IT equipment and software for training, modeling and data analysis for flood and forest fire prevention, protection and management in project SOLVE

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Abstract:
Recent disasters around the globe strongly indicate that most challenging territories for managing floods and forest fires are the cross border ones. Various reasons (economic, social, political, cultural) make it difficult to agree, establish and implement joint strategies and policies dealing with climate change impacts, societies' resilience and emergency management. A huge identified deficit in exploitation of research and projects' outputs to strengthen civil protection systems exists at border areas. Available technological advancements and innovations do not reach fire brigade, forestry and civil protection services. This is due to lack of personnel, high rigidity in existing plans and procedures, inability to create cross border standard operation procedures and most importantly to identify the cross border area as a single area of intervention prior and during an emergency. Project Cross Border Complex Floods and Forest Fires Prevention and Management (SOLVE) focuses on joint actions for most common risks (forest fires and floods). This paper gives an overview of the modern IT equipment and software for training, modeling and data analysis for flood and forest fire prevention, protection and management acquired within this project. The paper also, emphasizes future potentials of the equipment in terms of using data gathered in the project for prediction in combination with potentials of machine learning.

Keywords: floods, forest fires, cross border, IT equipment, machine learning in fire/flood prediction

1. Introduction

Recent global disasters underscore the complexities faced in managing floods and forest fires, particularly in border regions. Economic, social, political, and cultural differences pose barriers in establishing joint strategies and policies for climate change adaptation, societal resilience, and emergency management. These challenges have resulted in an identified deficit in leveraging research and project outputs to fortify civil protection systems, hindering the adoption of technological advancements by fire brigades, forestry, and civil protection services.

The Republic of North Macedonia and Greece came together to strengthen their civil protection services and emergency management by initiating the "Cross Border Complex Floods and Forest Fires Prevention and Management" project with the acronym SOLVE. This project is an indication how borders can benefit rather than limit neighboring nations, especially in times of crisis and emergency.

The project's objective is to minimize risks from forest fires and floods in the long term, transforming cross-border regions from vulnerability to resilience. By implementing joint actions, conducting large-scale exercises, and emphasizing immediate results utilization, SOLVE sets a good practice example for effective disaster risk reduction that emphasizes cross-border cooperation.

Main outputs of the project were: a) Modern equipment and joint training of operational teams (1st responders), b) Provision of scientific support and knowledge (through innovative approaches,

methodologies and tools to operational decision making, c) Capitalization and mainstreaming of results, and d) active citizens' participation to prevention of activities through Participatory GIS platform and focused actions. Such approach is novel and fosters the cross border cooperation at a sustainable basis, following the provisions of new civil protection law 4662/2020 and the 2020 cross border collaboration guidelines of DG ECHO.

SOLVE has a dual character approach: a) Working on most common risks, building on past and ongoing successful projects' results and b) joint actions not only at the levels of risk assessment, early warning and management procedures, but also at conducting large scale joint exercises, common training and immediate exploitation of results both at policy and operational levels. The overall SOLVE objective is to minimize the risks from forest fires (including Wild Urban Interface ones) and Floods (including flash and urban floods) for the Florina regional unit & Pelagonia region in a long-term basis and in a way that can be replicated in other cross border areas.

The project's lead partners were the Decentralised Administration of Epirus and West Macedonia based in Ioannina, Greece, the Center for Development of Pelagonia Region, University St. Kliment Ohridski – Bitola (UKLO), and the University of Western Macedonia.

About 45 professors, involved from UKLO, shared their academic expertise and scientific knowledge with the community and relevant institutions, with the aim of increasing risks and preparedness for attacks by forest fires and floods at five levels. The first level included fire and flood prevention and was based on risk assessment. The second one was protection and included the application of structural and eco-system measures to reduce the dangers of forest fires and floods. The third level was preparedness and included the activities of hazard forecasting, early warning and preparation of appropriate emergency plans. The fourth level was response and included activities related to how to raise the quality of stocks immediately after the occurrence of a forest fire or flood. The last level titled recovery was concerned with identifying measures for short and long term recovery of areas affected by fires and floods.

