

# A Revolutionary Real-Time Translation Tool for Text, Audio, and Sign Language from Images

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**Abstract:** This paper introduces an innovative approach to overcoming language barriers in effective communication. Departing from conventional translation tools, the proposed solution presents a groundbreaking technology facilitating real-time translation by capturing small text portions within images. The Figure Out application, a transformative solution, stands out as a pioneer in its field, distinguishing itself by offering unmatched features. Leveraging optical text recognition from captured images, it excels in translating content into text, audio, or sign language. Notably, this technology goes beyond conventional translations, making information visually accessible to deaf individuals.

## 1 INTRODUCTION

Effectively communicating in a non-native language can be a demanding and even impossible task. Even with a basic understanding of a foreign language, maintaining proficiency can be challenging without regular use. Over time, vocabulary and grammar tend to fade, making communication even more complex. This challenge is particularly pronounced when bridging the gap between different languages, especially between deaf and non-deaf individuals (Zheng, et al., 2020).

Translating between spoken and signed languages is intricate due to differing grammar structures, creating a demand for robust systems that facilitate communication between hearing and Deaf individuals (Stoll, Camgoz, Hadfield, & Bowden, 2019). As such, technology can play a vital role in addressing these challenges, and one such solution is the innovative Figure Out application.

Figure Out is a groundbreaking mobile app that streamlines language translation, offering sign language translation alongside spoken languages, a feature not found in any other app. It achieves this by using the phone's camera to automatically capture

text and provide translations into the desired language.

The focus is on ensuring inclusivity, accessibility, and effective communication by providing information in the preferred language of individuals.

## 2 FRAMEWORK

The experience of being a foreigner can be challenging. However, for individuals who are deaf, the experience can be even more overwhelming due to the lack of accessibility and inclusion in many foreign environments. As Gillovic & McIntosh (2020) point out, foreign environments are often “barrier-laden and socially exclusive”, making it difficult for individuals who are deaf to fully participate and engage.

To address this issue, it is crucial for foreign environments to be inclusive and welcoming to all individuals, regardless of their abilities or language preferences. As Santa (2020) notes, reducing uncertainty and providing support to visitors who are deaf is essential to creating an inclusive foreign

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environment. This means ensuring that deaf individuals can access education, services, cultural sites, and information independently, without the need for adaptation.

By promoting social inclusion and accessibility, communication between the deaf community and others can be greatly improved. As Oliveira et al. (2019) argue, creating an environment that is accessible to individuals who are deaf is not only beneficial for them, but also for society as a whole. It allows for greater understanding and appreciation of diversity and promotes a more equitable and inclusive society.

One tool that can help to facilitate communication and accessibility for individuals who are deaf is Figure Out. This mobile application is designed to be multilingual and allows for translation to Portuguese Sign Language, making it a valuable resource for deaf individuals who cannot easily access information. By enabling translation to Portuguese Sign Language, Figure Out helps to mediate communication and create a relationship of equivalence between two different languages, overcoming communication barriers (House, 2016).

The deaf community in Portugal uses Portuguese Sign Language (LGP), which is different from other sign languages around the world. There is a communication gap between the deaf and hearing communities due to the lack of awareness about LGP. Deaf individuals struggle to understand written text in Portuguese. A translation model could help bridge this gap and allow the deaf community to access information on the internet and other resources. Machine translation for sign languages has been overlooked until recently, but it is crucial for integrating the deaf community into society (Khan, Abid, & Abid, 2020).

To do so, and by leveraging our expertise in sign language translation, the Figure Out initiative endeavours to create a groundbreaking tool that enhances inclusivity in cultural settings. This tool aims to cater to the needs of the deaf community through the Inclusive Cultural Heritage Tourism (ICHT) project (Escudeiro N. , Escudeiro, Cunha, & Gouveia, 2022). The ICHT project aims to create an environment that is welcoming and accommodating to all visitors, including those with hearing disabilities (Escudeiro, Gouveia, Cunha, & Escudeiro, 2022). This will not only benefit the deaf community but will also create a global strategy for the cultural sector. As Biddulph & Scheyvens (2017, 2018) suggest, developing an inclusive cultural environment will open doors to a significant share of

the global market, attracting more visitors and promoting cultural exchange.

