Chapter 2
Map Specifications and User Requirements

**Sandrine Balley, Blanca Baella, Sidonie Christophe, Maria Pla,
Nicolas Regnauld and Jantien Stoter**

Abstract In traditional generalisation flow lines, the target map is specified upstream, manually, by cartographers and is intended to answer generic, well-identified user needs. In the emerging context of on-demand mapping, maps have to be derived automatically for users whose requirements are not known in advance, and who may need to integrate their own data. The definition of suitable target map specifications thus becomes part of the service, which raises challenges that are explored in this chapter. The first challenge is to set up a formal map specifications model, rich enough to guide the whole map derivation process. The second challenge is to collect requirements and to assist the user, who is not supposed to be a map designer, in the specification of a map usable for their task and one that respects cartographic standards.

S. Balley (✉) · N. Regnauld
Ordnance Survey Great Britain, Southampton, UK
e-mail: Sandrine.Balley@gmail.com

N. Regnauld
e-mail: Nicolas.Regnauld@1spatial.com

B. Baella · M. Pla
Institut Cartogràfic de Catalunya, Barcelona, Catalonia, Spain
e-mail: Blanca.Baella@icc.cat

M. Pla
e-mail: Maria.Pla@icc.cat

S. Christophe
Laboratoire COGIT, IGN, Saint-Mandé, France
e-mail: Sidonie.Christophe@ign.fr

J. Stoter
Delft University of Technology and Kadaster NL, Delft, The Netherlands
e-mail: j.e.stoter@tudelft.nl

2.1 Introduction

Using current generalisation solutions, it is possible to derive a considerable range of different maps and datasets from the same database. This potential is still under-exploited (Mackaness et al. 2007). If generalisation could be more flexible it could adapt to various needs depending on the context of use.

The idea of adaptive generalisation was first studied to enable advanced location-based services (Reichenbacher 2004). Here, maps have had to adapt to new, but well-defined parameters defining user requirements: taking account of the user's location and mobility, the screen size and resolution, and the user's task (Sarjakoski and Nivala 2005). A demonstration of this was done by the EU-funded GiMoDig project (Sarjakoski and Sarjakoski 2007), with the first prototype of adaptive generalisation in a mobile context. Beyond location-based services, in the wider domain of web cartography, user requirements are more diverse and their description is a key research topic, as illustrated by the working groups on usability, map use and user issues (at Agile[1] from 2001 to 2006, at ICA[2] since 2005).

On-demand mapping is the research domain that seeks to derive automatically maps tailored according to expressed user requirements. Although some aspects of on-demand mapping have been studied and some prototypes designed (Cecconi 2003; Jabeur 2006; Sarjakoski and Sarjakoski 2007; Foerster et al. 2010; Christophe 2011; Balley et al. 2012), the whole issue remains a to-be-solved, cross-domain puzzle (Balley and Regnauld 2011). This chapter focuses on one of the challenges of on-demand mapping, which is the acquisition and interpretation of the user's needs in order to specify a usable target map. Another challenge lies in the automatic design and orchestration of the target map's derivation process, in particular the generalisation part of it (Chap. 7).

On-demand mapping can provide an answer to an increasingly common activity, namely creating a cartographic mash-up. A mash-up is a map combining cartographic layers from different data sources. As in Fig. 2.1, mash-ups are often composed of a background topographic layer (accessed through the API of a major provider such as a national mapping agency, Google or OpenStreetMap), and of a user-generated, thematic layer in the foreground. Mash-ups are prone to legibility issues for two main reasons. Firstly, since the data currently available online to the general public is not customisable, the content and legend of the background layer cannot be adapted to the foreground layer. In the example in Fig. 2.1, this results in a too dense road network and unnecessary topographic features (such as the details associated with the parks). Secondly, mash-ups often fail to depict the spatial and semantic relationships between themes (Jaara et al. 2012). In our example, the map does not clearly indicate that cycle facilities *follow* roads and that some cycle support services are *associated with* the roads. Instead, cycle

---

[1] http://www.agile-online.org/, accessed 28 May 2013

[2] http://icaci.org/commissions/, accessed 28 May 2013

facilities appear as standalone entities and over-dominate the roads. Highlighting
relationships between themes requires conflation tools and map design skills that
cannot be expected from every mash-up author. The idea is that such tools could
be embedded in an on-demand mapping system in the future. One of the chal-
lenges for this system would be to take account of the user's inputs in terms of
their requirements (e.g. the intended map use, the nature of the thematic data and
the user's preferences), to identify the most relevant background content and inter-
theme relationships that it was important to show on the map.

This chapter focuses on the translation of expressed user requirements into map
specifications, i.e. into the formal description of a target map in terms of content
and representation. Since the state of the art is still limited, this translation is
explored not only with respect to generalisation but more generally with respect to
the whole mapping process. How to adapt the map making process to reach these
specifications is out of the scope of this chapter. Section 2.2 describes the trans-
lation process and defines the needs, requirements and specifications. Section 2.3
focuses on user's requirements, how they influence map specifications and how
they can be automatically interpreted. Section 2.4 focuses on the acquisition of
user requirements. Three Case studies are then presented. Section 2.5 presents an
initiative to collect and formalise the cartographic constraints of national mapping
agencies for a European generalisation test bed. Section 2.6 describes a research
model for map specifications dedicated to on-demand mapping including user data
at Ordnance Survey Great Britain (OSGB). Section 2.7 presents a dialogue-based
prototype from the COGIT laboratory (IGN France) that enables the automated
creation of personalised legends. Section 2.8 is an overview of the issues and
identifies future research challenges.

2.2 Key Concepts: Needs, Requirements and Specifications

2.2.1 Deriving a Custom Map: Process and Definitions

While on-demand mapping is a long-term research goal, mapping agencies do
currently deliver customised maps. Automatic services are available, but the
customisation is still limited to the spatial extent, scale, title and cover of the map.
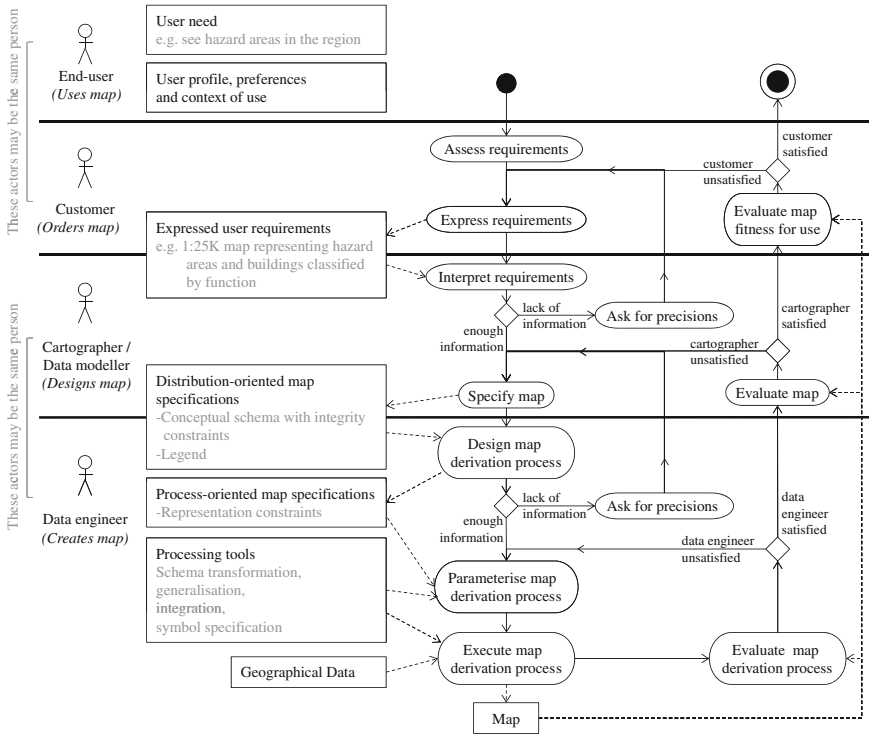
Fig. 2.2 The manual process of deriving a customised map. On-demand mapping is an automatic version of this process

With the increasing use of multiple-representation databases, these services will soon be able to deliver instant maps with different, predefined levels of detail. More flexibility can be achieved through a manual approach, represented in Fig. 2.2. Since this process is iterative and involves several actors, it is very costly and affordable to professional users only. Going through this process, this section introduces the concepts used throughout this chapter.

At the root of the process, the *end-user* (Fig. 2.2) has a *need* (e.g. to plan a trip or to carry out an analysis task) and it is assumed that they will require a map in order to answer it. The end-user also has a *profile* (i.e. a few personal characteristics such as age and nationality), some *preferences* regarding the map, and a *context* in which the map will be used (at some place, using some device—e.g. an emergency situation). The combination of these parameters is called *user requirements.* Unfortunately, the end-user is not always given a chance to express their require-ments. Instead, they are assessed by the *customer* who will order the map (the user and customer may be the same person). The customer expresses the assessed requirements to the *cartographer*, whose role will be to design a product that best fits those requirements. The expression and interpretation of requirements is typi-cally an iterative process. The cartographer progressively translates the interpreted

requirements into *map specifications*, i.e. a description of the target map in terms of information content and information representation. At this stage, these are distributed-oriented specifications: they are human-readable and informative. They are typically composed of a conceptual schema, potentially enriched with some integrity constraints that are specific to the user's need, and a legend. The role of the *data engineer*, who may be the same person as the cartographer, is to create and run a map derivation process including the choice of source data, content selection, restructuration, generalisation, integration and symbolisation. By examining the specifications, and requesting clarifications from the cartographer if required, the data engineer creates *process-oriented map specifications* which will be used to parameterise each sub-process. Unlike distribution-oriented specifications, process-oriented ones must be machine-readable and detailed enough to guide the automated parts of the derivation process. The cartographic constraints used in automated generalisation are examples of process-oriented map specifications. The map derivation is followed by an iterative evaluation process. The map is reviewed by the data engineer (who can select other tools or modify their parameters to make the output closer to the specifications), by the cartographer (who can change or tighten the specifications) and by the customer (who can express new requirements). The process terminates when the customer is satisfied.

On-demand mapping is an automatic version of the process represented in Fig. 2.2. The cartographer and data engineer are replaced by an expert system interacting directly with end-users. No distribution-oriented map specifications are required but only process-oriented ones, which play a crucial role since the map derivation process is fully automated. The next section deals with the content and formalisation of these specifications.

2.2.2 Process-Oriented Map Specifications

From this point, we will use "map specifications" to refer to "process-oriented map specifications". The next section details the content of map specifications. The following one clarifies the relation between map specifications and the cartographic constraints used in the generalisation process.

