COLOR HUE AS A VISUAL VARIABLE IN 3D INTERACTIVE MAPS

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ABSTRACT

This paper presents a study about color hue as visual variable 3D thematic maps. Color is a powerful map visual variable and it has been largely studied for cartographic solutions applied to 2D maps. However, the computing technology today allows us to build and view on computer screen 3D representations of geographic phenomena. So, it is necessary to develop research in order to understand the effects of color in 3D maps. In order to understand the consequences of color variability on 3D objects of a virtual world scene we built a virtual model as a set of prisms with different color hue. Using this model, we tested the effects of different shading on 3D model objects. Based on the results of this work, we concluded that if we use 3D representations for depicting some thematic characteristics of the geographic phenomena, as nominal variables, we must know how better to define the color for every object and how better to control the light source location.

1. INTRODUCTION

This paper aims to analyze a three-dimensional interactive model composed by a set of prisms depicted with different color hues, where some different illumination sources were used. In order to understand the consequences of using different illumination sources it was necessary to analyze the 3D model from the user's different positions. Another model was generated and visualized as well, where the color hue is used to represent some thematic classes related to the buildings of our university Campus. The results presented in this article are part of a master's degree dissertation entitled "Three-dimensional Interactive Cartographic Representation: The Study of the Visual Variable Color in a VRML Environment" [1].

The technological advance that took place in the last decades has stimulated cartography modernization. Today, a large set of three-dimensional data and technological tools are available for modeling, structuring and viewing 3D representation of the phenomena. The use of those tools based on cartographic principles is discussed here. One of these tools is the VRML (Virtual Reality Modeling Language), which is a modeling language for building virtual worlds to be seen through the Internet, where the user has quick and easy access to an interactive three-dimensional model.

Although cartographers have been developed research works in order to know better how to use color on two-dimensional thematic maps, there is not enough knowledge about applying visual variables to three-dimensional presentations. Among the map visual variables, the color hue stands out as the most relevant one. Therefore, this work was developed based on the question: "how to efficiently use color hue to represent thematic classes of a geographic phenomenon in an interactive 3D environment?" And the hypothesis proposed as an answer to this question is "if this visual variable is used in an appropriate way, then the user will efficiently notice the information depicted on the 3D map.

The 3D environment, in this work, is represented on a computer screen, which is flat, then it demanded some solutions based on computer graphic techniques in order to allow the user to view it as a three-dimensional one. One of these techniques is illumination. However, illumination may bring some disadvantages for the representation of cartographic data, and these disadvantages must be known and minimized so that they will not damage the 3D map interpretation.

2.PRISMS MODEL IN VRML

VRML is a language that allows for the creation of virtual environments where one can navigate, visualize objects from different angles and interact with them. A VRML world is a set of objects that may contain geometries, sounds, images, etc. Its geometric primitives are: cube, cone, cylinder and sphere. The color model adopted by VRML is RGB, and it is simple to apply color on the models generated by this language. However, the RGB color of the different faces of a 3D object can be modified as a function of the defined light source and of the user's point of view. The VRML has a default light source that is positioned in the model closer to the observer's head, as like she/he is wearing a helmet with a flashlight and this flashlight follows each of the viewer head movement. Consequently, the more illuminated faces of model's objects are those located in the direction of the light source, which causes the other objects' faces to proportionally be darker (less illuminated). The illumination differences cause a variation in saturation on every object's face.

A model, composed by prisms with different color hues, was created in order to analyze the application of different light sources that can be explored in the VRML environment. This model, illuminated by the VRML default light source (headlight) is now described. This "headlight" light source will always illuminate the geometry face positioned in front of the user with a higher intensity, while the other faces will proportionally receive less light. The Figure 1 shows a sketch of the generated model, the system axes and the user (or observer) position.

