ADAPTIVE MAP VISUALIZATION: FROM CONTEXT SELECTION TO WEB SERVICE CONFIGURATION

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Abstract
The paper presents advantages of contextual cartography (or adaptive cartography) for the Digital Earth vision. Theoretical background connecting Digital Earth and contextual cartographic visualization is followed by practical example from an environment where the time is crucial: Crisis management. The example includes configuration process of Contextual Web Map Service (CWMS) called Sissi that was developed for providing map adaptation in web environment. The process described from cartographic point of view begins with selection and definition of contexts and context types, continues with appointing relevant spatial data and ends with implementation of cartographic methods in Sissi. The whole configuration process is documented with several map examples.

Keywords: *adaptive map, contextual map, Contextual Web Map Service, WMS, crisis management*

INTRODUCTION

The vision of Digital Earth promises access to the virtual world of information and knowledge resources for any citizen of the planet. Many steps are necessary for achieving that final stage, from political decisions, through financial funding up to technological solutions. Special attention should be paid to the development of effective methods of presenting such large amounts of data, otherwise the virtual world could become a virtual labyrinth and users could easily get lost. The conventional way of dealing with this matter is a combination of quality metadata and a robust catalogue service. However, there exists at least one alternative way based on adaptive visualization and user context.

A crucial advantage of map displayed on an electronic device is that it can easily change its content and form of visualization in time. Therefore, the map is able to adapt to the user’s needs or – more generally – to the user’s context which is also changing in time. The adaptation means above all highlighting the most relevant information along with suppressing the irrelevant; thus, the adaptation process also serves as a relevancy-selector of spatial data. Adaptation and context in the field of geoinformatics were introduced by Bill Schilit (Schilit et al. 1995). T. Reichenbacher (2004) and A.-M. Nivala (2005) have initiated this research branch in cartography.

ADAPTIVE MAPS FOR DIGITAL EARTH

Bylaws of the International Society for Digital Earth and the Beijing Declaration (ISDE 2010) suppose that information about our planet and relevant phenomena should be stored in databases and accessible via the internet to users all over the world. An important role in this vision should be played by geographic information systems, remote sensing and geo-spatial information infrastructures. It means that extremely large amounts of data must be collected, stored and published on the Internet. The world data centres should be connected and coordinated to avoid discordance among databases.

We can recapitulate the requirements of this vision:
1) Data collection – A lot of data have been already collected and even much more will be collected in the following years. There is a plethora of powerful sensors producing great amounts of data, e.g. satellites for remote sensing, etc.
2) Data storing – The most of collected data have been already stored in digital form in data centres. Costs of hardware and storing capacity is decreasing; on the other hand, media capacity is enlarging. Cheap or open source database software can be used by anyone.
3) Data publication – The Internet is more and more widespread and data transfer rate is increasing. Data *from* many databases are accessible via web interface. In some cases, data are even collected *to* databases via web.

The vision of Digital Earth requires dealing with extremely large – and still growing – amounts of data. It is estimated that the size of the digital space was 500 EB (1 exabyte = 10^9 gigabytes) in May 2009 and it is growing faster and faster. Digital space is doubled every 18 months (IDC 2010). In order to collect, to store and especially to access the data effectively, it is absolutely necessary to use high-quality metadata, because without it the Digital Earth could easily become a digital labyrinth.

Metadata, metadata portals and catalogue services

One important problem of connected databases of Digital Earth is the *way how users can find information they are looking for*. Metadata, metadata portals and catalogue services can be used for this purpose. Catalogue services support the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects (OGC 2007).

Metadata must be produced for all data provided in Digital Earth databases. Metadata help to search the data and to find information about it – e.g. where it is, how users can get it, how up-to-date it is, who is responsible for the data, etc. Data without metadata is useless and junk information for the Digital Earth.

Adaptive maps

Searching for data with the use of metadata is useful for users who know what they are looking for. But there are also *users who do not know what to look for*. The only thing they know is that they are in some kind of situation that must be solved. They are not sure what data they need and where to look for it. Using catalogue services is also time consuming; therefore, it is not appropriate in situations in which *quick reaction* is crucial, such as in crisis management. For these situations, there is a suitable solution – adaptive maps.