2.2.2.1 Content of Process-Oriented Map Specifications

This section lists the required content of process-oriented map specifications. It relies on proposals issued not only for generalisation, but also for data production (ISO 2005; Inspire 2008), data integration (Gesbert 2005) and legend design (Bucher et al. 2007; Christophe 2009).

Map specifications must describe the *information content* of the target map. This includes the spatial extent, the geographic concepts represented (e.g. roads and buildings), the scale (for paper maps) or scale range (for digital maps), and the

overall level of detail. In addition, for each concept represented on the map, the specifications must make explicit the entities selected for representation (e.g. for a map of car accidents: only important roads, plus roads involving a high number of accidents). This specification element provides clues as to the choice of source data, the feature selection and the generalisation process.

Map specifications must also describe the expected *geometric modelling* of concepts: (1) the primitives used, (2) the conditions under which entities must be represented as aggregates (e.g. buildings are combined if they are within 50 m of each other and collectively cover at least 1,000 m^2), and (3) the spatial relations that should occur between themes (e.g. cycling facilities *follow* roads). This information will guide the generalisation steps (e.g. collapse, aggregation) and the integration of user's data.

The *thematic modelling* of each concept must be specified, i.e. the represented properties and their domain of values (e.g. the "importance" of roads, with an enumerated domain of values: "low", "medium" and "high"). This information influences the choice of source data and may lead to some data restructuration. This information can govern a specific option for data integration, where the user's data is not displayed geometrically but is projected as new properties on the referential features (as exemplified in Sect. 2.6).

If the target product is a vector map, map specifications may include information about the expected *data schema*, i.e. the organisation of entities and their properties into feature types, attribute types and association types. This information drives possible schema transformations (Balley 2007; Letho 2007) which are part of model generalisation (Foerster et al. 2010).

The last specification element describes how represented entities should be *symbolised* on the map. The styles must be defined, possibly supported by the explicit mention of relations between themes (association, opposition or order) as defined in the theory of semiology (Bertin 1967).

From this discussion we make three observations. Firstly, every specification element may involve relationships between objects and between themes that will guide some step of the map derivation process. Spatial relations (e.g. cycling facilities *follow* roads) may strongly influence data integration and generalisation; while semantic relations (e.g. cycling facilities *are attached to* roads) may influence schema transformation and symbol specification. The modelling of spatial relations in automated environments is the topic of Chap. 3.

Secondly, map specifications must be a description of how the final map should be, and not of how it can be generated. Consequently, map specifications should not refer to any data source, derivation algorithm or implemented tool. This ensures the sustainability of map specifications independently of the evolution of data models and tools, which inevitably occurs in map production environments. This also enables reuse of specifications in different environments, (e.g. being able to create the same type of map in different countries).

Thirdly, for the same independence purpose as above, map specifications should not refer to implemented feature types but to constructs from higher abstraction levels. In standardised contexts such as the INSPIRE infrastructure,

these constructs can be feature concepts taken from a feature concept dictionary (ISO 2009). Feature concepts can be seen as interfaces for feature types proposing a meaning and a set of properties. In non-standardised contexts, where no assumption can be made on the schemas of available datasets, specifications can rely on generic feature types pointing to geographic concepts (e.g. road or city) from an ontology. Defined by Gruber (1993) as "the specification of a *conceptualisation*", ontologies of real world concepts were introduced in GIS by Fonsesca (2001) and have been used more and more intensively since then for various applications (Klien et al. 2006; Lemmens 2006; Regnauld 2007; Touya and Duchêne 2011; Gould and Chaudhry 2012; Abadie et al. 2010; Dominguès et al. 2009). The specification models proposed in Gesbert (2005), Touya and Duchêne (2011), Balley et al. (2012) refer to ontologies of topographic concepts. Because map specifications strongly rely on spatial relations, an ontology of spatial relations was proposed by Touya et al. (2012) (Chap. 3).

2.2.2.2 The Relationship Between Process-Oriented Map Specifications and Cartographic Constraints

Map specifications are a set of conditions that the on-demand map should satisfy. In the context of generalisation, such conditions have long been represented through cartographic constraints (Beard 1991; Ruas and Plazanet 1996). This section clarifies to what extent process-oriented map specifications as defined in the previous section can be formalised by cartographic constraints.

The reader should refer to Zhang (2012) and Touya (2011) for an up-to-date review of developments in cartographic constraint methodologies. Several classifications of constraints have been proposed (Harrie and Weibel 2007). Following the EuroSDR testbed of generalisation software (Sect. 2.5), Burghardt et al. (2007) produced a fine-grained classification of cartographic constraints (Fig. 2.3). Constraints are first categorised according to the generalisation goal: improving the map legibility or preserving relevant visual characteristics. They are then classified by the constrained property (e.g. minimal dimensions, topology, position, shape, etc.), by the number of objects involved, and by the geographic concept affected.

Cartographic constraints (as presented in Fig. 2.3) can express some of the specification elements listed in Sect. 2.2.2:

- The information content can be partly specified. Minimal dimensions constraints can help delimit the set of represented entities. The concepts that should not appear can be specified by removal constraints (e.g. "if the use of the building equals 'habitation', then the building should not be represented"). However, the entities that should appear cannot be specified. This is due to the fact that, in generalisation, the information content of the target map is implicitly determined by the information content of the original map.
- The geometric modelling can be partly specified by topological constraints (e.g. "no intersection between roads and buildings") and position constraints
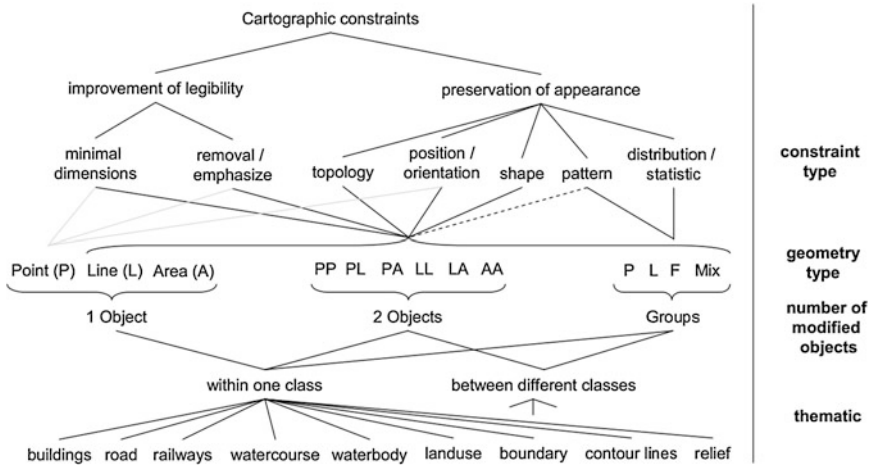
Fig. 2.3 Typology of cartographic constraints for automated generalisation (Burghardt et al. 2007)

(e.g. "cycle itineraries follow roads"). However, in their generalisation form, many of these constraints are expressed through a maximum degree of variation between original and final states. This may not be adapted to on-demand mapping, where the source data is not supposed to be known in advance.

It appears that more categories of constraints—they could be generically called representation constraints—are needed to express the other specification elements (thematic modelling, data schema and symbol specification) in order to support more of the steps in the map derivation process. The research models now presented could help fill the gaps.

Gesbert (2005) designed a model to formalise database specifications and applied it to products of IGN France. The model consists of linking database feature types with topographic concepts via four types of representation rules. Selection rules are used to determine whether or not a real world object must be represented in the database. Cutting rules state whether a real world object is represented individually or by its parts. Aggregation rules state whether a real world object is represented individually or in a grouping of similar objects. Instantiation rules indicate in which class and with which attributes a real world object and its properties are represented. The entities affected by a rule are delimited by constraints related to their nature, properties and relations to other entities. The model is used at IGN France for schema matching (Abadie 2009) and database discovery (Mechouche et al. 2013).

Bucher et al. (2007) proposed a map specification model intended for legend design that enabled the definition of relationships between themes (order, association or difference) and communication levels (e.g. a group of elements that need to be given visual emphasis). Christophe (2011) proposed a version of this model

especially enriched for the description of colours. This model is exploited in the dialogue-based system for legend design presented in Sect. 2.7.

Building upon the contributions described in this section, a map specification model based on representation constraints is being experimented with for on-demand mapping at OSGB (detailed in Sect. 2.6).

2.3 Inferring Map Specifications from User Requirements

This section deals with the instantiation of process-oriented map specifications inferred from user requirements. It investigates how to automate the activity "design map" traditionally performed by the cartographer (Fig. 2.2). Here, "user" refers to the end-user and not the customer. Section 2.3.1 analyses how the user requirements may influence map specifications. Section 2.3.2 reviews knowledge-based mechanisms that enable inference of map specifications to be made. Section 2.3.3 focuses on the knowledge required by these mechanisms.

2.3.1 User Requirements and Their Influence on Map Specifications

As defined in Sect. 2.2.1, user requirements are a combination of user needs, user profile, preferences and a context of use. We propose to further decompose these elements into "user variables". Figure 2.4 synthesises common user variables and states again, the map specification elements described in Sect. 2.2.2.

The needs of the user are determined by the task of the map user (e.g. "hiking" or "plan an itinerary"). This task determines the map topic, which in turns influences the represented concepts and their assigned symbols. For instance, a topographic map depicts the nature of the terrain features with a "neutral" legend, while a navigation map focuses on and emphasises communication networks and landmarks. The needs "visualise hazard zones" and "perform a risk analysis" call for the same map topic but for different generalisation levels (potentially going up to schematic maps) and legend choices. To perform this analysis, professional users need task-specific concepts, that sometimes do not exist generically and need to be derived (Harding 2011). They also need a suitable data schema, (e.g. one with explicit network structures).

