Improvement of Colour Contrasts in Maps: Application to Risk Maps

Elisabeth Chesneau[1]
University of Technology of Compiègne, Department of Urban Systems Engineering, AVENUES research team, centre PG 2, 1 rue Dr Schweitzer, BP60319
60203 Compiègne Cedex, France
Elisabeth.Chesneau@utc.fr

1 INTRODUCTION

A map is an important tool to know and manage a geographical space, to communicate information about it, to act, etc. Lots of professions need this tool, their expectations are multiple. Thus, numerical tools enable everyone to create and use maps according to his needs.

A requirement appears: to have reliable maps in information and legibility or to be able to product it. The importance of legibility can be illustrated by maps portraying natural or anthropised risks. In these maps, data are often numerous and dense. Thus, their cartographic portrayal is difficult, their legibility is uncertain and their use uneasy.

This long paper will discuss the problem of legibility: the chapter 2 will show that risk maps do not always give good satisfaction in their legibility. It justifies a specific research to define what a good legibility is and how to achieve it. This research is the objective of the chapter 3 where data of different disciplines dealing with perception, semiotics, colour, etc are considered. Further to our findings, we propose a model for the automatic improvement of colour contrasts in maps, here precisely for risk maps, described in the chapter 4.

2 LEGIBILITY PROBLEMS IN RISK MAPS: THE ROLE OF COLOUR

Today, professionals and citizens can product and use maps by the development of high technology tools. Some of these persons study complex thematic (e.g. risk) and the map is especially necessary to help them in their work. Yet, technological tools are not conceived to guide users in the cartographic conception. Then, maps are less efficient, particularly because the cartographic message is not reliable or not correctly and quickly understood by its users. An explanation of this fact is a legibility problem of cartographic signs.

We suggest studying legibility problems in risk maps. Indeed, risk is a complex data (2.1) which often leads to the creation of few satisfying maps because few legible (2.2).

2.1 Why is Risk Difficult to Portray?

Risk is the conjunction of latent hazard (uncertainty about realisations of an accident) and vulnerable elements (elements threatened by a hazard). It is characterised by:

- *Its varied type*: it can be natural (inundation, avalanche), technological (industrial or nuclear accident), urban (criminality, accident on road), health or environmental (famine, epidemic).

[1] This long paper is an original presentation of the PhD research of Elisabeth Chesneau (Chesneau, 2006) made at the COGIT Laboratory of IGN France, 2/4 av. Pasteur, 94165 Saint-Mandé cedex, France.

- *Its numerous spatial areas and temporalities*: e.g., the dryness risk, rather frequent and wide in space is different from the seismic risk, rarer and limited in its geographical frontiers.
- *Its spatial, temporal and social uncertainties*: there are several methods to compute hazard and vulnerability of elements at risk. It implies cartographic portrayals based on data in variation.

Thus, risk is difficult to describe, then to portray and there are consequences on its legibility.

Furthermore, objectives of risk maps are varied (expertise, prevention, crisis management, information (Chesneau, 2006)). Therefore, there are different cartographic portrayals issued from the same data. E.g., to portray the natural hazards of a district for children and negotiators, two maps will be produced: the first one including simplified information like the major risk areas and some structuring elements of the district and the other one being more exhaustive and precise in the localisations of phenomena.

The intrinsic nature of risk and the numerous objectives of maps create difficulties to have an efficient risk map. One parameter of efficiency is legibility, on which we decide to target our research. The next part describes some problems of legibility in risk maps.

