

An Integrated EO-based Toolbox for Modernising CAP Area-based Compliance Checks and Assessing Respective Environmental Impact

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Abstract—As part of its ongoing move to simplify and modernise the EU’s Common Agricultural Policy (CAP), the European Commission has adopted new rules that allow a range of modern technologies to be used in the check systems for area-based CAP payments. This includes the possibility to use geotagged photos to support and complement checks when the latter do not lead to conclusive results and additionally to help avoid wasting time and money on the spot checks. They can also be used as ground truth information provided by farmers or other stakeholders. A system that can support the farmer in collecting the needed geotagged photos is presented here. The system will help with the automation and acceleration of a heavily manual process by facilitating the interaction between the farmers and the relevant authorities.

Keywords—Common Agricultural Policy; Earth Observation; remote sensing; drones; geotagged photos; environmental performance; farmers’ compliance.

I. INTRODUCTION

The DIONE project proposes a close-to-market area-based direct payments monitoring toolbox that addresses the Modernised Common Agricultural Policy (CAP) regulation of using automated technologies to ensure more frequent, accurate and inexpensive compliance checks. In particular, the toolkit showcases the capability of Sentinel data to monitor the crop diversification rules and integrates the generated crop-type maps in a way directly exploitable by the paying agencies. It includes in the analysis the so far neglected Ecological Focus Area (EFA) types, such as fallow land of all sizes, buffer strips, hedges and trees, by making use of super-resolution technology that improves the 10-20m Sentinel resolution to an improved resolution range. The toolkit also complements the use of Earth-Observation (EO) data with a system of reliable, ground-based geotagged photos, captured by the farmers, that exploits advances that allow for improved positional accuracy, low-footprint encryption techniques for improved data security and reliability and image detecting manipulation techniques. The system allows for an improved Land Cover/Land Use annotation and ensures the process is untampered.

The main objective of this paper is to provide an overview of the geotagged photos in-situ component for complementing EO-data which are developed within the frame of the DIONE project. The geotagged photos are

captured using smartphones and allow for an improved method for the provision of additional evidence regarding the CAP compliance monitoring. The added benefit is the quality and trust of the transmitted data as well as the application characteristics with respect to location accuracy and data collection process through the use of Augmented Reality (AR) features.

Finally, a central data processing and storage system gathers the data, ensures their quality and provides user-friendly Application Program Interfaces (APIs) for the curated data contained. The system ensures that only authorized parties are used as sources of the received data, that the integrity of the data and metadata [10] is not compromised, that no data with highly variable/outlier nature is going to be used and that appropriate forms of data storage are used to ensure easy retrieval.

The rest of this paper is organized as follows. Section II describes the design of the system, core tech functionalities and use cases. Section III addresses the front-end side of the mobile application and describes the User Interface (UI)/User Experience (UX) aspects. Section IV offers some thoughts on the outcomes and future work. The acknowledgement and references close the article.

II. SYSTEM DESIGN

The data collection process is supported by a mobile application that exposes to the user all the related content about his/her parcels while enabling the conclusion of the process and the provision of the final photos to the Paying Agencies (PAs). On the other hand, a set of backend processes [15] [16] provide the necessary instructions for farmers to reach a given parcel as well as directions regarding the process of capturing appropriately a photo of a given parcel.

In particular, the application enables the user to check if there are any requests from the Paying Agency for the provision of geotagged photos and, based on this, facilitate the overall process. The latter includes the provision of information on map related to the user’s parcels and his/her current position, navigation to the correct spot in the parcel for the photo acquisition, as well as use of AR to dictate the exact spot and direction he/she needs to place his/her mobile device while superimposing parcel boundaries to facilitate the process.

