CO-249

OPTIMAL VISUALIZATION OF SATELLITE IMAGERY AND SUPERIMPOSED VECTOR DATA; A NEW TREND TO THE CONCEPTUAL VISUALIZATION OF LAND-USE MAPS

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Abstract

Satellite images play a major role in realistic visualization of the earth's surface. There is hardly a local-scale map, which satellite images are not used in its visual appearance. The key issue to be addressed is the fact that satellite images are not powerful enough by themselves, regarding the cartographic communication. Using vector maps (e.g. roads, urban and rural areas, etc.) and adding other information (e.g. text materials) on these images, will increase their communicative function. In most cases, satellite imagery is used as a background of other data for general representations such as Google Earth. In this way, users will get more oriented toward the represented area. In this regard, various cartographic rules should be taken into account. Satellite images include different kinds of color composites, so a wide variety of colors on the map would be created. This color variation may suppress other features' cartographic communication.

In this research, cartographic aspects are considered to optimize the visualization of satellite images and superimposed vector or textual data, regarding the hierarchical organization and visual variables. Consequently, some rules and cartographic points related to the smoothing and filtering along with variables of 'halo', 'mask' and 'callout' for providing the textual data on satellite images are taken into account. On the other hand, considering the maximum allowable classes in making selective visual perception, the number of represented classes is optimized based on the concept of land-use changes. Thus, conceptual visualization is suggested to optimal visualization of changes and interpretations related to the land-use maps. All of the discussed topics are implemented in visualization of land-use changes of hydrological regime of Sattarkhan dam basin and also rivers of Jolfa city in Iran, practically.

Key Words: Visualization, Cartographic communication, Selective perception, Satellite imagery, Vector data, Land-use

1- Introduction

Nowadays, making use of satellite images plays a major role in visualization of vector data. Furthermore, maps of land-use and the trend of related changes, as the main products of satellite images, are included as a powerful tool for land management and planning. Along this, appropriate representation of obtained results and interpretations needs special visualization for successful communication between user and map.

Visualization process is considered to be the translation or conversion of geospatial data from a database into map (Kraak and Brown 2001). In this way, cartographic principles are used as a path to transition of spatial perception (Dodge et al. 2008); and they are followed as optimal design of a map. In present research, a combined representation of raster and vector data is studied and cartographic aspects for their optimal representation based on hierarchical organization and visual variables, are inspected. Furthermore, according to the vital function of assessing land-use change maps and outcome interpretations, visualization is presented as a concept, based on perception property of the data. Towards this end, according to the selective visual perception, the number of presented classes is optimized based on the concept of changes. All the discussed subjects and principles are implemented in cartographic visualization of land-use changes of the hydrological regime of the rivers of Jolfa city, and also for extracting the land-use changes of Sattarkhan dam basin.

The rest of this paper is organized as follows. We shall first highlight some cartographic rules in relation to integrated visualization of satellite imagery and vector data. Then, conceptual visualization is discussed and is implemented to optimize the visualization of land-use changes and related interpretations.

2- Combined visualization of satellite imagery and vector data

Figure-ground relationship is one of the most important aspects of visual hierarchy. It should be observed properly; otherwise the cartographic visualization would be ambiguous (Tyner 2010). Satellite images are often used as a background of vector data. On the other hand, vector data is used to represent the main phenomena proportional to the map design purpose. Task relevant information should be visually salient (Dent 1999). Therefore, vector data should carry more visual weight than other elements represented on the map and should be recognizable enough from the ground in a nominal level. In this regard, color as the most effective variable in creating selective visual perception (Elzakker 2004) plays a decisive role in making appropriate figure-ground relationship. In the next section, some cartographic rules will be provided for the purpose of optimal visualization of the vector data and satellite imagery in presence of each other.

2-1- Representation of satellite imagery

To achieve optimum representation of satellite images as a background of vector data, wide variety of cartographic rules should be considered to orient the users more than ever. As a matter of fact, following points should be taken into account:

• The selection of background image is intensively related to the spatial resolution of vector data. For example the appropriate background of vector data in the 1:2000 scale in a city region could be a high resolution image (e.g. IKONOS) and the usage of Landsat or SPOT images is not practical and it may reduce the map's clarity.

• High color diversity of satellite image influences other features that are superimposed on it. For example, red color in false color composition (bands 4, 3, 2) for Landsat ETM+ images will cause downplay or eliminate of roads and feature, which are shown in red. This tip is true in other color compositions. For this reason, it is tried to use true color composition (TCC) of multi-spectral images for visual purposes as much as possible.

