SILVANUS Dashboard for Wildfire Management

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ABSTRACT

The world is constantly exposed to the negative effects of wildfires, which occur for various reasons, often beyond human control. In such a case, it is highly advisable to develop appropriate countermeasures that will comprehensively approach the problem of wildfires. In response to these needs, the SILVANUS project was created. The goal of SILVANUS is to use new and existing technologies in the field of fire management, such as mobile applications for citizens, dedicated user interfaces or special applications for training firefighters in VR. The set of these tools is intended to support Integrated Fire Management. In this paper, we propose a web-based interface which facilitates crisis management during fires, especially wildfires. The Dashboard is an interactive map for monitored areas, with layers corresponding to different sources of data. It also supports communication between citizens and firefighters through mobile applications and social media. The main objective of the system is to help with decision making process so that the user will ultimately decide whether data is relevant or not. The solution is directed mainly at firefighters, analysts, and public administration entities. The presented Dashboard is a work in progress.

Keywords

Dashboard, wildfire, decision support system, map.

INTRODUCTION

Climate changes, voluntary or involuntary human activities, natural causes like lightning, are main reasons of wildfires that have a negative ecological and socio-economic impact on different countries. “Every year about 45000 forest fires occur in southern Europe, burning approximately 0.5 million hectares of forests and other rural lands.” (Moreira et al., 2011). Forests in Europe cover over 35% of total land area (FOREST EUROPE, 2020) and are responsible for many ecosystem services necessary for human well-being such as purifying the air, filtering water supplies, controlling floods and erosion, and many more. Unfortunately, when facing wildfires, forests are losing their ability to adapt and become more vulnerable to other dangers (Forzieri et al., 2021). We distinguish controlled and unplanned forest fires. The purpose of a controlled burning, among other things, is to reduce the risk of uncontrolled fire and to initiate it intentionally to support the forestry and agricultural sectors or to reduce greenhouse gas emissions (Grebner et al., 2013). An unplanned forest fire is unwanted wildland fire which affects an increasing number of countries, therefore the need to take remedial actions is also growing.

While researching countermeasures to prevent the increasing number of wildfires, more and more authorities are turning to IT solutions. They are flexible, relatively easy to use and low cost, and can potentially be customized with information the user considers most necessary (Hunter & Westerman, 2009). The prevention and management of forest fires, restoration of areas destroyed by fire are the topics that the Horizon 2020-funded project SILVANUS addresses. It aims to create a stable forest management platform that is resistant to climate change. It is intended not only to effectively prevent and suppress uncontrolled and dangerous forest fires, but also to help plan prescribed burning. As part of the project, SILVANUS uses the expertise of specialists in the areas of environmental, technical and social sciences. Scientists and engineers are supporting civil protection authorities by helping to effectively monitor forest resources, assess biodiversity, create accurate fire risk indicators and promote safety regulations among local fire-affected communities through awareness campaigns. The project lasts 42 months and, with the involvement of 49 partners from around the world, is to develop the best possible solution in the fight against wildfires (SILVANUS, 2021).

One of the tools developed as part of the SILVANUS project is the Dashboard. It is an interactive panel that represents various data graphically, often through the use of charts, tables, maps, and other visual elements. The main purpose of this interface is to facilitate timely and easy user access to important information, as well as to enable monitoring of key indicators or metrics (Few, 2013). The SILVANUS Dashboard consists mainly of a map and corresponding layers intended to assist relevant authorities in making important decisions. The platform obtains information from various sources, such as robots, drones, computer analysis and even from residents who have the Citizen Engagement Application installed on their phones, which is another tool of the SILVANUS project prepared to increase citizens' awareness about forest fires. The aim of this article is to provide information about the Dashboard prepared for the SILVANUS Project.

The article is structured as follows: the first two sections outline the context of the problem and present the current state of knowledge in the field of fire crisis management. The next section defines the SILVANUS Dashboard system requirements, presents the system description and its architecture. Finally, conclusions are presented, summarizing the contribution of this work to solving the original problem and presenting plans for further works.

STATE OF THE ART

Dashboard is a useful tool which is being used and analyzed for emergency management in various areas to help with the decision support process. Mordecai & Kantsepolsky (2018) prepared a framework to improve management in extreme weather conditions. They propose a system to effectively use data for decision making processes through open to change deployment and visualization of data streams and indicators. The functionality was developed on the basis of clear system requirements, received from real end-user needs. Another example is the ELD-BS tool suite which, among other things, is a web-based dashboard developed to help with the administration work in the event of a disaster. It also supports the exchange of information between the authorized units (Hellmund et al., 2022).

Numerous works are also being undertaken to analyze the problem of forest fires and their effects. The Sanborn Map Company proposed a commercial solution called Forestry in which they focus mainly on mapping, land modeling and spatial analytics. This tool supports urban tree canopy management, heat island mitigation and the work of wildfire fighting agencies (The Sanborn Map Company, Inc., n.d.). A different platform developed by a company Technosylva is a software called Wildfire Analyst™ for real-time analysis and simulation of fire behavior, with particular emphasis on performance. The user receives various useful information in the form of charts, reports or GIS maps. It is also cloud based which makes it very flexible. Examples of three Technosylva dashboard views can be found in Figure 1. (Technosylva, Inc., n.d.).

