1-1-2011

# Design With Nature 2.0 – A Geodata Infrastructure Approach to Map Overlay

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# Design With Nature 2.0 – A Geodata Infrastructure Approach to Map Overlay

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**Abstract.** McHarg's "Design With Nature" was a precursor of the layer model in modern geographic information systems. We are reviewing the layer overlay approach from a geospatial data infrastructure (GDI) perspective and experiment with weighted map overlay using Web map services. A case study for natural hazard risk assessment for Southern Quebec illustrates this visual approach to multi-criteria analysis using online mapping. We conclude with a call for more research on thematic mapping and its use for decision support within GDIs.

**Keywords.** Geospatial data infrastructure, map overlay, multi-criteria analysis

## 1. Introduction

Ian McHarg is widely credited with inventing the layer model that was adopted in geographic information systems (GIS) (e.g. Goodchild 1992). In his seminal book, "Design With Nature", McHarg (1992) used semi-transparent map overlays for "suitability selection processes", including highway route selection. His printed map transparencies represented social and environmental values around potential routes by degrees of grey shades. The overlay resulted in sensitive areas being "masked" through multiple overlaid maps while more suitable areas remained translucent. Subsequently, the computational overlay of maps has been formalized in map algebra and cartographic modeling (Berry 1987, Tomlin 1990). Map algebra conceptualizes a set of mathematical operators applied to raster data to derive new map layers. It includes various overlay operators and is implemented in commercial GIS software. However, the visual overlay via regular map layer management is the most immediate implementation of McHarg's (1992) approach in today's desktop GIS.

Map overlay is also a key feature of geospatial data infrastructures (GDI). A basic tenet of GDIs is to leave datasets under the custody of an authoritative provider; access them through distributed Web services; and overlay them on the end-user's screen. The OpenGIS Web Map Service (WMS) (de La Beaujardiere 2006) is among the services that support visual overlay à la McHarg, while recent developments aim to support computational overlay, e.g. Holzmeier and Ostländer's (2005) Web Map Algebra Service. While WMS is extensively used, it is usually employed for general reference maps, e.g. road maps. There are few examples of thematic maps within GDIs in general, despite the capability of maps to visualize spatial patterns of natural, demographic, and socio-economic phenomena, and support associated planning and decision-making.

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In this paper, we replicate McHarg's "Design With Nature" in a GDI environment in order to illustrate decision support capabilities of simple, visual overlay of online thematic maps. Section 2 provides a brief overview of weighted overlay and multi-criteria analysis as they apply to this work. In Section 3, we summarize the pertinent aspects of the WMS specification, the OpenLayers development platform, the alpha blending approach for the rendering of semi-transparent map overlays, and the use of styled layer descriptors. Section 4 illustrates the user interface and functionality of the prototype client. Section 5 describes a case study of using online map overlay for natural hazard assessment in the context of global environmental change. Finally, Section 6 concludes the paper with a summary of results and outlook on future work.

## 2. Weighted Map Overlay and Multi-Criteria Analysis

Weighted overlay of map layers in GIS is an extension of the general idea of map overlay described above. Eastman et al. (1995) were among the first to systematically describe raster data overlay and provide an implementation in the Idrisi GIS. The authors distinguish between "constraints" and "factors". A constraint limits the set of feasible alternatives in a decision situation by establishing strict boundaries or threshold values to be met. In contrast, a factor "enhances or detracts from the suitability of a specific alternative for the activity under consideration" (Eastman et al. 1995, p.539). In other words, higher or lower measurements on a factor will affect the suitability of locations without setting specific minimum or maximum thresholds.

This terminology links weighted map overlay to the broader field of GIS-based multi-criteria analysis (Malczewski 1999). Each map layer represents a criterion that measures the outcome of a decision. Weights are used to represent different levels of importance attributed to the criteria. Weighted criterion layers can be summed using map algebra tools to create a weighed average of criterion values across a study area.

