Spatio-Temporal Visualisation in Naturdetective and Beyond

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Abstract. Visual investigation of time-referred data requires highly interactive presentation with powerful and convenient instruments for controlling display time, i.e. time moments or intervals represented. We propose an approach to visualisation of time-dependent data, in particular, cartographic visualisation, involving interactive manipulation of display time. We have developed a set of interactive devices, called "time controls", allowing this manipulation. The proposed tool is applicable to various kinds of time variation: occurrence of events, changes in existence of objects, their spatial locations or shapes, or changes of attribute values. Thus, it has been applied to cartographic visualisation of observation records (occurrence) and of migration routes of storks (changes of spatial location) within the "Naturderective" project.

1   Introduction

Analysis of phenomena that vary in time is required in various areas of human activities. Current state of computer technology potentially can significantly support investigation of dynamics of phenomena. Thus, graphic presentations that change their appearance in real time to represent changes in data can facilitate visual exploratory analysis of time-referred data.

We are especially interested in time-referred data that have also spatial reference. Spatial objects may be subject to different kinds of time variation that may happen separately or in combinations:

- variation in <u>existence</u>: within the studied time span some objects may appear or disappear. A special case is data about <u>occurrences</u> (e.g. earthquakes) that can be treated as "instant" events existing only at the moment they are registered;
- spatial <u>movement,</u> i.e. change of locations of objects in space;
- change of <u>geometry</u>, i.e. shapes or/and sizes of objects;
- variation of <u>attribute</u> values associated with spatial objects, e.g. population number in cities.

Visual analysis of spatially referenced data requires presentation of them in maps that can convey to the analyst information about spatial properties and relationships. When data change in time, the maps should be *dynamic.* However, this does not mean mere animation. Analysis requires high interaction between the analyst and the presentation. The analyst should be able to consider in detail the state of the studied phenomena at any selected moment, to compare states at different moments, to consider dynamics on selected intervals, to access magnitudes and speeds of changes etc. For such analyses s/he needs interactive devices to control "display time". The presentation of data should be sensitive to user's actions on these devices. Specifically, the module performing presentation should be able to filter the data records according to time moments they refer to and to show only those belonging to a user-selected interval $[t_1, t_2]$. In particular, t_1 and t_2 may be equal. In this case only the data referring to the specified moment should be presented.

Recently we have developed a map display module having such capabilities as well as a set of interactive devices to manipulate the temporal dimension of the presentation. The work has been done for the project "Naturdetektive" (URL: http://lo.san-ev.de/natdet/). Within this project schoolchildren may register their observations of nature: when and where certain plants or animals occurred to them for the first time in the current year. Dynamic visualisation was used to present the observations registered (an example of *occurrence* data). Another application within the same project was to data about *movement*. We used our tools for presentation of migration routes of storks from Europe to Africa in autumn 1998 and back in spring 1999.

2   Interactive tool to control time-related presentations

As we pointed out above, an important feature of the display of time-referred data should be the possibility to set a limitation on the time interval $[t_1, t_2]$ that is to be represented. Giving some increment to t_1 and t_2 or only to t_2 should make the display dynamically redraw. Recurrent fulfilment of this operation supports investigation of *dynamics* of the phenomenon represented. When the operation is performed automatically, we receive *animation*. For manipulating time-related presentations (in particular, map displays) in the described manner, we have developed a set of interactive widgets, the so-called <u>time controls</u>.

One of the controls (see Figure 1) is the <u>time slider</u> that allows selection of an interval or moment to present and at the same time shows the relative position of the currently represented interval within the whole time span. The width of the slider is proportional to the length of the interval. The user can manipulate the presentation directly through the slider widget: s/he may, by mouse click, set the beginning of the interval to be represented, or gradually move the slider forth or back causing the map being dynamically repainted. The beginning of the interval can be specified more precisely through entering the date in the edit field below the slider area. The next edit field is for setting the length of the shown interval, and the field below it controls the step, i.e. the value to be added to the beginning and the end of the interval in the course of studying dynamics.

