Creative cartography based on dialogue

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ABSTRACT: As anyone can become a mapmaker thanks to the profusion of cartographic tools and GIS, it is important now to help users making better maps. This paper aims at proposing a model to assist users designing correct and satisfactory legends. We use dialogue techniques in order to support the cartographic expertise, to manage user's preferences, and to support negotiations between the user and the system. Our dialogue engine is based on design strategies, various ways to retrieve the user's constraints, with the help of map samples or of painters' palettes. They aim at proposing several suitable legends according to constraints: Constraint Satisfaction Problem methods are used to solve this problem. Those intermediary legends are evaluated and proposed to the user, which can select the most satisfactory of them, respecting the cartographic rules or not. Refinements tools are provided to the user to improve again his legend, offering him a wider degree of creativity. At the end, the final legend is designed, when all themes are completed and the user is satisfied. A prototype is also presented.

KEYWORDS: Cartography, creativity, legend, map design, colours, styles, man-machine dialogue

Introduction

Map design is not merely a matter of experts: it is well-known that many people use maps, and many become mapmakers too (Wood 2003, Plewe 2007). Nevertheless, even if they show a huge motivation, they may lack the theoretical and technical cartographic knowledge. In parallel, existing cartographic applications do not adapt themselves to this new generation of users: no assistance is provided to the user. New mapmakers need help in terms of cartographic expertise and need to be given the opportunity to be creative.

This work is an on-going PhD in the COGIT laboratory of the French National Mapping Agency (IGN). Its purpose is to propose a methodology to assist a user in conceiving efficient, satisfactory and creative legends on the Web. In (Christophe et al. 2007), we propose dialogue techniques to support the cartographic expertise, to manage user's preferences, and to support negotiations between the user and the system. But we face various difficulties: how to retrieve the user's preferences? How to manage both constraints from the user and the system? Then how to propose to the user various suitable legends? And finally, how to make him select and refine the most satisfactory of them? In this paper we aim at specifying our model of dialogue. In the first section, we present how suitable legends can be proposed according to constraints. Then we clarify our dialogue and its processes, including the previous step, which manage the all design of the most satisfactory legend.

To design suitable legends according to constraints

Our first problem consists to design suitable legends that fit a number of constraints coming from the user and from the system. We first clarify the objects the system manipulates: legends and constraints. Then we propose methods to resolve this constraints' problem.

Our model of a legend is presented in (Christophe 2007) and illustrated in Figure 1.

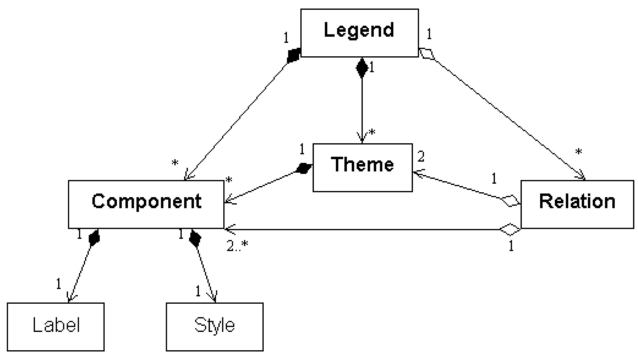

Figure 1 : Model of Legend

We call:

- *Component*: a *Label* and a *Style*.
- *Theme*: a set of components with relations (association, order).
- *Relation:* what binds components (association, order) or themes (association, order, and difference).

At the beginning of the dialogue process, the legend is empty and aims to be fulfilled during the process of dialogue. It has three main statuses:

1- *Status of completeness*: while the dialogue is going on, the system stores the preferences of the user and fills in the model step by step. When themes, relations, components and styles are all informed, the legend is completed.

2- *Status of satisfaction - User's side*: the satisfaction of the user is measured by the level of respect of his enunciated constraints.

3- *Status of satisfaction - System's side*: the satisfaction of the system is measured by the level of respect of the cartographic rules.

Finding a legend that satisfies a number of constraints is actually similar to a Constraint Satisfaction Problem (CSP) (Russell et al. 2006) which is defined by a set of *variables* X1, X2…, Xn which can take some possible *values* that should satisfy a set of *constraints* C1, C2…, Cn. In our context of legend design, the variables are the *themes*, the values are the *colours* each theme may take, and the constraints are the user and the cartographic ones. The problem can be solved with a recursive algorithm of search called backtracking (Russel et al. 2006). The principle of this algorithm applied to our problem is the following: initially, all themes are uninformed. At each step, the system chooses a theme to which all colours are assigned in turn, according to current constraints: a first one may be that all themes have different colours. When all colours have been tried, the associated legend is created and stored, and the algorithm backtracks. With such an algorithm, our system is able to find all suitable legends that respect the given constraint of "all themes have different colours" as presented in Figure 2:

