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Web Application based Image Geolocation Analysis to Detect Human Trafficking

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Abstract

Migrant smuggling is a dangerous phenomenon threatening international peace and security. This global concern for many countries is mainly due to the high use of multimedia devices and social media. There are great demands to specify an in depth gathering of information about a suspect's mobile device while investigating cases of human trafficking and migrant smuggling. The primary purpose of this study is to help resolve the human trafficking problem that currently faces Sudan. In this paper we cover the steps used to geolocate images captured from suspects and victims' mobile devices cameras. The obtained images are then analyzed using our specialized developed web application. This latter is built using open-source tools such as the Laravel framework and a Google Maps API which is considered as the main component of the web application. The results of the developed web application on a real case in Sudan has proven its usefulness in easing and speeding up the digital investigation process.

I. Introduction

Smuggling of immigrants is a serious practice that threatens world peace and security and is a global concern for many governments. Human trafficking affects several countries, either as locations of origin or transit. In exchange for money, smugglers transport migrants across borders and countries. Research on migrants and smuggling through multiple migration routes indicates that travel restriction related to COVID-19 has not halted this criminal activity. In fact, the economic consequences of the pandemic did not hamper the criminal networks from flourishing their activities due to the rise of demand for their services [15]. This rise has pushed the criminal networks to follow riskier methods regardless the restrictions on entry points and increased patrols. As a result, smugglers are risking the migrants' lives by exposing them to violence, abuse and the risk of contracting Coronavirus [1].

The crime of smuggling migrants is a complex issue due to the secret nature surrounding it, as well as the difficulty of determining the time of smuggling of victims by smugglers. Migrant smuggling is closely related to the use of forged travel documents and is linked to other crimes such as illicit money circulation, corruption, terrorism, and trafficking in illegal goods and people. Smugglers

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take advantage of the enormous number of immigrants attempting to flee from their home countries due to conflicts, famine, and poverty, as well as the difficulty of accessing European countries via legal ways. Migrants are subjected to ill treatment, sexual exploitation, torture, beatings, and humiliation by smugglers, and they often die in deserts, or drown in the sea. There are major smuggling routes in Africa that stretch from eastern, northern and western Africa to Europe. Some smuggling operations include the detention of victims on roads and in homes in exchange for money from people in Europe to release the victim, and in this case the operation is called human trafficking [1]. Sudan is one the countries that has witnessed many cases related to migrants summgling.

In some cases, mobile devices such as phones are seized from the smugglers and migrants' (victims) possession. Analyzing the content of this mobile devices unveil valuable information, such as pictures taken on roads, valleys and mountains related to the roads and locations that the smugglers follow. The main motivation behind conducting this study is to assist investigators in human trafficking and smuggling cases by detecting and identifying the routes that smugglers and migrants (victims) take during their entry into Sudan. Fig. 1 illustrates detected illegal routes into Sudan. By analyzing images captured on cell phones, quick decisions can be made in collaboration with border police and human trafficking experts to tighten control, guard, or unearth houses where victims are being held. Hence, in this study, we have developed a web application program that analyzes images taken from the smugglers or victim's devices to determine the geographic location of an image in order to help an investigator in making a quick decision if there are detained victims, gathering point, or roads taken prior to arrest.

A main part in this project is to design a user interface using a web application that an investigator in human trafficking cases can use while analyzing the images extracted from the victim or smuggler's phone. Where the web application extracts metadata from the phone because the metadata contains information that may be useful for the investigation. The outcomes of this study can provide

Fig. 1 The illegal path that used to enter Sudan.

contributions to the investigators in the field of human trafficking in the event of arresting suspects and victims, in coordination with the judiciary, the prosecution, the border police, and human trafficking. Indeed, the application developed in this study will help the investigators and related teams to track down the victims and the accused, determine the ways they pass, tighten supervision, and establish focal points on them in the future. Our paper is focusing on the human trafficking and smuggling issue. We have collected in our testing criteria some relevant images and real investigation images that we have tested in our research.

