Floreon+: Integration of different thematic areas

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Abstract

The main goal of this article is to present an overview of the different thematic domains integrated in the Floreon+ system. Previously being just an online flood monitoring and prediction system, Floreon+ was primarily developed for the Moravian-Silesian region in the Czech Republic; however, the system is now also providing real-time data and simulations from the areas of traffic monitoring and modelling, toxic pollution and population mobility. The main focus of the Floreon+ system is to provide comprehensive information about the current or future situations with the interactions between different thematic domains, therefore providing additional information for the decision making process of the crisis staff.

Keywords: Floreon+, decision support system, hydrological modelling, traffic monitoring, cloud pollution, mobility, domain interaction

INTRODUCTION

In the case of major emergencies and crisis situations, the security community in general, and especially the part that is assigned to the operational centers of the integrated rescue system and crisis staff members at all levels of hierarchy, are exposed to massive workload of more or less valid information from affected areas.

The overall picture of the situation is composed based on the information from the intervention commanders, representatives of the affected municipalities, and citizens. More recently, this information has been passed on to the operational centers or to the crisis staff orally, by telephone, radio, or fax. Now smart phones capable of conveying photos, video, GPS coordinates, etc. can play a key role in providing information about the situation on the scene of the event. The follow-up information is provided to the contact staff of these centers through social networks, the media community, territory data (smart city projects, smart region) and, in the near future, via IoT (Internet of Things) data.

Both the operational center and crisis management staff are then expected to properly evaluate all of this information and data, connect and quickly decide on the best solution that will lead to as little loss of life, health, and property as possible. The fact is that the tools which are currently available within most operational centers of Integrated Rescue Services in the workplace of crisis staff are more or less self-serving and often require a considerable routine ability.

A major problem is the situation where a number of extraordinary events occur simultaneously in the same affected area (e.g. flood, toxic cloud pollution, disruption in some parts of the transportation system, etc.). In this case, it is virtually impossible to model both the current situation and its expected development scenarios as correctly and quickly as possible as well as promptly propose partial steps to eliminate the consequences.

Floreon+ is a decision support system, which integrates a number of different thematic areas and tools to quickly analyze the possible impacts of emergencies, crisis situations, and interactions between them in the affected area. This system offers additional information for the decision making process of the crisis staff during the crisis situations.

