The Reality Check: Evacuation Planning done by Mixed Reality and Simulation

Daniëlle Keus
Edwin van Veldhoven
TNO
P.O. Box 96864
2509 JG The Hague
The Netherlands
+31-88-8661098, +31-88-8663912
danielle.keus@tno.nl, edwin.vanveldhoven@tno.nl

Fanny van Heemskerck Pillis
Arcadis
Lichtenauerlaan 100
3062 MA Rotterdam
The Netherlands
+31-10-2532184
fanny.vanheemskerckpillis@arcadis.nl

Thijs van den Brink
Jennie van Laar
Bridgis B.V.
Sint Walburgkerkpad 3
4001 MG Tiel
The Netherlands
+31-344-636242
t.vandenbrink@bridgis.nl, j.vanlaar@bridgis.nl

ABSTRACT: *Severe natural or man-made disasters that occur in urban areas often require evacuation measures to protect or rescue the population. In crisis situations, different kinds of knowledge are necessary to get insight in the consequences of the proposed set of measures. In addition, there are typically many different parties involved in the decision making process. These decision makers can be supported by simulation models that assist in assessing and predicting the emergency situation and assist in the development of effective evacuation plans. There are currently many existing (simulation) models available for evacuation planning. However, the population data which is an important input parameter for the models, usually consists of generic or even fictive information.*

The mixed reality project "Reality Check", which is part of the Dutch research program "Flood Control 2015", aims to feed more reliable data into an evacuation model. This input data can be either static data, for example extracted from population registers, or dynamic real-time data. Both types of data improve the situational awareness of the decision makers dealing with a calamity and provide them with better simulation results to assess their options.

The "Reality Check" tool combines several population databases, a road database and a scientific evacuation model. The tool has been realized using the MiReCol architecture (Mixed Reality for Collaboration). MiReCol enables the integration of scenarios, protocols, (scientific) models and data sources, in order to provide decision makers with real-time output from predicting models during crisis situations. In the MiReCol architecture, all components are linked through a network data bus, and web services are used to exchange information between data sources, evacuation models, and assessment or presentation tools. The "Reality Check" tool makes the knowledge and information from different sources and models available to all involved participants.

This paper will present the design and development of the "Reality Check" tool and discuss our initial results.

1. Introduction

Severe natural or man-made disasters that occur in urban areas often require evacuation measures to protect or rescue the population. In crisis situations, different kinds of knowledge are necessary to get insight in the consequences of the proposed set of measures. In addition, there are typically many different parties involved in the decision making process.

In such situations, crisis managers have to make decisions like: *do we evacuate or not*; *how many and what kind of people are in the threatened district*; *how long does it take before everybody has left this area*; *what do unexpected traffic blockades and delays mean for the evacuation time line and evacuation strategies?*

These are some of the most important questions that operational decision makers have to answer when faced with the dilemmas regarding evacuation. The questions have one common element: they all cover the primary objective of operational decision makers during crises: the safety of the population in a threatened or affected area.

The decision makers can be supported by decision support systems that assist in assessing and predicting the emergency situation and assist in the development of effective evacuation plans. There are currently many existing decision support systems available for evacuation planning.

Interestingly enough, up till now the population data that was fed into these decision support systems, has been static. The data used does not allow for fluctuations in population density at different times of day and during the week. The results provided by current decision support systems therefore have a very high level of uncertainty. In practice, operational decision makers are aware that the results thus generated are “unreliable” and for this very reason they tend to ignore these systems during actual crisis situations.

The remainder of this paper is organized as follows. Section 2 introduces our new solution, the Reality Check. Section 3 and Section 4 explains the architecture of the tool and the used MiReCol framework. Section 5 and Section 6 present two components of the Reality Check, the evacuation model and the Bridgis data source, in more detail. Finally, Section 7 presents our conclusions.

2. The Reality Check

The purpose of the Reality Check is to demonstrate the increase of the situational awareness of decision makers with the use of different and more data sources for an evacuation model. The visualization of these different data sources in combination with the model gives more insight for the decision makers. The Reality Check project aims to feed more reliable data into an evacuation model.

The input data can be either static data, for example extracted from population registers, or dynamic real-time data. Both types of data improve the situational awareness of the decision makers dealing with a calamity and provide them with better simulation results to assess their options.

