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AN INCLUSIVE EDUCATIONAL TOOL

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ABSTRACT

Communicating in languages other than one's mother language is a demanding task. Even when mastering basic skills in a foreign language, communication is challenging unless you are a frequent user. The vocabulary and grammar rules tend naturally to be forgotten over time. This is even more critical when distinct channels are used by one's mother language and a given foreign language; this is the current setting when communication among deaf and non-deaf users is undergoing, even in the same country. We expect that the use of technology may assist users in such cases, notably through the Figure Out application. Figure Out is a mobile application designed to translate text, automatically captured by the mobile camera, to a given language. This application will allow translation from and to any language, including sign languages. The aim is to enable everyday users like, students, and all individuals to access information in their first language or the one they choose. By simplifying access to information, the application will improve accessibility, inclusion, and communication, namely between the deaf and non-deaf communities. With Figure Out it is possible to enhance the access of, students, tourists, and the deaf population to education, culture, and international mobility while reducing communication barriers.

KEYWORDS

Educational Communication, Inclusive Technology, Automatic Translation, Accessibility, Inclusion.

1. INTRODUCTION

In this paper, the authors suggest an alternative for the already known translators. The aim is to overcome limitations these may have with other precise solution, which enables translation in real-time through an image containing small parts of the text. This innovative, full-developed and tested technology not only allows individuals to read or hear the translation in the default language but also allows deaf individuals to understand the message through visual capture. No application on the market meets the features of Figure Out gathering optical text recognition from a captured image and converting it to text, audio, or sign language (Escudeiro, et al., 2017).

This application is designed to help everyone interested in communicating autonomously and in their first language, since communication between people who do not share the same language can be a challenge, whether their spoken language users or sign language ones.

Sign language faces low diffusion among the hearing community, making this assistive technology helpful for the deaf community when using services and infrastructures, visiting cultural venues, or reading text information, and even for deaf students by allowing them to use the same educational written material as their classmates. The same happens with Erasmus students, that can be certain that access to information will not be an obstacle by relying on this application.

2. ACCESSIBILITY AND INCLUSION

Foreigner environment "is not always accessible or inclusive (…) due to its barrier-laden and socially exclusive nature" (Gillovic & McIntosh, 2020). When talking about an inclusive foreigner environment we cope with

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the need to reduce uncertainty for everyone who comes to visit us, ensuring that they are welcomed and supported, even if the host does not know sign language (Santa, 2020).

This will ensure that everyone can take advantage of learning and education, using services and infrastructures, visiting cultural sites, or accessing information independently and without the need for adaptation (Gillovic & McIntosh, 2020).

By promoting social inclusion and accessibility, communication between the deaf community and others will be improved (Escudeiro, et al., 2015). That is the aim of Figure Out.

2.1 The importance of Translation

Figure Out is not limited to users that travel outside their own country; the mobile application is helpful to every deaf who cannot easily access information, since it is designed to be multilingual and allow translation to Portuguese Sign Language.

By enabling translation to Portuguese Sign Language, this tool mediates communication, creating a relation of equivalence between two different languages thus overcoming communication barriers (House, 2016).

To do so, the Figure Out project exploits our previous experience in automatic translation of sign languages to develop a unique innovative tool that will boost an inclusive cultural environment addressing the deaf through the Inclusive Cultural Heritage Tourism (ICHT), project number POCI-01-0247-FEDER-69949. Developing an inclusive cultural environment will open doors to a significant share of global worldwide strategy for the cultural sector (Scheyvens & Biddulph, 2017).

3. METHODOLOGY

Figure Out aims to promote accessibility for all into our cultural heritage. Figure out is focused on creating digital tools and digital content in different languages, including sign language, to be available online, and on a mobile device.

A methodology was implemented to guide the implementation of the augmented reality application to promote cultural heritage sites in sign language. Figure Out provides an online collaborative platform to support the touristic process from end to end (promote/raise awareness, visit, follow-up/feedback).