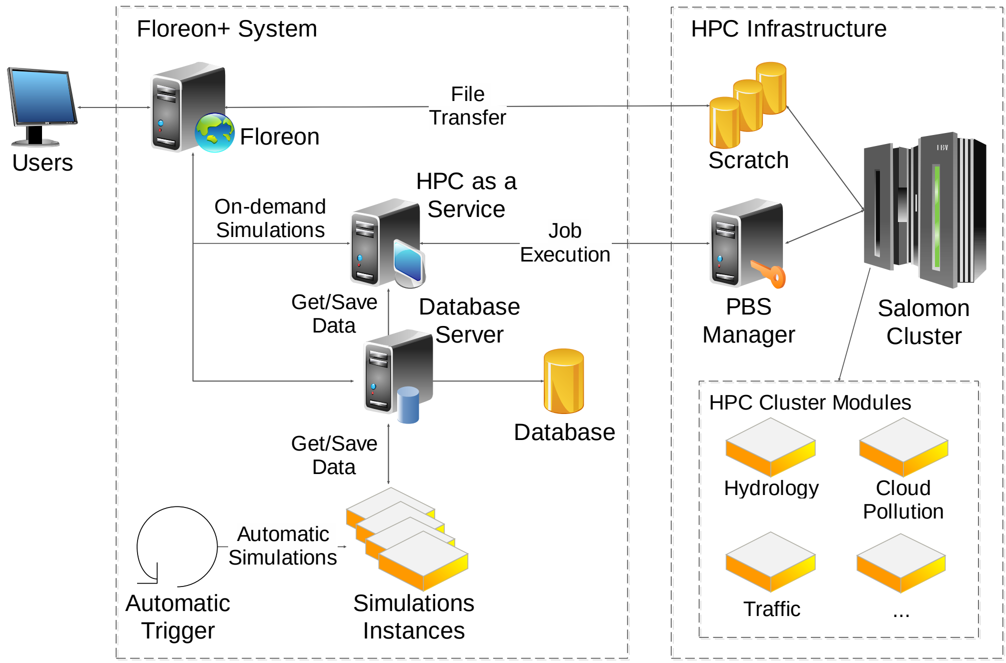

Figure 1. Floreon+ system architecture overview

FLOREON+ SYSTEM ARCHITECTURE

The architecture of the Floreon+ system consists of a number of interconnected parts and modules (see Figure 1). The system's application logic is represented by a web server that hosts the web graphical user interface of the system, a database server used to access the relation database, and a number of support applications or services used mainly for monitoring, security, and data management purposes.

This architecture integrates our in-house developed application framework for cluster remote execution called HPC as a Service Middleware (Svatoň, 2017). Via this middleware, the Floreon+ system is able to utilize the HPC infrastructure within IT4Innovations National Supercomputing Center (the Anselm and Salomon HPC clusters). Therefore, the users of the Floreon+ system are able to execute computationally demanding applications or simulations in an HPC environment through a web GUI without the necessity of a direct cluster access.

Dynamic Data Processing

The Floreon+ system can be roughly divided into two main parts in terms of dynamic data processing. The first system's part deals with automatic simulation execution, while the second part consists of on-demand user-initiated simulations designed specifically for HPC cluster execution.

Automatic Simulations

Automatic data processing includes processes and simulations that are being executed automatically in a predefined time intervals and subsequently visualized directly in the web interface of the system.

The simulations consist mainly of hydrologic modelling. Measured hydrological data provided by the Povodi Odry state enterprise in the 10-minute interval. The system computes hydrographs and inundations from these measured values at hourly intervals (Kubíček, 2008) and makes these results available to users via web user interface.

Automatic processes are further responsible for the automatic update of the current traffic load of road segments (FCD – floating car data), traffic information about accidents, road closures (ITIS - Integrated Traffic Information System), camera snapshots for a set of crossroads provided by OVANET and mobility of population calculated from the mobile operators' data.

On-demand Simulations

Apart from the automatic simulations, the system allows users to initiate custom on-demand simulation with the user-defined parameters in the form of What-If analysis. Due to these parameters, the on-demand simulations can be much more computationally demanding than the predefined automatic simulations, and thus they are natively executed within an HPC environment. Therefore, these on-demand simulations (What-If analysis) are implemented as HPC modules and prepared to be executed on one of the supercomputers.

The system currently offers three types of What-If analysis: hydrological simulation, cloud pollution modelling, and traffic modelling. Hydrological simulation calculates the water flow and inundation based on the user-defined precipitations for a selected set of measuring stations, river basin, schematization, and rainfall-runoff model. Cloud pollution modelling simulates the spread of hazardous substances through the air and traffic modelling is able to visualize the changes in the traffic flow during some unexpected situations.

Stored Events

Floreon+ system contains so-called stored events data model. This model enables the system to detect some relevant/crisis situations that may occur and archive the data for later analysis or to visualize these events automatically in a web interface. The example of such hydrological event is for example the exceedance of level of flood activity (SPA) for one of the measuring stations. This model is applicable also for other thematic domains (traffic modelling, cloud pollution modelling, etc.) and for the both automatic and on-demand simulations as well.

THEMATIC DOMAINS

The Floreon+ system currently integrates data, models, and simulations from the four main thematic domains: hydrological modelling, cloud pollution modelling, traffic modelling, and mobility of population.

