GIS and Cartographic Visualization for Crisis Management, general approaches and practical examples

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1. Crises management
2. Adaptive visualization
3. Conceptual background
5. Metainformation
6. Contextual map service
7. Pilot scenario
8. Conclusion
1. CRÍSES MANAGEMENT
Objectives

- Project
  - deals with transfer of geoinformation towards crises management users
  - geoinformation, cartography, and psychological aspects
  - individualization of cartographic representation
  - research project
CRISES MANAGEMENT

• Complex of activities focusing on
  – analysis and evaluation of safety risks
  – planning, organising, realisation and control of activities related to the crises situation.

• Complex task
  – It deals with people, material, financial and other resources.
  – There exists many possible solutions to lower the risk/the crises stage/its consequences and to recovery
  – It necessitate the huge amount of various information that must be accessible on the right place in the right time to support decision making of both, the crises authorities and units of integrated rescue system. Geoinformation are essential.
Crises management and cartography support

• State-of-the-Art
  – used static digital sources (or analogous maps)
  – no interconnection of databases (disabled spatial analysis)
  – no real time cartographic (geographic) support
  – insufficient map legibility
  – existing maps are thematically oriented
Project motivation

- variety of emergency **SITUATION** (leak of dang. substance, earthquake...)
  - Different relevancy of data
- different **ACTIVITIES** (organizing intervention, resourcing...)
  - Different roles of geoobjects
- variety of **CM ACTORS** (fire brigades, army, mayor of the municipality...)
  - Need of data sharing
- variety of **USERS** (different age, ability of map use...)
  - Need of alternative visualization methods
- various **TECHNOLOGY** (screen size...)
- various **CONDITION** (weather, light...)
Project aim

• crises management decision-making - cartographic support in all stages of the disaster
• effective cooperation enablement
• work over unique database
• reduction of the time for interpretation
• improvement in map legibility
• data relevancy assessment
2.

ADAPTIVE VISUALIZATION
Adaptive visualization

• originally in information technology - „context-aware computing“ (Weiser, Dey and Abowd, Schillit)

• 2000s: introduction to cartography (e.g. T. Reichenbacher)
Adaptive visualization

**Basic principles**

- method of representation of displayed objects and/or phenomena is selected (and/or modified) according to context

- **Context** = sum of all information that can be used to describe circumstances under which the visualization is used
Adaptive visualization

MAP
symbolics
resolution
contents
cartographic method

ACTION
spatial extent
task
feature relevance

TECHNOLOGY
display size
transfer rate
interactivity

SITUATION
location
time
orientation
environment

USER
education
knowledge and skills
cultural background
preferences
3. CONCEPTUAL BACKGROUND
Map as decision making tool

Ontology of data manager

Ontology of crises manager
Example: one object – more roles

Source information:

Database: education
Entity: **school**
Attributes: type
  no. classes
  no. pupils
  no. staff
  ……

**Context 1: preparation for flood situation**
Endangered object: people with special protection
No. of affected people

**Context 2: evacuation during factory damage**
Emergency accommodation
capacity

**Context 3: navigation to place of intervention**
Orientation POI
• **Data content**
  – Question of relevancy – What information is necessary for decision?

• **Symbology**
  – Symbol must reflect the role of spatial phenomena in decision making process

• **Generalization**
  – Amount of information on map
Is spatial object/phenomena relevant for the application?
Symbol adaptation

• **Intensity of emphasising** (symbol size, colouring) depends on the degree of relevancy
  • more important → more highlighted

• SPATIAL IMPORTANCE
• SEMANTICAL IMPORTANCE
• TEMPORAL DYNAMICS
Spatial importance

• houses **vs.** expected flood extent

![Diagram showing houses inside, close to, and out of the expected flood extent.]

