Accessibility-as-a-Service an Open-Source Reading Assistive Tool for Education

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Abstract: As technology evolves, more and more articles and materials are readily available on the internet for the world to use. This project proposes and demonstrates the implementation of an application to further increase the accessibility of web pages, through the use of image recognition techniques, object detection, and optical character recognition (OCR). The proposed application allows users to input URLs and the application will process the web page in under a minute and outputs a modified web page with translated words detected from images.

Keywords: Accessibility assistive technology, anything as a service (XaaS), optical character recognition (OCR), open-source education package

1. Introduction

To get the latest events and happenings around the world, as humans, we rely on news to get updates. Traditionally, people read the latest news from the newspaper or books for research. As of current, the internet is part of everyone's daily lives. With technology, many new ways of reading news articles emerge. One of the ways is through websites. It helps to connect people around the world with news, materials for school projects, e-commerce, and more. With websites, it enables easy access from anywhere to the latest news around the world to the public. Similar to research papers published online, readily available.

As time goes by, more and more web pages will be added to websites with updated news and content. As of 18th June 2021, there are over 1.86 billion websites online with more than 547,200 new websites created globally every day [1]. In addition to web pages, companies may have a lot of physical documents archived within the company. To keep up with modern trends, and to save physical storage space, companies will want to convert their physical documents to digital.

Many web pages include images associated with the article and provide additional context. Printed documents and images take up more space than text. It may cause some trouble for companies to store, archive, or search documents and webpages, as the websites may take up a lot of space. Another issue is newspapers and online news articles are usually presented as visual media. it is mainly written in plain texts and images related to the article. It is inaccessible to people who are visually impaired or blind. For the visually impaired to read, Braille is used for the visually impaired where they can use their fingers to read from a series of raised dots [2].

Many technologies are in the market to aid visually impaired users. Using other human senses of hearing,

one such technology is Text-To-Speech. It helps in translating plain text to voice, using Artificial Intelligence (AI). The visually impaired people can listen to the converted text instead of reading [3].

There are different types of visual disabilities. There might be visually impaired people who may still be having the ability to read the text but might not be able to view images due to color blindness or blurred vision [4]. To combat these problems, there are several Artificial Intelligence (AI) technologies available to read and translate these images to help companies in easy searchability and reduce the storage space of their documents and websites. It also lets the visually impaired know the message of what the images trying to convey. Image Recognition technologies help in detecting and translating images to plain text.

2. Literatures

2.1. Background

News is one of the essential parts of communication. It keeps humans informed of the ever-changing events happening around the world. In the past, one of the most common forms of relaying the news to people in newspapers. However, those who are visually impaired or blind, might not be able to read newspapers as it was mainly visual media.

One of the ways to allow visually impaired people to read the news is through audio. In the early days of technology, in [5], adoptive news reading out the application was built to aid visually impaired people. The application comprises 3 modules, especially the speech recognition and text-to-speech synthesis module. The application can be navigated with the use of voice commands via the application's speech recognition module. When the user wants to read the article, the text-to-speech module will convert the news article to a voice for the visually impaired. An experiment was conducted with five people and the result was positive.

With technologies rapidly changing, there are various ways to convert images to text to make the machine easier to read and can be later converted to speech.

2.2. Optical Character Recognition (OCR)

One of the ways to convert images to text is using OCR technology. OCR is one of the common use cases in Deep Learning. OCR analyses the letters and numbers in the scanned images or images with text and converts them into text. It can help convert complex documents fast with few errors [6].

In [7], illustrates the idea of a text recognition system using a portable camera for the visually impaired. The proposed system aims to read printed text, product labels, and more and convert the detected text to speech. It uses binarization and filtering to remove the background of the images, only leaving the detected text. With the text remaining, the system will perform OCR to identify the text found in the images and outputs in plain text.

OCR can help with converting hardcopy documents to digital for better storage and audit purposes. In [8], it researched the technique of transforming physical documents like scanned documents and hardcopy documents into a digital format using OCR. After processing using OCR, the converted text will be stored in the database for the future to make searching for documents easier.