There are as many classifications of user profiles (Fig. 2.4) as applications exploiting them. Users can be categorised according to their familiarity with maps (professional users, non-professional users, non-professional users who are novices in the use of maps), their age, gender and nationality. The user profile influences the level of detail of the map. For example, children or sight-deficient readers may need maps representing a limited number of concepts, a limited amount of objects with a high level of generalisation and/or large symbols.
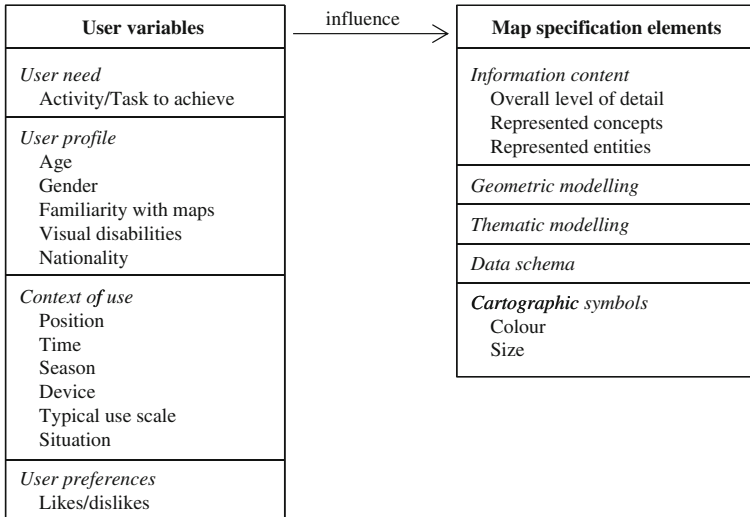
User variables		Map specification elements
	influence →	

User variables
User need
Activity/Task to achieve
User profile
Age
Gender
Familiarity with maps
Visual disabilities
Nationality
Context of use
Position
Time
Season
Device
Typical use scale
Situation
User preferences
Likes/dislikes

Map specification elements
Information content
Overall level of detail
Represented concepts
Represented entities
Geometric modelling
Thematic modelling
Data schema
Cartographic *symbols*
Colour
Size

Fig. 2.4 User variables influencing map specification elements

However, the definition of what constitutes an "expert" and its influence over the ability to interpret maps efficiently is a controversial issue (Ooms et al. 2011). Non-professional map users may be accustomed to maps displaying many different concepts (e.g. tourist maps). The profile also influences the choice of colours. For instance, as detailed in Christophe (2009), children like primary colours and European people tend to prefer different hues from North-American people. Colour-blind users need specific colour arrangements to enhance the perceived contrast (Brewer 1997; Dhée 2011).

The context of use (Fig. 2.4) refers to the place, time and situation in which the activity is carried out. If the map is needed to situate the user in a mobile context, the user's position, and more specifically the type of place they are located in (e.g. in the underground, in the city or on the mountain), influences the choice of represented concepts. The type of media (paper or digital map, screen size, battery life), time and season (for contrast reasons), influences the generalisation level and choice of colours, as studied by projects on ubiquitous mapping (Sarjakoski and Nivala 2005; Hoarau 2011). The situation variable may refer to "on-field study" versus "office study", "real time" versus "post-analysis", "standard" versus "emergency". As analysed by Duchêne et al. (2011), an emergency situation generates specific constraints on the map content—the message must be as simple as possible—and on the generalisation process itself—the map must be delivered quickly.

User preferences are the last set of variables. They enable the end-user to express direct constraints on any component of the map specifications. They must be used with caution: as pointed out by Harding et al. (2009), it is easier for users to describe what they want to do (i.e. their task or activity) than to define what geographical information they need. In addition, privileging user preferences over

the expertise of the map designer may put at risk the map's efficiency and consequently, the user's satisfaction. However, as the manual process represented in Fig. 2.2 shows, user's preferences about maps derived on-demand can help refine the system's proposition (Sect. 2.4).

2.3.2 Knowledge-Based Mechanisms Used to Infer Map Specifications

This section focuses on systems that infer personalised map specifications from user requirements. Interfaces to collect requirements are discussed in Sect. 2.4.

One approach is to first set the requirements and to follow a static reasoning process using rules. Forrest (1999) designed an expert mapping system based on this approach. The targeted maps were small scale thematic maps. The initial user inputs consisted of a map topic selected from a list (e.g. geological, industrial, topographic, etc.), a map purpose (detailed study or general overview), a user profile (naive or expert) and an output medium. Using rules and importance scores defined by the cartographer, the system proposed background themes for the user to choose from, while limiting the amount of information on the map. The system proposed a legend (number of subclasses and symbols) by taking into account the map topic, scale and level of detail. The GiMoDig system used a similar approach, but added a form of machine learning (Sarjakoski and Sarjakoski 2005): map specification templates were manually created to suit a few predefined combinations of context parameters. These templates constituted the initial knowledge base of the system. For each new combination, an inference engine was used to select and refine the template that best matched the user's parameters. In both approaches, the user was allowed to refine the system proposal, e.g. to add or remove a theme.

More sophisticated systems rely on negotiation: user's preferences and cartographic knowledge are represented as constraints that the system tries to reconcile. The process is iterative: the user can react to proposed map specifications by expressing new preferences. This approach was proposed by Hubert (2003) to translate user preferences into generalisation parameters and by Christophe (2011) to collaboratively design legends. The latter system is presented in Sect. 2.7.

2.3.3 Cartographic Design Knowledge

We call cartographic design knowledge the knowledge that enables the system to infer suitable map specifications from user requirements. This section focuses on the acquisition and formalisation of that knowledge. Expert cartographers are the primary source of this knowledge. They describe the map specifications they judge usable for certain user requirements, but also compliant with the standards of cartographic design. Usability surveys are the second source of knowledge.

They must be carefully interpreted: as pointed out by Harding et al. (2009), data usability is sometimes difficult to distinguish from the usability of systems and interfaces used to manipulate the data (Haklay 2010).

2.3.3.1 Knowledge on Information Content and Structure

Different approaches have been used to describe the ideal information content of a map or a dataset. A pragmatic option is to use templates. With ScaleMaster, (Brewer and Buttenfield 2010) provide formal guidelines for the information content of multi-scale topographic maps, and "recipes" to derive them with a minimal workload. A library of styles is defined for each scale range. When the scale is decreasing, style modifications are preferred to geometric transformations, which only occur over significant changes in scale. The ScaleMaster model was implemented by Touya and Girres (2013) to monitor automatic multi-scale generalisation. Templates can also be used to record the knowledge on data schemas (Gnägi et al. 2006; Balley 2007): data providers, using internal knowledge and users' feedback, can suggest schema profiles, i.e. useful feature types which are initially implicit, but can be derived at no cost from their products. A second option, more flexible than using templates, is to represent the knowledge in the form of an ontology. In their ontological approach to data enrichment, Lüscher et al. (2007) relate spatial and temporal context information (e.g. "urban area", "Victorian period") with potentially relevant high-level geographic structures. The system relies on ontologies of geographic and GIS concepts, and application ontologies provided by domain experts.

Only a few projects have attempted to collect knowledge directly from the end-users. Usability researchers at OSGB conducted a survey of 56 professional users (Harding 2011) and captured the information content and structure needed for their tasks. Building on the interview results and on space descriptions from non-professional volunteers, Battye (2010) tried to assess which feature types are mentally encompassed by place types at various scales (from "locality" to "country"). The extracted knowledge resulted in guidelines for the design of usable products.

2.3.3.2 Knowledge Related to Legends

Most of the knowledge currently used in legend design was enunciated by semi-ologists such as Bertin (1967) and Robinson (1952) amongst others. The Color-Brewer system (Brewer 2003) proposes predefined, harmonious ranges of colours suitable for thematic maps with qualitative, sequential or diverging classifications. The suitability of each colour range to different devices or users (printed maps, projector, colour-blind people, etc.) is indicated. In his experiments on European legends, Renard (2008) asked cartographers to characterise 19 legends applied to the same three sample datasets. The result was a knowledge base where each legend is labelled with the themes it best suits (e.g. roads or habitation), the kind of

zone it best represents (e.g. urban, rural or mountainous area), and also the general feeling it conveys. This study was building upon a corpus of emotional terms (e.g. rich, luminous, sober or happy) created through a user survey (Dominguès and Bucher 2006). It was used to characterise a collection of legend samples based on different colour schemes. The knowledge base and legend samples were used in an on-demand mapping prototype described by Jolivet (2009).

2.4 Collecting User Requirements

The previous section presented some solutions to the challenge of inferring map specifications from user requirements. This section discusses interfaces suitable to acquire these requirements. It focuses on the activity "express requirements" represented in Fig. 2.2, traditionally performed by the customer at the beginning of the process and during the evaluation phase. On-demand mapping would enable any end-user to express their own requirements, but it would require more support than currently provided. As a matter of fact, most map design wizards are essentially collecting specifications. This is feasible for simple maps if the background data is predefined and requires limited processing. Examples are provided in Sect. 2.4.1. Section 2.4.2 focuses on more sophisticated systems that require detailed process-oriented map specifications. It is important that intuitive solutions can be found that readily allow the user to influence these specifications.

2.4.1 Specifying a Thematic Map Through Contextual Menus

More and more services enable users to map thematic data over contextual data. Two types of integration services are available.

In the first type, some thematic data are projected on referential objects through a gazetteer. With a minimum of guidance, users can choose the background themes, select thematic data or upload their own data. Textual menus and cursor selection can be used to select which attributes and classes of values will guide the thematic classification. GeoCommons[3] and Geoclip[4] are examples of such services.

In the second type, the thematic data are simply overlaid on the contextual background. If no geometric adjustment is performed, users can simply set some of the user variables listed in Fig. 2.4 through menus and checkboxes, and let the system do the rest. If a geometric adjustment was performed, interfaces would be

---

[3] http://geocommons.com, accessed 28 May 2013.

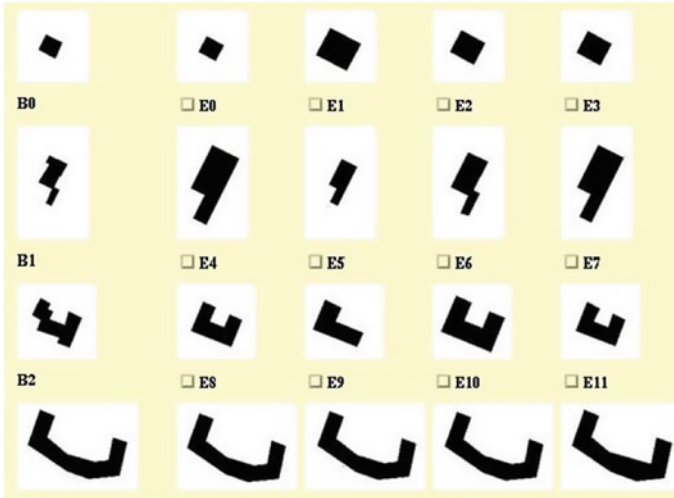[4] http://www.geoclip.net, accessed 28 May 2013.

Fig. 2.5 Extract of a dialogue interface to adapt generalisation constraints to user preferences (Hubert and Ruas 2003)

required to let the user choose their reference objects and the spatial relations that must be satisfied. Such services are being investigated (Jaara et al. 2012) but no interface has yet been fully specified.

2.4.2 Collecting Preferences Through Map Samples

Unlike other user variables, user preferences are difficult to collect through contextual menus because they may relate to specification elements that are difficult to conceptualise. Being able to visualise the influence of these elements on a map is much more intuitive and easy to comprehend. This section reports on proposals whereby user preferences are collected through map samples, in order to help the user see what the resulting map would look like.

