GIS-BASED INTELLIGENT DECISION-MAKING SUPPORT SYSTEM FOR THE DISASTER RESPONSE OF INFECTIOUS DISEASES

S. J. Son [1], M. Y. Lee[1], J. H. Kim[1], S. H. Cho [1]

[1] Sundosoft Seoul, Republic of Korea - (sjson, mylee, jhyeonkim, chosh)@ sundosoft.co.kr

KEY WORDS: GIS, System Platform, Remote Sensing, Water Pollution, Disease.

ABSTRACT:

The study aims to develop GIS technology for managing pathogen contamination disaster situations to cope with the occurrence of disaster situations caused by the climate crisis. This study was conducted in a situation where the budgets of institutions with many emergency rescue workers are being invested worldwide, and there are various risks such as water pollution due to climate change, so it is necessary to develop technologies to respond to them.
In this study, methods and technical means for emergency response to pathogen contamination were prepared through professional analysis results based on spatial information, and rapid and accurate pathogen detection, situation recognition, event control and response methods, risk assessment and epidemiological investigation methods, and technologies were developed.
Technological means include collecting and analyzing water quality data using satellites and drones, and evaluating the severity and degree of water pollution using social media data and photos. Through these technologies, a GIS platform that can effectively manage and provide data sources, data collection, interoperability, data harmonization, data management, and data processing is established, and commercialization is aimed at real users and field-oriented. These technology developments enable rapid response and response in disaster situations, and can reduce threats to life and safety.

1. INTRODUCTION

There are more than 7.5 million first responders working in various organizations such as fire services and emergency medical services worldwide, with a total budget exceeding 400 billion euros and about 15 billion euros being spent on equipment and other needs. In addition, water pollution caused by torrential rains caused by climate change and rising temperatures can have a fatal impact on our health, and the number of cases of waterborne infectious diseases at home and abroad continues to increase. Accordingly, the importance of technology on how to respond to the occurrence of disaster situations caused by the climate crisis is increasing.

In domestic and foreign technology development, many technologies for natural disasters have been developed, but there is no technology development and response system platform for technologies related to biological and medical risks, which are social disasters. Therefore, it is intended to provide methods and technical means for emergency response to pathogen contamination by calculating professional analysis results based on information obtained through spatial information. It also aims to develop rapid and accurate pathogen detection technology, situational recognition technology, event control and response methods, and technology, risk assessment and epidemiological investigation methods and technologies to strengthen the technology capabilities of first-time field responders.

2. METHODS

2.1 Headings

We developed a decision support system that manages pathogen contamination using sensors and information obtained from the field. This includes risk assessment and epidemiological investigation technologies developed through artificial intelligence and big data. Three techniques have been applied to analyze contaminated areas.

First, you can preview data taken by satellites and collect images of water bodies to analyze and inform pollution levels. Secondly, the turbidity of water through the cam is provided by data from the continuously photographed waters. Finally, it also builds a water quality monitoring system based on data analyzed from water samples obtained from drones.

These images were taken in an area that was not easily accessible to humans. This technology provides both spatial analysis results and images to users through PathoGIS. In addition, data and photos on social media are analyzed to provide the severity of water pollution along with specific spatial locations.

2.2 Integrated Technologies

The purpose of this technology is to use the REST API to obtain data from PathoWARE provided by other components of PathoCERT and to be implemented through an open API.
Information source connection and web-GIS setup have been completed, and IMS system configuration is being advanced. Statistical data from the Data Connector (harmonization and non-harmonization) is stored in a database using Signus, a technique from FIWARE.

The platform uses a NoSQL database implemented using MongoDB, which stores all statistical data in json format, collects it from the PathoWARE platform, and transmits it from other PathoCERT components. It supports data management in GeoPaces with servers implemented using GeoServer.

It uses a webpi format implemented using OpenResty (nginx), which allows authorized users to search for media files (images, videos, geotypes, pdf, etc.) collected on the PathoCERT platform. The folder structure is divided into data providers (PathoCAM, PathoDRONE, etc.), and each data provider can identify and use folders to store files.

