Training for Emergencies - How Germany is Preparing for Large-Scale Emergencies Using the EUROMED 2024 Civil Protection Exercise as an Example

Veronika Gstaiger[1,*], Nils Machinia[3], Nina Merkle[1], Dominik Rosenbaum[1], Ronald Nippold[2], Manuel Muehlhaus[1], Pablo d'Angelo[1], Corentin Henry[1], Xiangtian Yuan[1], Reza Bahmanyar[1], Franz Kurz[1], Christa-Maria Krieg[3]

[1]Remote Sensing Technology Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany
[2]Institute of Transportation Systems, German Aerospace Center (DLR), Berlin, Germany
(veronika.gstaiger, nina.merkle, dominik.rosenbaum, ronald.nippold, manuel.muehlhaus, pablo.angelo, corentin.henry, xiangtian.yuan, reza.bahmanyar, franz.kurz)@dlr.de

[3]Federal Office of Civil Protection and Disaster Assistance (BBK), Bonn, Germany

Keywords: Aerial Camera System, Rapid Mapping, AI Image Analysis, Civil Protection, Exercise.

Abstract

Every year, numerous major events with thousands of participants take place around the world, for which extensive safety measures are taken to ensure the well-being and safety of visitors. Nevertheless, incidents that lead to injuries and deaths occur time and again. This year, Germany is looking forward to the UEFA EURO 2024, an international football championship for which the host country, Germany, has made extensive preparations on several levels. One component of this is the Medical Task Force (MTF) of the Federal Office of Civil Protection and Disaster Assistance (BBK), which has trained a possible medical service deployment in the event of a mass casualty incident with a specially coordinated series of exercises. The extent to which current remote sensing data can make a useful contribution and be meaningfully integrated was analyzed during the large-scale EUROMED exercise with the help of an airborne camera system on board a helicopter. The system provided up-to-date aerial images of the exercise site, but was also used to record the traffic situation during the transfer of the vehicle convoys to the exercise site. In addition, state-of-the-art AI-based image analysis methods were tested on site and the results were provided and evaluated. An important operational exercise to bring science and practice together step by step in order to be better prepared for an emergency.

1. Introduction

Russia's war against Ukraine changed European security policies profoundly. Besides military policies, the protection of a nation's citizens (civil protection) is of utmost importance for a reliant national defense (Kling, 2023). In the event of military attacks, terrorism, or natural disasters the population may be affected by mass casualty incidents (MASCAL). A MASCAL is characterised by an imbalance between the number of patients (injured and/or ill) with their ad hoc needs and the available resources (Lorenz and Rebuck, 2023). To provide adequate medical care for the population, the Federal Republic of Germany is implementing 61 specialized medical task forces (MTF) in addition to the precautionary measures of the federal states. To ensure sufficient treatment for as many affected persons as possible, the use of disaster medical procedures is obligatory. A single MTF provides treatment for up to 100 patients in mobile treatment centres or 50 patients over 48 hours. Every MTF consists of 27 emergency vehicles and 138 emergency personnel. Besides civil protection purposes, local disaster relief agencies are also supported by the MTF (BBK, 2018). To ensure a rapid diversion, regular investigation of available transportation infrastructure and environmental information perception is necessary (Jin et al., 2020).

This summer, Germany is hosting a large-scale international football championship ("UEFA EURO 2024"). To ensure a safe championship, federal state and local governments agreed on extensive security measures. As part of these measures, the Federal Office for Civil Protection and Disaster Assistance (BBK) conducted the EUROMED exercise series with more than 17,000 participants from the MTF emergency personnel. In addition, a large-scale medical exercise with 700 participants was carried out on March 2nd, 2024 in Hamburg in order to comprehensively train the operational procedures within the MTF as well as in interaction with other players in civil protection (see Figure 1) (BBK, 2024).

Figure 1. Mobile MTF treatment center at the EUROMED exercise (© BBK 2024).