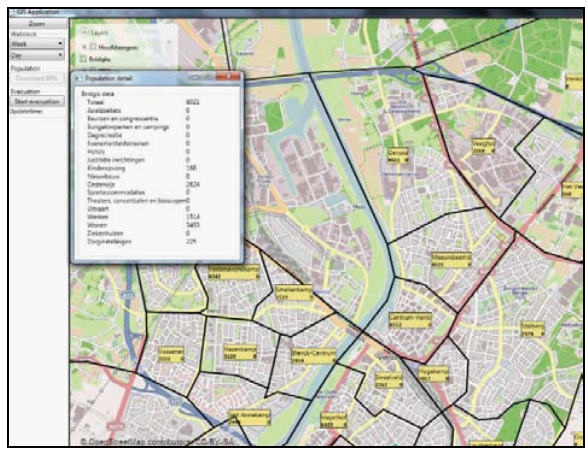

Figure 2.1: Screen shot of the Reality Check tool

Because the purpose of the Reality Check is operational use, the calculation time of the model has to be as short as possible. During a disaster the fidelity is not an issue but the situational awareness and a short interaction time. Most evacuation models have a long calculation time. The Reality Check is a combination of different data sources and an evacuation model. The combination of different sources and the evacuation simulation is tuned to the usage by the crisis managers in crisis situations. This resulted in an evacuation simulation with a short calculation time and as a consequence a low fidelity level.

The Reality Check is a part of a group of models which are part of the MiReCol project. The purpose of MiReCol (Mixed Reality for Collaboration) is to build models for safety and urban strategy. The models use different components of safety and urban models. These components can interact with each other.

During the development of the Reality Check tool, we have asked operational decision makers and information managers of national and regional crisis coordination centers how they would use the Reality Check:

- In the first stages of a crisis, they would use the tool to get a) a more accurate and realistic picture of the population density in a threatened area and b) a first impression of the level of self sufficiency of the population there.
- They would then feed the population data into an evacuation model to explore which evacuation strategies are feasible, given the circumstances (such as content of the threat, area affected, weather circumstances, road capacity, and capacity of the emergency services). Depending on the outcome of this exploration, they would then decide on one or several evacuation strategies combined.
- They would then use the Reality Check to monitor the evacuation process and, in case of unforeseen developments, feed the "new" data into the evacuation to explore the necessity of adapting the evacuation strategies used.

3. Architecture of the Reality Check

The Reality Check tool combines a number of data sources (OpenStreetMap, Statistics Netherlands, Bridgis Populator®) and an evacuation simulation model (EVA). To make this combination possible, the MiReCol IMB bus is used. The IMB bus enables the communication between the different sources and models using messages as simple as possible.

We will briefly describe these data sources and the evacuation model. The Bridgis Populator® is also discussed in more detail later in this paper.

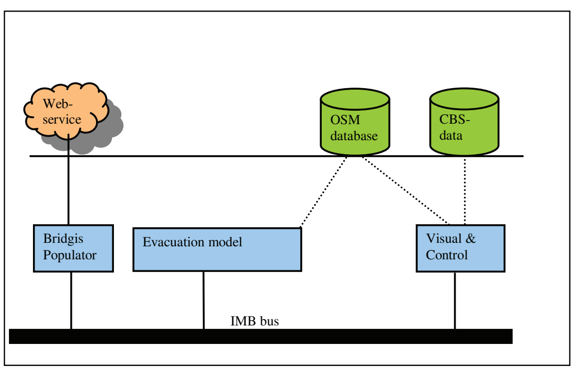

Figure 3.1: The architecture of the Reality Check

3.1 OpenStreetMap

OpenStreetMap (OSM, [1]) is a project aimed at a creating a freely available and freely editable map of the world. Since 2004, information on streets, rivers, borders and areas is collected worldwide, and stored in a freely accessible database. Adding and editing this information is fully done by volunteers. The OpenStreetMap data is licensed under the Creative Commons Attribution-ShareAlike license ([2]), which means that everyone is allowed to use the information, provided that OpenStreetMap and its contributors are credited. The Reality Check tool uses both the generated maps (for visualization), and the raw data (for the simulation and visualization of the evacuation).