3.1 Concept

The mobile application was developed to translate small pieces of text captured as an image to any given language in an augmented reality scenario. The output is also reproduced as speech. The language of the signs can be from any language. The translation is to be made to some predefined language selected by the user. The translation should be reproduced on the augmented reality application to text, sound, and sign language for deaf people. The reproduction of sign language must be implemented for any Sign Language. With the mobile diary, tool participants are enabled to quickly make diary entries whenever and wherever they use their mobile devices. This way, participants can easily document their current thoughts, actions, and surroundings. This tool should support mobile context-based co-creation in different development phases, including their prototypical technical realization and experiences of their practical application. The aim is to use this tool in a Living Lab. A Living Lab is an open innovation environment where users are integrated into the innovation process as much as possible. The best would be to get all relevant user information (ideas, feedback, concepts) from a real-world environment (not in a lab).

Thus, this mobile application is an innovative feature that allows deaf users to access information in sign language by capturing an image that contains written text of any kind. This technology is different from other options on the market that only allow the translation of written text or speech, and not from a real-time captured image.

The target audience is the daily users that want to read signs in a language different from their own. This way they can understand the signs and get continuous assistance from this mobile application. There are many situations where the user will require this kind of assistance, like translating small text snippets, reading text information from public transportation signs, timetables, tickets, receipts, or even restaurant menus (Escudeiro, et al., 2017).

Figure Out was created on top of the Virtual Sign technology, a full-developed translator that allows translation of the text to sign language (Escudeiro, et al., 2011).

3.2 Objectives

The scope of the Figure Out Project is to plan, design, build, and implement a system composed of a mobile application and website that enables the translation of written words to a given language.

The translated results may be presented to the mobile application users in written, audio, or sign language.

The mobile application records the word translated and the GPS position where the application was used and then these data are stored in a central database for statistical purposes.

Users can then access a website and check the stats about the application usage, such as most translated words and countries where the application is most used. Translation can be achieved with third party APIs.as for the application development, as the team has no mobile programming skills, this will be achieved with a cross-platform code generating framework using web APIs.

The scope of this project includes all requirements gathering, planning, design, development, and implementation of the Figure Out tool. In concrete, Figure Out pursued the following specific objectives:

- Development of a website to promote the product (the Website should allow the users to analyze usage statistics, analyzing the frequency and the place where the Figure Out application was used).
- Allow participants to create diary entries (Mobile Diary) at any time, from any place where they have their mobile phones, either by leaving a spoken message, picture, video, or sending a text message (a call results in multiple pieces of related data: e.g., a transcription of the voice message, an audio file, a timestamp, geo-tag, the participant ID, and the duration of the message, etc…).
- Collection of results in real-time, allowing for quick iterations on the tool and research method. This is great for customizing to individual studies (automated messages, e.g., push notifications, are sent to participants as gentle reminders to prompt an entry as well as to encourage ongoing participation).
- The possibility to analyze and easily report the data, after collecting the data.
- Support four different user types: administrator (technical and management), content specialist, mobile diary related users, casual browsers (unregistered general audience).
- Different application interfaces (layout) according to the user type. Interface language according to the user lingo. Message strings are stored in a way that allows easy translation.
- User registration is required for commenting and for submitting additional information (on submission the content specialist confirms the additional information and accepts or refuses the submission).
- Figure Out provides information on how to use the tools and the functionalities available to the user.
- The submission of additional information (photo, videos, …) will be stored in a directory on the server. All characteristics of these submissions will be stored in the database.
- Exploratory interface (search and retrieval of information given specific needs).
- Restrictions on data size, for videos and high-definition sound and images are adjusted to the user profile.

4. TECHNICAL RESOURCES

Given the technical knowledge required for mobile development, we saw fit to choose a framework that could serve both platforms simultaneously and with the most code re-usage possible. From the analysis of the available platforms, we ended up choosing PhoneGap.

4.1 Frontend Technology

The Front-end requirements can be divided into two main parts. The application and the website. Starting with the application development, we choose Ionic. Ionic is an open-source SDK for hybrid mobile application development. In simple terms, it can be used to create mobile applications, for both Android and iOS, with minimal changes, and create desktop websites, again with minimal changes to what has been done before. Regarding the website we choose Angular, as it is similar to Ionic because it is based on the same framework, making it easier, faster for the developers and most of our developer team already knew the technology.