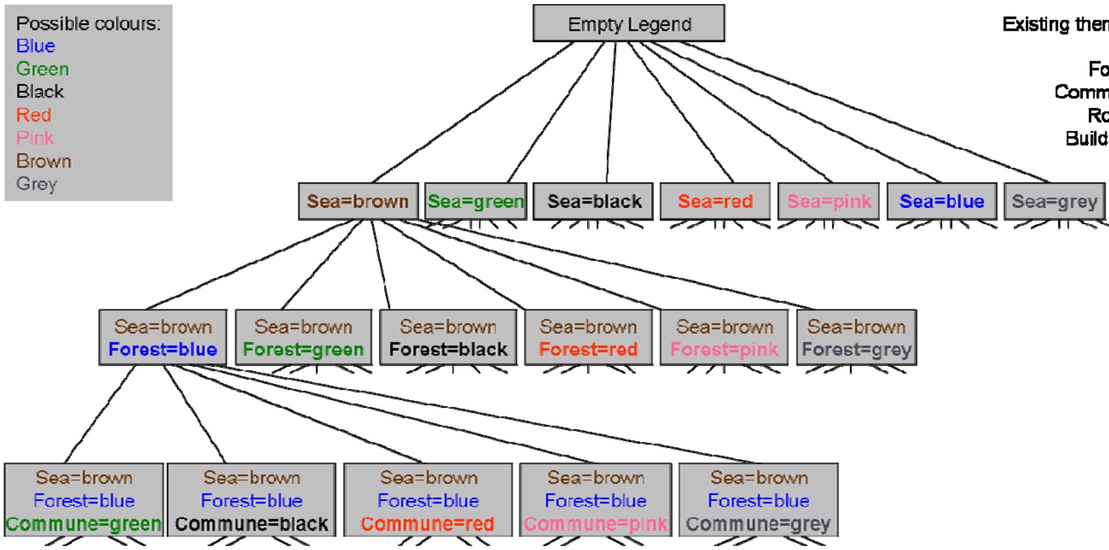

Figure 2 : Exploration tree for the legend design (one constraint: to have different colours for each theme)

We thus propose to translate the tastes and needs of the user, and the cartographic rules into *constraints* that will guide the process of design.

Our dialogue engine relies on a cartographic knowledge base conceived with the help of the *cartographic rules* inspired by Bertin(1967), Robinson(1995), MacEachren(1991) and Monmonnier(1995). Some cartographic rules may be listed as following:

Rule 1: "*Conventional colours have to be used*"

Rule 2: "*A differential relationship between two themes is rendered by a sufficient difference between hues*"

Rule 3: "*An association relationship between two themes is rendered by a minimised distance between hues*"

User's tastes and needs are various. The context of the application may be diversified: the user may have to conceive a map for professional purpose and may not be a cartographer. He has some realistic purposes ("I need to render the urban zone, the hydrographical network, the electrical network and the power stations") and some aesthetic purposes ("I would like an attractive map", "I like this blue for the sea").

From these rules and preferences, we extract some simple constraints on the map, on the legend and on all the objects of the legend (theme, relation, style…). Moreover, we propose to model a constraint as an object with the four following characteristics:

- Its object of interest: a map, a legend, a theme, a colour …

- Its value: identification of a legend, name of a theme, RGB-code, a method…

- Its preference: approved by the user / positive for the system (+), disapproved by the user / negative for the system (-)

- Its probability of satisfaction: high, medium, low.

Figure 3 presents some constraints extracted from the listed cartographic rules and their formalization:

The Rule 1 gives:
Constraint 1: "The sea and the hydrological network are rendered in blue"

Constraint 2: "The vegetation is rendered in green"

The Rule 2 gives:
Constraint 3: "If this theme road has the colour XXX, other themes must not have the colour XXX"

Constraint 4: "If the theme road has the colour XXX, another theme must have a colour included between angles of x degrees."

Constraint 1:	Object: sea theme
	Value: bleu
	Preference: ++
	Priority: 1

Constraint 3:	Object: building theme
	Value: XXX
	Preference: --
	Priority: 1

Constraint 4:	Object: building theme
	Value: Angle()
	Preference: ++
	Priority: 2

Figure 3 : Formalization of some cartographic rules

Figure 4 presents some constraints extracted from user's tastes and needs. As our research work focuses on style definition; we manage only constraints about styles.