Let us imagine the following situation. A mayor organizes evacuation of municipality by buses because of flood. He uses GIS and finds the data layer of buildings in surrounding municipalities that can be used as large-capacity shelters (e.g. schools) and he finds the shortest ways to them. But he did not remember to turn on the data layer of closed roads. A bus driver does not find out that recommended shortest route is closed until during the evacuation. The bus must come back and a new way must be found. The evacuation is delayed and danger is increasing.

Now imagine that the mayor only enters the code “evacuation” into the system. Then the system shows him automatically (based on pre-arranged settings) all layers he needs – shelters, routes, traffic problems, emergency landing areas, etc. A system of adaptive maps can do this, because an adaptive map changes its content with respect to various conditions, e.g. user situation, hardware possibilities, etc. Our mayor’s situation is described as an “evacuation”. The same system would produce an absolutely different map in the case of a “tourist trip”. The synthesis of the above-mentioned conditions which can influence an adaptive map is called *context* (see Dey & Abowd 1999).

THE PROCESS OF CREATION OF CONTEXTUAL ADAPTIVE MAPS

In order to create a set of contextual maps, several steps have to be taken. The starting point is an analysis of user’s needs and exact delimitation of purposes of the maps. Consequently, suitable parameters of context are selected and specified. The next phase is represented by selection of adequate data sources and cartographic methods of data visualization, followed by configuration of the web map service. Finally, the resulting maps are tested in practice and adjusted according to user's observations and comments.

Determination of map purpose

In the presented paper, the entire process is documented in an example of maps created for operators of the Regional Operation and Information Centres of the Fire Rescue Service of the Czech Republic. The example is in more detail described in Zboril (2010).

Currently, maps used by operators in individual regions are different, as visualization methods are not selected centrally but individually by GIS administrators (mostly with no cartographic background) and in many cases, it is apparent, that resulting maps do not provide optimum support for decision making. Therefore, this area provides a lot of space for improvements.

Operators of the Regional Operation and Information Centres receive all available information about an emergency event (location and type of incident, verbal description of incident, etc.) from the Emergency Call Centres in the form of a structured XLM document called data sentence. Their principle tasks include deciding how many and which units of the fire rescue service will deal with the emergency event, following progress of the operation and providing information support for units in the field.

In order to determine which units will be sent to the site of the incident, the operator needs to have basic information about the site and its vicinity and about dislocation of available fire rescue service units. Therefore, the most important data layers in this stage are those that enable general orientation in space (communications, water bodies, land use, etc.). However, the level of relevance of individual data layers significantly varies depending on the type of incident. For example in case of a fire, it is crucial to have information on type of buildings/land use and localize places with high concentration of people; on the other hand, in case of a traffic accident these information are of little importance and their visualization in map unnecessarily increases user's cognitive load.

Selection of context parameters and delimitation of contexts

The most important contextual information is location of the incident. In the data sentence, it can be determined in multiple ways (e.g. street address, road number and kilometre/mile-spacing). However, each data sentence must also contain *geographic coordinates* (entered by operator of the Emergency Call Centre). These coordinates are used for automatic centering of the displayed map section.

For selection of suitable form of visualization, the key context parameter is *incident type*. Its classification is based on classification used by the fire rescue service, where incidents are divided into fires, traffic accidents, natural disasters, leakages of hazardous chemical substances, technical accidents, radiation accidents and other incidents. In the presented example, contextual maps were created for *fires*, *traffic accidents* and *other incidents*. Maps for other types of events were not considered because such situations either require highly specialized maps and level of information support that exceeds competence of concerned operators (radiation accidents, floods and some other types of natural disasters, etc.) or, conversely, do not require any information support in the form of map (e.g. technical accidents such as opening of locked spaces, salvage, etc.).

An analysis of working practices of operators of the Regional Operation and Information Centres also revealed, that for purposes of orientation, they often find useful to study an orthophotomap of the area. Therefore, context parameter *background version* was added; it allows selection of either a standard *map* or an *orthophoto* of the area.