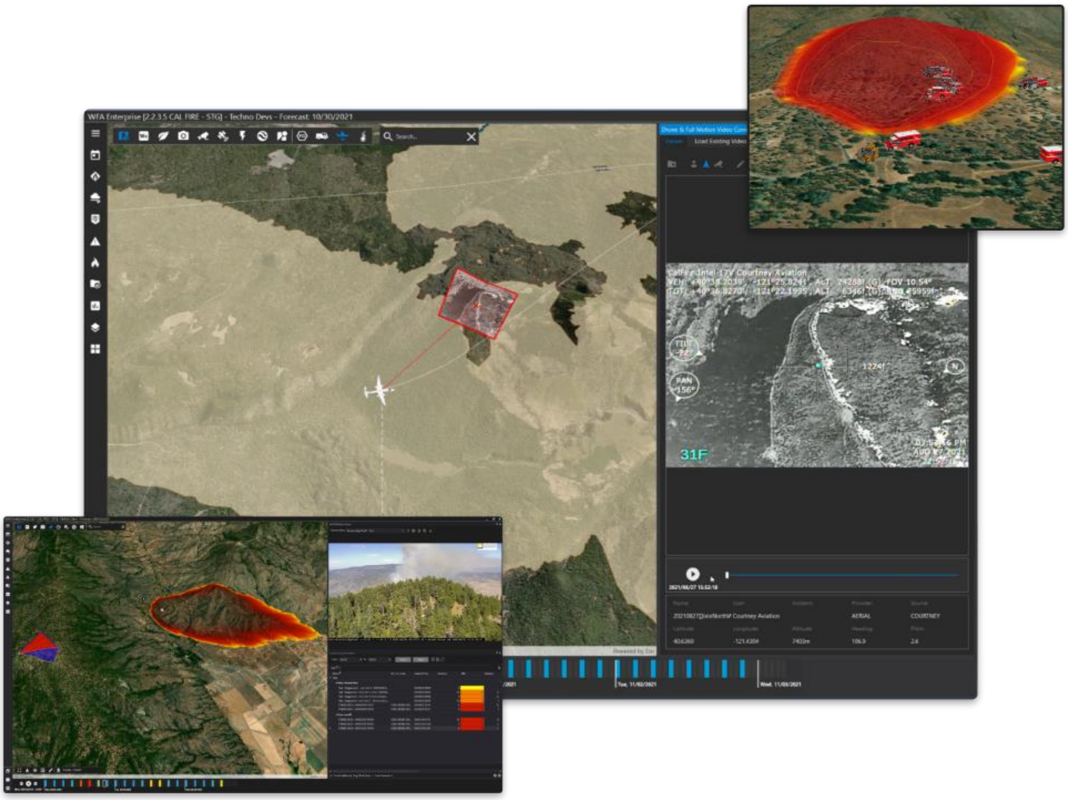

Figure 1. Technosylva dashboard (Technosylva, Inc., n.d.)

Another example is EMXSYS owned by Bruce Schubert and their CPS Wildfire Management Tool. It is free to use software for fire forecasting. Wildfire Management Tool uses the logical structure contained in Campbell Prediction System, which is a fireground-specific language system that wildland firefighters learn from (Schubert, n.d.). An example of the EMXSYS dashboard view is shown in Figure 2.

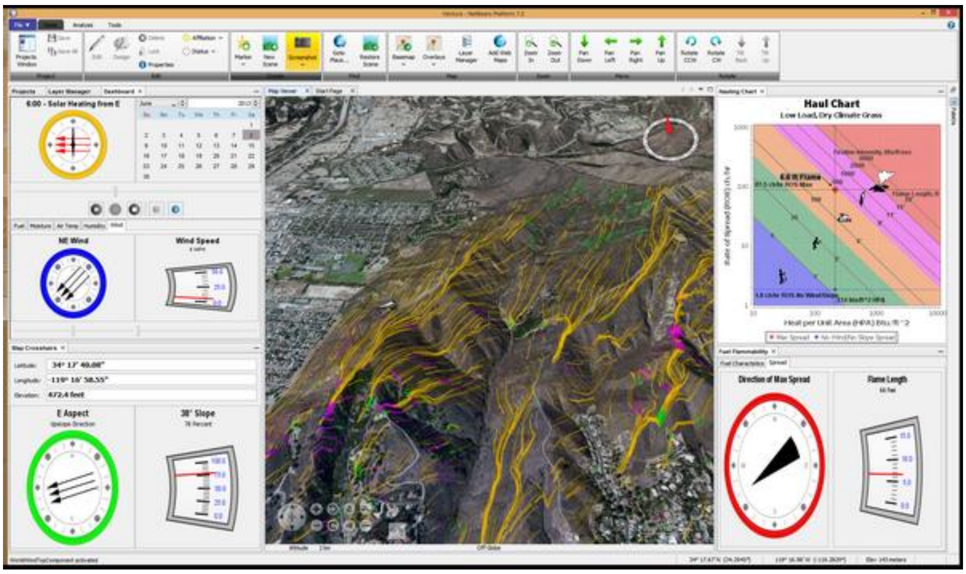

Figure 2. EMXSYS dashboard (Schubert, n.d.)

A comprehensive review of the literature shows that works on forest fires have been a topic often undertaken by specialists. One of the examples is the online GIS platform named AEGIS, which is a tool supporting the decision-making process in managing fire risk in Greece. It uses both spatial and non-spatial data to present the most useful information for the user about fires. The user can also conduct a fire simulation to understand how the fire will behave. Authors also used artificial neural networks to assess the risk of fire outbreaks, taking into account various parameters, learning methods, activation functions, data pre-processing techniques and network structures

(Battiston et al., 2019).