2.2 Legibility Problems in Risk Maps and the Role of Colour

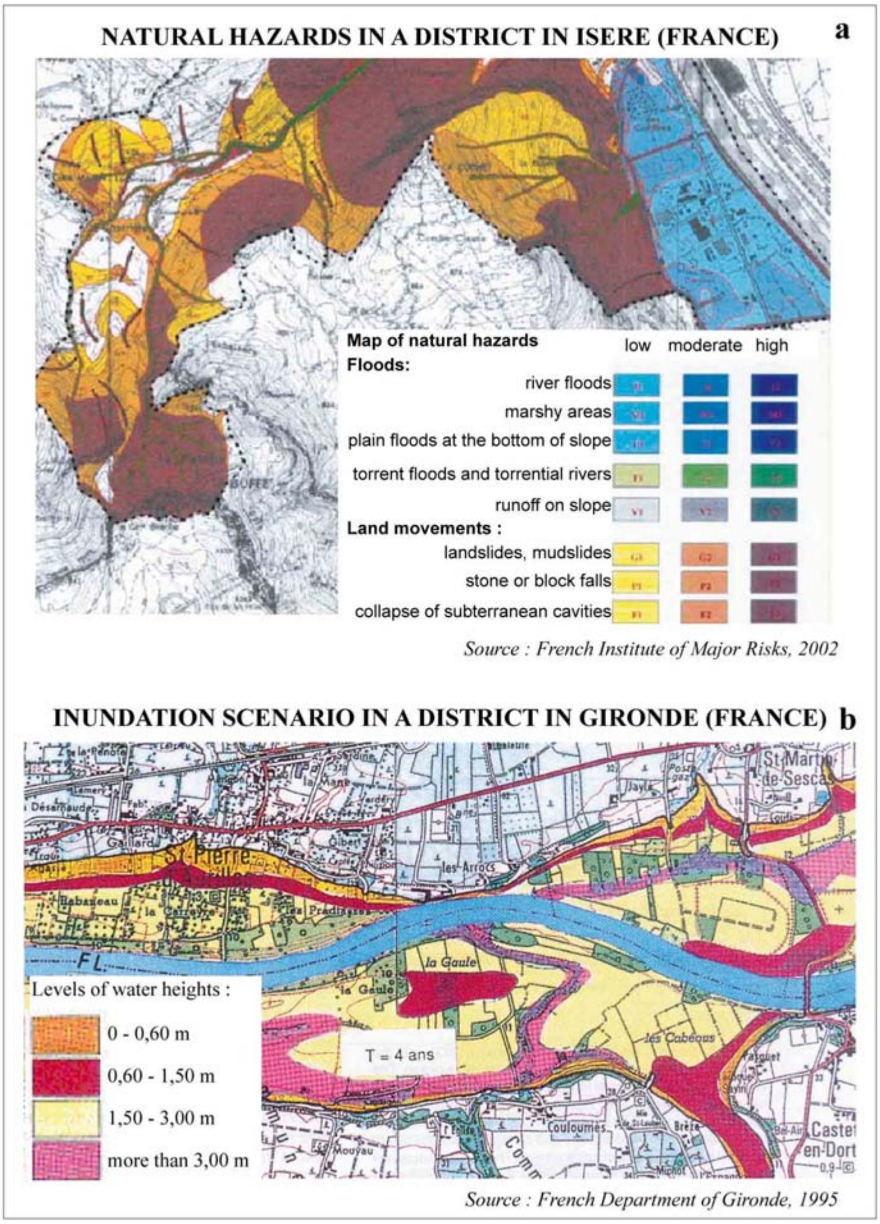


Figure 1: Two risk maps.

The map on Figure 1a portrays the natural hazards in a district of the French department *Isère*. They are superimposed onto a grey background of topographic elements. The map on Figure 1b portrays an inundation scenario in a district of the French department *Gironde*. The two maps are at 1:25 000. Three legibility problems can be mentioned:

- *Hierarchical organisation of data*: the maps are organised in visual levels where the more important information appears at first (figure) and the others at last (ground). Here, colour separates the two levels: the coloured signs compose the figure (hazards) and the grey portrays the ground (elements at risk and topographic elements). However, the elements at risk are not easily seen on the maps, particularly because of the grey under the colours.
- *Graphic density*: the two maps have a dense background, increasing the lack of clarity.
- *Graphic choices*: an illegible map could be misunderstood and graphic choices can explain it. In the map of Figure 1b, orange, red, yellow and pink areas badly portray the relationship of order between the ranges of water heights.