3.2 Statistics Netherlands

Statistics Netherlands (in Dutch: Centraal Bureau voor de Statistiek, CBS) is "responsible for collecting and processing data in order to publish statistics to be used in practice, by policymakers and for scientific research" [3]. For the Reality Check tool, Statistics Netherlands provides the static data about the neighborhoods which make up Dutch cities, and the population in these neighborhoods.

3.3 Bridgis Populator®

The Bridgis Populator® calculates how many people are potentially present on average in a certain area (in the Netherlands) at a certain moment (working day/weekend day, day/night). It is a digital service that integrates data sources from different Dutch organizations. For a certain geographical area, the Populator® returns the population data of that area, divided into 17 categories, such as living, working, education, and day care.

3.4 EVA

The evacuation simulation model EVA is a mathematical model which was developed at TNO as a prototype. The goal of EVA was to gain insight in the entire process of an evacuation. The model is restricted to an evacuation of people by cars. For the Reality Check tool, we made an implementation of EVA in MATLAB® [4], which is a software environment for mathematical applications.

4. MiReCol Architecture

The Reality Check has been realized within the MiReCol framework. The kernel of the framework is formed by the IMB bus, which has been developed by TNO. This bus uses a distributed approach which has been based on ideas from the HLA (High Level Architecture) standard for distributed computer simulation systems. The IMB bus uses TCP/IP and has been developed as a robust and as simple as possible interface between models and data sources. It uses a client/server communication structure with a central “broker” (server) in which the models and their interfaces are the clients.

The IMB bus supports a publish/subscribe services and, like in HLA, clients can subscribe to a “federation”. Only within the same federation, clients can communicate directly to each other. Timing has to be done by the models themselves. Because the Reality Check tool only uses one simulation model and a lot of data sources, the timing is not an issue for the Reality Check.

Currently, the IMB bus has interfaces for the following programming languages: Microsoft Visual C++, Microsoft Visual Basic, Java, Borland Delphi, and Fortran.

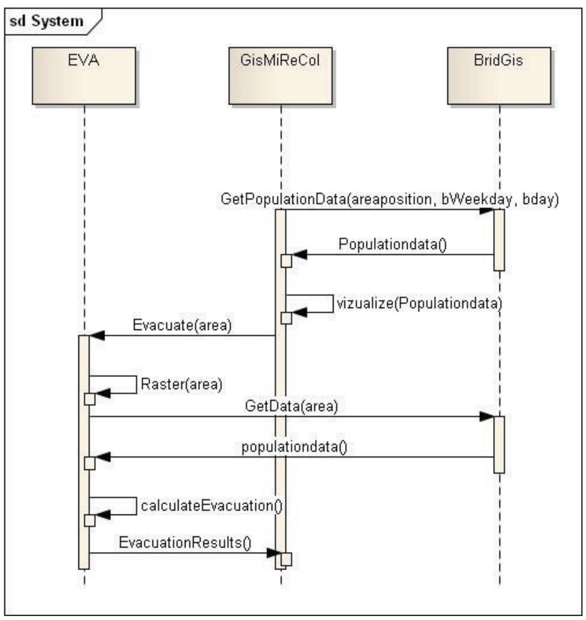

Figure 4.1: Sequence diagram for retrieving and exchanging data

Using the MiReCol framework, the Reality Check tool retrieves the OpenStreetMap and Populator® data from the internet. A cache mechanism is used to store the downloaded data, in order to prevent superfluously downloading the same data twice and to allow the use of the application even if the internet connection fails or is unavailable. The data from Statistics Netherlands (the neighborhood boundaries) is stored in a local database.

When a user selects an area in which an evacuation must be planned, the following data is retrieved:

- from the Statistics Netherlands database: the geographical boundaries of the neighborhoods;
- from the Bridgis Populator®: population data per neighborhood, for four periods (working day/weekend day, day/night);
- from OpenStreetMap: the road system and rendered map data of the area.

Based on this information, the user can quickly get an impression of the number of people to be evacuated. After selecting the neighborhoods to evacuate, defining exit points, and placing possible road blocks, the evacuation can be simulated by EVA.

5. Evacuation Model EVA

The input of EVA consists of the road system of the area to evacuate, the number of people present round these roads, the exits along which the people can leave the area, road blocks, and a departure time curve (specifying the percentage of people leaving over time).

EVA only requires the road system within the evacuation area. Therefore, only road segments that have at least one end point within the evacuation area are fed into the evacuation model. Road segment data includes information like the number of lanes and the maximum speed. The population data is downloaded from the Populator® for small areas (either zip code areas, or squares in a fixed grid), and spread among the road segments within these small areas. The departure time curve is currently fixed.