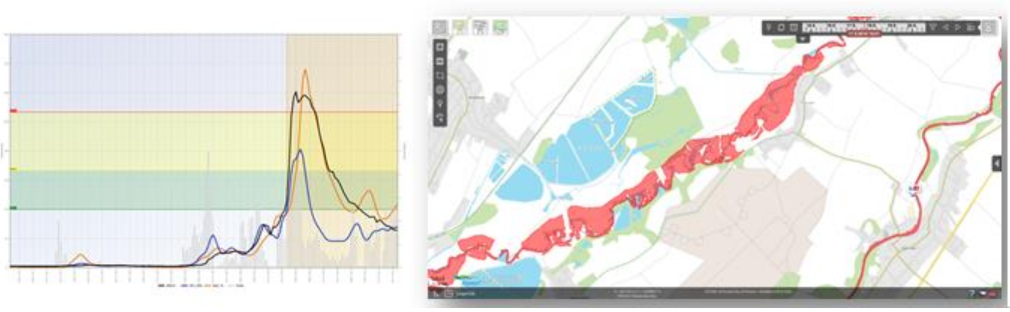

Figure 2. Hydrograph and flooding

Hydrologic Modelling

The hydrological analysis is a very powerful tool for simulation of river floods and river inundations depending on the selected precipitations in a critical situation. Hydrological simulation available in the Floreon+ system may be computed for each of the main four basins in the Moravian-Silesian region (Opava, Odra, Olše, Ostravice).

Hydrological modelling in the Floreon+ system consists of several steps. The first part consists of real measured values from measuring stations together with the predicted rainfall-runoff values. These data are retrieved and updated every 10 minutes from Povodi Odry and the predicted precipitation values are computed from the Medard predictive model (Medard, 2016), provided by third parties. The data is processed and then stored permanently in the system's database.

Based on these data, hydrographs with the real rainfall-runoff values and the predicted flow will be computed. The system currently uses HEC-HMS (CPD-74A, 2010) and

Math1D (internal model developed in cooperation with the Department of Applied Mathematics at VSB) (Kubíček, 2008) hydrological rainfall-runoff models to compute the hydrographs. The hydrographs are then used as the input for the hydrodynamic models to compute inundations. The hydrodynamic model 1D HEC-RAS (CPD-68, 2010) is used for computing the inundations.

The results obtained in the form of hydrographs and flood lakes are visualized directly in the map interface of the Floreon+ web GUI. The hydrographs can be viewed in the detailed view of a particular measuring station. Inundations are visualized by the map layer that highlights the areas which are in the critical zone with the risk of real flooding in red color (see Figure 2).

The above-described process is fully automatic, therefore always showing actual hydrologic situation for the Moravian-Silesian region. In case of the on-demand hydrological simulations the user fills in the starting time of the simulation, simulation's duration, and precipitations for selected precipitation stations. This type of simulation also allows the user to edit the default parameters of sub-basins and channels (Halmo, 2006).