Colour, among several parameters, operates in a preponderant way in legibility problems. Therefore, we concentrate our research on the improvement of legibility by a better use of colour.

3 A BETTER LEGIBILITY OF MAPS BY THE COLOUR CONTRAST

The part 3.1 proposes an interdisciplinary study to determinate parameters influencing the legibility of a map, in particular colour. This general approach of legibility will show common interests between different disciplines in the analysis, understanding and meaning of a sign. Then, the part 3.2 describes knowledge about colour contrasts that will be used in our future model.

3.1 Legibility Parameters

In France, in the sixties, the cartographer Bertin writes a fundamental book *Sémiologie Graphique* (Bertin, 1967), in which he defines graphic rules established according to our visual perception:

- *Appropriated graphic rules*: Which visual variables translate properly the semantic relationship (difference, association, order) between cartographic signs? E.g., the variation of size is perceived as a relationship of order.
- *Graphic density*: A good graphic density is not too high (too much information in a small space) and not too low (too much empty space in a map).
- *Angular separation*: It corresponds to the good perception of a sign in a map and its good separation and differentiation with another sign.
- *Retina separation*: Our eyes structure a visual scene from significant signs to non significant signs.

Targeting our research on colour, we propose to analyse perception phenomena in the information-processing throughout works in psychology and cartography:

- At the beginning of the twentieth century, the Gestalt theory, created by the German psychologist Wertheimer, stipulates that everyone structures his environment in perceptual groups according to different criteria like similarity, proximity, common fate or good continuity (Figure 2):

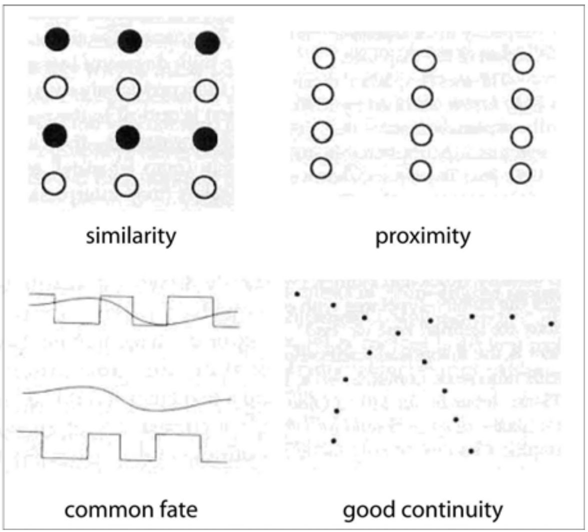


Figure 2: Perceptive groups by similarity, proximity, common fate, good continuity (Belbin, 1996).

Moreover, an element in a visual scene is perceived differently according to its environment. E.g., in Figure 3, circles at the centre are not perceived on the same size because of the neighbouring circles.

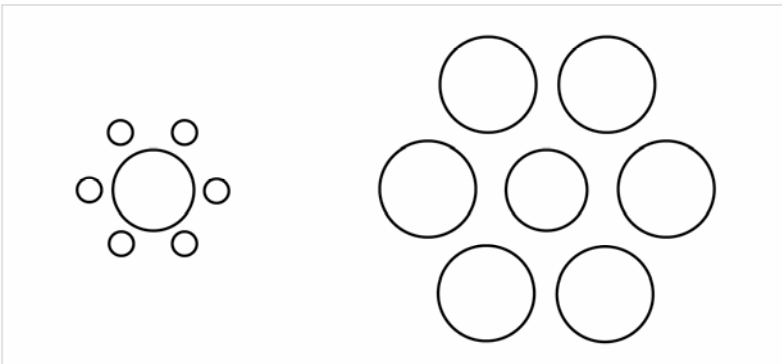


Figure 3: Illusions of Titchener.