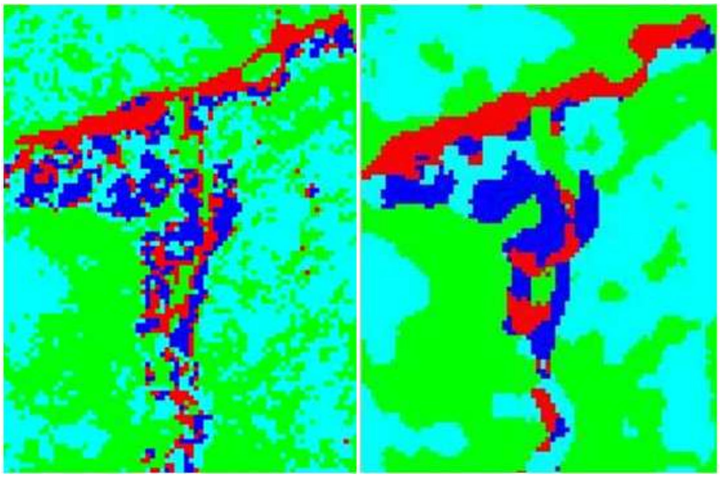
Figure 1, representation of water features on TCC, Spot

• Various parts of images are always adjusted and made obvious from contrast and lightness point of view. An example of lack of histogram matching in adjacent images on a provided map of Google Earth is illustrated in Figure 2 .It is shown that this kind of representation effects negatively on cartographic communication of the map.

Figure 2, non-observance of histogram matching, Google Earth, 46◦23' E 38◦02' N

The visualization of land-uses maps extracted from satellite images, as one of the important raster data in geospatial information systems (Weng 2010), is one of the other important factors discussed in raster and vector data representation. After image classification and before converting to vector, some necessary processes such as filtering make a better visual representation. For example, high pass filter with the kernel size of 3*3 is used to adjust the result of classification and elimination of the individual effects of pixels in the basin of Hajilarchay River, (Figure 3).The visualization of land-use maps extracted from satellite images, as an important raster data in geospatial information systems (Weng 2010), is one of the main factors discussed in raster and vector data representation. After image classification and before vectorization, some necessary processes such as filtering will help achieving a better visual representation.

For example, low pass filter with the kernel size of 3*3 is used to adjust the result of classification and elimination of the individual effects of pixels in the basin of Hajilarchay River (Figure 3).



a. before filtering b. after filtering

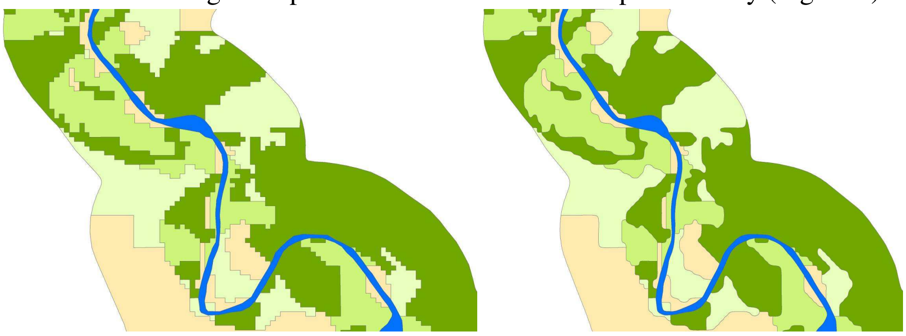
Figure 3, visual optimization of classified image by filtering, Hajilarchay river, TM

2-2- Representation of vector data

In order to apply more visual weight to point and line symbols on the satellite imagery, the appropriate selection of color and thickness is indispensable. Using visual variable of transparency provides possibility of the representation of non-continues areal features (e.g. townships area or dam reservoirs). Nonetheless, the representation of the real texture of continuous polygons on the satellite imagery would be difficult and this is not currently possible. Such representations may be created with interactive tools.

In order to make vector data including lines and points more recognizable on a high colorful surface, some exaggerating in visual elements will be needed. Using a solid color for vector layer (line spots, polygons or points) on the surface with high color variation will not satisfy the map clarity. In this way, variables of value and transparency would improve the map's clarity. In the case of colorful representation, showing extensive vector layers (like roads, hydrography or power transmission networks) on the panchromatic images involves less cartographic challenges.

