4.3 Creation and Utilisation of Standardised Digital

Symbols in a GIS

Graphic symbols are the most fundamental element of cartographic lan-

guage on geomorphological maps. They must be created to clearly

express the geographic location of the feature and to display relationships

between features with respect to differences, quantities or ranking

(Rouleau, 1993). There are few ready-made symbol sets for standard GIS

software freely available (Otto and Dikau, 2004; Otto, 2008) and there-

fore legend symbols commonly will need to be created. By defining the

symbol type used for each data set, digitised points, lines or areas are

automatically replaced by map symbols. Every graphic element on a map

is a symbol that is systematically linked to the data and content of the

map. In contrast to other thematic maps that commonly display numerical

data, geomorphological maps depict a composition of real-world features

and their interpretation, for example process activity, or genesis of land-

forms. Just like topographical maps, where contour lines represent eleva-

tion and therefore the shape of the land surface, geomorphological maps

refine this representation of the surface using symbols, commonly with

topographical maps providing base or background information. The

majority of geomorphological symbols represent qualitative rather than

quantitative data, because most geomorphological maps focus on the

inventory and location of objects on the land surface. Land surfaces are

commonly composed of a complex set of landforms and processes creat-

ing a very dense display of information. To allow good legibility and

facilitate understanding of the map, symbols need to be created that are

easily distinguished and understood. Understanding is closely connected

to familiarity of what we see. Thus, well-chosen illustrative symbols can

remind the viewer of the related feature. Abstract symbolisation requires a

greater ability of spatial thinking and visual perception. However, as many

users of geomorphological maps are familiar with landscapes, they will be

able to perceive the map content as a whole even if some of the symbols

are not familiar, as long as the map is readable and permits the perception

of the land surface.

In the past, geomorphological maps and the symbols used have been

drawn by hand. The transfer of these handmade symbols into a GIS often

suffers from graphical restrictions produced by the computer and has to

do with the composition and reproduction of vector graphics on the

computer.

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Symbols are generally composed of different graphic objects. Although

point symbols usually consist of a single graphic, complex line and area

symbols are constructed by combining different graphics to create the final

symbol. For example, a ridge is commonly represented by a line symbol

that consists of a solid black line in the centre and solid, black triangles on

both sides indicating the directions of the two adjacent slopes (Figure 9.7).

This symbol is thus composed of three different layers: (1) the black line,

(2) the triangles facing upwards and (3) the triangles facing downwards.

Two important restrictions need to be considered when working with

complex symbols in GIS. (1) Symbols generally do not scale automatically

as do features. Thus, symbol size and line thickness have to be customised

to the appropriate map scale in order to display correctly. (2)

Reproduction problems commonly arise when using complex lines sym-

bols. Line vector graphics are composed of nodes (points) and edges

(lines) connecting the nodes. When a line is digitised, nodes are set by

clicking the mouse and the edge is generated automatically between the

nodes. Curvature of the line is a function of node density, or generated

automatically by the graphics program by smoothing. If additional graphic

Figure 9.7 (a) A composed line symbol, constructed from three layers of symbols.

(b) Typical problems of undercutting and overshoot of symbol representation in GIS.

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objects are positioned along the line, for example triangles on the left and

the right, overshoots and misplacements of the symbol parts can occur in

GIS (Figure 9.7). Because the software automatically places these symbol

parts between the nodes of the line, an exact and regular positioning is

not always possible. This effect can however be removed manually by

changing the node position.

4.3.1 Creation of Point Symbols

Symbols for geomorphological point features are generally used for single

landforms and/or single processes that are too small to be represented at

scale. Thus, point symbols are commonly applied where features have

been generalised and their shape and size commonly does not represent

the real extent of the object. Point symbols are the most illustrative sym-

bols and are generally created using drawings (simple bitmap graphics) or

font characters. These predefined images are created in graphic or special

font character software and later imported into the GIS. Point symbols

can show orientation of an object defined by an angle of rotation. If the

feature direction varies between different objects, the rotation angle needs

to be stored within the feature’s database (e.g. attribute table).