Faculty of Information and Communication technologies (FICT) as a unit of UKLO was responsible for the preparation of the technical specifications and technical offer of modern IT equipment and software for training, modeling and data analysis for prevention, protection and dealing with floods and forest fires. These deliverables were carried out in 4 lots in Bitola, with financial assistance from Interreg IPA Cross-Border Cooperation Program "Greece - Republic of North Macedonia 2014-2020".

The rest of the paper is stuctured as follows. The next main section of the paper describes the technical specifications and technical offer about IT equipment and software within the SOLVE project. The content is subdivided and presented according to the 4 project lots in Section 2.1, Section 2.2, Section 2.3 and Section 2.4, respectively. We conclude in Section 3 and discuss potentials of the equipment in combinations with prospects of machine learning in Section 4.

2. Technical specifications and technical offer about IT equipment and software

The management of disasters and emergencies is a multi-faceted task that requires involvement of a wide range of actors. These actors typically include public authorities, civil protection authorities, local governments, police, fire brigade, first responders, volunteers, and critical infrastructure operators. The entirety of aforementioned actors shall be equipped with a mixture of competencies, in order to prove effective during crises. The basis of the project implementation is the exploitation of the emerging IT equipment and software for training, modeling and data analysis for prevention, protection and dealing with floods and forest fires. For the purpose of the project the preparation of the technical specifications and technical offer about IT equipment and software was made in 4 lots i.e.:

- **Virtual reality mobile training center** (Projection Dome, Fire simulator training software, Laptops),
- **Software tools for citizen participation in civil protection**
- **Specialized equipment for analysing flooding data** (aerial vehicle – drone, wireless sensor network with LoraWAN sensors for water level detection and flood detection)
- **Specialized equipment for analysing forest fire data** (aerial vehicle – drone, wireless sensor network with LoraWAN sensors for forest fire detection)

2.1. Virtual reality mobile training center – Lot No.1

The basis of the Lot No.1 is the exploitation of the emerging technology of Virtual Reality. This technology has grown rapidly in recent years and the ability to fully immerse into virtual worlds and realistic experiences makes it highly effective in educational, experiential or training applications. According to [1], people remember 10% of what they read, 20% of what they hear, 30% of what they see, and 90% of what they do. Therefore, VR is an incredibly powerful tool for training so far as it is based on a learning-by-doing approach. For that purpose, a **3 meter open faced dome** was procured within the project [2]. For collaborative and immersive learning experiences to students the dome is placed in the Center for Virtual Engineering in the Faculty of information and communication technologies - Bitola, Figure 1. Its dimensions are the following ones: height: 3 m, area 7.1 m^2, screen 14,1 m^2, capacity (seating/standing) 5/7.

The dome theater is a new format of seeing and showing things, where a VR immersive experience is not individualized, but actually, a shared social activity. When it comes to digital dome projection, the quality of the projected image is of the utmost importance.