- In the eighties, psychologists and cartographers make experimentations in visual search and eye movements to understand better which parameters influence our perception of a visual scene (Chesneau, 2006). Among parameters funded, the colour, important point for our research, is preponderant. Colour creates contrast between signs in a visual scene. "Contrast is the basis of seeing. The critical eye seems to accept moderate and weak graphic distinctions passively and without enthusiasm, while it relishes greater contrasts" (Robinson, 1995) (Figure 4).

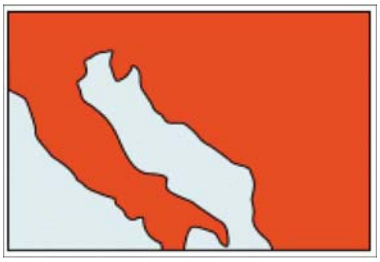


Figure 4: Colour contrast.

Thus, it appears that a map having a hierarchical organisation becomes more legible. In particular, heterogeneity between elements facilitates their discrimination and their visual order. Contrast is necessary for heterogeneity and colour enables to create contrasts satisfying precedent exigencies. Therefore, we target our research on the improvement of cartographic legibility by colour contrast.

3.2 Knowledge about Colour Contrasts for our Future Model

The objective of our model is to automatically improve colour contrasts in risk maps. Figure 5 shows a schematic design of this model:

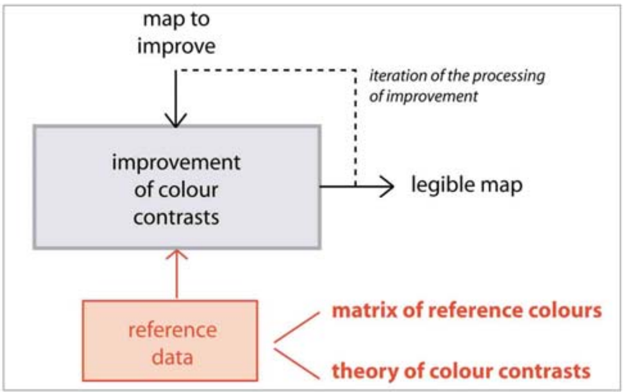


Figure 5: Schematic design of our model.

Two reference data are necessary for our model: a matrix of reference colours and a theory of colour contrasts.

Reference colours are chosen according to two points:

- *Hierarchical organisation*: Risk maps are often constituted of two information levels: figure for hazard or vulnerability areas and ground for less vulnerable elements at risk and other topographic elements. We create saturated colours to portray the figure and coloured greys for the ground.
- *Semantic relationships*: In a map, signs are organised according to relationships of difference, association or order. To facilitate their analysis, we differentiate our colours with the three physiological parameters of colours (hue, lightness, saturation) (cf. Munsell system in

Chesneau, 2006): *hue* to differentiate colours; *lightness* to order colours (the clearest means *less* and the darker *more*) and *saturation* to create a hierarchy between data semantically different or near (saturated colours, coloured greys and greys).

We used Itten (Itten, 1969), Brewer (Brewer, 2003) and Mersey (Mersey, 1990) researches to choose our colours. We obtain fourteen saturated hues, fourteen coloured greys and the grey, each declined into several levels of lightness. We obtain 163 colours (Figure 6).

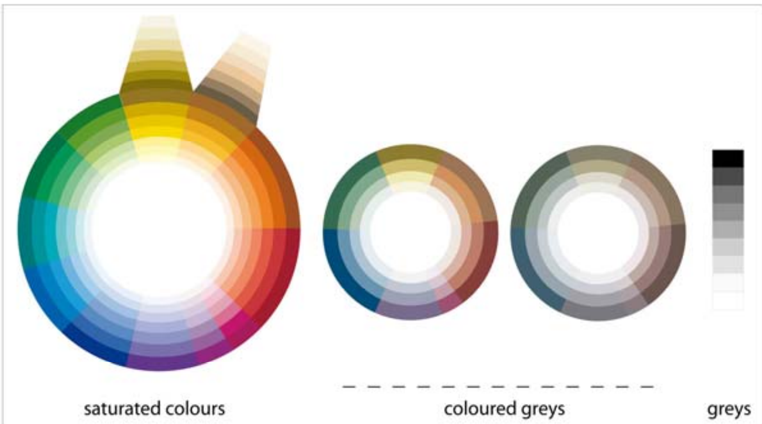


Figure 6: Reference colours.