4.3.2 Creation of Line Symbols

Line symbols are commonly applied for structural and linear features, for

example ridges, moraines and rivers. Simple line symbols use solid, dotted

or hashed lines. More complex symbols combine pictures or characters

that are added to the line or replace the line along its length. Line sym-

bols can have a direction, for example indicating the flow direction of a

river, or the direction of valley. Direction then is indicated by a special

arrangement of the symbol elements. In GIS, line direction is commonly

dependent on the direction of digitising, but can also be changed by flip-

ping the start and end node of the line.

4.3.3 Creation of Area Symbols

Not all geomorphological mapping systems make use of area symbols.

However, if they are applied, area symbols mostly represent spatially con-

tinuous information, for example subsurface material or slope gradient.

Area symbols are generally composed of colour or hatch (texture) fills.

Variation in area symbols is therefore performed by changing colour,

hatch orientation and density, or by changing the texture shape. A typical

example is symbolisation for grain size, which can be depicted by

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increasing dot size according to different grain sizes. In contrast to line

and point symbols, areas cannot indicate a feature orientation. However,

this information is not relevant to most features depicted by area symbols.

4.4 Map Reproduction

Despite dissemination of maps via the Internet or within journals, many

geomorphological maps are still reproduced on paper. Whichever method

is chosen, the choice affects many steps of map design and production.

Maps that will be printed have different requirements concerning, for

example, colours or resolution than maps that are viewed on a computer

screen. The map design thus has to be customised with the output

method of the map in mind.

Special attention is required when preparing maps that will be printed.

One common problem is that the colours of the printed map do not match

the ones composed on the computer. Problems of colour management are

related to the different use of colours on computer screens and printing

devices. The main difference in colour representation is the process of col-

our combination, which can be additive or subtractive (Rouleau, 1993;

Slocum et al., 2005). Computer monitors use the combination of three col-

ours, red (R), green (G) and blue (B), to create all other colours. The RGB

system is an additive method which means that when all three colours are

added, white colour is generated. RGB colours are composed giving a

value for each of the three colours (e.g. the combination of R: 250,

G: 250, B: 0 produces a bright yellow colour). The RGB colour system

should primarily be used for maps that are viewed on the computer. When

a map is printed, simple computer printers generally are able to reproduce

RGB colour; however, more sophisticated computer and commercial prin-

ters require a conversion into the CMYK colour system. This colour

system is a subtractive process using the basic colours cyan (C), magenta

(M), yellow (Y) and black (K). When combining the first three colours C,

M, Y all light is absorbed or subtracted from the vision and the result is

black. The same yellow given in the example above would be composed in

CMYK by choosing: C 11%, M 0%, Y 91%, K 0%. Graphic software usu-

ally enables a conversion of colours from RGB into CMYK and vice versa.

Another issue for map production is the display or print resolution of

the graphics. Computer monitors display at a lower resolution in compar-

ison to printed maps. Image resolution is measured in dots per inch

(DPI), which describes the density of individual points that are placed

(displayed or printed) within a linear inch. Computer monitors have a

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resolution of 96 DPI, whereas printers generally require a minimum reso-

lution of 300 600 DPI in order to produce sharp graphics. This needs to

be considered when the map is prepared for printing.

The final step of production is the transfer of the map to the printer.

Printers generally use different file formats than the standard graphic format

generated by the graphic or GIS software. The digital map file needs to be

converted into this printer file format, which is generally done by the appli-

cation software (GIS or graphics). The most common file format used for

printing is the PDF (portable document format) that contains the graphic

and page description information. PDF is a standard format that can be pro-

cessed by many graphic software and printers without loss of information.

