WEB GIS AND CLOUD COMPUTING FOR DEFENSE DECISION MAKING

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Abstract: *The paper presents a workflow for managing and analyzing a national crisis through modern geospatial modeling techniques available in GIS. The transition of such a situation into reality leads to the planning of a complex operation, in which the mode of action must be coordinated and formed by a decision-making process based on truthful information and reflecting reality as best as possible. Modern techniques of geographic information systems support the decision-making act from the beginning of awareness of the situation, model possible actions and help to make the best decision. This modeling of reality can prevent disasters that can cause massive environmental damage, economic crises or direct threats to the population. The main goal of the work is to expose this modeled reality in a flexible way, accessible from anywhere, without having specialized knowledge based on a framework where all geospatial analysis runs independently in a centralized area, in cloud and the interaction is done through web GIS application.*

Keywords: *WebGIS; cloud computing; defense; attacks; incidents*

1. Introduction

GIS (Geographic Information System) technology has become an essential field in defense, providing significant capabilities for analysis, visualization and management of geospatial data. The use of GIS for defense has evolved rapidly, from initial use for terrain mapping and operations planning to the advanced integration of spatial data, IoT (Internet of Things) technologies and complex analysis to support tactical and strategic decisions [1].

The volume and complexity of data from various sources have grown exponentially, requiring advanced solutions for their management and analysis. Adding a spatial component to these datasets, allows users to easily understand the phenomena they encounter by placing them in space and highlights the connection.

The need to store these large volumes of data has led to centralized storage solutions that gather in one place resources that have gone through the verification and validation process and tend to eliminate redundancy. This approach led to the concept of Web GIS where all geospatial resources are stored in the cloud and shared over the Internet, thus being available from anywhere. Cloud Computing adds an additional dimension to this technology, enabling large-scale data processing and analysis.

Web GIS and Cloud Computing are transforming the way geographical information systems (GIS) are used for decision-making. Cloud GIS, which applies Cloud Computing features to GIS, offers several advantages over traditional GIS, including easy and fast data collection, storage, and delivery. This integration can lead to the development of e-government platforms that leverage web GIS and Cloud Computing for improved public service delivery [2].

Complex analytics can be performed in the cloud without consuming local resources and can provide real-time updates. This ensures fast and efficient access to critical information, increasing responsiveness and collaboration across organizations regardless of location. This connection between

Web GIS and Cloud Computing allows decision makers to model reality through tools made available as web services based on complex geospatial analysis and the result to be intuitively presented in a geospatial context that is accessible to these users who are not GIS specialists. Overall, the combination of web GIS and Cloud Computing is transforming the decision-making process by providing real-time access to spatial data, enabling collaborative decision-making, and offering scalable and flexible decision-support systems [3].

The main motivation for the development of this study is given by the involvement in the field of national defense and the intention to combine modern Web GIS technologies with the performance and advantages of Cloud Computing. The main goal is to demonstrate their benefits in the whole decision-making flow within an organization. The technical defense literature presents how geospatial information interfaces with military operations at different tactical levels and is based on four main functions: derive, manage, analyze, disseminate.

Thus, GIS techniques contribute to supporting military actions by analyzing OCOKA (Observation and Fields of Fire, Cover and Concealment, Obstacles (man-made and natural), Key or Decisive Terrain, Avenues of Approach) factors, establishing landing zones or drop zones or by presenting geospatial information of interest. Military leaders plan an operation based on five aspects of terrain analysis. Observation (Fields of Fire) is the condition of weather and terrain that permits a force to see the friendly, enemy and neutral personnel and systems and key aspects of the environment. Cover (Concealment) is protection from the effects of fires, while concealment is protection from observation or surveillance. Obstacles are any natural or man-made obstruction designed to disrupt, fix, turn or block the movement of an opposing force and to impose additional losses in personnel, time, and equipment on the opposing force. Key terrain is an identifiable characteristic whose seizure or retention affords a marked advantage to either combatant. Avenue of approach is a path used by an attacking force leading to its objective or to key terrain [4]. Terrain data integrated into GIS optimizes the analysis of these critical factors for any type of mission and provides beneficial information for decision making. The concept of Cloud Computing is approached from the perspective of enterprise cloud environment that further reduces the need for on-site equipment and allows units to function as a more unified force when conducting dispersed operations [4]. The classic GIS techniques for mapping information of interest to commanders have been combined with dedicated programming languages for expanding predefined capabilities and integrating them with dedicated cloud-computing platforms. This approach was chosen not only for storing and disseminating geospatial data, but also for gathering information in various ways as input data for functions running in the cloud and presenting the results of analyzes to the commander, who is in the position of a thin client.

