High-Quality Cartography in a Commodity GIS: Experiences in Development and Deployment

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ABSTRACT
Traditionally, Geographic Information Systems (GIS) were not noted for the cartographic quality of their map outputs. As such, GIS tended not to be used for the final map output stages of the workflows of major national mapping agencies or commercial map publishers. However, recent developments in the ESRI ArcGIS product suite have introduced powerful new facilities for database-centered cartographic production, capable of generating map outputs at visual quality levels comparable with those from specialized cartographic software or high-end professional graphics packages, while retaining the advantages of efficiency, consistency and automation arising from use of the GIS database. This paper describes the concepts and architecture of this new GIS-based cartographic workflow and illustrates the cartographic capabilities with visual examples. It then analyses gains and challenges involved in developing and deploying this new technology.

1 INTRODUCTION

1.1 Historical Context

For over 40 years, Geographic Information Systems (GIS) have developed to be a powerful and proven way to collect, store, and analyze geographic data [Longley et al 2005]. Such systems have also been used in workflows to produce cartographic products including maps and mapping datasets. For over 30 years, a primary trend in GIS has been to hold key data in a central relational database. However, existing map production systems built on GIS databases have failed to gain full benefit of relational database technology, mainly because most systems stored geographic information—geometry and attributes—in the relational database, but stored map definition and symbolization information in separate files. Also, map symbolization was accomplished by applying symbology to sets of categorized features, a system that is seen by many cartographers as being too restrictive in not allowing one to interactively change individual cartographic graphic representations.

1.2 GIS Cartographic Technology

This state is now changing, with the appearance in the market of GIS software specifically developed to meet production cartographic requirements, centered on a relational database holding cartographic information in the form of dynamic symbolization and geometry processing rules tightly coupled with the GIS data in the database. The representation of features is achieved initially by applying these sets of rules without manual intervention. If the cartography is particularly demanding, the system then affords the cartographer the freedom to intervene and override any individual representation to achieve the desired cartographic appearance. Such overrides can include changes to symbolization as well as to geometry, and provide the artistic freedom to counterbalance the rigor of the database-driven automation rules [Hardy et al 2005].

2 DATABASE-CENTERED WORKFLOW

2.1 Transactional workflow

In the new world of GIS cartography, the geodatabase lies at the center of a transactional workflow (see figure 1 below), in contrast to the linear pipelines of conventional map production.