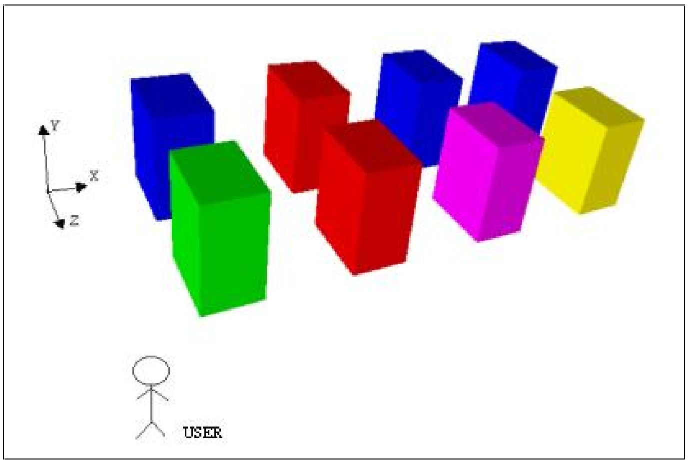


Figure 1 – Light source HeadLight

Figure 2 presents the same model where the user changed their position, which is exactly in front of the model. It is clearly noticeable that there is variation in saturation between the directly illuminated faces and the lateral sides from the prisms, which are less illuminated. On Figure 3, the model is seen as if the user changed her/his viewpoint position to where approximately 180° from original position. And once again, variation in saturation among the illuminated faces of each prism can be noticed.

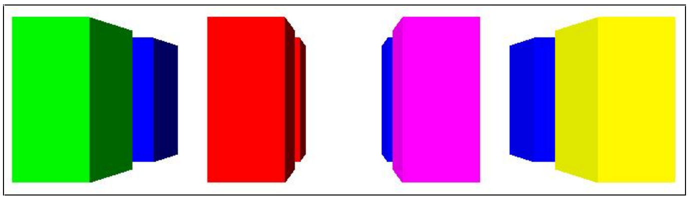


Figure 2 – Light source HeadLight (front position)

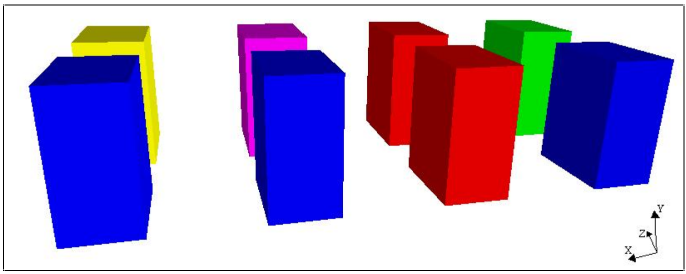


Figure 3 – Light source HeadLight (opposed lateral position)

Next, the same model is viewed under the effect of a light source called "DirectionalLight". This light source is positioned in the infinite and illuminates the model through a positive direction of the x-axis (Figure 4). Thus, only the geometric faces in the light source direction are illuminated, regardless of the user's point of view.

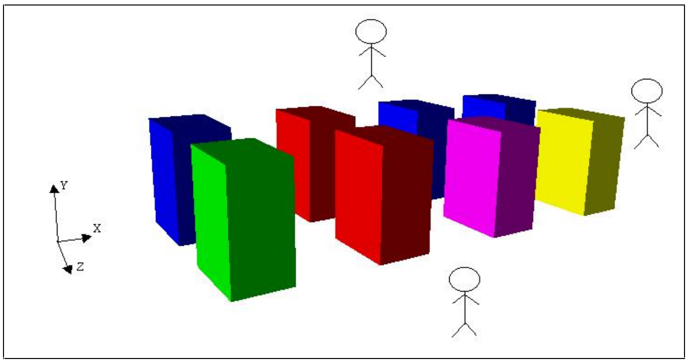


Figure 4 – Light source DirectionalLight

On Figure 5, the user's point of view is located in front of the model (as illustrated on Figure 4) and since the light source is on the x-axis, perpendicular to the user's angle of view, she/he can only see the prisms' illuminated faces that are at her/his right side. Therefore, it is not possible to visualize the prisms' edges that are located at the user's left side, such as the green prism. This result can be relevant in some cartographic applications. Furthermore, two or more geometries defined with the same color, like the red prisms, can become indistinguishable because visually there is no limit between the two prisms. This visual perception results are caused by the position of the model in relation to the light location, and as consequence more than one face are been illuminated by a same light intensity and consequently impoverish the three-dimensional notion of the object. These results are important to cartographic solutions because of the visual perception difficulties for detecting the limits between two separate objects' faces, and so discriminating on the scene the existence of two different objects.

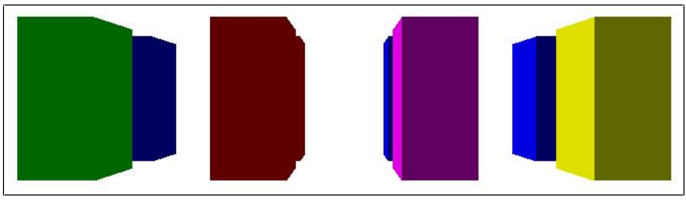


Figure 5 – Light source DirectionalLight (front position)

On Figures 6 and 7, the user changes her/his point of view and, keeping the light source fixed. As a result we can notice that the light intensity on the faces does not change as function the user's position. Consequently, Figure 8 shows a situation where the edges of the prisms cannot be seen because the user position is in the opposite side of the light source. On such case, the user cannot perceive the objects volume.

