Systemic Aspects of Urban Area Emergency Response Information System Development

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Abstract
In the process of development of the Geographical Information Processing for Environmental Pollution-Related Security within Urban Scale Environments GEPSUS, the collective adaptive systems approach has been addressed in order to increase the efficiency and accuracy of the system. Theoretical considerations are provided as well as technical details of the implementation. Paper provides description of the prototype hardware system as well as software implementation. Results are provided which are used by the decision maker groups in the case of air-pollution accident.

Keywords: simulation, air pollution, decision support system, emergency

1 Introduction
Development of information system for urban area emergency response is complex task, which has been addressed in our previous research (Stojanović et al., 2012a, 2012b, 2012c; Škraba et al., 2012a, 2012b. Dragović et al., 2012. Popović et al., 2012) in the field of air pollution. In order to successfully control complex emergency situation the overall system structure has to be known with the main feedback loops identified. The hierarchical structure
has to be defined to allow modeling the considered processes and to allow the implementation of advanced anticipative control which contributes to the better response in the emergency situations. One of the possible new concepts which should be considered are collective adaptive systems which are one of the largest classes in nature: insect colonies, bird flocks, fish shoals, animal herds, human crowd, cars on streets, computers in internet, cellular phones, molecules in bio-synthetic systems and many other examples (Kernbach, 2009). All these domains are "collective systems": social, networked, swarm, collaborative, colloidal, nano and others, however all of them indicate the same essential property: elements provide "more" functionality when they are causally coupled. State of the art in the research of collective adaptive systems (Kernbach, 2009) includes bio-inspired and self-organizing branches, evolutionary and adaptive-control strategies, different software and hardware approaches. A roadmap of CAS structure can be found in (Kernbach et al., 2009).

2 System Approach
The aforementioned work, provide initial description of the collective adaptive systems concept which should be considered at the implementation of emergency response system. By adding the collective modelling ability M to the system structure the new concept of collective anticipation will provide better functioning of the system. Figure 1 shows the concept of collective adaptive systems applied to the example of air-pollution scenario. The goal of the system is to identify the conditions that allow minimal consequences to the urban area surrounding the new infrastructure.

Figure 1: Collective Adaptive System Framework
The system consists of two main branches marked with (A) and (B). The branch (A) represents the application of the simulation model for simulating air-pollution dispersion accident (e.g. resulting from air-pollution accident operations).

The simulation scenarios are typically provided by the decision group, by the population and by an expert group. An important aspect of GEPSUS is the possibility to engage, within the system, of all three groups that will be thus empowered by the Collective interactive system. It is important to note that the engaging collective intelligence introduced within the system provides better information flow and control of the system as a whole. As shown in Figure 1, the Population and Expert Group provide the information that determines the simulation model (Škraba et al., 2003, 2007).

Branch (B) of Figure 1 represents the control process of the real system. This is in our case the decision from the Decision group, based on the results of the simulation model as well as on the information coming from the Collective interaction system.

Within the branch (A) the results of the simulation model are passed to the decision group as well as to the Population and Expert Group. Here the comparison of the output of the real system with the output of the simulation system is performed to validate the scenarios as well as the model.

An important aspect is the anticipative loop that will provide information for improved decision-making process.

### 3 Air pollution modelling

The dispersion modeling is performed in MATLAB (2013) starting from generalized Gaussian plume equation (Chitumalla et al., 2008, ,Stojanović et al., 2012a, 2012b, 2012c):

\[
C(x,y,z) = \frac{Q}{2\pi WHyH_z} e^{-\frac{y^2}{2\sigma_y^2}} \left( e^{-\frac{(x-H)^2}{2\sigma_x^2}} + e^{-\frac{(x+H)^2}{2\sigma_x^2}} \right) + \Sigma T
\]

(1)

\[
ST = \sum_{n=1}^{k} e^{-\frac{(z-H-2nz_j)^2}{2\sigma_z^2}} + e^{-\frac{(z+H+2nz_j)^2}{2\alpha_z^2}} + e^{-\frac{(z-H-2nz_j)^2}{2\alpha_z^2}} + e^{-\frac{(z+H+2nz_j)^2}{2\alpha_z^2}}
\]