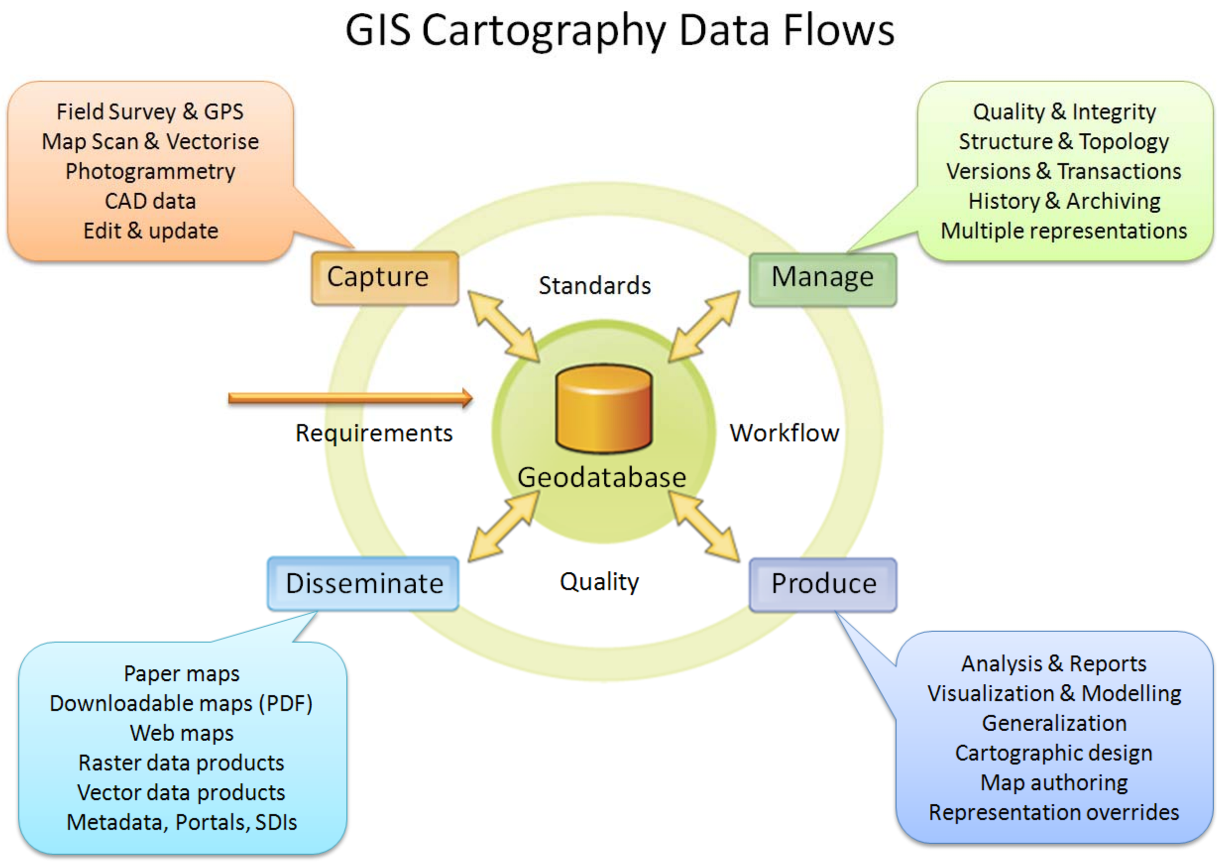

Fig 1 – Data Flows in GIS Cartography Production Workflow

2.2 Database Cartography Data Flows

In figure 1, the four main aspects of 'Capture', 'Manage' 'Produce' and 'Disseminate' all feed, nurture and exploit the live data in the central shared geodatabase.

- The 'Capture' quadrant is responsible for gathering and updating the master geography – the 'Digital Landscape Model' or DLM.
- The 'Manage' quadrant builds and maintains the data schema, handles changes through time, and improves and enforces data quality.
- The main cartographic design and map authoring tasks take place in the 'Produce' quadrant, which includes the creation of the cartographic representation rules for multiple cartographic representations, and their overriding for cartographic freedom. Along with analysis,

modeling and generalization to create derived data, these generate the 'Digital Cartographic Model' or DCM.

- The 'Disseminate' quadrant includes the outward-facing aspects – provision of visual map products in all the necessary media, both hardcopy (paper) and softcopy (PDF downloads or web mapping). It also includes the higher level metadata, search and portal technologies that can position GIS cartography at the heart of a spatial data infrastructure (SDI).

3 CARTOGRAPHIC REPRESENTATIONS

3.1 Database Stored Representations

A key aspect of the new GIS cartography is the storing of cartographic representations in the geodatabase, tightly coupled to the feature data of the DLM. Adding a cartographic representation to an existing feature class adds two more columns to the database table (figure 2). The first field (the Rule ID) is an enumeration saying for each feature which representation rule to use. The second field (Override) is originally empty and will only get populated if the override mechanism is used, as described in section 3.3 below. A feature class can hold multiple representations, each with two columns, to allow the generation of different cartographic products using the same feature data, such as topographic maps, tourist maps and town plans.