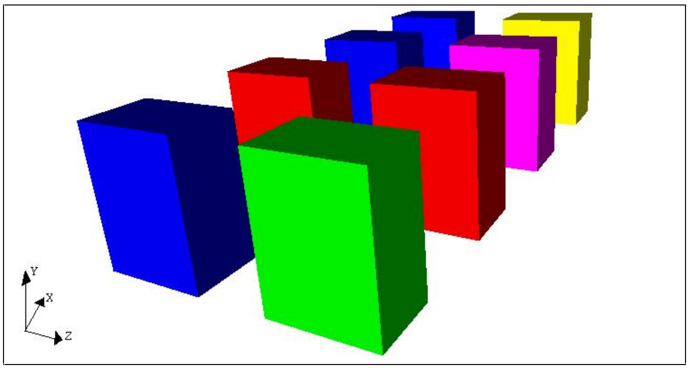


Figure 6 – Light source DirectionalLight (lateral position A)

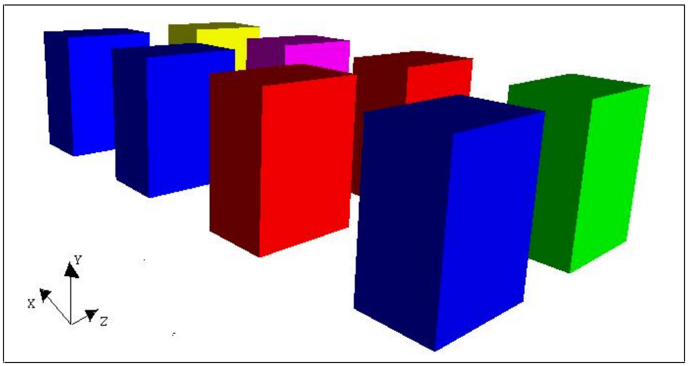


Figure 7 – Light source DirectionalLight (lateral position B)

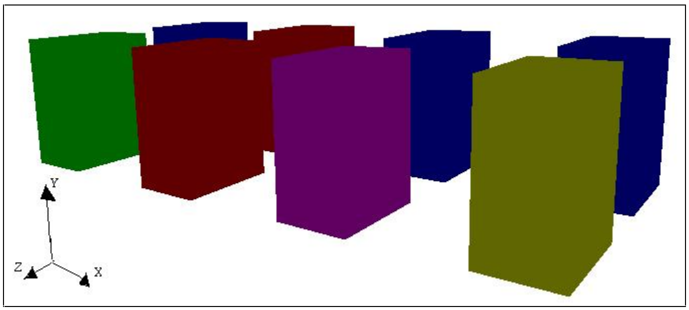


Figure 8 – Light source DirectionalLight (lateral position C)

The next model (Figure 9) presents the result of a light source called "PointLight" that has been located at the center position of the four central prisms, irradiating light to all directions. On such case, only the prisms that face the center of the model intentionally receive more light. Figure 9 represents the point of view of the user that is exactly in front of the model. On Figure 10 and 11, the user's point of view is changed, and on those two pictures we can notice the illumination of the prims' faces simultaneously turned to the light source and to the user.

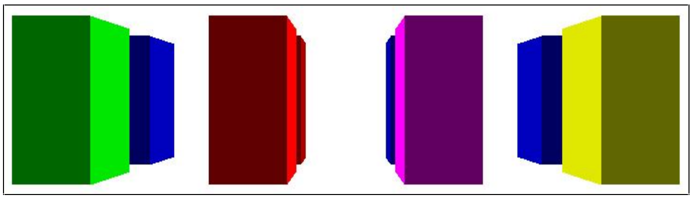


Figure 9 – Light source PointLight (front position)

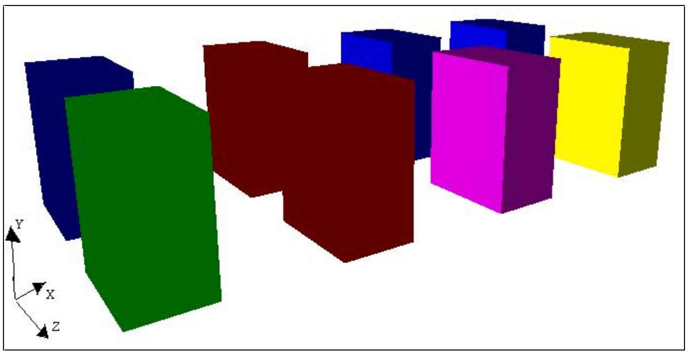


Figure 10 – Light source PointLight (lateral position A)