Since comprehensive situational awareness plays a fundamental role in both civil defense and disaster control, and remote sensing as well as derived spatial information have been making an important contribution to this for many years (Boccardo and Giulio Tonolo, 2015, Tomaszewski et al., 2015), aerial image ac-

* Corresponding author

quisition was decided to be part of the large-scale EUROMED exercise.

The paper is structured as follows. In Section 2, the VABENE aerial camera system is described briefly. The main part, Section 3, deals with research topics that are to be answered with the help of the remote sensing tools and techniques, explains the course of the exercise, and demonstrates the results of the AI evaluation procedures implemented on site. Finally, Section 4 summarizes the findings and provides an outlook on subsequent research activities.

2. The VABENE Aerial Camera System

For several years now, the German Aerospace Centre (DLR) has been operating aerial camera systems developed in-house on various aircraft and helicopters in its research fleet, as well as on external platforms. The VABENE system is one of these helicopter systems that was developed and built for situational awareness and mapping (see Figure 2) (Kurz et al., 2014). The system was applied during the floods along the river Ahr in Germany in 2021 (Wieland et al., 2023) and is regularly used for research purposes, for example to collect data for traffic applications (Kurz et al., 2022). After a recent upgrade, it consists of a sensor head that includes two standard Canon EOS 1-D X Mark II cameras with 20 Mpx as well as a PhaseOne iXM-RS150F camera with 150 Mpx. The Canon cameras enable an acquisition angle of up to 60 degrees and thus allow a comparatively wide flight path to be captured, while the PhaseOne camera delivers images with the highest level of detail. The computing unit inside the helicopter then merges the recorded images with the corresponding position data from the high-end Inertial Measurement Unit (IMU), orthorectifies them using a terrain model, analyses the images as required, and transmits the data via an LTE data link. Once on the ground, the data is made accessible via a geoservice (https://geoservice.dlr.de/web/) and can be integrated directly into geographic information systems (GIS), for example.

Figure 2. VABENE aerial camera system mounted on a helicopter (DLR (CC BY-NC-ND 3.0)).

3. The EUROMED Exercise

3.1 Research Topics

The EUROMED exercise provided an opportunity to bring science and practice closer together, to test new developments in practice, and to gather practitioners' feedback for future development. The following research topics were formulated by science and practice in order to harmonise mutual expectations and goals in advance.

- Deployment of large-scale units such as a MTF is a logistical challenge. For instance, a single MTF forms a 3 km convoy with an average speed of approximately 60 km/h. Therefore, regular training for drivers and executive personnel is necessary. To optimize deployment times and fuel efficiency, aerial imagery is used to analyze the distance between vehicles, average speed and actions performed by civil motorists.

- In case of an emergency, executive officers also need to assess safe routes and deployment sites beforehand to ensure vehicles and personnel won't get restrained by destroyed infrastructure. Due to dynamic events, the information for finding a safe route is subject to constant change. The VABENE system will be used to find out to what extent aerial images from a helicopter can provide the necessary information for this purpose.

- Following the further development and implementation of new transmission interfaces, the EUROMED exercise is the first major stress test for the VABENE system. Both the operation of the system with image acquisition, image processing, and transmission of the data as well as the information flow between the aerial camera system, operations management, and emergency personnel are tested to provide information on possible improvement potential for optimizing the system and its integration in operational procedures.

- As part of research projects, issues in the field of transport research can be analyzed using remote sensing data and AI-based evaluation methods (Mühlhaus et al., 2023). The EUROMED exercise offers the opportunity to analyze existing methods on a special traffic case and its effects as well as the monitoring of a convoy. It also allows algorithms to be further developed with the help of the data obtained, e.g. to automatically recognize and track vehicles and convoys of authorities and organizations with security tasks from the air in the future and thus, for example, to usefully supplement additional information to a common situation picture in the event of a major incident involving various parties.