This paper is organized as follows. Section II reviews literature papers. In Section III, we introduce our methodology and approach. Section IV experiments real case with our web application. Section V addresses the limitation and future work of our research. Lastly, Section VI summarizes the study.

II. Related Work

A. Human Trafficking and Smuggling

Hassan [1] studied human smuggling and trafficking in eastern Sudan. The author mentioned the scale and patterns of human smuggling and trafficking in eastern Sudan, including the techniques and methods used in the process by smugglers and traffickers. He highlighted the main characteristics of human smugglers and traffickers, as well as their clients and victims. In addition, he focused on presenting recommendations that can help stakeholders in combating human smuggling and trafficking practices and in protecting victims and vulnerable groups. In [3] studies of human trafficking in West Africa were also conducted. Paolo

[2] studied the organization of migrant smuggling across the Mediterranean. Indeed, the paper deals with the activities of smugglers operating between East and Central African countries through the state of Libya, where migrants are collected in the state of Libya in preparation for their smuggling to Europe [4].

Guido et al. [4] discussed the flow of irregular migrants from Africa and the Middle East into Europe, along land and sea routes, under the control of human smugglers. The end of the Gaddafi regime in 2011 marked the opening of the Central Mediterranean Route for irregular border crossing between Libya and Italy. This resulted in the immediate expansion of the global smuggling network. Shorter distances increase the willingness to migrate especially for youth, (medium) skilled individuals and those with a network abroad. The effect is stronger in countries closer to Libya and with weak rule of law. Zhang et al. [6] presented migrant smuggling using a collection of empirically based research projects. Getmanski et al. [7] studied building physical barriers along borders to prevent human trafficking. Guido et al. [8] showed that the spatial dimensions of smuggling networks and changes over time have resulted in reduced trafficking in human trafficking between African and European countries.

B. Images and Tracing

Caleb et al. [5] discussed the importance of image metadata as a source of information in any digital investigation process. This latter includes information about where a picture was taken, what time it was taken, what device took the picture, and so much more. They designed and developed a Java application to help aid investigators by pulling relevant metadata out of a set of images inside a folder. Once this metadata was retrieved, they displayed it in a user-friendly fashion with the goal being to help an investigator draw insight into the pictures that were taken.

Thomas et al. [9] discussed image storage and sharing services that permit users to store and share images. Similar applications typically organize images chronologically. Chronological organization fails if the timestamp or location information stored in the image metadata (e.g., Exchangeable image file (EXIF)) is incorrect. Images are shared through messaging or social media and the shared image may have the time of sharing, not the time of capture.

In another example, geolocation data maybe deleted when an image is shared. Image timestamps can be inaccurate when multiple users contribute images to a single shared album from cameras that are not time synchronized [10]. Lionel et al. [11] studied the future of GPS and cameras on smart phones that store location information in the EXIF when a capture is taken. The geo tags could be useful for investigators in analyzing criminal activity. Also, free tools available on the market that can help computer forensic investigators to cover a wide range of geographic information related to criminal scenes or activities have been mentioned.

C. Using API for Image Location

Kerim et al. [12] studied mapping the location of a suspect by extracting and analyzing images taken from their own mobile phone. The location information of photos taken with today's mobile phones is stored in the same photo file with a structure called EXIF. Using the software developed, an analysis of the places where the suspect had been in the past was carried out by reviewing the location information of photos from suspects' mobile phones. In this study, the image files found in the mobile phone of a person were determined as suspicious. (1.850) image files were taken with the software developed in the C# programming language, and those with and without the location information of these image files were distinguished. Files with location information and capture date were received. This information is used in the program without changing the location mapping of the suspect [12].

III. Methodology and Approach

As shown in Fig. 2, our methodology is illustrated. At first, we import the images from the user and insert them into the program process. This latter includes storing the image in the web server and extracting the longitude and latitude coordinates

from the metadata to display those coordinates as geolocation from the Google API. In the subsections below (from A to F), the different phases of our methodology are detailed.

A. Suspect and the Mobile Device

From a digital forensics' perspective, during the investigation we might refer to the digital media that have been used by the suspect. In this case, the foremost step is to identify whether the suspect has an android phone or other smartphone. By identifying the smartphone operating system type, the tools suitable that might be used during the acquisition and the extraction stage of the mobile device are specified.