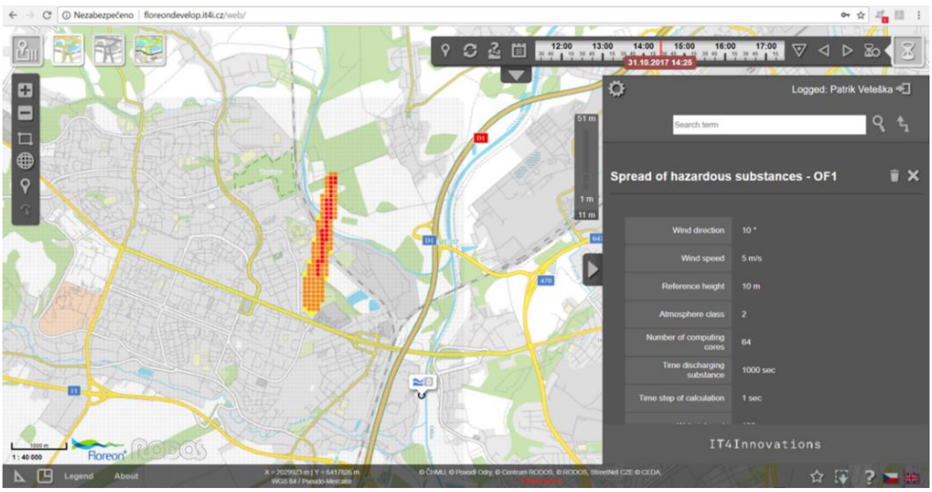

Figure 3. Cloud pollution modelling

Cloud Pollution Modelling

Another type of thematic domain implemented in the Floreon+ system is cloud pollution modelling. This type of analysis is only available as a user-defined What-If analysis. Using this analysis, the user can simulate the spread of a dangerous substance in the air. This simulation is utilizing the OpenFoam solver to compute the diffusion of a specified substance into the environment (Ronovský, 2017).

Users must fill in the submission form with a set of input parameters such as the area of interest (AOI) for the pollution simulation, epicenter for substance discharge, wind direction, wind speed, reference height, atmosphere class, and diffusion coefficient. AOE is used to query Geoserver instance so that the 3D model of a selected area could be generated. This 3D model together with the user-defined parameters is used as an input for the OpenFoam solver.

The result of the solver is calculated for a 3D model that describes the spread of the defined substance into the environment. The Floreon+ system currently does not support 3D visualization. Therefore, the result is visualized in 2D for the vertical cuts (in meters) and the time selected on the timeline of the map interface (see Figure 3). Changes to the distribution of a dangerous substance are visualized simply by changing the time on the timeline and by selecting the level of vertical cuts.

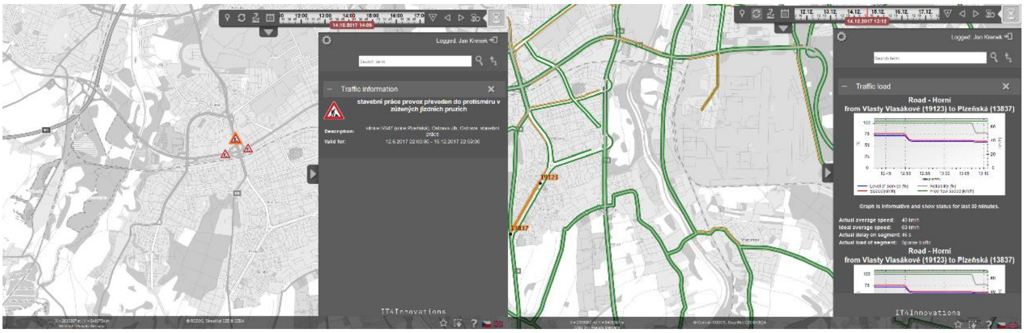

Figure 4. FCD and traffic information

Traffic Monitoring and Modelling

In the domain of traffic monitoring and modelling, the system displays current and historical traffic situations, snapshots from the cameras located on the main crossroads of the City of Ostrava and provides the routing algorithm for route planning on the map and simulates traffic flow for a selected area with traffic-based What-If analysis.

Traffic Information and Floating Car Data

The Floreon+ system is able to visualize actual or historical traffic constraints and floating car data (FCD). The data for segments of routes comes from RODOS[1] and data for Traffic Information from ŘSD[2]. The traffic constraints may be permanent (closure, other danger) or short term (accident, grass cutting). Floating car data is visualized as segments of streets in the map colored by actual or historical traffic load of these segments (see Figure 4). The segment can have one of these values: sparse traffic (Green), medium traffic (Orange), heavy traffic (Red).

Cameras

The user can select one or multiple cameras located at a crossroad and subsequently view the video stream from them in GUI of the Floreon+ system. Data from the cameras

[1] http://www.centrum-rodos.cz/

[2] https://www.rsd.cz/wps/portal/

are provided by OVANET provider. The users working with the Floreon+ system can visually verify constipation where cameras are located.