Constraint 1: "I like the colour 231-120-125 for the roads theme"

Constraint 2: "I do not like the colour 120-200-180 for the vegetation theme"

Constraint 1:	Object: road theme
	Value: 231-120-125
	Preference: ++
	Priority: 1

Constraint 2:	Object: vegetation theme
	Value: 120-200-180
	Preference: --
	Priority: 1

Figure 4 : Formalization of some user's constraints

In this section, we proposed a model of constraints and a method to create suitable legends meeting some constraints. In the following section, we present our model of dialogue that instantiates the various constraints both from the user and the system, and that manages the interactions with the user in order to make him selecting the most suitable legend.

To manage a dialogue to design the most satisfactory legend

In the previous section, we presented a method to propose suitable legends according to constraints which is a part of the global process of legend design. In fact, it raises many other problems. How to retrieve the user's needs and adapt to them? Once several legends are proposed to him, how to make him selecting the most satisfactory? In this section we describe first a global model of dialogue allowing the management of these issues. Then the global process of dialogue is presented, divided into three main steps:

- Step 1 – Proposition of intermediary legends by the system
- Step 2 – Evaluation and visualisation of intermediary legends by the system
- Step 3 – Refinement of a suitable legend to make the satisfactory legend by the user

Our conceptual model of dialogue is divided into four types of concepts with the help of man-machine dialogue models, and in particular negotiation model, proposed by (Caelen and Xuereb 2007). It is presented in Figure 5:

The controller of the dialogue manages the dialogues *globally*. It monitors it and evaluates at any step if it processes well or not.

The design strategies manage the dialogue *locally* and are various methods to propose intermediary legends: they consist in a framework of predefined *actions* from the system and interpretations of user's *actions*. Two of them are described in the Step 1.

The objects of strategies described in Step 1: *The Map Samples DataBase* (*MSDB*) conceived by Domingues and Bucher (2006): about fifty legends have been applied on a dataset at two different scales in order to create map samples; *the palettes database* that we conceived (Christophe 2008): we extracted colours from famous paintings that called "palettes"; *the reference colour space*.

The CSP Methods described in Step 1.

The evaluation, visualisation and refinement methods described in Step 2 and Step 3.

The objects of the dialogue: Legend and Constraints described in the previous section.

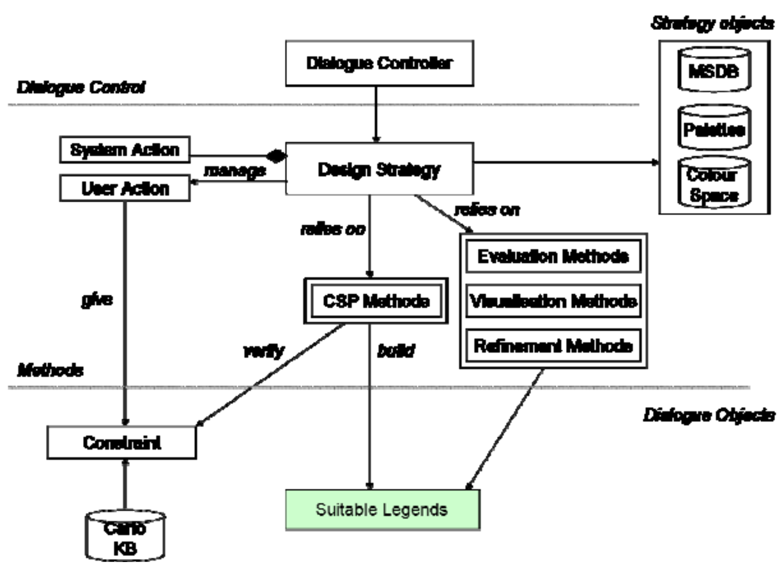

Figure 5 : Our model of dialogue

Global process of dialogue

At the beginning of the dialogue, the controller makes the user select a design strategy. The purpose of the strategies is to propose *intermediary suitable legend(s)* quickly and as close as possible to the expected legend. If the process of one strategy is too long or endless, the controller may propose to switch to the strategy. Figure 6 presents these steps.

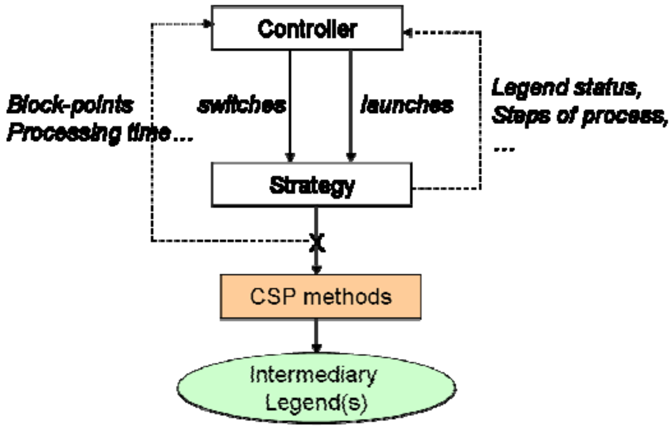

Figure 6 : Goal of a strategy and feedback to controller

Once one or several intermediary legend(s) have been created, the strategy launches evaluation methods on them: criteria as the global contrast in the legend or the global respect of conventional rules are used. Legends notes are returned to the controller. Then, the user selects one of the intermediary legends and may refine it with the help of the refinements methods proposed by the strategy: all refinements are considered as new user's constraints. These steps are represented in Figure 7. During this step of refinements, the on-going legend is still evaluated. The intermediary legend becomes the final legend, when:

- all themes are completed (completeness of the legend)
- the user is satisfied.

