CO-262

EFFECTIVE COLOR SCHEMES FOR 3D ANIMATIONS OF URBAN LANDSCAPES WITH A SPATIAL AND TEMPORAL DIMENSION

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1. INTRODUCTION

Major advances in computing have pushed graphics and the visualization of geographic information, or geovisualization, as a major medium for the presentation of spatial information (Unwin, 2008). Currently, the ability to analyze and convert spatial data into comprehensible information remains a difficult task at current rates of data acquisition. Due to the seemingly endless methods of visualizing spatial data, there has been an ongoing call to identify efficient, effective and replicable techniques for generating maps. To create effective and efficient visual displays, data must be presented in ways that make it both intelligible and insightful for users (Buckley et al., 2000).

Dynamic maps expand the option for graphic symbolization (DiBiase et al., 1992), allowing, for instance, cartographers to enhance data with temporally visualized techniques (MacEachren et al., 1992: 126). With the rising popularity of 3D animations, dynamic displays are increasingly produced without adequate attention paid to their effectiveness in accurately portraying spatial and temporal data. Thus, it is imperative to formalize design principles as cartographers have only "scratched the surface" of 3D visualization techniques for dynamic displays (Harrower & Fabrikant, 2008). Buckley et al. (2000: 3) note that, "we are currently at a point where basic research on the theoretical and conceptual, as well as methodological aspects of geographic visualization is necessary and critical." To fill this existing void in research, cartographic principles need to intersect theories of visualization, animation, cognition and spatial information acquisition with 3D and urban GIS landscapes. Central to this is how color perception affects user spatial information acquisition. Focusing on the effects of such acquisition for different color schemes can allow users to better comprehend spatial information and maximize the accuracy and efficiency of data presentation for display methodologies.

This paper seeks to begin filling a gap in the cartographic literature by exploring different color schemes for creating logical and perceptive dynamic 3D visual spaces. Three similar animations with altering colors and color schemes will be tested to identify effective color schemes for 3D dynamic visualizations for presenting urban spatio-temporal data.

1.1 Cartographic Visualization and Animation Advancements in design and display technologies today offer countless ways to visualize and represent (via maps) interrelationships between society and space (Dodge et al., 2008). Geographic data can now be displayed dynamically in numerous dimensions (i.e. 2D, 3D, or 4D). With this, the number of ineffective and inaccurate maps is growing. In How to Lie With Maps (1996), Monmonier details numerous ways maps can deceive users. Unless the purpose of the map is manipulation for political or territorial ends, the cartographer must work to accurately convey geographic information in a controlled manner and to avoid, as much as possible, user misinterpretation of the visualized data (Meng, 2009). With this comes a large and in some cases unexplored responsibility of cartographers to generate adequate design principles to create more effective and accurate maps. Harrower and Fabrikant (2008: 57) note that very little is known about effective geovisualization tools for "knowledge discovery, learning and sense-making of dynamic, multidimensional processes."

DiBiase et al. (1992) categorize animations by identifying three dynamic variables in map animations: duration (of a scene), rate of change (magnitude of change between scenes) and order (chronological or attribute). For this study, chronological order has been chosen because of its effectiveness in representing urban change over time. One step in choosing an accurate symbolization of temporal data lies in selecting a meaningful and appropriate color scheme. According to results from Cuff (1973), Gilmartin (1988) and Monmonier (1996) (see also MacEachern 2004: 134), color value and saturation appear ordered but "hue differences usually fail at portraying differences in…intensity measures because spectral hues have no logical ordering in the mind's eye" (Monmonier, 1996: 167). To test if this concept holds true for 3D spatio-temporal data, this study will employ both sequential color schemes and random hue color schemes to compare their effectiveness in visualizing these types of data.

The issues in generating adequate sequential color schemes lie in choosing which colors to use. Gnambs et al. (2010) cite various studies arguing that the color red impedes performance (especially in males) in certain cognitive tasks. However, no performance impedance was found for the color blue. For this reason, this study will evaluate how red and blue sequential color schemes affect the acquisition of spatial information in two separate 3D animations. Further, a random hue color scheme animation will be used as a control to test if it provides a logical ordering to users when displayed in a 3D animation, possibly raising differences in how users acquire and make sense of data in and through different dimensional spaces.