Specific contexts were determined by combining individual values of parameters *incident type* and *background version*. In this way, the following contexts were defined:

- traffic accident (standard map),
- traffic accident (orthophotomap),
- fire (standard map),
- fire (orthophotomap),
- other incident (standard map),
- other incident (orthophotomap).

Selection of data sources

Selection of suitable data sources is a task that very much depends on circumstances related to the purpose of created maps. In some cases, data are abundant and the main problem lies in their evaluation and/or joining data from several sources; in other situations, relevant data are missing and have to be created. Despite that, some general rules apply – in a contextual map service, only data layers covering the entire area of interest can be used. Data can be stored on WMS servers of different providers; however, it is necessary that all selected WMS servers support at least one common coordinate system. It is also advisable to prefer servers which support use of symbols defined with the use of SLD styles – their use allows contextual map service providers to select their own means of data representation.

Selection of visualization methods

When creating the map legend, it is necessary to bear in mind, that most users will not use individual contextual adaptive maps separately. It can be assumed, that within a certain time period, each user will successively use several (or all) maps available in the given set. Therefore, it is recommendable to design the map legend in a manner comparable to creation of map legends for atlases – when there are different symbols used in different contextual maps for representation of the same phenomenon, it is necessary to preserve in all cases some common determining feature, which will allow identification of the phenomenon across all contexts. Thus, experience gained from working with one contextual adaptive map can be used during consequent work with other maps from the same set.

Selection of specific visualization tools and methods is based mostly on purpose of the created maps (as mentioned above) and characteristics of users. In case of operators of the Regional Operation and Information Centres, a high level of expertise can be assumed – users have extensive experience with the used software and method of data representation (gained either in practice or during training courses). Therefore, symbolic (abstract) signs are preferred over figural (replicative) symbols.

Taking into account all the above-mentioned aspects, for each of the six defined contexts a list of data layers that are visualized in the given context was created, and for each layer method of visualization and scale extent in which the method is used was set. The created contextual adaptive maps are visualized with the use of contextual map service Sissi, which is described in the following chapter. Examples of contextual maps can be seen in Figs. 1-3.