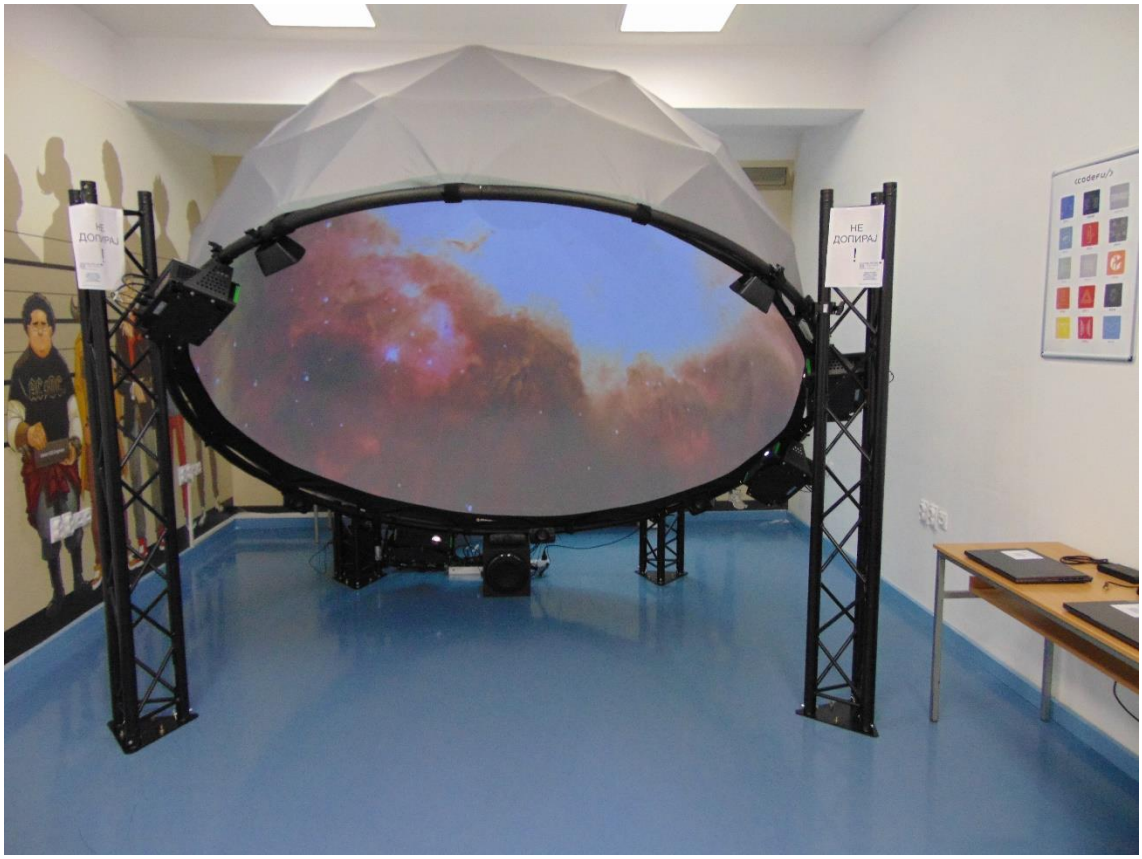

Figure 1: 3 meter open faced dome

There are many factors that influence the final image, but three components of the dome projection system which can be particularly emphasized are: the screen, the projectors, and the media server.

- **The screen** - is the thing the whole audience is looking at, but ideally, they should not really see the screen, just the image. Negative-pressure technology, suspends the screen evenly inside the dome, stretching it outwards to create a wrinkle free surface. Screen gain, the amount of light reflected off the surface, is critical. In a dome, the reflected light falls on other parts of the screen, lowering the contrast of the image, whereas in a regular cinema the reflection would hit the walls, ceiling, and floor. Therefore, a dome screen is not white, as might be expected, but grey. Exactly what shade of grey depends on the size of the dome and the projectors. Because projectors are placed around the perimeter of the dome in proximity to the screen, all the fabrics are tested and certified as a flame retardant.

- **The projectors** - the system consists of four digital light processing (DLP) projection modules mounted around the dome perimeter on a rig with resolution 3K. FP HD X4 provides an image quality that is six times better than that of a regular single-channel projection system. A fully immersive effect and an unforgettable experience are guaranteed with these projectors.
- **The media server** - the heart of the projection system is the media server (this dome uses a single-server solution). Unlike some systems where there is one media server for each projector, with content pre-split for each, another server to synchronize everything, and perhaps another for calibration and blending, this single-server solution supports up to 64 projectors. This includes fully automatic camera-based calibration, which eliminates the need for manual masking, blending and pre-splitting content. Fulldome.pro media server supports Fulldome live real-time content input from external sources.