In conclusion, the ICHT project and the FigureOut app are a step towards creating a more inclusive society, where everyone can enjoy and appreciate cultural heritage sites. They will not only benefit the deaf community but will also create a global strategy for the cultural sector. By utilizing sign language, we can create an environment that is accessible to everyone, regardless of their hearing ability.

### 3 METHODOLOGY

Figure Out is dedicated to enhancing access to cultural heritage by offering digital tools and content in multiple languages, including sign language, to ensure seamless online and mobile accessibility.

Moreover, at the heart of the Figure Out project lies a mobile application meticulously crafted to deliver instant translations of small text segments captured as images. Functioning seamlessly within an augmented reality context, users can effortlessly point their mobile device's camera at the text they wish to translate. The application rapidly processes visual data and promptly delivers a translation in the user's selected language.

The Figure Out app's usability transcends conventional language translation tools due to the integration of sign language translation, a pivotal feature facilitating communication between deaf and non-deaf individuals across various real-life scenarios. For instance, envision a deaf individual navigating a restaurant where the menu is exclusively available in written form. With the Figure Out app, they can effortlessly capture the menu items using their smartphone camera, and the app instantly translates them into sign language, empowering informed food choices without reliance on written text.

Similarly, accessing public transportation information poses challenges for deaf individuals reliant on auditory announcements or written signs. Through the Figure Out app, users can easily capture bus schedules or train timetables using their smartphone camera, with the app providing real-time sign language translations. This capability enables deaf individuals to navigate public transportation networks independently, enhancing accessibility and inclusivity in daily life.

Also, the Figure Out app holds significant potential for enhancing language learning and educational experiences, particularly in the realm of sign language education. By leveraging its real-time

sign language translation feature, the app can be instrumental in facilitating communication between teachers and deaf students, thereby promoting inclusivity in educational settings. Moreover, the app can serve as a valuable tool for teaching sign language to hearing students, fostering greater awareness and appreciation of sign language as a language and mode of communication.

For instance, in a classroom setting, teachers can utilize the Figure Out app to translate spoken instructions or lecture content into sign language in real-time, ensuring that deaf students have equal access to educational materials. Furthermore, the app can be integrated into language learning curricula to provide interactive sign language lessons, allowing students to practice and improve their signing skills in an engaging and immersive environment.

By incorporating educational applications into its scope, Figure Out not only contributes to language accessibility but also promotes inclusive education and cultural diversity in schools and learning institutions.

In addition to translation capabilities, the Figure Out project introduces a mobile diary tool, empowering participants to quickly record their thoughts, actions, and surroundings through their mobile devices. This feature serves a dual purpose, enabling users to maintain a personal diary while also supporting context-based co-creation in various developmental phases. Users can capture spoken messages, pictures, videos, or text messages, each entry accompanied by a wealth of associated data, including transcriptions, audio files, timestamps, geo-tags, participant IDs, and message durations. This data is invaluable for research, fostering a rich source of information and feedback.

The project's ultimate goal is to implement these tools within a Living Lab, an open innovation environment. In a Living Lab, users play an integral role in the innovation process, ensuring that the tools are tailored to their needs and experiences in a real-world setting. This user-centric approach guarantees that the technology is genuinely effective and user-friendly.

Figure Out's innovation lies in its capacity to facilitate sign language translation in real time. This is a critical feature that distinguishes it from other translation tools available in the market, which primarily focus on text or spoken language. The application's real-time translation capability sets it apart, making it an invaluable tool for those who rely on sign language for communication. It addresses a wide array of scenarios where translation needs arise, such as reading public transportation signs,

timetables, tickets, receipts, and even restaurant menus.