Hubert et al. (2003) designed a dialogue engine enabling non-generalisers—but still experienced map makers—to influence the cartographic constraints used by a generalisation process, and consequently the geometric modelling of entities on the map. In the implemented case study, the system and the user tried to reach an acceptable solution for the generalisation of buildings. In this dialogue, the user and the system were communicating through map samples and simple natural language statements:

- The system proposed a list of map samples representing an initial building set and their generalised counterparts (Fig. 2.5). Each generalised sample was internally associated with the parameters of the cartographic constraints used to generalise it.
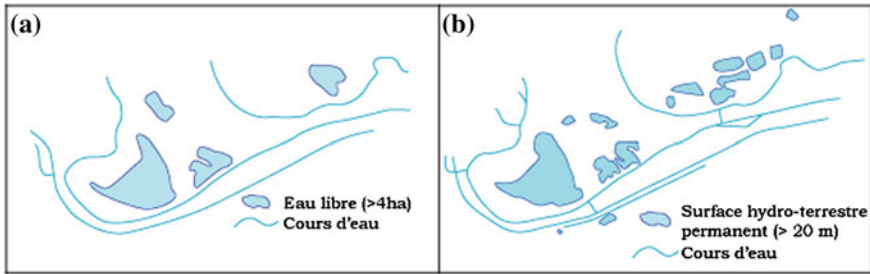
Fig. 2.6 A web interface using feature examples to explore databases specifications (Gődér 2003). IGN France BDTopo® (**a**) and former BDCarto® (**b**) represent hydrographic features with different selection criteria

- The user was reacting either by selecting one or several map samples, or by commenting on them (e.g. "too big", "too square"). These comments led the system to choose other combinations of parameters and present the associated map samples.

Another dialogue engine based on map samples for legend design, and more specifically for the choice of colours, is described in Sect. 2.7 (Christophe 2011).

The shape of objects and the colour of symbols are only part of the specifications required for on-demand mapping. More example-based solutions need to be imagined to allow users to express preferences influencing the information content, geometric and thematic modelling, data schema and other legend variables. For example, in Fig. 2.6, data samples are used to illustrate differences in the selection of entities between two databases (Gődér 2003).

2.5 Case Study I: Specifying Generic and Specific Map Specifications—A EuroSDR Case Study

Jantien Stoter, Blanca Baella and Maria Pla

The previous sections explained the process of deriving map specifications for automated generalisation from user requirements. This section explains how this was realised within a EuroSDR project.

The EuroSDR project on the state-of-the-art of automated generalisation software was a cooperative project of Universities, NMAs and private industry across Europe (Stoter et al. 2009a, 2010). The main objective of the project was to study the state-of-the art of currently available commercial generalisation software packages, examining their capabilities at generalising a complete map. The map specifications were defined by the NMAs and harmonised before use. Additionally, the project sought to gain insight into other issues, such as how to specify

requirements for generalisation, how do generalisation processes work, how to set up a case to study the-state-of-the-art in generalisation, and how to perform evaluation of generalisation output. Evaluation aspects are covered in detail in Chap. 9.

Between June 2007 and Spring 2008 tests were performed by project team members (from NMAs and research institutes) on out-of-the-box versions of four generalisation systems: ArcGIS (ESRI), Change/Push/Typify (University of Hanover), Radius Clarity (1Spatial) and axpand (Axes Systems). At the same time the vendors carried out tests with the same test cases with improved and/or customised versions of their systems.

This section presents the approach employed in the EuroSDR project to define a shared model of generalisation constraints. This requirements analysis (carried out in 2006/2007), resulting in generic and NMA-specific map specifications, consisted of four steps:

- Selection of test cases representative of typical generalisation problems (Sect. 2.5.1).
- Formalisation of NMA map specifications for automated generalisation (Sect. 2.5.2).
- Harmonisation of the specifications resulting in one generic set of NMA map specifications within the context of the study (Sect. 2.5.3).
- Analyses of the defined specifications to learn more about similarities and differences between map specifications of NMAs (Sect. 2.5.4).

2.5.1 Selecting the Test Cases

The first step in the requirement analysis was the selection of test cases representing problems for automated map generalisation. To meet this objective, the EuroSDR project team generated a list of outstanding map generalisation problems based on the OEEPE research (Ruas 2001) complemented with the research team's own experiences. Examples of these problems are: building generalisation in urban zones, mountain road generalisation, solving overlapping conflicts in locally dense networks, pruning of artificial networks, and ensuring consistency between themes in particular areas such as coastal zones. Some of these problems have been tackled in research, resulting in at least partial solutions. However, the EuroSDR project wished to evaluate complete solutions in commercial systems, and, therefore, these problems were also identified as representative map generalisation problems. Four test cases were selected that included all these problems (Table 2.1). The test cases were provided by Ordnance Survey Great Britain (OSGB), Institut Géographique National (IGN France), The Netherlands' Kadaster (Kadaster) and Institut Cartogràfic de Catalunya (ICC).

Table 2.1 Test cases selected for the EuroSDR research

Area type	Source dataset (k)	Target dataset (k)	Provided by	No. of feature classes	Main feature classes
Urban area	1:1250	1:25	OS Great Britain	37	Buildings, roads, river, relief
Mountainous area	1:10	1:50	IGN France	23	Village, river, land use
Rural area	1:10	1:50	Kadaster, NL	29	Small town, land use, planar partition
Coastal area	1:25	1:50	ICC Catalonia	74	Village, land use (not mosaic), hydrography

The NMAs modified their test datasets to prepare them as input for the generalisation tests. For example, details such as rich classifications were removed from the datasets and the datasets were translated into English. In addition, to be able to define specifications of the output maps with respect to symbolised objects and to assure uniform outputs, the four NMAs defined symbols for the output maps. Figure 2.7 shows samples of the source datasets. These inputs differ slightly with the original datasets and symbols as used in production, since they were adjusted (i.e. simplified) for the project.

2.5.2 Formalisation of NMA Map Specifications for Automated Generalisation

In the task of formalising map specifications for automated generalisation, the EuroSDR project distinguishes between two stages. The first stage is to describe the specifications in a way that the users (in this case the testers of the systems) fully understand what they should try to obtain from the system. The second stage is to translate these specifications in a format understandable by the generalisation system. The first stage was completed by means of cycles between the data providers and the research team. The testers completed the second stage during the test process.

To implement research theories, NMA map specifications were defined as a set of cartographic constraints that had to be respected. As mentioned in the theoretical part of this chapter, the use of constraints is a common method for defining specifications and to control and evaluate the automated generalisation process. Constraints express how generalisation output should look without addressing the means—for example the sequence of operations—by which this result should be achieved.

A template was developed for a uniform definition of the constraints in the four test cases. In the template, specific properties of the constraint can be defined such as conditions that must be respected and the geometry type and feature class(es) to which the constraint applies (Table 2.1). The template distinguishes between
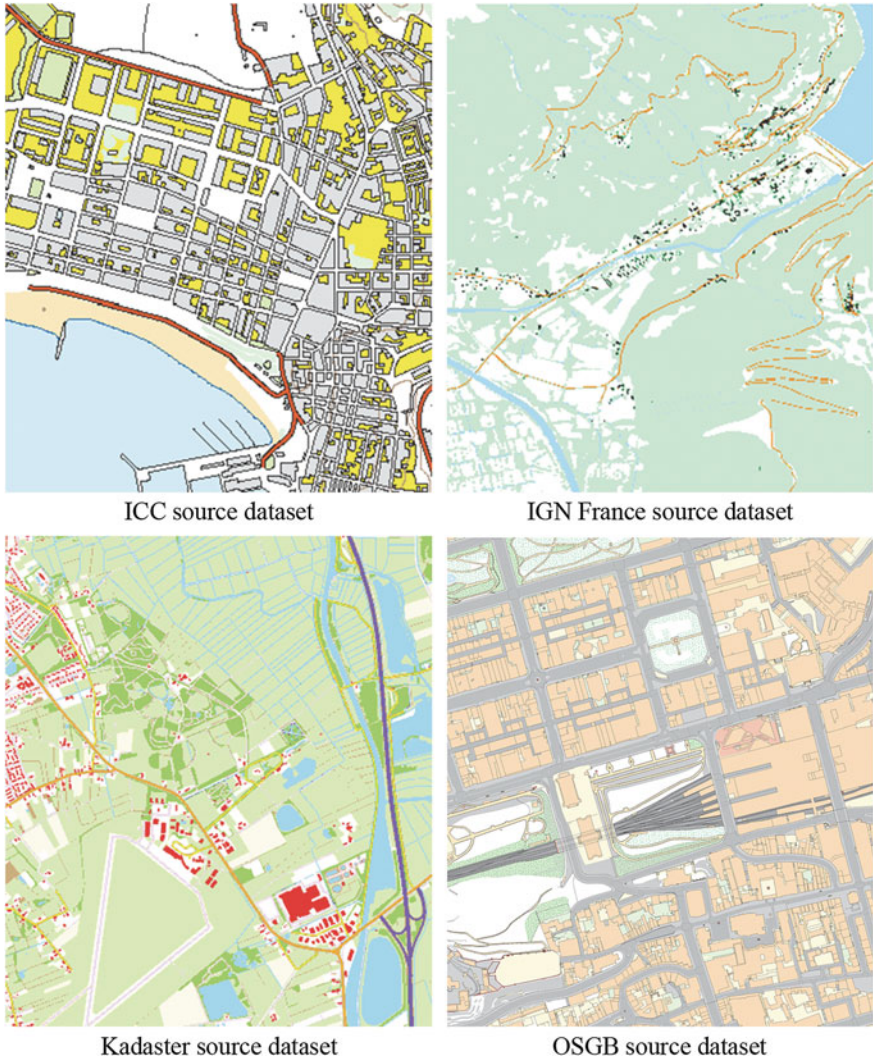
Fig. 2.7 Samples of source datasets in the EuroSDR generalisation study (maps are reduced in size)

constraints on one object, on two objects, and on groups of objects. An importance value indicates the importance of satisfying the specific constraint in the final output. This value does not indicate in what sequence the constraints should be solved (Ruas 1999). Satisfying less important constraints first may be necessary to satisfy more important constraints later. For example, generalisation of buildings should start by reducing density before trying to cope with overlaps, even though non-overlapping constraints are more important than density constraints. NMAs

could also propose an action to support the tester in finding the most desired generalisation solution. This is because in some cases NMAs know what action should be taken to meet the constraint optimally. For example the constraint "minimal depth of protrusion of a building" can be solved by the two actions "exaggerate detail" or "eliminate detail" but each provides very different results. Touya et al. (2010) elaborated on this outcome of the EuroSDR project afterwards, by proposing a model mixing constraints and rules to define generalisation specifications (see also Case study I, Chap. 7).