A GeoPDF includes one or multiple map frames within the PDF page

associated with a coordinate reference system. It enables the sharing of

geospatial maps and data in PDF documents. Multiple, independent map

frames with individual spatial reference systems are possible within a

GeoPDF, for example, for map overlays or insets. Geospatial functionality

of a GeoPDF includes scalable map display, layer visibility control, access

to attribute data, coordinate queries and spatial measurements. Adobe

Readert(starting with Version 9.0) supports geospatial functions of

GeoPDFs. However, full functionality of GeoPDFs require a free and

user-friendly plug-in for Adobe Readert, the TerraGottoolbar (see

www.terrago.com). GeoPDFs can be created either directly from GIS

(e.g. ArcGIS 9.3) or using a specific software called TerraGo Publishert

that is integrated into GIS applications such as ESRI’s ArcGISt,

Intergraph’s GeoMediator ERDAS Imaginet. A GeoPDF enables fun-

damental GIS functionality turning the formerly static PDF map into an

interactive, portable georeferenced PDF map. It is an interesting and valu-

able way of dissemination of geomorphological maps. Some geospatial

data providers such as the United States Geological Survey (USGS) and

the Australian Hydrographic Service (AHS), have already started publish-

ing interactive maps using the GeoPDF format.

5. GEOMORPHOLOGICAL MAPS ON THE INTERNET

With the digital production of geomorphological maps, the dissem-

ination of research outputs now extends beyond simple paper products.

Internet technologies can contribute to both the dissemination of

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geomorphological maps and access to geomorphologic data and help to

make geomorphological knowledge available to the general public.

Indeed, many national geological surveys employ end-to-end digital

workflows from data capture in the field to final map production and dis-

semination (e.g. USGS see http://seamless.usgs.gov/). This section

therefore deals with the potential of web mapping applications for the dis-

tribution of geomorphological information.

Mitchell (2005) mentioned two general types of Internet maps: static

and dynamic maps. Static maps, scans or image exports from GIS soft-

ware, are the easiest way of displaying maps on the Internet. They are

simply embedded in web pages as images and detailed knowledge of web

development is not required. Because static maps have been produced

using GIS or graphic software, no limitations to design or symbology

exists. However, web sites constrain extent and graphic resolution of the

map to the capabilities of the computer screen. The term ‘static’ refers to

the definite status of the map. Just like hard-copy maps, static maps on

the web cannot be modified by the user. This implies spatial navigation

and views at variable scales are impossible. There is no spatial reference so

the image cannot be used by other applications, even if the map has been

previously produced in a GIS.

Dynamic maps, in contrast, are characterised by interactive capabili-

ties: the user can interact with the map by zooming, panning or adding

further thematic layers, with the map refreshed after each task. Web map-

ping applications such as Google Maps are currently very popular and

widespread and have increased the interest and access to mapping.

Depending on the system components, advanced symbology, map over-

lays from different applications and their integration into a Desktop GIS

is possible. The interoperability is achieved through the use of interna-

tional open standards that include mechanisms for the integration and

visualisation of information from multiple sources.

The motivation to write about the online distribution of geomorpho-

logical maps originates in the increasing number of web mapping applica-

tions available today. They indicate that the Internet has become a medium

for displaying geographical information in rich forms and user-friendly

interfaces. So, why not use the Internet to distribute geomorphological

maps and enhance their practical application? Web mapping can play a key

role in the movement towards the global dissemination of geomorphologi-

cal information. We present two examples, WebGIS and Google Earth,

and focus on the generation and display of complex symbols.

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5.1 Principles of WebGIS

A WebGIS is a common way of presenting dynamic maps online. It links

the Internet with GIS technology. The GIS processing is performed

online and maps are visualised in interactive web viewers. Although there

are many ways in establishing a WebGIS, depending on the software com-

ponents used, most applications are based on the same principles

(Figure 9.8).

The user works with a web client displayed in their Internet browser.

The client contains the demanding GIS functions (e.g. zooming or pan-

ning), compiles the map requests and forwards them to the application

server. The server passes the map requests to the mapserver, the central

software performing the GIS processing. The mapserver, having access to

the spatial data, executes the map requests and returns the maps as images

to the web server, which finally sends them back to the user’s web map-

ping client. The application acts as a web-based information system.

Another way is using a web service, for example a Web Map Service

(WMS), a software function that is accessible by a desktop GIS pro-

gramme providing direct access to the mapserver.

WMS is a widely supported, standardised protocol for accessing maps

online that contains the map request and parameters specifying GIS pro-

cessing for the mapserver, for example choice of layers or spatial extent.