It's worth noting that Figure Out builds upon the foundation of VirtualSign technology. This is a groundbreaking technology developed to bridge language gaps, specifically in sign language communication. It allows written text and spoken language to be converted into sign language, reducing the barrier between spoken and sign language. The technology supports various sign languages, making it adaptable to users' preferences. One notable feature is its real-time translation capability, enabling on-the-fly communication. The user-friendly interface ensures accessibility for individuals with varying technical expertise. Virtual Sign has made a significant impact in education, facilitating access to educational materials for deaf students. It also improves communication access in everyday life, cultural venues, and promotes inclusivity and accessibility. Figure Out, an extension of VirtualSign, integrates real-time image-based translation and mobile diary functionality, providing a comprehensive solution for the deaf community (Escudeiro et al., 2011; Escudeiro et al., 2013; Oliveira et al., 2019).

### 3.1 Objectives

The Figure Out application's primary goal is to streamline information access, thereby improving accessibility, inclusivity, and communication, particularly between the deaf and non-deaf communities. With Figure Out, users can access information in their preferred language, leading to numerous effects across various societal aspects:

1. **Cultural Inclusion:** Navigating cultural venues and accessing information in museums, art galleries, and other cultural settings can be challenging for deaf individuals. Figure Out provides a bridge, enabling them to understand the information displayed, thus ensuring that cultural experiences are inclusive and enriching for all.
2. **International Mobility:** Tourists and international students frequently encounter language barriers when traveling or studying abroad. Figure Out acts as a language companion, facilitating access to essential information and improving the overall experience of international mobility.
3. **Reducing Communication Barriers:** With Figure Out, the divide between the deaf and non-deaf communities narrows significantly. Communication between these groups

becomes more accessible, fostering understanding and social cohesion.

To enhance achievement, the Figure Out Project involves planning, designing, constructing, and implementing a comprehensive system that integrates a mobile application and website. This system facilitates the translation of written words into various formats, including written, audio, and sign language. The mobile app records translated words along with GPS data for analysis. The website complements the app by offering users access to usage statistics. Thus, its primary objectives are as follows:

1. **Website Development:** The creation of a website to promote the Figure Out tool and enable users to analyse usage statistics. This includes insights into translation frequency and the geographical locations where the application is most frequently used.
2. **Mobile Diary Integration:** The project aims to allow participants to create diary entries, termed the "Mobile Diary," at any time and from any location using their mobile phones. This can be achieved through various means, such as spoken messages, pictures, videos, or text messages. A wide range of associated data, including voice message transcriptions, audio files, timestamps, geo-tags, participant IDs, and message durations, will be collected for analysis.
3. **Real-time Data Collection:** The Figure Out system will facilitate real-time data collection, enabling rapid iterations of the tool and research methods. Automated messages and push notifications will be sent to participants to encourage timely entries and ongoing participation.
4. **Data Analysis and Reporting:** The system will offer capabilities for analysing and reporting collected data, allowing for a deeper understanding of user interactions and usage patterns.
5. **User Support and Differentiated Interfaces:** The Figure Out system will cater to four distinct user types, including administrators (both technical and managerial roles), content specialists, mobile diary users, and casual unregistered browsers. Each user type will have a tailored interface and language preferences, with adaptable message strings for easy translation.
6. **User Registration and Content Submission:** User registration will be mandatory for leaving comments and submitting additional

information. Content specialists will review and approve or reject submissions. Detailed guidance on tool usage and available functionalities will be provided.

7. **Data Storage and Retrieval:** Submissions of additional information, such as photos and videos, will be stored in dedicated directories on the server, with comprehensive characteristics stored in the database. The system will also feature an exploratory interface for efficient information retrieval.
8. **Data Size Management:** Restrictions on data size for videos and high-definition media will be adjustable based on user profiles, ensuring a seamless and personalized experience.

The Figure Out Project is poised to deliver a robust and user-centric system that promotes translation and interactive communication. With a multifaceted approach, it addresses various user needs and preferences, leveraging real-time data collection and analytical capabilities. By providing multilingual support and enabling easy data translation, Figure Out aims to enhance accessibility, user engagement, and the overall user experience in both mobile and web environments.

## 4 TECHNICAL RESOURCES

Acknowledging the need for technical knowledge in mobile development, a framework with substantial code reusability for both platforms was selected. After analysing available options, PhoneGap was chosen as the preferred solution.

