A Conceptual Design of Visualization of temporal vegetation data

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Introduction:

A strategy of designing visualization is to transform the data in such a way that it should create an easy, comprehensible environment for obtaining information of the real environment. The sophisticated computing technology has opened up numerous approaches to create visual displays which ultimately facilitate thinking and problem solving. The aim is to create knowledge construction through the designing of data visualization. When this concept of visualization deals with geographic data it becomes geovisualization. Geovisualization involves transferring the information about characteristics and nature of data to human brain by exciting the sensory system through the proper use of graphics. Hence to study the geospatial datasets in detail geovisualization is one of the ways.

Geovisualization has make room to represent the geospatial data through innovative scene construction which is essential to study the complex phenomena of natural and social sciences. It includes techniques of catography and geographic information science. Cartographic techniques and methods are mainly applied to translate the data into graphics, which include map like products (Kraak, 1998).

Traditional maps only display the geospatial data but interactive maps offer more exploration options. Interactivity enables the user to study the data from different perspectives like combine map with other graphics, diagrams, photographs and videos. The multivariate representations of geospatial datasets by different creative graphics have more impact than traditional mapping methods. In this context it can be said that maps are the tools for thinking about the characteristics of geospatial data.

In the world many geographic data are dynamic in nature (e.g. weather data, urban growth, vegetation growth) and many users are interested to view the changes over time. The users not only want to view the changes but also to analyze the phenomena. This calls for interaction with the data. Series of interactive static maps is one of the ways to visualize such changes, but in this case the sense of dynamics is very limited, it has to be constructed in the mind of

the user. Animation seems to be a suitable technique to represent the dynamism. It is a subject of great interest among the computer graphics. It facilitates the function for seeing the whole process of change. The study aims at integration of graphics with animation and, in effect, developing an effective tool for exploring temporal NDVI data.

Characteristics of spatio-temporal data:

On the earth surface each phenomena involve number of complex physical processes. These processes vary spatially and temporally. To study these complex processes advanced statistical and computational modeling were used by geographers to explore and understand how geographic system function. In today's world effort is being made to collect the information about these complex processes through earth observation satellites. To monitor, explore and analyze different geographic phenomena, spatio-temporal data plays a major role. The analysis of spatio-temporal data helps to predict the future, analyze the changes, do trend analysis, model generation and effect estimation (Blok, 2000). Hence comprehensive understanding of spatio-temporal phenomena is necessary before representing the complex geographic phenomena.

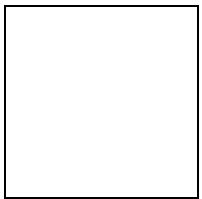
According to Peuquet spatio temporal data involves space (where), time (when), and objects (what) (Peuquet, 1994, cited in Andrienko et al., 2002). It can be explained as, during a specific time at a particular place an object can change its characteristics or an object can change from time to time at different places. The other one is object and location both is changing from to time. It can be explained as:

When + where ⟶ what
When + what ⟶ where
Where + what ⟶ when (Andrienko et al., 2003)

Based on this, the questions can be framed as:

What is the object present at location *'l'* during the time *'t1'*?
Where is the location of object '*o*' at time *'t1'*?
When the object *'o'* occupied the location *'l'*?
All these questions are very common while dealing with the analysis of changing spatial distributional pattern. Hence to answer these questions a proper visualization is essential which can be helpful for monitoring the dynamics of the object.

In this study temporal NDVI images have been used for entire INDIA for the month of November, December, January, February, March, April, May, October and December. Those are used along with the landuse/ landcover map for the same region generated from the above NDVI images. It is derived from SPOT 4 VEGETATION data for the year 1999-2000. It has four spectral bands –blue (0.43-0.47mm), red (0.61-0.68mm), infra-red (0.78-0.89mm) and short wave



infrared (1.58-1.75mm) at a spatial resolution of 1 km and temporal resolution of 1 day. The plant pigments chlorophyll a and b absorbs wavelengths of 0.66 mm and 0.65 mm respectively in the red region and infrared wavelength reflected in the wave region 0.78 – 0.89 mm is not interfered by water absorption. This gives precise information of amount of green vegetation on the earth surface calculated as ratio of red and infrared wavebands in NDVI. It represents the ratio of

$$\left[\frac{NIR - RED}{NIR + RED}\right]$$

The values range from –1 to +1. Negative values indicate water, zero indicates bare soil and positive value indicates healthy vegetation. In this study NDVI values are rescaled from 0 to 255. These are the general characteristics of the data.