On the other hand, converting the raster data to vector and improving its visual presentation are very important in spatial information systems (Jian-Wei et al. 2008). Obtained data from vectorization (e.g. land-use polygons), should be visually compatible with real world. In this regard, smoothing has an outstanding impact on the produced map's successful communication. The process of polygon smoothing should be done in a way that its attribute does not change and extra smoothing in excess of need that causes getting far from reality should be prevented. Pixel size is one of the influential factors on the smoothing radius. In the present study, diameter or twice the pixel size is considered approximately as the radius of smoothing and optimal results are obtained experimentally (Figure 4).



a. before smoothing b. after smoothing

Figure 4, smoothing of classified image, Hajilarchay river, Spot

2-3- Representation of texts on satellite imagery

Although maps are generally symbolic in nature, most maps contain considerable text material. Text on maps serves one of four purposes: (1) to label, (2) to explain, (3) to direct or point, or (4) to establish a hierarchy or show size (here type acts as a symbol) (Tyner 2010). Each of the mentioned cases in combined visualization of satellite images and vector data is applicable. The key issue is the fact that high diversity of color on satellite images may reduce text legibility and thus the efficiency of the cartographic communication. Likewise, in the case of panchromatic images (e.g. IRS), dark texts would be faded (Figure 5).

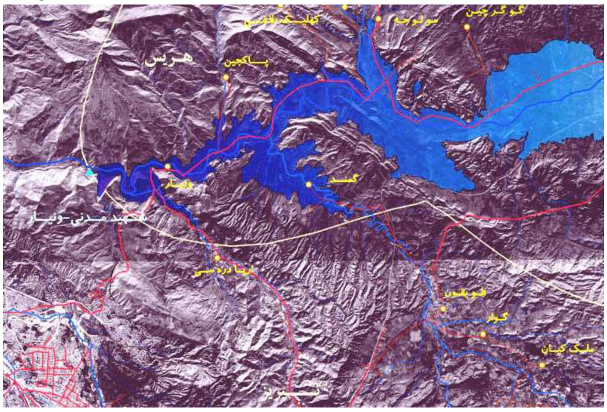
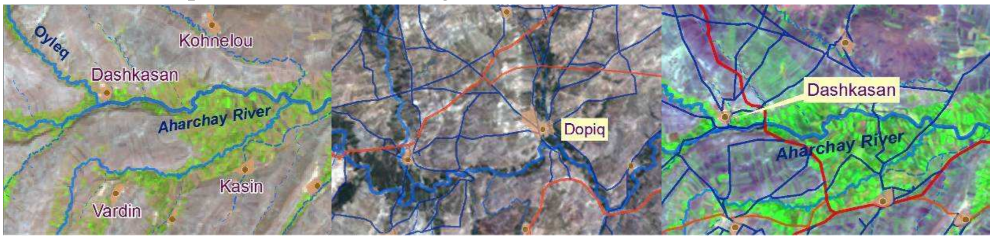


Figure 5, illegibility of texts on the panchromatic image, IRS

In this study, halo, mask and callout are considered for optimal representation of texts on colorful surface of a satellite image. Halos extend the outline of letters much like a drop shadow and make the lettering stand out (Figure 6-a). According to Tyner (2010), masks are rectangles that are placed under the type, but over the other graphics, creating special space for the lettering. These must be used with care because if they are too large they can obscure the underlying map information (Figure 6-b). Callouts are masks with leader lines that point to the feature (Figure 6-c).



a. halo, IRS 2007 b. mask, ETM 2001 c. callout, Spot 2005

Figure 6, making the texts standout on satellite images, Sattarkhan dam basin

3- Conceptual visualization

In process of information transfer, users must encode the visual features of the display. Next, they must map these onto the conceptual relationships that they convey (Pinker 1990; Herrmann and Pickle 1996). Visual variables are considered as foundation of visualization (Helali and Niroumand J. 2008). Bertin (1967, 1983) mentioned these variables as form, orientation, color, texture, value and size. Proper use of these variables involves determining the measurement scale and corresponding visual perception as a basic element of human visual information processing (Xing 2004) and also visual variables. The overall process of cartographic symbology is shown in Figure 7 (Niroumand J. et al. 2010).

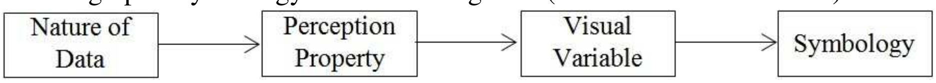


Figure 7, the process of cartographic symbology

In terms of data measurement scale, four categories of nominal, ordinal, interval and ratio are classified. Perception property of these categories and the degree of visual perception of each variable are classified in Table 1 (Elzakker 2004).