4.2 Backend Server and Technology

Regarding the backend requirements, the team has a NodeJS server providing all the REST API routes to both our Application and Website. This way they have a centralized system, in which they have more control and easier maintenance. The reason for choosing NodeJS is that is widely used and quite easy to work with and find documentation. To store our data they choose firebase, given that some of our development team already had contact with the technology they found it appropriate to include.

4.3 APIs, Libraries, and Framework

This project requires a lot of APIs, frameworks, and libraries. For example, they will be using Adobe for the making of the promotional video, has it been a widely used software for this purpose. For capturing text with a camera, text to audio, text translation, they will use Google´s APIs. To translate from text to sign language it will be used the Virtual Sign translator (Escudeiro, et al., 2013).

4.4 OCR Integration

Added to the fact that the application should be able to run in both operating systems, Android and iOS should also be able to implement an OCR tool for the image to text recognition. Given the framework limitations compared to native development, the choice for an OCR was scarce and proved to be more difficult than anticipated.

After several types of testing with different OCR tools, we concluded that such tool integration with the chosen framework was not feasible. There were several types of incompatibilities and problems when trying to find a suitable OCR that worked suitably on its own, let alone being capable of working together with PhoneGap.

Given the situation, some new tests were made with a new multi-platform framework, Xamarin. This framework is based on C#, so the difference and availability of a new kind of OCR tools pointed that a new path could be opened. Sadly, although there are at least two fully functional and free OCR tools that work very well when running natively in operating systems like Windows or Windows Phone, they were not compatible with Xamarin.

4.5 Native Development

Even though the team lacked technical knowledge for complete native development, there was knowledge to build an application for Windows Phone, which regardless of not being in the requisites, was an opportunity to make a quick test with native development.

That test proved that native integration and availability of an OCR tool is by far the most recommended path to follow. It also added more proof to the information retrieved from the OCR search, which constantly pointed to native OCR for both Android and iOS platforms.

4.6 System Architecture

Figure Out was initially conceived to be centralized in a web service made available constantly and responsible for providing access to both data and resources of other components. We devised a 3-layer logical architecture, divided into UI, Server, and Data. The user interface is the layer that interacts with the user, through the mobile application or website. The web service layer is where the UI requests are attended, and the translation process takes place. The data is a persistence mechanism built for statistical purposes.

The technologies that were chosen for the development of the project were carefully selected to address the development team skills (figure 1).

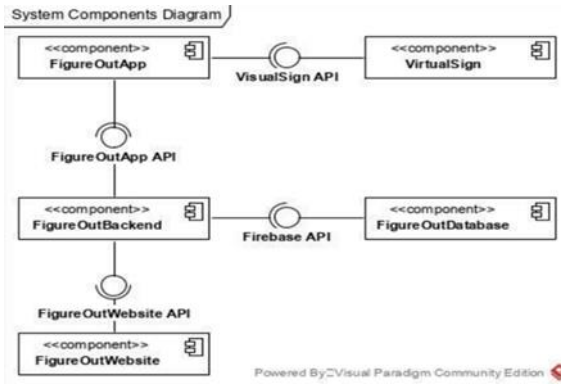

Figure 1. Logical Architecture

The technology selected for the development of the mobile application was Ionic, because of its cross-platform and the support of Android and iOS platforms. The development of the functionalities of the capture of images, text conversion to audio, and text translation to another language, can be developed with the use of Ionic plugins. For the sign language view, the VirtualSign API (Oliveira & Escudeiro, 2018) is going to be integrated with the mobile application, to allow the conversion of text to sign language.

The backend server was developed in Node.js and Express, allowing for the fast creation of a web server to communicate with the database and the Figure Out mobile application. For the database, it was used Firebase, allowing to push notifications to the mobile application and manage users.