The specific characteristics of temporal NDVI data are:

- It is a ratio type data.
- Vegetation growth is a discrete phenomena.
- Vegetation growth takes longer time so the duration of this change event is long.
- Magnitude of change is different at different places.
- Magnitude of change is different in different season.
- Number of physical factor is responsible for changing for example climate, physiography, soil

In this study the major concern is to represent the specific characteristics of temporal NDVI data with a proper visualization technique which can be helpful to answer the three fundamental queries of user like where? When? What? Apart from the study of data characteristics, user study is constantly required to design any kind of data visualization.

User's requirement for exploration of spatio-temporal data:

To study the spatio-temporal data users have different and distinct needs. It varies between presentation and exploration of data. "The needs are made up of series of tasks or a list of processes that are undertaken and invoked within the confines of the users thought processes" (Ogao, 2002). For example,in the field of forestry a user would like to use the spatio temporal NDVI data for monitoring the vegetation growth, for understanding the phenological pattern of different vegetation species and to discriminate them, for calculation of biomass, to classify the land cover and to identify the cropping pattern etc. (From a discussion with faculty and researchers working in the field of forestry at IIRS, Dehradun).

In this case the user may use different statistical operations in order to achieve the above objectives. In the field of geovisualization to explore these events numerous techniques could be applied for the exploration of spatio-temporal

characteristics. For example to explore the temporal datasets static techniques may not be able to fulfill the user's task. Alternative techniques (like linking between maps and different datasets, interactive manipulable maps etc.) could be applied for this type of datasets." Identify, locate, associate and compare form the basic visualization operations that are widely used for analyzing spatio-temporal datasets" (Ogao, 2002).

Hence user's requirement for studying the dynamic events using spatio-temporal datasets is an important aspect along with data characteristics during the designing phase of visualization tool. For example, if a tool is developed for visualization of temporal NDVI data using animation, without considering some of the user's need like extensive query operations related to locational and attributinal changes, linking with other climatic database, then the visualization tool would be simply an attractive animation movie with all kinds of basic display functionalities but will be of no use to the user, in terms of applicability.

Different aspects of spatio-temporal vegetation data:

The data used in this research contains the vegetation reflected value. The values are not constant but changing from time to time and area to area. The values are indicated by NDVI. For example in case of time t1 the pixel values of an area is same, in time t2 a portion of the area has changed(in the figure-1 it showing by x1 value). In time t3 more changes can be seen like in the figure1 from x, x1, x2.

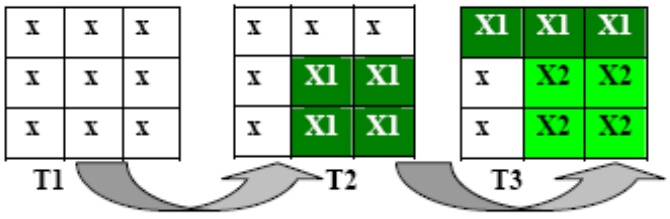


Figure1: Pixel values are changing from time to time

In each successive time period changing values are not uniform and changing pattern is not uniform. In spatio-temporal data the changes are generally locational, thematic and attribute in nature. In present temporal data the changing pixel values indicate the locational changes and amount of values indicates the attribute changes. In the above figure nine cells are representing nine pixels. It is a case of SPOT-4 images. Each pixel are representing 1 km area. If one area have same type of species then it will reflect same values (e.g. in the figure 1, four cells are showing x1 values in t2.) and that values may change from time to time (e.g. in t3 the previous x1 values become x2) due to the chlorophyll concentration. It is applicable for other areas also. In reality different types of vegetation cover can be there within 1km area. Therefore growth rate also varies

within one kilometer area. All these changes are depend upon physiography, species, climate and chlorophyll concentration. In this research the main emphasis is to represent the locational changes and attribute changes through animation.

To show change or trend	Location	Attribute
Temporal Images contain NDVI	Map iteration (Animation with statistical information and positional information	Numeric change (pixel value and spectral profile of temporal images)

In this dataset geometrical aspect is not considered. NDVI images showing complex phenomena where shape and size is not easy to identify. The main focus is to study the changing spatial distribution of objects. Changing spatial distribution is related to three basic questions. According to Pequet (Peuquet, 1994, cited in Andrienko et al., 2002) these are when, what and where.