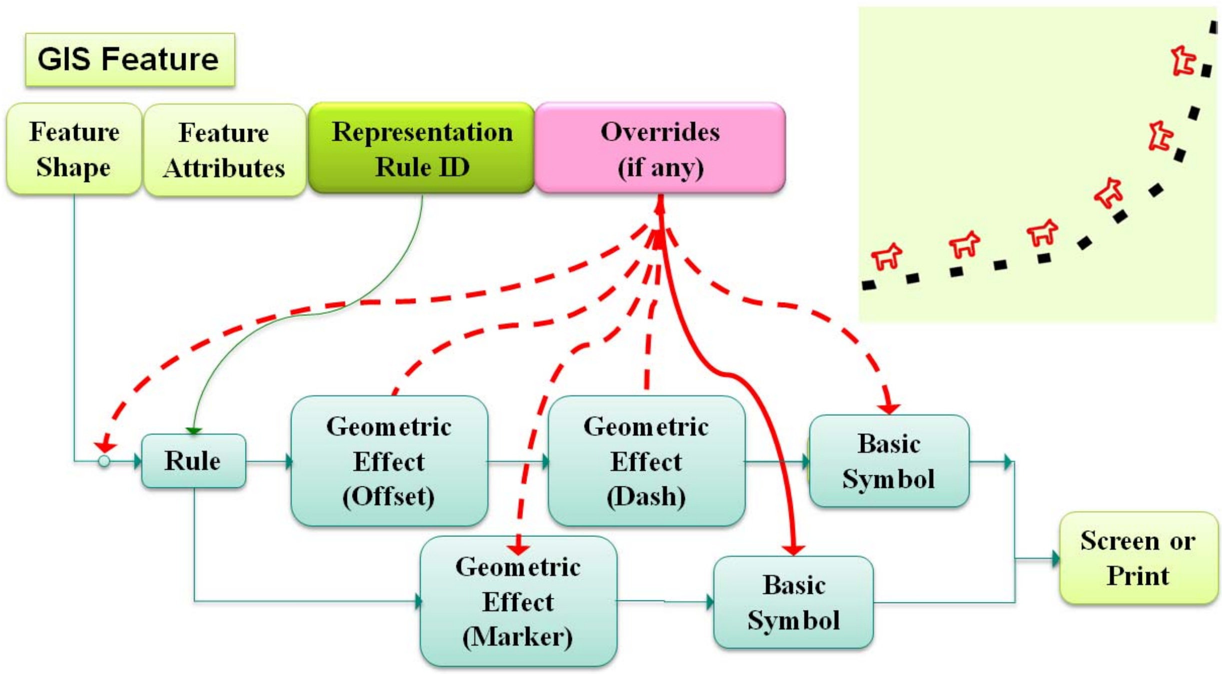

Fig 2 – Representation storage and rule execution

3.2 Representation Rules

The representation rules are also stored in the database, in system tables. They are exposed through a graphical user interface (see Figure 3) to allow easy and intuitive definition and refinement of the visual appearance (symbology), either to meet a demanding existing cartographic specification, or to push the frontiers of mapping to create exciting and rewarding new cartographic styles.