2.5.3 Harmonising NMA Map Specifications for Automated Generalisation

NMAs defined their map specifications for automated generalisation in the developed template by analysing text-based map specifications, mapping applications and cartographers' knowledge. Initially a large number of constraints were defined for the four test cases (about 250), but which often covered similar situations.

In the next step, the EuroSDR research team harmonised the constraints. The aim was to identify constraints that are similar in the specifications provided by different NMAs, and replace them with a single one that can be tuned. This was needed for two reasons. Firstly, to simplify the tests; once a tester had defined the constraint within the software, they could perform the same actions to express a similar constraint for a second test case. Secondly, harmonisation allowed comparison of results for similar constraints across the test cases. An additional reason for this harmonisation process was that it provided important knowledge on how similar the constraints (and hence the specifications) were among different NMAs.

For the harmonisation process, similar constraints across the four test cases were identified by carefully comparing the four constraint sets. The harmonisation resulted in a list of generic constraints. A few constraints were so specific that they remained as specific constraints. Examples are OSGB constraints addressing how buildings should be aggregated depending on the initial pattern. Table 2.2 shows examples of generic constraints on one object, two objects, and a group.

Once all four NMAs had agreed on the harmonised constraints, they redefined their initial constraints in terms of the generic constraints with their own feature classes, thresholds, parameter values, and preferred actions. Table 2.3 is an example from the ICC (all NMA specific information is indicated in bold, italic). This resulted in about 300 NMA specific constraints, i.e. 50 more than initially expected. This is because the harmonisation process looked at the specifications across NMAs and pointed at specifications that were identified by one NMA but were missing in the other set. It should be emphasised that these constraints do not completely resemble the NMAs' map specifications, since they have been altered in order to meet the needs of the project.

Table 2.2 Examples of generic constraints

Constraint type	Property	Formal generic constraint
Constraints on one object		
Minimal dimensions	Area	Target area > x map mm²; target area = initial area ± x %
	Width of any part	Target width > x map mm
	Area of protrusion/recess	Target area > x map mm²
	Length of an edge/line	Target length > x map mm
Shape	General shape	Target shape should be similar to initial shape
	Squareness	[initial value of angle = 90° (tolerance ± x°)] target angles = 90°
	Elongation	Target elongation = initial elongation ± x %
Topology	Self-intersection	[initially, no self-intersection] no self-intersection must be created
	Coalescence	Coalescence must be avoided
Positon/Orientation	General orientation	Target orientation = initial orientation ± x %
	Positional accuracy	Target absolute position = initial absolute position ± x map mm
Constraints on two objects		
Minimal dimensions	Minimal distance	Target distance > x map mm
Topology	Connectivity	[initially connected] target connectivity = initial connectivity
Position	Relative position	Target relative position = initial relative position
Constraints on a group of objects		
Shape	Alignment	Initial alignment should be kept
Distribution and Statistics	Distribution of characteristics	Target distribution should be similar to initial distribution
	Density of buildings (black/white)	Target density should be equal to initial density ± x %

Table 2.3 Example of ICC map specifications defined as constraints that extend the EuroSDR harmonised constraints

Item in constraint template	Example on one object	Example on two objects	Example on group of objects
Constraint ID	ICC-1-22	ICC-2-21	ICC-3-18
Generic-Constraint-ID	EuroSDR-1-8	EuroSDR-2-3	EuroSDR-3-13
Geometry type	Polygon	Polygon—line	Polygons
Feature class 1	Quay_adjacent_to_sea	Building	Building
Condition for object being concerned with this constraint (for class 1 if there are two objects)	Depth of protrusion > 1 map mm	Distance between building and road < 0.5 map mm	
Constrained property	Width of protrusion/recess	Orientation	Density of buildings (black/white ratio)
Condition depends on initial value?	No	Yes	Yes
Condition to be respected	Target width > 0.2 map mm	Building must be parallel to road	Target density should be equal to initial density ±20 %
Action	Collapse to a line		
Importance of constraint (1 to 5, 1 is less important)	3	3	3
Exception			
Schema to illustrate if needed			
Additional for constraints on two objects			
Feature class 2		Road	
Condition for both objects being concerned with this constraint		Objects are parallel (±15°)	
Additional for constraints on group of objects			
Kind of group			Urban block
Kind of objects of the initial data composing the group			Buildings surrounded by minimal cycle of roads (in urban areas)

2.5.4 Analysing the Test Cases

To obtain more in-depth knowledge on NMA requirements for automated map generalisation, the final step of the requirements analysis was the comparison of constraints across the four test cases. One should note that the constraint sets do not reflect all the generalisation problems of NMAs, because the NMAs had to limit their constraints to those describing the main problems in the test area and to constraints that were more or less straightforward to formalise.

For the comparison of constraints among the four test cases, three criteria were considered: (1) the number of objects taken into account in the constraints, (2) the type of constraints, and (3) the feature class for which the constraints were defined.

The following observations were made. Firstly, most constraints are defined for one object in all four cases, whereas the fewest constraints are defined for groups of objects. This is probably because it was difficult to formalise constraints on groups of objects. In addition, constraints for ensuring minimal dimensions are important in all four test cases, probably because it is straightforward to define this type of constraints. Another observation is that position and orientation constraints are rarely specified by all NMAs, and they refer only to buildings. A final conclusion of this analysis concerns the feature classes that were included in the constraint definitions. All four test cases contain many constraints on buildings, land use, and roads. The reason for the importance of these classes in the constraint sets is most likely because these are the most frequently occurring objects and the most significant for users of the map and therefore most (interactive) generalisation is applied to these objects.

In conclusion, the EuroSDR project was significant in examining generalisation from a cross-countries perspective. Therefore it was possible to deliver a harmonised model of generic and NMA-specific map specifications. The harmonised constraint set, although not complete, serves as a common base for better understanding of the complexity of the generalisation process, for developing and improving automated generalisation solutions as well as for automated evaluation of automated generalisation (further discussed in Chap. 9).

2.6 Case Study II: A Map Specifications Model for On-Demand Mapping at Ordnance Survey

Sandrine Balley and Nicolas Regnauld

Section 2.2.2 pointed out the difficulty of representing map specifications precisely enough to drive a complete map-making process. This section describes an experimental model designed at OSGB for on-demand mapping. We particularly focus on how this model supports data integration.

2.6.1 Context

OSGB has designed and is populating a new multiple-resolution database which will feed the production systems of existing products and provide a flexible environment to create new products (Regnauld 2007). However, with the current design, components will be chosen and combined manually. Thus, creating new products will still be relatively slow and expensive and custom products will only be viable for a few large customers. An exploratory project launched in 2010 investigated a more advanced use of this database in order to bring the benefits of custom products to a wider range of customers (Balley and Regnauld 2011). In this approach, the geographic components are picked and mixed to create products on demand automatically, therefore at low cost. This opens the door to products that support integration of customer data with OSGB reference data providing a contextual background.

A high-level distributed architecture was proposed for this on-demand mapping system (Chap. 7, Fig. 7.1). Starting from the target product specifications, a derivation engine utilises its internal knowledge, the descriptions of available data and the descriptions of available services to build a map derivation workflow. All these resources can interoperate by using shared concepts from a semantic referential (Kuhn 2003) composed of an ontology of geographic concepts (e.g. "road", "itinerary"), an ontology of GIS concept (e.g. "polyline", "feature type", "colour") and an ontology of operations (e.g. "filter", "reclassify").

We now present the map specifications model and how it can represent data integration requirements for the derivation engine.

2.6.2 The Map Specifications Model

The model adopted for the project relies on representation constraints, enclosing and extending the concept of cartographic constraints used for generalisation. Types of representation constraints were inspired by the model of Gesbert (2005) concerning dataset specifications. These constraints are expressed over Mapped Concepts (i.e. geographic concepts from the semantic referential) and their properties, as described by Touya and Duchêne (2011) or Zhang (2012). Figure 2.8 lists the different types of representation constraints together with examples. The model allows redundancies and correlated information: for instance, the fact that "Land cover" is a background mapped concept and the fact that it is represented in a faded colour can both be represented in the specifications (under symbolisation constraint), even if the latter has (or could have) been inferred from the former. The integration need is more specifically expressed through modelling and symbolisation constraints, as detailed in the next section.
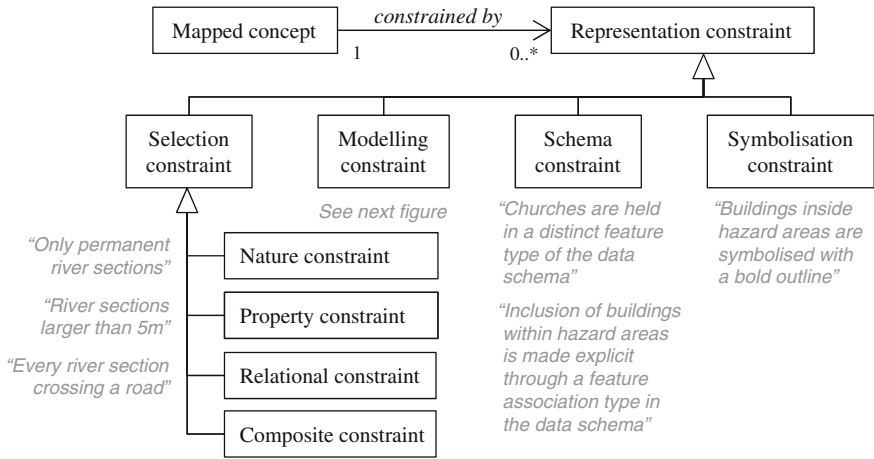
Fig. 2.8 Representation constraints of the map specifications model

2.6.3 *Representing Integration Requirements Using the Specifications Model*

The integration requirement is twofold: putting user's data into context, and making user's data geometrically consistent with the referential. For each facet, we list the required specification elements and their representation in our model.