As vegetation growth rate is a continuous phenomena and its changing aerial extent is not definite therefore in this study aerial changes is not considered in case of representing the locational changes. The study concentrates mainly on about the representation of changing vegetation growth rate at different locations due to chlorophyll concentration. Hence pixel wise changing growth rate has to determine. The concept is when one is able detect the landuse changes by changing pixel value then it becomes easier to identify the types of changing landuse by the changing nature of pixel value of particular land class. Thereafter measurement of changing vegetation growth rate is important to explore the datasets.

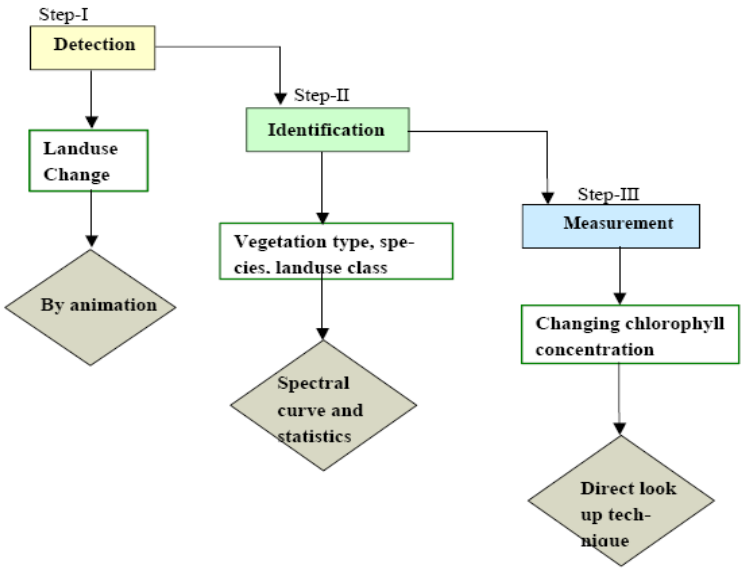


Figure 4.3: Conceptual Framework for the Design of Prototype

Figure 2: Conceptual Framework for the design of Prototype

The design concept is described in flow chart Figure 2. The concept is detection, identification and measurement simultaneously should be incorporated with animation though the significance of these three tasks are

different. Through animation locational and geometrical change (landuse change) can be recognised. While attributinal change (vegetation type, species, landuse class) can be recognised through statistical information and changing property of object (changing chlorophyll concentration) can be visualised through direct look up technique. An option should be there that functioning of these three steps (mentioned in Figure 2) also present in static mode. Thus the combination of dynamic and static approach can reveal more information through visualization.

Prototype Design Concept:

The overall prototype design is based on data characteristics and user's requirement for the exploration of NDVI images.
In the prototype nine datasets have been used. Some data are missing. Datasets of July, August and September are not used due to presence of cloud cover. To detect and identify the changes simple animation has been used. It is a frame based animation and is built in Macromedia FlashMX. Action script is used to make all basic functionalities like zoom, pan, play, back, stop and other buttons.
No interpolation is made for making animation. Legend in the map is also interactive. By clicking on any of the colour it will show the corresponding pixel value. Movie showing state wise changes, selection of static images and graph movie is also made in flash using action script. The prototype is named as 'TEMPVIZ'.

In the 'TEMPVIZ' spectral profile, histogram and textual information are the main graphics linked with animation. A single pixel for all nine images is important for change detection and identification for the present datasets. On the other hand information of a single pixel value and how it changes with time is useful for studying the phenological variation of the particular landuse category, however to take into account the variability of the pixels within a particular class the pixels in the spatial neighbourhood should also be considered. Hence an option to generate the profile using the nearby 3*3 pixels is also provided.

The main objective being that while animation is running user can interact by clicking at any pixel and it will give information in terms of spectral profile of a particular landuse class/pixel. This mouse clicking functionality is present with static mode as well as dynamic mode. A separate window is also present in 'TEMPVIZ' which provide *rgb* value and *xy* coordinate of points. (In order to relate the pixel to the geographic location). To increase the user interactiveness a window provides a facility so that the user can select any image and is able to get statistical information like mean, median, mode and the histogram plot of whole month. It can help to compare the statistical information from month to month. Thus the combination of animation and static view of same datasets can help to analyse the phonological variation in detail.