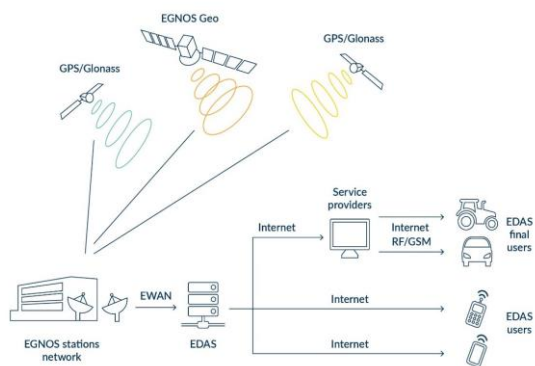


Figure 1. EDAS High-Level Architecture

Ensuring the best possible positional accuracy is another essential requirement [12], whilst the application allows the exploitation of raw Global Navigation Satellite System (GNSS) measurements and enables the user to evaluate his/her positional accuracy. The photo acquisition process can also be initiated without an initial request from the Paying Agencies, allowing users to act proactively and provide geotagged photos in advance so as to assist compliance evaluation for their parcels.

Moreover, aiming to support ease of use, the application provides local language menus, user friendly visualisation of detailed parcel information, as well as a tutorial with step-by-step information of how to capture photos.

Following the collection of the needed photos, the application enables the transmission of the collected figures along with their associated metadata. The minimum required metadata that are stored during the data acquisition process include:

- Time, date and geographical location of the photo acquisition: This information is extracted directly without manual interference from the GNSS antenna embedded in the mobile devices. The positional accuracy can be improved to a meter or even sub-meter one, for the devices that can harness multiple location differentiators and European Geostationary Navigation Overlay Service (EGNOS) services.
- Orientation, heading, of the camera at the time of photo capture: Its goal is to ensure the proper acquisition of the photo, pointing at the correct parcel. This information can be extracted from the compass system embedded in the device (10 degrees deviation) while also being deduced by exploiting the AR features of the geotagged photos framework. Regarding the latter, AR allows to identify and superimpose on the photo the land parcel border or other identifiable landmarks, and subsequently to capture multiple photos as needed and properly adjust the device positioning.
- Identification of the operator.
- Basic information on the mobile device and inbuilt camera i.e., mobile device brand, camera model, and focal length.

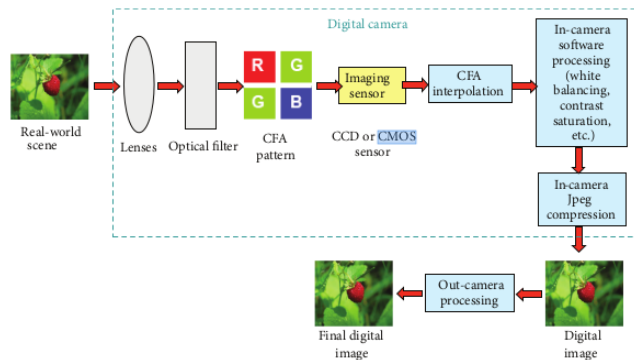


Figure 2. A scheme representing the steps composing the usual life cycle a digital image undergoes. Imperfections in the CMOS manufacturing process introduce noise in the photos taken.

The application is available to operate both in online and offline mode. In this context, all data needed for the guidance of the user must be fetched beforehand and preferably while on a Wi-Fi connection. Thus, all actions and data acquired on-site must be stored locally in order to be sent to the backend later.

The format of the acquired photos is stored according to the most commonly used standards in digital cameras. In this context, appropriate settings were considered towards ensuring appropriate quality of the photo as well as avoid losing image details due to compression levels.

Users of the application are able to receive detailed instructions in order to fulfil the data acquisition process. In line also with the EU guidelines, a macro/panoramic photo is captured with the camera pointing higher at the horizon showing the corresponding field. In some cases, this type of format may represent the optimal evidencing option (i.e., mixture of crop as EFA cover crop).

On the other hand, in order for the photos to be reliable there is a need to validate their integrity and origin and detect any attempts of digital manipulation of the photos. This is achieved through a server-side process (framework) that runs successively different image forensics techniques to locate any digital manipulation and ensure that the photo is taken by the correct user (farmer) in the correct parcel. The component firstly ensures that the file of the photo comes from the same device that the farmer used to authenticate himself/herself in the mobile application. In the second step, the photo file is checked aiming to detect any tampering from the time the image was taken and until it was uploaded to the system while also using methods to ensure location integrity. In the next steps of the process, forensics techniques specifically designed for photos are executed. In these steps, the goal is to verify that the user did not manipulate the photo digitally.