In the current tense context of armed conflicts worldwide, numerous damages and attacks appear in the online environment through various sources, reported by the population. Based on this aspect, the case study models a national security situation, i.e. the national territory is subject to an aerial attack. In order to have a centralized situation of attacks that occur and are observed by the citizens, it is desired to report them to the responsible organizations. This information gathering should be simple, quick and to the point to show the important information.

The attacks are collected and reported on the map through a survey developed in ArcGIS Survey123 which is shared on the Internet and the data will be stored in databases hosted in the cloud. The survey is developed to collect information through three fields: "Attack location", "Take a picture" and "Other details". These elements generate three fields in the hosted feature layer that is associated with this survey and will represent the input geospatial database in the following analyses. The first field collects the coordinates of the attack by interactively placing its position on the map, thus it is a field that stores the geometry of the event. The second field is of attachment type and allows to add or instantly take a photo with mobile devices. The last field is a string field and allows the free textual addition of relevant details associated with the attack. Each report will generate in the database a record in which the three fields will be filled in, namely an attack determined by its position (point determined by coordinates), photo with the effect of the attack and details. As these are population responses, they cannot be taken as true from the outset. For their verification, an algorithm is developed in Python to extend the capabilities of predefined GIS functions. The algorithm runs continuously on ArcGIS Notebook Server and provides up-to-date answers. Data dissemination is done through Web GIS application developed in ArcGIS Dashboard that shows an overview of verified and unverified attacks. With this approach, the commander observes which areas are affected in real time with the help of the population, but can also analyze and understand which areas are being reported hostile attacks, anticipating next moves and making the best decisions for the conduct of the military operation. Figure 1 schematically shows the chosen geospatial workflow that supports the decision-making process.

Fig. 1. Geospatial workflow for decision-making process

2. Data

2.1. Crowdsourcing

Crowdsourcing has emerged as a powerful approach for engaging the public in participatory decision-making processes, particularly in the context of geographic information systems (GIS) and spatial planning. Crowdsourcing allows large numbers of people to contribute data, knowledge, and perspectives, which can then be integrated into GIS-based decision support systems [5]. This can provide decision-makers with a more comprehensive understanding of the issues at hand and enable more inclusive, collaborative decision-making.

Several studies have explored the integration of crowdsourcing and GIS for various applications, such as waste management [6], flood management [7] and green space management [8]. These studies have demonstrated the potential of crowdsourcing to capture volunteered geographic information and stakeholder input, which can then be analyzed and visualized using GIS tools to support decision-making processes.

However, the integration of crowdsourcing and GIS also presents some challenges, such as ensuring the reliability and quality of crowdsourced data and managing the participatory decision-making process to enable meaningful stakeholder engagement [9]. Addressing these challenges is crucial for leveraging the full potential of crowdsourcing in GIS-based decision-making.

2.2. Geotagged images

The expansion of digital cameras and smartphones has led to an exponential growth in the number of geotagged images being captured and shared online. These images, which contain embedded geographic coordinates and other metadata (known as EXIF data), have become a valuable source of information for a wide range of applications in geographic information systems (GIS) [10].