One of the ways to consider dynamics is to push repeatedly the buttons marked by ">"or "<". Upon each button operation the presentation "moves" forth or back in time, respectively, by the number of time units (in our example days) specified as the step. By pressing the button ">>" or ">>…" the user gets an animated presentation. In this case the display time runs forward with constant speed regulated by specifying the delay. The button ">>…" makes the system automatically start animation from the beginning after the end of the time span is reached. In this case the system will loop the animation until the user stops it by pushing the button "|".

Figure 1. Time controls to manipulate presentation of time-dependent data.

Selection of the check box "keep showing old events" makes the map present the data from the very beginning of the total time span (i.e. the earliest moment referred to in the data set) up to the end of the currently selected interval. In fact, in this case specification of the starting moment of the interval has no impact on the presentation, and all operations (moving the slider, adding or subtracting the value of the step) are applied only to the end of the interval.

So, our tool allows both animation (when the system automatically runs the presentation) and full user control over the display time. The user can also regulate parameters of animation such as interval length, step, and delay.

3   Application I: presentation of observations

Within the project "Naturdetektive" German schoolchildren register when and where they have seen certain plant or bird. For some plants different states are distinguished: appearing of first leaves, start of blossoming, appearing of fruits. The observations registered were to be represented in map form. One of the requirements to
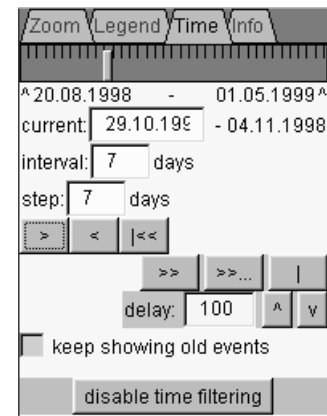

Figure 2. Presentation of data about observations. All observations irrespective of time are shown.

the presentation was to show the time aspect of the data collected. For this purpose we applied the dynamic map display manipulated through the time controls described above.

The map display with observations presented in it is seen in Figure 2. The map can be zoomed and shifted. It allows the user to access the data records about the observations: when the cursor points at an icon representing an observation, all relevant data are shown in the lower right section of the map window. A user can select specie to be shown through the radio buttons below the map.

Besides the overall view on the data (i.e. consideration of all observation made irrespective of time), it is possible to watch how new observations appeared with the flow of time. Figures 3 and 4 simulate this *dynamic view* on the data. Both shot sequences represent observations of dandelions in 3 different states during the same period, by 2-weeks intervals. Figure 3 has been produced with the option "keep showing old events" turned on. This option enables a cumulative view: the map shows all data from the beginning of observations until the specified date. When this option is off, the map represents only the observations made on the time interval specified. In Figure 4 each shot shows observations of dandelions made on 2-weeks intervals.
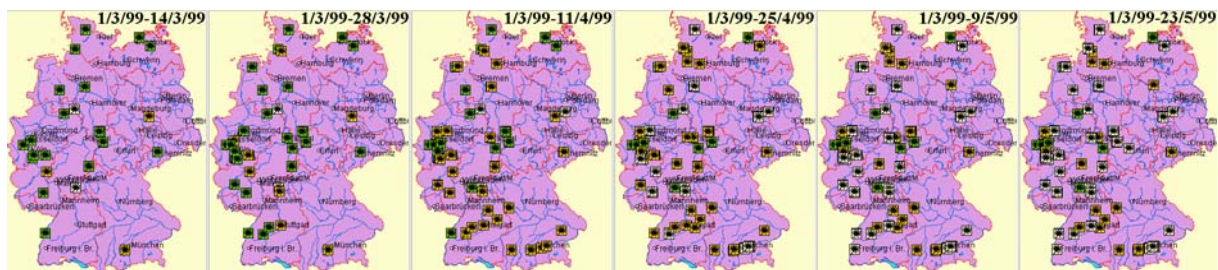