2.2.1. Limitations

However, translating or recognizing images into text has its limitations. It depends on the clarity of the images. To make OCR perform optimally, need to make sure that the images are clear. Any blurred image may cause inaccuracy in the conversion. In [7], it shows that the system was not able to correctly detect the text due to several reasons. One such reason found was due to illumination problems on the image. The system was not able to detect the text on the image.

In [8], it was found that using the technique of performing OCR on scanned documents has varying accuracy performance. 75.38% for extracting attributes and 66.92% for extracting values from scanned

documents. However, the technology is invaluable for easy search and editing of documents.

A solution to the accuracy problem of OCR, during OCR post-processing, [9] proposed to use Google's Online Spelling Suggestion (GOSS) to find possible word replacements. GOSS has data that contains a lot of terms and word phrases to replace the words in the document for those words that are misspelled. Experiments were conducted and showed that the GOSS helped in detecting and correcting the errors as a pose to the traditional method.

2.2.2. Tesseract vs OCR

There are several OCR libraries available on the Internet: Tesseract and EasyOCR are a couple of popular OCRs. N. Awalgaonkar [10] has tested these two libraries by detecting license plate images, they found that EasyOCR produced better results with accuracy around 90%, compared to Tesseract's which is only 62% in detecting the license plate characters. In additional, EasyOCR provides a more lightweight model with good performance as compared to Tesseract [11].

2.3. Image Recognition

Another way to translate images is through image recognition. Using Machine Learning, image recognition identifies the places and objects and more in digital images. The computer can see the image as numerical values of the pixels in an image to recognize a certain image based on the patterns of the numerical data [12].

In [13], a smart personal AI assistant application was proposed with the image recognition feature as one of its modules. The proposed application is implemented on Android devices. It provides visually impaired users an efficient way to interact with the environment with the help of technology. Using its image recognition feature, captured images are analyzed and the results will be returned with a confidence score.

2.3.1. Limitations

Similar to OCR, the accuracy of the image recognition depends on the clarity and complexity of the image. In [14], the research talks about using Convolutional Neural Networks (CNNs) to perform image classification. The paper talks about several limitations found. To perform image recognition, large training data is required to provide better accuracy. Small data will result in a high difference in training and testing accuracy. In addition, the image accuracy will differ depending on the lighting conditions, the background of the image, and the angles of the image.

3. Methodology

The proposed methodology will be focused on the proposed application development to enhance the accessibility of the online documents to have the ability to translate images into readable text and include it in the online document. The application will be written in Python language. Users will be able to navigate the application with a Graphical User Interface (GUI). The processing of the images will be done at the back-end and the users can export files with embedded results once the processing is done. Below lists the steps and libraries used to build the application.

3.1. Procedure

The below section describes the steps taken in the development of the proposed application.

3.1.1. Reading and extraction of content

Users will need to provide the URLs to the webpage they want to translate from images to text. To read the contents of the webpage, the webpage contents will be parsed using BeautifulSoup. BeautifulSoup is a Python parser library to extract data from HTML and XML files. It helps in navigating and searching for content via HTML elements [15]. Scalable Vector Graphics (SVG) is one of the image formats readable using

the application. However, to allow the image recognizer to read the image, the SVG image is needed to be converted to a different image file format. CarioSVG is a library that converts SVG to PNG images [16]. The images from the webpage will be downloaded and later used for image recognition.

3.1.2. Image recognition

Each image found in the contents of the webpage still needs to be further broken down. Images may contain text or graphical content. Both types of images needed different kinds of image recognition to fully get the information out from the images. The application will process both types for each image.

For images that contain text, OCR is an automated solution to read and convert text within images. One such library available that performs OCR is EasyOCR. EasyOCR is an open-source OCR engine, created by JaidedAI, that uses deep learning to detect text within images. It works by recognizing character patterns from images and can recognize more than 80+ different languages [17].

For the other images, like an image of a car or apple, image prediction is required to detect what is image is illustrating. ImageAI is an open-source Python library that uses a list of Machine Learning algorithms to perform image prediction, object detection and training, and more [18]. The application will perform image prediction, using its built-in 1000 data set, to determine the object the image is close to.