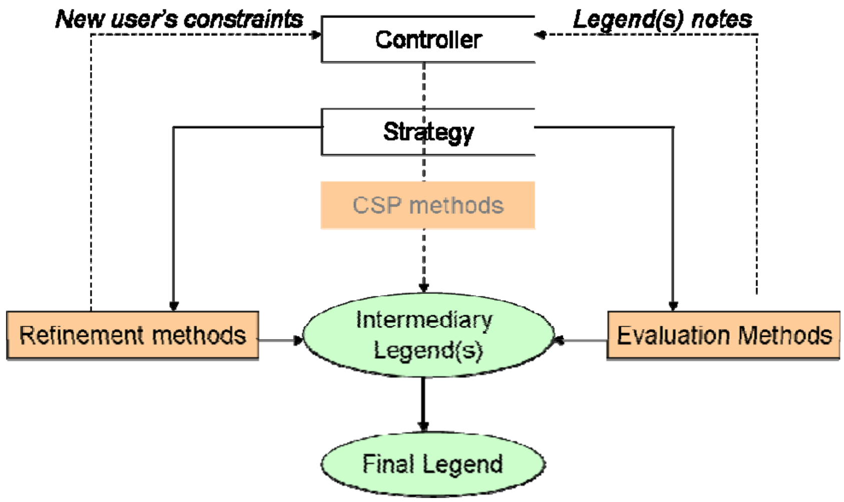

Figure 7 : Intermediary to final legend

After this general presentation of the process of dialogue, we present each step of this process: proposition of intermediary legends, evaluation of them, and refinement of one of them to design the final satisfactory one.

Step1 - Proposition of intermediary legends by the system

We remind that design strategies manage the dialogue locally and are different ways to design legends. They aim at proposing one or several intermediary legends.

Process of the strategy "Select a sample or pieces of samples"

This strategy consists in helping the user to select a sample or pieces of samples in the MSDB, on which the future legend for his data will be based. As we focus on style definition, the pieces of samples the user can get here are the colours for each theme. The process consists in a basic sequence of actions, from both user and system, repeated until one of the following actions from the user, presented in Figure 8:

- Colours for some theme of the legend are approved: the system relies on the CSP methods described in the previous section to search all suitable *intermediary legends*.
- A satisfactory map sample is selected: the legend of the map sample, applied on the user's data, becomes the *intermediary legend*.

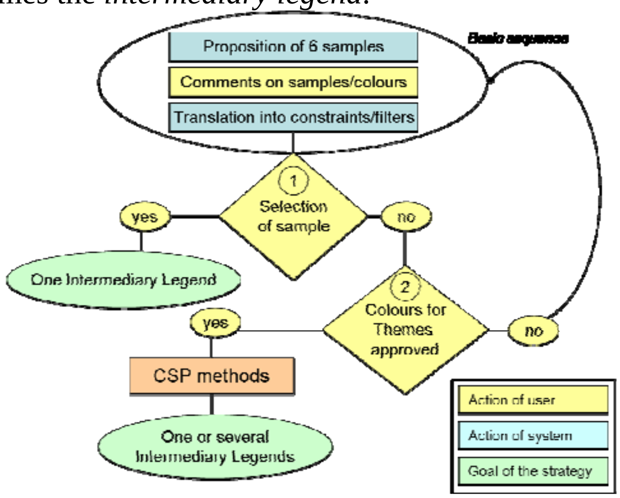

Figure 8: Process of the Strategy « Select a sample or pieces of samples »

The basic sequence between the user and the system is divided into three parts.

1- Proposition of a board of six map samples by the system

The first construction of a board of six map samples is a random selection from the MSDB. At each interaction between the user and the system, this making integrates the current user's constraints (Cf § 3). The system proposes then the board to the user.

2- Comments on samples and/or colours by the user

The user visualises and comments the board of six map samples, by selecting/rejecting a colour for a theme, and/or by selecting/rejecting a map sample. At this step, if he finds a map sample that satisfies him, he can directly select its legend for his own data, makes it applied on his data, and this legend becomes the intermediary legend.