1.2 Cognition and Spatial Information Acquisition It is important to note that the visualization of data “is foremost an act of cognition, a human ability to develop mental representations that allow geographers to identify patterns and to create or impose order” (MacEachren et al., 1992: 101). Buttenfield and Mackaness (1991) affirm the power of graphic representations in the process of map reading, suggesting the need to better understand the human process of acquiring and understanding spatial information. Friedhoff and Benzon (1989: 12) argue that visualization can help to eliminate much of the information processing from users. This moves the method of acquiring information into preconscious visual processing, that is, the “lower-order information processing that is outside of voluntary control” (12). By approaching map-making through the principles of preconscious visual processing, one must choose “a better color scheme [which] results in congruent messages via the color and form channels so that forms are readily identified without conscious effort” (13). In this way, maps can provide most of the inferences and perceptions for users intuitively (Larkin & Simon, 1987: 92). In order to create such intuitive maps adequately, it is vital that user-centered research be undertaken to better understand how preconscious visual processing functions in relation to different graphical attributes.

Garrett (2003) has stressed the importance of a “user-centered design” when creating a web site. Keeping the user in mind at every stage of development for the final output will assist in developing more coherent, intuitive and intelligible interactions for users. Similarly, a cartographer can apply this principle in the creation of a map, resulting in a more cohesive and unambiguous final output. Hegarty & Kriz (2007) argue that we shouldn’t assume there is a “most effective” display method without first looking at the individuals and their different abilities and skills to comprehend the animation. By researching effective techniques for developing animations through understanding user needs and cognitive capabilities, cartographers can gain insights in creating more effective, efficient and intuitive maps. Moreover, understanding a user’s level of knowledge, age, gender, etc. are important in understanding the effects an animation can have on their acquisition of spatial information. Due to this issue, in this study qualitative information will be collected for each of the respondents (i.e. age, GIS level, grade level, etc.) to better understand and analyze spatial learning capabilities.

1.3 The Third Dimension and Urban GIS Landscapes Shepherd (2008) identifies what can be gained by moving from 2D to 3D spatial representations. Of significance, he mentions the additional display space available, allowing for extra data variables (such as height) because of the new z-axis. 3D space provides different display techniques for urban environments, thus making representations of their height and spatial location more intuitive. This added dimensionality also allows users to accurately inspect urban features such as buildings, and consequently draw inferences such as spatial-object relationships. The third dimension additionally offers a more familiar view of the built environment, which may lend towards a more intuitive interpretation of data.

Zanola (2009) found that users tend to favor photorealistic 3D simulations because they influence users’ confidence in the credibility of the data. On the other hand, Jahnke (2009) found that while photorealism captures user interest, it dominates their attention and supersedes their capability to draw out information. Through simplification and reduced visual complexity, he argues, viewers will be able to deduce more information from a 3D environment. The research in this paper was originally designed to compare both realistic and simplistic representations. Upon completing a realistic animation, several colleagues agreed that the display was extremely complex and users were not able to deduce any spatio-temporal information. Due to this finding, only simplified representations of buildings through color will be tested in this study. Each animation of this study will evaluate effective design techniques. Further, they will offer another way for cartographers to visualize and understand historical change and urban growth patterns through time.

2. RESEARCH QUESTIONS

The following three questions guide the approach and framework of this study:

Question 1: What are effective color schemes for displaying temporal change in 3D urban map animations? More specifically, how do different colors and schemes (i.e red versus blue and sequential versus random) compare in affecting user abilities to acquire spatio-temporal information in 3D urban map animations?

Question 2: What other factors (i.e. exaggeration and a generalized base map) affect user abilities in acquiring spatio-temporal information in 3D urban map animations?

Question 3: How can we use eye-tracking analysis to further explain and interpret the results of specific color schemes?

3. METHODOLOGY

To test user ability to comprehend spatio-temporal information as depicted through 3D map animations, the research will be implemented in five stages:

(1) data acquisition and preparation,

(2) animation creation,

(3) user survey and eye-tracking,

(4) statistical and qualitative analyses, and

(5) final results (see figure 3 below).

The first stage details the acquisition of the entire dataset used in the study as well as the steps taken to prepare the data for animation. The second stage describes the methods employed to create the six (three main and three additional) animations to be compared in the research. All of the animations utilize the same data, demonstrating the historical urban growth of each decade for the San Diego State University (SDSU) campus over six decades (the 1950's through the 2000's) with various building representations. In the third stage, a user survey will question the viewers' ability to recognize and comprehend spatial information as shown in the animations. Eye-tracking software will also be utilized to record major areas of focus for nine users as the three main animation play on a screen. The fourth stage details the analyses, both statistical analyses for the user survey (yielding quantitative and qualitative results) and qualitative analyses from the eye-tracking software results. Finally, stage five yields the final results, joining all results to draw final conclusions from the research. The entire process of defining formal color guidelines for 3D spatio-temporal animations is iterative, where any stage in the research may require repeating a previous stage and changing procedures.