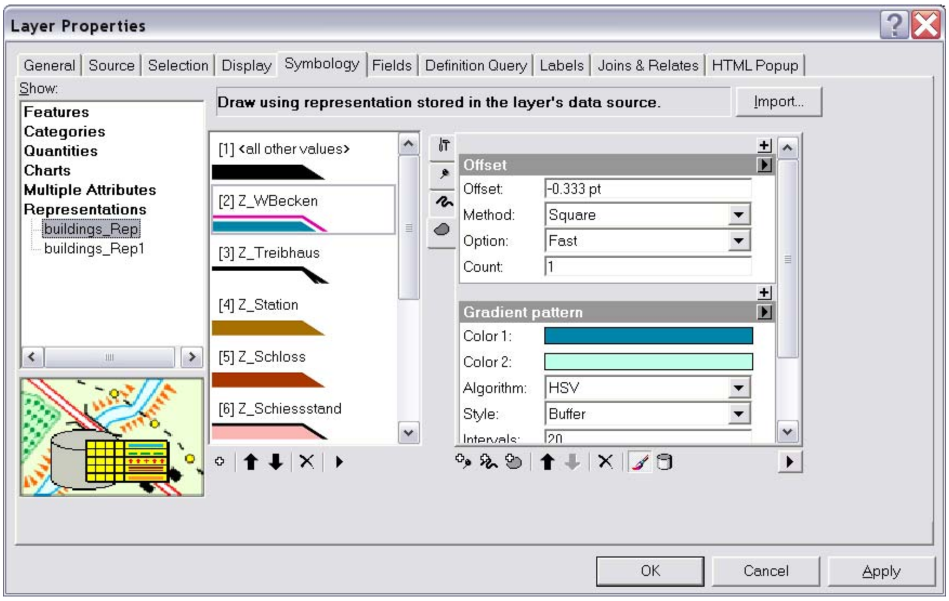

Fig 3 – User interface for rule definition – offset effect then gradient fill, plus line and marker

A single representation rule can re-use the feature shape geometry multiple times, passing it through one or more ‘geometric effects’ to cartographically enhance the appearance before invoking stroke, fill, or marker symbols. In the example used in figure 2 (of a racetrack), the rule takes the original center line geometry, and uses it twice, once to place animal marker symbols along the path, and once with an offset effect to displace it sideways before applying a further ‘dash’ effect to produce the desired offset dashed line.

3.3 Overrides

One design goal of the representations mechanism was that the automated symbolization available through the rules, effects and symbols should be sufficient to achieve 99% of the required cartographic appearance, without intervention on particular features. However, there are often cases where to achieve clarity it is necessary to break the general rule in a special context (e.g. in a corner of a map sheet). Also for some kinds of mapping, there are situations where the cartographic presentation is dependent on combinations of features (e.g. two administrative polygons sharing a common boundary). To allow the cartographic freedom to override the rule in these cases, a mechanism for exceptions is provided which uses the ‘override’ field to store per-feature changes to the standard representation arising from applying a particular rule.

Overrides can affect any of the graphical properties of the symbol – color, width, size, or cap style. They can also affect any of the parameters to geometric effects, such as offset distance, dash length, or radial angle. Finally, the override field can store an alternative feature shape (display geometry), to be used just for this representation. In the example in figure 2 above, the color of the animal marker has been overridden to change it from black to red.

These exceptions can be made interactively, using a user interface designed specifically to suit the cartographer, containing tools familiar to users of desktop graphics packages such as Adobe Illustrator or Freehand. In addition, there are various geoprocessing automation tools which can set overrides on features, such as ones to set line cap style for dead-end roads, or to identify shared boundaries for synchronization of dash patterns.

3.4 Representation Markers

In addition to stroke (line) and fill (area) styles, the cartographic representation mechanism provides a versatile marker symbol capability, with an in-built marker editor (figure 4) for the design and amendment of cartographic symbols. Markers are drawn using a similar mechanism to that for cartographic rules, so can make use of many of the same geometric effects and fill and line styles, including color gradient fills.