Another Horizon 2020 project called HEIMDALL also works on the problem of wildfires. It aims to enhance both immediate and long-term collaborative strategic planning at the regional level for the multiple stakeholders involved in disaster risk management and response. Their main goal was to create for decision-makers and other interested parties a platform that offers various tools to support crisis management. Many specialists from various specializations were engaged in the project. HEIMDALL platform predicts the spread and behavior of fire under a variety of fire conditions (Battiston et al., 2019).

Despite the large number of already existing solutions in the field of fire crisis management, the need to deal with the problem of wildfires is still urgent. According to our research and experience - it is important to use existing data to create new tools. The solutions do not have to be competitive, but rather complementary. For this reason, work on the SILVANUS project was started. This platform aims to minimize the number of fires, detect them faster and to help manage forest restoration better.

SILVANUS DASHBOARD

SILVANUS Dashboard is a web-based interface which is created to provide useful information, enabling users to quickly understand the situation on the field to make informed and good decisions. The interface is designed to be used mainly by trained personnel e.g. firefighters, analysts or public administration representatives to facilitate Integrated Fire Management. It combines prevention and firefighting strategies, taking into account social, economic, cultural and ecological analyses. Its goal is to minimize losses caused by fires and maximize the benefits that may come from them. In addition, it also covers four stages of crisis management: mitigation, preparedness, response and recovery. To use the Dashboard, a person must successfully undergo training conducted by a specialist. They also must demonstrate an understanding of fires, forest fires, legal regulations and how firefighting units operate in the served area.

To understand the needs of future users and to decide on the technology, contributors asked for opinion partners, firefighters and specialists through meetings, dashboard demonstrations and participation in pilots organized as part of the project. The whole process is shown in Figure 3.

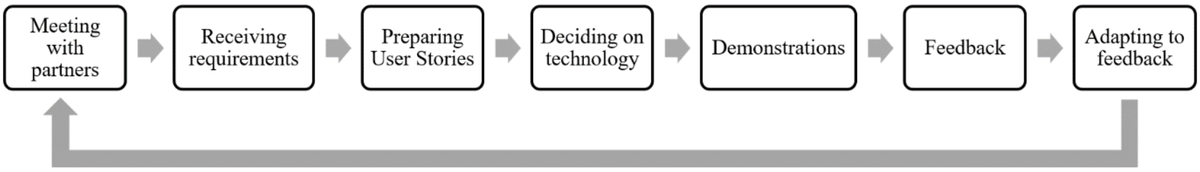

Figure 3. Process of developing Dashboard functionalities

The requirements collected at all meetings and levels were divided into functional and non-functional. They describe the constraints with which the system should perform its functions. All requirements are presented in Table 1 together with their descriptions.

Table 1. SILVANUS Dashboard functional and non-functional requirements

SRS-ID	Requirement	Description
SRS-F-1	Log in/out	A user must be able to log in/out to the existing account.
SRS-F-2	Displaying Layers	A user should be able to turn on/off the GIS layer while being in a map view.
SRS-F-3	Displaying Notifications	When the system gets an update about a new event the user must be notified about it on the map and on the notification bar.
SRS-F-4	Displaying right information drawer	When the user sees the new event on the map, he will be able to interact with it to see more information about it.
SRS-F-5	Displaying left information drawer	The left drawer must display layers, pin list, map typer, filter options.
SRS-F-6	Filtering	A user must be able to filter different layers by date and time range and different variables (depending on the layer).
SRS-F-7	Zooming in/out	A user must be able to zoom in/out the map.

SRS-F-8	Displaying Smoke/fire detection layer	A user must be able to browse pins with smoke/fire detection on the map.
SRS-F-9	Displaying Social Media Fire Events layer	A user must be able to browse pins from social media posts such as platform X with information about probable fires.
SRS-F-10	Displaying ID Social Media layer	The Dashboard must display a layer with area scope (set of coordinates) with information about it from social media in 3+ different languages.
SRS-F-11	Displaying Unmanned Ground Vehicles layer (UGV)	The Dashboard must display a set of pins on a map to show the route of UGV with photos and information gathered.
SRS-F-12	Displaying ID DSS layer	The Dashboard must display a layer with area scope (set of coordinates) with analytical information about it in different time ranges.
SRS-F-13	Displaying Fire Spread Simulation layer	The Dashboard must display a fire spread simulation as a polygon (set of coordinates).
SRS-F-14	Sending warnings	The user must be able to send warnings to citizen using Citizen Engagement Mobile App after clicking on a map and filling out the form.
SRS-F-15	Mapping a fire	The user must be able to draw a polygon on a map which will mirror the ongoing fire.
SRS-NF-1	Security	The Dashboard must be secured against unauthorized access.
SRS-NF-2	Performance	The Dashboard must be able to handle the required number of users with a constant flow of new information from the backend without compromising performance.
SRS-NF-3	Maintenance	The Dashboard should be easy to maintain and update.
SRS-NF-4	Simplicity	The interface would be used by people who have different knowledge in IT solutions so it should be easy to use.
SRS-NF-5	Verification	The Dashboard must meet with all applicable laws, terms and regulations, including Horizon 2020 terms (for example privacy by design).
SRS-NF-6	Reliability	The interface must be reliable and compliant with user requirements.
SRS-NF-7	Availability	The Dashboard must be available during system maintenance.