This component also addresses the need to preserve private and personal information that may be exposed in the taken photos when they are reviewed by the inspectors of the Paying Agency. Thus, the last part of the server-side framework is an anonymization tool that is responsible for blurring any faces or license plates detected in the photos.

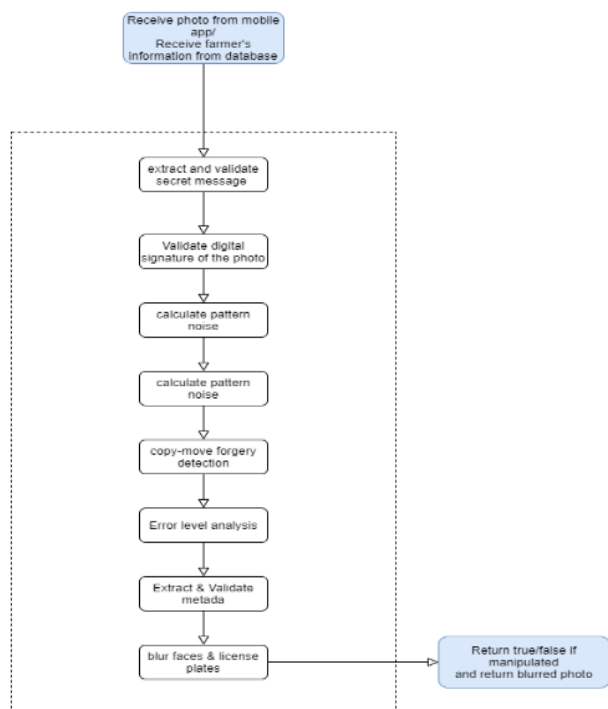


Figure 3. The overall integrity process.

Data acquisition. The starting point for the application use is through the transmission of a push notification by the toolbox API to the geotagged photos component regarding the parcel requiring the acquisition of geotagged photos. A geotagged photo consists of saving at least the location as latitude and longitude coordinates, date, time, orientation and the mobile device/camera information into a JavaScript Object Notation (JSON) file for each Portable Network Graphics (PNG) photo file. The notification is transmitted downstream to the mobile application in order to notify farmers regarding the parcel requiring geotagging. Through the geotagging photo app, farmers can view the route towards the parcel under investigation. Subsequently, they receive guidance regarding the process of taking a photo of the parcel with the use of AR techniques. The photo taken is uploaded and checked for integrity by the backend of the geotagging component and it is stored in a database. The compliance dashboard requests the geotag photo object which is fetched through the toolbox API.

All app users are linked to their respective farmer unique id. This is achieved during the authentication-authorisation process and is facilitated by the toolbox API that is dynamically connected with the Paying Agencies systems.

Moreover, in order to benefit from all modern differentiators, a recent Android device is needed, that provides access to real time data extracted from raw GNSS data. The platform has strict limitations since the photos taken must represent the real state of a parcel at a very specific time and day. As many techniques as possible are needed in order to maximise the accuracy of the position. The user is able to monitor positional metadata extracted from raw GNSS data.

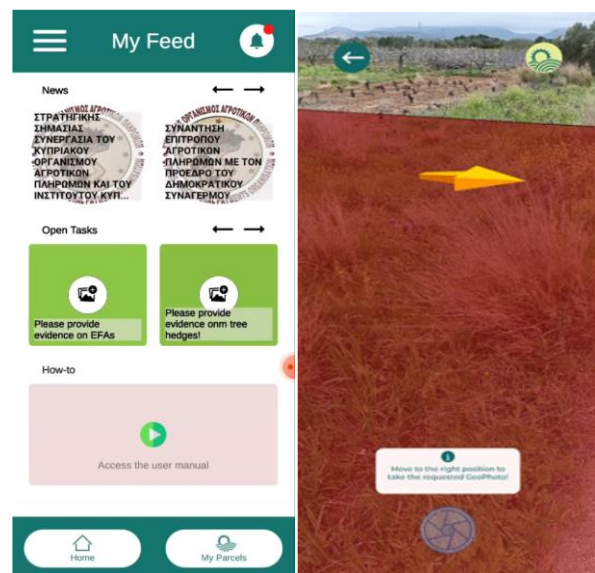


Figure 4. Screenshots from the mobile application: (a) Overview page, (b) AR support for photo capturing