3- Translation of comments into constraints and filters by the system

Comments on map samples and colours give *filters* on the MSDB to construct the following propositions of more and more satisfying samples. Moreover comments on colours give *constraints* on the legend.

The comments on map samples are considered as *filters* (represented in orange in Figure 9) for the selection of a new board of samples: "I like this sample" implies the tagging of the sample as *approved*, while "I do not like this sample" implies the tagging of the sample as *disapproved*.

The comments on colours for a theme are considered as *user's constraints* (represented in purple in Figure 9): "I like this colour for the roads theme", implies the storage of the colour as a *suitable colour* for this theme, while "I do not like this colour for the roads theme" implies the storage of the colour as *unsuitable colour* for this theme.

These comments imply also *new filters* for the selection of a new board: the sample with the approved colour is approved too, and other samples with the same colour for the theme are approved too (same process for disapproved colours).

To manage filters and to improve the choice of a board of samples, priority is attributed to the approved samples: a high priority (1) is for samples directly approved by the user, then medium priority (2) is for samples which have a colour directly approved, and low priority (3) is for other samples indirectly approved. In order to improve the selection of a new board at each turn, the systems selects first samples with high priority, then medium and low, and finally in the rest of the MSDB. Figure 9 summarizes the conversion of comments in constraints and filters.

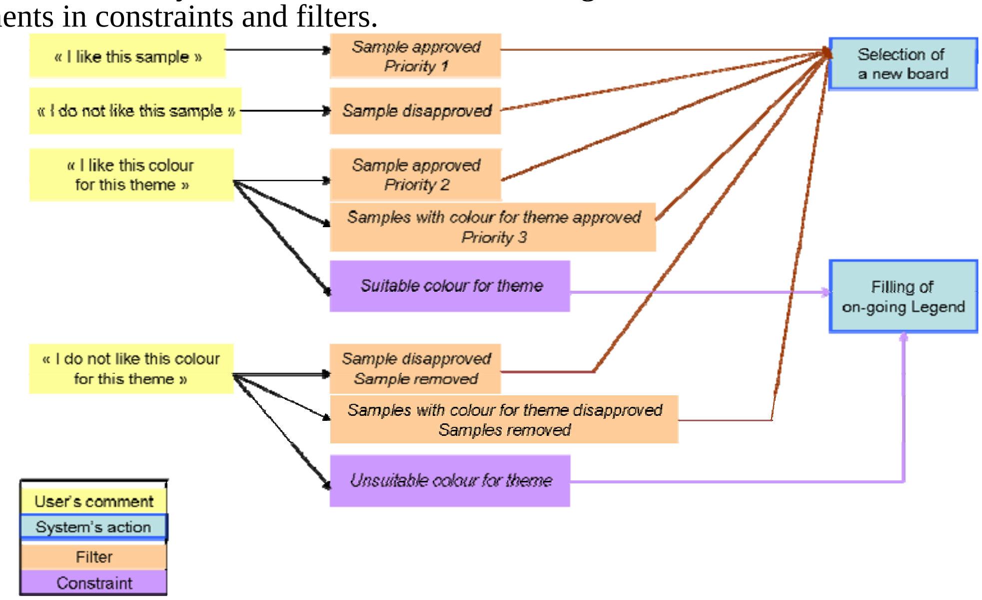

Figure 9 : Analysis of user's comments

The strategy "Samples or pieces of samples" proposes one or many intermediary legend(s). We describe now the process of the second strategy whose result is the same.

Process of the strategy "By means of painters' palettes"

The strategy "By means of palettes' painters" consists in helping the user select aesthetic combinations of colours and improves the step of exploration of colours in style definition. In (Christophe 2008) we conceived palettes from famous paintings, characterised mainly by a rich choice of colours: we talk about the Matisse Palette which is obviously not the real palette of Matisse, or the real palette of the painting "La Tristesse du Roi", but a selection of characteristic colours in a painting. We also developed a tool to conceive topographic legends with the help of painters' palettes. This tool is integrated to our dialogue engine as a legend conception strategy. We remind in Figure 10 the main steps of this process:

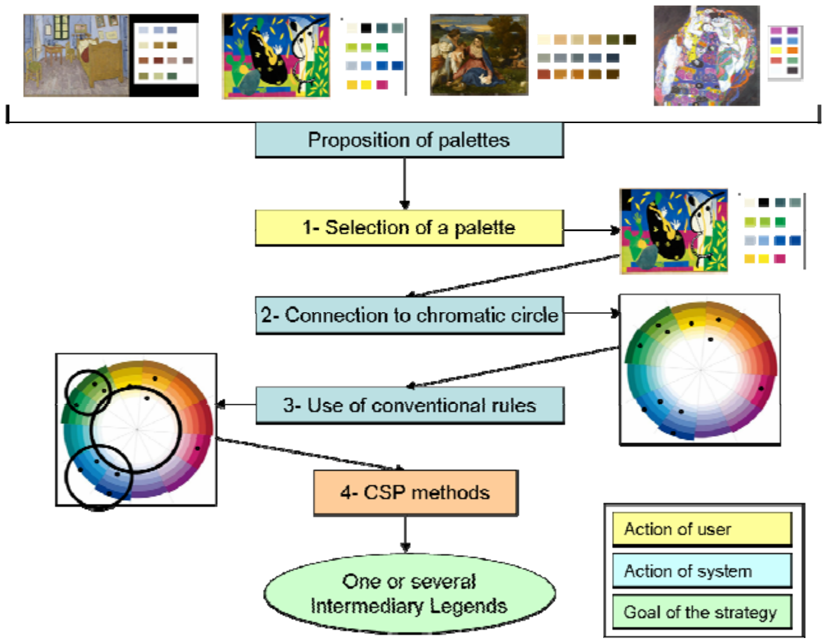

Figure 10 : Main steps of the strategy "Palettes"

1- Selection of a palette by the user

The user selects a painting associated with a palette among the proposed ones. We see in Figure 10 some existing palettes; the following examples use the Matisse Palette.

2- Connection to the chromatic circle by the system

On the contrary to the previous strategy, the system tries to integrate cartographic rules prior to the construction of suitable legends. In order to manage the existing cartographic rules, we use the chromatic circle as reference colour space proposed by Chesneau (2006) and improved by Buard and Ruas (2007). Measures of distances between hues and values can easily be done, allowing the integration of cartographic rules such as "*An associative relationship between two themes is rendered by a minimised distance between hues* ". Moreover, we can easily detect some colours families, if necessary. The system connects the colours of the palette to the colours of the circle by measuring Euclidian distances between them as shown in Figure 11.

3- Use of conventional colours for sea, vegetation and background themes by the system

With the help of the chromatic circle, the system defines *colours families* that are intended to render some themes:

- The Green Family is intended mainly for the vegetation.
- The Blue Family is intended mainly for the sea and hydrographical networks.

For instance, a blue in the Matisse Palette is automatically considered as "a suitable colour" for the hydro theme of the user's data. Moreover, it is also recommended to use clear colours for the background (commune in our dataset) in order to maximize the colours' contrast: lowest values in the circle are intended mainly for background. Therefore, a white or one of the clearest colours in the palette is automatically considered as "a suitable colour for the commune theme". Figure 11 presents the families of possible colours with the Matisse Palette.

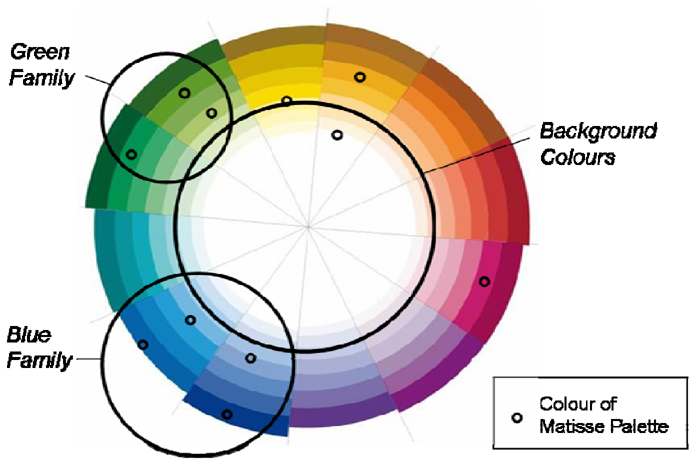

Figure 11 : Colours families of the Matisse Palette

4- CSP methods for the other themes by the system

For the rendering of the other themes, the system relies on the CSP methods. Figure 12 presents the exploration tree the system used when colours of sea, vegetation and commune have been selected yet:

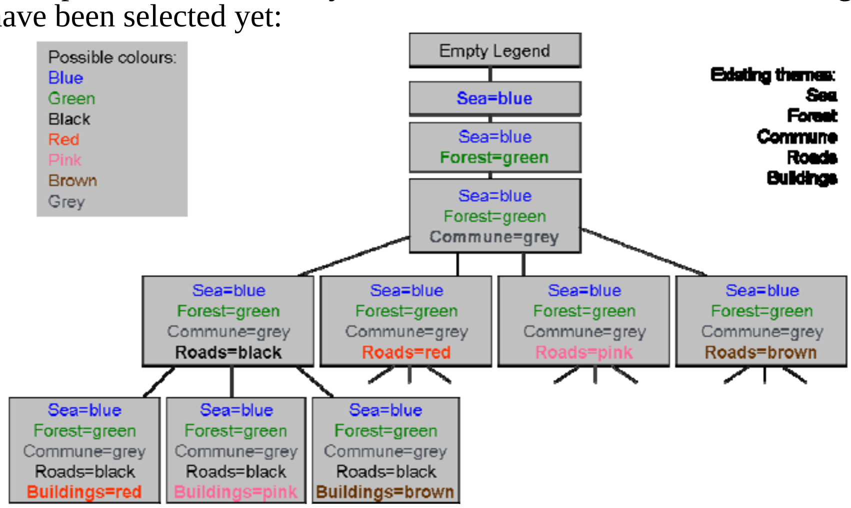

Figure 12 : Backtracking

As at the end of the first strategy, many intermediary legends are created at the end of the strategy "By means of painters' palettes".

Step 2 - Evaluation and visualisation of intermediary legends by the system

Many intermediary legends have been created. The aim of the Step 2 is to make the user selects one satisfactory intermediary legend. In order to help him to make a choice, all legends are applied on user's data, evaluated, and proposed to the user.

The evaluation is done according to the following criteria:

- Attribution of a global note of contrast given by the tool proposed by Buard and Ruas (2007).

- Attribution of a note of respect of conventional rules: if the Colour Family is respected for two themes, the note is: 2/total number of themes.

- Attribution of a note of respect of cartographic rules: we sum the two previous notes to have an idea of the respect of cartographic rules.

The system proposes various sorting methods to display the legends to the user:

- "The most different": measured by calculating all Euclidian distances between each colour theme by theme: Figure 13 presents the list of comments made by a user and Figures 14 and 15 present the two most different suitable legends according to these comments:

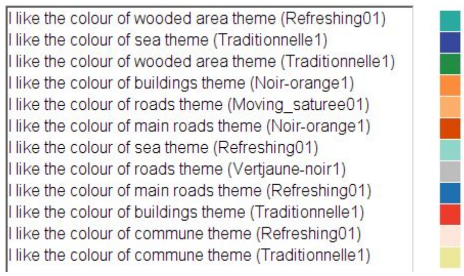

Figure 13: List of user's comments

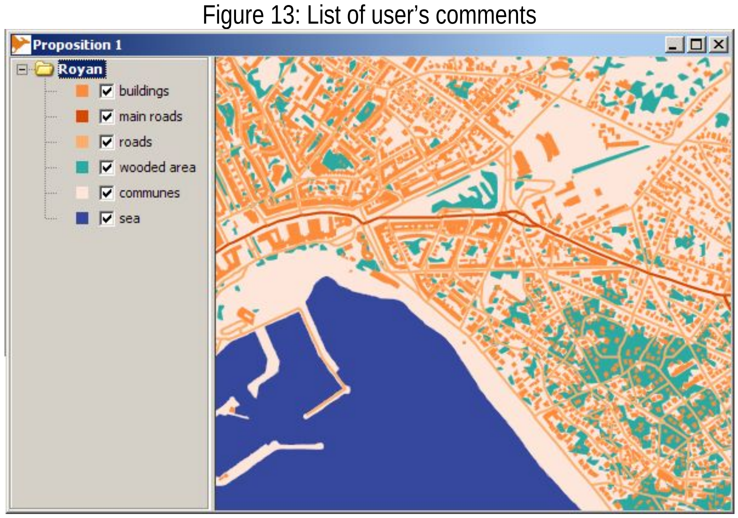

Figure 14: First suitable legend

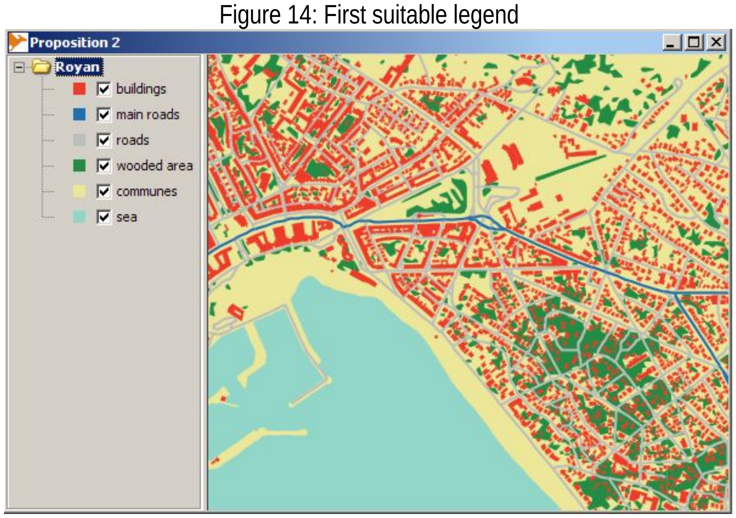

Figure 15: Second suitable legend

- ‘The most contrasted”: measured by a global note of contrast.
- “The most conventional”: measured by a note of respect of conventional rules

The end of the step is characterised by the selection of one intermediary legend by the user that he could immediately validate as his final legend if it is satisfactory or refine to make it better.