3.1.3. Embed to the original content

Once the translated image results are gathered after the image recognition, the results will be embedded into a new copy of an HTML or PDF file. For HTML, the results can be added with an ALT tag to the image or create a new line below the image showing the translated result. For PDF, the results will be embedded into the content of the webpage or PDF. A new copy of the webpage in HTML or PDF can be recompiled and exported to the local machine.

3.2. Application Workflow

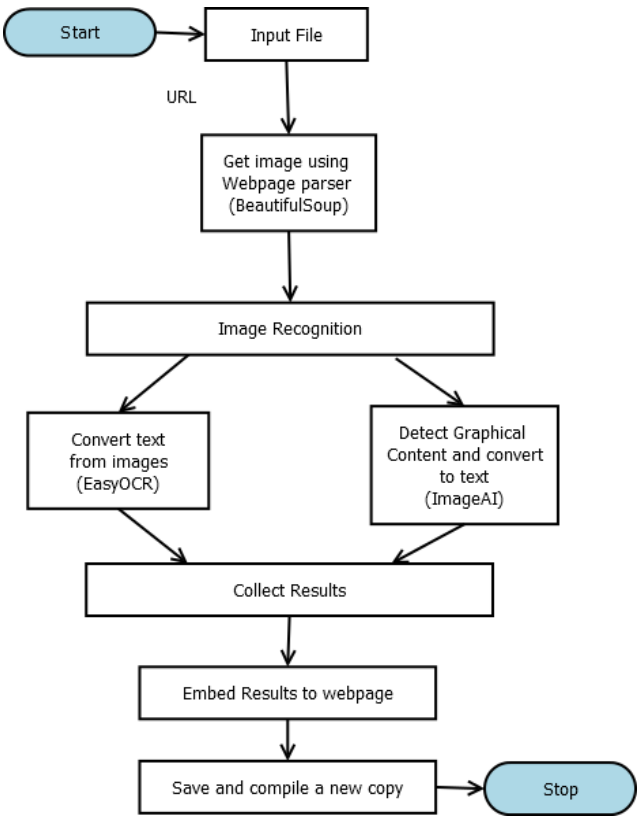

Fig. 1. Magnetization as a function of applied field.

Fig. 1 shows the flow of the proposed application. Upon starting the application, a Graphical User Interface will pop up. Users will need to input an URL link into the application to read the webpage. The webpage content will be parsed using the BeautifulSoup Library The parser will find images within the webpage through the image HTML tags.

Once all images are found, the images will be processed to convert images to text using 2 different libraries. For images containing text like scanned documents or posters, EasyOCR, an OCR library, will be used to recognize the alphabet characters in the image and convert it into readable text. The images also will be processed using ImageAI, an image recognition/object detection library, which performs image prediction to determine what the image is supposed to be and the objects within the image.

After images are processed and translated results are returned, the results will be embedded back into the webpage below each image of the webpage content. The webpage will be recompiled and generated to a modified copy of the original webpage and a text-only version of the web page.

