DELIVERABLE 2.2

Novel Datasets and AI Tools

Coordinator name:	Prof. Marios POLYCARPOU
Coordinator email:	mpolycar@ucy.ac.cy
Project Name:	**Disaster Management Artificial Intelligence Knowledge Network**
Acronym:	ARTION
Grant Agreement:	101017763
Project website:	**https://www2.kios.ucy.ac.cy/ARTION/**
Version:	1.0
Dissemination level:	Public

Funded by
European Union
Civil Protection

The project has received funding from the European Union's Call for proposals in the field of Civil Protection under the Union Civil Protection Knowledge Network under grant agreement 101017763.

Contents

1. INTRODUCTION 3

2. DATASETS 4

2.1. A Flood Exercise Scenario 5

2.2. A Search-and-Rescue Exercise Scenario in a Village after an earthquake or tornado 6

2.3. A Search-and-Rescue Scenario at the Seaside (rocky scenery) 7

2.4. Real Floods in Sardinia, Italy 7

3. AI TOOLS 9

3.1. Aerial Person Detector 9

3.2. Disaster Detector and Classifier 11

3.3. Web-platform and Mobile application 12

1. INTRODUCTION

This deliverable presents the datasets and AI-powered tools that have emerged through the ARTION Knowledge Network. The datasets, which are captured during realistic field exercises or during real disaster events, are invaluable tools for Artificial Intelligence (AI) scientists in the development of new AI tools for emergency response and equip first responders with relevant data to plan, mitigate and manage disaster. In particular, they are necessary for the training of AI algorithms as well for the testing of AI algorithms during their development phase in order to verify their effectiveness and efficiency. All datasets presented here are currently available in open access mode and can be accessed and downloaded by researchers as well as first response practitioners.

The AI-powered algorithms and tools that are presented in this document are developed to be used by and aid first responder organizations during emergency response operations. The first two algorithms (presented in subsections 3.1 and 3.2) are available in open access and can be accessed and used by anyone. The web-platform and mobile-application duo of subsection 3.3 is fully operational. However, it is currently undergoing modifications and improvements after the last practical testing mission and it is, therefore, not yet in a status of general availability. This algorithm is an extensive tool which normally requires a longer amount of time until it reaches the production release stage.

The present document is structured as follows. The datasets are listed in Section 2, whereas the AI tools are presented in Section 3.

2. DATASETS

During the field exercises that were conducted in the framework of the project, data was collected. Realistic data is invaluable for the scientific community in the process of research and in the development of new AI algorithms. More specifically, when it comes to the development of new AI and Machine Learning (ML) methods, data is usually necessary in two phases, for training the algorithms as well as for testing them in terms of efficiency and effectiveness.

Due to the important role that data plays in the field of AI, the collection of data during the field exercises or real disaster incidents was one of the tasks of ARTION. Three types of data were captured during various events (though not all data types are collected in every data collection event). In particular, the following types of data are collected throughout the project:

- Aerial videos captured by drones
    - In most cases drones were flying at a static position as this type of footage is more suitable for the development of many algorithms (like the aerial person detector that is presented later in the present document). Alternatively, there are also videos captured by moving drones that could serve for the development of other algorithms.
- Aerial photographs
- GPS traces of first responders
    - The traces are captured through a dedicated mobile application that uses the GPS receiver of the first responders' smart phones.

Data of the same type are captured during different field exercise events with similar scenarios. For example, we have drones' footage captured during several search-and-rescue operations. We would like to stress that this is not a redundancy. On the contrary, all exercise scenarios are executed at areas with different scenery and landscape, therefore, a collection of such videos aim to complement one another. This is evident in the figures illustrated in the remainder of this section (i.e., in the following subsections), where we show snapshots from the videos captured at different events. When training or testing an AI algorithm based on computer vision, it is important to have a variety of images or videos taken from different-looking locations in order to make sure that the algorithm is effective in various conditions, and not only for a specific landscape. For example, if one develops a person detection algorithm using only a footage from a forest, the algorithm might not be equally effective for detecting a person in a river or a person in an urban area.

In the following subsections we present all data that is collected during the project organized per event. All data is available through the *Disaster Management AI Portal*[1] that is created in the framework of ARTION, and hosted in the Zenodo repository[2], which is a general-purpose open repository developed under the European OpenAIRE program and operated by CERN.

[1] https://www2.kios.ucy.ac.cy/ARTION/disaster-management-ai-portal/
[2] https://zenodo.org/communities/disastermanagementai/?page=1&size=20