Table 1, measurement scales, related visual perception and variables (4 excellent, 3 good, 2 fair, 1 bad)

Measurement Scale	Visual Perception	Visual Variable					
		form	orientation	color	texture	value	size
nominal	associative	3	3	3	2	1	1
	±selective	1	2	4	3	3	3
ordinal interval	ordered ordered	1	1	1	2	4	3
ratio	quantitative	1	1	1	1	1	4

To get a areal symbolization of acquired land-use from classified satellite images, the classes with various types (garden, wasteland, residential regions, etc.) are from nominal type and regarding table 1, visual perception would be corresponding to 'associative' or 'selective' types. From within effective visual variables in making associative and selective perception, color is considered as a fast variable regarding the response time (Garlandini and Fabrikant 2009) and the most applicable variable in areal symbolization of land-use maps. The classes from one type and different levels (rangeland class1, rangeland class 2, etc.) are from ordinal type and the visual perception corresponding to that is ordered. Thus, 'value' is the most effective variable for symbolizing these kinds of data (table 1).

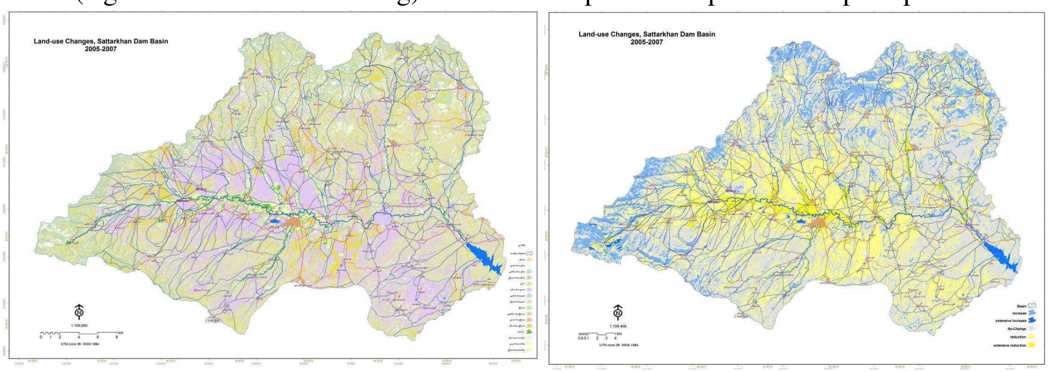
Categorizing is one of the visualization operations that the user will have to execute during the exploration process (Keller and Keller 1992, Wehrend and Lewis 2000). This operation plays an important role in representation of land-use classes to make a selective perception. In most cases for representing land-use changes, the number of presented classes is raised considerably. The importance of this subject is that the permitted variety number for each variable is limited for making selective perception (table 2) (Elzakker 2004). Color as an appropriate variable to facilitate the categorizing operation (Koua et al. 2006) is limited to maximum eight classes for areal features (table 2). Thus, special visualization is required for reduction and optimization of the number of classes to represent land-use changes and obtained interpretations. In this paper, the concept of changes in relation to the aim of map design is used. In the rest of the research, conceptual visualization of changes and interpretations of land-use are discussed in detail and the obtained results are implemented.

Table 2, Maximum number of classes to enable selective perception

Visual Variable	Symbols		
	Point	Line	Area
Size	4	4	5
Value	3	4	5
Texture	2	4	5
Color	7	7	8
Orientation	4	2	-

3-1- Land-use changes

These changes are represented in related statistical tables. Through the fact that user cannot obtain spatial based information in such way (Tyner 2010), the visualization process should be applied. In last section, it was indicated that in almost all cases, the number of land-use changes classes is more than the permitted cartographic limitation. If '*n*' is the number of land-use classes, the number of maximum classes of related changes is obtained from the equation n^2. Representation of all classes without considering the changes concept disturbs the process of data transfer to user. Accordingly, it is essential to reduce the changes classes as much as possible and also concept of classes should be oriented toward the map purpose. For example, in representation of land-use changes related to water basin of Sattarkhan dam, by considering four land-use classes of wasteland, dry-farming, farming and rangeland, 16 classes related to the changes are brought into being (Figure 8-a). To make the change classes more comprehensible according to the aim of the project (assessing the effect of land-use changes on hydraulic regime of the dam), five conceptual classes toward extensive reduction of water, reduction of water, no change in quantity, increasing water and extensive increasing of water are considered (Figure 8-b). For instance, converting farming to wasteland is become comprehensible toward extensive reduction of water resources. In this way, common colors (e.g. blue for water increasing) are used to improve the spontaneous perception of the users.