In addition to reference colours, our model needs knowledge about colour contrasts. The Swiss painter Itten, representative of the Bauhaus movement, proposes a theory of colours integrating contrast: "We speak of contrast when distinct differences can be perceived between two compared effects" (Itten, 1969). Figure 7 shows his seven colour contrasts.

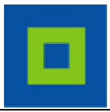
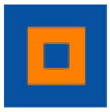
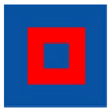
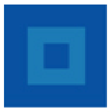
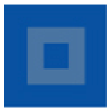
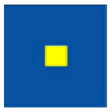
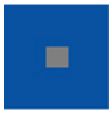
name	definition	illustration
hue	Juxtaposition of different colours. *"Contrast of hue is the simplest of the seven"* (Itten, 1969).	
complementary	*"We call two colors complementary if their pigments, mixed together, yield a neutral gray-black"* (Itten, 1969).	
cold-warm	*"It may seem strange to identify a sensation of temperature with the visual realm of color sensation"* (Itten, 1969). A warm colour near a cold colour creates the cold-warm contrast.	
light-dark lightness	The light-dark contrast opposes a colour lighter than another colour. *"Day and night, light and darkness, this polarity is of fundamental significance, in human life and nature generally"* (Itten, 1969).	
saturation	*"Saturation, or quality, relates to the degree of purity of a color. Contrast of saturation is the contrast between pure, intense colors and dull, diluted colors"* (Itten, 1969).	
extension	*"Contrast of extension involves the relative areas of two or more color patches. It is the contrast between much and little, or great and small"* (Itten, 1969).	
simultaneous	*"Simultaneous contrast results from the fact that for any given color, the eye simultaneously requires the complementary color, and generates it spontaneously if it is not already present"* (Itten, 1969).	

Figure7: Colour contrasts of Itten.

The reference colours and the colour contrasts constitute knowledge for our model that the chapter 4 describes.

4 MODEL FOR THE AUTOMATIC IMPROVEMENT OF COLOUR CONTRASTS IN RISK MAPS

For an automatic improvement of colour contrasts in a map, two components can be analysed: the legend of the map or the map itself. In Figure 8, colours in the legend, organised according to their semantic relationship are legible while the same colours in the map, influenced by their coloured neighbourhood and their spatial extension, are not necessarily legible (like the grey on the blue of the moderate hazard).

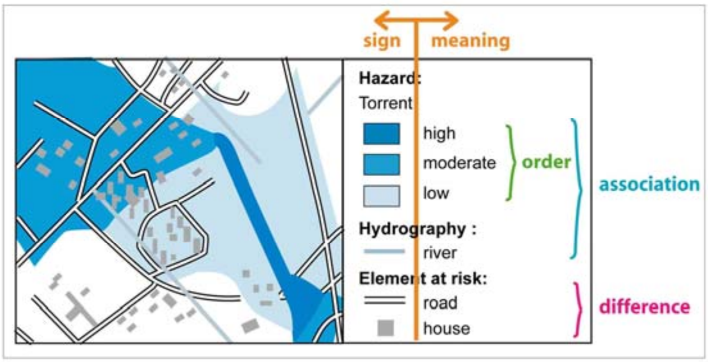


Figure 8: Two components of analysis.

We propose to evaluate colour contrasts around each cartographic sign in the map according to its neighbours. It necessitates analysis at many levels. Then, improvements could be proposed.

Figure 9 describes the constitutive elements of our model: a schema to organise the data (1), knowledge about colours to analyse and improve their contrasts (2), and a process to improve contrasts (3). Our model uses these elements to conceive a final legend creating a more legible map (4) (cf. Chesneau, 2006).