Step 3 - Refinement of a suitable legend by the user

The two previously strategies make the user select an intermediary legend that is close to his tastes and needs. He can however refine it by clarifying/darkening or modifying some colours. With the help of a menu, the user modifies each previously selected colour of the legend. The menu proposes him a palette of colours that integrates the cartographic constraints and the ones given by the user during the process. Palettes may be of three different types:

- All other colours available

- Only conventional colours for this theme (presented in Figure 18).

- Different values of the current hue of this theme (presented in Figure 18).

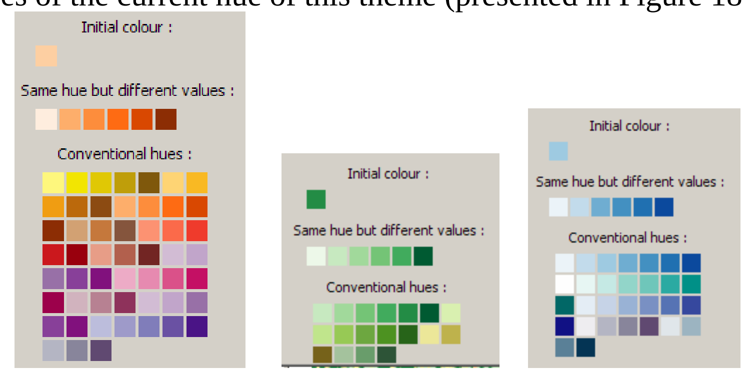

Figure 16: Propositions of palettes to refine the legend (for roads, wooded area and sea)

The user can switch between the different palettes according to his tastes and needs. In parallel, the system updates the user’s constraints and its evaluations on the legend. If necessary, the system warns him about the respect of cartographic rules: the user may decide to respect them or not. At this step, all themes are completed, so the intermediary legend becomes the final legend, when the user is satisfied and validates it. He thus gets a wider degree of creativity; he can select a final legend that does not respect all constraints.

Prototype

A prototype based the presented model is developed in Java:

-For the visualization and manipulation of geographical data and legends, we use OpenJump (http://openjump.org/)

-For the storage of geographical data, palettes and map samples, we use PostgreSQL/Postgis DBMS (http://www.postgresql.org/),

-For the management of the geographical data, we use the Geoxygene platform developed in the COGIT Lab (Badard et al. 2003)(http://oxygene-project.sourceforge.net/).

Moreover, interactions between the user and the system appear through intuitive and simple interfaces.

Conclusions and Perspectives

The purpose of our paper is to assist users to design satisfactory legends. We propose a model of dialogue to retrieve the constraints of the user, to manage cartographic constraints, to design many suitable legends according to these various constraints and to finally help the user to choose his final satisfactory legend among the suitable ones. We specify various processes based on design strategies, CSP methods and evaluation and refinement methods. A prototype is implemented: processes and resulting legends are promising.

As we mainly focus our attention on the proposition of suitable legends, we do not deal with the selection and extraction of user's data and on the structuration of the legend yet. Our dialogue engine should rely on various other modules that allow processing these steps. Figure 16 shows these modules and their interactions with our dialogue engine:

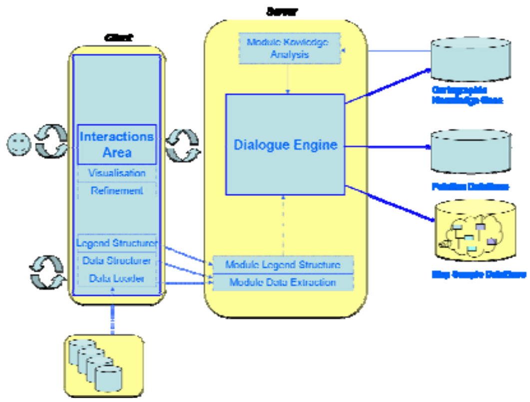

Figure 17 : General architecture and links to other modules

Moreover, our application should rely on colour improvement tools such as the contrast improvement tool proposed by Chesneau (2006) and Buard and Ruas (2007), in order to propose better colours for the themes concerned by a bad contrast. And then we have to integrate more complex styles in our system.

Finally, another main issue is the management of the cartographic and user's constraints. In the CSP methods, we assume that we have a sufficient number of colours during the exploration of suitable solutions, but it is not always the case; moreover the user may make many comments on colours translated into too many constraints on the legend. Criteria of priority and importance have to be added to each Constraint object: if we have too many constraints, some of them should be relaxed in order to reach a solution.

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