Geotagged images and their associated EXIF data can provide insights into human mobility patterns [11], environmental monitoring, urban planning and disaster response [12]. The geographic coordinates embedded in the images allow them to be mapped and analyzed alongside other spatial data, enabling researchers and decision-makers to gain a better understanding of the relationships between physical locations and human activities.

Furthermore, the EXIF data, which includes information such as camera settings, timestamp and device type can be leveraged to extract additional contextual information about the image and its capture. This metadata can be used to infer user behavior, identify patterns in photography trends and even assist in forensic investigations. The integration of geotagged images and EXIF metadata into GIS can be a powerful tool for spatial analysis and visualization. By georeferencing the images and linking them to their associated EXIF data, researchers can create rich, multi-layered maps that provide a deeper understanding of the physical and social environments being studied.

One key aspect of this integration is the ability to filter, query and analyze the geotagged images based on their EXIF metadata. The accuracy of the geographic coordinates embedded in the images can vary depending on the device and the conditions under which the image was captured. Additionally, the EXIF data can be manipulated or removed, potentially compromising the integrity of the information.

3. Case Study

3.1. Introduction

The case study is based on a scenario, created to highlight the planning and management of a national crisis situation using Web GIS and Cloud Computing methods. It is assumed that the national territory is subject to an aerial drone attack. Due to the speed of the action, the population is invited to contribute to the understanding of the conflict by reporting attacks (strikes) in the areas where they are located. These reports can generate an overall picture of the conflict and are the input to geospatial analyses that contribute to decision-making. In addition, as the method of data collection is shared over the internet and it is not known exactly who will contribute to incident reporting, validation is required [13].

The technologies used to solve this scenario are ArcGIS Online for storing and sharing geospatial data and developing GIS web applications, as well as the Python programming language with ArcPy and ArcGIS API for Python for developing geospatial analytics running in the cloud.

The diagram below shows the workflow and technologies used to conduct the case study.

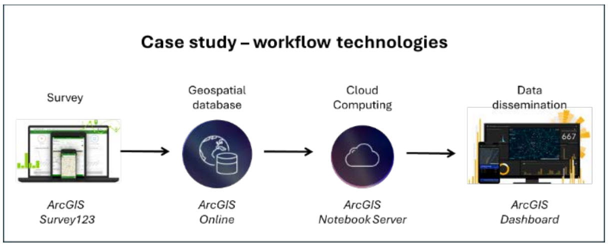

Fig. 2. Diagram workflow [14]

3.2. Collection of Input Data

Population-based information has proven to be a considerable source of data in decision-making as it generates in a short time sufficient, diversified and widespread data across the area of interest due to the large number of people involved [10]. In order to have a positive impact on the analysis, it needs to be collected and transmitted in a time as close to reality as possible, which implies how to report and access it. The simplest form of data collection can be the use of devices that can connect to the Internet and use a browser (smartphone, workstation or laptop).

The fulfillment of the requirements is possible using ArcGIS Survey123, which allows data to be collected in a standardized way via a web browser, without the need for additional resources from the user. Form creation in ArcGIS Survey123 is available from ArcGIS Online. Relevant to an incident (attack) are its location, images, and other details that could provide an advantage to decision makers. Thus, items are added to the form to collect these types of data.

To obtain the coordinates of the incident, a web map is used to place a pin corresponding to the position in the field. The simplicity of the survey lies in the way it is perceived by the group of people it is intended to reach. This is a crisis situation, so the completers are put in a position to quickly access and provide the necessary information in the shortest possible time. For these reasons, only the aspects considered most important to achieve the best results were selected (location of the incident, picture from the place of attack and details).