4.7 The FigureOut app

The figure out mobile application aims to be intuitive so it can be used without training or any significant cognitive effort. The prototype mock-ups demonstrate the usage workflow: capture a photo using the mobile camera, configure the translation process if distinct from the default configuration previously set by the user, and proceed to translation.

The app homepage gives direct access to the translation feature in a straightforward way. From the homepage, the user may also access the About page providing access to the FigureOut webpage and additional information.

By starting a translation procedure, the user is directed to take a picture of the text to be translated with the mobile camera. The application will then identify and isolate the text area detected in the photo and present it together with the configuration panel. The user has a chance to use the default configuration or reconfigure each translation according to specific needs. The configuration of a translation involves choosing the languages pair and the output format. The output format is chosen from the three available alternatives.

An input field is also available so the user can type in the sentence to translate instead of capturing it using the camera.

5. PROJECT EVALUATION AND QUALITY SCENARIO CONTROL

The project evaluation followed a methodology that consists of functionality and user experience evaluation to assess a quality scenario. This is achieved with the quality efficiency framework.

The framework is called QEF (Quantitative Evaluation Framework). QEF will measure quantitatively the quality of the system being developed.

The quality scenario created was supported by the QEF framework and consisted of three major levels: dimensions, factors, and requirements. Each dimension aggregates a set of factors, and each factor includes a set of requirements.

The questionnaires which have supported the evaluation process at the Usability Dimension were based on System Usability Scale (SUS). It consists of a 10-item questionnaire with five response options for respondents; from Strongly agree to Strongly disagree (Brooke, 1995).

5.1 QEF Dimensions, Factors, and Requirements

The quality scenario for the Figure Out System measured with the QEF framework includes three main dimensions: Functionality (F), Adaptability (A), and Efficiency (E) (ISO 9126). The Functionality dimension is composed of four factors: functional, user interaction, content quality, and connectivity. The Adaptability dimension is composed of versatility and maintenance. Efficiency aggregates three factors: strength, consistency, and integrity (Escudeiro & Escudeiro, 2012).

The requirements identified for the quality scenario factors were:

- Functional: select the primary language; select the secondary language; navigation/position coordinates capture; avatar reproduction of sign language; audio reproduction of audio translation; translate capture to selected secondary language; download APP Android from the website; download APP iOS from the website; download User Manual from the website; language translation working on the website;
- User Interaction: android application is intuitive; iOS application is intuitive; applications have the same design in both versions; applications have the same navigation experience in both versions; scoreboard/statistics view - top five most searched words. scoreboard / Statistics view - top five highest usage countries; scoreboard/statistics view – topmost searched words in a certain period; scoreboard/statistics view – topmost searched countries in a certain period; scoreboard/statistics view - most searched word (the user can access the scoreboard/statistics view most searched word).
- Content Quality: all product information is well organized (all product information must be divided into functional areas); texts are well written and all the sentences make perfect sense (annexed standards) (the sentences are short and fulfill elementary grammar principles); all messages are easy to understand and human personified (no message presents illegible codes or similar codification form); all the contents are related to the product (all application contents must be strictly related to the product and present no dummy or irrelevant data);
- Connectivity: peripherals use permission (camera); peripherals use permission (GPS); peripherals use permission (internet); access audio repository (communication between applications and Google API); access storage repository (communication between applications and server while sending post request); Image capture (applications can capture the text on the image)
- Versatility: different desktop browsers compatibility (the application works correctly with different desktop browsers); different mobile browsers compatibility (the application works correctly with different mobile browsers)
- Maintenance: Adding the possibility of new features (Applications can add new features (for example the language))
- Strength: product has a good structure and allows users to access contents in an intuitive way to the main functions (each application has menus that allow the user to have an intuitive experience of usage); the application user interface is quick and fast responsive (the application does not freeze or lock when the user is working with it).
- Consistency: continuous operation (the application works continuously with other tasks, e.g., a call); outputs according to user inputs (the application responds according to what the user expects); all applications have a consistent audio and video experience (audio and video reproduction are timed with the operation); contents related with the product (the contents of the application meet the user expectations, meaning that they are what they should be from the user perspective).