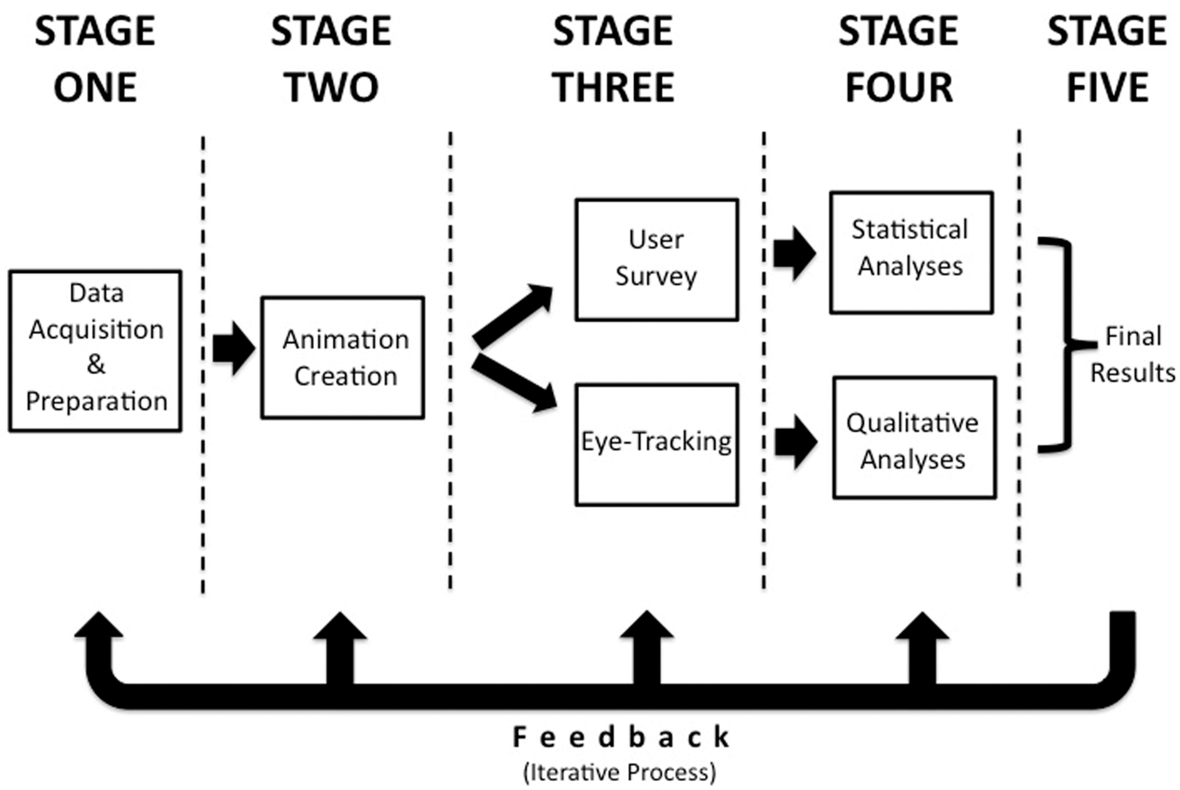

Figure 3. Flow Chart of Methodologies

3.1 Stage One: Data Acquisition and Preparation The campus building construction data was obtained through the SDSU Facilities Planning Design and Construction Department. All main campus buildings were listed by date of completion and organized into an excel spreadsheet. As the aim of this project is to explore how general spatial information is acquired, building completion dates have been grouped into decades rather than specific years. Additionally, to simplify the number of color steps, or classes visualized, only buildings completed from 1950 through 2000 are animated (excluding 1930 and 1940). The grouping was implemented through ESRI's ArcMap. Buildings included in the animation were those enclosed within the central campus area, bounded by 55th Street, Canyon Crest Drive, Montezuma Road and College Avenue (see Figure 3.1.1 below).