To effectively provide and manage information on the platform, the system consists of seven layers: source management, data collection, interoperability, data harmonization, data applications, data processes, and security. Lists all components of PathoCERT that integrate with PathoWARE in various ways, as shown in Figure 1.

Figure 1. Integrated Technologies

The technologies that integrate with PathoWARE are. PathoTWEET which provides data to PathoWARE, particularly the analysis done on tweets. PathoSAT that provides data to PathoWARE, particularly satellite data obtained through analysis of satellite images of Water Body. PathoCAM which provides data to PathoCAM by continuous monitoring of turbdity value of some pilot lakes. PathoSENSE IoT Gateway that provides data to PathoWARE regarding information collected from water sensors. Real Time Analytics which provides data to PathoWARE regarding detection of alarms. PathoDRONE which provides data to PathoWARE about images captured by the drone. PathoIMS that consumes and produces data to PathoWARE about the resolution of alarms in progress. PathoTHREAT not closely related to PathoWARE except from the perspective of user authentication. PathoINVEST that consumes and provides data to PathoWARE about the missions, requests, and reports it generates. PathoGIS which consumes data from PathoWARE in order to display it on a map. PathoVIEW which produces and consumes data from PathoWARE to display and create alarms from users.

2.3 Provide Information

All components within the data collection, interoperability and data harmonization, data management and security and privacy layers provide information for users to utilize on that platform. It also completed the link between the information source and

the Web-GIS setup and stored the statistical data in the database. The platform is designed to store all statistical data in json format. Data can be managed in Geospaces with servers implemented using GeoServer.
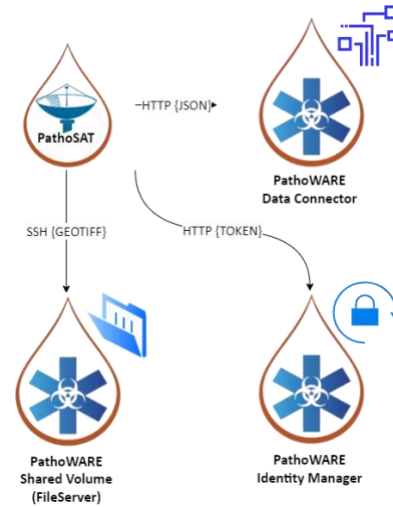
2.4 PathoSAT

Figure 2. PathoSAT Configuration Diagram

2.4.1 GeoTIFF Image
PathoSAT is part of the data source layer of the PathoCERT architecture. Artificial intelligence algorithms allow you to.
First, each pixel generates a GeoTiff file representing a chlorophyll value in mg/m^3 units at a specific location in the lake when entering a satellite image of the water referring to the specified X. Second, specifying three satellite images as inputs produces a GeoTiff image in which each pixel assumes a precautionary value of chlorophyll-ammonium/m³ at a future date (five days after the three most recent images taken as input) [4]. In both cases, PathoSAT transmits not only the GeoTIFF image, but also the JSON of statistical data calculated from that image.

Because PathoSAT can generate GeoTIFF images that reference the same water region, but with different dates, thanks to continuous monitoring, it can generate multiple satellite images that reference a single water region. Several rules have been defined that can be quickly and easily integrated because the PathoSAT image must be published to GeoServer.

2.4.2 Statistical Data
Statistical Data, along with the GeoTIFF image, sends statistical data to a component of PathoWARE called a data connector when PathoSAT creates a data product.

This statistical data is in JSON format and features the following fields.
productID (representing the identifier of the satellite image used to generate the GeoTIFF), productURL (the URL of the satellite image used to generate the GeoTIFF), productBbox (a GeoJSON and indicates the area of the image), sensingDate (the date to which the GeoTIFF image refers), outputLocalServerPath (the name of the generated file), storageFormat (representing the format of the satellite image), productFormat (representing the format of the generated product), productType (Information about the prvenience of the satellite image used in terms of which satellite captured the satellite image) processedBbox (a GeoJSON and indicates the

area of the image that was processed), Id (a unique string identifier of the GeoJSON).

statisticalValues, It is a GeoJSON containing some statistical information calculated from the image values. In particular, it is structured as follows.

measureName (representing the type of measurement), value (the value of the measurement), unitOfMeasure (the unit of measurement of the value) suggestedThreshold (three ranges of suggested thresholds).

cloudInfo, when dealing with satellite images, one must take into account the possibility of clouds making the image unusable. Therefore, this field present in the JSON sent by PathoSAT is itself a JSON with the following fields.

value (the value of the cloud coverage, in terms of percentage of the image area under the clouds), suggestedThreshold (two thresholds that indicate over how much cloud cover makes the product affected by noise, and therefore with high uncertainty).