Main goals for this platform are to be transparent, intuitive and tailored to the needs of future users. After analyzing the collected requirements, a list of basic dashboard functionalities was created which are presented in Table 2.

Table 2. SILVANUS Dashboard functions

Function	Description
Layers	All data gathered from partners are displayed as layers in the form of highlighted areas, a collection of pins or a slider to show different images.
Pins	A pin is a feature to show a specific location. The user can interact with the pin by clicking on it to see more information about the event.
Area scope	This is a layer where the information concerns an area, i.e. a set of coordinates. The user can interact with the area by clicking on it to see more information.
Zoom in/out	The Dashboard allows to zoom in/out the map for better

	understanding by using a scroll on the mouse.
Notifications	When new data is delivered to the Dashboard, the user receives a notification. The user can delete the notification.
Filtering	All pins layers can be filtered by date and time.
Log in/out	Users can log in/out using an authorized account prepared by the admin.
Slider	The slider is used to quickly change the displayed graphics on the map (heatmap, fire spread simulation).
Drawing on the map	The user can specify an area on the map by placing points on the map. It can be edited or deleted.
Sending a poll to citizens	The Dashboard allows communication with Citizens Engagement App. The user of a Dashboard can send a warning or an announcement for specific area and time.
Map types	The map can be displayed in different types (satellite, street map).

Technical Information

This section describes the technologies used in the Dashboard interface and the general reasoning behind usage of said solutions. There is also a description of the data flow in the Dashboard as well as general architecture of integration of Dashboard with rest of SILVANUS through SAL (Storage Abstraction Layer).

Technologies

The core of the interface is written in ReactJS, which is one of the more recognizable, opensource libraries for building user interfaces based on components - standardized, interchangeable building blocks of UIs. It is being constantly developed and supported by a wide community of individual developers and companies. The library being open source ensures there will not be additional costs hidden in solution for SILVANUS being used and further developed in the future. Moreover, a wide variety of places where ReactJS is being currently used (ie. Facebook, Instagram, Netflix) can guarantee that it will be constantly improved and updated in the foreseeable future. These factors were considered as well in all libraries listed below, for keeping solution viable and without unnecessary costs.

Dashboard makes use of TypeScript - a free and open-source high-level programming language that adds static typing with optional type annotations to JavaScript. TypeScript speeds up development experience by catching errors and providing fixes.
Following libraries are being used in dashboard:

- REACT – Redux Toolkit – Redux is a library implementing Flux pattern, for managing and updating application state, using events called "actions". It serves as a centralized store for state that needs to be used across entire application, with rules ensuring that the state can only be updated in a predictable fashion. It allows more efficient control and testing of the application.
- Leaflet - an opensource JavaScript library used to build web mapping applications. Leaflet's goal is to be a tool focused on ease of development, focused on efficiency and user-centric design. It seamlessly operates across various platforms, both mobile and desktop, offering comprehensive documentation and extensive plugin options for customization.
- Material UI - an open-source React component library that implements Google's Material Design, Material Design aims to reflect the way objects react to the light and cast shadows in the physical world, operate with bold, intentional elements from print typography and introduce fluidity of movement for their interactions. Material Design uses more grid-based layouts, responsive animations and transitions, padding, and depth effects such as lighting and shadows.
- KeyCloak JS - As an OAuth2, OpenID Connect, and SAML compliant server, Keycloak can secure any application and service as long as the technology stack they are using supports any of these protocols. For some programming languages, Keycloak provides libraries that try to fill the gap for the lack of support of a particular security protocol or to provide a richer and tightly coupled integration with the server.

General SILVANUS Architecture Overview

SAL is the module of SILVANUS responsible for transferring data between different components in SILVANUS. The primary function of SAL is to abstract the object store, offering two key advantages. Firstly, it enables flexibility in managing data at rest, allowing for efficient data management practices. Secondly, it decouples data from user products in a multi-source, multi-client environment, providing support for security, policy, privacy, and business constraints. From the perspective of Dashboard, the main purpose of SAL is to store and provide access to data produced by User Products.

Figure 4. showcases the flow of ingestion and provision of data by SAL from external and internal sources, as well as user products. Each ingestion method requires a distinct SAL interface to facilitate communication.