The protocol standard is specified by the Open Geospatial Consortium

(OGC), a non-profit international standards organisation with members

from commercial, governmental and research organisations, including

Google and Microsoft. It is leading the developments of standards to

establish interoperability and ensures platform and software independent

frequently used protocols in web mapping, which is supported by many

open-source and commercial software (Table 9.3).

The introduction to all available software components for WebGIS

applications would go beyond the scope of this chapter. One popular

package available for Windows is Maptool’s ‘MapServer for Windows’

(www.maptools.org/ms4w/), which uses open-source components to

provide a mapserver environment including libraries for data input and

output. MapServer is GIS software running on a web server that enables

interaction with GIS data over the Internet and generates cartographic

output of geographic content. In addition, the Geospatial Data

Abstraction Library (GDAL, www.gdal.org), a powerful tool for data

translation and processing (which is used by several GIS programmes

including GRASS, and ArcGIS) is included. An introduction to the most

common WebGIS tools is given by Mitchell (2005).

Figure 9.9 shows a WebGIS that visualises the results of a geomorpho-

logical field mapping campaign in the Turtmann valley (Switzerland),

which is available online at www.geomorphology.at. The application

employs MapServer generating the maps as WMS, the spatial database

management system PostgreSQL (www.postgresql.org) maintaining the

geometries and the web mapping client Mapbender (www.mapbender.

Table 9.3 List of Several Open-Source (\*) and Commercial Software Products

Providing and Supporting the WMS Format

WMS Servers Web Mapping Clients Desktop Clients

UMN Mapserver\* OpenLayers\* GRASS GIS\*

GeoServer\* Mapbender\* Quantum GIS\*

Degree\* ka-Map!\* ArcGIS/ArcView

ArcGIS Server Mapbuilder\* ArcGlobe

ArcIMS Chameleon\* MapInfo

GeoMedia ArcGIS Explorer Global Mapper

Express Viewer Autodesk MapGuide Autodesk AutoCAD

ERDAS Apollo Server Oracle Map Viewer ERDAS Imagine

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org). Aerial images and a shaded relief map are provided as base layers and

several thematic layers present information on process domains, surface

materials, landforms and single processes. Due to MapServer’s powerful

cartographic engine, complex geomorphological symbols can be imple-

mented and displayed. Symbols based on the legend for high mountain

systems established by Kneisel et al. (1998) have been implemented. The

WebGIS map thus uses the same symbology as the printed map of the

same area (Otto and Dikau, 2004). The MapServer uses one symbol file

that defines the composition of symbols for all types of vector geometries.

Point information, such as individual landforms, is displayed using a geo-

morphological font (Otto and Dikau, 2004) and the spatial orientation of

each character is achieved by providing the rotation angle as attribute

data. Line features, for example crests and ridges, are constructed

using multi-level symbols and advanced polygon symbology is supported

by hatching or image fills. The Turtmanntal WebGIS offers simple func-

tionality of a desktop GIS such as spatial navigation, coordinate queries,

length and area calculations as well as selection of single layers of informa-

tion. The composed image of the map frame can be exported in high-

resolution PDF (300 dpi) in A4 and A3 landscape or portrait orientation.

For educational purposes, a glossary delivers definitions of geomorpho-

logical terms.

Figure 9.9 The graphical user interface (GUI) of the geomorphological WebGIS

application Turtmanntal (Universities of Salzburg and Bonn, available at www.

geomorphology.at).

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The WMS online resources are accessible through an export tool and

the maps can be embedded in other web or desktop GIS applications, thus

the Turtmanntal WebGIS provides geospatial services as well. Figure 9.10

shows different applications of the same WMS services viewed in the origi-

nal WebGIS application (a), as an overlay on Google Maps data in a web

mapping application hosted on another server (b) and finally in two

desktop GIS programmes, ESRI’s ArcMap (c) and Quantum GIS (d), both

supporting the WMS format as a data source.