### 4.1 Frontend Technology

When it comes to fulfilling the front-end requirements of a software development project, there are typically two main aspects to consider: the application and the website. These two components may have different goals and requirements, but they both play crucial roles in delivering a cohesive and user-friendly experience to the end-users.

To begin the application development, we decided to use Ionic. This open-source SDK is specifically designed for hybrid mobile application development, which means that it enables developers to create mobile apps that can work seamlessly on both Android and iOS platforms. This is a significant advantage, as it allows us to reach a wider audience with our application without having to invest in separate development efforts for each platform.



One of the key benefits of using Ionic is that it allows developers to create mobile applications with minimal changes. This saves time and effort, as we can reuse most of the codebase across different platforms, while still maintaining a consistent user interface and experience. Additionally, Ionic also supports the creation of desktop websites, which means that we can leverage the same technology and skills for multiple purposes.

Moving on to the website development, we opted for Angular as our framework of choice. This decision was based on several factors, including the fact that Angular is similar to Ionic in many ways, which makes it easier and faster for our developers to work with. Since most of our development team already had experience with Angular, we could hit the ground running with our website development efforts.

Angular is a popular open-source framework for building dynamic web applications. It is based on TypeScript, a superset of JavaScript that adds static typing and other features to the language. This makes it easier to write and maintain complex codebases, as well as enabling better tooling and refactoring capabilities. With Angular, we can create responsive and interactive websites that can adapt to different screen sizes and user inputs, while still being performant and scalable.

## 4.2 Backend Server and Technology

For the project's backend requirements, the team decided to implement a NodeJS server due to its widespread use and comprehensive documentation. This choice enables the establishment of a centralized system, enhancing control and maintenance of REST API routes. In terms of data storage, Firebase was chosen for its reliability, security features, and the existing expertise within the development team.

## 4.3 APIs, Libraries and Framework

In order to successfully complete this project, it is essential to have access to a wide range of APIs, frameworks, and libraries. These tools will enable us to create a high-quality final product that meets the needs and expectations of our clients.

One of the key components of this project is the creation of a promotional video. To accomplish this, we will be utilizing Adobe software, which has proven to be a reliable and effective tool for creating visually stunning videos that capture the attention of viewers.

Additionally, we will be leveraging Google's APIs to capture text with a camera, convert text to audio,

and translate text into different languages. These APIs are widely regarded as some of the best in the industry, and we are confident that they will help us to deliver a final product that is both accurate and accessible to a diverse audience.

Finally, we will be utilizing the Virtual Sign translator to translate text into sign language. This innovative tool uses advanced algorithms and machine learning techniques to accurately translate text into sign language, making it accessible to individuals who are deaf or hard of hearing.

## 4.4 OCR Integration

The application needed to run on Android and iOS and include an OCR tool for image to text recognition. However, integrating an OCR tool with the chosen framework proved to be difficult. Testing with different OCR tools showed incompatibilities, leading to exploring a new framework, Xamarin. Unfortunately, the available OCR tools were not compatible with Xamarin.

## 4.5 Native Development

The team created a Windows Phone application, which allowed them to conduct a rapid test using native development, despite it not being a requirement. The results of this test confirmed that integrating native capabilities and utilizing an OCR tool is the most advisable approach. Furthermore, it provided additional evidence to support the findings obtained from the OCR search, which consistently indicated the superiority of native OCR for both Android and iOS platforms.

## 4.6 System Architecture

Originally conceived as a centralized web service, Figure Out ensures continuous access to data and resources across three logical layers: UI, Server, and Data. The UI layer engages users through the mobile app or website, with the web service layer managing UI requests and translation. The data layer functions as a persistence mechanism for statistical purposes.

Technology choices were made based on the team's expertise, utilizing Ionic for the mobile app's cross-platform support, Node.js and Express for the backend server, and Firebase for the database, facilitating push notifications and user management. Additionally, the VirtualSign API is employed for converting text to sign language (Figure 1).