The fulfillment level for each one of these requirements was discretized to pre-defined values that depend on the requirement. Some are simply assessed with either 0% or 100%, others rely on a 1-5 Likert scale, others are assigned to 3 (0%, 50%, 100%) to 5 percentage thresholds, such as 0, 25%, 50%, 75%, 100%. To reduce ambiguity when filling in the evaluation questionnaires all these levels are characterized for each requirement.

5.2 Evaluation Methodology

The project team assessed the product under development at several moments during the development lifecycle, including those reported here: alpha testing, beta testing, and final assessment. QEF provides a clear, quantitative view of the quality of a product at any stage during its development. The evaluation was based on a set of questionnaires that were designed to assess the requirements foreseen in our quality scenario (Escudeiro & Bidarra, 2008).

These questionnaires were answered by a group of twenty-two students from the Multimedia and Graphical Systems Master program from the School of Engineering of the Polytechnic of Porto. This controlled validation group used both Android and iOS mobile devices. The majority (73%) used Android. The concrete equipment used by each tester was not recorded. The following test protocol was settled and followed by all participants in the assessment:

1. On the website, create an account.
2. Watch the promotional video.
3. Scan/read the user manuals.
4. Download and install the mobile application.
5. On the mobile application, login with the previously created account.
6. Perform a text-to-text translation.
7. Use the video/image capture feature.
8. Perform a translation of the video/image captured before.
9. Provide feedback for the actions performed above.
10. Send a diary entry of any format.
11. Check the diary entries available.
12. Go further on using the application and exploring its features to provide answers to the assessment questionnaires

QEF uses the level of fulfillment of its underlying requirements to compute a quality value that lies between 0% and 100%. This quality corresponds to the percentage of achievement of the current version of the product in comparison to an ideal/perfect solution. The ideal solution is a system that fulfills at 100% all its requirements.

5.3 Evaluation Results

The overall FigureOut average quality, measured at each one of the formal evaluation moments, improved, as is expected, as the project evolves:

- Alpha testing: 76%
- Beta testing: 77%
- Final assessment: 96%

The overall quality is an aggregation of the quality measured at each dimension (Table *1*).

Table 1. Quality measurements

Evaluation moment	F	A	E	Overall
Alpha	51%	85%	74%	76%
Beta	53%	86%	74%	77%
Final	87%	100%	97%	94%

The evolution of the quality of the product between Alpha testing and Beta testing is marginal, from 76% to 77%. The improvements implemented from the Beta version to the last version are already significant. The boost was assured mostly by the Functionality dimension that improved 67% from the Beta version to the production version; Efficiency improved 31% while Adaptability improved 16%. This might indicate that the development team started pushing for the non-functional requirements – aiming to have a sound platform able to support the required functional features – before investing efforts in the functional requirements.

The features that are not fully met at the current version are:

- FF10 – Website – Applications can be downloaded from the website
- FF23 - Application - Replace text to the selected translation language in real-time (AR)
- FUI01 - Website – The website is intuitive
- FUI02 - Application - Android application is intuitive
- FUI03 - Application - iOS application is intuitive
- FUI06 – Application – Reduced sensory overload in AR view
- FCQ04 - Promotional Video - The storyline must be composed of two friends that go on a trip

- FCQ05 - Promotional video - Includes taxi receipt, airport sign, train station timetable, metro station placard, restaurant menu
- FCQ06 - Promotional video - Includes Portugal, UK, Slovenia, Cyprus, Greece, Germany, and Brazil
- EC05 - All applications have a consistent audio and video experience

6. CONCLUSIONS

Figure Out aims to cope with communication barriers of everyday users, by enabling access to information in their first language. This simplified access will improve the daily life of any tourist or individual such as a deaf student who finds it challenging to communicate in a language other than their own.

The development of this assistive technology serves not only as means to facilitate communication for everyone but also to promote the inclusion of those who use sign language to communicate and constantly strive to understand and to be understood.

We are evolving the current version of FigureOut in two fields: designing a more appealing visual identity and adding more national sign languages and International Sign into it.

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