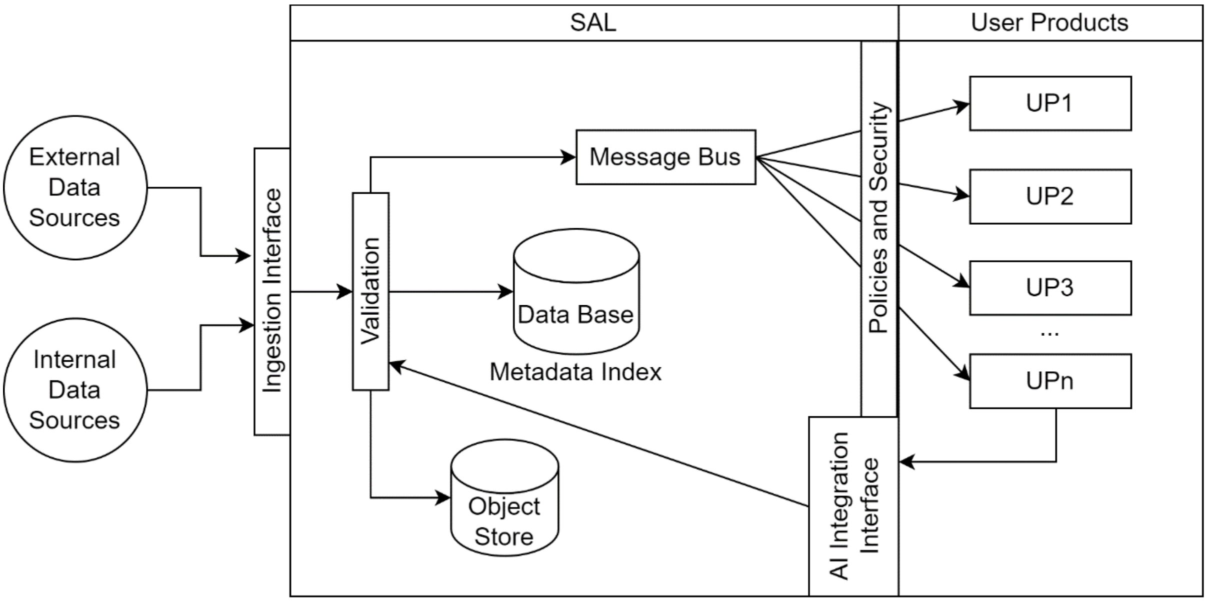

Figure 4. The interaction between SAL and other components in SILVANUS platform

Integration with SAL

The data is produced by the UPs (User Products) and stored in SAL. Between the UI and SAL the middleware exists in the form of Proxy Backend, which is responsible for downloading and transferring the data from SAL to the dashboard. Connection between Proxy Backend and UI is being authorized through Keycloak.

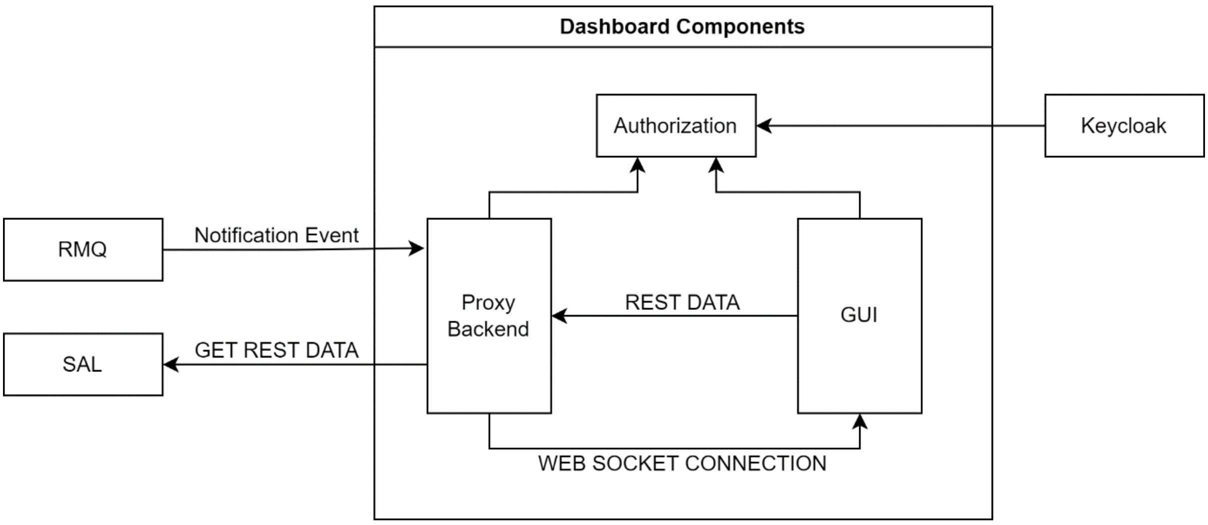

Figure 5. Dashboard – SAL integration general architecture

Proxy Backend – the component performs the task of communicating with the SAL component via a REST API by fetching data and transforming it into the final format that is delivered to UIF. In addition, it receives notifications from the RabbitMQ queue and forwards them via WebSocket.

Data

There are two different types of data which could be digested by dashboard:

- Geolocalised events (visualised via pins)
- State of the area (visualised via polygon/raster)

Both of those data types are standardized throughout SILVANUS in a certain form of geojson. The data are either static or live, which determines the way in which they are downloaded from SAL. Static data are being downloaded through REST API and live through WebSockets.

Dashboard is able to work with outside GIS servers to manage data flow for less complex layers with static data. The advantage of such a solution is that there is no need to handle data on the side of dashboard and multiple different sources of such data could be applied to the dashboard. On the other hand, there is limited customization and interaction from the dashboard available in such cases.

Dashboard Layers

The SILVANUS dashboard displays a map with several layers representing the work of different User Products (UP). UPs are users' creation in the form of products, content or services. The list with names of UPs and corresponding layers is presented below in Table 3.