2.6.3.1 Putting User's Data into Context

Putting data into context consists of providing a map background with relevant themes. In that purpose, the user must inform the system of the meaning of their data, by "joining" the semantic referential at some level (e.g. "cycle routes" or "accidents" or, at a higher abstraction level, "itineraries" or "punctual events"). As in other expert mapping systems (Forrest 1999; Sarjakoski and Sarjakoski 2005), rules or specification templates can be used by the system to identify contextual mapped concepts (e.g. "roads" and "landmarks"). For a finer selection, the system needs clues about the thematic and spatial relationships the user wants to emphasise (e.g. "the sections of itinerary equipped with cycle lanes" or "the accidents occurring at crossroads"). Using this information, the system will organise themes into different reading levels, from the "first-sight" themes to the background themes (Bucher et al. 2007), which is formalised through symbolisation constraints (Fig. 2.9) and will govern the choice of styles. The choice of symbols for the map foreground will also be guided by the geometric modelling
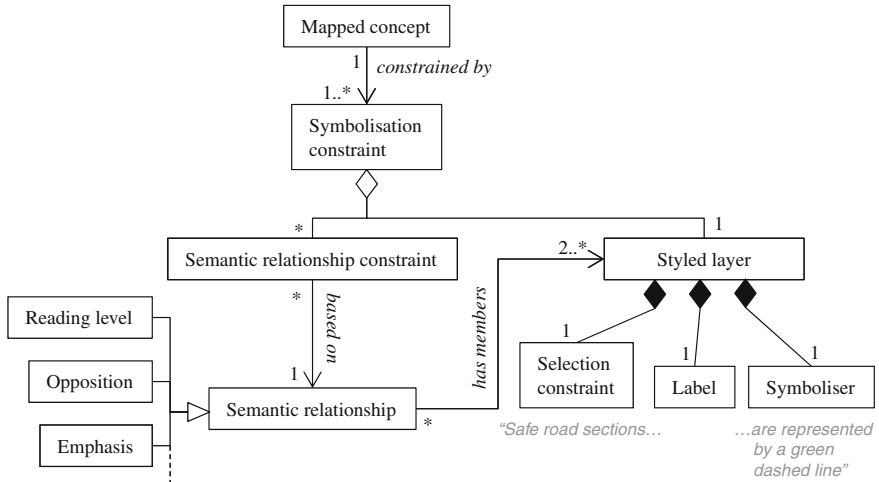
Fig. 2.9 Symbolisation constraints (detail of the map specifications model)
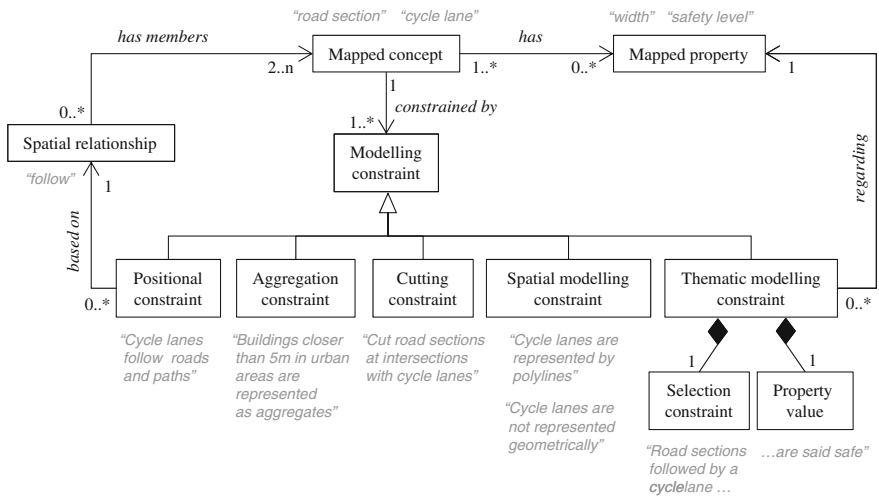

Fig. 2.10 Modelling constraints (detail of the map specifications model)

(see Spatial modelling constraint, Fig. 2.10) of features constituting the map background, and vice versa. For example, it is better not to use red hues for the background data if the user's data deals with risk (to avoid disturbing the cartographic message), or if the user has expressed a preference for displaying their own data in red (to ensure a good contrast) (Chesneau 2007).

2.6.3.2 Making User's Data Geometrically Consistent
with the Referential

Ensuring geometric consistency between data sources is the second integration requirement: it makes the map accurate and readable, and emphasises spatial relations that are relevant to the user (e.g. the fact that cycle routes follow roads). Depending on the map use and theme, three integration options are possible.

The first option consists of overlaying and geometrically aligning user's objects on the referential background. This makes sense if the target product is for visualisation purpose only, and if the user's objects represent physical features that are not already represented in the reference data (e.g. public phones). This choice can be expressed through a positional constraint (Fig. 2.10).

The second option consists of discarding user's object geometries and projecting their properties on the referential objects as new thematic attributes. This makes sense if the product is meant to be used for thematic analysis, if the user's data represents non-physical entities (e.g. statistical data or itineraries), or if it represents physical entities that already are in the referential with less thematic attributes but better geometric accuracy. This can be expressed through a thematic modelling constraint (Fig. 2.10).

The third option consists of keeping user's object geometries, aligning them and adapting the referential topology accordingly. Depending on the user's need, it may for instance be useful to reorganise the road network using the user's objects as new nodes. This requirement can be expressed through a positional constraint and a cutting constraint (Fig. 2.10).

2.6.4 Conclusions

The map specifications model presented in this Case study extends the principle of cartographic constraints to support not only generalisation, but also other processes required by on-demand mapping, notably data integration. The specification model was instantiated for a use case where user-generated cycle routes are integrated with a reference road network. It was implemented and utilised by an on-demand mapping prototype to demonstrate the proposed high-level architecture (Balley et al. 2012). The model now needs to be tested against various scenarios. In the current stage of the project, map specifications (and not user requirements) are the input of the on-demand mapping system. Collecting the user requirements and setting the map specifications dynamically will be investigated in later phases.

2.7 Case Study III: COLorLEGend—Design of Personalised and Original Maps

Sidonie Christophe

Selecting colours to symbolise features on a map is still a complex problem. Though cartographic theory provides some recommendations about colours (Bertin 1967; Robinson et al. 1995), there is no generic method for handling colours in a map. The following question remains: "How to select and combine colours to render data, according to the message that the map is supposed to convey?". The problem has no unique or optimal solution: only the cartographer is able to validate a solution judged satisfactory. In the context of on-demand map design, the problem may be mostly stressed by the level of cartographic expertise of the user (i.e. the map maker). The user may have no skills to correctly manipulate the colours of cartographic objects. The suitability of colour choice requires basic knowledge that may not be provided by cartographic tools.

The Case study presented here is the COLorLEGend (COLLEG) system, a cooperative method to help users to make personalised and creative colour choices (Christophe 2009). This application has been implemented in the IGN-France production services. The project consisted of providing both knowledge and methods to help users choose colours to render their geographical data. The principle of COLLEG is a dialog engine interacting with the user and relying on a knowledge base on colours. Cartographic knowledge has been previously identified, acquired and stored to be used as a knowledge base in the COLLEG system (Christophe 2011). A specific approach to collecting user's preferences is proposed through *inspiration sources* (Sect. 2.7.1). Then, user's preferences, considered as constraints on the map legend, are validated against cartographic expertise in order to infer some cartographic solutions that are acceptable to the user (Sect. 2.7.2). The challenge is to find suitable cartographic solutions in cases where user's preferences and cartographic knowledge on colours may a priori appear to be incompatible.

2.7.1 Collecting User's Preferences

It is not easy for users to express their colour choices. Colours preferences may be difficult to specify on a blank page, whether it be by writing a text or by clicking on colour squares: the set of possibilities is too numerous for the user to manage. Once chosen, the user may change their preferences once they have seen the consequences of their choice. So the user should be able to modify or refine them anytime during the cartographic process. They should be allowed to express their feelings on colours regarding the overall map or in greater detail, e.g. regarding a single geographical theme.

Fig. 2.11 Inspiration sources 1 (extract)—harmonic (Dominguès and Bucher 2006) (*left*) and European (Christophe 2009) (*right*) map samples

The proposition of collecting user's preferences is inspired by the work of Hubert and Ruas (2003) where a dialogue engine presents to the user some examples of generalisation results that can be selected to help them to parameterise generalisation processes (Sect. 2.4.2). This analogy between examples and related parameterisation of a process is reused in the present context: examples are presented to facilitate the selection of colours and of how they are used on the map. Users can draw from two types of *inspiration sources:* map examples and famous paintings.

2.7.1.1 First Inspirational Sources: Cartographic Examples

Previous research has provided a database of map samples: several colour schemes were drawn from a book about colour harmony (Sawahata 2001) and applied on the same geographical dataset with the same legend structure (Dominguès and Bucher 2006). This database has been extended with new colour schemes coming from European topographic map legends (Renard 2008; Christophe 2009) (Fig. 2.11). It was considered that these inspirational sources may be useful in helping the user to pick satisfactory colours schemes for a map, or satisfactory colours independently for a geographical theme.

2.7.1.2 Second Inspirational Sources: Famous Paintings

In order to encourage creativity and to open the user's mind in terms of choices of colours, inspirational sources drawn from another graphical domain were investigated. A few famous paintings were selected, together with their associated colour palette and colour patterns (general surfaces, repartitioned in spots or area, neighbouring colours) (Christophe 2011) (Fig. 2.12). It was considered that these inspirational sources may be useful in helping the user to pick harmonious combinations of colours, i.e. not only a colour palette, but also a specific colour composition. The user may prefer a colour palette, some colours in a palette or a colour for a geographical theme.

Fig. 2.12 *Inspiration sources* two paintings and related colour palettes
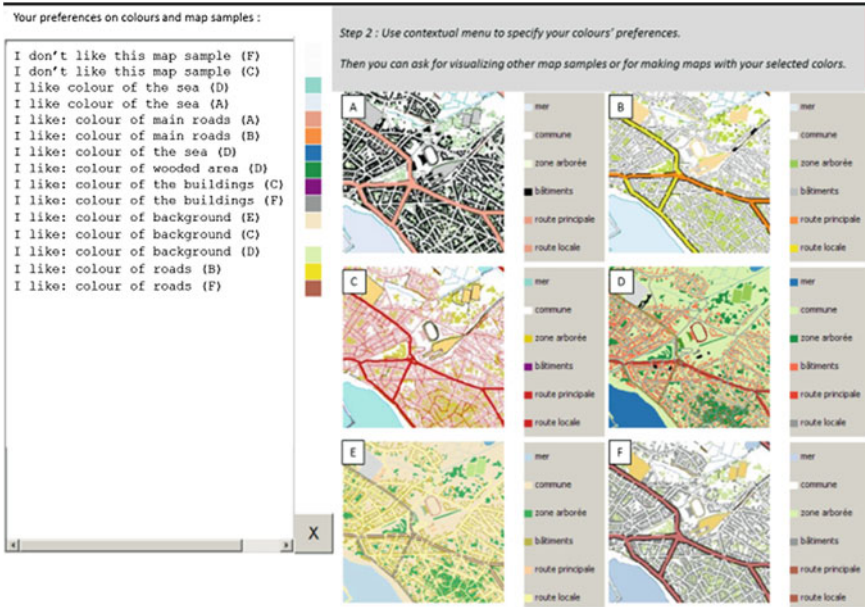

Fig. 2.13 User's preferences on colours on map samples

2.7.1.3 Specifying Preferences on Colours

With the help of the COLLEG system, the user starts the map design process by selecting one type of inspirational source (map samples or paintings). Then they pick their preferred colours in the proposed inspirational sources.