Traffic Routing

The system uses its own routing algorithm, which takes information about the start and end points of the route (collected from the map in GUI) and the route parameters (choose shortest or fastest route) as the input parameters. The result from the selected parameters is shown in GUI as a vector layer. Extension of the routing algorithm that combines the route planning while avoiding the flooded roads during extraordinary events (floods) is under preparation.

Traffic Modelling

For traffic modelling in the Floreon+ system, the custom implementation of betweenness centrality (BC) algorithm from Ulrik Brandes (Brandes, 2001) is used. It is an algorithm based on the shortest paths with our vertex importance extension (Hanzelka, 2018) in the background. Input for this algorithm is the graph of the traffic network and importance of each vertex. This importance consists of selecting two properties that increase betweenness on the shortest paths from or to selected vertices.

Using this simulation, the user can select an area of interest through the web GUI, in which they can define impassable areas and set the road priorities in the selected sub-areas by polygonal selection. This simulation can also be based on an already computed simulation, which allows for more detailed specification of these crisis conditions and can exclude or include an additional area and sets its importance coefficients. If a newly executed simulation is based on some older one, the system is also able to show comparison between the old and the new simulation.

The result of simulation is saved and then visualized as a new map layer where the selected area can be seen with the resulting edge (road) evaluation as thickness. Thicker edges mean bigger betweenness score, which represents increased traffic flow on these edges (see Figure 6).

Using this approach, the user can see how traffic flow changes when a road is closed by removing some vertices from the graph of traffic network in definition of simulation. Another example can be modifying vertex importance of an area. This can simulate, for example, when a music festival ends and everybody leaves that place.

Mobility of Population

The Floreon+ system allows users to show information about the population in the region divided to square grid and population flow among the districts. This functionality allows the user to monitor travelling between districts in the region and actual concentration of people in the parts of the region.

The data processed in the Floreon+ system is acquired from mobile operators in anonymous and aggregated form. Then, calculations based upon the number of network events in a given location (phone calls, SMS events) are running over the data. Finally, the calculation data is stored and subsequently visualized in the system.

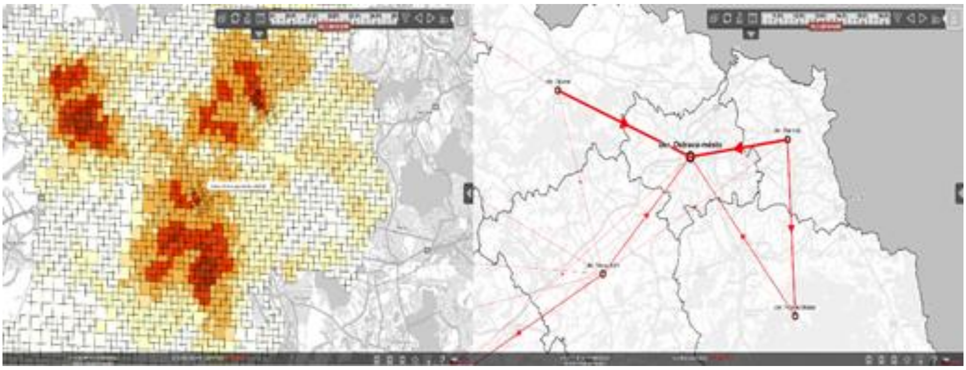

Figure 5. Mobility events and Mobility flow for the Moravian-Silesian region

Mobility Concentration

Population concentration is visualized as a raster network. Depending on the value of individual concentration at a given moment, the given segment is displayed in individual color scales for each value. The detailed view of the individual raster segment shows actual concentration and indicated total mobile events on the hovered segment. The system also lets you view the concentration history for the segment and visualize that data in the graph. As an example of the use of this functionality, we can see actual individual concentration of the population in the part of the Moravian-Silesian region in the left part of Figure 5.