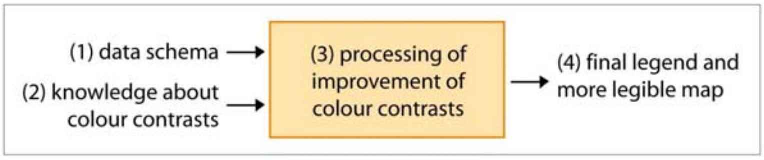


Figure 9: Constitutive elements of our model.

4.1 Data Schema (Figure 10)

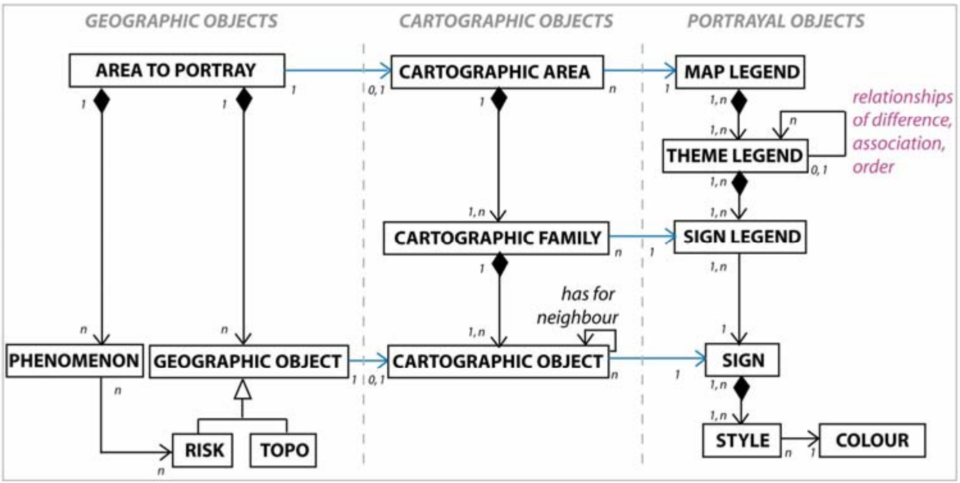


Figure 10: Data schema.

Geographic objects are user data, they are not directly portrayed. In a context of risk, an *area to portray* is composed of *phenomena*, catastrophic events that could happen in the area. It is also composed of *risk objects* (hazards or vulnerable elements) and *topographic objects* (objects accompanying the thematic of risk).

A *cartographic object* is a portrayed *geographic object* on which analysis of colour contrasts is made. A *cartographic object* is defined by its localisation in (x, y) on the map and its portrayal referring to a meaning in a legend. The analysis of colour contrasts on each *cartographic object* being too local, we operate at higher levels: a *cartographic family* regroups *cartographic objects* of the same meaning and the *cartographic area* is composed of all the *cartographic families* of the map.

Cartographic objects use portrayal objects for their cartographic portrayal. A portrayal object corresponds to a line in a map legend. It is graphic (*sign*) and semantic (*sign legend*). A *sign* is constituted of *styles* (point, line, area), each linked to a *colour*. To know the meaning of the *sign*, we create a *sign legend*. All the *sign legends* compose the *map legend*. *Theme legends* give information concerning relationships of difference, association and order between *sign legends*.

4.2 Dynamic of our model

The dynamic of our model is founded on a progressive state change controlled by graphic knowledge and evaluation. To create convergence, we choose a single sequential method solving cycle by cycle the worse contrasts. A cycle enables to go from a valid state to a valid state and a state is the map portrayal at a given time. At the end of a cycle, few colours are changed but the state of the map is improved. The last cycle corresponds to a satisfying final state (Figure 11).