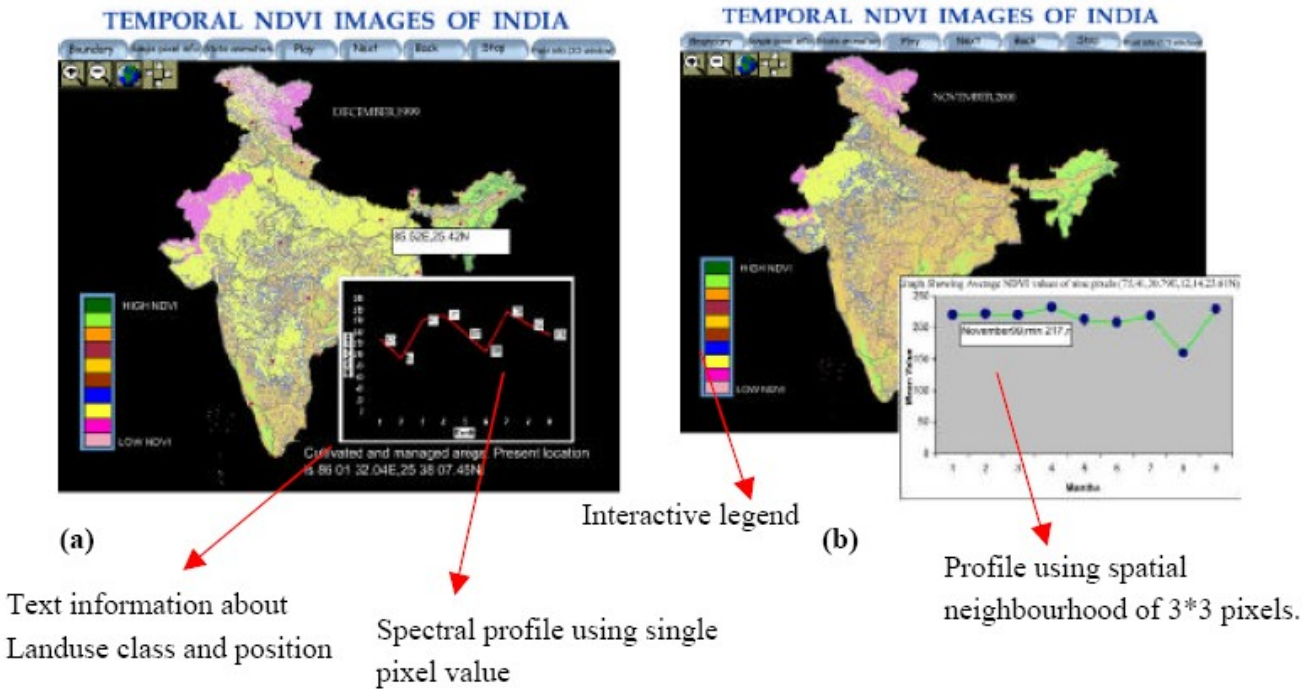


Figure 3: Functionality of TEMPVIZ

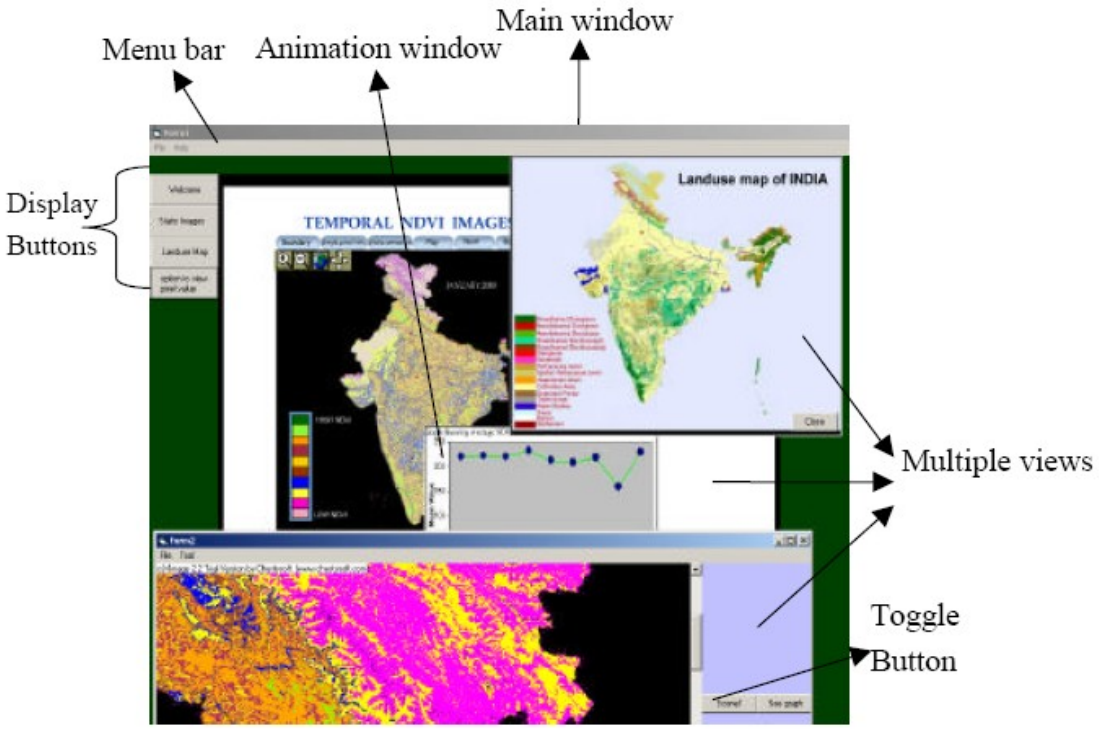


Figure 4: Main Display Window

Multiple views are useful for visual comparison of different state of change. In animation mode user is able to

detect the changes and on the other hand static view of same image can help him/ her to compare the changes visually. Animation within animation (state wise animation) has made to facilitate the view of local changes as per the user's interest. It can be a debatable issue. But when an animation is showing changes of large area then to view the changes of small area this type of representation could be effective.

Despite all the functionalities the prototype 'TEMPVIZ' has some limitations:

- It lacks GIS functionality: queries at any spatial location cannot be carried out in a dynamic mode.
- No database is linked with this prototype.
- Only NDVI values have been considered here. Other parameters like rainfall, temperature, which are responsible for vegetation growth, have not been used.
- Pixel information is also available for some sample pixels not for the entire image.
- No other temporal datasets can be used in this prototype.
- It is a conceptual design, which can be improved.

Analysis of the design:

The research prototype has been evaluated through user testing methods. In this evaluation focus group in combination with questionnaire method has been followed. User's view about the usability of the prototype 'TEMPVIZ' is analyzed quantitatively in terms of effectiveness, efficiency and satisfaction.
The overall response about effectiveness, efficiency and satisfaction are: 41.65% participants expressed that the prototype is moderately effective and 24.85% of participants stated that it is highly effective. While 44.43% of participant expressed that it is moderate in terms of efficiency and 27.95% of participants addressed that it is a highly useful tool. On the other hand 75.5% participants are moderately satisfied with the system and 25.5% of participants expressed that they are highly satisfied with system as it fulfils their requirement.