Whenever PathoSAT generates a GeoTIFF image it must also construct this JSON which it will send immediately after sending the GeoTIFF image to the middleware.

2.4.3 Viewing PathoSAT Data Products on PathoGIS

On the PathoGIS platform, satellite images are shown as Figure 3. When users click PathoSAT in the left sidebar, the data integrated with PathoSAT is displayed on the screen. Thanks to the technical integrations described in Sections PathoGIS gets data generated by PathoSAT and PathoGIS gets data generated by PathoSAT (Forecast), PathoGIS is able to obtain from PathoWARE both types of Data Products generated by PathoSAT: actual and forecast ones.

So, users can check how polluted the river is with satellite images. The measured Algae value is expressed in color according to the legend, and the layer displayed on the map can be controlled through the data panel at the bottom.
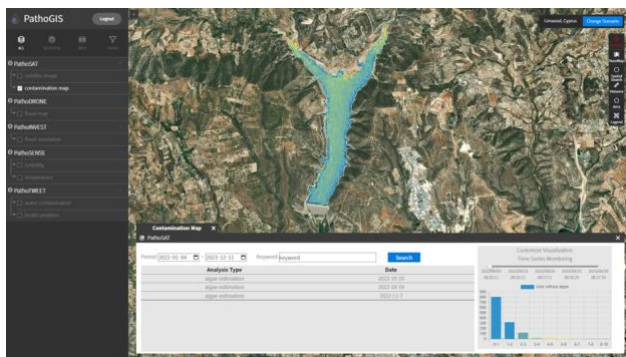

Figure 3. PathoSAT on PathoGIS
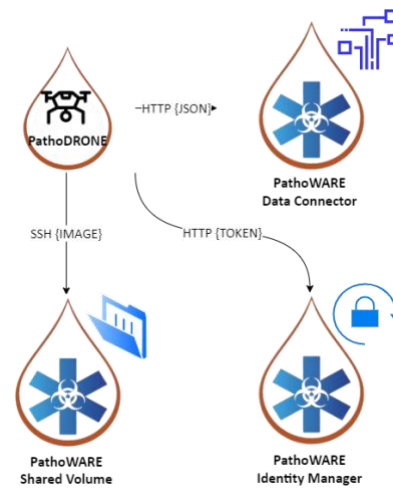
2.5 PathoDRONE

Figure 4. PathoDRONE Configuration Diagram

PathoDRONE is a technology that collects water samples using drones and takes them to the laboratory for analysis [2]. However, this technology is used to capture images of areas so that users can see them. Therefore, the integration between PathoDRONE and PathoWARE requires two types of data to be transmitted: json of images and associated metadata.

On the PathoGIS platform, PathoDRONE is shown in Figure 5. When the user clicks PathoDRONE in the left sidebar, the data integrated with PathoDRONE is displayed on the screen. Thanks to the technical integrations described in Sections PathoGIS gets data generated by PathoDRONE, PathoGIS can be obtained from the actual product and PathoWare, the data product types generated by PathoDRONE.

So, users can check where the drone is located in the form of points. Click on each point displayed on the map to check detailed information in a pop-up form.