B. Tools used by the investigator

As a digital forensics' specialist, there are specialized tools that can be referred to during the investigation. For example, they use tools such as the write-blocker to avoid any edit or modification on the chain of custody. Also, they use a specific device such as a laptop to store the image and the files extracted from the victim's mobile. Once one connects the device to the laptop, if the phone is an android phone, as shown in Fig. 3, it will ask about permission to allow the laptop or the computer to have access to the mobile device. As illustrated in Fig. 4 and Fig. 5, the digital investigator can access the images and multimedia files that are inside the device [13].
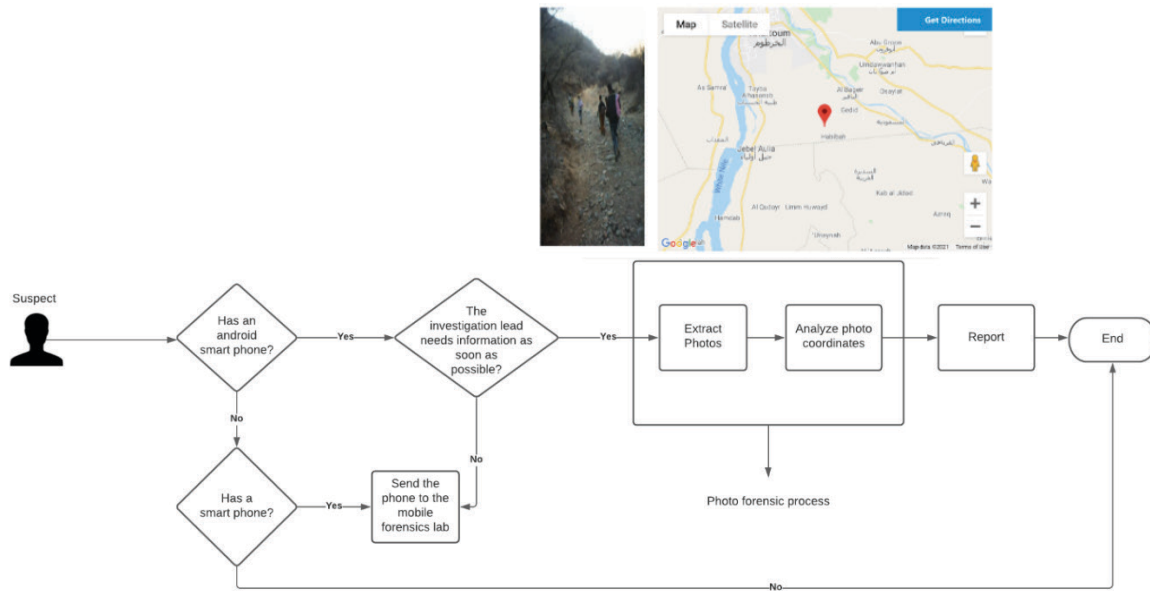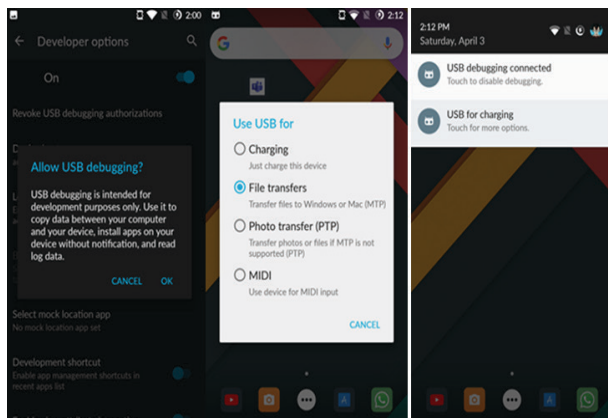

Fig. 2 Application Process.