The weighted average, also known as weighted linear combination, is among the most common multi-criteria methods (Malczewski 2000). This process results in a arithmetic combination of input layers into a single output layer, the cell values of which represent suitability or desirability of each location for the decision to be made. McHarg's (1969) approach can be seen as a purely visual implementation of geospatial multi-criteria analysis, since the grey shades resulting from semi-transparent map overlay represent site suitability in the same way as the GIS-based weighted overlay. We propose to use weighted map overlay as a decision support approach within GDIs.

## 3. Geospatial Data Infrastructures and Web Mapping Concepts

### 3.1. Web Map Servers – Use of GeoServer

A GDI is an online platform that provides analysts, decision-makers, and the general public with access to geographic information in the form of maps and geospatial data. Web map servers in a broad sense are a key element of any GDI, and the OpenGIS Web Map Server (WMS) specification provides a widely accepted foundation for mapping services. A WMS must respond to two basic requests: GetCapabilities, which provides information about available themes and map layers, their geographic extent, and the available graphic output formats; and GetMap, which retrieves an image of a

map that has been prepared on the server using parameters set by the client, including data layer, map extent, and output format.

A styled layer descriptor (SLD) is an XML schema that extends the WMS standard and allows user-defined symbolization and colouring of geographic data (Lupp 2007). The SLD implementation specification defines an XML styling language that allows users to define rules to control how data are rendered. A layer-specific symbolization can be included in a WMS request by adding an SLD parameter to the request URL.

In this project, GeoServer was used to provide access to the case study data. GeoServer is an open source Java software package for sharing geospatial data. It implements several OpenGIS service standards, including the WMS with SLD.

### 3.2. Web Map Client – Use of OpenLayers

The client application in this project was built using OpenLayers, an Open Source Geospatial Foundation (OSGeo) project, which provides a JavaScript library that allows for the integration of maps from distributed sources into the HTML code of a Web page. The map overlay client also uses the jQuery JavaScript library, which helped to define the control elements such as the menu tab used in this application.

### 3.3. Alpha Blending

Alpha blending is an algorithm used in computer graphics to combine overlapping, partially transparent picture elements. It adds an alpha channel to an image's colour information. The alpha channel contains information about the opacity of pixels, with 0.0 being transparent and 1.0 being opaque. For example, a 50% black colour in an RGB colour model would be represented by the tuple (0.0, 0.0, 0.0, 0.5), where (0.0, 0.0, 0.0) is the RGB encoding for black and the additional alpha value is set to 0.5.
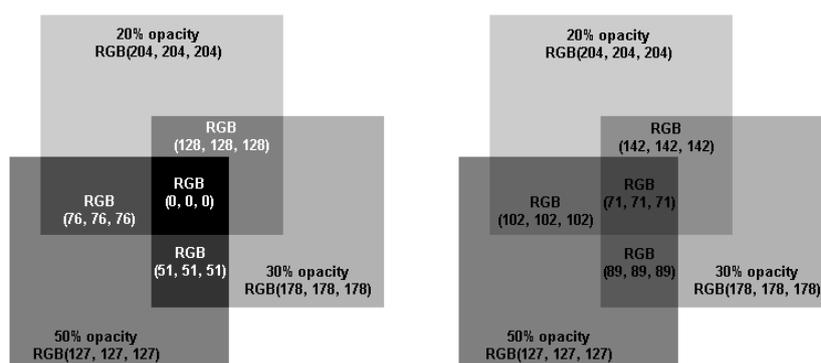


**Figure 1.** "Logical" overlay of partially transparent (translucent) picture elements with additive combination of opacities (left), compared with graphical overlay with multiplicative alpha blending (right)

The use of alpha blending as the default image overlay method in Web clients creates an inconsistency in visual overlay of weighted map layers. In a greyscale scenario, the three layers shown in Fig.1 have opacities of 50%, 30%, and 20%. If opacities are considered to represent criterion weights, their weights should add up to 100%, as shown in Fig.1 (left). However, alpha blending does not use additive opacity.