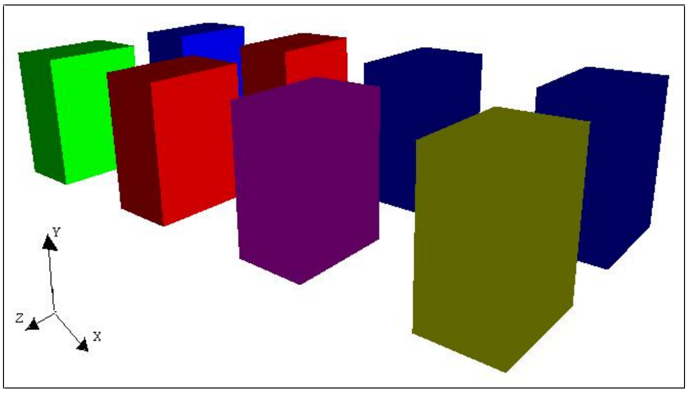


Figure 11 – Light source PointLight (lateral position B)

On the following example (Figure 12), a cone-shaped light source (SpotLight) is represented which is also located at the center of the model at a certain height above the prisms. Such light source can be used to illuminate a region that is defined by the distance to the light source and by the maximum illumination angle. Therefore, its conical shape is able the illuminated a limited region of the model, even when a prism's face turned to the light source.

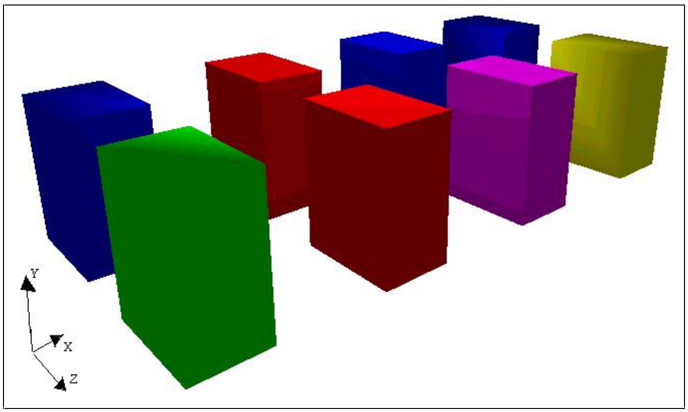


Figure 12 – Light source SpotLight

Finally, the model is represented without any light source. Thus, regardless of the user's position, the model is seen as a set of dessaturated color prisms and the three-dimensional notion is lost, as we can see on Figure 13 and 14, which depict the same model at different points of view.

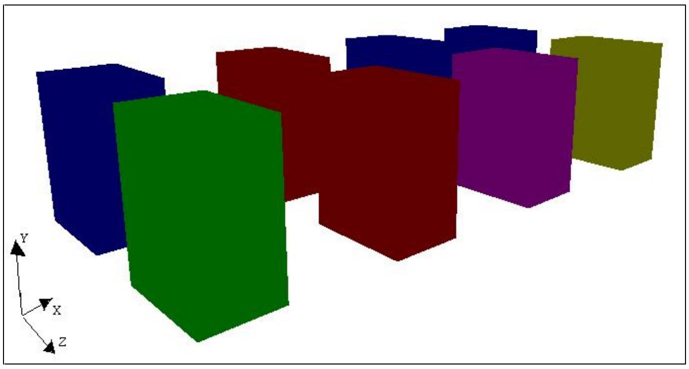


Figure 13 – Without light source (A)

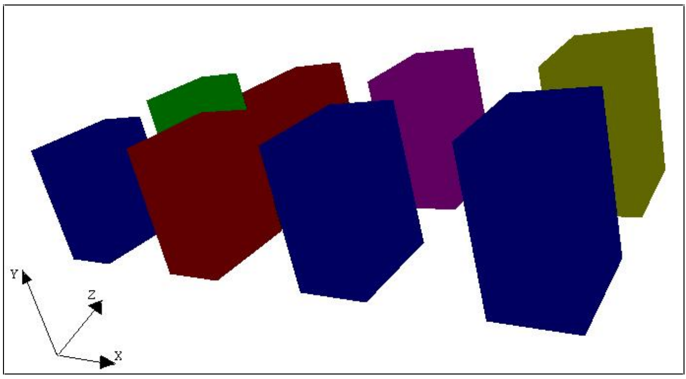


Figure 14 – Without light source (B)

As some partial conclusions of this study it is noticed that illumination can significantly change the color of an object represented in VMRL. Such color's alteration in saturation is linked to the position and the type of the light source used in the virtual environment, and to the user's position related to the represented objects.