- The relocation of convoys, especially in densely populated urban areas, represents a special traffic situation. In the case of the EUROMED exercise in Hamburg, the large number of bridges in the urban area and the Elbe tunnel also create constraints and bottlenecks that can lead to a large number of interactions with the surrounding commercial and private traffic. Since the end of the Cold War, there has been virtually no measurement data available for such events in Germany. The parameterization and calibration of simulations of such results is correspondingly difficult and fraught with great uncertainty. One research objective is therefore to collect traffic data on the movement of convoys and their interactions with the surrounding traffic flows in order to derive knowledge for a more realistic simulation of such events. The aim is to gain a better understanding of such special traffic situations so that accompanying traffic management measures can be derived or adapted accordingly.

3.2 Exercise Procedure

In real emergency situations, the smooth interaction of all involved parties is of great importance. The interfaces within a MTF, between several MTF units and across federal states, must function seamlessly. For this reason, various aspects of healthcare in civil protection were combined and practiced in the EUROMED exercise, including the request and transport logistics of medical supplies (medical supplies stockpiling), the pre-hospital care of casualties, their transport by land and air (civil defense helicopter) and the clinical care of all casualties, taking into account hospital alarm and deployment planning. The volunteer emergency services trained the alerting, relocation and operation of three MTF units from Hamburg and Lower Saxony on the training grounds of the President Ebert barracks of the Bundeswehr in Hamburg (BBK, 2024). The relocation of the convoys is an important part of the exercise, as rescue vehicles such as these have special traffic rights in Germany and, in particular, dealing with other road users can pose particular challenges for drivers in these special situations. Figure 3 shows a part of a MTF convoy making use of its special traffic rights on its way through Hamburg and using the opposite lane to cross the intersection.

During the exercise, a total of three flights lasting around 2.5 hours were carried out to acquire aerial images using the VABENE system. The main tasks consisted of monitoring the units on their way to the treatment center, recording the surrounding traffic, and of course, observing the development of assembly and dismantling activities as well as operations at the treatment center. The acquired images were georeferenced on board, transmitted via LTE and displayed directly at the exercise management headquarters for situation assessment.

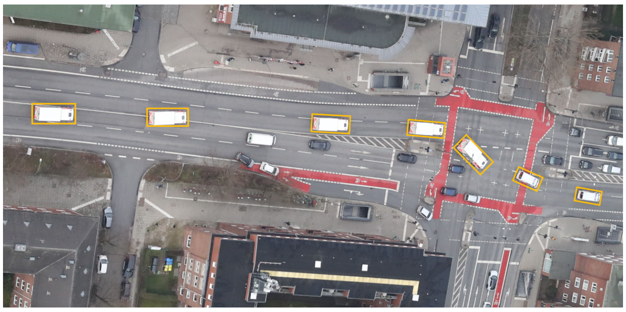

Figure 3. Aerial image of MTF convoy (orange) with special driving rights travelling through Hamburg.

3.3 Traffic Monitoring

In addition to providing geo-referenced aerial images for the exercise control centre, the convoys of the exercise participants were also monitored with ground-based sensors in the form of a PVD system (probe vehicle data) based on the Hamburg taxi fleet. These additional traffic information were provided to the exercise control centre through a special web portal called “KeepMoving” by the DLR (Neidhardt et al., 2019). As basic functionalities, the KeepMoving portal offers the display of the current and predicted traffic situation as a zoomable map based on different data sources (see Figure 4). Additionally, this portal provides other services such as convoy-adapted routing, reachablitiy analysis, and travel time monitoring of strategic routes. Furthermore, comparable trajectories of past weeks and months can be displayed in a dashboard and compared with the current traffic situation.