After installing the projectors and pointing them in roughly the right direction, a camera with a fisheye lens is placed in the center of the dome. The operator connects the camera to the single media server and starts the calibration process. Fully-automated calibration software takes care of the rest. Each projector displays a series of patterns on the screen, which are captured by the camera and analyzed. The software works out where each projector overlaps with others and maps the intensity over the entire screen and a full calibration is completed in under 15 minutes. In most cases, calibration only needs to be performed once for a perfect dome image. But there are times where a few tweaks may be required. Settings can be adjusted to compensate for stray light, objects inside the projection dome, and other factors. Once these parameters are set, the system will be able to calibrate despite the interference.

An extensive fulldome content starter package is included with the purchase of every Fulldome.pro projection system.

An integral part of Lot No.1 represents a **software for Fire Simulation and Training SimUshare** [3]. SimUShare is a state-of-the-art fire simulator software package, designed to produce ultra-realistic simulations including fire incidents, hazardous material situations, and a wide range of other emergency scenarios. With incredible realism, it delivers a truly immersive training experience, improving the decision-making skills that are vital for emergency responders. Screenshot of creating a basic simulation using this software is presented in Figure 2.

Figure 2: Creating a Basic Simulation with SimUshare

The features that make this software the most versatile fire simulator on the market are [4]:

- **Possibility to use own pictures** – a realistic situations can be created by including pictures of buildings and structures within response area. Also images of apparatus and tools for a fully immersive experience can be added.
- **Support of critical training requirements** - SimUshare's customizable training environment

creates the conditions and elements needed for company officer, incident command, and size-up training.

- **Possibility to conduct remote or in-person real-time simulation training** - flexibility is key and SimUshare allows to conduct real-time simulation training, regardless of participant location – virtual or on-site.
- **Possibility to embed the simulations** – simulations can be embeded into learning management systems, websites, or emails for easy access.
- **Possibility to build simulations across all industries** – first response training goes beyond fire departments. SimUshare is the proven leader in other first-response environments like the military, industrial safety, schools, and more.
- **Interactive walkthroughs** – interactive walkthroughs of any building through a simple click of a button can be created.
- **Promotional exams** – SimUshare is the perfect tool to create promotional exam scenarios that provide instant performance feedback to the team members.
- **Simple to use** - Unlike others, SimUshare is incredibly intuitive and easy to learn. There is nothing to download and they offer helpful tutorials. Highly responsive support team is also at disposal.
- **Evolve simulation conditions** – SimUshare allows to configure simulations to change conditions on the ground based on elapsed time or participant decisions.
- **Built-in checklist functionality** – one can easily create helpful checklists, so participants can follow prescribed SOP's and protocol.
- **Internal messaging** – SimUshare's built-in messaging function allows participants to communicate with each other in real-time.

For training, modeling and data analysis for flood and forest fire prevention, protection and management in project SOLVE seven laptops Legion Slim 5 16APH8 were also procured [5]. Their configuration is as follows: Processor: AMD Ryzen 7 7840HS, Graphics: NVIDIA GeForce RTX 4070 8GB GDDR6, Max Memory: Up to 32GB DDR5-5600 offering, Storage Type: M.2 2280 SSD 1TB, Display: 16" WQXGA (2560x1600) 300nits, Camera: FHD 1080p, with E-shutter, fixed focus, Warranty: 24 months, Operating System: Installed licensed Windows 10 pro.

2.2. Software tools for citizen participation in civil protection– Lot No.2

Participatory **GIS application "SOLVE"** for participation of citizens in civil protection prevention, preparedness and management activities was developed for the Lot No.2, Figure 3.