Table 3. User Products - Dashboard Layers

UP	Dashboard layer
Fire detection based on social sensing	Social Media Sensing Layer ID Social Media Sensing Layer
Fire detection from IoT devices	IoT Layer
Fire detection based on UAV/UGV	UGV Layer
Fire spread forecast	Fire Spread Forecast Layer
Citizens engagement programme and mobile apps	Mobile Subscribers Layer

Depending on the data collected, layers are divided into those displayed in the form of pins and those that represent a certain area. All layers can be enabled simultaneously and each separately. Figure 6 represents a use case diagram of all layers with pins. A pin is a point on the map which geolocation was sent along with other necessary data by a specific device. Currently, there are four layers of this type: Unmanned Ground Vehicle (UGV), Internet of Things (IoT), Social Media Sensing, Mobile Subscribers.

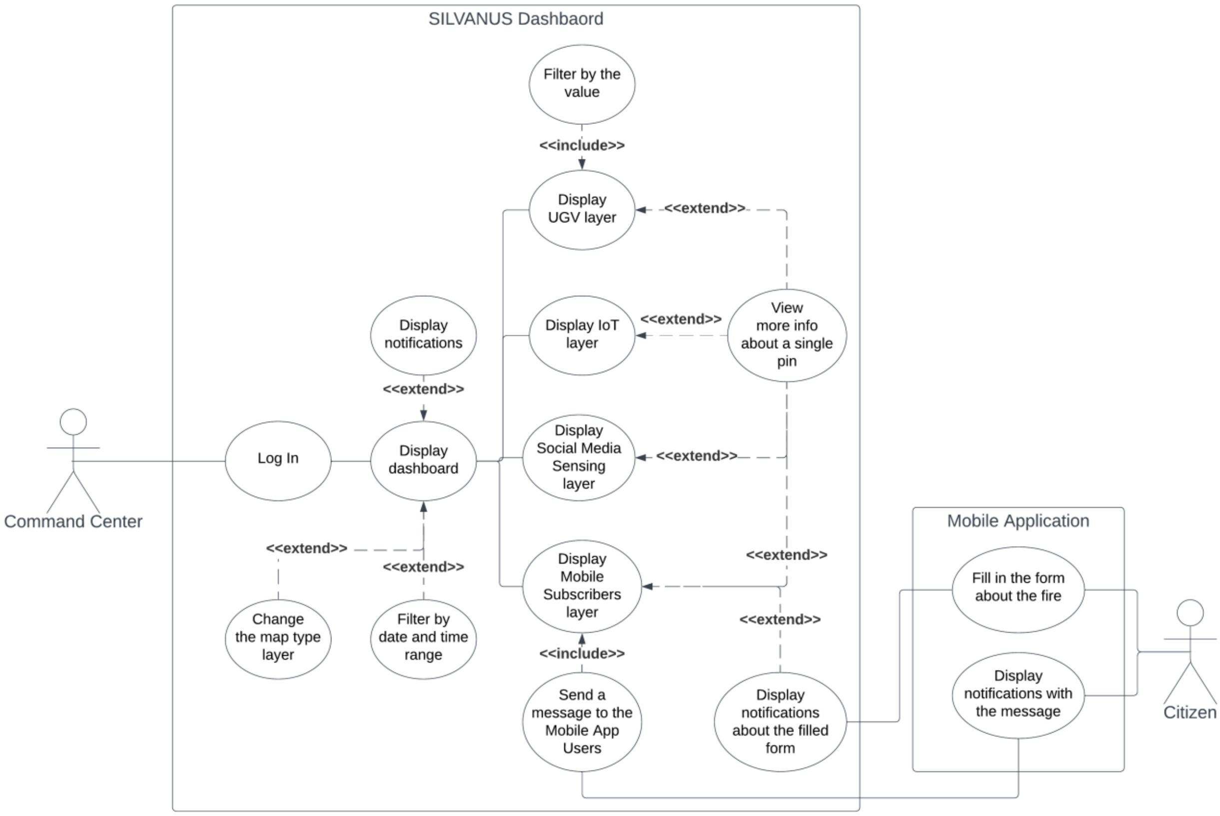

Figure 6. Use Case for SILVANUS Dashboard layers with pins

UGV is a vehicle that operates on the surface of the earth without human intervention on board. These devices move along the previously indicated route, collecting photos and indicators that are sent to the SILVANUS Dashboard every few minutes. They help, among other things, understand the actual state of the field in order to possibly detect a fire. It can be filtered by date, time and value.

IoT is a layer where the device is attached to a fixed and stable place, for example a tree, equipped with sensors and a camera. Similarly, to UGV, it periodically sends data along with photos to the SILVANUS platform. When fire or smoke is detected, it is appropriately recorded with an indicator that affects the color of the pin, thanks to which the dashboard user obtains information about a possible threat faster. The user can filter it by date and time.

Social Media Sensing layer receives alerts from social media, which are generated based on data from social media such as the X platform (formerly Twitter) or Facebook. They contain information about fire, smoke and other fire hazards. It can be filtered by date and time.

Mobile Subscribers is the layer where information comes from citizens who are using mobile devices with the SILVANUS mobile application installed. When they face a fire threat, they can send a photo along with information about it. Moreover, the SILVANUS Dashboard user, having already learned about a fire in a specific area, can send a warning to users of the mobile application. It is possible to filter by date and time.

