kong deaf community. The development of resources specific to HKSL, rather than relying on the adoption of other sign languages, is essential for fostering inclusivity and effective communication.

1.2 Problem Statement

There is a wide range of online resources available for learning popular sign languages like American Sign Language (ASL) and British Sign Language (BSL). Websites, video tutorials, and interactive applications offer structured lessons, vocabulary builders, and practice exercises for those interested in these sign languages. On the contrary, options for learning Hong Kong Sign Language (HKSL) are limited, resulting in a significant gap in accessible learning materials. This scarcity of resources creates challenges for individuals wanting to learn HKSL, putting them at a disadvantage and hindering effective communication with those who have hearing or speaking impairments. There is a need for comprehensive and engaging HKSL learning resources to foster a more inclusive society in Hong Kong.

1.3 Market Research

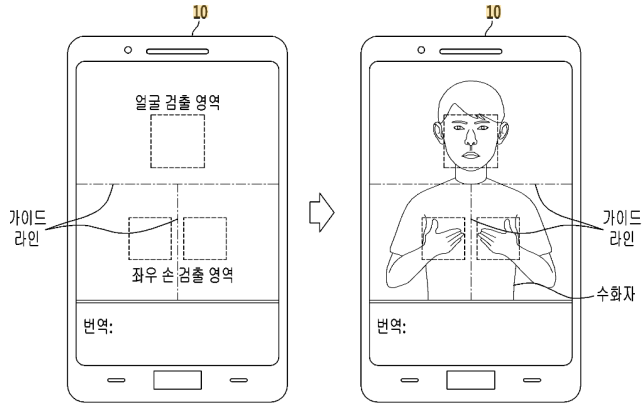
Existing Solutions	Strengths	Weaknesses
HKSL Dictionaries	<ul style="list-style-type: none"> ● Provide a comprehensive reference for vocabulary, allowing learners to look up specific signs and their meanings ● Help standardize the signs used in HKSL, which can be beneficial for consistent learning 	<ul style="list-style-type: none"> ● Do not offer interactive or engaging learning experiences, which can hinder motivation and retention ● Absence of visual demonstration often lead to misunderstandings and incorrect sign execution
HKSL classes	<ul style="list-style-type: none"> ● Provide a structured curriculum designed to teach HKSL effectively ● Able to practice with instructors and peers, enhancing signing skills through real-time feedback 	<ul style="list-style-type: none"> ● Lessons can be expensive, may not be affordable for everyone, especially students, low-income families etc. ● May not be widely accessible for those living in rural areas
YouTube tutorial videos	<ul style="list-style-type: none"> ● Offer a wide range of videos, from beginner lessons to advanced topics, catering to different learning levels ● Freely accessible, allowing everyone to learn at their own pace 	<ul style="list-style-type: none"> ● Do not provide interactive elements or personalized feedback, which can limit the effectiveness of learning ● Quality of content can vary significantly

1.4 Patent Search

Initial market research highlighted a need for interactive and effective HKSL learning tools readily available on mobile devices. This initial market analysis was followed by a more detailed technological investigation, including a comprehensive Google Patent search, to identify and analyze solutions employing similar technologies.

1. Sign language translator, system and method (KR101777807B1)

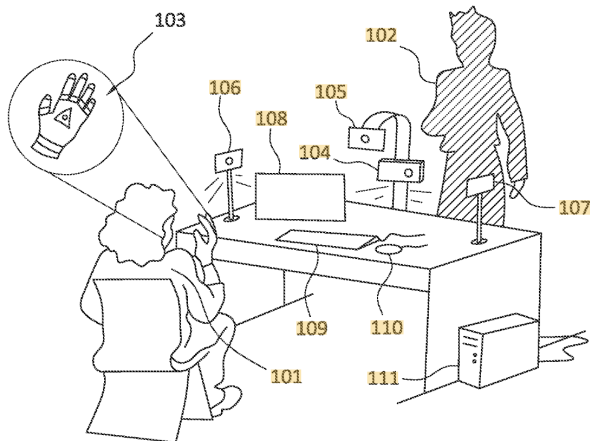
This system is a portable sign language translator that uses image input from a camera to recognize hand gestures and facial expressions, translating them into text or speech. Similar to our project, it relies on a database of sign language data to perform the translation.



Limitations: This application focuses on translating sign language into text in real-time, not on teaching sign language. While useful for occasional translation needs, relying on such a system for all communication between individuals who use sign language is impractical. The nuances of sign language, including contextual cues and cultural aspects, are often lost in direct translation, hindering effective communication and potentially leading to misunderstandings. Furthermore, constant reliance on a translator can impede the natural flow of conversation and limit opportunities for genuine connection.