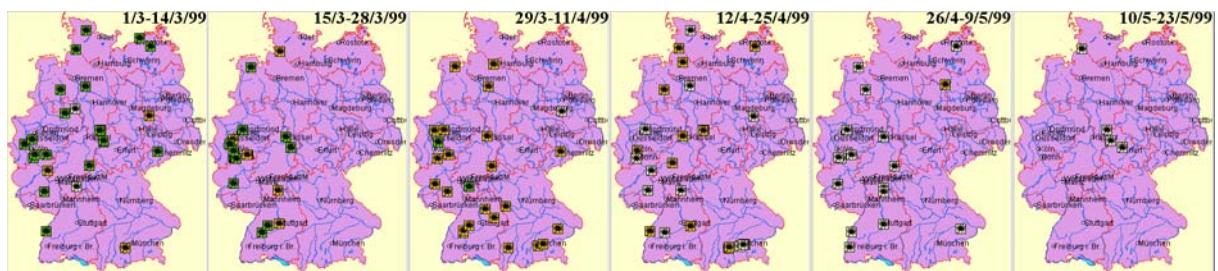*Figure 3. Each shot presents all observations from beginning until the specified date (2 weeks step)*

Figure 4. The same observations split into 2-weeks intervals according to the dates they were made.

4 Application II: visualisation of seasonal migration of birds

The data set we dealt with contains results of telemetric observation of migration of four storks to Africa in autumn 1998 and back to Europe in spring 1999. The data were provided by the German Research Centre for Ornithology of the Max Planck Society (http://vowa.ornithol.mpg.de/~vwrado/). This is an example of data about spatial movement. Although this is another kind of temporal variation as compared to the previous application, the same approach to visualisation and display manipulation can be taken.

Figure 5 presents the overall view on the data, i.e. the trajectories made by the birds during the whole time span considered. Each bird is assigned its particular colour hue. The hues are used to differentiate visually the routes made by different storks. We also applied variation of degree of darkness to represent the temporal ordering of data: older data are shown in lighter, less saturated colours, and darker and more saturated colours are used for later observations. Without this technique, although the arrows indicate directions, it was quite difficult to figure out the relative order of route segments because the birds returned to the places from which they had started their movement. In addition, the routes are in some parts self-crossing.

To increase the legibility of the display and concentrate on investigation of movement of a specific bird, it is possible to switch off presentation of data about the other birds.

Besides the *overall view* on the data illustrated by Figure 5, the visualisation enables *moment view* (seeing locations of the storks at any specified moment) and *interval view* (seeing the paths the birds made on any specified interval). Either moment or interval view may be combined with *dynamic view* when the considered moment or interval is shifted along the time axis with dynamic redrawing of the map. As in the previous application, there is an option to see the paths made from the beginning of movement until the specified moment, as is shown in Figure 6.