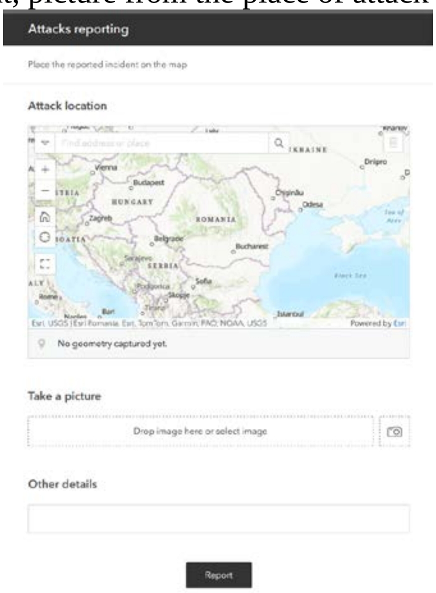

Fig. 3. Survey for reporting attacks

This will automatically generate a map showing attacks in user-declared locations that will contain an image captured with a smartphone and details. The image below shows a web representation of all reported incidents (orange dots).

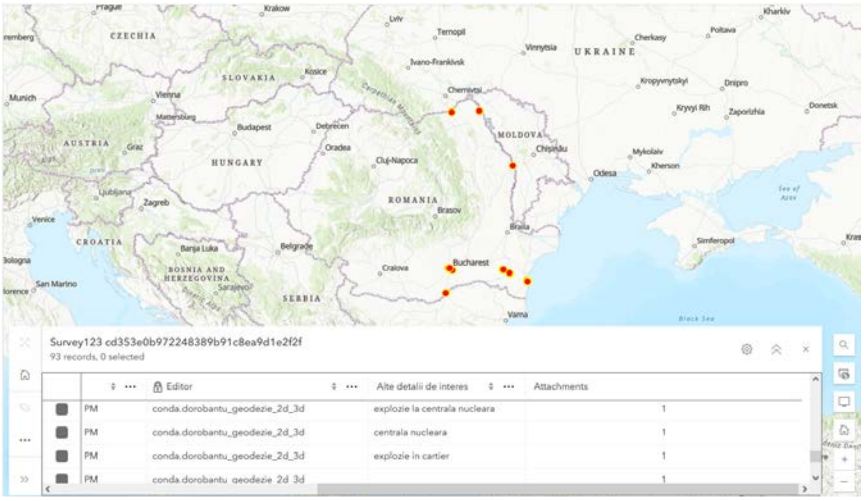

Fig. 4. Map of attacks declared by the population - ArcGIS Map Viewer

4. Incidents Validation – Cloud Computing

Because access to the survey is not restricted, the resulting data may not reflect reality, but rather represent a hostile scenario in which malicious entities place fictitious incidents to generate contradictory and false results that affect decision-making. With this objective in mind, the incidents were verified using a Python algorithm.

The images captured with a smartphone have in their metadata information about the position where they were taken, based on the satellite receiver integrated in the device. Thus each incident will be considered verified and well-intentioned if an incident has been reported near it (100 meters radius buffer) that contains a geolocated image and confirms the position.

To solve this validation, an algorithm was developed that uses ArcGIS API for Python for data management from ArcGIS Online and ArcPy for geospatial analysis. The algorithm can be structured in the following stages:

Download attachments (images). The data resulting from filling out the survey is stored in ArcGIS Online as geospatial services. To access them and download attachments (images taken with a mobile device), is used the GIS method and access credentials to connect to ArcGIS Online. Each element has a unique ID associated with it, so is identified the desired layer, it iterates through each record, selects the attachment and downloads it. After connecting to ArcGIS Online and identifying the hosted feature layer associated with the survey, the following code sequence downloads the attachments.

```
FeatureLayer = gis.content.get(FeatureLayerID)
layer = FeatureLayer.layers[0]
query_result = layer.query()

# Iterate through each feature
for feature in query_result.features:
    oid = feature.attributes['objectid']
    attachment = layer.attachments.get_list(oid)

    attachment_data = layer.attachments.download(oid, save_path=savePath)
    if attachment_data:
        print("Download {0} with id {1}".format(attachment_data,oid))
```