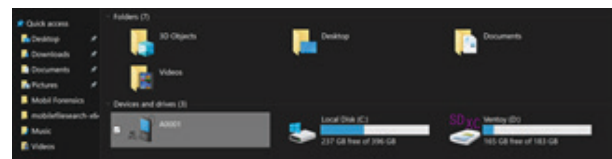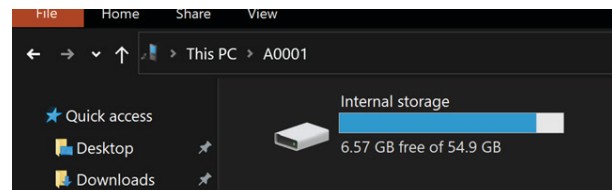Fig. 3 Allowing the Device to be Accessed.

Fig. 4 Selecting the Device.

Fig. 5 Device Storage.

C. Extraction Process

NirSoft Mobile File search [16] is a free-to-use tool for extracting files from multiple android devices and external storage, as shown in Fig. 6 process. It can be used for extracting JPG, PNG, and GIF. Also, it is possible to set the date and time frame by the file creation or modification. This tool shows how an investigator can set the conditions [14]. After clicking search, another window will pop up showing the results of photos found in the devices as shown in Fig. 7. From there, the investigator can navigate the pictures and export the suspicious photos in a folder.

D. Chain of Custody

The most important part from a digital forensics' perspective is to preserve and maintain the chain of custody. This latter will ensure the integrity of the evidence and preserving them from any alterations. In other words, the images or the files that are inside the victims' hard drive memory should be protected from writing or editing. By result, the evidence extracted are most likely to be approved and confirmed in the court of law. Therefore, the HashCalc tool to validate the hash value of the images extracted is used.

F. Analysis Process for Photos' Coordinations

Once the upload is successful to our web application, the first step of the process is to store the metadata of the image in a database. In the developed application, an open-source database MySQL has been used to store information such as the filename, date of upload, type of the image, whether it is a JPEG, PNG or JPG image. Also, the most important part of the developed application is the longitude and latitude. In order to do so, a function has been developed to extract the image coordinates which is: $exif = exif_read_data($image, 0, true)$;
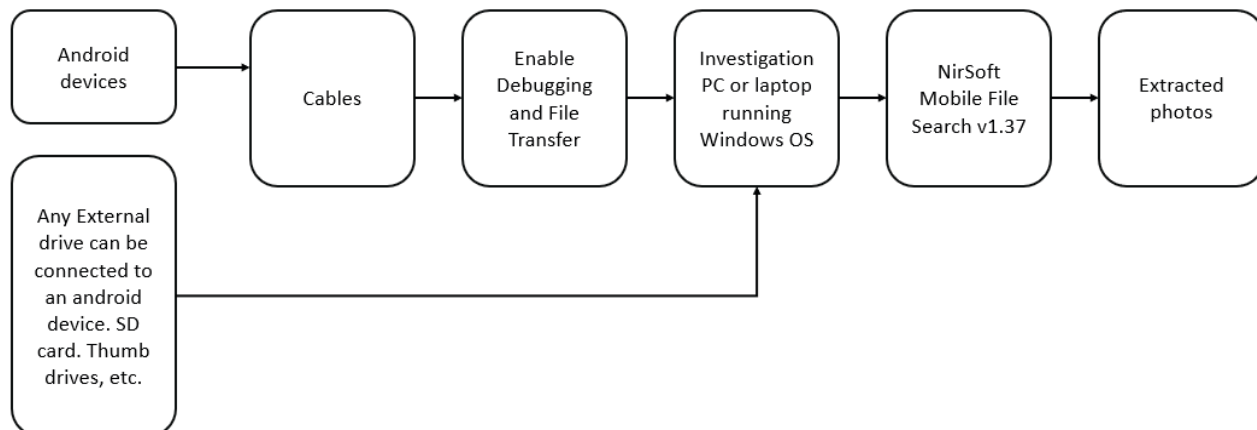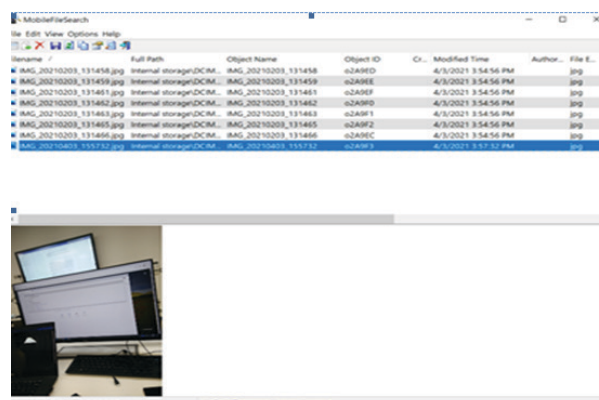