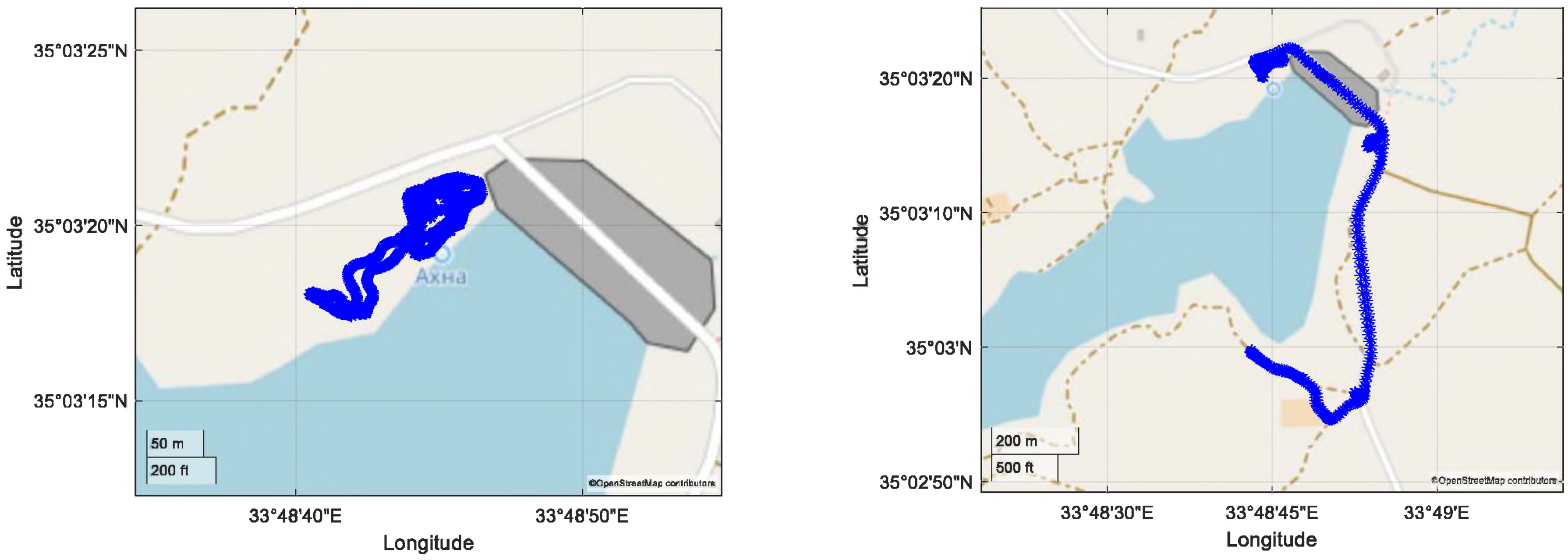
2.1. A Flood Exercise Scenario

A flood exercise scenario was executed on the shore of an artificial lake in Achna, Cyprus on the 21st of February 2021. The operations included: water pumping, establishment and operation of an emergency operation center and first aid station, and search-and-rescue of three missing persons (one found in the water).

The exercise was organized and conducted by the Cyprus Civil Defence (CCD) and data collection was performed by KIOS-UCY (KIOS Research and Innovation Center of Excellence at the University of Cyprus). Specifically, videos recorded by static drones capturing the entire exercise and first responders' traces are accessible at: https://www2.kios.ucy.ac.cy/ARTION/flood-exercise-scenario/

A snapshot from a drone's footage and two first responders traces projected on the map are shown in Figure 1.

(a)



(b)

Figure 1: Data samples from a flooding exercise scenario (a) A snapshot from a drone's video (b) GPS-traces captured from first responders' mobile phones projected on the map

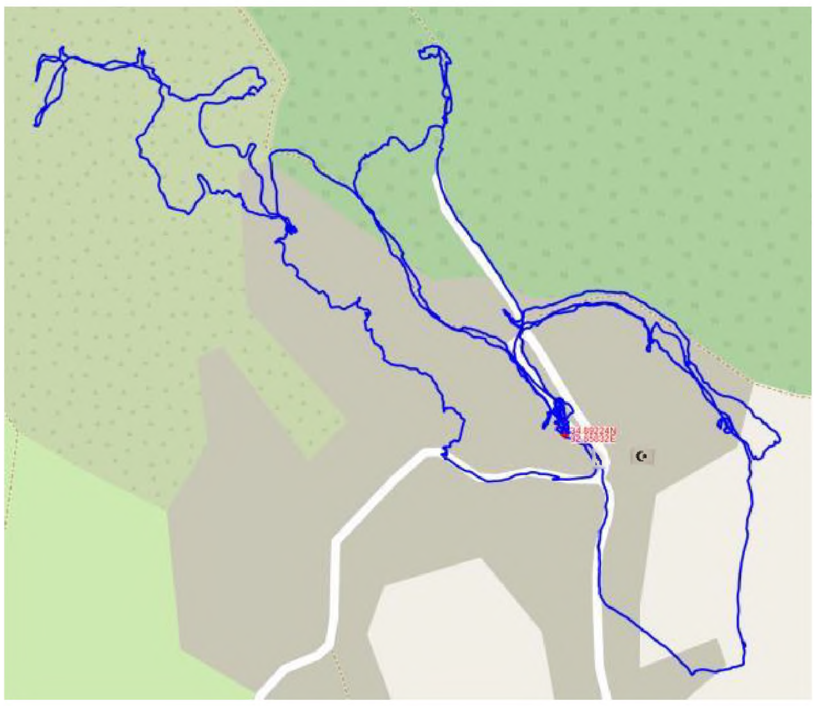
2.2. A Search-and-Rescue Exercise Scenario in a Village after an earth-quake or tornado

A search-and-rescue exercise scenario was executed in the abandoned village of Vretsia in Paphos district, in Cyprus, on the 11th of April 2021. The exercise scenario was the following: After a tornado or earth-quake, seven campers who were in the village at the time are reported as missing. Some of them are injured. The operations included: establishment and operation of an emergency operation center, first aid station, and drone operation center. For the search-and-rescue operations two rescue teams, a first re-sponder with a rescue dog and a drone were deployed.