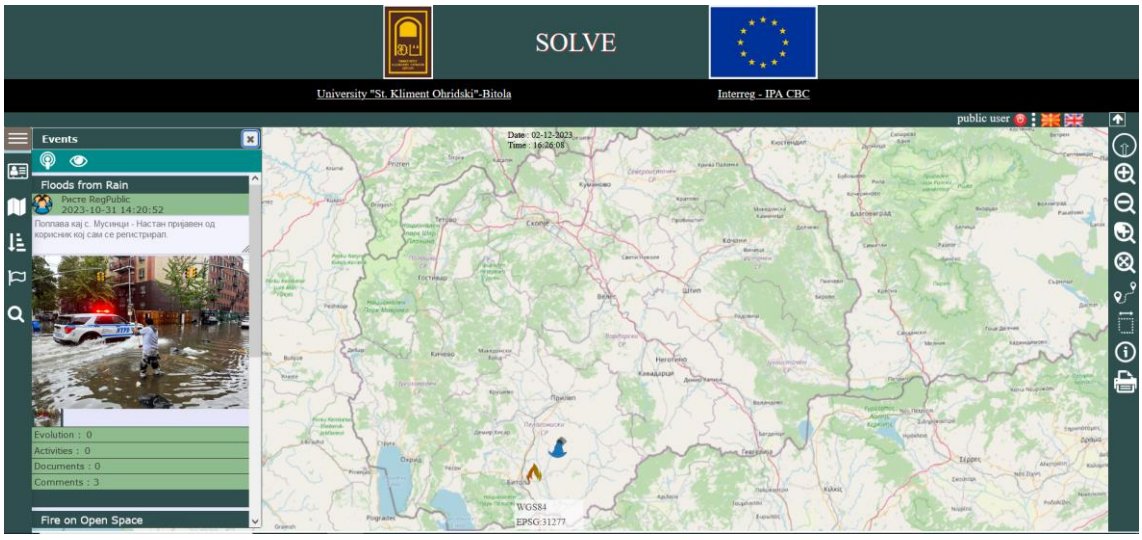

Figure 3: Main page of the application "SOLVE"

Authorities who have access can publish events with all specific details that will be publicly visible for all users. Users (registered or not registered) can put comments with pictures for the published events but will not be able to change and add official data of the event. Gathered information from them will be only through comments to avoid abuse and mislead. Particular users, groups or agencies can be given rights by super-administrator to change and add official data.

For each published event, a corresponding icon is displayed on the map at the location of that event. If multiple images are uploaded for a given event, each image can be viewed separately by clicking on the corresponding thumbnail in the bar below the large image window.

"SOLVE" is GIS application which contains geospatial maps and also allows super-administrators to introduce new geospatial maps trough settings menu. Every information for events is time tagged and date and time of publishing is clearly shown so development of each event can be followed.

"SOLVE" is developed as WEB, Android and IOS application hosted on solve.mk domain [6].

2.3. Specialized equipment for analysing floods– Lot No.3

Specialized equipment for analysing floods (Lot No.3) consist of one aerial vehicle – drone (DJI Mavic 3), four pices of Milesight EM500-SWL LoRaWAN and two of Ultrasonic Distance/Level Sensor EM500-UDL sensors for water level detection and flood detection.

The **DJI Mavic 3 drone** can be a valuable tool in managing and responding to flood situations, Figure 4. It stands as a testament to the drone industry's phenomenal growth and innovation. This high-end consumer drone is a marvel of engineering and design, showcasing a perfect balance between advanced features and user-friendly functionality. One of the most striking features is its dual-camera setup, offering both a wide-angle and a telephoto lens, ensuring that aerial photographers and videographers have more creative options than ever before. With a robust flight time, the Mavic 3 ensures remaining in the air longer, capturing those critical shots.

By using a comprehensive set of sensors, the Mavic 3 can navigate complex environments with ease, making it safer for both beginners and professionals. The O3+ Transmission system guarantees a stronger, more stable connection between the drone and controller, even in environments filled with interference. Furthermore, its compact and foldable design ensures portability without compromising on the features.