Users can check the date and time when drone data was generated. Through this, the reliability of the data can be secured, and users can check the flow of change in the data.
The data currently available from PathoWare is the file path of the actual image taken by the drone. We will map the file path to the PathoGIS platform so that it can be displayed in pop-ups.
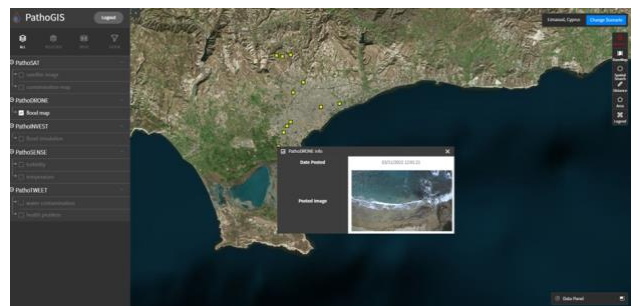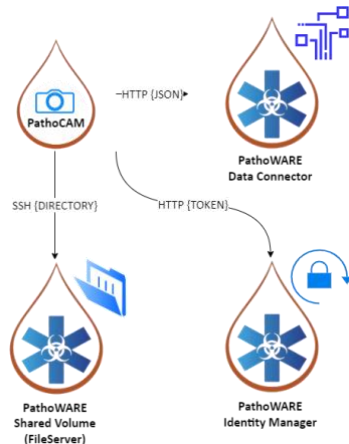

Figure 5. PathoDRONE on PathoGIS
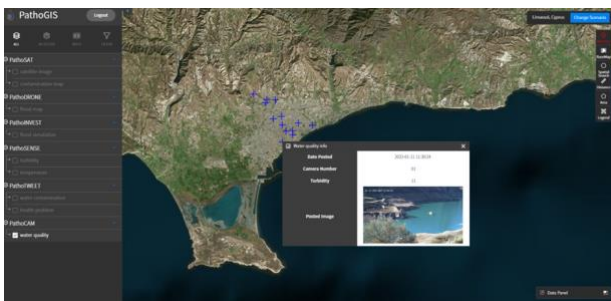
2.6 PathoCAM data visualization on PathoGIS

Figure 6. PathoCAM Configuration Diagram

PathoCAM's main goal is to monitor potential contamination events in surface water using double-spectrum cameras (CETs), to analyze anomalies through water pollutants (optical lenses), and to establish PathoCAM methods and technologies to support pathogen contamination awareness.

It collects satellite, Twitter, and camera data for analysis, and is currently undergoing infinite crawling and Twitter analysis.
Event detection methods are integrated into the pathotweet pipeline and event transmission to pathoware is being tested.
The pilot execution of the event detection method and various values for the event detection threshold are being tested to analyze and verify the most suitable value for the use case. A relevance estimation model is in progress.

On the PathoGIS platform, PathoCAM is shown in Figure 7. When the user clicks PathoCAM in the left sidebar, the screen displays data integrated with PathoCAM. Thanks to the technical integrations described in Sections PathoGIS gets data generated by PathoCAM, PathoGIS can be obtained from actual products and PathoWare, the data product types generated by PathoCAM.

So, users can check the location information being measured in the form of a point by installing a camera. Click on each point on the map to view details in a pop-up format. Users can check the date the camera took the image. Through this, data reliability can be secured, and users can check the flow of data change. In addition, the measured turbidity of water can be checked by numerical values through the camera. The actual image taken by the camera may also be displayed. Situation managers can check and respond to actual dangerous situations in the area by looking at actual photos taken by cameras.

Figure 7. PathoCAM on PathoGIS

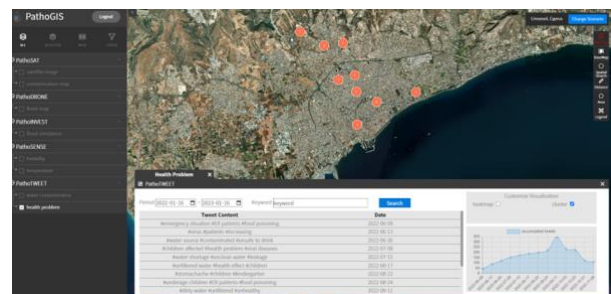## 2.7 PathoTWEET data visualization on PathoGIS

On the PathoGIS platform, PathoTWEET is shown in Figure 8. When the user clicks PathoTWEET in the left sidebar, the screen displays data integrated with PathoTWEET. Thanks to the technical integrations described in Sections PathoGIS gets data generated by PathoTWEET, PathoGIS can be obtained from actual products and PathoWare, the data product types generated by PathoTWEET. So, users can check the location information posted on Twitter in the form of points. Click on each point displayed on the map to check detailed information in a pop-up form.