The exercise was organized and conducted by CCD and data collection was performed by KIOS-UCY. Spe-cifically, videos recorded by static drones capturing the entire exercise and first responders' traces are accessible at: https://www2.kios.ucy.ac.cy/ARTION/search-and-rescue-exercise-scenario/

Figure 2 shows graphically a sample of the collected data, in particular, a snapshot from the drone's footage (a) and a GPS-trace projected on the map (b).

(a)



(b)

Figure 2: Data samples from a flooring exercise scenario (a) A snapshot from a drone's video (b) A GPS-trace captured from a first responder's mobile phones projected on the map

2.3. A Search-and-Rescue Scenario at the Seaside (rocky scenery)

This operation took place on the 13th of February 2022 at the seaside of Agios Georgios Pegeias near the city of Pathos, in Cyprus. The exercise simulated a search-and-rescue scenario and was organized and conducted by CCD. Data collection was performed by KIOS-UCY.

The dataset consists of raw video files (.mp4) captured by drones and is accessible at: https://www2.kios.ucy.ac.cy/ARTION/drones-footage-of-a-search-and-rescue-scenario-at-seaside/. Collection of GPS-traces was not possible as the selected location was not covered by a 4G cellular network for providing Internet access, which is necessary for the mobile phones to send their GPS locations to the server.

In Figure 3 we see two snapshots from the captured videos. The selected location exhibits a distinct scenery that is very different from the videos of the other field exercises.

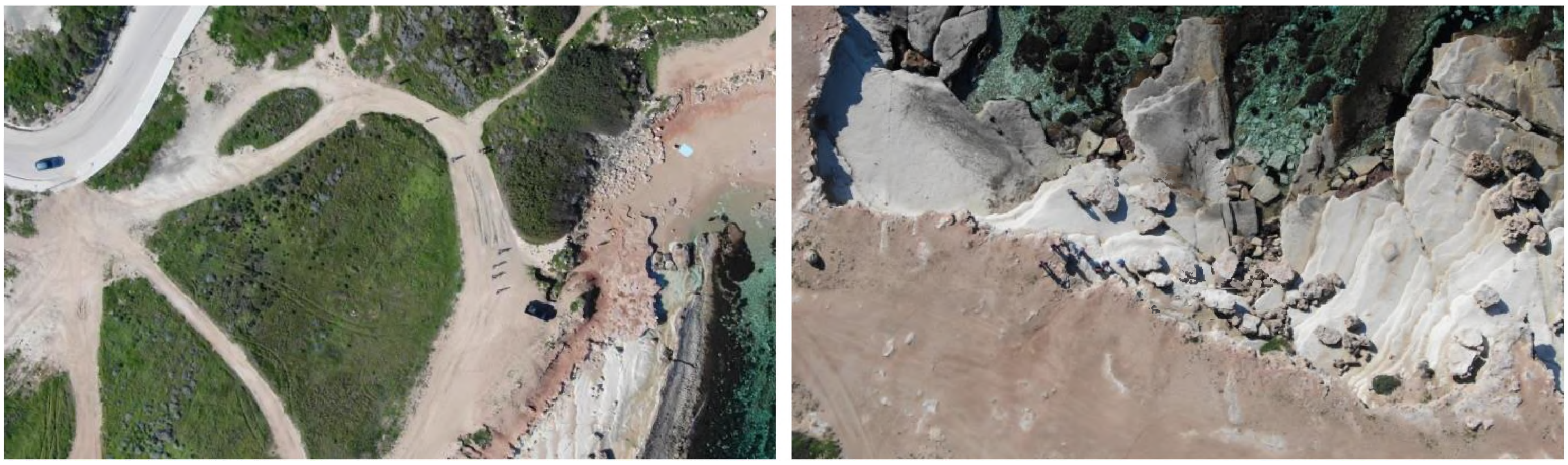


Figure 3: Two snapshots from the aerial videos

2.4. Real Floods in Sardinia, Italy

This dataset, consisting of photos and videos, was gathered during the deadly flooding in November/December 2020 in Bitti, a municipality in Sardinia. A destructive massive mudslide, caused by the heavy rains, poured along the main street in the town, and its height was 4 meters. Some of the residents have been moved to avoid the worst. The drones captured videos and photos from the day after the storm, November 29th, up to December 4th. There is a sequence of operative actions undertaken by the people involved, such as the Civil Protection Department, Firefighters, Police, Carabinieri, volunteered associations, and many more. As shown in Figure 4, this dataset consists of images of floods situated in a residential area. The aerial videos and photos are available at: https://www2.kios.ucy.ac.cy/ARTION/drones-footage-from-floods-in-sardinia-italy-november-december-2021/

Figure 4: An image from the dataset of real floods in the area of Bitti, in Sardinia.

3. AI TOOLS

In this section we present briefly the three tools that are developed within the framework of ARTION. In particular, we have developed two AI algorithms based on computer vision. The first, an aerial person detector and tracker, runs on aerial videos. The second, a disaster detector and classifier, runs on images.

In addition, in collaboration with the CCD we developed an interactive web platform and mobile app. This duo provides enhanced communication functionalities during emergency response operations and was very positively perceived by first responders who have used it during a test mission. Our vision is to integrate AI algorithms in order for the platform to evolve, beyond its communication functionalities, into an AI-based decision-support system. Currently, as a first step, an AI object and person recognition algorithm is successfully integrated into the platform. The following subsections describe in more details the three aforementioned AI tools.