In the map samples strategy, the process consists of presenting a set of six samples that a user may annotate (by their likes/dislikes for the maps and their colours). According to these initial preferences, a new set of six samples are proposed again to collect more preferences. This continues until the user decides to launch the making of maps. In the example shown in Fig. 2.13, the user "disliked" two map samples and "liked" thirteen colours for a theme. The purpose is to explore a large amount of possibilities and then to converge towards satisfactory colours: this process relies on a classification of map samples (Christophe 2009).
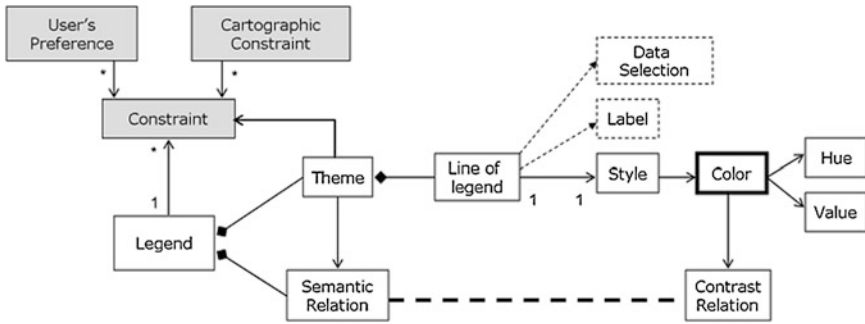
Fig. 2.14 Simplified version of the UML model of the map legend Christophe (2009) extended and improved in Hoarau and Mustiere (2011)

The principle of the paintings strategy is to let the user select a painting and its related palette or some specific colours in this palette. Using this strategy, the step of specifying user's preferences is relatively simple.

2.7.2 Inferring Colour Specifications from User's Preferences

Once the user's preferences are acquired, the COLLEG system translates them into constraints on the map legend. Thus COLLEG is able to infer various map solutions.

2.7.2.1 From User's Preferences to Constraints on the Map Legend

COLLEG manages a model of the map legend structured in themes rendered by a specific symbolisation. At this stage, COLLEG translates the user's preferences, i.e. some likes and dislikes of colours, into constraints on the legend. The user's preferences are divided into two types of constraints: a colour may be applied to any theme of the legend, or, a colour should be applied to the specific theme specified by the user. Thus the user's constraints are managed as objects impacting the map legend and the theme objects (Fig. 2.14).

2.7.2.2 From Constraints on Map Legend to Various Map Solutions

COLLEG relies on a constraint satisfaction problem: each geographic theme may be rendered by any user's colour satisfying constraints, resulting in various map solutions. As detailed in Christophe (2011), the constraints reflect a cartographic knowledge of colours:
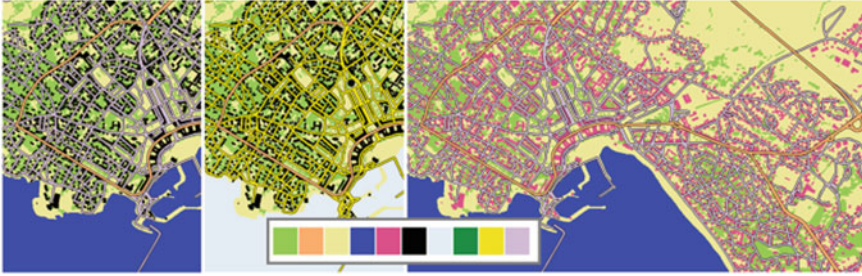
Fig. 2.15 Three possible maps coming from user's preferences on map samples

Fig. 2.16 Various maps coming from Derain's palette and user's preferences on colour uses

- Semantic relationships between themes (association, difference, order) should be rendered by specific contrasts between colours of the related themes.
- Background colour should be high contrasted in value with other themes.
- Conventional colours should be used to render sea and wooded area.

Figure 2.15 shows examples of maps resulting from the user's preferences based on the samples presented in Fig. 2.13: semantic relationships between road themes and conventional colours are preserved. Figure 2.16 shows various maps coming from a painting, according to cartographic or artistic constraints: not only cartographic conventions, but also artistic colour compositions of the painter may be enforced or relaxed.

As a final step, COLLEG proposes a refining tool, similar to an elaborated colour picker, in order to improve application of colours in the given map

solutions: the refining tool is adapted to current maps and therefore proposes suitable colours to refine those maps according to existing cartographic and artistic knowledge. Some flexibility in interactions with COLLEG enables the user to rework the map design process at any stage, or to change initial preferences in order to make more satisfactory maps.

2.7.3 Conclusions

A usability test of the COLLEG system has been implemented and reviewed (Christophe 2009). According to participants, the system was clearly helpful in designing creative maps and was deemed efficient at proposing suitable map solutions, and exploring the space of possibilities bounded by cartographic knowledge and user's preferences. Two strategies were investigated to collect and manage user's preferences on colours; while the strategy based on map samples collects preferences upstream, the strategy based on paintings collects preferences directly on resulting maps and through the refining tool. In the future learning techniques will be utilised to improve the collection of preferences, in order to propose suitable strategies and to make the process faster according to user's profiles. Bigger databases of inspirational sources may be also considered: associated automated tools to extract required information and thus better interpret user's preferences are also worth developing (Christophe et al. 2013).

2.8 Conclusions

Generalisation is not restricted to the production of predefined map series anymore. The current challenge is to automatically adapt to changing user requirements. This chapter presented the issues related to the creation of formal map specifications resulting from user requirements. The objectives of this research are:

- to enable on-demand generalisation and on-demand mapping, resulting in good quality, usable maps that support integration of user's data,
- to make advanced mapping processes available to those users who do not have the skills to create map specifications.

This chapter has shown that map usability is receiving more and more attention as the ranges of map users and map uses grow. Applications delivering maps adapted to predefined user profiles have emerged, especially in the domain of mobile maps. In parallel, map and dataset specification models have become more expressive and more interoperable.

However, no global specification model to date is able to drive the entire map-making process. The first reason lies in the fact that on-demand mapping

encompasses many processing steps. Specification models—and associated user profiles—relevant for different steps of the map-making process need to be integrated, which requires re-examination of the very concepts underlying these models. The second reason is that some of the cartographic knowledge still cannot be—and might not be in the medium term—formalised as map specifications (Stoter et al. 2009b). This should not be an obstacle to on-demand mapping. We need to consider again what we mean by map quality, in order to deliver maps that are not as "good" as maps involving manual editing, but are usable for a task and given context.

The emergence of such specification models will lead to the issue of their instantiation, first by cartographers, and then by the end-users of the service. More formalised knowledge on map design will be required to assist these users (Ory et al. 2013). Reusable map specifications might be useful. This would assume that the specification model is shared, that specification templates are proposed, and that "map provider profiles" are formalised, enabling mapping agencies to retain their own trademark.

The collection of user requirements and their automatic interpretation has not been sufficiently explored. Innovative interfaces based on map samples, and their associated interpretation mechanisms, have been designed for a few steps of on-demand mapping. Could the approach be extended to other steps such as content selection and user data integration? As the optimal map specifications depend on the task the user wants to achieve, task-oriented interfaces could be envisaged, as well as interfaces dedicated to users who are getting more accustomed to map-making and need to interact at different expertise levels. At each expertise level, we must decide how, and by how much, cartographic standards can incorporate user preferences.

References

Abadie N (2009) Formal specifications to automatically identify heterogeneities. In: Proceedings of the 12th international conference on geographic information science AGILE, pre-conference workshop "challenges in spatial data harmonisation", Hannover, 2–5 June 2009

Abadie N, Mechouche A, Mustière S (2010) OWL-based formalisation of geographic databases specifications. In: Proceedings of the 17th international conference on knowledge engineering and knowledge management, Lisbon, 11–15 Oct 2010

Balley S (2007) Aide a la restructuration de donnees geographiques sur le Web—Vers la diffusion a la carte d'information geographique. PhD Thesis, Université Paris Est

Balley S, Regnauld N (2011) Collaborating for better on-demand mapping. In: Proceedings of the 14th ICA workshop on generalisation and multiple representation, jointly organised with ISPRS commission II/2 working group on multiscale representation of spatial data, Paris, France, 2011

Balley S, Jaara K, Regnauld N (2012) Towards a prototype for deriving custom maps from multisource data. In: Proceedings of the 15th ICA workshop on generalisation and multiple representation, jointly organised with EuroSDR commission on data specifications, Istanbul, Turkey, 2012

Battye E (2010) Conceptualising space project: final report. Ordnance Survey Great Britain Research, unpublished

Beard K (1991) Constraints on rule formation. In: McMaster R, Buttenfield B (eds) Map generalization: making rules for knowledge representation. Longman Group, UK, pp 121–135

Bertin J (1967) Sémiologie Graphique. Gauthier-Villars, Paris. English edition: Bertin J (1983) Semiology of Graphics (trans: William JB). University of Wisconsin Press,Wisconsin

Brewer CA (1997) Spectral schemes: controversial color use on maps. Cartography Geogr Inf Syst 24(4):203–220

Brewer CA (2003) A transition in improving maps: the Colorbrewer example. Cartography Geogr Inf Sci 30(2):159–162

Brewer CA, Buttenfield BP (2010) Mastering map scale: balancing workloads using display and geometry change in multi-scale mapping. Geoinformatica 14(2):221–239

Bucher B, Buard E, Jolivet L, Ruas A (2007) The need for web legend services. In: Ware JM, Taylor GE (eds) Web and wireless geographical information systems. 7th International Symposium W2GIS, Cardiff, 28–29 (2007) Lecture Notes in Computer Science, vol 4857. Springer, Heidelberg, pp 44–60

Burghardt D, Schmid S, Stoter J (2007) Investigations on cartographic constraint formalisation. In: Proceedings of the 11th ICA Workshop on Generalisation and Multiple Representation, Moscow, Russia, 2007

Cecconi A (2003) Integration of generalisation and multi-scale databases for enhanced web mapping. PhD Thesis, University of Zurich

Chesneau E (2007) Improvement of colour contrasts in maps: application to risk maps. In: Proceedings of the 10th International Conference on Geographic Information Science AGILE, Aalborg, 8–11 May 2007