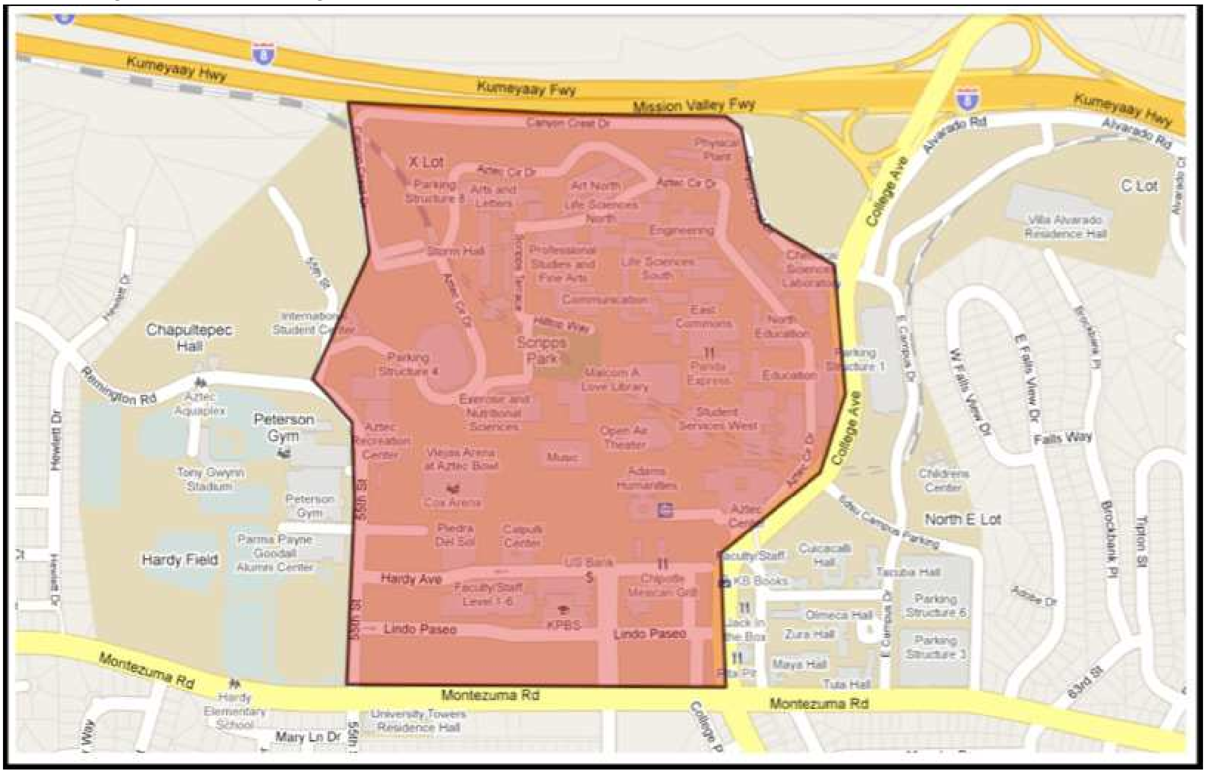

Figure 3.1.1 Image of Central/Main Part of Campus Used in Study (area in pink) created in Google Maps

To avoid issues of occlusion (i.e. smaller outlying buildings such as the boiler rooms, etc. obstructed by larger buildings due to the viewing angle), only major campus buildings were used in the animation. In addition, campus parking lots were omitted in the final animations, as some were ground level while others may appear in 3D. The animation was created with the intention of visualizing urban growth of major campus buildings occupied and/or used by the student population. Due to these stated omissions, the decade of 1980 reveals no building growth (the only buildings completed in this time were smaller, largely unused buildings by the student population). To omit these buildings, the editor feature was used in ArcMap to delete the polygons previously mentioned. The final buildings depicted in the animations (see figure 3.1.2) were those shown on the main SDSU campus building map (within the stated enclosed area of the central part of campus) as found on the https://sunspot.sdsu.edu/map/sdsu_map.pdf website (see figure 3.1.3 below). In the original buildings feature class, many structures were originally adjoined and required additional separation into different polygons (using ESRI's ArcMap software), as portions of buildings were constructed in subsequent years.