2. Computer vision based sign language interpreter (US20240070405A1)

This computer based interpreter translates sign language into a target language using a combination of data from a data glove worn by the user and a camera. The system processes motion capture data from the glove and visual data from the camera, breaking down the captured movements and visual information into phonemes or sign fragments. These fragments are then assembled into possible sign sequences, which are checked for grammatical correctness. Grammatically correct sequences are translated into the target language, and finally, output is generated in that target language.



Limitations: This system, while offering a potential method for sign language translation, faces several limitations hindering its feasibility and applicability for daily use. The reliance on specialized and potentially costly hardware, such as a data glove and camera, creates a significant barrier to accessibility. The data glove itself may be cumbersome and interfere with natural signing, impacting accuracy and limiting its real-world applicability.

1.5 Project Mission and Objectives

SignMaster's primary goal is to offer a comprehensive yet interactive platform that facilitates effective learning, overcoming the limitations of dictionaries and traditional classes. By integrating real-time feedback and interactive elements, SignMaster will provide learners with the visual demonstrations necessary to grasp the nuances of HKSL, ensuring they can master sign execution with confidence. Additionally, we seek to make our solution accessible and affordable, reducing the financial barriers that often prevent individuals from pursuing sign language education.

Through our innovative approach, we aim to foster connections between individuals with and without hearing impairments, promoting inclusivity and understanding in society. By empowering users to communicate fluently in HKSL, we directly contribute to achieving United Nations' Sustainable Development Goal 10: Reduced Inequalities. Ultimately, we hope to diminish communication barriers, and pave the way for a future without discrimination.

1.6 Target Beneficiaries

1. Individuals with Hearing Impairments

The primary beneficiaries of SignMaster are individuals with hearing impairments, including those who are deaf or hard of hearing. By providing an interactive platform for learning Hong Kong Sign Language (HKSL), SignMaster aims to empower these individuals to communicate more effectively. Enhanced communication skills can lead to greater independence, improved social interactions, and increased opportunities for education and employment. This initiative will help bridge the communication gap, allowing users to express themselves confidently and engage more fully in their communities.

2. Family members

Family members of individuals with hearing or speaking impairments will experience substantial benefits from SignMaster. By learning Hong Kong Sign Language (HKSL), they can cultivate deeper connections and minimize misunderstandings. Enhanced communication will not only facilitate smoother interactions but also promote a more inclusive home environment, fostering a sense of belonging and strengthening family dynamics. This meaningful learning experience will also further deepen their understanding of the challenges faced by individuals with hearing or speaking impairments.

3. Friends and caregivers

Friends and caregivers of deaf individuals are another key target group. By learning HKSL through SignMaster, friends can enhance their relationships with their peers who have hearing or speaking

disabilities, breaking down barriers that might affect social interactions. Caregivers will also benefit from improved communication skills, enabling them to provide better support and care. This not only enhances the quality of life for individuals with hearing impairments but also alleviates some of the emotional and practical burdens that caregivers face.