3.3. Use-Cases

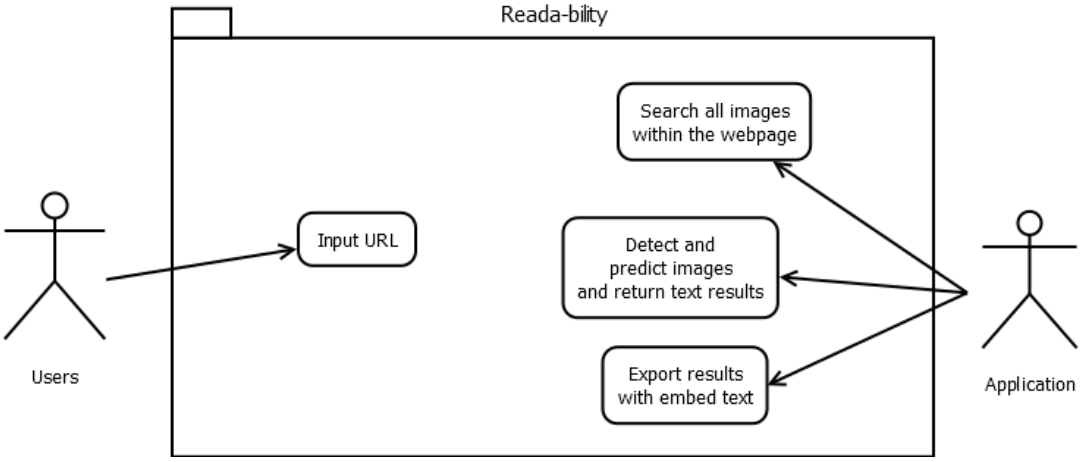

Fig. 2. Use-case diagram of the proposed application.

Fig. 2 shows the use case diagram of the proposed application. The users will have the ability to input the URL link to the webpage they want to translate.

The application will crawl the webpage and find all images within the webpage. The images found will be downloaded to the user's computer and the downloaded images will be detected and predicted using image recognition libraries. After the application finished processing the webpage, the webpage will be downloaded and updated with the predicted results. The modified webpage will be downloaded and saved locally.

3.4. Updated Proposed Application

This section below talks about the application in detail, how it works, and the sample result. The application is made simpler and streamlined as compared to the wireframe application. The current application is easier to use. The users only need to provide the URL to the webpage and the application will perform the rest of the processing. The application starts with the user entering a URL into the text input in the GUI. Once clicked on 'Read file', the application will start reading the webpage and search for images within the webpage.

As the application is processing the webpage, the GUI will show that the application is processing. The application will download the images from the web pages and run the images through OCR and Image Recognition and get the translated results. The translated results will be appended below the location of the image. Once the processing is done, the progress bar will show as 100% complete, and below will show

some details of the web crawling and the number of images found. A copy of the modified HTML webpage will be saved in the same folder of the application. Similarly, for the downloaded images.

The output can be found in the modified downloaded webpage. The translated results can be found below the image showing the image name, followed by the result from the image recognizer, and lastly, the readable text result from the OCR.

Table 1. Time Taken to Process

#	URL	Domain	Time (Seconds)
01	https://www.todayonline.com/singapore/hdb-flat-first-yishun-sell-more-s1m-analysts-say-such-sales-there-wont-be-common-1843051	Today Online	6
02	https://www.gla.ac.uk/	UoG	26
03	https://en.wikipedia.org/wiki/Glasgow	Glasgow Wikipedia	39
04	http://internetsfault.blogspot.com/	Personal Blogspot	6
05	https://www.bbc.com/news/world-europe-62106446	BBC	30
06	https://blog.google/products/android/5-of-our-favorite-android-widget-features/	Google Blog	Unable to read website
07	https://www.forbes.com/sites/bernardmarr/2018/05/21/how-much-data-do-we-create-every-day-the-mind-blowing-stats-everyone-should-read/?sh=71110d7060ba	Forbes	2
08	https://www.flaticon.com/search?word=technology	Flaticon	16
09	https://towardsdatascience.com/graph-neural-networks-in-python-c310c7c18c83	Towards Data Science	403 Forbidden Error
10	https://portswigger.net/daily-swig/high-severity-openssl-bug-could-lead-to-remote-code-execution	Portswigger	57

4. Results and Analysis

The proposed application is implemented to provide accessibility for various types of users. To test the application the application was tested by running approximately 10 URLs on the application. The URLs come from a range of different types of websites from image-based websites to new articles. The application will be tested with different criteria, from speed to accuracy of the processing of the websites.

Below is the list of web pages used to test the application:

- Today Online
- University of Glasgow's (UoG) official website
- Wikipedia: Glasgow
- Blogspot
- BBC
- Google’s Blog
- Forbes
- Flaticon
- Towards Data Science
- Portswigger

4.1. User Inputs

The main interaction of the application by the users is mainly through the input of URLs. The user will supply an URL link for the web page he/she wants to be translated. To test the inputs, several inputs consisting of valid links, broken links, and other miscellaneous input will be used to test what kinds of URLs are allowed and able to be read by the application.