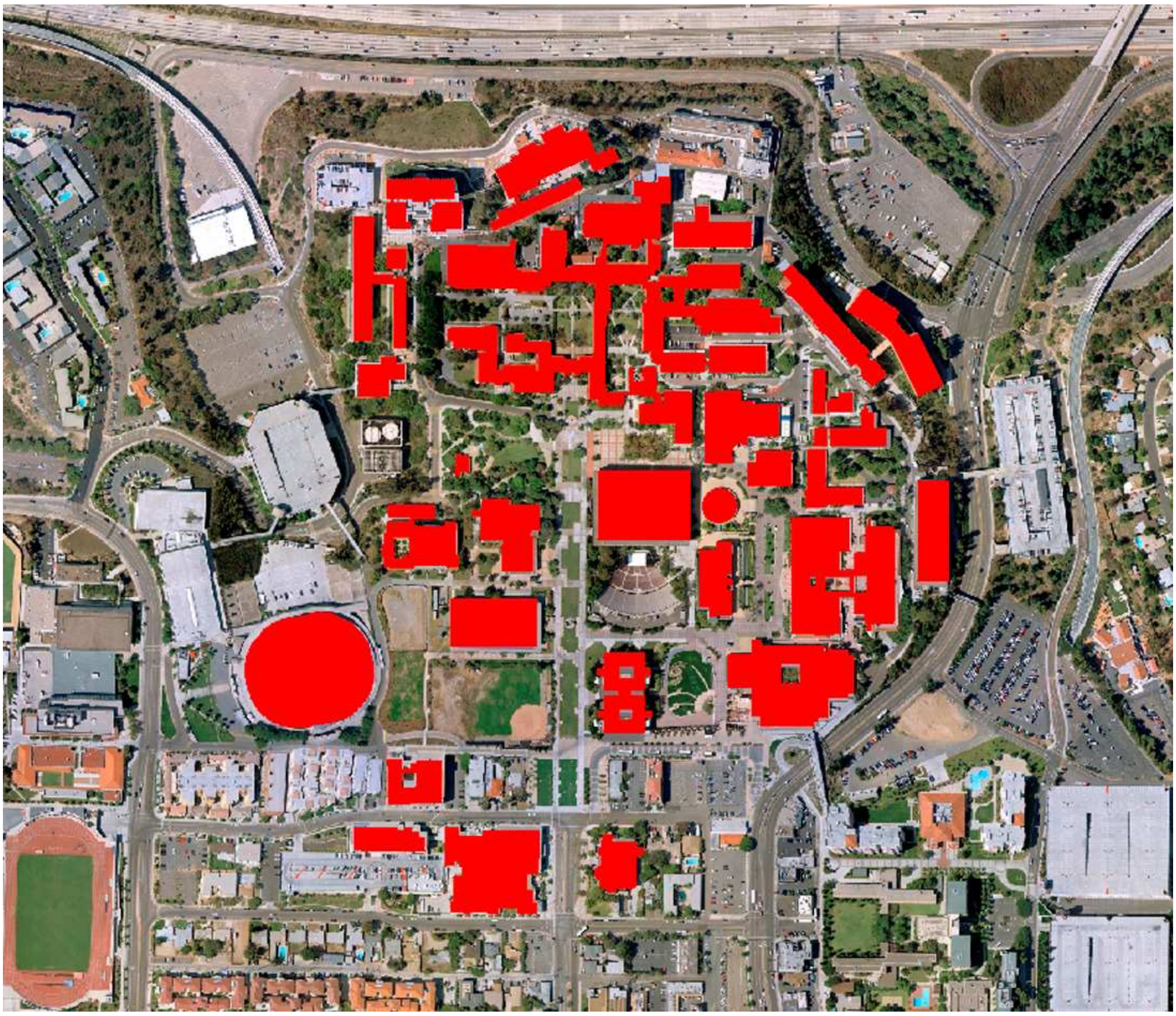

Figure 3.1.2 The Simplified Building Polygons (shown in red) used in the Animations