2. CAMPUS MODEL IN VMRL

Another three-dimensional model was generated, from real data, to represent the Campus of the Federal University of Paraná - UFPR. On this model, color hue was used to represent a set of classes of thematic information, based on the cartographic principles applied to two-dimensional maps. Figure 15 illustrates, as a 2D representation, the thematic information to be modeled in three dimensions. The third dimension is originated from the buildings' heights and from the Elevation Digital Model of the terrain. Such modeling was generated using the ArcView 3.2 software and reformatted to VRML. In order to analyze the color variability the default light source was applied.

The visual variable color hue was used to represent different thematic classes, which are defined at the nominal measurement level. Such classification is based on the different administrative and technical sectors UFPR's Campus, which are: Administrative Sector, Biology and Physical Education Sector, Technological Sector, Earth Sciences Sector, Exacts Sciences and Engineerings Sector, Technical School and Bank and Associations.

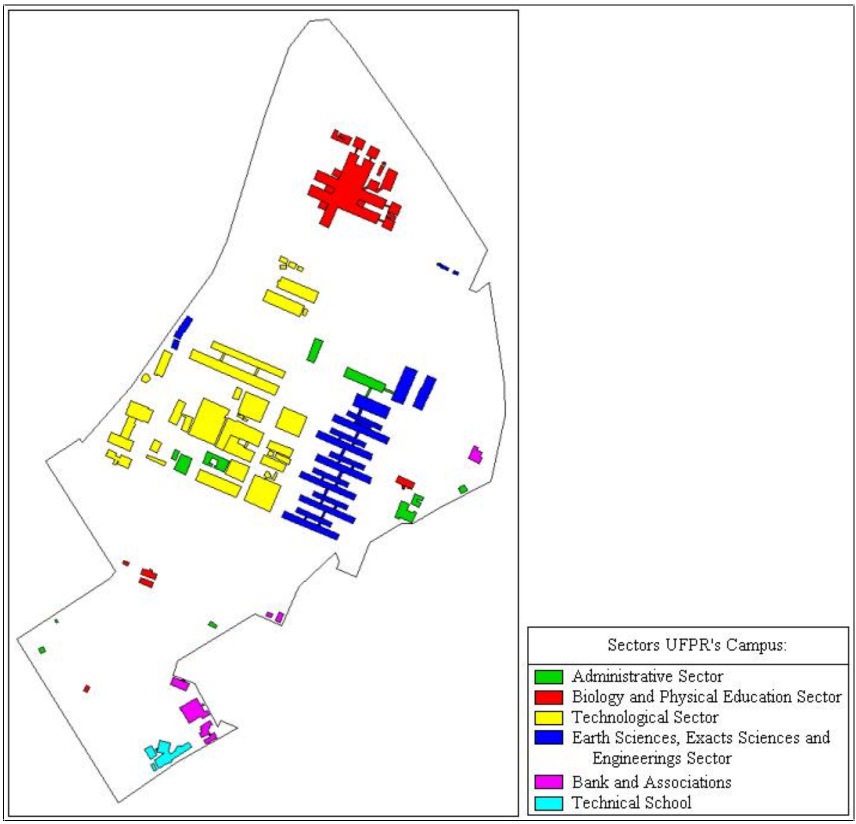


Figure15 – Thematic classes

On Figure 16, the generated three-dimensional model is seen from different points of view, where the variation in saturation on every object colored with the same hue, is perceived. Such variation is also different for every color hue, such as yellow and blue. This result is a consequence of the colors' natural brightness, which varies to each color and, as we can observe on the spectrum visible by the pictures below, yellow (Figure 17a) is brither than blue (Figure 17c), and green color (Figure 17b). Thus, the variation in saturation resulting from the light source shadings will be different for different color hues. It directly influences the perception of objects forms and also introduces undesirable visual emphasis.