Below lists the inputs used for the tests:

- https://www.gla.ac.uk/

- www.gla.ac.uk
- gla.ac.uk
- https://gla.ac
- not a valid url
- <html></html>

Through the tests, the application is only able to read the URL link (https://ww.gla.ac.uk) Th application will only allow URLs starting with "http://" or "https://" to be able to run on the application. The rest of the inputs used for the testing was considered invalid URLs. The output of the application will show as "The provided URL is Invalid".

4.2. Speed

To test the speed of the application crawling each website, a timer function will be added to the application's code. The timer will start after the user entered an URL and end after the processing is completed. From Table 1, it is found that the time taken to process each URL varies in time. Some websites take less than 10 seconds, while some websites take more than 30 seconds to complete. There are a few factors that will affect the processing time when using the application. First, it depends on the number of images within the webpage. A website with more images will take longer to process. For comparison, Glasgow Wikipedia has 125 images and takes 39 seconds to complete, while Forbes only has 1 image and takes 2 seconds to complete.

The second factor is the size of the images. In order for the images to be used with the OCR or image recognizer, the image first will be downloaded to the local machine. All images will be read from the folder of all downloaded images and translated into text. Images used in websites vary in size, from icons to full art images. If the image file size is large, it will take time to download the image. Hence, increase processing time.

Lastly, the internet speed. Due to the need of downloading the images to perform image recognition, the application processing speed is also dependent on the user's download speed. It may take longer if the user has a slow internet speed.

4.3. Accuracy

To test the accuracy of the translated images, the accuracy will be checked based on each image recognition library, ImageAI, and EasyOCR.

4.3.1. Object detection

The task of object detection in the proposed application is to detect the objects on the images and provide context to the images. To test the accuracy of ImageAI's image recognition, the test was run on the application using UoG's main web page. The application ran 4 times, one for each ImageAI built-in CNN model. The CNN models are pre-trained networks using images from ImageNet and used to classify images from 1000 different categories. The purpose of this test is to find out how accurate is the translation and which model is the best for image classification for the proposed application.

Table 2. UoG Campus Image Accuracy Results

Model	Probability Score (%)	Results
ResNet50	23.494	Pop bottle
MobileNetV2	12.814	Castle
InceptionV3	45.380	Drilling Platform
DenseNet121	25.350	Fountain

Table 3. Graduating Students' Image Accuracy Results

Model	Probability Score (%)	Results
ResNet50	20.906	Vestment
MobileNetV2	3.395	Academic Gown
InceptionV3	96.452	Academic Gown
DenseNet121	57.615	Academic Gown

After processing, two images within UoG's website were observed for testing. The first image depicts the University of Glasgow's "castle-like" campus situation in Glasgow, Scotland. The second image depicts the students wearing graduation gowns on campus. Based on the results obtained from ImageAI, each CNN model returned different predicted results. A probability score was tied to each result. Overall, it is observed that the accuracy of the results produced by ImageAI is subjective. Each CCN model is built differently and works for different kinds of applications and purposes.

Out of the 4 models, despite the low probability scores shown in ImageAI, the MobileNetV2 model is found to be the most accurate in classifying the images, based on the two images observed, with the results "Castle" and "Academic Gown". The results observed for the test, MobileNetV2 are found to be the closest to the objects found in the images.

4.3.2. OCR

The task of OCR in the proposed application is to detect words (if any) from the images in the web pages and output them to text. To test the accuracy of EasyOCR's Optical Character Recognition, like image recognition, the test will be running the application on UoG's main web page.

Two images were observed for the testing, one from the UoG's website and another from a personal Blogspot. The first image depicts a poster for a good university guide with the words "THE TIMES THE SUNDAY TIMES GOOD UNIVERSERSITY GUIDE 2022 SCOTTISH UNIVERSITY OF THE YEAR". The OCR result from EasyOCR is translated as "THE EA TIMES THE SUNDAY TIMES GOOD UNIVERSITY GUIDE 2022 SCOTTISH UNIVERSITY OF THE YEAR".