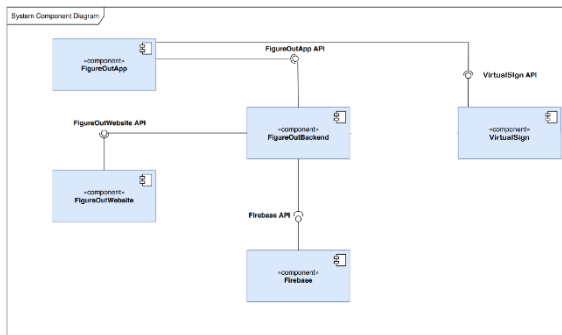


Figure 1: Logical Architecture.

#### 4.7 The FigureOut App

The Figure Out mobile application is designed to be user-friendly and intuitive. The prototype mock-ups have been meticulously crafted to ensure a smooth and seamless user experience.

The application workflow is straightforward and easy to follow. Users simply need to capture a photo using their mobile camera, configure the translation process if necessary, and proceed to translation. The app homepage provides direct access to the translation feature, making it even more convenient for users to get the translations they need.

In addition to translation, the app also provides users with access to the About page, which offers more information about the FigureOut webpage and other features. This makes it easier for users to learn more about the app and its capabilities.

When a user starts a translation procedure, the app directs them to take a picture of the text they wish to translate using their mobile camera. The application then identifies and isolates the text area detected in the photo and presents it together with the configuration panel. Users can choose to use the default configuration or reconfigure each translation according to their specific needs. This involves choosing the languages pair and the output format. The app offers three output formats, giving users plenty of flexibility and options.

For those who prefer typing over capturing images, an input field is also available. Users can simply type in the sentence they wish to translate, and the app will take care of the rest.

Overall, the Figure Out mobile application is a tool for anyone who needs quick and accurate translations on the go. Its user-friendly design and intuitive interface make it easy to use, while its advanced features and options offer plenty of flexibility and customization.

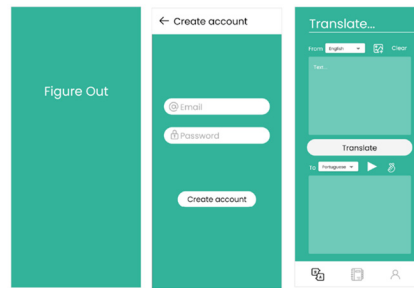


Figure 2: Mobile Application.

## 5 PROJECT EVALUATION AND QUALITY SCENARIO CONTROL

The project evaluation adhered to a methodology that incorporates the assessment of functionality and user experience to gauge the quality scenario. This evaluation process was underpinned by a framework known as QEF (Quantitative Evaluation Framework). QEF is designed to quantitatively measure the quality of the system under development (Escudeiro & Bidarra, 2008; Escudeiro & Escudeiro, 2012; Heidari & Loucopoulos, 2014).

The quality scenario, structured within the QEF framework, consists of three key levels: dimensions, factors, and requirements. Each dimension encompasses a group of factors, and each factor comprises a set of specific requirements (Escudeiro & Bidarra, 2008; Escudeiro & Escudeiro, 2012; Heidari & Loucopoulos, 2014).

### 5.1 QEF Dimensions, Factors and Requirements

The quality assessment of the Figure Out System, based on the QEF framework and ISO 9126 standards, comprises three dimensions: Functionality (F), Adaptability (A), and Efficiency (E). Functionality dimension encompasses four key factors, which are functional aspects, user interaction, content quality, and connectivity. The Adaptability dimension consists of two factors, namely versatility and maintenance. Efficiency encompasses three factors: strength, consistency, and integrity (Escudeiro & Escudeiro, 2012).

The functional factor includes critical aspects such as language selection, navigation, sign language avatar reproduction, and translation capabilities.

User interaction focuses on intuitive design and consistent experiences across Android and iOS

platforms, incorporating features like a scoreboard and statistics view.

Content quality emphasizes organized information presentation, adherence to grammar principles, and relevance to the product's purpose.

Connectivity addresses the system's interaction with external resources, while versatility ensures compatibility with various platforms and devices.