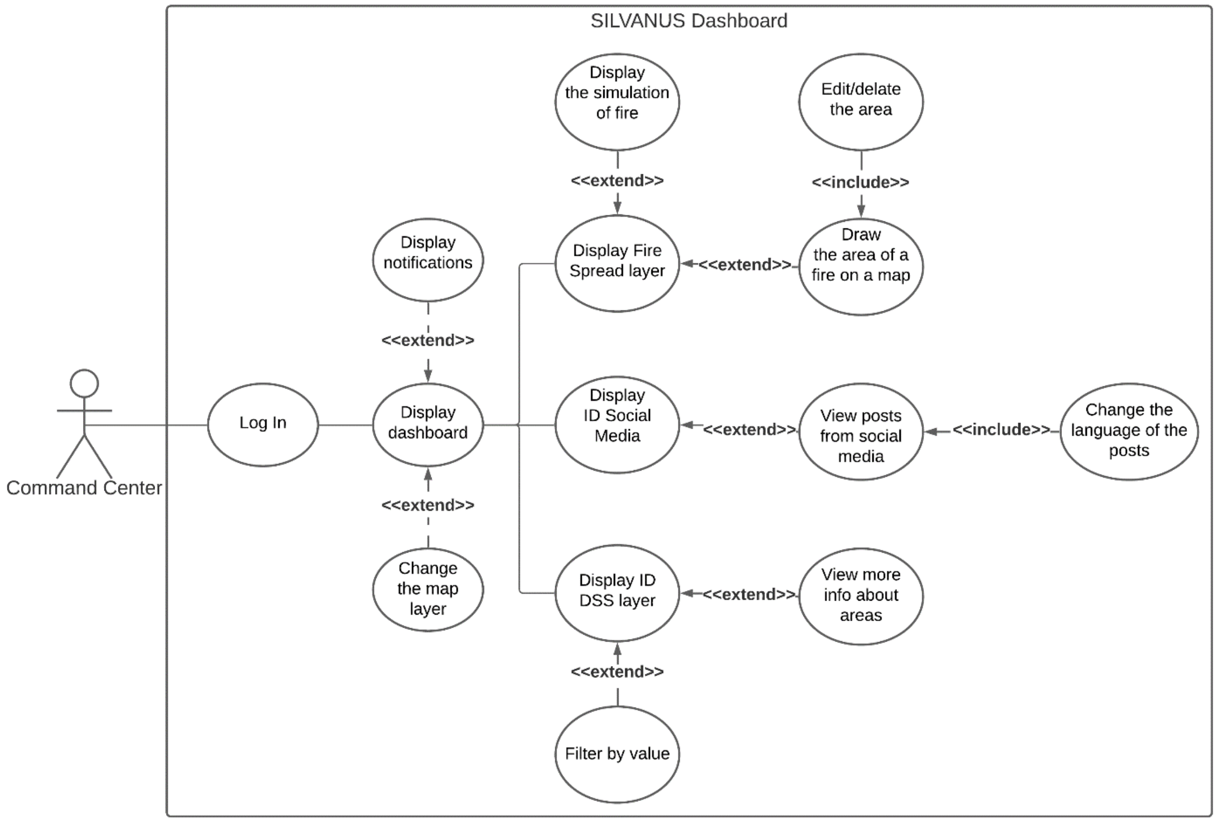

Figure 7. Use Case for SILVANUS Dashboard layers with areas

The next type of layer represents data on areas which is shown on the use case diagram in Figure 7. We distinguish Fire Spread layer (FS), ID Social Media Sensing and Decision Support System for analytics purpose (ID DSS) both prepared for Indonesia region. FS is a layer with simulation of fire spread. The user can view simulation results for a given time in future by moving the slider to a different time range given in minutes. This will display the simulated fire spread, which is shown on the map in the form of a grid. Next, we have layers focusing on the Indonesian area. ID Social Media Sensing layer is very similar to the layer mentioned earlier, they differ primarily in the form of data presentation, in this case they are not pins but areas. ID DSS is the analytical layer that collects statistical data for easy comparison, where the data is presented in the form of charts. Most of the layers can be seen in use on the SILVANUS Dashboard screenshot in Figure 8.

Figure 8. SILVANUS Dashboard

On the left side of the interface there is a panel that allows the user to select the layer with filtering option and the list of all displayed pins. The main view of the platform is a map which, after selecting a layer, displays the data of interest to the user. Each pin contains information that the user can read by clicking on the pin icon, which will cause the panel to slide out on the right side of the dashboard.

INTEGRATION WITH THE CITIZEN ENGAGEMENT MOBILE APP

The Citizen Engagement Mobile App (CEA) is a specialized mobile application featuring various modules designed to involve citizens in combating forest fires. In addition to citizen engagement modules, such as Guidelines, Quizes, Practical Tips or News, a "Situational awareness and information sharing" module for receiving alerts and sharing event reports in direct communication with firefighters deployed at the scene is also being implemented. The idea is to provide tools for citizens to communicate with firefighters as close to the incidence site as possible. The two main supported use cases are "Fire Warning" and "Fire Reporting". The following Figure depicts the basic actors and use cases.