Figure 4: DJI Mavic 3 drone

The DJI Mavic 3 has a maximum Flight Time of 46 minutes and maximum Hovering Time of 40 minutes in an environment with windless conditions [7].
In Flood Situations, DJI Mavic 3 can play a role in following scenarios:

- **Damage assessment**: The Mavic 3's ability to fly over flooded areas provides a clear view of the extent of flooding, which is crucial for assessing damage to infrastructure and properties.
- **Monitoring water levels**: By capturing images and videos over time, the drone can help monitor changes in water levels, which can be used to predict future flooding or understand the impact of ongoing flooding.
- **Search and rescue**: Similar to its role in fire situations, the Mavic 3 can aid in search and rescue operations by identifying people stranded in flooded areas or assessing conditions from a safe distance.
- **Infrastructure inspection**: The drone can inspect critical infrastructure such as bridges, roads, and dams to identify potential damage or weaknesses that could exacerbate flooding.
- **Data collection**: It helps gather valuable data for research and planning purposes, aiding in better preparation for future floods and improving response strategies.

EM500 series is a sensor mainly used for outdoor environment through wireless LoRa network. EM500 series sensors is made up of a LoRa transceiver and a sensor. Among them, ultrasonic sensors and gas sensors are combined with LoRa transceiver.

EM500 device is battery powered and designed for multiple mounting ways. It is equipped with NFC (Near Field Communication) and can easily be configured by a smartphone or a PC software.

Sensor data are transmitted in real-time using standard LoRaWAN protocol. LoRaWAN enables encrypted radio transmissions over long distance while consuming very little power. The user can obtain sensor data and view the trend of data change through Milesight IoT Cloud or through the user's own Network Server. Features include [8]:

- Up to 15 km communication range;
- Easy configuration via NFC;
- Standard LoRaWAN support;
- Milesight IoT Cloud compliant;
- Low power consumption with 19000mAh replaceable battery.

EM500 series can be monitored and configured via ToolBox App or ToolBox software. LoRaWAN settings are used for configuring the transmission parameters in LoRaWAN network. EM500 devices support configuration backup for easy and quick device configuration in bulk.

EM500 series can be managed by Milesight IoT Cloud platform. Milesight IoT cloud is a comprehensive platform that provides multiple services including device remote management and data visualization with the easiest operation procedures. Before operating following steps, a Milesight IoT Cloud account is needed.

Submersible water level sensor EM500-SWL, Figure 5, is designed for measuring liquid level in harsh environments and transmitting data using LoRaWAN technology.

With this low power consumption technology, EM500-SWL can work up to 10 years with 19000 mAh battery [9]. Combining with Milesight LoRaWAN gateway and Milesight IoT Cloud solution, users can manage all sensor data remotely and visually. EM500-SWL is widely used for applications like tank level monitoring, river level monitoring, etc.

Ultrasonic Distance/Level Sensor EM500-UDL, **Figure 6,** is designed to make measurements of various kinds of liquids or objects much easier through ultrasonic waves, making it applicable in industries of many kinds. Supported with ultrasonic waves, a non-contact detection technology, the device is able to detect a wide range of liquids, including corrosive chemicals while providing impressive measuring precision of up to ±1% accuracy [10]. This allows the device to integrate seamlessly with numerous industrial applications, especially in the plastic, petroleum, fertilizer, and other industries that involve large usage of chemicals. The device offers an extensive measurement range of 0.25 to 10m with a variety of probing options depending on the choice. It is also highly competent in measuring containers of distinct sizes, including containers with small openings. The device can be tailor-made for diverse scenarios. The device is boasted with an exceptional IP67 and UV resistance performance that allows it to perform superbly even in harsh working environments, making it ideal for industrial and outdoor applications like ski resorts, manufacturing industries, and more.

Figure 5: Submersible water level sensor EM500-SWL

Figure 6: Ultrasonic Distance/Level Sensor EM500-UDL

2.4. Specialized equipment for analysing fire – Lot No.4

Specialized equipment for analysing fire (Lot No.4) consists of one aerial vehicle – drone (DJI Mavic 3) and ten pieces of Carbone Dioxide Sensor (4 in 1) EM500-CO2.