3.1. Aerial Person Detector

This AI-based software for identifying individuals consists of two main components, detection and tracking. This is achieved by utilizing footage captured from various test missions using drones (including the video-datasets presented in Section 2 of the present document). Person detection is done by means of computer vision algorithms and a Convolutional Neural Network whereas tracking is achieved by means of a combination of algorithms. Furthermore, upon detecting and tracking the persons, all the data collected from the whole process is then saved in CSV files for further analysis.

For the person detection algorithm, YOLOv4[3] was trained. YOLOv4 is an object detection algorithm that is an evolution of the YOLOv3 model, which is a real-time object recognition system that can recognize multiple objects in a single frame. For the model to recognize persons, a dataset of images was initially created. Around 2500 images were collected and annotated. Some of those were captured from real life test missions and the rest were taken from the Heridal Database[4]. In order to increase the accuracy of the detector and to increase the dataset size, some image augmentations were implemented on several images and used as separate images for the training dataset. These augmentations include brightness, contrast, sharpness, and saturation. Image augmentation helps to enhance the details of the images which is helpful since the altitude at which the drones fly is usually high. The training was done using the Darknet Framework, an open-source neural network framework written in C and CUDA.

Upon detecting the persons in a frame, tracking algorithms starts processing them. Initially the tracking utilizes the Hungarian Algorithm[5], which uses the Intersection of Union of the detections compared to the previous detections as a similarity metric score. The matching association for each person detection is executed in the current frame with the highest achieved Intersection over Union score of the previous

[3] A. Bochkovskiy, C.-Y. Wang, and H.-Y. M. Liao, "Yolov4: Optimal speed and accuracy of object detection,"arXiv preprint-arXiv:2004.10934, 2020

[4] D. Božić-Štulić, Ž. Marušić, S. Gotovac: Deep Learning Approach on Aerial Imagery in Supporting Land Search and Rescue Missions, International Journal of Computer Vision, 2019

[5] G. A. Mills-Tettey, A. Stentz, and M. B. Dias, "The dynamic Hungarian algorithm for the assignment problem with changing costs,"Robotics Institute, Pittsburgh, PA, Tech. Rep. CMU-RI-TR-07-27, 2007

frames. Apart from the Intersection over Union matching, a distance matching algorithm is also implemented, assuming the scenario of having no detections matched with previous person already detected, using the Intersection over Union score. The distance matching algorithm calculates the Euclidean distances of a person's last position, to all other detected persons of the current frame. Then, if the nearest bounding box area and size match approximately the area of the previously tracked person's box, the newly detected person is the previously targeted person. Furthermore, a Kalman filter is used to estimate the position of the tracked person in case of any occlusion, such as trees, or if the detector fails to detect the person but the person was moving. The Kalman filter updates its variables using the x, y coordinates of the matched box in the current frame, assuming a nearly constant speed model. Finally, all the data collected from the whole process are saved in CSV format files in order to be further processed for data collection and analysis. These files contain the location and trajectories of the persons in x,y pixel coordinates, and the moving direction for each person for each frame.

The algorithm can be run offline on recorded videos, but it is also lightweight and fast enough to be run in real-time on an ordinary laptop at the emergency operation center. Snapshots of the algorithm running on the drone's footage captured in the field exercises referred to subsections 2.1 and 2.2 are shown in Figure 5.

The algorithm is openly available at: https://www2.kios.ucy.ac.cy/ARTION/aerial-person-detector/

Figure 5: Snapshots from the aerial person detector running on videos captured in the field exercises of Subsections 2.1 and 2.2

3.2. Disaster Detector and Classifier

This AI algorithm detects and classifies fires, floods, and building disasters (for example, after an earthquake or fire) on images which are provided as input to the algorithm.

The data that was used for the training and testing of the algorithm was taken from images from the Internet (YouTube, Kaggle) and from various missions that KIOS captured using drones (mostly for fires). The data was trained using Google's online classifier[6]. A TensorFlow model was then exported and further used for detecting where exactly in the image or video frames a disaster is found.

In order to convert the classifier to an object detector, a multi-step procedure is followed (illustrated schematically in Figure 6a). Upon capturing video frames, the image is rescaled to smaller images like a pyramid (as illustrated schematically in Figure 7Figure 6b). Then, for each rescaled frame a sliding window with a fixed size is passed through the image and classifying each region of interest. These classifications are converted to boxes, therefore having multiple sized boxes depending on frame size. Finally, non-maxima suppression is used on these boxes to get the final detection boxes on the original frame. A snapshot from the execution of the disaster detector and classifier on images featuring damaged buildings and fires is depicted in Figure 7.

The algorithm is openly available at: https://www2.kios.ucy.ac.cy/ARTION/disaster-detector-classifier/