We found combination of dynamic and interval views (see Figure 7) to be especially productive for examination of data about movement. In animation with interval view object routes look like worms crawling on
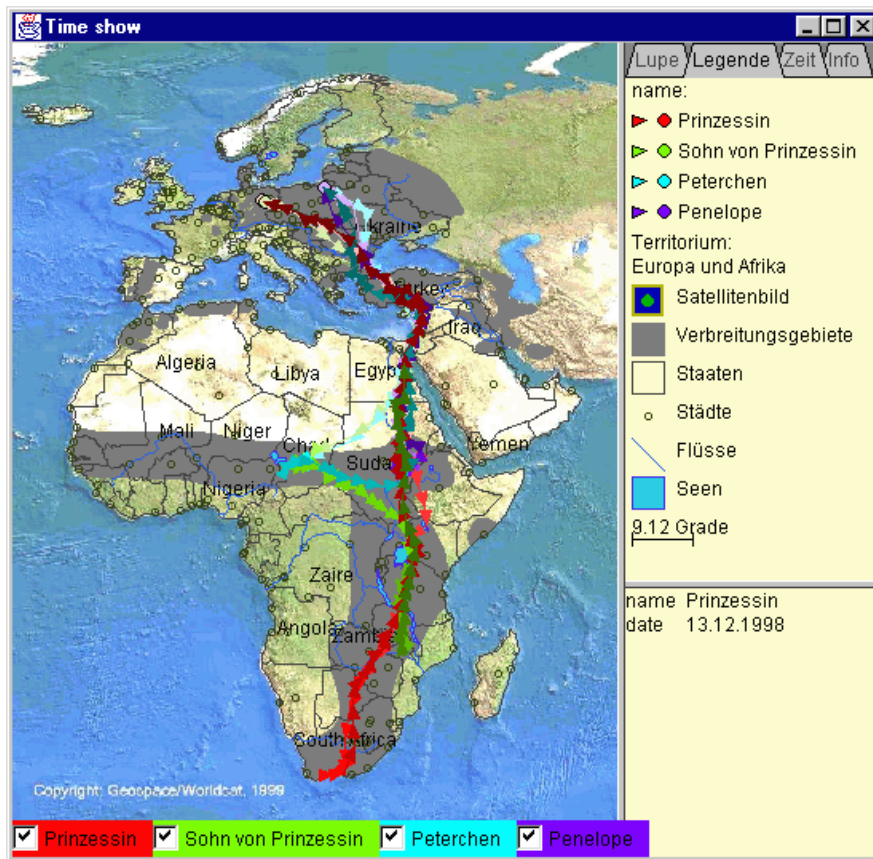
Figure 5. Overall view on routes of birds.

the map. Visual appearance of these "worms" helps to study important dynamic characteristics of movement. The lengths of the "worms" show speeds of object movement. A "worm" being shrunken signalises the movement of the object slowing down, "worm's" elongation means that the movement becomes faster. Sometimes a "worm" reduces to one point (shown in the map by a circle) meaning that the object stopped its movement and stayed for some time in the same place. All these observations would be practically impossible with state-oriented animation.

In Figure 7 one can see a sequence of screenshots illustrating the concept and the features of the interval-oriented dynamic view. The shots represent six 10-days-long successive intervals. The intervals overlap; the step between them is 5 days. The pictures show, for example, that one of the birds, named Sohn von Prinzessin, moved initially slowly over Chad and then with acceleration through Sudan and Uganda to the eastern bank of the Lake Victoria where it stopped for a while. Peterchen, which was initially in the same place in Chad, first made some minor movements around this place (probably, looking for better conditions) and then rushed to the east. Penelope relatively slowly changed its place of staying from the left side of Nile to the right. Prinzessin arrived at the southernmost end of Africa and circled there until a convenient place to stay (near Port Elizabeth) was found.

5   Directions for future work

The applications described mark the beginning of our work on visualisation and support of analysis of time-dependent spatially referenced data. Our ultimate goal is creation of a knowledge-based system to support visual exploration spatially referenced data characterised by different kinds of time variance. The knowledge base of the system will enable design of adequate presentations of spatio-temporal data, in particular, animated cartographic presentations, as well as selection of appropriate data transformations that can facilitate the analysis. Visualisation methods, data transformations, and manipulation techniques should be selected with respect to:

- "static" data characteristics, such as types of spatial objects, types of attributes, and relationships among the attributes;
- temporal characteristics of the data to present (i.e. which aspects of the studied phenomena vary: existence, spatial location, geometry, or attribute values), and
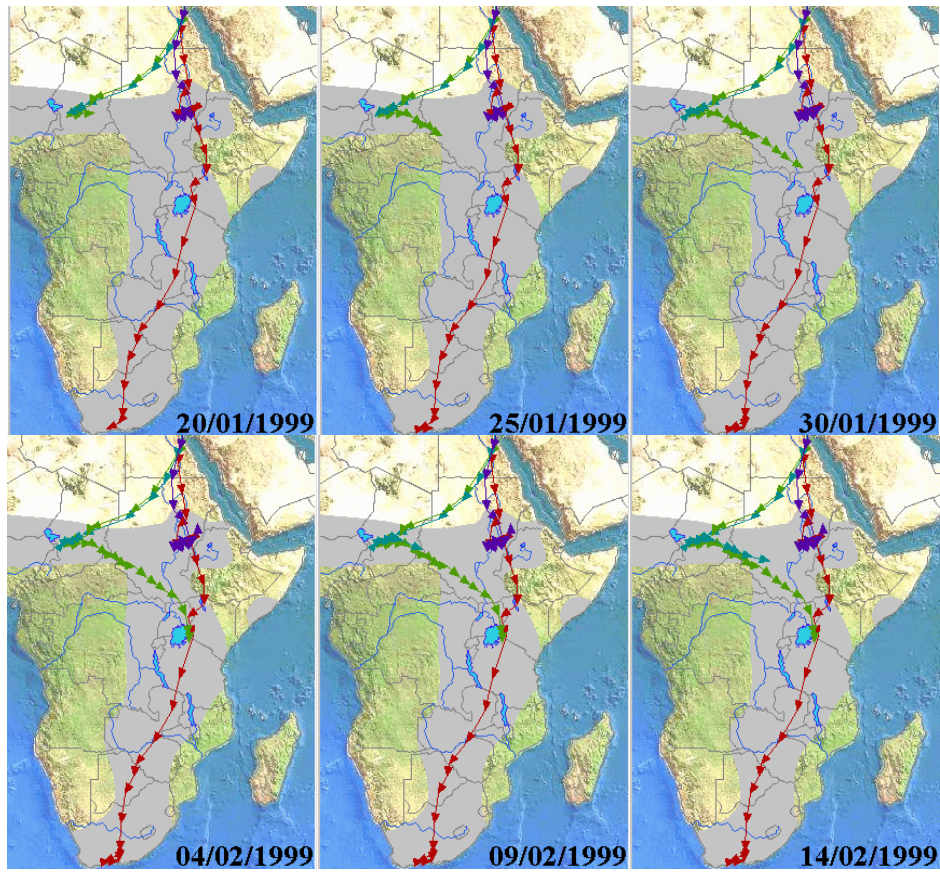- analysis tasks supposed to be done.

Figure 6. Cumulative paths of the birds made by the specified dates (with 5 days step).
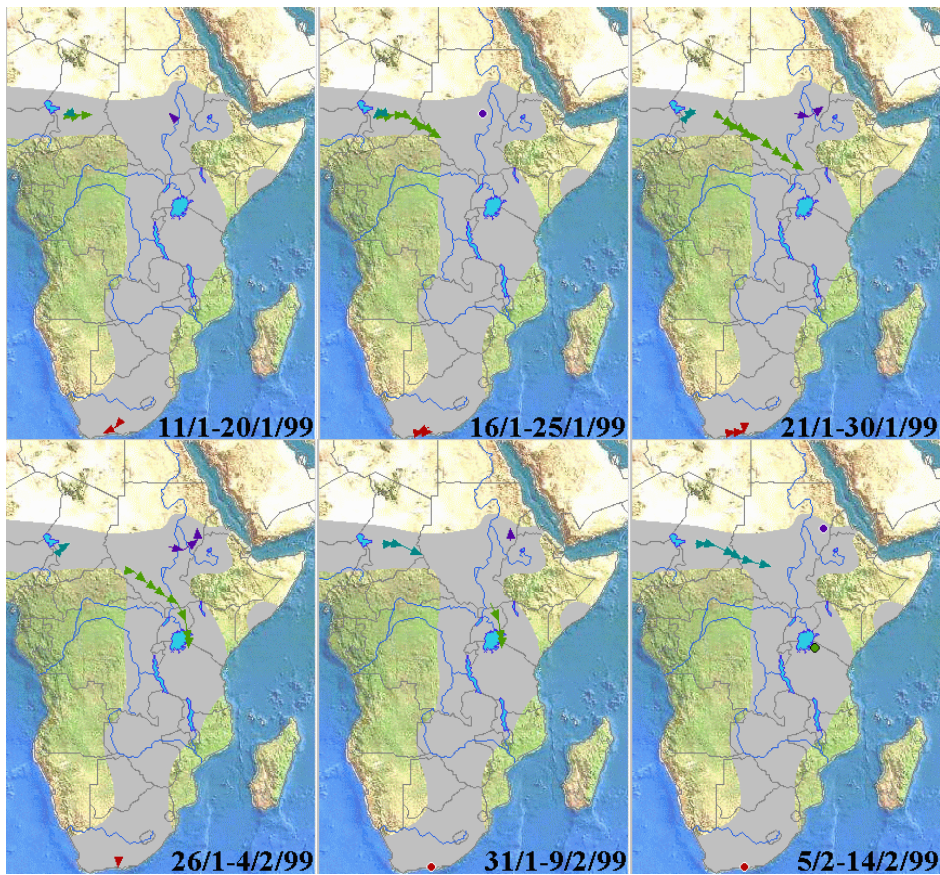