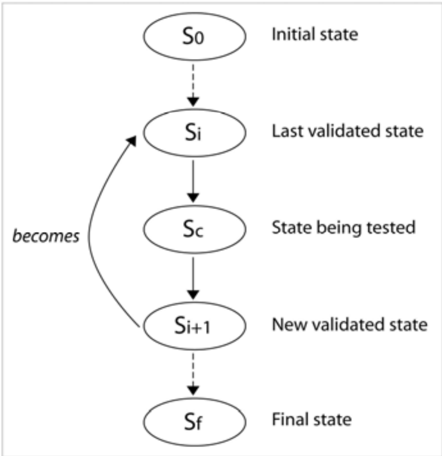


Figure 11: States of convergence.

A cycle is composed of four steps. We explain them with a scenario realised in an experimental prototype *ARiCo* (Automatic improvement of Risk maps by the Colour contrast), constructed on the GIS *Lamps2* of the *LaserScan* Ltd society (Figure 12). Today, only the improvement of contrasts of hue and lightness are implemented.

Figure 12: Initial map.

Step 1: *Identification of the problem*. The *cartographic area* determinates which *family* has the worse contrast in the map, i.e. should be improved. To do this, three actions are executed:

- An evaluation of contrasts is made between each couple of *cartographic objects* neighbouring in the map. For this, we define contrast marks between 0 and 5 for each couple of reference colours and each contrast. E.g., the contrast of hue is high (5) between red and green whereas it is low (1) between blue and green. These marks regroup calculations based on Hue, Luminosity and Saturation codes of colours and practical tests performed by cartographers, graphic designers and non-professionals of colour (Chesneau, 2006).

- An interpretation of contrast is realised. For this, we define ideal contrast marks between 0 and 5 for each couple of reference colours according to their semantic relationship in the map. E.g., if two signs are semantically different, their contrast of hue should be high (5). If they are semantically near (association), it should be low (1). The difference between contrast mark and ideal contrast mark gives a contrast quality: if it is equal to 5, it is perfect; if it is equal to 0, it is bad.
- An aggregation of the contrast qualities is established at different levels: *cartographic object* with all its neighbours, *cartographic family* and *cartographic area* on which a map satisfaction is computed.

Figure 13 presents these data between a building and a low hazard: they are semantically far but their contrasts of hue (0.4) and lightness (0.7) are low. Thus, for *ARiCo*, the both contrast qualities are bad (2.9 and 3.2).

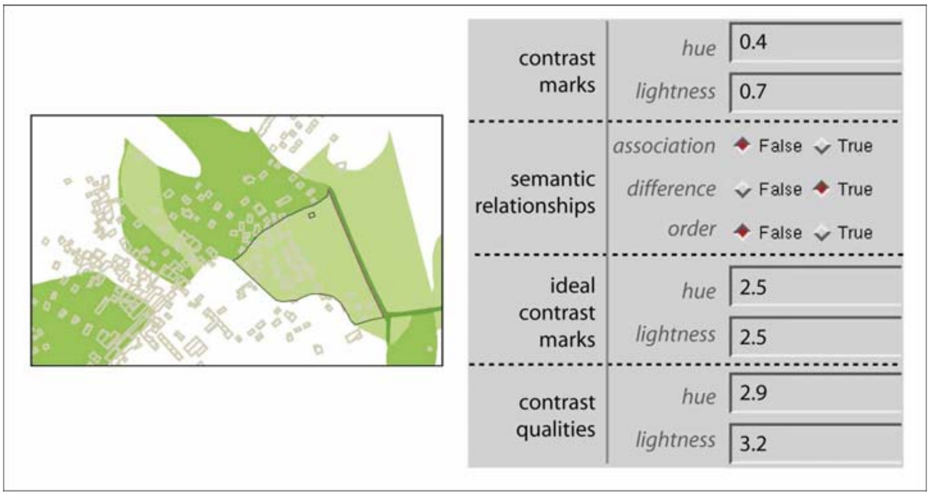


Figure 13: Contrast marks and qualities between a building and a low hazard.

Step 2: *Propositions of solutions.* Each neighbouring *family* proposes new colours for the *family* to change so that their semantic relationship is correctly portrayed in the map. For this, a searching of solution spaces on the chromatic circles is made. In our example, the building, initially 'medium light yellow grey', is badly contrasted with the low hazard 'light green'. Our system proposes to change it into a 'medium light purple grey' (Figure 14).