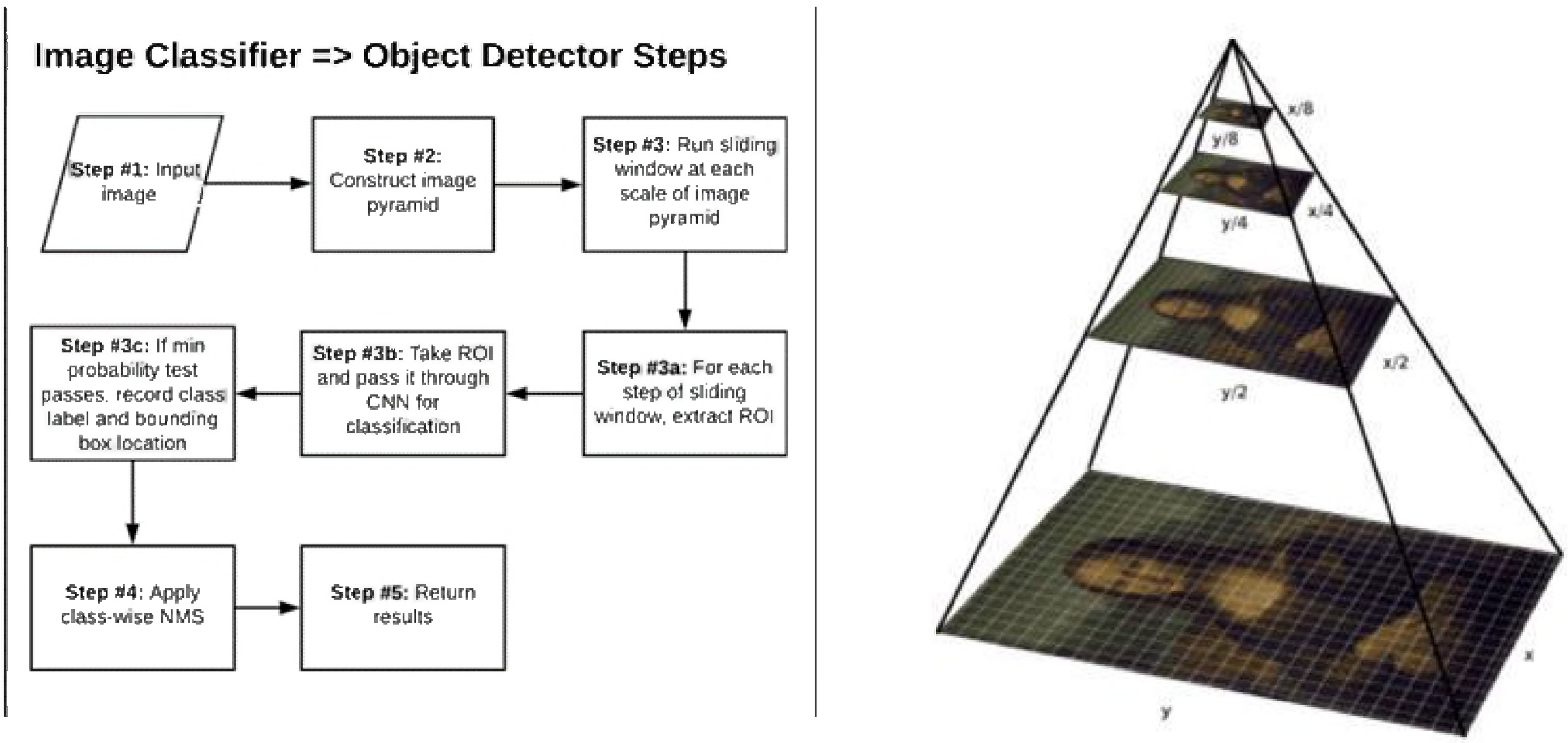


Figure 6: (a) Classifier to Object Detector steps (b) Frame pyramid rescaling

[6] Teachable Machine. (last accessed on 1/2/2022) https://teachablemachine.withgoogle.com/