Figure 7. Combination of dynamic and interval views on data about movement.

In analysis of time-dependent data it is important to assess changes occurring with the time flow. In particular, regarding numeric data, an analyst should be able to evaluate magnitudes of change, both absolute and relative, the speed or other characteristics of change. Usually these values are not available in the source data sets and should be calculated. The designed intelligent system will be able to determine, which calculations are necessary, to do these calculations automatically, and to present the results visually enabling, in particular, dynamic view on the derived characteristics.

The implementation is being done on the basis of the existing system Descartes [1] (see also the demo version of the system in the Internet at the URL http://allanon.gmd.de/and/java/iris/). This is a knowledge-based system capable of automated presentation of spatially referenced data on maps. It equips the user with tools for interactive manipulation of the maps that support visual analysis. The currently available arsenal of visualisation methods and manipulation tools is suitable for analytical tasks involving study of data at a single time moment. When automated calculation of characteristics of change is added to the system, the available knowledge-based visualisation and tools for manipulation will enable analysis of changes of numeric data that happened between two specified time moments. The next step will be extension of the knowledge base to dynamic presentations and incorporation of the time control tools developed within the "Naturdetektive" project.

6   Implementation notes

The tool described has been implemented as a Java applet. The variant used for presentation of observations contains some application-specific modifications to provide the use of special icons and to replace numeric codes in data by meaningful texts children can understand. In general, the tool is universal and can be applied in various domains. Thus, without any change in the program code we made it present data about earthquakes that happened in Europe during XX century. Since the user interface of Descartes is also implemented in Java, it is easy to incorporate in it the time controls developed.

Both applets are available in the WWW and may be tested using a WWW browser. The applets can be accessed from the pages of the "Naturdetektive" project (with German interface). The URL of the home page of the project is http://lo.san-ev.de/natdet/. It is also possible to run the applet showing the data about storks with English interface at http://borneo.gmd.de/descartes/java/birds/index.html.

7   Conclusion

To do visual exploration of time-referred data, one needs powerful and convenient interactive facilities to control display time within the presentation. These facilities should support various tasks an analyst may undertake in the course of exploration: the tasks requiring overall, moment, or interval view on the data, the tasks involving comparison of moments, and the tasks on studying dynamic characteristics of data variation.

We have designed and implemented an interface to manipulate presentation of time-referred data. The tool developed has been applied to data with different kinds of temporal variance: observations of occurrences and data about spatial movement. Our experiments with the tool have shown that, being combined with appropriate visualisation, it can really support the designated groups of analysis tasks. The tool is made as a reusable component that can be applied to various kinds of time-dependent data and diverse types of visual presentation, including non-map displays. In the future the results of the work will be incorporated into the knowledge-based system Descartes supporting visual exploration of spatially referenced data.

References

1.   Andrienko, G. and Andrienko N. "Interactive Maps for Visual Data Exploration", *International Journal Geographical Information Science*, Vol.13, no.4, pp.355-374, 1999