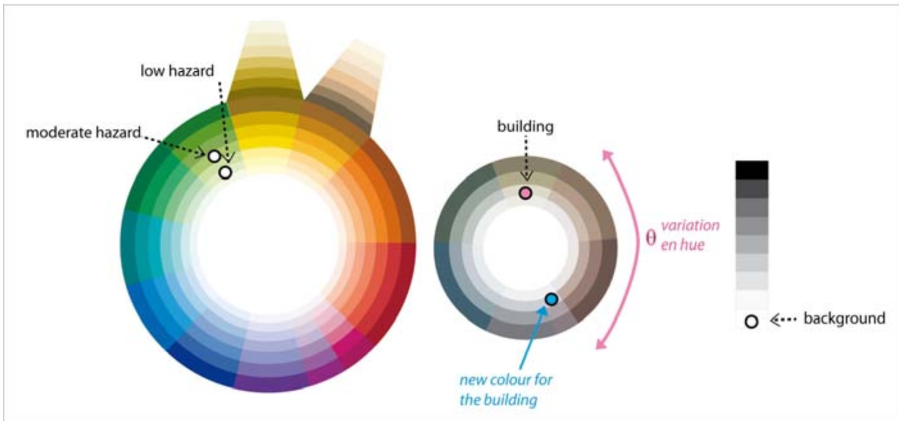


Figure 14: Position of colours on the circles: initial and new colour for the *family* 'building', colours of the neighbouring *families.*

Step 3: *Validation of the chosen solution*. A new analysis is executed and a new map satisfaction is computed. If it is better than the previous, the chosen solution is validated and the next step begins. Otherwise, our model comes back to the previous step to try another solution. In the scenario, the new map satisfaction is better (4.4 instead of 4), then the new state is validated (Figure 15).

Figure 15: The map after a first cycle of convergence.

Step 4: *Stop of convergence.* If the state of the map is good or stagnates after some cycles, convergence is stopped. In the scenario, it is not the case, a new cycle begins. In the next cycle, our system proposes a darker purple grey for the buildings (Chesneau, 2006).

5 CONCLUSION

Our research aims at improving the intensive production of less legible maps. Here are some possible directions to complete and carry on our research:

- *Improvement of our model*: *ARiCo* could be completed and improved:
- analysing the other contrasts than the contrasts of hue and lightness;

- improving the contrast marks, especially with stronger practical tests;
- testing more complex methods of resolution than convergence like stochastic or mechanistic methods;
- making *ARiCo* more interoperable with its development on a new plate-form. It is being implemented on the GEOXYGENE plate-form conceived at the COGIT laboratory of the French Mapping Agency.

* *Evolution of our model*: We could integrate other legibility parameters as graphic density or angular separation.

At the COGIT laboratory of IGN France, researches are made to conceive maps more adapted to the expectations of their users: our own research belongs to this project. It proposes to a user, via the Internet, an interface in which he defines his choices of map and legend. Once the map is created according to his needs, our model would improve its legibility (Figure 16).

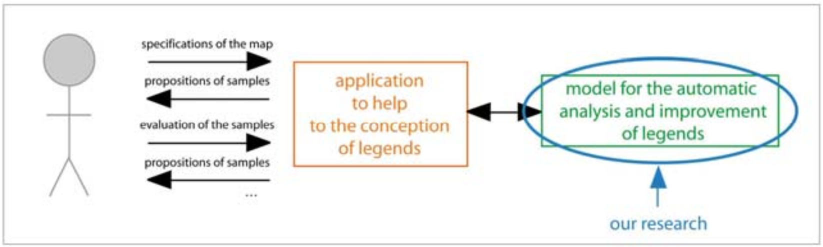


Figure 16: Our model in a more global research project at the COGIT laboratory.

6 THANKS

Thanks to Anne RUAS for her help in the writing of this paper.

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