Fig. 6 Extraction Process.

Fig. 7 Selecting the Device.

This function allows to extract the EXIF information of the image that has been uploaded to the web application. Furthermore, two parameters which are the GPS Latitude and GPS Longitude have been used to extract the existing longitude and latitude that exist on the image metadata and then to insert those coordinates into the MySQL database.

G. Testing Criteria

As per the testing, criteria have been used for the JPEG and JPG images. The web application has tested some smuggling cases from Sudan country. The total images that have been collected during the testing phase were a total of 9 images. Some of the images did not get the web application requirements such as the PNG image extensions. Since it is not supporting the longitude and latitude coordinates, thus this extension was excluded from the testing criteria part. Fig. 8 illustrates the analyzing process that includes 6 main steps explained as follows:

Step1: the first page when the user logs in to the web application as shown in Fig. 9. The user should select the image from his device.

Step2: after the user selects the image from his device as shown in Fig. 10, the image name will appear to upload it to the web server.

Step3: after the successful upload as shown in Fig. 11, the user can see the image ready to be selected.

Step4: the user can upload more than one image as shown in Fig. 12.

Step5: after clicking on the sample image, the geolocation results will appear as shown in Fig. 13.

Step6: viewing the geolocation of the image. When the location information of (10) images was examined, it was determined that (9) JPEG and JPG were correct location, and (1) PNG image did not have the longitude and latitude coordinates in its metadata.

IV. Implementation

After the image is uploaded, and the metadata stored on the MySQL database the image is ready to be used. An important part in the developed application is to display the location of where the related image has been taken and what is the direction to that location. In this study, the Google API service has been used to embed a google maps' view. This latter will allow the display of the image location and parse the longitude and latitude to the Googlemaps. Google account has been created for this task and an API key is generated from Google service. The objective of this task is initiating a google maps view for displaying the coordinates from the image longitude and latitude metadata that have been extracted from the metadata of the image. Fig. 14 shows a sample of human trafficking image which its location has been extracted using the developed web application.
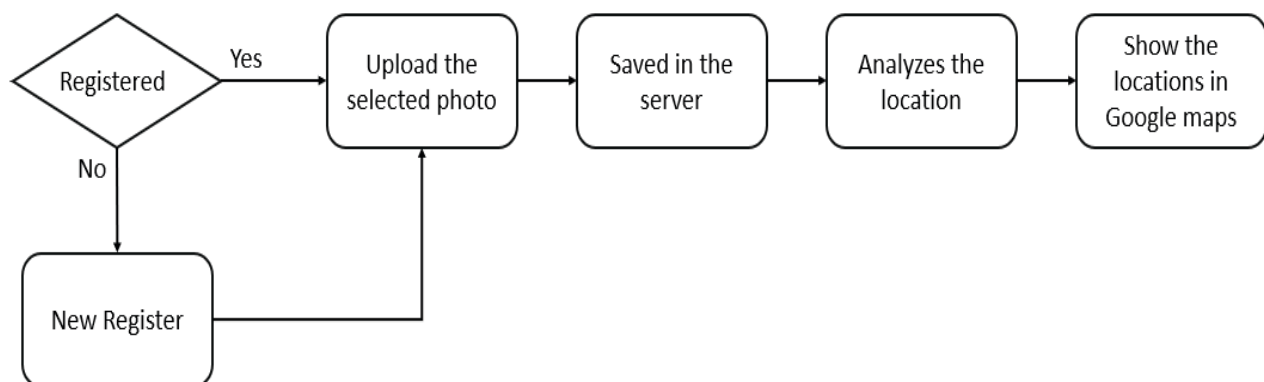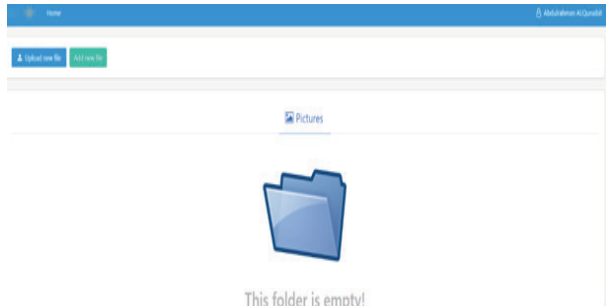