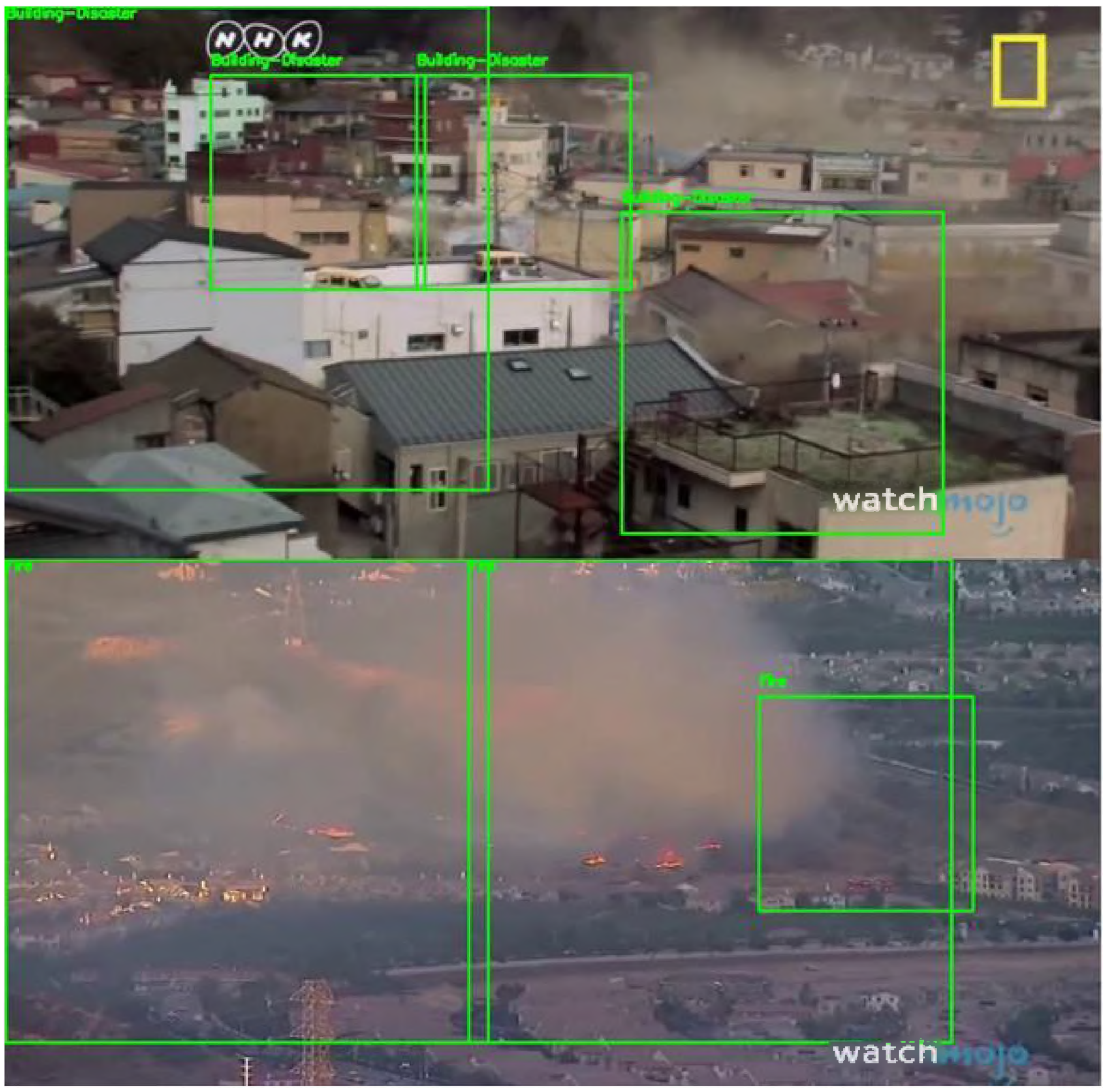


Figure 7: A snapshot from the execution of the disaster detector and classifier on images featuring damaged buildings and fires.

3.3. Web-platform and Mobile application

During the framework of ARTION, KIOS-UCY has developed a web-platform and mobile application for facilitating the communication between the first responders that are operating in the field and the disaster management experts at the command and control center. The requirements for the development of these tools were set in close collaboration with the CCD.

The web-platform is accessed at a computer at the command and control center. There, the mission commander can create a new mission at the platform and enters the teams of first responders that will operate in the field. Figure 8 shows the home page of the web-platform (after signing-in), where all missions (completed and on-going) are shown.

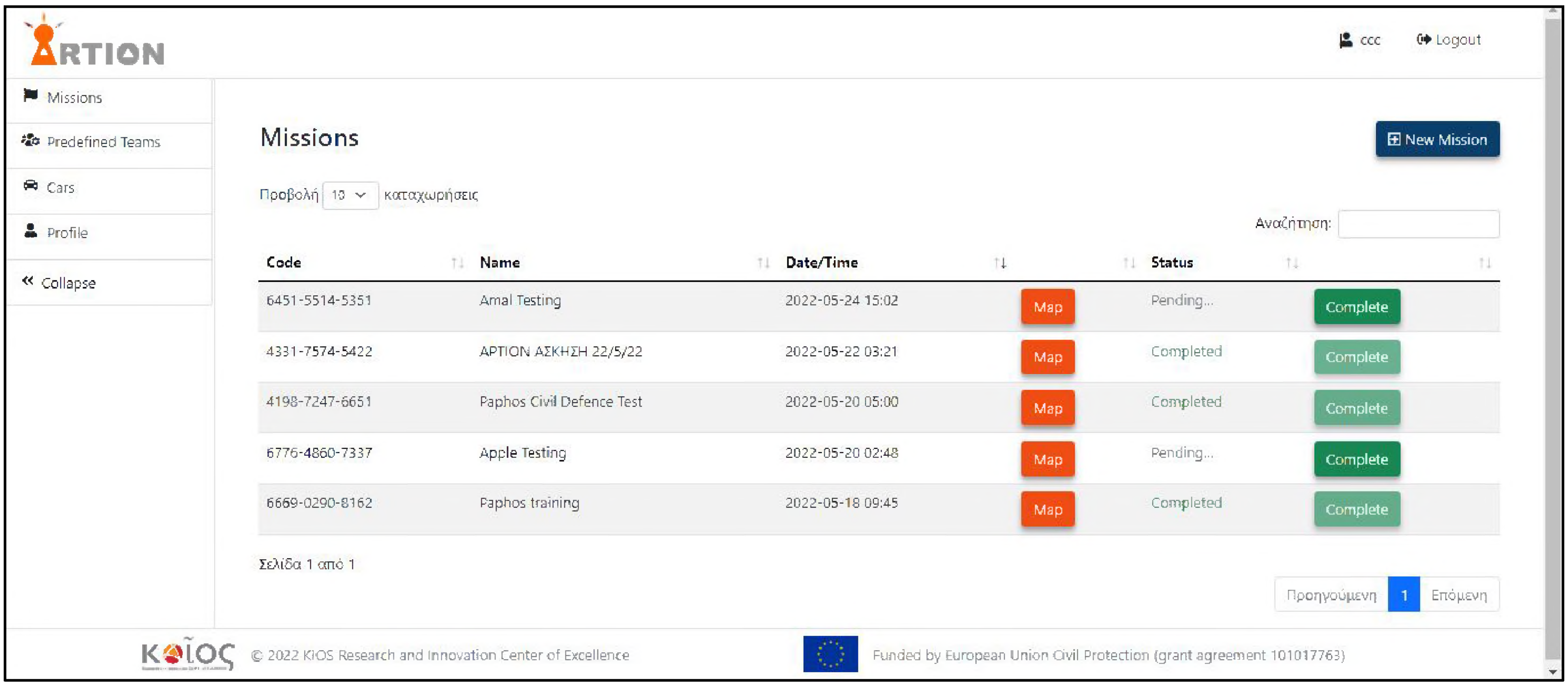


Figure 8: The home page of the web-platform where all missions (completed and on-going) are shown.