Based on the user's device and Internet connectivity, they are able to benefit from different European Global Navigation Satellite System (EGNSS) differentiators (e.g., dual frequency GNSS [13]) to achieve improved positional accuracy and to assure positional data integrity. Positional accuracy requires data connection to be able to receive correctional data from the EGNOS Data Access Service (EDAS) service (Fig. 1). EDAS provides a wide variety of products, in different formats and different protocols [14]. Among these products, EDAS provides the EGNOS augmentation messages, as normally received by users via the EGNOS geostationary satellite. This message is transmitted in real-time by the EDAS Signal-In-Space (SISnet) service and is useful for users that won't have an EGNOS supporting device.

Positional data integrity can be achieved by analysing raw GNSS data for Open Service Navigation Message Authentication (OSNMA) [1][2][3] verifying Galileo signalling. In order to identify the Galileo messages, the raw bits of E1 I/NAV messages are taken from the receiver using Android calls and from there, the OSNMA relevant bits are extracted for authentication. Since all photo metadata must be as accurate as possible, the application makes sure that the positional accuracy is below the required threshold before the image capturing.

Data integrity. In order to ensure that the file of the photo is not manipulated and is the same from the time the photo was taken, the technique of steganography [4] is utilised. Steganography is the practice of concealing a message within a file. In our case, we conceal a secret message right after the photo is taken and try to extract this message on the server side. Knowing that the message is concealed within the file, a successful extraction of the message would mean that the file is not tampered with. In the second step, a light-weight signature scheme [5] [6] aims to

facilitate the secure transmission of the photo and operates as a pairing mechanism between the farmer and the mobile device used. During the sign in process, a pair of a private and a public key would be generated, and the public key is sent to the server to be saved. Every time the farmer takes a photo, the private key is used to sign the photo. The signing procedure ensures that the photo which was sent to the server was taken by the same device the farmer used to sign in. The signing scheme operates as a second level of assurance that the photo was not tampered on top of the steganography, as in the case of tampering, the signature is not able to be verified in the server process.

In the next phase of the server-side procedure, an algorithm is executed so as to identify the device used to capture the photo. The identification becomes possible due to the fact that each component in a digital camera leaves intrinsic fingerprints in the final image output, which due to manufacturing choices are unique for each device. The component of the camera that makes possible the identification is the CMOS image sensor, which inserts a pattern noise in the photos which is unique for each device [7]. The process is depicted in Fig. 2. This step is useful to confirm that the noise matches the device the farmer is using.

In what follows, two photo specific forensic algorithms are implemented. The first one is the copy-move forgery detection algorithm. In the copy-move forgery, the malicious actor replicates a portion of the photo inside the photo [8] [9]. The detection algorithm allows to avoid this kind of forgery. The second technique regards the way the information is saved inside the photo. As shown in Fig. 2, different processing steps take place before the final photo/file is created. The final step is the appliance of a compression. Every photo file is compressed using a specific algorithm. Taking this into consideration, the entire photo should be roughly at the same level; if a difference is detected, then it likely indicates a digital modification. So, the second forensic algorithm constitutes an investigation of the compression levels. One example of such an investigation is the error level analysis.

In the next step of the procedure, a tool is used to extract the metadata that is embedded in the photo. This extracted data is verified with the data that have been stored in the database i.e., parcel location, time of photo etc. The main information to be obtained involves the location of the photo. Using the Galileo OSNMA, it can be guaranteed that users are utilising non-counterfeit navigation data coming from the Galileo satellites.

Finally, a pre trained convolutional neural network is used so as to locate faces and license plates and blur them. The overall process is depicted in Fig. 3.

For the implementation of the data integrity framework, the python programming language is utilised. For the first two steps, there are respective libraries (stegano and crypto libraries) that are exploited for the implementation. One thing to consider here is that we have to be careful in the choice of the techniques used due to the fact that some parts are implemented in the mobile application. So, we have to ensure that the respective parts should be possible to be implemented in C#, which is the language of the

implementation of the mobile applications. Finally, one more benefit that python gives is the ability to execute bash commands and interact with other tools. A final consideration that should be taken into account, is which variation of the steganography technique to implement. That is because, we could make the algorithms in the last steps unable to be used due to the structure alteration of the photo, by embedding a secret message.