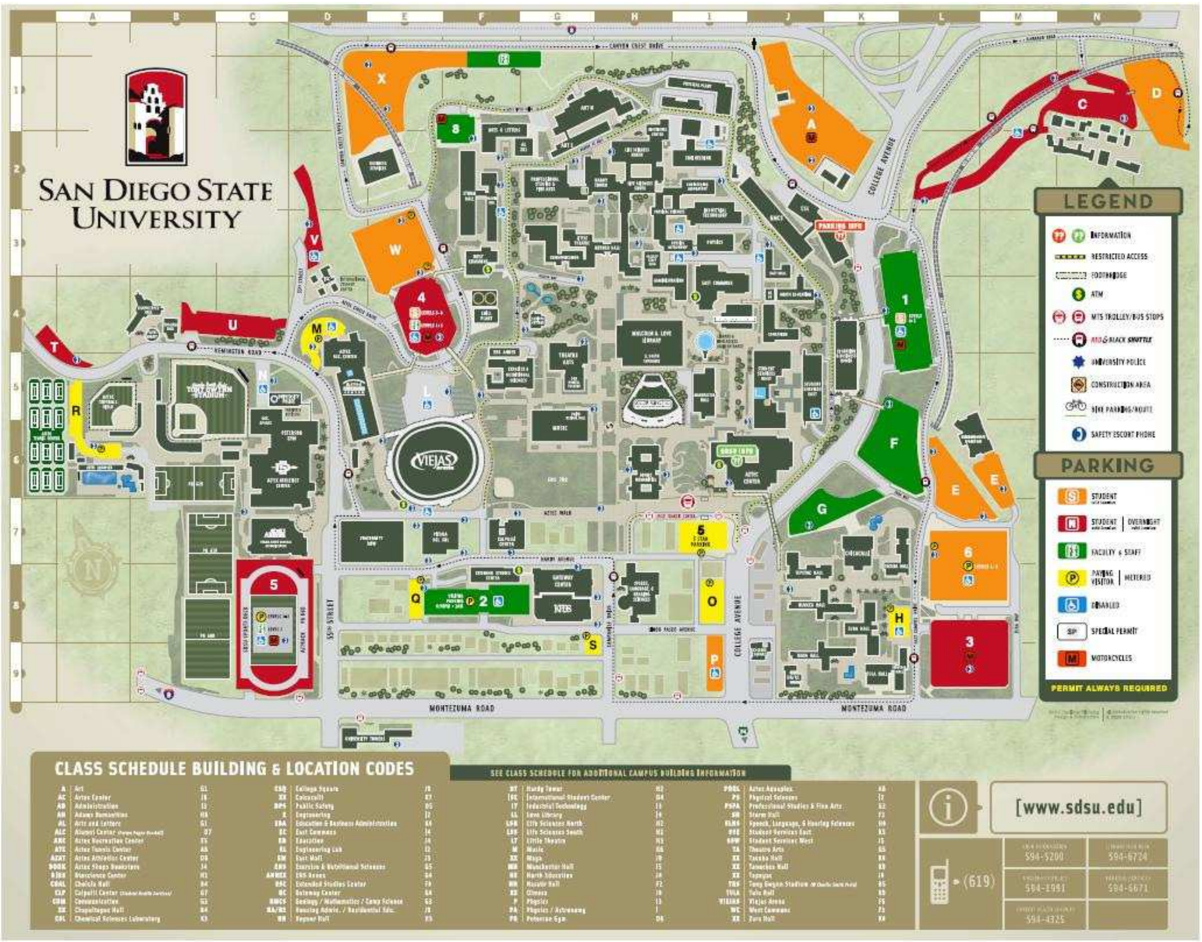

Figure 3.1.3 Campus Map obtained from https://sunspot.sdsu.edu/map/sdsu_map.pdf

To create the realistic terrain of the surrounding landscape, an orthophoto was draped on top of a digital elevation model (DEM), then further extruded to ground surface heights in the ArcScene software. Digitized building polygons have been utilized in ArcScene and extruded to their actual z-value height in scale to create a 3D representation. The SDSU facilities management department provided the orthophoto, digital elevation model and campus building polygons.

3.2 Stage Two: Animation Creation Three main animations have been created using ArcScene and Adobe Flash CS4, each re-illustrating the urban growth of San Diego State University campus buildings over six decades. Each animation is presented through a different color scheme, where campus buildings vary in hue or value for each subsequent decade. As time moves forward, buildings appear as their actual height in scale. To create the animation, 3D images of each decade were exported from ArcScene in JPEG format. Next, the images were imported into Adobe Flash and played chronologically to create the final animations. Legends and decades were inserted onto the display at appropriate time intervals to assist users in ascertaining the spatio-temporal information presented. Lastly, four buildings (Love Library, Viejas Arena, Aztec Center and Gateway Center) have been labeled to allow for additional spatial and temporal relationship questions in the survey.

The first animation was created using an arbitrary color scheme that represents newly constructed buildings. In every subsequent decade, buildings appear in a different hue based on their construction date (see figure 3.2.1 below).

Figure 3.2.1 Animation with Random Color Scheme

The second and third animations utilize a red and a blue sequential color scheme for representing the spatio-temporal data. Every color step (from light to dark) represents each sequential decade of building growth (see figure 3.2.2 and 3.2.3 below).

Figure 3.2.2 Animation with Red Sequential Color Scheme

Figure 3.2.3 Animation with Blue Sequential Color Scheme

All of the color schemes were obtained from www.colorbrewer2.org (see Harrower & Brewer 2003). They have been extensively tested for users abilities to differentiate all of the colors for each of the schemes used. While it is noted that people with red-green color blindness cannot differentiate the colors from the random hue scheme (due to the large amount of classes, or decades), the research will first test each participant for red-green color blindness as well as assess if they can still distinguish decades as they appear in the animation. There may also be an advantage for those with color blindness as each decade appears at a different time.