Users can check the date on which the Twitter data [1] was generated. Through this, the reliability of the data can be secured, and users can check the flow of change in the data. In addition, if the image is included in the Twitter data, the image is also displayed in the pop-up. Hashtags that post related information are also displayed in the Hashtags area. It will also allow TwitterURL to be displayed.

Figure 8. PathoTWEET on PathoGIS

The layers clicked by the user on the map can be controlled through the data panel at the bottom. In the case of point data, there are two ways to visualize it. The first is a heat map and the second is a cluster. Users can check where and how densely Twitter data is generated through the heat map by color changes. Situation managers can identify and respond to which areas are directly affected through citizen reports. When the cluster in the data panel is clicked, it is displayed as shown in Figure 9. Twitter data generated in adjacent areas are expressed in specific figures. Situation managers can make statistical judgments through specific figures. Twitter data graphs show how stacked Twitter is by date. Users can check the number of Twitter accumulated on a higher-than-average date to check when the damage occurred and whether it was mitigated.


Figure 9. PathoTWEET Clustering on PathoGIS

2.8 PathoGIS

The function and visualization information of the platform for providing the functions described above in the platform are as follows.

We provide information by mapping global scenarios through 3D globe mapping. The heat map and cluster represent the location and frequency of the area where the data occurred, and map the check plane layer of the lake or river, satellite images, and water quality change time series monitoring layers on the map.It has implemented a warning pop-up of data beyond the threshold, estimating the distance in the area where the data is collected, and searching for data within the customized range [3]. Data Panel allows users to efficiently control the visualization of each layer, search for periods and keywords, and check trends through graphs [5].
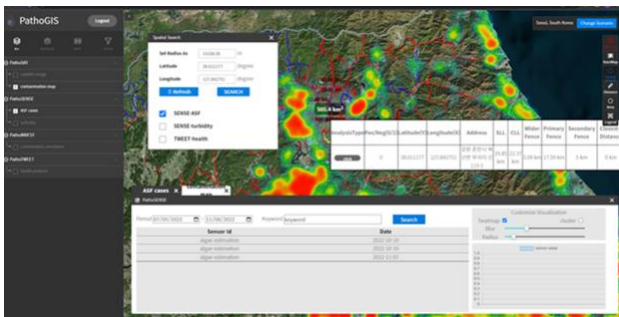
Figure 10 Feature and visualization information for the PathoGIS platform

3. RESULTS

Considering the functions of the system, the following platform can be applied in three fields. "Detection of pathogens and water pollution/situational response/post-investigation", "Infection management and decision support system " and "Protection and management of the first responder".

Two test locations were selected and the pilot case study was conducted in each location.

3.1 Limassol Pilot Case Study

An earthquake near Limassol caused flash floods and landslides, polluting the Kouris Dam which is a primary reservoir in Limassol.
 The water pollution over time can be checked by satellite images analyzed through PathoSAT. The turbidity and temperature of water detected by PathoSENSE and the results of satellite image analysis can be checked on the PathoGIS platform. The user can check the areas heavily affected by flood and the magnitude of the tide is visualized on the PathoGIS data panel through graphs. A warning alert appears when the pollution level exceeds the threshold and the user can check. If victims report the location of polluted areas on Twitter, it can be checked through PathoTweet.