III. MOBILE APPLICATION

The application is developed in the Unity game engine to benefit from the integrated AR solution that ships with the engine. Unity is a cross-platform game engine developed initially as a Mac OSX exclusive game engine. As of 2018, the engine had been extended to support more than 25 platforms. The engine can be used to create multi-dimensional, virtual reality, AR applications. AR Foundation is a cross-platform framework built for the Unity engine that allows to build AR experiences once, then build for either Android or iOS devices. The package presents an interface for Unity developers to use, but does not implement any AR features itself. To use AR Foundation on a target device, separate packages are also needed to target platforms officially supported by Unity: (i) ARCore XR Plugin on Android (ii) ARKit XR Plugin on iOS.

Along with Unity, some native android plugins were developed, mainly to handle the low-level operations required for the raw measurements handling and integrity aspects [11]. The AR component aims to provide directions to farmers in order to enable retrieval of representative photos of a given parcel. The photo taken, along with the required metadata, is uploaded to be verified by the data integrity, validation and anonymization component of the geotagged photos framework and to be stored in the Central Database.

Home screen – Authentication/Authorization. The geotagged mobile application provides translated text interface to accommodate for the users in different countries. The application is not open for general use, it is available only for registered users. In order to achieve this, the user must have registered themselves in the platform.

Content visualization. The application displays recent news from the respective Paying Agency i.e., aspects of importance with respect to the application period, news on CAP implementation in their country, along with the latest pending Tasks for the user (Fig. 4), while the latter displays all the user's declared parcels. A Task is an action required from the farmer by the Paying Agency Inspector. It is related to a specific parcel and its location can be specified by the Inspector. Each parcel has its own unique page in the mobile app to host the various Tasks related to it. However, a user can also act proactively and facilitate the compliance assessment process for their parcel, without receiving notice from the PA Inspector. More than that, the settings page is there to provide visual feedback in the form of the traffic light approach about the EGNSS differentiators supported by the device.

Push notifications. A Paying Agency Inspector may create a new Task for the user at any time through the Compliance monitoring tool. In order to notify the user

efficiently, a new Task in the Toolbox API triggers a push notification to be sent towards the mobile device. The Tasks have an associated status based on their progress which can be open, pending or completed. The push notification system for the mobile application, relies fully on the OneSignal service.

Navigation to parcel and defined spots. After launching a specific Task, the user is presented with a map view. Its purpose is to guide the user to the Parcel this Task is associated with. The mapping platform of choice is the open source Mapbox which along with its very useful APIs, provides the building blocks for a complete position solution. Mapbox is a provider of custom online maps for websites and applications whose data is taken from open data sources, such as OpenStreetMap and NASA, and from purchased proprietary data sources. The Mapbox Software Development Kit (SDK) that is used in the context of the mobile application, constitutes an open-source toolset for building mapping applications for Android devices. An essential part of the SDK is the Native Location Provider that allows the application to make use of the native Android positioning module. That way, the Unity mechanism for position can be overridden and along with it, the low precision it offers. The routing functionality is provided by the Mapbox Directions API external service. The information is denoted on the map by connecting the user's position and destination, along with turn-by-turn text instructions.

Augmented reality photo capture. When requesting geotagged photos from the farmer, the intention is to obtain sufficient information in order to avoid any physical field visits by the Paying Agencies' Inspectors. Therefore, the collected images should provide an overview of the parcel, but not necessarily cover its entirety and all the details (Fig. 4). There are two types of photos that are required from the user, landscape or portrait.

A landscape photo should depict a larger part of the field and include elements other than the main object such as crop and activity, if possible. This type of photo aims at reducing the uncertainty linked with the limited accuracy of the geotag and at providing an overview of the field condition. A portrait photo must serve to enable the robust identification of the element to evidence. This subject could be a mixture of crop as EFA cover, presence of rare crops that cannot be reliably discriminated in the Sentinel data etc. In the context of a Task created by a Paying Agency Inspector, the type of photo as well as the preferred camera orientation are specified during the creation of the Task in the Compliance monitoring tool.