The WMS protocol enables the easy implementation and integration

of distributed WMSs from different servers and so the collection of huge

“own data” pools becomes unnecessary. For simple visualisation of geo-

morphological data, a public WMS serving aerial photographs could be

used as a base layer that is overlain with the WMS delivering the mapping

results to produce the online geomorphological map (Figure 9.11).

(a) (b)

(c) (d)

Figure 9.10 An OGC-compliant WMS service in different web and desktop applica-

tions. (a) The original WebGIS application Turtmanntal (available at www.geomor-

phology.at), (b) as a WMS overlay on Google Maps data using the javascript library

OpenLayers as web mapping client, (c) the WMS as data source in ArcGIS and (d)

Quantum GIS.

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We believe that the value of geomorphological data increases the

more it is linked to other available information. Geomorphologists should

consider the opportunity to present and share their data in a way users

can easily tie to other data sources.

5.2 Maps in Google Earth

Google Earth is a free and convenient desktop application available for

Windows and Mac OSX offering high performance access to global geo-

graphic data. The software provides an easy-to-use interface to a variety

of data. Base data in Google Earth is the same as in the browser-based

Google Maps application. A major difference lies in the way maps can be

viewed and manipulated. Google Earth enables Earth image browsing in

a three-dimensional view on a virtual globe (Brown, 2006). Butler (2006)

noted Google Earth’s popularity to a growing number of scientists is due

to its excellent background imagery and the ability to place spatial data

on top of them. However, Google Earth has only limited analytic func-

tions and it is not designed to replace professional GIS software. A tool

like Google Earth increases researchers’ awareness to explore more

powerful GIS techniques due to its easy visualisation (Butler, 2006).

Google Earth uses the keyhole markup language (KML) to manage

three-dimensional spatial data and also supports WMS as image overlays

turning the application into a WMS client.

KML, also an OGC standard, enables the organisation and exchange

of vector geometries. Numerous tools, such as GDAL, are available for

data translation into KML. KML handles each type of vector geometry

differently; however, advanced visualisation by complex symbology is

(a) (b) (c)

Figure 9.11 A map based on distributed WMSs from different servers (a) Orthophoto

WMS of the Bavarian Survey Administration showing the Reintal basin, Bavaria,

Germany (WMS available at http://www.geodaten.bayern.de/ogc/getogc.cgi?), (b)

WMS displaying the spatial distribution of sediment storages in the Reintal basin

(available at www.reintal-webgis.de) and (c) the final map.

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limited. Point symbols are displayed as images, which enables a more

complex symbology although data specific rotation is not possible. Line

features are simply displayed with additional specifications of line width

and colour, but multi-level symbols are not supported. Polygon features

only support simple colour fills, with no hatching or patterned fills, and

the style for polygon perimeters is the same as for line symbols

(Figure 9.12). This restricts the use of KML for complex geomorphic fea-

ture visualisation and limits its suitability for the dissemination of geomor-

phological maps. As a rule of thumb, one should keep the symbology for

a KML file as simple as possible (see Chapter 8 for further discussion on

spatial data formats).

One possible method to distribute geomorphological maps for Google

Earth is to display the map as an image overlay. The image is exactly posi-

tioned on Google’s virtual globe by a bounding box. A single image will

only be displayed at the scale the image was created and zooming will

deliver blurred data. The best performance is achieved if the image is

served as a network link through a WMS. The image is refreshed after

each navigation task and delivers high resolution at different scales. The

WMS map request can be embedded in a KML file and stored on a local

hard drive. In addition, the use of Google Earth as a WMS client allows

the display of additional information from any publicly available WMS.

(a) (b)

Figure 9.12 WMS overlays and the corresponding KML files in Google Earth. (a)

Geomorphic features as WMS overlays in Google Earth. This lesser known feature

allows the display of any publicly available WMS. The WMS appears as an image

overlay that is refreshed after each navigation task. (b) The same data as a KML layer,

the KML file was generated using the GDAL/OGR tool (GDAL, www.gdal.org).

Compared to the WMS overlays, more sophisticated symbology like hatching, multi-

level symbols or symbol rotation is not supported within the style reference of KML.