(2)

in which the concentration of pollutant \(C(x,y,z)[g/m^3]\) in point \(x[m],y[m],z[m]\) depends on mass emission rate \(Q[g/s]\), wind speed \(u[m/s]\), dispersion coefficients \(\sigma_x[m], \sigma_y[m], \alpha_z[m]\) and effective stack height \(H[m]\), which is a sum of actual stack height \(h_[m]\) and plume rise \(\Delta h[m]\), \(H=h_s+\Delta h\). The \(ST\) is a summation term related to the inversion from mixing height \(Z_i\), while \(k\) is a summation limit for multiple reflection, usually \(\leq 4\). More detailed description could be found in Stojanović et al., 2012a, 2012b, 2012c. Important implementation which should be mentioned is well known ALOHA, which is used as the reference point for the new
development (ALOHA 2007). Recent developments in this area include fluid models of dispersion in urban area.

4 Technical Development
Several system should be integrated in order to provide the GEPSUS system functionality. Figure 2 shows GEPSUS chemo-meteo station in running, up-left. Station in urban zone near critical object, petrol station, shown up-right, sends data by wireless link to receiver conected to the laptop. At the bottom of the Figure 2, simulation of air pollution disperssion in real-time, for two wind speed and direction is shown. Here the GIS is used in order to provide geospatial awareness of the decision group and public. Safe route algorithms have been developed in order to determine safe route in the road network. The crucial results for the decision makers is notable; the road that intersect RED zone is detected and marked. This is the area which should be avoided by the traffic due to the fatal level of air-pollution concentrations. Critical road information is one example of the information which is provided to the decision makers and the public.

![Figure 2: Technical details of the GEPSUS system implementation; meteo-station subsystem](image)

Figure 3 shows the detail of the anemometer which is shown in the Figure 2 and provides the main input to the system. This mobile unit should be positioned in the exposed area in order to gain valid data on the site. Important aspect is wireless transmission of the data and provision of the data to the GEPSUS system.
Figure 3: Anemometer detail

In order to provide the input from the collective information system as proposed in Figure 1 the mobile application has been developed. Figure 4 shows the tripod with anemometer attached with the wireless transmitter which provides the input from the environment. However in order to provide the information to the wide public the mobile application has to be developed. In our case, on the right of the Figure 4 the mobile application for the Android has been develop providing near real-time data to the population as well as experts.

Figure 4: Tripod with anemometer (left), Android application (right)

5 Results

Results of the developed subsystem provide the information about the pollution concentrations in hypothetical air-pollution accident area. Figure 5 a), b) and c) shows results
of several different simulations based on three different atmospheric conditions. It has to be noted, that the input to the simulation model is near real-time which provides high accuracy. In our previous research (Stojanović et al., 2012a, 2012b, 2012c; Škraba et al., 2012a, 2012b), the coupling with the meteorological data has been described which provide means for the prognosis on a larger time scale. The results are passed to the GIS, which provides geospatial orientation for the expert group and public. One has to note, that the air-pollution accidents are rapid in response and dependent on the atmospheric conditions which are by its nature nonlinear i.e. chaotic. The “kml” file format is used as an interface between MATLAB and GIS. It is an open standard officially named the OpenGIS RKML Encoding Standard (OGC KML) and is maintained by the Open Geospatial Consortium, Inc. (OGC). In addition the kml format can be read by a majority of GIS browsers.

Figure 5: Example of system results according to the input from the hardware and developed simulation model.
6 Conclusion
Proposed systemic approach considered important aspect of collective adaptive systems which are crucial for the GEPUSUS system applicability. One has to provide input to the system from the public, expert groups and decision makers as well as the input to all three mentioned groups. There are several technical challenges in order to realize such system from mobile sensing equipment, simulation to mobile applications. Presented work addresses only one aspect of Geographical Information Processing for Environmental Pollution-Related Security within Urban Scale Environments. Further research will address fluid dynamics in air pollution spread as well as mobile UAV sensing devices.

Acknowledgement
This research is sponsored by: NATO's Public Diplomacy Division in the framework of “Science for Peace” project GEPSUS SfP 983510.

Literature

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