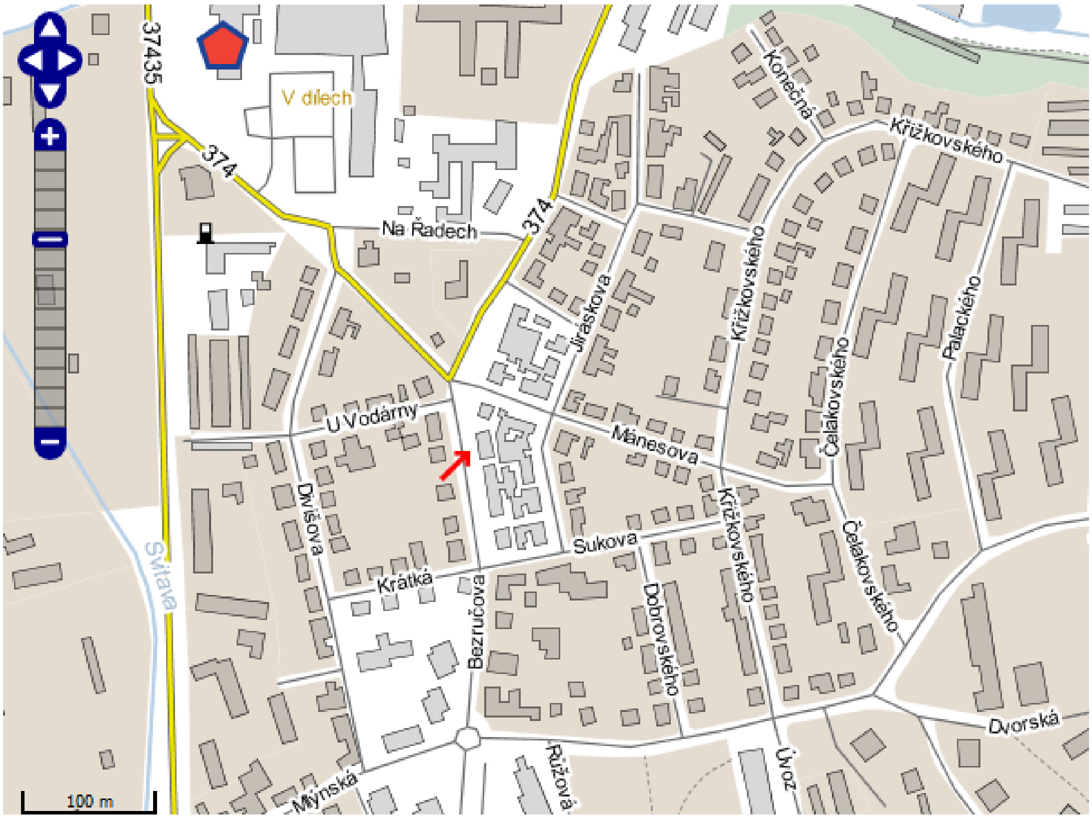

Figure 1. Example of contextual adaptive map for context "traffic accident (standard map)" in scale 1:5000

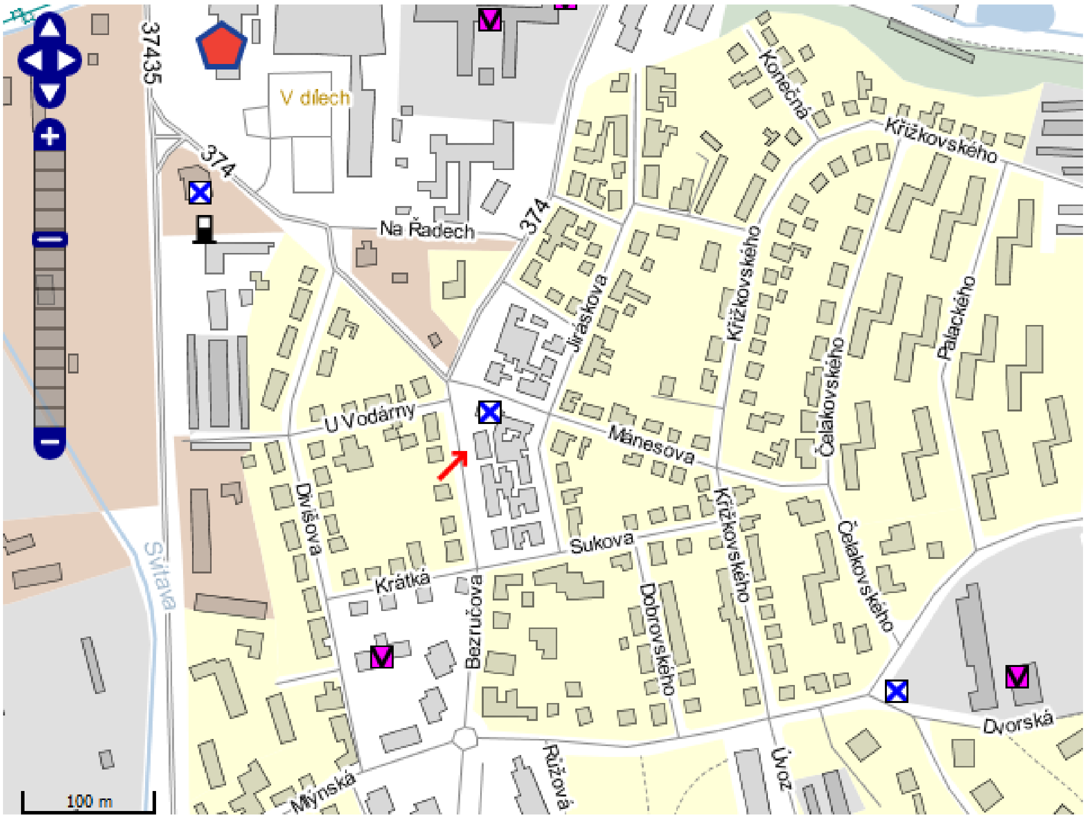

Figure 2. Example of contextual map for context "fire (standard map)" in scale 1:5000