By using ARFoundation, the user is instructed on what is required of them, like where to take the photo from, camera orientation etc. Since a user can take geotagged photos either proactively or in the context of a Task, the application restricts the location of a photo accordingly. If the farmer takes initiative without having a request, he/she is allowed to take a photo from inside the parcel or near each one of the parcel's corners. On the other hand, if there is a Task, the farmer is only allowed to take a photo within a

radius from the location that the Inspector has selected when creating the specific Task.

While in the AR session, the application continuously looks for active applications running in the background, that may tamper with the GNSS signal by mocking the actual location. In conjunction with ARFoundation, the "AR + GPS Location" Unity asset is used to position 3D objects in real-world geographical locations via their GPS coordinates. This asset helps place all points of interest in the AR session so that they correspond to their real-world positions. Unity provides a mechanism to access location data, however this data is of low precision. This, in turn, leads to a lower position accuracy and a lower fidelity for the AR session in general. To overcome this, a method has been implemented to get the native location information directly from the Android system.

The positional accuracy is being tracked and the digital content is drawn only when the accuracy is below a specific ceiling. On top of this, all the AR content is re-drawn whenever the accuracy is improved, so that the overall experience is improved as well. The geotagged mobile application does not use the traditional camera application to take the photos and this is because of the AR session occupying the camera hardware. Hence, there is no mechanism to automatically embed the Exchangeable image file format (EXIF) metadata to the file as it usually happens. Thus, a dedicated mechanism is employed, that takes the background of the image and in the resulting PNG file a custom method is applied to decode and embed the required metadata.

Offline mode. The nature of the farming activities and the geotagged mobile application's purpose mean that the most significant actions in the application's lifecycle take place outdoors. Agricultural parcels are often situated in remote and mountainous places that are not covered by mobile network signal. Therefore, it is crucial that the functionalities of the application can be performed when no mobile signal reception is available.

Since the data presented to the user needs to be as recent as possible, the first steps of the process require an Internet connection to fetch the relevant data. This data, in turn, is temporarily stored and is available while the application is "running" subsequently offline.

Also unavailable is the access to the map view via Mapbox. The map relies on getting tile information via the Internet so no useful information can be presented otherwise. However, a user can download (automatic process) some initial map tiles in the map view, disconnect from the Internet, and have these initial tiles as guiding reference to the parcel in question. The entirety of the AR session is working offline. The AR content that is superimposed is based on the initial data fetched for the user from the Toolbox API. The photos taken are stored locally in the phone's internal memory so that when a network connection is available, the user can browse through them and upload the most appropriate ones. As mentioned, the time and date of a taken photo are very important to the project as they provide a timestamp for the snapshot of the evolving crops in a parcel. The time integrity component is working offline as

well. It can provide a date and time irrelevant of the phone's settings or other external providers that require network to function. The only requirement is the reception of GNSS signals, which is a trivial task when outdoors.

IV. CONCLUSION AND FUTURE OUTLOOK

The presented solution offers a reliable and secure way to modernise the EU's CAP. The farmers are given the ability to capture geotagged photos to support their applications and complement other systems when the latter do not lead to conclusive results. More importantly, it strengthens the interaction between the farmers and the relevant authorities.

In order to improve the UX of the application, more guidance will be needed for the application user, especially anyone unfamiliar with such technologies. Hence, a screen needs to be added with brief instructions on what is required of them, how to take a photo, the restrictions applied etc. An instructional video may also be added. Since AR systems rely heavily on location accuracy as explained in the above-mentioned sections, the implementation of the EGNOS-EDAS augmentation needs to be finalised, harnessing the required augmentation messages provided by the SISNet service of the EDAS platform. In parallel, various filtering methods may be utilized to stabilize existing position. In the backend side of things, the creation of a JSON schema is in order, to annotate and validate the JSON documents uploaded by the geotagged mobile application. By describing the data format, the quality of the submitted data can be ensured. With respect to the geotagged photos integrity framework, the OSNMA implementation needs to be integrated and subsequently a full test to be realised aiming to assess all the different cases.

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