DJI Mavic 3 in Fire Situations, can play a role in following scenarios:

- **Aerial surveillance**: The Mavic 3 can provide real-time aerial views of fire-affected areas. This helps firefighters assess the extent of the fire, identify hotspots, and determine safe routes for firefighting efforts.
- **Mapping and planning**: The drone's high-resolution camera and advanced imaging capabilities allow for the creation of detailed maps and 3D models of the fire-affected areas. This helps in planning evacuation routes, resource allocation, and strategy formulation.
- **Search and rescue**: Equipped with thermal imaging, the Mavic 3 can assist in locating people who might be trapped or in distress, especially in low visibility conditions or dense smoke.
- **Damage assessment**: After the fire, the drone can be used to assess damage and gather information for insurance claims, recovery planning, and rebuilding efforts.

EM500-CO2, Figure 7, is designed for monitoring CO2 concentration, temperature, humidity and barometric pressure in outdoor scenarios. EM500-CO2 is designed for measuring gaseous carbon dioxide (CO2) concentration in harsh environments. It is useful in applications where knowing CO2 level is important such as e.g., greenhouse, building ventilation, fruit and vegetable storage. Besides, it also supports temperature, humidity and barometric pressure measurement. EM500-CO2 can function properly even in demanding outdoor and harsh environments [11].

Figure 7: Carbone Dioxide Sensor (4 in 1) EM500-CO2

3. Conclusions

University St. Kliment Ohridski – Bitola, together with the Center for the Development of the Pelagonian Planning Region - Bitola and two partners from Greece, the University of Kozani and the Region of Western Macedonia, with the project SOLVE joined with the aim of increasing the capacities of the region to deal with forest fires and floods. SOLVE created a coherent risk prevention and

management strategy and capacity building framework to exploit on existing or underdeveloped prevention and mitigation strategies and tools. SOLVE approach transforms cross border area from problematic one concerning disaster risk reduction and management into a promising one fostering and facilitating cooperation. With this project, UKLO actively engaged with its knowledge to contribute to the community's efforts to reduce the risks of forest fires and floods. It received modern IT equipment and software for training, modeling and data analysis for flood and forest fire prevention, protection and management worth more than 100,000 euros. With this project, UKLO represents a regional leading institution in the areas of risk assessment and strengthening preparedness for dealing with natural disasters.

4. Further Research

As an addition to the work done in project SOLVE, we would like to discuss the prospects of the equipment procured in the project in correlation to the potentials of machine learning in leveraging the data gathered from the sensors and drones and also software application created in the project.

There are numerous scientific efforts where artificial intelligence and machine learning are used in the field of fire and flood management. Autors of [12] invented the concept of Intelligent Software Agents (ISA) for forest fire prevention and fighting. In [13] a decision support system for managing forest fire casualties is created. The system integrates GIS technologies and utilizes a common user interface based on semi-automatic satellite image processing (fuel maps), socio-economic risk modelling and probabilistic models that would serve as a useful tool for forest fire prevention, planning and management. Federal Emergency Management Agency (FEMA) uses Software for Flood Mapping whose data could be used to implement prediction models of flood prevention [14].

Machine learning algorithms have the potential to recognize patterns and correlations within data, so prediction of the possibility of fires and floods or the progression of their expansion could be done. Similarly, the vulnerability of particular regions to fire/flood could be estimated. Moreover, predictions can then be used to inform management and policy decisions, as well as assist in the planning of response actions [15].

Fire and flood risk management is only effective if all stakeholders contribute their resources under a common goal of increasing capacity and reducing vulnerability. Machine learning plays a significant role in predicting forest fires and floods by analyzing vast amounts of data and identifying patterns that can indicate the likelihood of these events.

Our sensors could be used to detect fire or flood, drones could be used for remote oversight, but in order to implement machine learning driven solution for fire and flood management there is no unique solution. Consequently, we have to explore the possibilities of our equipment, to enlarge the scope of data acquisition from different sources, e.g. weather forecast, satellite images, etc. and define the model of machine learning for fire and flood prediction. Further research in this field will open potentials for even earlier reaction on the emerging disaster and effective management, lowering the risks and performing faster and more successful regeneration.

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