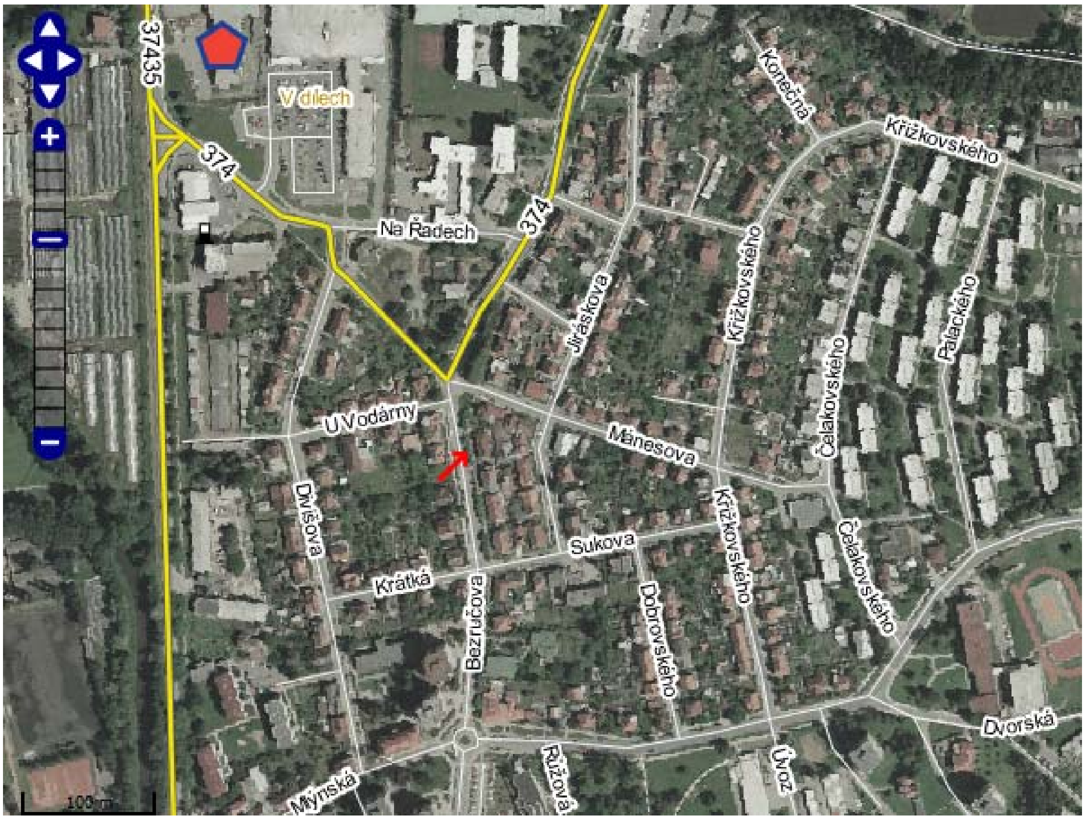

Figure 3. Example of contextual map for context "traffic accident (orthophotomap)" in scale 1:5000

CONFIGURING CONTEXTUAL WEB MAP SERVICE SISSI

Contextual Web Map Service (CWMS) called Sissi along with a contextual client was developed for implementation of contextual cartographic visualisation (or adaptive visualisation) in web environment (see Kozel & Stampach 2010). Sissi enables publishing contextual map on the Internet and, furthermore, the whole process is based on standard map interface Web Map Service (WMS, see OGC 2002).

Sissi configuration process consists in configuration file filling and editing. The configuration file is an XML file with a predefined structure. Kozel (2009) described the configuration process in detail, while this paper presents only the key parts of the process. These parts are:
1) Filling fundamental service metadata
2) Filling source WMS servers
3) Filling elementary context types and elementary contexts
4) Filling supported contexts and contextual maps
These four steps roughly correspond to previous sections of this paper.