Solution Overview

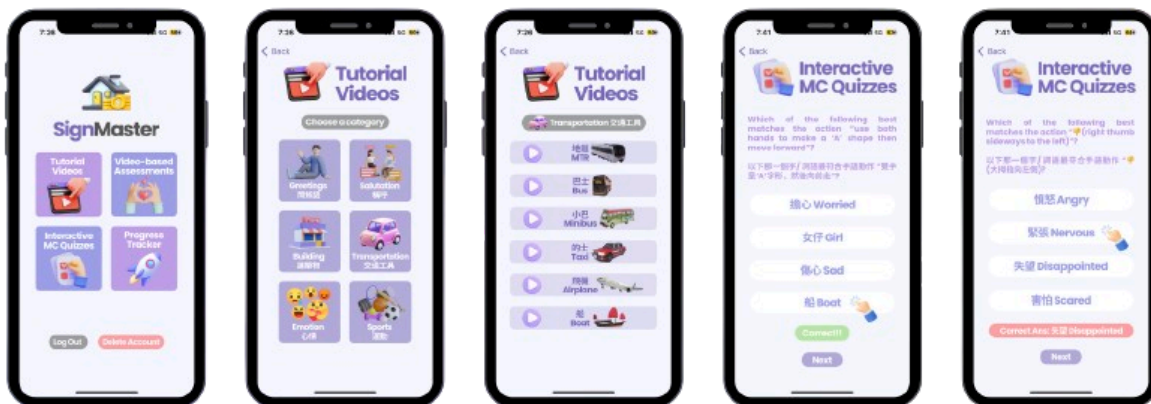
2.1 In-depth App Description

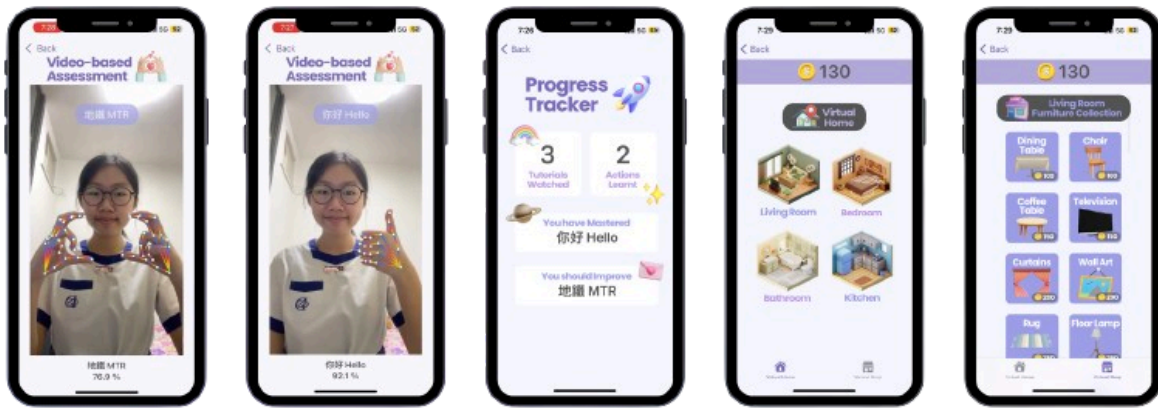
SignMaster is the first-ever app specifically created to teach Hong Kong Sign Language (HKSL) on both iPads and iPhones, offering users an additional platform for convenient access. The app utilizes Firebase authentication to simplify the login and account creation process, enabling seamless navigation once users are logged in.



To begin their learning journey, users can watch tutorial videos that introduce commonly used signs, such as "goodbye" and "MTR." They can then assess their signing skills through an AI-powered video assessment that provides real-time feedback on their proficiency. Additionally, the app includes a progress tracker to help users monitor their learning advancements and a multiple-choice quiz with randomized questions to enhance their understanding of HKSL. To encourage ongoing engagement, users can earn virtual coins within the app, which can be spent on furniture and customization options for their personalized virtual home.

A standout feature of the app is its capacity to assess users' sign language postures, facilitating precise learning and practice. This is made possible through machine learning algorithms that analyze hand and arm movements, using approximately 30 joint points, and compare them against the training dataset. With the integration of AI technology, SignMaster provides personalized learning experiences, keeping users both challenged and engaged throughout their learning journey.





2.2 App development methodology and technologies

During the development process, we conducted comprehensive research and rigorous testing. For example, we explored various AI model training platforms to evaluate their capabilities and performance. Ultimately, we selected the following technologies based on their feasibility and effectiveness.

1. Xcode

SignMaster was developed using Swift on Xcode, which provides a comprehensive suite of tools that streamline the app development process, including a powerful code editor, debugging tools, and Interface Builder for designing user interfaces.

Xcode's integration with CoreML made it particularly suitable for our project, as it allows for easy incorporation of machine learning models for real-time hand gesture recognition. This capability was essential for providing immediate feedback to users, a core aspect of the SignMaster experience. Overall, Xcode's comprehensive tools and frameworks enabled us to efficiently develop a high-quality app that meets our goals for accessibility and user engagement in HKSL education. Additionally, Xcode's built-in simulators and testing features facilitated rapid prototyping and iteration, enabling us to refine the app based on user feedback.

2. Firebase

We utilized Firebase Authentication to facilitate a seamless account creation process with their emails, ensuring they can log into the SignMaster app with their preset password easily. In addition to authentication, Firebase's analytic tools enable us to keep track of user engagement by monitoring various metrics, such as the number of actions performed within the app and the furniture purchased for their virtual homes. This data is stored in a structured manner, allowing us to manage and analyze user interactions effectively.