The first responders are informed about the code of their mission. From their side, first responders need to have the mobile application running on their mobile phone. Each first responder signs in to the application with her own credentials and enters the mission (by using the mission code). From the moment a first responder signs-in and enters her mission, she appears on the map at the web-platform and is continuously tracked. Therefore, the command and control center is able to know at all times the location of all first responders in the field. Figure 9 shows an example of a test mission in which four responders are using the mobile app and their locations are shown on the map.

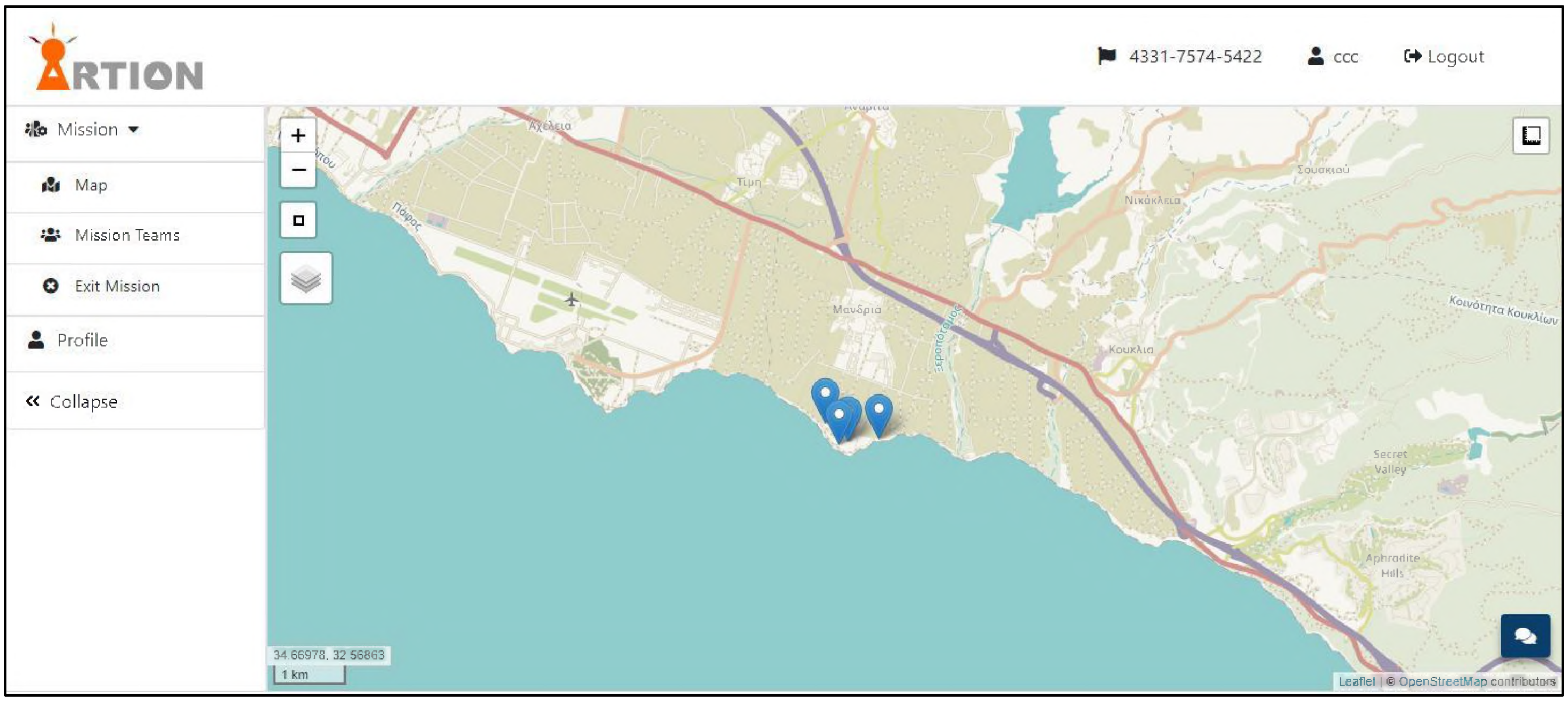


Figure 9: The current locations of four first responders are shown on the map at the web-platform during a test mission.

Furthermore, the mobile application and web-platform facilitate bidirectional communication between the first responders and the command and control center and between first responders in the same team. In particular, it is possible to exchange text messages, photos that are taken with the phone, as well as locations and routes drawn on the map. According to the feedback we received, the application – in its current version – is very practical and useful for emergency response operations as it offers an enhanced level of communication in various forms (photos, points of interest, etc.) while, at the same time, it is very easy to use. Figure 10 shows an example of three screenshots of the mobile application. In particular, in Figure 10 (a), (b) and (c) we see respectively the initial screen for joining a specific mission, the map on which the first responder drew a route which can be shared with others, and a message-exchange screen.

(a) *(b)* *(c)*

Figure 10: Three screenshots of the mobile application (a) the initial screen to join a specific mission (b) map on which the first responder drew a route (which can be shared with others) (b) a message-exchange screen.