Fig. 8 Analyzing Process.
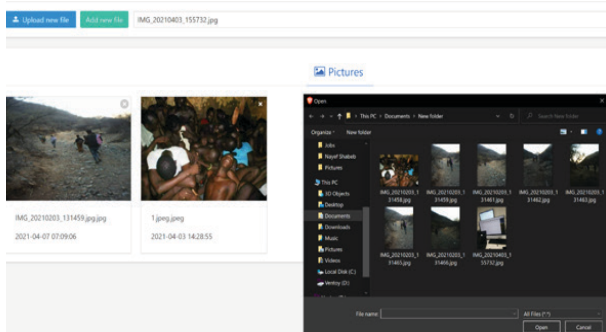
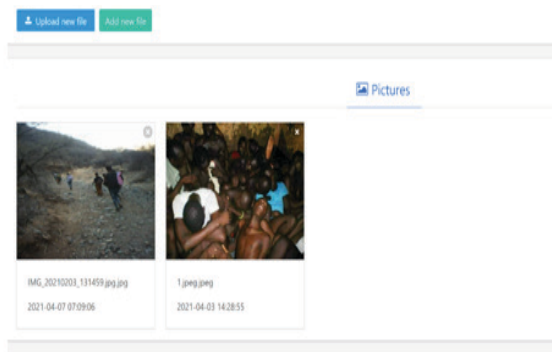Fig. 9 Selecting the Device.

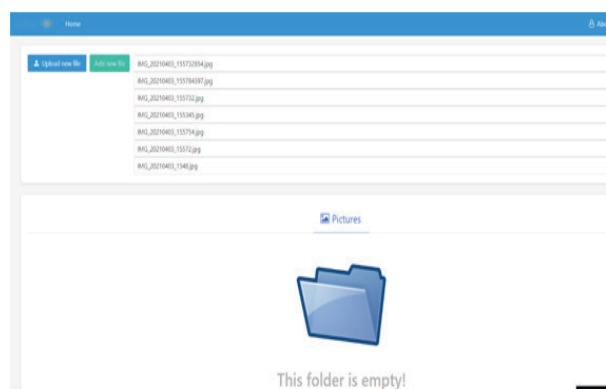Fig. 10 Selecting the Device.

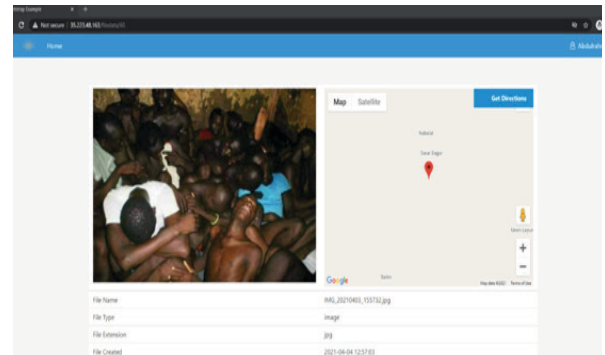Fig. 11 Selecting the Device.

Fig. 12 Selecting the Device.

Fig. 13 Selecting the Device.

A. Laravel Framework

The first phase in the implementation process is designing the application. Some native programming languages in mobile applications such as React Native and Cotlin were tried at first. However, the issue with using these programming languages was the interoperability. Indeed, running these applications will not function the same way across all platforms. This has led us to use a single web application language that can run with the same design across all platforms, such as mobile devices, tablets, laptops, and desktops.