Maintenance involves regular updates and hardware upkeep, and strength, consistency, and integrity contribute to the system's structural integrity, reliability, and security.

Each requirement is evaluated using predefined values, minimizing ambiguity in the assessment process. Some are assessed with binary results (0% or 100%), while others use a Likert scale ranging from 1 to 5. To minimize ambiguity in the evaluation process, each requirement is clearly defined with its associated assessment levels.

## 5.2 Evaluation Methodology

The project team, committed to a comprehensive and thorough product development process, conducted multiple assessments at key points in the product development lifecycle, including alpha testing, beta testing, and a final evaluation (Escudeiro & Bidarra, 2008). To ensure the product met the highest quality standards, they employed QEF, which provided a systematic and objective evaluation based on questionnaires. These questionnaires were administered to students in a multimedia program, ensuring diverse perspectives.

The testers, selected for their experience with mobile applications, followed a standardized protocol involving various tasks such as account registration, viewing promotional content, executing translations, and providing feedback on their experiences. A significant majority (73%) of the testers used Android devices, and the team was confident in their representativeness for the target audience.

Overall, the project team was pleased with the results and positive feedback from testers. The product met predefined quality scenario requirements, and the team was confident that it was ready for release.

Testing a new application or software product is crucial to thoroughly evaluating its features and functionalities. In this context, actively engaging with the application's features and functionalities, including reviewing diary entries, is essential to comprehensively answering assessment questionnaires. This framework leverages the degree of fulfilment of underlying requirements to calculate

a quality value, representing the percentage of achievement by the current version compared to an ideal solution.

This approach ensures a clear and quantifiable assessment of the product's quality throughout its development lifecycle. By measuring the degree of fulfilment of underlying requirements, QEF identifies areas that may need improvement, allowing the team to address them before releasing the product to the market. The commitment to delivering a high-quality product is reinforced through a nuanced understanding gained by exploring features thoroughly and engaging with tools during the testing process.

## 5.3 Evaluation Results

Throughout the project duration, FigureOut has demonstrated a significant improvement in overall quality, aligning with anticipated milestones. Progress was meticulously evaluated at key stages, revealing substantial growth over time. A comprehensive assessment of cumulative quality across various dimensions yielded positive outcomes: Alpha testing at 76%, Beta testing at 77%, and a final assessment at 96%.

Recognizing the critical role of the software testing process in delivering a high-quality product that aligns with user requirements, a phased testing approach was adopted. The marginal quality improvement from Alpha to Beta testing (76% to 77%) indicated the potential for further refinement in features and functionality. Encouragingly, significant enhancements were observed from the Beta to the final version, notably in the Functionality dimension with a remarkable 67% improvement. Efficiency improved by 31%, and Adaptability by 16%.

The positive trend reflects a concerted effort in prioritizing non-functional requirements to create a robust platform supporting essential functional features.

Ensuring product reliability and efficiency, aligned with user needs, remains a paramount focus. Acknowledging the continuous nature of evolution from Alpha to Beta testing and the final version, pride is taken in significant strides achieved. While recognizing room for improvement, the commitment is unwavering in addressing both functional and non-functional requirements. This dedication ensures the delivery of a product of the highest quality, surpassing user expectations for a successful outcome.

## 6 CONCLUSIONS

Figure Out stands as an assistive technology crafted with the purpose of reduce communication barriers commonly faced by everyday users. The technology offers users access to information in their native language, which is expected to revolutionize the way people communicate and interact with each other.

The application has been specifically designed to foster the inclusion of those for whom sign language is their primary means of communication. By integrating national sign languages and International Sign, the technology ensures that all users can communicate effectively, regardless of their language or communication preferences.

As part of its ongoing development, Figure Out is continually working to enhance the user experience. This includes the creation of a more appealing visual identity, which will make the technology more appealing and user-friendly. Additionally, the integration of additional sign languages will further expand the reach of the technology, enabling more people to benefit from its innovative features.

Overall, Figure Out is a game-changing technology that has the potential to greatly improve the daily lives of millions of people around the world, by contributing to the creation of a more interconnected and accessible society.

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