Due to the limited number of participants available, three additional animations will be tested solely for qualitative analyses. This will be done in order to draw preliminary conclusions as to the effects of the animations on the acquisition of spatial information. One animation employs a generalized map footprint using a google map screenshot draped onto the DEM, replacing the realistic appearance of the orthophoto. The other two animations exaggerate building heights by extruding them to two and four times their actual heights.

3.3 Stage Three 3.3.1 User Survey Each participant will be randomly assigned to one of three formats (see figure 3.3.1 below). To compare map readability, users will be tested on the same information through a survey subsequent to viewing one of the randomly selected animations. With regards to sample size, at least 30 users will be tested per main animation (blue, red, or random) in order to have a large enough sample size to account for and represent the total population for meaningful statistical results and inferences. San Diego State University undergraduate and graduate students from geography courses in the 2011 spring semester will be participants in this research. Statistical patterns of spatial information acquisition will be compared to their previous training, age, gender, grade level, etc.

As recommended by Harrower (2003), users will be presented with a tutorial section detailing the interface and type of data to which they will be introduced before viewing the animation. Both the animations and survey will be deployed within a flash document using Adobe Flash CS4. Survey data will be used to test user ability to recognize and comprehend spatio-temporal information. The questions will test users about general spatial patterns through time. Programming code will be used in the survey, recording how long each respondent spends on each question, thus allowing for further analyses to compare time spent with correct or incorrect answers.

Upon watching the animation once, users will be prompted to answer questions to move forward in the survey. The user will watch the same animation again and answer the same series of questions. In this section of the test, users will be able to watch the animation as many times as they wish. This segment allows for comparison by permitting users to watch the animation unlimited times (versus once in the first section). Lastly, participants will watch the final three animations and will complete the survey through a set of qualitative questions with regards to their preferences and opinions. This survey section will provide data to qualitatively analyze the significance, preferences and impacts of all animations.