Christophe S (2009) Aide à la conception de légendes personnalisées et originales: Proposition d'une méthode coopérative pour le choix des couleurs. PhD Thesis, Université Paris Est

Christophe S (2011) Creative colours specification based on knowledge (ColorLegend System). Special issue: ICC Paris 2011. Cartographic J 48(2):138–145

Christophe S, Perret J, Hoarau C (2013) Extraction de palettes de couleurs pour l'aide à la conception cartographique. Revue des Sciences et Technologies de l'Information (in press)

Dhée F (2011) Amélioration des cartes topographiques pour les daltoniens. In: Proceedings of the 25th international cartographic conference ICC, Paris, 3–8 July 2011

Dominguès C, Bucher B (2006) Legend design based on map samples. In: Proceedings of the 4th international conference on geographic information science GIScience, Münster, 20–23 Sep 2006, pp 55–59

Dominguès C, Christophe S, Jolivet L (2009) Connaissances opérationnelles pour la conception automatique de légendes de cartes. In: Actes des 20èmes Journées Francophones d'Ingénierie des Connaissances, Hamamet, 25–29 May 2009

Duchêne C, Christophe S, Ruas A (2011) Generalisation, symbol specification and map evaluation: feedback from research done at COGIT laboratory, IGN France. Special issue: validation of EO-derived information for crisis management: a digital earth perspective in the Valgeo expert community. Int J Digital Earth 4(1):25–41

Foerster T, Lehto L, Sarjakoski T, Sarjakoski T, Stoter J (2010) Map generalization and schema transformation of geospatial data combined in a Web Service context. Comput Environ Urban Syst 34(1):79–88

Fonsesca FT (2001) Ontology-Driven Geographic Information Systems. PhD Thesis, University of Maine

Forrest D (1999) Developing rules for map design: a functional specificationfor a cartographic-design expert system. Cartographica 36(3):31–52

Gaffuri J (2011) Improving Web mapping with generalization. Special issue: internet mapping: selected papers from the 25th conference of the international cartographic association, Paris, 3–8 July 2011. Cartographica 46(2):83–91

Gesbert N (2005) Étude de la formalisation des spécifications de bases de données géographiques en vue de leur intégration. PhD Thesis, Université Paris Est

Gnägi HR, Morf A, Staub P (2006) Semantic interoperability through the definition of conceptual model transformations. In: Proceedings of the 9th international conference on geographic information science AGILE, Visegrad, 20–22 Apr 2006

Gődér G (2003) Représentation comparée de schémas et de spécifications de contenu. Mémoire de DESS de Cartographie et d'Information Géographique, Université Paris Est

Gould NM, Chaudhry O (2012) An ontological approach to on-demand mapping. In: Proceedings of the 15th ICA Workshop on generalisation and multiple representation, jointly organised with EuroSDR commission on data specifications, Istanbul, Turkey, 2012

Gruber T (1993) A Translation Approach to Portable Ontologies. Knowl Acquisition 5(2):199–220

Haklay M (ed) (2010) Interacting with geospatial technologies. Wiley, Chichester

Harding J (2011) Usability of geographic information: factors identified from task-focused user interviews. In: Proceedings of the 25th international cartographic conference, Paris, 3–8 July 2011

Harding J, Sharples S, Hakla M, Burnett G, Dadashi Y, Forrest D, Maguire M, Parker CJ, Ratcliffe L (2009) Usable geographic information—what does it mean to users? In: Proceedings of AGI Geo-community, Stratford Upon Avon, 23–24 Sept 2009

Harrie L, Weibel R (2007) Modelling the overall process of generalisation. In: Ruas A, Sarjakoski LT (eds) Generalisation of geographic information: cartographic modelling and application. Elsevier, Amsterdam, pp 67–87

Hoarau C (2011) Reaching a compromise between contextual constraints and cartographic rules: application to sustainable maps. Cartography Geogr Inf Soc J 38(2):79–88

Hoarau C, Mustière S (2011) GeOxygene, 'Semiology' Plugin—Base model for works on map legends in GeOxygene. http://oxygene-project.sourceforge.net/doc/geoxygene-semiology-0.4.pdf. Accessed 29 May 2013

Hubert F, Ruas A (2003) A method based on samples to capture user needs for generalisation. In: Proceedings of the 7th ICA workshop on progress in automated map generalization, Paris, France, 2003

Inspire Drafting Team on Data Specifications (2008) Deliverable D2.6: methodology for the development of data specifications. http://inspire.jrc.ec.europa.eu/reports/-ImplementingRules/inspireDataspecD2_6v2.0.pdf. Accessed 29 May 2013

ISO TC211 (2005) 19131 Geographic information: data product specification. International Standard

ISO TC211 (2009) 19123 Geographic information: Feature concept dictionaries and registers. International Standard

Jaara K, Duchêne C, Ruas A (2012) A model for preserving the consistency between topographic and thematic layers throughout data migration. In: Proceedings of the 15th international symposium on spatial data handling sDH, Bonn, 22–24 Aug 2012

Jabeur N (2006) A multi-agent system for on-the-fly web map generation and spatial conflicts resolution. PhD Thesis, Université Laval

Jolivet L (2009). Characterizing maps to improve on-demand cartography—the example of European topographic maps. In: Proceedings of the 17th annual conference on GIS reasearch GISRUK, Durham, 1–3 Apr 2009, pp 345–348

Klien E, Lutz M, Kuhn W (2006) Ontology-based discovery of geographic information services—an application in disaster management. Comput Environ Urban Syst 30(1):102–123

Kuhn W (2003) Semantic Reference Systems. Int J Geogr Inf Sci 17(5):405–409

Lemmens R (2006) Semantic interoperability of distributed geo-services. PhD Thesis, ITC, University of Twente

Letho L (2007) Real-time content transformations in a web service-based delivery architecture for geographic information. PhD Thesis, Helsinki University of Technology

Lüscher P, Burghardt D, Weibel R (2007) Ontology-driven enrichment of spatial databases. In: Proceedings of the 11th ICA workshop on generalisation and multiple representation, Moscow, Russia, 2007

Mackaness WA, Ruas A, Sarjakoski LT (2007) Observations and Research Challenges in Map Generalisation and Mutiple Representation. In: Mackaness WA, Ruas A, Sarjakoski LT (eds) Generalisation of Geographic Information: Cartographic Modelling and Applications, Elsevier, pp 315–323

Mechouche A, Abadie N, Prouteau E, Mustière S (2013) Ontology-based formal specifications for user-friendly geospatial data discovery. In: Guillet F, Pinaud B, Zighed DA, Venturini G (eds)

Advances in knowledge discovery and management, studies in computational intelligence 471. Springer, Heidelberg, pp 151–176

Ooms K, De Maeyer P, Fack V (2011) Can experts interpret a map's content more efficiently? In: Proceedings of the 25th international cartographic conference, Paris, 3–8 Jul 2011

Ory J, Christophe S, Fabrikant SI (2013) Identification of styles in topographic maps. In: 16th international cartographic conference, Dresden, 25–30 Aug 2013

Regnauld N (2007) A distributed system architecture to provide on-demand mapping. In: Proceedings of the 11th international cartographic conference, Moscow, 4–10 Aug 2007

Reichenbacher T (2004) Mobile cartography: adaptative visualisation of geographic information on mobile devices. PhD Thesis, Technische Universität München

Renard J (2008) Analyse et caractérisation de légendes européennes. Mémoire de stage, Ecole Nationale des Sciences Géographiques

Robinson A (1952) The looks of maps. University of Wisconsin Press, Madison

Robinson A, Morrison JL, Muehrcke PC, Kimerling AJ, Guptill SC (1995) Elements of cartography (6th edn). Wiley, Chichester

Ruas A (1999) Modèle de généralisation de données géographiques à base de contraintes et d'autonomie. PhD Thesis, Université Paris Est

Ruas A (2001) Automatic generalisation project: learning process from interactive generalisation. OEEPE official publication 39

Ruas A, Plazanet C (1996) Strategies for automated generalisation. In: Proceedings of the 7th international symposium on spatial data handling SDH, Delft, 12–16 Aug 1996

Sarjakoski LT, Nivala A (2005) Adaptation to context—a way to improve the usability of mobile maps. In: Meng L, Zipf A, Reichenbacher T (eds) Map-based mobile services: theories, methods and implementations. Springer, Heidelberg, pp 107–123

Sarjakoski T, Sarjakoski LT (2005) The GiMoDig public final report. Public EC report, GiMoDig project, IST-2000-30090

Sarjakoski T, Sarjakoski LT (2007) A real-time generalisation and map adaptation approach for location-based services. In: Mackannes WA, Ruas A, Sarjakoski LT (eds) Generalisation of geographic information: cartographic modelling and applications. Elsevier, Amsterdam, pp 137–159

Sawahata L (2001) Color harmony workbook. Rockport Publishers

Stoter J, Burghardt D, Duchêne C, Baella B, Bakker N, Blok C, Pla M, Regnauld N, Touya G, Schmid S (2009a) Methodology for evaluating automated map generalization in commercial software. Comput Environ Urban Syst 33(5):311–324

Stoter J, van Smaalen J, Bakker N, Hardy P (2009b) Specifying map requirements for automated generalization of topographic data. Cartographic J 46(3):214–227

Stoter J, Baella B, Blok C, Burghardt D, Duchêne C, Pla M et al (2010) State-of-the art of automated generalisation in commercial software. EuroSDR Official Publication

Touya G (2011) Orchestration d'un processus multi-modèles de généralisation d'espaces géographiques hétérogènes. PhD Thesis, Universite Paris Est

Touya G, Duchêne C (2011) Collagen: collaboration between automatic cartographic generalisation processes. In: Ruas A (eds) Advances in cartography and GIScience vol 1, Selection from ICC 2011 Paris. Lecture notes in geoinformation and cartography, Springer, Heidelberg

Touya G, Girres J (2013) ScaleMaster2.0: a scalemaster extension to monitor automatic multi-scales generalisations. CaGIS—special Issue ICC 2013 (in press)

Touya G, Duchêne C, Ruas A (2010) Collaborative generalisation: formalisation of generalisation knowledge to orchestrate different cartographic generalisation processes. In: Proceedings of the 6th international conference GIScience 2010, Zurich, 14–17 Sep 2010

Touya G, Balley S, Duchêne C, Jaara K, Regnauld N, Gould NM (2012) Towards an ontology of generalisation constraints and spatial relations. In: Proceedings of the 15th ica workshop on generalisation and multiple representation, jointly organised with EuroSDR commission on data specifications, Istanbul, Turkey, 2012

Zhang X (2012) Automated evaluation of generalised topographic maps. PhD Thesis, ITC, University of Twente