For example, the triple overlay in the centre of Fig.1 (right) does not receive full black opacity. Instead, the graphical overlay results in a grey shade with an opacity of $1 - (1-0.5)*(1-0.3)*(1-0.2) = 1 - (0.5*0.7*0.8) = 1 - 0.28 = 0.72$. The RGB tuple (71, 71, 71) corresponds to a 72% black.

## 4. Prototype User Interface and Functionality

A prototype implementation of the map overlay tool includes the following functions:

- Import layers from Web Mapping Services and overlay them in the Web client
- Set up with default collection of WMS URLs suitable for demonstration
- Switch layers on and off, and change the order of layers
- Basic functions of a Web mapping client such as panning and zooming
- Change layer opacity by distributing 100% over selected layers

The user interface (Fig.2) consists of two main elements: map and menu. The map includes controls for panning and zooming as well as control elements for choosing base layers and turning thematic layers on and off. The menu is organized into functional areas. The Add Data area provides text fields for adding layers from OpenGIS-compliant Web services along with sample WMS and WFS layers for direct access. The Change Opacities area contains the sliders for modifying the opacity of each layer. When a layer is added to the map, a new opacity slider is added automatically. Similarly, in the Layer Order area of the menu, buttons for controlling the layer arrangement are added automatically for each layer. The current layer order can also be seen in the control elements within the map.
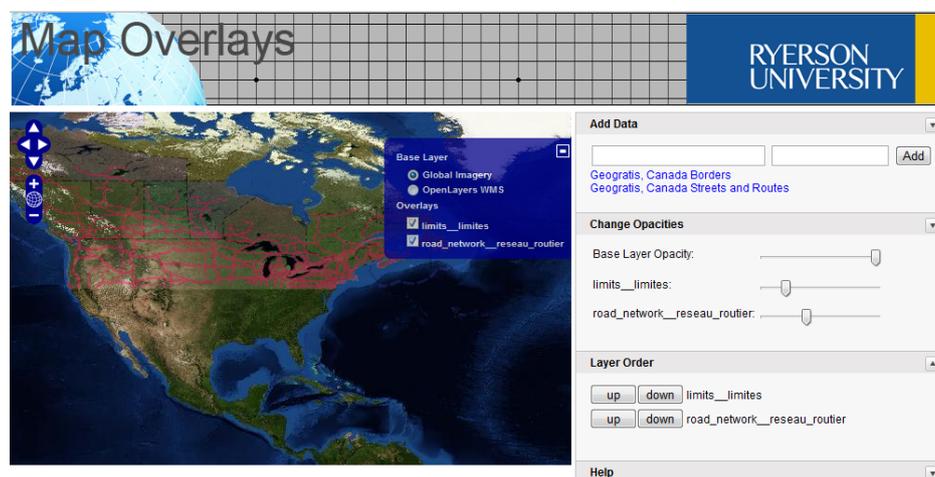


**Figure 2.** Screenshot of the prototype's user interface

## 5. Case Study – Natural Disaster Risk Assessment

The global risk data platform (Giuliani and Peduzzi 2011) is an international effort to collect and share information about natural hazards. Access to the data is provided as

maps on the site itself (http://preview.grid.unep.ch/), or through Web services. Their WMS offers different maps, including those of risk levels classified between very low and very high, with associated colour coding (e.g. dark red for highest risk). This fixed colour scheme and legend were not suitable for map overlay. Therefore, copies of the data were served from a custom WMS with SLD support. For illustration purposes, the colour black was given to all pixels that were encoded with any risk level above zero.
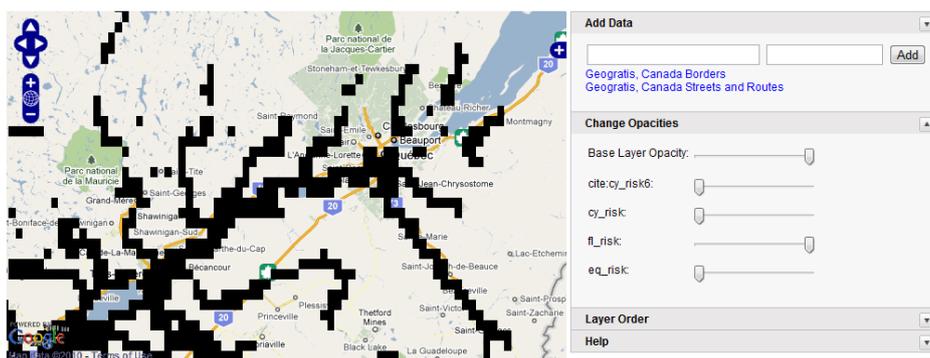