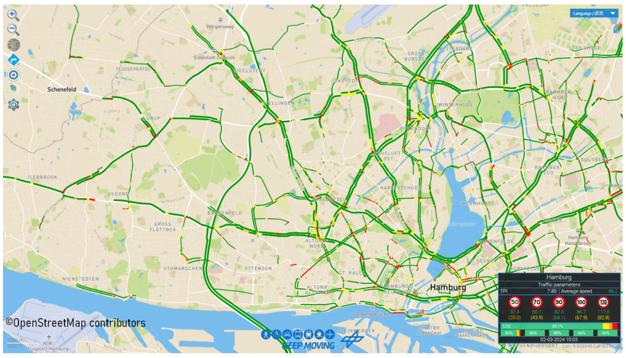

Figure 4. Overall traffic situation of the city of Hamburg displayed in the ”KeepMoving” portal. In addition to the OpenStreetMap map display in the center (©OpenStreetMap contributors; openstreetmap.org/copyright), traffic KPIs relating to previous weeks are displayed at the bottom right of the screen.

Restrictions or impairments to the traffic infrastructure that occur in the event of disasters or damage situations can be integrated in standardized formats such as GeoJSON and KML, which can be derived from additional sources such as georeferenced aerial and satellite images. These network restrictions affect the routing graphs accordingly and are taken into account by the underlying routing algorithms.

These restrictions are also considered in the analysis of the accessibility or reachability of arbitrary areas. Such regions with similar travel times are visualized using so-called “isochrone maps”. This represents a proven instrument for deployment planning and disposition. Furthermore, isochrone maps enable the estimation of whether response times can be met.

3.4 AI-based Image Analysis

For years, emergency mapping has used remote sensing data to assist in rescue operations, gathering information on affected areas by analyzing images captured before and after events via satellites, aircraft, or drones (Lang et al., 2019). However, the automatic extraction of such data and its rapid delivery remain a challenge. Recent advancements in computer vision and the rapid evolution of graphics processing units have led to the development of optimized, fast-running algorithms, thereby opening up new possibilities in disaster response and humanitarian relief efforts (Beduschi, 2022). Nowadays, images can be analyzed directly in the field on portable and affordable computers. In the following, we show results for three deep learning-based methods trained to automatically extract roads, buildings, and people from aerial images. The methods were applied to the data acquired during the exercise without being specially trained or adapted to the exercise scenario beforehand. The results were demonstrated to the exercise management and interested visitors on site (see Figure 5 and 6). More details about the methods and their performance can be found in (Merkle et al., 2023). All results shown were computed on an Alienware Area51m laptop with a NVIDIA RTX 2080 Super GPU, which can be easily transported and used in the field.