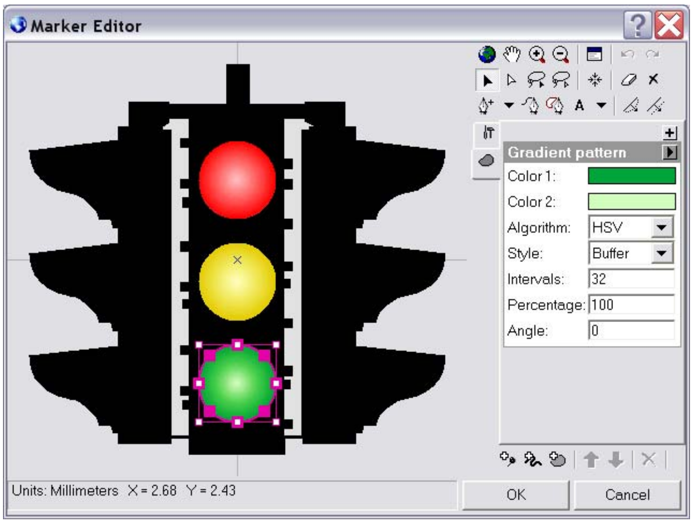

Fig 4 – Marker editor- modifying shape or gradient fill of symbol part

3.5 Free Representations

The combination of representation rules and overrides for exceptions should satisfy the needs of all but the most demanding of cartographers, and provides efficient, consistent and economic map production. However, for some specialist kinds of mapping, cartographers have traditionally used graphic design programs such as Adobe Illustrator, that allow ultimate human freedom in graphic presentation.

So, the new cartographic representations mechanisms include a further capability, to take a particular feature with its rule and any overrides, and capture it into a ‘free representation’ (again stored in the override field), which can then be edited graphically as if it were a representation marker symbol. This allows ultimate freedom to the human cartographer – to delete, resize, or reposition individual dashes of a dashed line, or individual markers in a marker fill pattern, or to add new strokes and fills to invent a new visualization for a special ‘one-off’ case (see figure 5).

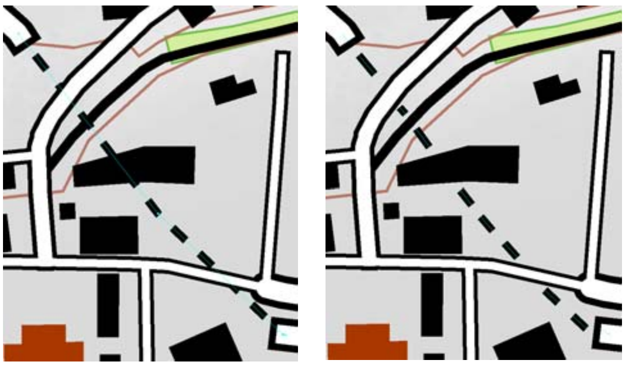

Fig 5 – Free representation: repositioning dashes of a tunnel line for maximum clarity

4 AUTOMATIC TEXT AND LABEL PLACEMENT

4.1 Cartographic Labeling

The text content of mapping products is very important to visual clarity and understanding of the spatial context. Traditionally, texts on maps have been entered and placed by hand – a time-consuming and laborious process. In the new world of database-driven cartography, texts can be generated from database feature attributes, and placed on the map by specialist label-placement software to minimize conflicts.

4.2 Maplex

Maplex is the advanced label placement engine available with ArcGIS. It is now available not only in desktop, but also in ArcGIS Server, making possible high-quality on-demand map production (e.g. as PDF, tailored to particular area of interest and content), as well as clear and communicative web-mapping.

In the past, automated text placement capabilities were limited to individual map sheets. However, web-mapping users are used to panning across vast maps without seams, and hence the ArcGIS text placement infrastructure has been re-engineered to cope with generating and placing texts over enormous continuous datasets covering whole countries or continents.

For more traditional paper sheet or atlas page mapping, the refined algorithms of Maplex combined with the power of modern desktop computers can fit more texts, faster, more clearly and with less conflict than ever before.

4.3 Deployment

The cartographic publishers HarperCollins, who do many well-known products such as the Times Atlas, have deployed Maplex to do automatic placement of the labels on their mapping. In the case of typical city maps, such as the sample in figure 6, the gain in throughput over the previous manual placement process was approximately ten-fold.