• moving vehicle **vs.** critical infrastructure (CI)

![Diagram showing a moving vehicle close to and out of the critical infrastructure area.]
Semantical importance

• Categorization relevant to application
Temporal dynamics

⇒ STATUS OF OBJECT

**Disaster dynamics** - change of the object status due to disaster

small water-power-station ➔ endangered ➔ destroyed

**Task dynamics** - change of the object status due to progress in task

house ➔ to be evacuated ➔ evacuation in process ➔ finished evacuation
Temporal dynamics of object
- Main colour schema

• functional
• endangered
• destroyed
• in action
• repaired
Example: BRIDGE – symbol syntax

BRIDGE

functionality
endangered
destroyed
action (repairs underway)

BASETOPO
(topographic database)

flow area under the bridge
blocked
action (block is being removed)

bridge is endangered, flow area is blocked
Example: COLOUR SCHEMA APPLIED ON ROAD SYMBOLS

<table>
<thead>
<tr>
<th>Category</th>
<th>HIGHWAY</th>
<th>ENDANGERED</th>
<th>DESTROYED</th>
<th>ACTION (REPAIRS ARE UNDERWAY)</th>
<th>REPAIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>From BASETOPO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROAD, 1st class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROAD, 2nd and 3rd class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROAD, other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAILWAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRAM, TRACK ...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TUNNEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Context map sample
Generalization

- **simplification** of the geometric model – thematic entities represented by point
- **aggregation** of the point symbols into representative
- **taxonomy-based reduction** of line entities
- areal entities **collapse** to point
4.

CONTEXT IN CRISES MANAGEMENT – CONCEPTUAL FRAMEWORK
Context

• set of factors that influence **legibility and usability** of the map
• What factors influence it the most?

  – **WHO** (identity context),
  – **HOW** (function context),
  – **WHAT- WHEN- WHERE** (emergency context)
• “Who will use the map? Who is responsible for what?”
• Influence:
  – Visualization method
    (a-different educat. background, b-diff. eyesight)
  – Authorization rights
    (which data are administered by the user)
• User groups: e.g. POLICE, FIRE RES.SERVICE, WATERCOURSE MANAGER, FLOOD AUTHORITY OF THE MUNICIPALITY...
“How the map will be used? What is the function of the map in the decision making process?“

Functions:

- **INFO** - to know “what is where”
- **CONTROL** - to update status of spatial objects (e.g. bridge is destroyed, road is closed)
- **ORGANIZE** - to create new object (e.g. place where intervention is necessary, place of ice blockage)

Influence GUI
Emergency core context

- **What?** – EVENT + ACTIVITY
- **When?** – STAGE
- **(Where?)** – OPERATIONAL RANGE

- refers to the issue of data content
- Influence cartography model
### Activity + Event

- **WHAT?**
  - What activity within which event should be supported with the map? What needs to be done?
  - GENERAL (in colour) vs. EVENT-SPECIFIC ACTIVITY

<table>
<thead>
<tr>
<th>events:</th>
<th>FLOOD</th>
<th>TRANSPORT</th>
<th>FOREST FIRE</th>
<th>RADIATION ACCIDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>activities:</td>
<td>ORGANIZATION</td>
<td>ORGANIZATION</td>
<td>ORGANIZATION</td>
<td>ORGANIZATION</td>
</tr>
<tr>
<td></td>
<td>RESCUE</td>
<td>PERIMETER</td>
<td>PERIMETER</td>
<td>PERIMETER</td>
</tr>
<tr>
<td></td>
<td>PREDICTION</td>
<td>MONITOR</td>
<td>.....</td>
<td>RESCUE</td>
</tr>
<tr>
<td></td>
<td>TECHN. SUPPORT</td>
<td>.....</td>
<td>.....</td>
<td>.....</td>
</tr>
</tbody>
</table>

- **Influences**
  - what information will be on map
    - amount of information presented on map is minimised to level of task being solved
Example: ACTIVITIES within EVENT

Flood and Transport

**Flood**

- **PREDICTION AND PROGRESS** - development and expected progress of the flood
- **TECHNICAL SUPPORT** – technical support in inundation area – support of Flood Security Activities
- **RESCUE** – evacuation of the citizens
- **ORGANIZATION** – organization of power and means
- **PUBLIC INFORMATION** – information for public about flood development, evacuation etc.