Fundamental service metadata

The first part of the Sissi configuration file contains fundamental metadata about the Sissi instance. Metadata includes text annotation, key words, contact to provider, supported coordinated reference systems, and bounding box covering presented region. Metadata structure is very similar to standard WMS service metadata (element Service in WMS 1.1.1., see OGC 2002). Sissi instance uses specified metadata for filling corresponding metadata elements of standard WMS GetCapabilities response.

Source WMS servers

The second part of the Sissi configuration file corresponds to data source selection described above. The list of selected data sources, or more precisely source WMS servers, must be stated in this part of the configuration file. Selected WMS servers must support all coordinate reference systems stated in the first part of the configuration file. Each source WMS server is represented by one element Mapserver and is described by given name and URL. Two WMS servers are entered in Fig. 4.

```
<Mapservers>
  <Mapserver name="lgc" href="http://mapserver.geogr.muni.cz/wms?" />
  <Mapserver name="dmu" href="http://geoportal.cenia.cz/cenia_b_ortorgb1m_sde?" />
</Mapservers>
```

Figure 4. Example of source WMS servers list in Sissi configuration file

Elementary context types and elementary contexts

The third part of the Sissi configuration file corresponds with relevant elementary context types selection described above. Elementary contexts stated in this part of the configuration file are used for generating supported contexts and contextual adaptive maps in the following part of the configuration file.

Each elementary context type (i.e. context parameter) is represented by one element Type and each elementary context is described by one element Context. Both types (i.e. parameters) and contexts (i.e. parameter values) are described by given names and titles. Two elementary context types with three and two elementary contexts selected above are entered in Fig. 5.

```
<ElementaryContextTypes>
  <Type name="incident" title="Indicent type">
    <Context name="accident" title="Car accident" />
    <Context name="fire" title="Fire" />
    <Context name="other" title="Other incident" />
  </Type>
  <Type name="version" title="Background version">
    <Context name="standard" title="Map" />
    <Context name="orthophoto" title="Orthophoto" />
  </Type>
</ElementaryContextTypes>
```

Figure 5. Example of relevant elementary context types and elementary contexts in Sissi configuration file

Supported contexts and contextual adaptive maps

The last and the largest part of the Sissi configuration file contains supported contexts and contextual adaptive maps. Any supported context is identified by names of elementary types and determinative elementary contexts (see Fig. 6).

```
<Elements>
  <Element name="incident" value="accident" />
  <Element name="version" value="standard" />
</Elements>
```

Figure 6. Example of supported context identification in Sissi configuration file

Each supported context contains also definition of the corresponding contextual adaptive map (see Fig. 7). Each map is composed of WMS layers stored on source WMS servers. Remote layers are identified by their name (element RemoteLayer) and by name of WMS server (element RefWms, attribute defaultMapserver). For better control of map symbols, it is possible to define standard SLD style (Styled Layer Descriptor, see OGC 2006) for each layer (element RefWms, attribute sld).

```
<RefWms defaultMapserver="lgc" sld="hzs_accident.sld.xml">
  <LayerGroup>
    <Title>Roads</Title>
    <Layer>
      <RemoteLayer name="hzs:motorways" />
      <Title>Motorways<Title>
    </Layer>
    <Layer>
      <RemoteLayer name="hzs:roads_1" />
      <Title>Main roads<Title>
    </Layer>
  </LayerGroup>
  ...
</RefWms>
```

Figure 7. Example of supported definition of contextual adaptive map

CONCLUSIONS

The paper presents the idea of adaptive contextual maps – maps that change their content and forms of its visualization on basis of user's context. This approach is an effective way of dealing with large amounts of digital data that are nowadays available and can be seen as a tool that helps to turn the concept of Digital Earth into reality.

All necessary steps in the process of creation of adaptive contextual maps are described – analysis of user's needs, delimitation of context parameters, definition of contexts, selection of suitable data sources and methods of their visualization and configuration of Contextual Web Map Service called Sissi.

Future work in this area will be focused on practical testing and verifying of map outputs and analysis of possibilities of introducing the idea of adaptive maps into other fields of human activities.

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