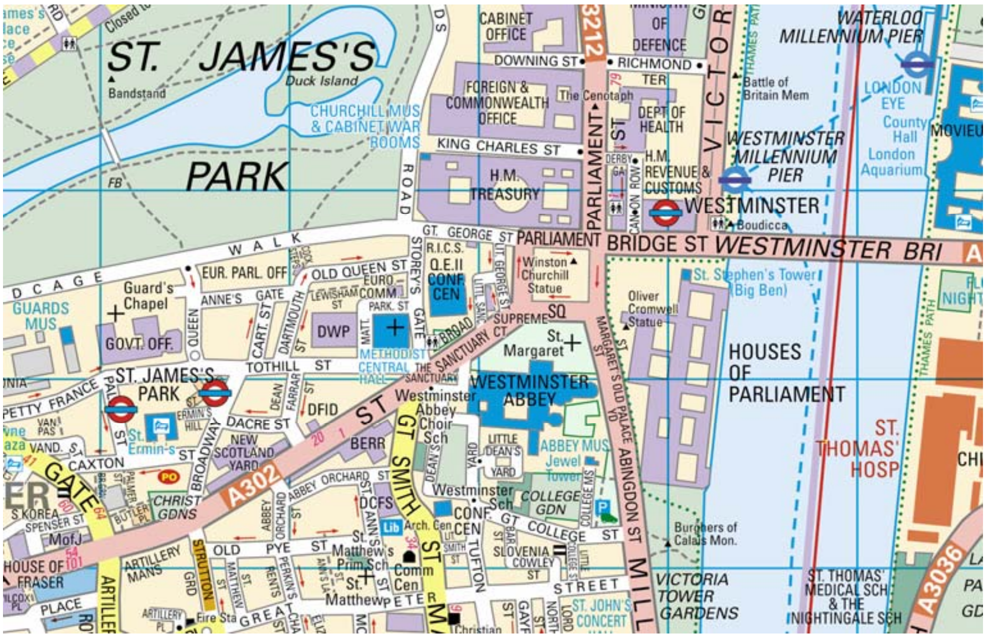

Fig 6 – Automatic label placement with Maplex (Copyright HarperCollins Publishers 2008)

5 DEPLOYING GIS CARTOGRAPHY

5.1 Swisstopo Use Case

The Swiss Federal Office of Topography (Bundesamt für Landestopografie), known as 'swisstopo', is the national agency responsible for geographical data and map products in Switzerland. As well as creating and maintaining the basic geodetic, topographical and geological data for the whole country, swisstopo also publishes and updates the internationally renowned Swiss national topographical map series at a variety of scales.

Swisstopo is currently completely changing how it produces geographical data and maps. In the past, the Swiss vector data was created by digitizing the existing paper maps, which already contain abstraction and generalization. The maps themselves were maintained in a graphical editing system with little or no knowledge of geography. Now, swisstopo is moving to a model (see Figure 7) in which a 'true-to-ground' 3D DLM called the Topographic Landscape Model (TLM) is built and maintained in a database by a system called TOPGIS, using ESRI technology. From this TLM is derived a series of abstracted Digital Cartographic Models (DCM). From the DCMs are then generated the extremely high-quality Swiss visual map products, in traditional paper form, but also in digital formats for use in customers' computer systems.

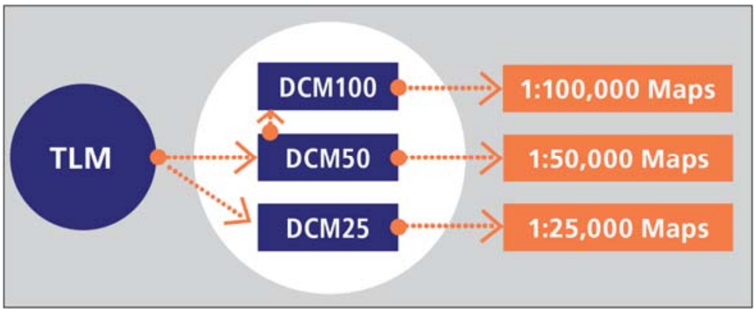

Fig 7 – Swiss TLM to DCM dataflow (Copyright swisstopo 2008)

Genius-DB is the cartography system for the generation, administration and maintenance of the DCM data. This is built on ESRI ArcGIS Desktop, and takes advantage of the cartographic representations technology that was new in ArcGIS 9.2. A third party system (SYSDAB) is involved in generalization for scale change between the TLM and the various DCM resolutions.