Mobility Flow

This visualization shows in what direction and how many users are going from the given location to the destination location and from the destination location to the given location. The amount is represented by thickness of the individual site interconnections. As an example of mobility flow functionality, we can mention commuting to work in the morning among the districts in the Moravian-Silesian region in the right part of Figure 5.

DIFFERENT DOMAIN INTERACTION

One of the main advantages of the Floreon+ system lies in the ability to combine different thematic areas. Possibly the main interaction of two different thematic domains is a combination of traffic modelling and hydrology modelling. The system is able to monitor and predict a hydrological situation in the Moravian-Silesian region and traffic modelling is able to work with the excluded or important road segments.

Figure 6 shows how traffic flow changes due to a road closures caused by the flooding. Left image shows the default traffic model output, and the right image shows the removed flooded area with different flow of traffic. Figure 6 shows how traffic model was changed and simulates how traffic flow increased around the affected area.

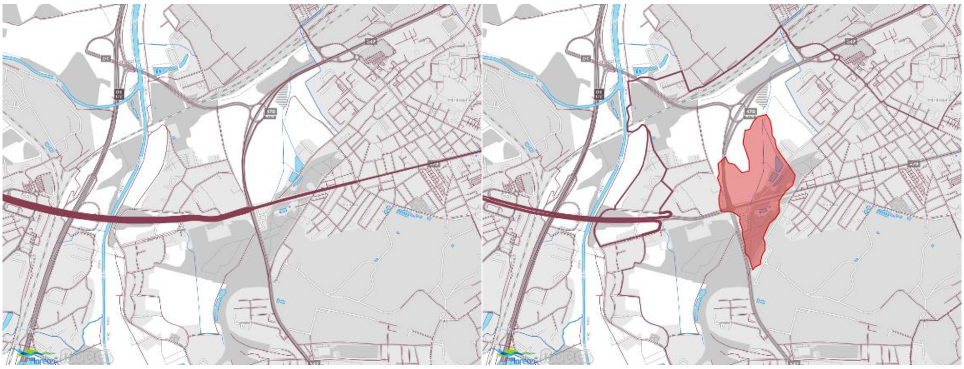

Figure 6. Traffic modelling around the affected area

Because the traffic modelling method is able to work with fairly universal excluded roads or prioritized roads, the interaction with the toxic cloud pollution or mobility of the population is also possible. These relevant areas (polluted parts of the city, closed roads during a concert, etc.) can be simply removed or changed in the graph of the traffic network that is used as input to traffic modelling analysis. The resulting analysis will show traffic flows for the original graph and for the graph with removed vertices. These two results can be then easily compared and, in the end, used for the route planning.

CONCLUSION AND FUTURE WORK

This article presented the Floreon+ system, a decision support system that integrates different thematic areas such as hydrological and traffic monitoring and modelling, toxic cloud pollution modelling, and mobility of the population. The system provides tools, analysis, and simulations from these thematic areas and aims to help the crisis staff in their decision making process during the critical events or to provide them with the possibility to simulate these situations beforehand.

It is important to mention that the system does not contain any decision making model, which would govern what should be done in case of some critical event. Throughout its results, the Floreon+ system provides additional information to the decision making process of crisis management staff or operational centers.

As the Floreon+ system is very extensive, this paper focuses mainly on the overview of the tools, methods and results in each thematic area that are available to the users of this system. From the data processing point of view, the system presents the current information about the hydrological, traffic and mobility situation. Moreover, it also offers the ability to execute user-defined on-demand simulations from these thematic areas that are utilizing the HPC infrastructure within the IT4Innovations National Supercomputing Center.

The future work will mainly focus on the fully automated process for the interaction of available thematic domains, thus enabling, for example, route planning based on the current hydrological, traffic, or mobility situation. The planned extension of the system involves new modules for flash floods and landslides.

ACKNOWLEDGEMENT

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