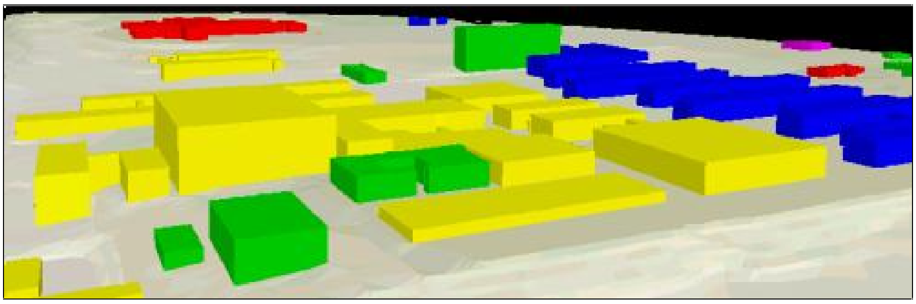
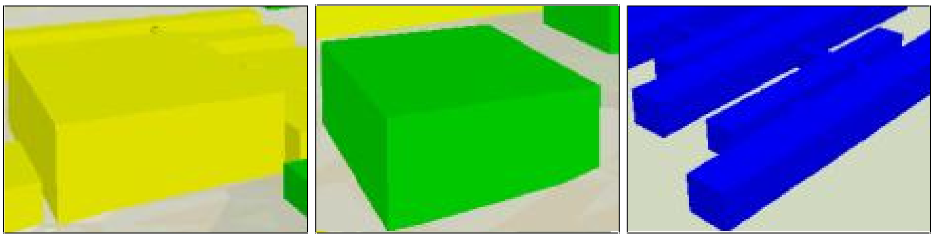


Figure 16 – Three-dimensional model



(a) (b) (c)

Figure 17 – Shading variation in the object's faces

Another relevant consequence derived from the natural brightness of colors, in a three-dimensional model, concerns to the limitation of the number of thematic classes represented in a 3D model. The number of classes limitation is caused by the low level of brightness of the darker prisms. As described earlier, the darker the object the more difficult to perceive its shape and volume (Figure 17c). So, at three-dimensional representations, the maximum number of classes from the phenomenon to be represented depends not only on capability for discriminating different intensity levels of different colors but also on our capability for discriminating the objects' shape, as a consequence of the different illumination levels on their faces.

Besides, in some situations, as already mentioned, the appropriate use of a specific light source can be useful for some tasks based on 3D maps, such as emphasizing some relevant objects' geometry or identifying some objects from a specific angle or distance. On the other hand, the improper use of certain light sources can damage the visualization information, especially on such 3D representations that bears a large number of same-color geometries in a proportionally small space, and the user cannot see the object as a whole, but only part of it.

3. FINAL CONSIDERATIONS

One more, the VRML has proved to be a potential language for exploring cartographic visualization, however some precautions must be taken concerning the usage of the visual variable color hue applied to a three-dimensional model. Through this variable it is possible to nominally classify a three-dimensional model, as in two-dimensional map. However, due to the illumination in the model for its representation as a perspective of a three-dimensional virtual world, the variation in color hue also suffers a variation in saturation, which results on an ordinal perception. Such variation in saturation is different for each color hue, due to its natural brightness, which is different for each one. Furthermore, on three-dimensional representations the maximum number of phenomenon classes depends not only on our capabilities for discriminating the different intensity levels of the different colors but also on our ability for discriminating the shapes of objects, in consequence of the different illumination levels on their faces. This has been an introductory study of one of the most used variables in two-dimensional cartographic solutions, that is, color hue. Due to the relevant role of color hue on map solutions we believe that future studies must be developed to better understand the application of color on 3D cartography.

4. ACKNOWLEDGEMENTS

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5. REFERENCE

[1] FOSSE, Juliana Moulin. **Representação Cartográfica Interativa Tridimensional: Estudo da Variável Visual Cor em Ambiente VRML** (Three-dimensional Interactive Cartographic Representation: The Study of the Visual Variable Color in a VRML Environment). Curitiba, 2004. 134 f. Dissertação (Mestrado em Ciências Geodésicas) – Setor de Ciências da Terra, Universidade Federal do Paraná. Disponível em: <http://www.cienciasgeodesicas.ufpr.br/projetos/campus>

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Was born on May 25, 1977, in Jerônimo Monteiro on Espírito Santo State, Brazil. Graduated in Surveying Engineering from Federal University of Viçosa, in Minas Gerais, Brazil (1997-2001). Received Master in Science Degree in Geodesic Sciences from Federal University of Paraná (2002-2003) and at present is student of doctorate of this same university. She works in the area of three-dimensional cartography.