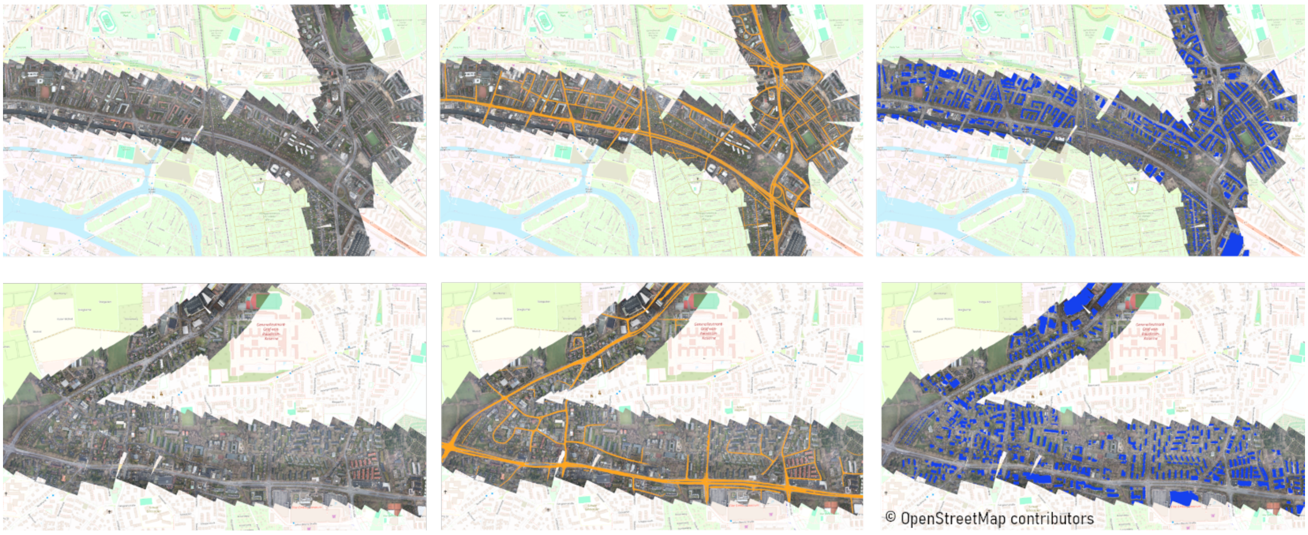

Figure 5. Samples of the road and building segmentation results: the image mosaic (left), the segmented road marked in orange (middle), and the segmented buildings marked in blue (right) displayed on a basemap of OpenStreetMap (©OpenStreetMap contributors; openstreetmap.org/copyright).

3.4.1 Road Segmentation: Current information about the road network is essential for the planning and execution of rescue operations or the transportation of relief supplies. By combining remote sensing and deep learning, the entire road network of an affected area can be extracted in just a few minutes. If images from before and after the disaster are available, it is possible to identify which roads are still intact and which may have been damaged. To extract the road network, we used a Dense-U-Net-121 architecture inspired by the well-established U-Net model, as outlined in (Henry et al., 2021). Both the encoder and decoder leverage the robust DenseNet-121 backbone, chosen for its optimal balance between result accuracy and computational efficiency. The model is trained on the DeepGlobe18 road dataset (Demir et al., 2018), which is a large-scale dataset containing over 1600km^2 of image data from Southeast Asia at a resolution of 50cm/pixel, with roads manually annotated pixel-wise.

Figure 5 shows two sample areas of the results obtained over the city of Hamburg, Germany. Most roads were successfully detected, and the predicted roads are regular and continuous, even though the model was not trained on images acquired over Germany. The computation time of the model to process the total area of 110km^2 with a resolution of 50cm/pixel was about 7min and 10s, which leads to a processing time of 3.9s/km^2.

3.4.2 Building Segmentation: Infrastructure, and more specifically buildings, is another important aspect to consider when managing a crisis. The number of buildings in the affected areas can be used to estimate the number of potentially affected people or locate highly populated areas. If pre- and post-disaster images are available, damage to buildings can be identified and the number of people affected can be estimated. We use the HRNet (Wang et al., 2020) to detect buildings. This network consists of four parallel and multi-resolution streams. This feature allows for more precise localization, which is crucial for the task of building segmentation. The Inria dataset (Maggiori et al., 2017) was used to train the model. This dataset contains 405km^2 of labeled image data at a resolution of 20cm/pixel from the USA and Austria.

Two sample areas show the predictions of the building segmentation models in Figure 5. The model produces consistent and reliable results over the entire area. Small and large buildings are extracted with high accuracy. The computation time of the model to process the total area of 110km^2 with a resolution of 20cm/pixel was about 31min, which leads to a processing time of around 16s/km^2.

3.4.3 People Detection: In order to improve the efficiency and effectiveness of relief efforts, e.g. for search and rescue missions, the safe delivery of supplies to affected areas, and the safe landing of drones, the location of people in affected areas is a critical requirement. Identifying people within large aerial and drone images, especially within complex scenes, presents a significant challenge. This challenge is due to several factors, including the small size of people compared with the vast number of pixels in the image, the varied poses and articulated nature of the human body, as well as changes in lighting, weather conditions, or camera angles. We use an adapted YOLOv3 (Redmon and Farhadi, 2018) object detection method that addresses challenges such as variations in scenes, poses, scales, and viewing angles posed by images during real humanitarian missions. The model was trained on the dataset presented in ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2023 (Bahmanyar and Merkle, 2023).