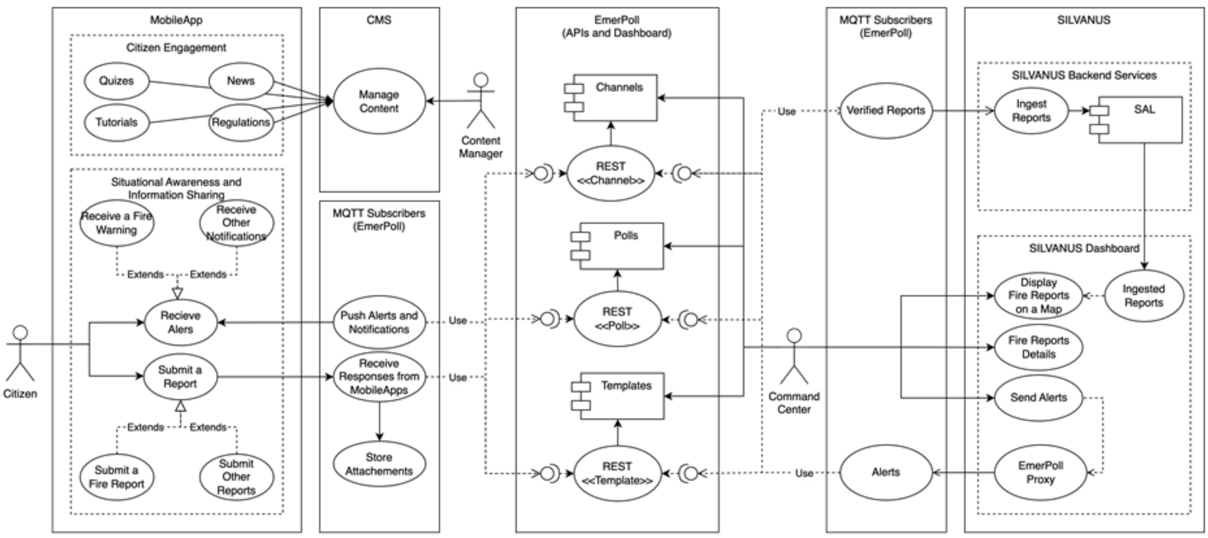

Figure 9. Use Case for the SILVANUS Mobile App and the EmerPoll backend

The main systems involved in the use cases are the mobile application (MobileApp), a content management system (CMS), the SILVANUS platform and the EmerPoll system.

The MobileApp encompasses the "Citizen Engagement" subsystem in which a Content Manager can manage and update the content of the citizen engagement modules and the "Situational Awareness and Sharing" subsystem in which functionalities for receiving alerts and notification as well as for submitting reports about a spotted fire or other events are supported.

EmerPoll is a response collection and aggregation framework which is based on the concept of Polls, Channels and Templates, proposed and described in (Balogh, 2016), for which it exposes both REST APIs for actions as well as a dedicated web-based Dashboard. EmerPoll is the main backend engine making possible the submission, aggregation and validation of individual reports or alerts. MQTT Subscribers are special services which facilitate communication between EmerPoll and other systems by compiling and forwarding MQTT messages.

The involved SILVANUS system comprises the Backend Services and the SILVANUS Dashboard subsystems. Verified reports coming from the EmerPoll system are ingested using the publish/subscribe paradigm to a storage abstraction layer component (SAL). Subsequently the SILVANUS Dashboard uses such ingested verified reports and displays them on a specialized map layer. Forms are used to send alerts or warnings from the SILVANUS Dashboard via the EmerPoll APIs to the Mobile App users.

Figure 10. Screen of CEA app receiving fire warning region

The CEA application serves as a mobile platform enabling citizens to report sightings of fires (Balogh, 2023) during outdoor activities. In addition to sending the information, users of CEA may receive updates on the severity of fires in their vicinity. Specifically, a polygon marked with a warning icon is displayed on the user's map (shown in Figure 10) to indicate areas of concern. These warning messages are relayed from the EmerPoll service initiated by the SILVANUS Dashboard, where responsible fire-rescue personnel, upon confirming a fire, designate the dangerous area requiring a response. Subsequently, the message is distributed to users through their registered channels as an MQTT message containing a GeoJSON payload with metadata describing the fire incident. In a similar manner, the CEA is also prepared to display evacuation routes from the endangered area, ensuring users have access to critical information for their safety.

CONCLUSIONS AND FUTURE WORKS

Dashboard is a web-based, graphical interface created for SILVANUS platform, which is the main access point for the user to obtain and interact with outcomes of data produced by SILVANUS' various modules. Panel is meant to be used both by representatives from authorities managing fire prevention and regular operators derived from firefighters. Data from different User Products is presented on separate layers in a way which is clear and easy to navigate. Dashboard facilitates timely and easy user access to important information. It provides a variety of tools and parameters upon which the operator is able to determine geolocated occurrences of smoke and fire to put adequate countermeasures to them.

It is important to know that for interface there is no single all-in-all solution, or design, which will answer every need from every partner. Each case should be considered separately and be customized based on the individual needs of every partner and characteristics of their region. Final solution will be applied case by case to different regions considering local challenges and accommodate them appropriately.

Dashboard is currently aimed to be visual representation of combined works undergoing in SILVANUS for the partners, authorities and representatives from different regions during pilots and field presentations. In 2023 it was presented during pilots in Podpolanie (Slovakia), Limoges (France), Palangka Raya (Indonesia) and Brisbane (Australia). During those presentations the feedback from possible end users was gathered and is currently being analyzed and considered for further improvements.

Dashboard is constantly evolving upon continuous testing and gathered feedback from actual environments involved in fire prevention, both from perspective of offered functionalities and undergoing improvements in design, usability and user experience. As for 2024 Dashboard is being prepared for upcoming pilots in Czech Republic, Brazil and Italy and the changes identified during previous pilots are being applied.

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