**Transport**

- **MONITOR** – monitoring of the vehicle with dangerous substance
- **PERIMETR** – organization in the place of the incident
- **ORGANIZATION** – organization of power and means
• **WHEN?**

• In what phase of the emergency event the activity is realised?
  
  – *prevention* (e.g. out of the flood)
  
  – *preparation* (e.g. shortly before the flood/before the potential vehicle accident)
  
  – *response* (e.g. during the flood, just after the vehicle accident)
  
  – *recovery* (after the flood)
Example: ACTIVITIES in different STAGES of FLOOD

activity:
- PREDICTION and PROGRESS
- TECHNICAL SUPPORT
- RESCUE
- ORGANIZATION
- INFORMATION

- RECOVERY: tech. reconstruction, reevacuation, org. recovery
- PREVENTION & MITIGATION: info. recovery, info. prevention, tech. prevention
- RESPONSE: info. response, org. response, evacuation response, tech. response, progress
- PREPARATION: tech. alarm, prediction, org. preparation, evacuation prep., info. prepar.
• **WHERE?**

• Where the event takes place? What is the event extent? What is the activity extent?

• Influences:
  – Amount of information portrayed on the map
    • According to the Level Of Detail – method of generalization
    • According to the Character of the Region (URBAN, SUBURBAN, RURAL) – lower importance of certain spatial objects in „information-dense“ regions, higher in „information-diluted“ regions
Operational range - definition

1. DETAIL – 0-5k
2. LOCAL – 5k-10k
3. MUNICIPALITY – 10k-50k
4. DISTRICT – 50k-200k
5. REGION/CATCHMENT – 200k-1M

- LOD’s 3, 4 and 5 is defined to capture appropriate administrative/natural unit on screen
Context composition – conceptual framework

**EMERGENCY CONTEXT**

- **What.....?**...needs to be done
- **When/in which phase.....?**...the activity is realised
- **Where.....?**
  - ...the event occurred
  - ...What is the extent.....?
  - ...of the activity

**IDENTITY CONTEXT**

- **Who.....?**
  - ...uses the map
  - ...is responsible for the activity
  - ...administers spatial data

**FUNCTIONAL CONTEXT**

- **How/what.....?**
  - ...will be the map used
  - ...is the function of the map in the decision process

**CONTEXT MAP**

- **central database**
  - **map symbol library**
  - **GUI**

- **selection of relevant spatial objects**
  - **in proper LOD**

- **symbolization according to the role of the spatial object**

- **setting of authorization rights**

- **selection of alternative visualization**

- **selection of GUI**
• *Cartography model* is defined for each emergency core context and the operational range in which the activity is typically done + one lower and higher LOD.

![Cartography Model Diagram]

(activity:)

- ORGANIZATION
  - MUNICIPALITY - 10k-50k
  - DISTRICT - 50k-200k (typical operational range)
  - REGION - 200k-1M

(operational range:)

+ -
Data content

• **Background data:**
  1. BaseTopo - Topographic Data and Other Background Data (Fundamental Base of Geographic Data 1:10k, Ortofoto, Cadastral mapping, Digital Terrain Model, Admin. boundaries)

• **Thematic data:**
  2. UniversalCrises – (Critical Infrastructure, Technical Infrastructure, Social Infrastructure, Environment)
  3. SpecificCrises – (Flood - Flood Zone Mapping, Flood Management Plan, Flood Modelling, Transport - Senzor data)
5.

META INFORMATION
• 23 institutions analyzed
  – 9 national (ČÚZK, AČR, CENIA, GŘ HZS, IOO, SÚJB, MŽP, MV, MZe)
  – 14 regional

• Used methods
  – Moderated questionnaire with the head of Crisis Management department and GIS/IT specialist
  – Accomplished with available information
Metadata in CM&EW institutions

- MICKA: 50%
- METIS: 15%
- MIDAS: 15%
- ARCCATALOG: 5%
- EMOF: 5%
- EXCEL: 5%
- ŽÁDNÝ

- ISO: 49%
- FGDC: 9%
- DC: 9%
- ISVS: 9%
- PROPRIETÁRNÍ: 5%
- ŽÁDNÝ: 5%
6.