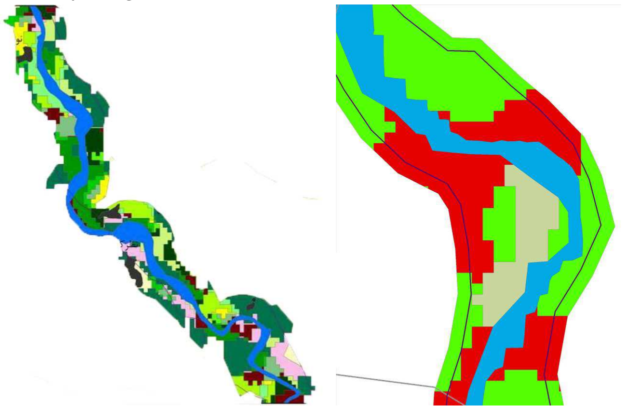


a. representation of all of the classes b. conceptual visualization

Figure 8, land-use changes map, Sattarkhan dam basin, (ETM+ 2001, Spot 2005)

3-2- Land-use changes interpretation

The regional water organization of East-Azerbaijan for planning against flood and land-use management in area of rivers' torrent needs to identify the current land-uses and also related changes in the period of 25 years. Different types of data (e.g. six-period of satellite images, large-scale maps of study area and hydraulic analysis) are used. Regarding the long length of the rivers and variety of land-uses and their changes, exact visual representation of above elements is required to supply the technician in preparing land-management plan. Thus, on the verge of disaster or unpermitted land-uses should be planned to remove. Toward this purpose, conceptual visualization is applied for hydrological regime of the rivers of Jolfa city (Figure 9-b).



a. representation of all of the classes   b. conceptual visualization

Figure 9, land-use changes map, Hajilarchay river basin, (ETM+ 2001, Spot 2005)

This cartographic process leads the users to have a successful selective perception. The general process of conceptual visualization of land-use changes is shown in figure 10.

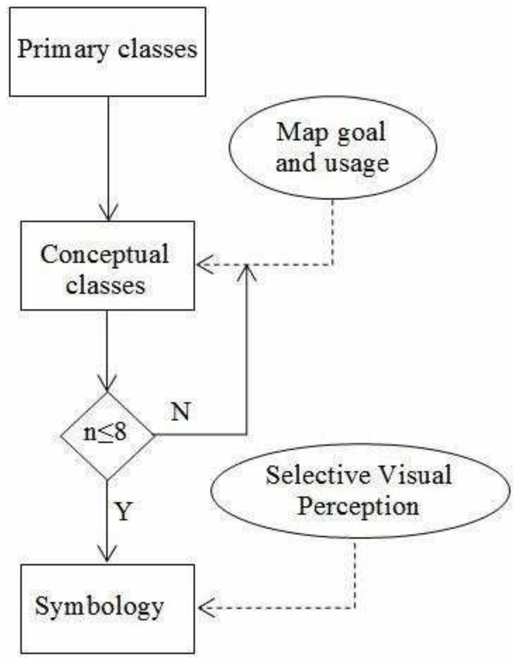


Figure 10, proposed diagram of the conceptual visualization of land-use changes

All of the implemented maps are available in large sizes at www.mniroumand.com/luvis.html.

4- Conclusion and future plans

Observance of cartographic principles has considerable importance in successful map-user communication of vector data superimposed on satellite images. In this paper, more visual weight is applied for vector data in the presence of satellite images and the variable of transparency is proposed to represent area symbols on the images. As one of our key conclusions, conceptual visualization is presented to optimize the land-use changes visualization. Visualization of different change classes requires making selective perception for creating an effective communication with users. Considering the large number of possible change classes (n^2, n: number of classes), the maximum number of eight classes is permitted to create selective perception. Thus, the concept of changes is used to integrate and reduce the number of classes. Regarding the map purpose, conceptual visualization facilitates users' selective perception. Meanwhile, the transformation of visual information gets meaningful. This type of visualization accelerates the management and decision makings about land-use. Some other aspects such as statistical analysis of human-map interaction, as a key issue to improve the efficiency of cartographic communication, are required to conduct more research which are remained as open issues for the future works.

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