The second image depicts a doodle with poorly written text of "Shield" and "Internet" The OCR result from EasyOCR is translated as "Shicbl".

The application using EasyOCR was able to detect the characters on the image and produce the most expected results for the first image. The only problem with the result is the results show the word 'EA' where it is supposed to be a logo. However, for the second image, the text in the image of the webpage is written poorly, and the word "Internet" is rotated. It is difficult for OCR to identify the text written on the images. As result, the word for 'Shield' is interpreted as 'Shicbl'. Also, the OCR couldn't identify the word "Internet" from the image. The image with text needs to be clear and readable for the OCR to work properly.

4.4. Errors

During the testing of the application, there are some errors found. Results from Table 1 show that the application was unable to read 2 of the 10 websites tested.

The application encountered a 403 Forbidden error when trying to crawl the TowardsDataScience website. The response code indicates that the server understands the request to access the website but refuses to authorize the request. The error occurs when the websites block web crawlers, as indicated in the robots.txt on the website. Robots.txt is used to block the search of important or sensitive directories within the website. Hence, depending on the website's permission, it may not allow access or crawling to be done on the website. For the Google Blog website, when trying to crawl the website, it encountered an error in finding images within the website. As the application was developed, it wasn't built with many different types of websites in mind. Different websites are coded differently. Hence, with many websites on the

internet, it's not possible to cater crawling of all types of websites.

4.5. Benefits of the Proposed Application

This section highlights the benefits of the proposed application.

4.5.1. Better searching of webpages

By having text describing the images instead of having only images, it allows for better searchability. For example, if the website is primarily consisting of printed documents and images, it would be difficult for online users to find the website. Usually search engines like Google or DuckDuckGo, mainly allow the users to input text to search. It will be difficult to search if the printed documents or images do not have any labels tied to them. With translated results embedded within the web pages, it will help to add text or labels to the images to better help search engines in finding the website the user required.

4.5.2. Processed for text-to-speech

The application provides a text version of the modified web page. It aids in better accessibility for people with visual impairment. People who are visually impaired may not be able to read visual text or images. As the webpage is processed to a text file, users can use the text file and run it on text to speech application.

4.6. Problems with the Current Application

This section highlights the problem found for the proposed application.

4.6.1. Inaccuracy

For OCR to work accurately, the text in the images or printed document needs to be clear and readable. Unclear text may result in gibberish text generated by the OCR. For image recognition, the accuracy is quite low. Many factors may cause image recognition to have poor accuracy. One of the factors is unclear images, like blurry or low-resolution images. The image may not be able to be properly detected by the OCR or image recognition libraries and produce an inaccurate result. Another major factor of inaccuracy is the different image recognition models available. For ImageAI, there are 4 compatible models to use. Upon testing the different CNN models for image classification. Each model will produce different results for each image.

4.6.2. Unable to read multimedia files locally from client

For browsers with images, after downloading the web page from the website, the web browser will not be able to read images locally from the client without some tweaks in the security settings. Upon opening the modified web page, there will not be images or other multimedia files available on the web page.

5. Conclusion

Technology is constantly evolving to aid companies to evolve and the visually impaired with their disabilities. The proposed application allows the users to simply input an URL link to a web page. The application will process the images within the web page using 2 different image recognition techniques, OCR (EasyOCR) and image recognition (ImageAI). The results will be embedded back into the web page. The application, finally, outputs the modified HTML web page, the text-only version of the modified web page, and the downloaded images from the web page. The application manages to complete processing in less than one minute per web page, after testing 10 different web pages. Whereas, for accuracy, it depends on the quality of the images and the image classification used. MobileNetV2 is found to be the better image classification model, out of the available models for ImageAI. The proposed application proves to simplify the process of translating images to text with the use of simple inputs and commands to allow better interaction between the application and visually impaired users and enhance accessibility to those in need.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Dr Peter ChunYu Yau is this project owner. Dr ChinSean SUM co-supervised to the final year student Shaun YAM who carried this study as part of this graduation project. Dr Qi CAO, and Dr Dennis WONG provide professional advice and comments to the methodology used in this study, from the technical perspectives. All authors had approved the final version.

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