Animation with linked graphics technique is moderately useful in terms of informativeness and coherence. It is one of the effective ways for representing spatiotemporal data. Though some parts of the design need improvement but overall the users in terms of attractiveness and applicability in the particular discipline appreciated the prototype design. The positive response on the development of such type of visualization tool is a supporting point for carrying out further research and improvements for designing of such type of visualization tool.

Conclusion and recommendation:

The study reveals that visualization of spatio-temporal data is mainly depend on nature of the data and user's need. On the basis of that numerous geovisualization techniques can be applied to design a visualization tool. Traditional cartographic techniques are not always helpful to analyze and interpret the whole scenario or phenomena. In this research it is found that simple animation techniques are not that effective to visualize the locational changes. Sometimes locational changes needs to be addressed along with attributes and geometrical properties for better perception and analysis, in such cases animation can be combined with linked graphics. Currently there is no proper theoretical and methodological background for the development of such type of visualization tools. The entire technique is based on user's need and characteristics of datasets. Hence an attempt was made to conceptually design a visualization tool for exploring and analysing the temporal NDVI datasets which has utility in various application like vegetation monitoring, crop monitoring etc.

Finally, it has lot of scope to do further research like interface can be made more user friendly in terms of adding sound, video, photograph particularly for this kind of datasets. If dynamic variables are added with this technique then it will increase more usability and interactiveness for the exploration of temporal datasets. If database is also combined to it then it will be more useful to enhance the utility of the visualization tool and increase the applicability of the prototype. Like for extensive analysis and using the NDVI datasets other parameters like rainfall, temperatures, which are responsible for vegetation growth, should be incorporated. It is well known fact that different exploratory techniques are required for different types of spatio-temporal data therefore to develop a useful dynamic visualization technique this animation with linked graphics techniques should be experimented by using different types of temporal data.

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