EVA calculates with flows of cars per hour. It determines, per time step, the inflow and outflow of cars for each crossing and road segment. Traffic jam queues, which occur when too many cars are on a road segment simultaneously, are taken into account by the model. During the simulation of an evacuation, EVA reports the number of people still present in the area, the number of people that have left the area via the exits, and the degree of the flow of traffic. This information is visualized in the user interface of Reality Check, allowing the user to see how fast the evacuation takes place and where traffic jams occur.

6. The Bridgis Populator®

The Bridgis Populator® calculates how many people are potentially present in any given area. It is a very useful tool for calculations related to security matters by showing the maximum capacity of buildings. It also offers information on the number of people potentially present in 4 timeframes: week day, week night, weekend day and weekend night. Besides a total number for a given area, it allows for differentiation in population types. These population types are further divided by type of location: structural or temporary.

Each type has its own data layer ensuring maximum flexibility in use and maintenance. Through linking with address coordinates and constructible areas the data are stored with a high level of accuracy on a by building basis.

There are 17 population types in the Populator®. The structural locations, where people dwell according to habitual patterns, are the following:

- residential;
- workplace;
- education;
- child care;
- judicial institutions;
- centers for asylum seekers;
- care institutions;
- hospitals;
- bungalow parks and campgrounds;
- hotels;
- new housing estates.

The temporary locations, where people dwell in irregular patterns, are:

- funeral homes;
- daytime recreation;
- theaters, concert halls, cinemas;
- convention centers and conference centers;
- large event sites;
- sports facilities.

The Populator® combines the data sources from (local) governments and renowned organizations and institutions. The various data files are collected and set up throughout the year. Subsequently, population data are registered in the Populator® database and maintained annually.

The statistic data of the Populator® is created from sixteen different data sources. The Populator® is based on research performed by Bridgis in 2005, with subsidies from the Dutch RGI innovation programme ([5]). The research was supported by a committee with representatives from the Netherlands National Institute for Public Health and the Environment (RIVM), the Ministry of Housing, the Spatial Planning and the Environment (VROM), the Directorate General for Public Works and Water Management (Rijkswaterstaat), the Netherlands Environmental Assessment Agency (MNP), and the Utrecht Country Region Firefighters (BRUL).

The Populator® can be accessed in several ways:

- through the generic web interface ([6]);
- through customized applications;
- through a web service, directly accessible in applications.

6.1 How does it work?

The Reality Check uses a web service to access the Populator®. This web service is SOAP compliant and calculates population numbers for a single area. This area is specified by means of a WKT (Well-Known Text) string. All specified areas are combined; the analysis is performed on the resulting area. It is also possible to define an area based on a radius around a particular address. The service is based on data relating to points. Only points within the area of calculation are included in the analysis.

The Bridgis web service ([7]) offers a number of functions. These functions provide options to retrieve information about a specified administrative area, a list with available activities/population types, or a list with available types of analysis (offering the choice of maximum population or population corrected by a computation rule). Also a population count for a combination of analysis and activities in a radius of address can be requested.

6.2 Future developments

One future development for the Populator® is the option to include real-time information. Currently, the Populator® only uses a static database that registers the maximum number of people per location. The structural locations can be differentiated by four timeframes, which is a considerable step forward. However, we aim for a higher level of accuracy. In case of a catastrophe, only actual numbers are relevant: is the stadium actually in use at that moment in time or not? Or is everybody caught in a traffic jam on the way, or are they returning home?

In the next version, Bridgis would like to include real-time traffic information and a real-time event calendar. Another option is including real-time mobile telephony data or real-time Bluetooth data.

7. Conclusion

The Reality Check project makes smart combinations between existing simulation tools and data sources. These combinations increase the situational awareness of the decision makers. The number of data sources with population information will increase in the future. The challenge is to match the right sources with simulation models at the corresponding fidelity level. Reducing the fidelity level of the tools can be an option to meet operational response times.

In the future, operators could use the Reality Check to monitor if and how many people are left behind in the evacuated area after an evacuation. In a non-crisis situation, crisis managers can use the Reality Check to develop adapting evacuation strategies to the behavior of the population during a crisis.

8. References

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