Fig. 5. Code sequence for download attachments

Geocode images. The algorithm uses the function *arcpy.management.GeoTaggedPhotosToPoint()* from ArcPy Python library for geocode the images on the map based on the coordinates extracted from the metadata. These images are the basis of the validation because although the incident was reported in a certain location, the coordinates in the metadata will show the true position from where the photo was taken, thus an incident is considered validated. The code below uses the downloaded images, extracts the coordinates from the metadata and represents them on the map as points.

```
out_geotagged = gdb_path + "\\" +"GeotaggedImg"
input_folder=r"path_to_folder"

arcpy.management.GeoTaggedPhotosToPoints(
    input_folder,out_geotagged,"","ONLY_GEOTAGGED",
    "ADD_ATTACHMENTS")
```

Fig. 6. Code sequence to plot geotagged photos

Check the intention. A new field called „intention" has been created for all records in the database. Based on geospatial analysis, it is determined whether each user report is verified by a photo. If this is confirmed the field „intention" gets the value 1 (green dots), otherwise the value 0 (red dots). A reported attack that has not yet been verified will be represented by a yellow dot and the „intention" field will be null. The code below shows how attacks are checked. First, all attacks are considered hostile and the „intention" field is 0. If the attacks are less than 100 meters from a geolocated image, they are considered verified and the „intention" field gets value 1 for them.

```
#all attacks are hostile
arcpy.management.CalculateField(
    "survey_points",
    "intentie",
    "0",
    expression_type="PYTHON3"
)

#select the verified attacks
arcpy.management.SelectLayerByLocation(
   "survey_points",
   "INTERSECT", out_geotagged,
    search_distance="100 Meters",
    selection_type="NEW_SELECTION",
)

#calculate field for the verified attacks
arcpy.management.CalculateField(
    "survey_points",
    "intentie",
    "1",
    expression_type="PYTHON3"
)
```

Fig. 7. Code sequence for check the attacks

This algorithm can be integrated on any server for geospatial processing, in the case of the study it was integrated in ArcGIS Notebook from ArcGIS Online. Due to the advantages offered by cloud processing, this verification method can be hosted on the server and run continuously regardless of the resources and availability of those using it.

The image below shows a web map in which the attacks are represented in the three categories (checked, hostile, unchecked). This representation shows commanders the context of the attacks and their type. Placing on the map helps to understand the phenomenon, to visualize the complex distribution of the crisis situation, to visualize the most attacking areas, the regions that need reinforcements, which are the most vulnerable areas and what are the intentions of the enemy. Viewing hostile attacks shows the deception attempt and the areas where the enemy wants to redirect the opponent.

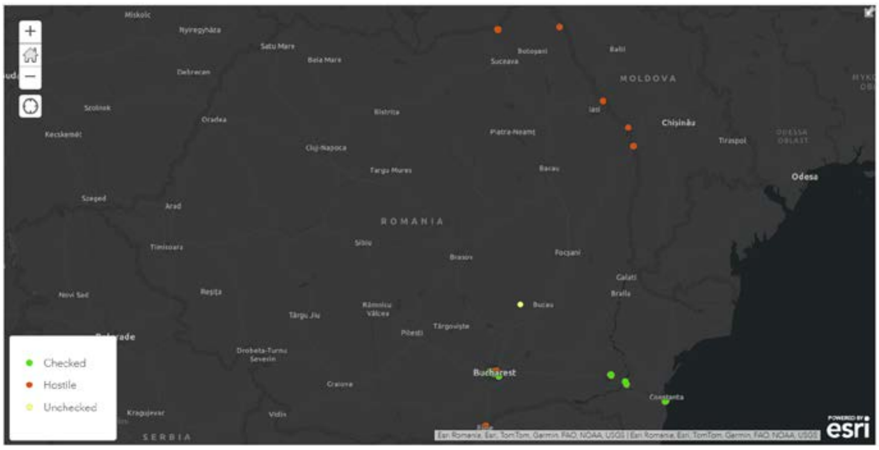

Fig. 8. Representation of attack intention

5. Data Dissemination

To share the information resulting from incident collection and verification, ArcGIS Dashboard is chosen, which will utilize the web map, so that any response is verified using the cloud algorithm and sent to the decision-making entity. Based on the web map, indicators are generated showing the total number of incidents, the number of hostile incidents, the number of verified incidents (green dots), the number of unverified incidents (yellow dots) and the number of hostile reports (red dots).