Currently, an AI algorithm for persons and object recognition is integrated in the platform and runs on all photos that are captured by first responders and sent to the command and control center. As the photos are taken by first responders in the field under not optimal conditions they might be of compromised quality. They might be, for example, dark, shaken, or taken from a large distance from the scene of interest. To this end, the detection of the objects on the image is useful and helps to identify persons and items which could be missed by a human eye who sees the photo due to a combination of factors, such as the bad quality of the photo and the rush that characterizes all actions during emergency events. Figure 11 shows a message-exchange box appearing at the platform in which a photo sent by one of the first responders out in the field is shown. The photo is located and shown also on the map. In fact, two photos appear on the map; the left photo is the original one, and the right photo is after the person and object recognition algorithm is executed. A detail of the right photo is depicted in Figure 12 where two persons are detected. Although the AI algorithm works well and persons and objects are indeed detected, during the last testing mission we identified that the marking of those on the photos could be bolder and this is one of the points that are currently undergoing a minor improvement.

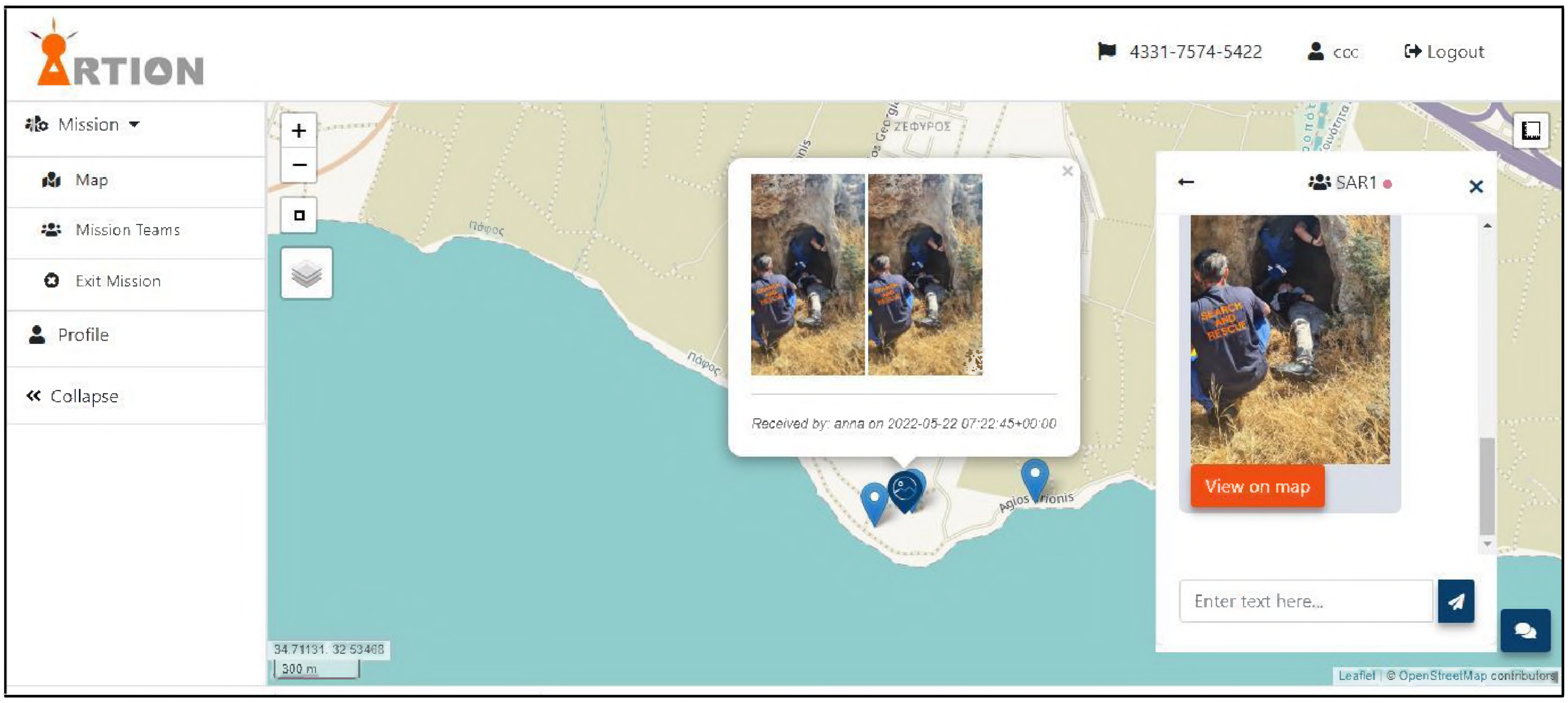


Figure 11: A message-exchange box appears at the platform showing a photo sent by one of the first responders in the field. The photo is located also on the map (left photo is the original one, right photo is after the person and object recognition algorithm is executed).

Figure 12: A detailed of the photo sent by a first responder, in which two persons are detected by means of an AI algorithm.

In the future, we plan to develop additional AI algorithms that will be integrated in the platform. Our aim is that the platform will evolve into a powerful tool that not only facilitates birectional communication, but offers also AI-powered decision-support functionalities.

The web-platform is not yet available for everyone to use; It is still operational on pilot basis and is undergoing some further improvements and modifications after it was tested during a field exercise. As for the mobile app, the Android version is ready and already tested, whereas the iOS version (for iPhones) is ready, but not tested yet.