Figure 6 shows the results of the person detection model over the treatment center in Hamburg, Germany. Overall, we achieved promising results and the model was able to detect most people in the scene. However, in order to improve the robustness of the model, the training dataset would need to be expanded to include a wider variety of scenes and situations. The computation time of the model to process the total area of the treatment center (0.14km^2 with a resolution of 3cm/pixel) was 1min and 24s, resulting in a processing time of 10min/km^2.

4. Conclusion and Next Steps

Recent remote sensing information can provide crucial added value in crisis situations, especially when made available at

This contribution has been peer-reviewed. The double-blind peer-review was conducted on the basis of the full paper.
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Figure 6. Person detection results over the treatment center in Hamburg, Germany. The left side of the image shows the entire area of the treatment center and the right side shows two zoomed-in areas of the treatment center. Green boxes mark predictions with a confidence score ≥ 0.5, whereas orange boxes mark predictions with a confidence score ≤ 0.5 (the higher the confidence score, the more confident the model is that a prediction is correct).

short notice. The VABENE system was able to provide professional aerial images in a timely manner, and processing, transmission and visualization components are currently being adapted to be real-time capable. An airborne situation survey to find a suitable location for a treatment center, as might be necessary in an emergency, was not required for the EUROMED exercise, as the exercise scenario had been determined in advance and the location for the treatment center had been defined. Nevertheless, the VABENE system has shown that it can provide suitable data for this application and monitoring the exercise using the aerial images also offered great added value, as both the set-up on the exercise site and the course of the exercise could be reconstructed.

Accompanying the convoys on their way to the treatment site also allows conclusions to be drawn about the driving behaviour in the convoy. The exact analysis of the driving behaviour of the individual vehicles in the MTF convoys concerning the distance between vehicles and driving speeds is still ongoing. But both the exercise management and the individual MTFs will receive feedback in this way and can adapt training concepts if necessary and train individual aspects in a targeted manner in the future if required.

The integration of AI-based evaluation methods was not initially planned as an integral part of the exercise. Nevertheless, the methods were applied directly to the aerial images sent and were able to deliver good results. It was possible to draw conclusions about the processing time, performance, and robustness of the algorithms in a real scenario. The presence of the remote sensing specialists on site was also of great importance. In this way, it was not only possible to communicate results but also to explain them and the processes behind them. With automated analyses in particular, it is important to explain the possibilities as well as uncertainties and limitations in order to create understanding and trust among non-specialist personnel and to gain direct feedback from users in the field. For a possible damage evaluation of buildings or the investigation of possible road damage, it is necessary to analyze and compare data before and after the damage event. For this purpose, a reference database and a process will be implemented in the future to automatically detect and analyze changes. The algorithm for automated person detection provided valuable results as a basis for future research projects. In order to be able to support the search for injured and missing persons with this method in the future, it will be necessary to expand the training data.

In order to be able to automatically detect MTF convoy vehicles as such and convoys as a whole in the future, training data sets are currently being created and procedures developed based on the acquired data.

In crisis situations, local traffic conditions are often unclear and can change rapidly. Current traffic information and appropriately adjusted routing for emergency responders and resource allocation are crucial. Automatically derived information from aerial images, such as damaged infrastructure or traffic volumes and flow, can enhance and support the evaluation of existing information. Integrated into routing portals, they can contribute to optimized routing, particularly improving routing for vehicles with specific constraints such as emergency vehicles.

Both the provision of current aerial images together with spatial information and the cooperation between science and practice in general have proven to be beneficial. Exercises like these are a good and important opportunity for direct exchange and provide both sides with large amounts of information and data to work more closely together in the future.

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