Firebase's real-time database capabilities also allow users to view their progress in the progress tracking page, providing insights into their learning journey. This feature enhances learning efficiency by offering clear visual representations of their achievements, such as the number of

signs learned and quizzes completed. When users are able to see tangible evidence of their progress, they are more motivated to set and achieve personal goals. Overall, Firebase's extensive features support the app's functionality, enabling a dynamic and engaging learning environment for users of SignMaster.

3. Training Data

Since we realized that there was no existing training dataset available online, we created our own dataset from scratch. We began by reviewing various HKSL tutorial videos on platforms like YouTube to familiarize ourselves with the signs. Throughout this process, we double-checked each sign to ensure accuracy and consistency. This foundational research led us to record a total of 1,750 videos, capturing 35 distinct signs for training our own AI model.

4. Model Training

To train our AI model, we utilized CoreML to develop a hand action classifier specifically designed for Hong Kong Sign Language (HKSL). We conducted numerous iterations during the training process, continually refining the model to enhance its performance.

After extensive training and validation, we achieved an impressive accuracy rate exceeding 90%. This high level of accuracy demonstrates the model's effectiveness in accurately recognizing and interpreting hand movements, ensuring that users receive reliable feedback on their signing proficiency. The rigorous training process not only validated the robustness of our model but also confirmed its potential to significantly enhance the learning experience for users of SignMaster.

5. Model integration

To import our trained AI model into Xcode, we utilized Core ML for seamless integration. We created a shared instance of the Core ML model using lazy initialization, ensuring that the model is loaded when needed. In our implementation, we set up a function to handle real-time inference, capturing video frames from the device's camera as input. This approach allows for continuous analysis of hand movements while users are doing a sign.

A pre-defined array of labels corresponding to the model's output classes was established, enabling accurate feedback on each recognized HKSL sign. By leveraging these frameworks, the hand action classifier model was effectively embedded into the SignMaster app, significantly enhancing its functionality and user experience.

2.3 UI/ UX Design

SignMaster's user interface and user experience design are designed for optimal user-friendliness. We employed a clean and direct, yet visually appealing layout to ensure the ease of navigation and accessibility for all users, regardless of their technical proficiency. Buttons and interactive elements are designed to be clearly labeled, and strategically placed for effortless interaction, ensuring that users can quickly and easily find the features they need. All in all, we strive to provide users with a comfortable and enjoyable learning experience by minimizing cognitive load.

2.4 Competitive Advantages

1. Its focus on Hong Kong Sign Language

Unlike many sign language learning resources that primarily focus on English Sign Language (ASL) or other widely taught languages, SignMaster uniquely caters to the Cantonese-speaking community. This specialization addresses a significant gap in the market, providing accessible learning for a population often underserved by existing resources. This immediately differentiates SignMaster and attracts a specific, dedicated user base.

2. Real-time Feedback

SignMaster leverages AI technology in two key ways: Firstly, it enhances accessibility by making the learning process available to individuals who may lack access to traditional classes or resources, expanding its potential user base considerably. Secondly, and more uniquely, the AI analyzes user posture to provide real-time feedback on sign accuracy. This instant feedback mechanism is a powerful tool for improvement, far surpassing the limitations of learning solely from pre-recorded videos or static images. This feature is a significant differentiator and a key selling point.

3. Personalised Learning Experience

The incorporation of gamification elements, such as quizzes and rewards, significantly enhances user engagement and motivation. This is a crucial competitive advantage, as it combats the common challenges of maintaining consistency and motivation in language learning. The virtual store and virtual home customization further personalize the experience, making learning more enjoyable and less like a chore.

4. Convenience and Portability

The app's accessibility through mobile devices allows users to learn at their own pace and convenience, fitting seamlessly into busy schedules. This flexibility is a major advantage in today's fast-paced world, making learning more accessible and less demanding on users' time.

2.5 Cybersecurity Considerations

1. Secure Password Management

SignMaster utilizes Firebase Authentication's hashing and salting mechanism as a crucial first line of defense. Hashing transforms passwords into one-way functions, meaning they cannot be reversed to obtain the original password. Salting adds a unique random string to each password before hashing, further enhancing security and preventing rainbow table attacks (where pre-computed hashes are used to crack passwords). This ensures that even if a database breach occurs, the actual passwords remain protected.

2. Firestore Security and Data Encryption

Data protection in SignMaster extends beyond password security. We have implemented rigorous Firestore security rules that act as a gatekeeper, controlling access to data based solely on user authentication status. Only authenticated users are granted access to their specific data, preventing

unauthorized access and data breaches. Furthermore, the application employs both encryption in transit (data is encrypted during transmission between the app and Firestore) and encryption at rest (data is encrypted while stored in Firestore). This dual encryption provides a comprehensive security posture, protecting data both in motion and at rest, significantly mitigating the risk of data exposure, even in the unlikely event of a database compromise.