CONTEXTUAL MAP SERVICE
Task workflow

Contextual map service

DYNAMIC VISUALIZATION

CARTOGRAPHIC INFRASTRUCTURE

CARTOGRAPHIC MODELS

DATA SOURCES

Symbols
Colours
Generalization

Semantic description
Selected tasks and methodology

general – thesaurus CM

Evaluated, description – metadata, usability, harmonization, generalization

Evaluation, description – metadata, usability, harmonization, generalization

Methodology of analytical tasks

Cognitive localization
Cognitive and perceptual processes

real-time models
sensors
Public admin.
Web service
existing
Traditional Approach to Web Cartographic Visualisation

WMS Client

WMS Servers

Description of a map

CONTENT = cars, buildings, gas stations, ...

SYMBOLOGY = default, blue, danger, ...

...
Contextual Approach to Web Cartographic Visualisation

Map Client

Map Server

Description of a context

SITUATION = Leak of flammable liquid
ROLE = Firebrigade operator
DISPLAY DEVICE = Color LCD 22"

...
Contextual Map Service (CWMS)

- Enables contextual cartographic visualization in web environment

- Extension of Web Map Service (WMS)
  - Additional request GetElementaryContextTypes
  - Additional context parameters in GetCapabilities request
  - Conceptual change of GetCapabilities response
Communication with CWMS

1.

Client

Get Elementary Context Types

CWMS

```
<ElementaryContextTypes>
  <Type name="role" title="Role">
    <Context name="fireman" title = "Fireman" />
    <Context name="policeman" title = "Policeman" />
    <Context name="ambulance" title = "Ambulance" />
  </Type>
  <Type name="situation" title="Situation">
    <Context name="fire" title="Fire" />
    <Context name="flood" title="Flood" />
  </Type>
</ElementaryContextTypes>
```
Communication with CWMS

1. Get Elementary Context Types

2. Get Capabilities + User’s Context

3. ...

Client

CWMS
**Sissi – implementation of CWMS**

**Description of a context**

- **SITUATION** = Leak of flammable liquid
- **ROLE** = Firebrigade operator
- **DISPLAY DEVICE** = Color LCD 22”

**Description of a map**

- **CONTENT** = cars, buildings, gas stations, ...
- **SYMBOLOGY** = default, blue, danger, ...

**Diagram**

- **Map Client**
- **Sissi CWMS**
- **WMS Servers**
Contextual map in CWMS client

Contextual map in OpenJump
7.

PILOT SCENARIO
Architecture of HAZMAT monitoring system

- Database
- Mapping server
- Intervention commander
- Commander at headquarters
How to achieve two-way communication?

- OGC specification WMS – Web Map Service (JPEG/GIF/PNG)
- OGC specification WFS – Web Feature Service
  - uses GML (Geography Markup Language) – based on XML
  - Specifies how to get or query features (i.e. to obtain real vector data)
How to achieve two-way communication?

- OGC specification WMS – Web Map Service (JPEG/GIF/PNG)
- OGC specification WFS – Web Feature Service
  - uses GML (Geography Markup Language) – based on XML
  - Specifies how to get or query features (i.e. to obtain real vector data)
- WFS-T (Transactional) – adds data manipulation operations
How to achieve two-way communication?

- WFS-T (Transactional) – adds data manipulation operations with the ability to:
  - create a feature instance
  - delete a feature instance
  - update a feature instance
Editing WFS-T map client
Editing WFS-T map client – new GUI
WFS-T conclusions

• All HW and SW components worked properly
• Positional differences in data corrected on server-side
• Extended for authorization database
• Process model (also in UML) improved
Field test pictures
8.

CONCLUSION