3.2 Korean Pilot Youth Case Demonstration

A person in close contact with ASF wild pigs visited a farm near Soyang Dam and all pigs on the farm had to be dislocated due to mass infection. Many positive ASF cases were reported near the Soyang River inevitably.
Due to the unusually high precipitation in summer, the Soyang River Dam overflowed and caused leaked leachate to flow into the Soyang River Dam. PathoSAT satellite images can be used to identify the boundaries of areas that can be potentially damaged by flooding. The time series visualization shows that water pollution is more severe near the location of ASF-positive cases. Since the government needs to respond to the rapidly

increasing number of ASF cases, the results of ASF case analysis can be checked using the analysis application. Using such data to prevent African swine fever from spreading south, analysts can determine the optimal distance from SLL (Southern Limit Line), CLL (Civil Defense Limit Line), primary fence, or the need for additional fence installation. As the number of ASF-positive cases increases, pollution in tap water can be easily found in Seoul since a large portion of water originates from Soyanggang Dam. The PathoSENSE turbidity sensor notifies the current situation regarding water pollution. If the turbidity of tap water increases, Twitter reports on health problems also increase in Seoul simultaneously.

4. CONCLUSIONS

4.1 PathoGIS gets data generated by PathoSAT

The main goal of PathoGIS is to display the satellite data collected by platform on a map.
Therefore, such integration is critical in order to ensure this. The PathoSAT component, in fact, generates GeoTIFF images that must be displayed on a map by PathoGIS.
These GeoTIFF images are referenced to a specific water body for a specific date, and contain information about the value of chlorophyll at each individual point in the water region
Then, each GeoTIFF image is also associated with a JSON of statistical data produced by PathoSAT.

4.2 PathoGIS gets data generated by PathoTWEET

PathoTWEET sends data from analyses done on a set of tweets. This data is consumed and displayed by PathoGIS. In particular, PathoGIS is able to take the analysis given by PathoTWEET in a specific area for a specific period.

4.3 PathoGIS gets data generated by PathoDRONE

PathoDRONE generates and sends to PathoWARE images captured with the drone and metadata in JSON format associated with each image. This data can be visualized by PathoGIS.

4.4 PathoGIS gets data generated by PathoCAM

PathoCAM is concerned with continuously monitoring some water body pilots in order to calculate their turbidity value. Periodically, in fact, PathoCAM sends to PathoWARE the results of the analysis done on a Water Body. These results include two different types of data: a JSON file containing statistical data such as the date of the observation and the location, and a folder containing images from which the analysis was calculated. Both types of data are then displayed by PathoGIS on a map.

4.5 Expected Effect of PathoGIS

A platform that contains a database related to the spread of pathogens and provides AI-based information regarding the dangers of the situation will certainly help in responding to infectious diseases.
It will be able to strengthen its ability to respond to infectious diseases and disasters by using it as a tool to improve the capability of the first responder and reduce the time required to detect and respond to the situation.
In particular, there will be an effect of reducing industrial accidents by improving the ability to respond to unidentified

risk situations that are likely to be encountered by first-time field responders.

By improving the ability to respond to unidentified situations, the number of industrial accidents will likely decrease. Shortly, when database expansion and the cost of maintenance becomes stable, in-depth data analysis of epidemiologic big data will be possible using pattern recognition and deep learning models.

REFERENCES

Asif, A., Khatoon, S., Hasan, M. M., Alshamari, M. A., Abdou, S., Elsayed, K. M., Rashwan, M., 2021. Automatic analysis of social media images to identify disaster type and infer appropriate emergency response. *Journal of Big Data, 8, 83.*

Berktay, A., 2008. Assessing water quality in the Beysehir lake (Turkey) by the application of GIS, geostatistics and remote sensing.

Emmanouil, D., Nikolaos, D., 2015. Big data analytics in prevention, preparedness, response and recovery in crisis and disaster management. *RECENT ADVANCES in COMPUTER SCIENCE Proceedings of the 19th International Conference on Computers (part of CSCC '15) (pp. 476- 482)*

Koparan, C., 2020. UAV-Assisted Water Quality Monitoring. All Dissertations. 2703.

Santillan, J., Morales, E. M. O., Makinano-Santillan, M., Amora, A. M., 2019. A WEB GIS-BASED VISUALIZATION AND ANALYTICAL PLATFORM FOR NEAR-REAL TIME FLOOD CHARACTERIZATION, FORECASTING AND IMPACT ASSESSMENT. *In 40th Asian Conference on Remote Sensing 2019 (ACRS 2019) (pp. 1-6). Daejeon Convention Center, Daejeon, Korea.*