**Figure 3.** Flood risk areas in Southern Quebec – overlay of UNEP WMS with Google Maps base layer

Three layers representing the risk of cyclones, floods, and earth quakes were included in this case study. The map extent was set to Southern Quebec, Canada. This area borders the Saint Lawrence River, a major shipping route that connects the Great Lakes with the Atlantic Ocean. Quebec City is one of the oldest settlements in North America and its historic district is a UNESCO world heritage site. The City lies at a narrowing of the Saint Lawrence River and can be seen slightly east of the centre of the maps in Fig.3 and Fig.4.

Fig.3 shows black pixels (given full visual weight) that represent areas identified as prone to flood risk by Giuliani and Peduzzi (2011). These areas include the shore of the Saint Lawrence River upstream from Quebec City as well as many of its tributaries.
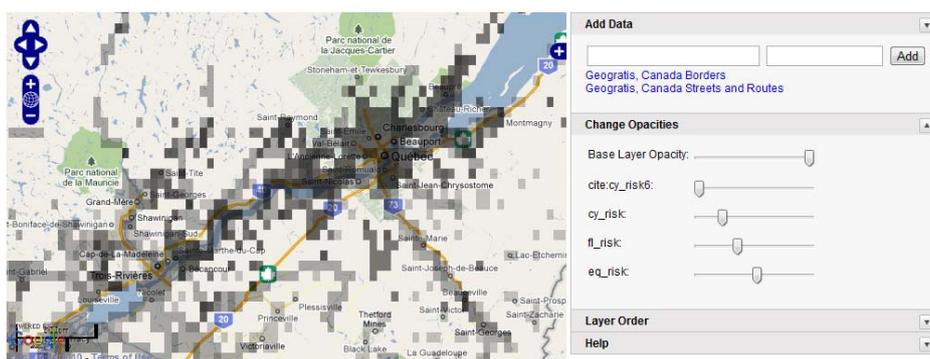


**Figure 4.** Overlay of three thematic WMS layers using transparency to represent hypothetical importance weighting – cyclone risk (20%), flood risk (30%), and earthquake risk (50%)

In Fig.4, darker grey shades visually indicate the overlap of multiple natural hazard risks. The risk of cyclones, floods, and earthquakes are given hypothetical weights (opacities) of 20%, 30%, and 50%, respectively. The study area shows generally low

levels of risk with a concentration of higher risk near Quebec City and along the Saint Lawrence River. An inspection of the three individual layers confirms the similarity in geospatial patterns and considerable spatial coincidence of natural hazard risk in Southern Quebec.

## 6. Summary and Outlook

The goal of this research was to illustrate the concept of weighted map overlay in a GDI environment, and spark discussion about the use of WMS for spatial decision support. An interesting advantage of the purely visual, non-computational overlay used here is that distributed data sources of different qualities (e.g. spatial resolution) can be jointly explored by the end-user without requirements on compatibility.

The prototypical implementation of a map overlay client was fast and cost-effective, in part due to the use of open source software tools. The current tool needs updates in a few functions, in particular the control of layer weights adding up to 100% in accordance with multi-criteria analysis methods. In addition, we plan to expand the testing of the tool to a regional or local scenario with more decision criteria and involvement of stakeholders who would provide feedback on the weighting approach.

More broadly, we argue that thematic mapping merits more attention from GDI researchers and developers. While specifications and tools are in progress that support the computational combination of data (e.g. Web Processing Service), the basic overlay of thematic map layers in GDIs has not been studied and promoted enough. Geospatial Web services are still a far cry from being able to replace professional GIS mapping.

## Acknowledgements

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