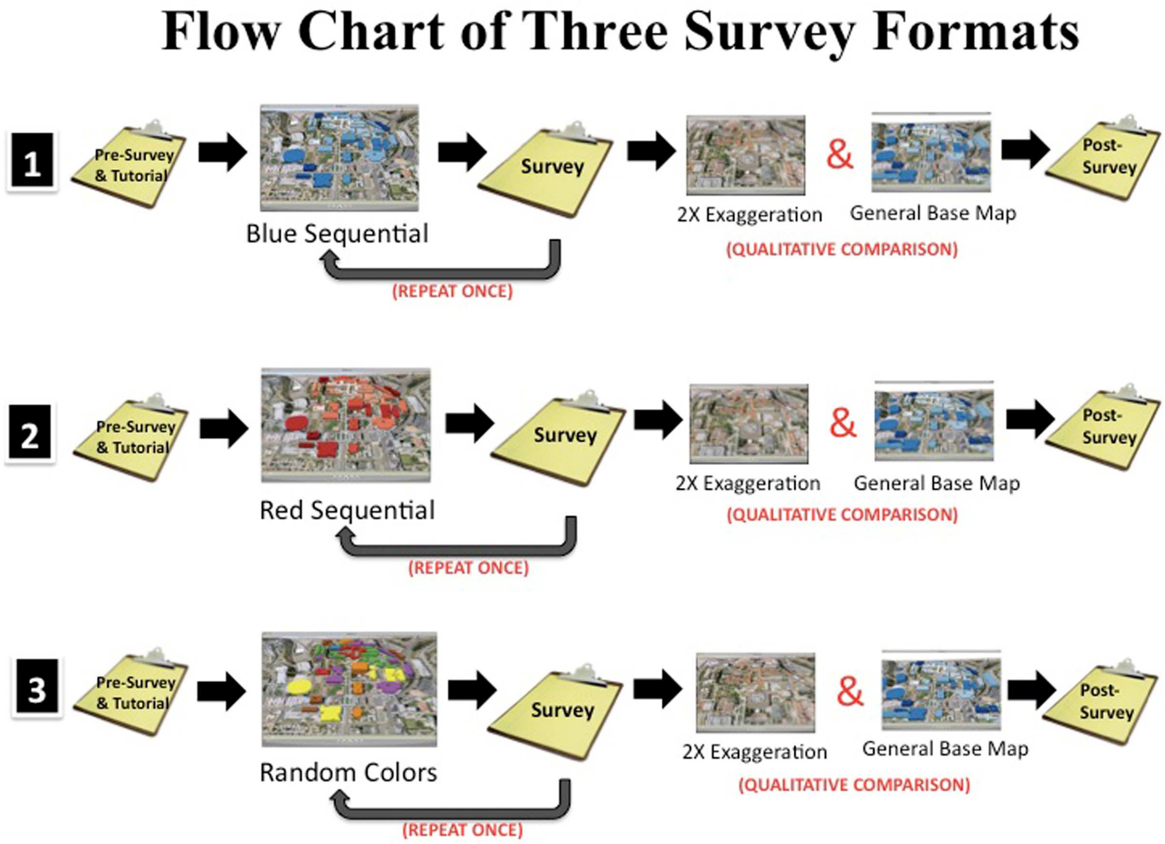

Figure 3.3.1 Flowchart of Three Survey Formats Randomly Assigned to Each Participant

3.3.2 Eye-Tracking Under the supervision of Dr. Sandra Marshall, eye-tracking software will track the eye movement of at least nine participants as they watch the three main animations. Three participants will be tracked for the blue sequential animation, three for the red sequential animation and three for the random animation. The data will be gathered using EyeWorksTM software (developed by Eyetracking, Inc.) in conjunction with Seeing Machines FaceLAB eye-tracking System.

3.4 Stage Four: Analyses Upon viewing the results of the survey within the database, variables will be statistically compared for each animation to find the varying levels of spatial information acquisition of SDSU campus growth. Class level, age and gender will also be evaluated to see if they are possible conditions of information acquisition. For the statistical comparisons, one-tailed T-tests, two-tailed T-tests and ANOVA will be used to analyze correct and incorrect answers to test if any animation appears more effective in presenting spatial information. As the animation will ask decade specific questions, decades will be weighted more heavily that occur closer to the correct answer (e.g. if the correct answer is 1970, then a response of 1960 and 1980 will be weighted higher than a response of 2010). The data obtained from the eye-tracking software will provide qualitative support to further explain the statistical results from the survey. These analytical methods were chosen based on the following hypotheses:

Hypotheses

Null Hypothesis 1 (Ho1): There are no statistically significant differences in the acquisition of spatio-temporal information between the sequential and random color schemes. 1A. No statistically significant differences between the sequential and random color scheme survey accuracy. 1B. No statistically significant differences between the recorded time to answer questions for the sequential versus random color schemes.

These hypotheses are analyzed by comparing accuracy results for each survey and test response times for each question over the entire survey.

Null Hypothesis 2 (Ho2): There are no statistically significant differences in the acquisition of spatio-temporal information between the sequential red and sequential blue color schemes. 2A. No statistically significant differences between the sequential red and sequential blue color scheme survey accuracy. 2B.

No statistically significant differences between the recorded time to answer questions for the sequential red versus sequential blue color schemes.

These hypotheses are analyzed by comparing accuracy results for each survey and test response times for each question and the entire survey.

Alternate Hypothesis 1 (HA1): Altering the color scheme (sequential vs. random) as well as the color itself (red vs. blue), will affect abilities to acquire and understand spatial information. Specifically, it is expected that the sequential red color scheme will hinder the acquisition of spatial information, particularly among males.

3.5 Stage Five: Final Results While the testing is ongoing at this time and no final results are currently available, it is anticipated that research will be completed by May 2011. All quantitative and qualitative analyses will be compared (from both the survey and eye-tracking system) and synthesized to determine meaningful conclusions. Analyses and final results will be presented at the International Cartographic Conference in Paris, France in July 2011.

4. LIMITATIONS AND CONCLUSIONS

As this research is part of an emerging area of cartography and geographic visualization, it is hoped that future researchers will use this empirical study as a foundation to further test and identify effective techniques for displaying 3D animations. While attempts were made to control all aspects of the experiment, there are notable limitations to discuss. First, sample size may be of issue because only one animation and survey will be tested per student respondent. In this case, at least 30 students will be used per survey to yield reliable results. Secondly, due to the nature of 3D animations, there are many issues that can alter the results of the survey. The duration of each scene (or decade), perspective (or looking angle on the setting), and ability to loop the movie will all be possible problematic issues. Lastly, it must be noted that the sample of participants will be chosen due to convenience and access. Moreover, it is plausible that even slightly altering the hue, saturation, and values of each color as well as changing the detail of information presented and the spatial scale may produce different results. Thus, while statistically significant results may be yielded from this research, it is recognized that the outcome may not carry over into other studies due to the specific nature – especially the duration, colors and perspective – of this study. Despite these limitations, it is still necessary to investigate cartographic techniques in order to lay a foundation for future research.

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