A set of DCMs is built, corresponding to the various map scales of the Swiss national map series. To support the cartographers' work, especially in handling future changes (incremental updates), relationship links are maintained between TLM and DCM features. Multiple map products are then created from DCM data, the most important being the famous national topographical map series (Figure 8). The visualization of the DCM database to create map products makes extensive use of the cartographic representation rules and overrides to achieve the demanding Swiss cartographic design specifications.

The initial priority for deployment of database-driven cartographic production is the DCM25 and the resultant 1:25K topographic map series. The out-of-the-box functionality of ArcGIS Desktop has been extended by ESRI Switzerland for swisstopo using the ArcGIS customization framework. This has added custom editing tools, quality control processes and attribute interfaces that are specific to the Swiss data model, as well as defining and refining appropriate representation rules.

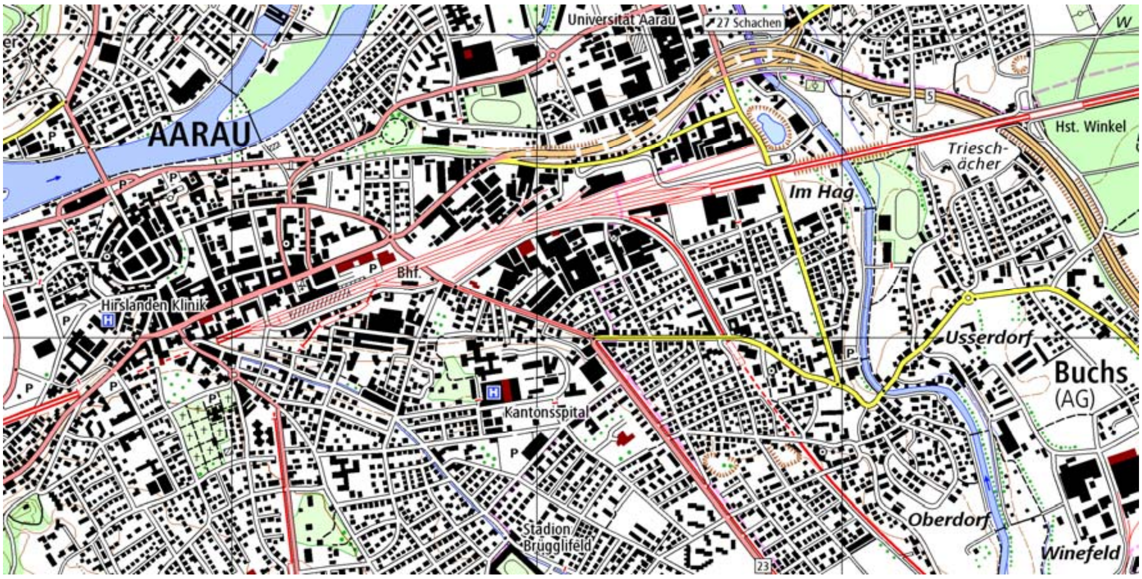

Fig8 – Swiss database-driven cartography using cartographic representations (Copyright swisstopo 2008)

6 CONCLUSIONS

- GIS software and database technology have recently gained powerful capabilities for cartographic production, capable of generating and maintaining high-quality map products.
- The database-centered cartographic production paradigm avoids the traditional multiple linear workflows, and allows the 'capture-once, use many times' dream to become reality.
- GIS cartography provides advantages of efficiency, consistency and automation arising from use of the database and data model, software toolset and process models.
- Automated text and label placement within a GIS has reached maturity and can provide many-fold gains in efficiency and consistency over traditional manual placement.
- The combination of cartographic representation rules with the override mechanism provides the efficiency and consistency of automation, together with the freedom of the artist or designer, to satisfy both the data manager and the cartographer.

7 REFERENCES

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