3. Comprehensive error handling

SignMaster's codes include error handling to catch and gracefully handle various scenarios, particularly those related to authentication. This includes situations such as incorrect passwords, network connectivity problems, server-side errors, and invalid user inputs. The system's response is carefully crafted to ensure that no sensitive information is inadvertently revealed.

Implementation

3.1 Mobile Application Performance

We constantly reviewed SignMaster's performance, focusing on its core functionalities and user experience. Our rigorous testing and development processes have resulted in a high-performing application.

1. Application code and functionality

We have implemented rigorous quality assurance processes throughout the development cycle. These processes include unit testing, integration testing, and user acceptance testing to ensure the flawless operation of all codes. The result is a highly stable and responsive application, providing users with a smooth navigation experience and uninterrupted access to all features.

2. AI Model Performance

For the AI model, we have focused on continuous improvement, regularly expanding and replacing the training dataset with new high-quality videos to enhance the model's accuracy in recognizing and evaluating various signs. This ongoing refinement directly contributes to the app's ability to provide reliable and precise feedback to users, supporting their learning journey. We will continue to monitor and improve the model's performance through ongoing training and testing.

3.2 User Testing

The first round of user testing focused on gathering initial feedback and identifying any usability issues early in the development process. We invited schoolmates and teachers to participate, enabling them to experiment with the SignMaster application. Before commencing the testing, we distributed a short survey to understand their backgrounds and prior experience with sign language. This was crucial for contextualizing the feedback we received. The survey revealed that a significant portion of the initial testers lacked prior knowledge of sign language, thus would give us insights into the app's accessibility and ease of use for complete beginners. The testing sessions themselves involved observing users interacting with the app, noting any difficulties they encountered, and collecting their verbal feedback.

To gather expert opinions and ensure the app's accuracy and effectiveness, we also set up booths at various exhibitions. These booths allowed us to interact directly with professionals specializing in technology innovation or sign language education. This targeted approach provided valuable feedback on the app's accuracy in evaluating signs and the overall effectiveness of the learning experience. Professionals were able to offer more nuanced feedback based on their expertise, identifying areas for improvement that might have been missed by novice users.

3.3 User Feedback

User testing of SignMaster resulted in positive feedback, emphasizing the app's unique and innovative approach to teach Hong Kong Sign Language. Participants reported increased interest and understanding of HKSL, directly attributable to the app's interactive design and its provision of real-time feedback on their signing skills.

While users were highly satisfied with all the existing features, some suggested expanding the app's vocabulary. Increasing the number of words and phrases within SignMaster's dataset would significantly enhance its value, leading to more comprehensive learning outcomes and a more complete HKSL learning experience. Therefore, we are working on the addition of approximately 30 new words to SignMaster's dataset. This expansion will be achieved through process optimization, reducing the number of training videos needed per word while maintaining the model accuracy.

Summary

4.1 Conclusion

SignMaster revolutionizes Hong Kong Sign Language learning by leveraging AI technology to deliver a tailored and highly effective experience. Immediate evaluation and feedback on signing gestures, combined with a motivating reward system, ensures consistent engagement and motivation. This innovative approach significantly empowers users to improve their signing fluency, thus promoting a more inclusive society for all.

4.2 Future Development

1. VR/ AR technology: Apple Vision Pro

As the newest technologies emerge, we hope to incorporate them into our product in the future. One such element is the integration of Apple Vision Pro, which will provide users a more immersive and engaging learning experience. With everything being three-dimensional, users will be able to do the signs more accurately.

2. Partnering with deaf organizations

We would also like to forge partnerships with some deaf organizations in Hong Kong, such as the Hong Kong Society for the Deaf, to evaluate our sign language app and ensure its reliability and accuracy. Furthermore, we aim to convert the virtual coins users gained in our app into tangible

real-life donations through a cryptocurrency-based system built on blockchain technology, allowing us to directly benefit the deaf and mute community with the revenue generated from our product, while ensuring the utmost safety and transparency of these transactions.

3. Android and web based version

Additionally, we hope to expand the reach and accessibility of our app by developing both an Android and a web-based version, in addition to the existing iOS version. This will remove any device-specific restrictions, and empower more individuals, regardless of their device's operating system to use our app.