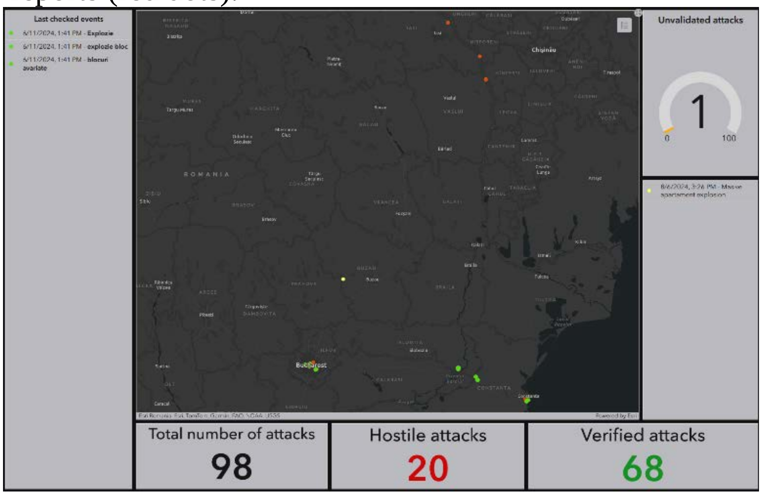

Fig. 9. Dashboard attacks overview

6. Conclusion

The study highlights the practical ways in which geospatial analysis supports decision making throughout the decision-making process. Placing events in space, by representing them on a map, provides the decision-maker with a simpler way of understanding the phenomenon being analyzed. Furthermore, through GIS-specific spatial analysis, reality is quickly modeled to answer the question "What if?".

Summarily, the study contributes to the understanding of the dimension of a hazard caused by an air attack, when the population is involved in reporting these events through modern Web GIS techniques. Validation of the veracity of attacks is achieved through flexible algorithms developed by programming languages dedicated to geospatial analysis. The integration of these algorithms with cloud-based processing, storage and online sharing of geospatial data as a service, gives the decision-maker the flexibility to analyze the evolution of the phenomenon in real-time and make an informed decision without using high resources.

The study focuses on how Web GIS technologies, Cloud Computing and Python scripting automation integrated into ArcGIS Notebook Server can support and optimize decision-making in crisis management. It presents the implementation of an automated workflow for validating reported attacks using a Python script that downloads, geolocates and verifies real-time photos obtained from the field.

The main point is that the photographs may at first sight be considered as auxiliary data to the reports, but the associated coordinates obtained with the mobile devices with which they were taken form the basis for verifying the attacks. This verification of photo metadata provides accurate, fact-based information for decision making and is a stealth approach to limiting hostile engagement. The ArcGIS API for Python library manages geospatial data stored in the cloud and is processed using the ArcPy library. The resulting script is integrated with ArcGIS Notebook Server and ensures continuous processing, thus the management of the decision-making act is carried out in real-time.

This practical approach highlights new methods of real-time verification of open-source data through solutions not traditionally found. This method is generated by the need to support decision-making process and can be adopted for different types of organizations. Through this continuous validation visualized on a map, the decision-makers determine the areas where damage is caused and can mobilize the necessary forces for evacuation. Also, based on hostile reports, the commander understands enemy intentions, anticipates next moves and can plan a defensive operation.

In conclusion, public involvement in decision making is optimized and improved by validating open-source information with new methods, according to the needs of each organization, through the flexible Python programming language integrated with Web GIS and Cloud Computing technologies for real-time results placed on web maps.

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