In the so doing, the Laravel framework has been used due to the existence of already made open-source templates that can be easily imported and edited from the development perspective [10]. Laravel is created and built-in from the PHP programming language. This is because of the general ease and ability for the language to be learnt, at the same time there are and lots of resources and teaching materials for this language.

As a back-end developer, the main issue during the development stage is the back-end development and the functionality of the back-end service. In this study, the Laravel framework contains built-in functions, such as extracting the longitude and latitude *$exif = exif_read_data($image, 0, true)*; from an image that was taken from a device. Indeed, this framework supports extracting the longitude and latitude coordinates and embedding those coordinates into the image by reading and extracting the metadata of the uploaded images.

B. Laravel Framework Installation

Used a ready-made template was the second step in the implementation process. We started the Laravel installation steps which were written in the official site of Laravel. Some bugs and issues during the installation were faced, such as the PHP version used and some of the required packages from Laravel did not install correctly. However, these issues were resolved by upgrading to the last version of PHP after cleaning the previous installations. After the installation stage, we referred to multiple functions that could be used in this study. For example, a function called "get image location", which is used to extract the longitude and latitude coordination metadata that is embedded in the web application.

More specifically, built in libraries were imported from Laravel framework to reduce the building and development time frame. The PNG metadata does not support the functionality of parsing the longitude and latitude coordinates. The developed web application framework was uploaded to the Google cloud service as host of the application which facilitates its run as well.

C. Geo location of the image

From the web application that has been created, a report can be generated based on the extracted location coordinates from the longitude and latitude of the image to be attached to the crime case report as shown in Fig. 14.

V. Limitation and Further Research

As an initial web application that extracts the longitude and latitude from the image, there are extended features that will be added to the web application, such as image classification for multiple images. Many issues were faced during the development stage such as analyzing some of the image extensions. For example, PNG extensions do not have the needed metadata such as longitude and latitude. Another faced issue is that when transferring the images using social media platforms such as WhatsApp instant messaging platform. Furthermore, the developed web application design can run with all the platforms, but the compatibility issue is raised when dealing with platforms such as tablets and smartphones and desktops and laptops. Each platform has its own height and width dimensions.
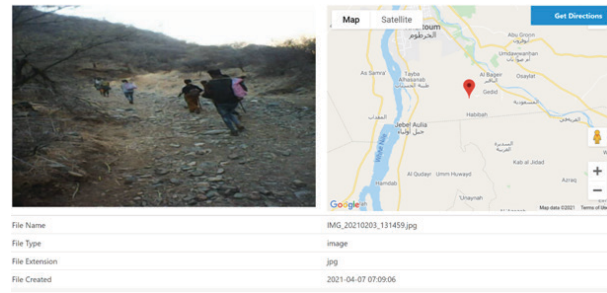

Fig. 14 Selecting the Device.

Another extended feature is enforcing the security of the web application. During this study, we run the web application on an isolated environment due to the missing security. Another important feature is compressing the images sizes to reduce the computation time consumed by the CPU and RAM storage of the webserver. This latter may accept at least more than 50 images during the investigation. Also, a future phase is to define a machine learning model for classifying the images as a group in case there was more than one image in the same location area.

VI. Conclusion

The speed with which investigators can extract images captured by a mobile phone camera in the event that smugglers or victims are arrested poses a significant challenge in cases of human trafficking and migrant smuggling. Because these images contain information that can be useful to the investigator after their analysis. The geographical location of the photographs, as well as the routes and locations from where these images were taken, may be established using a web application. It could also be useful in the border crossings where they entered Sudan or the detention centers where the victims were held. The developed web application is simple to use and can be accessed and used from any location, allowing the investigator to work from anywhere. We have uploaded (20) photographs from real-life human trafficking and smuggling instances, and the outcome reveals us where those photos were taken. Our web application may be modified in the future to include more features for encrypted movies and messages. By using this online tool, human trafficking and smuggling detectives will be able to cut the time it takes to study huge photos and track criminal locations.

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