

Temporal Concept Analysis with SIENA

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Abstract. Temporal Concept Analysis (TCA) is an extension of Formal Concept Analysis (FCA) aiming at a conceptual description of temporal phenomena. We present the latest version of the TCA tool in the program SIENA, a part of the ToscanaJ Suite. This TCA tool allows for *animations* of trajectories of temporal objects in line diagrams of concept lattices. Such concept lattices represent views of the given temporal data, as for example a map of a landscape. For generating views of suitable granularity the many-valued temporal data have to be scaled using conceptual scaling tools as for example CERNATO. In the TCA tool in SIENA the temporal database has to satisfy the condition that the many-valued attributes for *temporal objects* and *time* together form a key. Then the *state* (of a temporal object o at a time t in a view \mathcal{Q}) is defined as a certain *object concept* of a formal object of the formal context generated by the view \mathcal{Q} . The general case of temporal data bases with an arbitrary key leads to the notion of *distributed objects* which are at each time at possibly many places, as for example a high pressure zone on a weather map. A *state* of a distributed object is defined as a certain *set of object concepts*. In this workshop we give a demonstration of SIENA presenting animations of trajectories of temporal objects. In ToscanaJ we visualize changing distributed objects.

Keywords: Temporal Concept Analysis, states, trajectories.

1. Temporal Concept Analysis

1.1. Introduction

Temporal Concept Analysis (TCA) [3, 4] is an extension of Formal Concept Analysis (FCA) [2] aiming at a conceptual description of temporal phenomena. TCA offers a general way of understanding change of concrete or abstract temporal objects in continuous, discrete or hybrid space and time.

1.2. Scaling temporal databases

We start from a temporal database, i.e. a complete many-valued context containing at least one many-valued attribute explicitly used for describing time. In conceptual scaling [2] one selects for each many-valued attribute a suitable formal context, called

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a *conceptual scale*. From the *scaled many-valued context* its *derived context* \mathbf{K} is used to generate specific sub-contexts by selecting interesting subsets of the attribute set of the derived context. Any such subset \mathbf{Q} is called a *view*. The concept lattice of the formal context \mathbf{K}_Q of a view \mathbf{Q} is used for many purposes, namely conceptual descriptions of space, time, and (temporal) objects; for a mathematical definition of *Temporal Relational Semantic Systems* and their *temporal objects* we refer to [4].

1.3. Conceptual description of space, time, and objects

To describe changes of objects in a general conceptual setting one has to represent conceptually not only *space* and *time*, but also *objects*.

Space. For the conceptual description of a space, e.g. a landscape, we take the concept lattice of the formal context \mathbf{K}_Q of a suitable view \mathbf{Q} , for example a set of attributes derived from the many-valued attributes of longitude and latitude. The formal concepts of \mathbf{K}_Q can be used for describing spatial notions, as for example countries, towns, places, streets and so on.

Time. For the conceptual description of time often several many-valued attributes are used, e.g. for days, months, and years. The corresponding scales are usually ordinal or interordinal scales. For the seven days of a week one may wish to choose a cyclic scale. For temporal notions as for example *early morning* and *late evening* one has to introduce a suitable scale for describing the meaning of these notions by suitable scale concepts. In any case, the scales for the set \mathbf{T} of many-valued time attributes should be chosen in such a way that the corresponding derived context \mathbf{K}_T represents the desired concepts, as for example time intervals.

Objects. For the conceptual description of objects one might take the formal objects of a many-valued context. That is sometimes appropriate, but in temporal data it is often useful to take time points, e.g. days, as the formal objects. Since the formal objects of a many-valued context form a key it is a restriction to assume that the objects or the time points also have to form a key. Usually, there are many kinds of objects and also several kinds of times, e.g. local times. Therefore, in TCA we emphasize to describe temporal objects as formal concepts of scales of many-valued attributes. Then the formal objects of the used many-valued context just represent row labels of the statements given in the rows of the data table.

2. The TCA tool in SIENA

The well-known ToscanaJ Suite [1] contains a program SIENA which has a tool for drawing (nested) line diagrams of concept lattices. Into this drawing tool Peter Becker has embedded the TCA tool. It allows for *drawing and animating* trajectories of temporal objects in line diagrams of concept lattices. The menu of the TCA tool can be shown by clicking in SIENA on *View \ Show Temporal Controls*. Before using the TCA tool the many-valued context of a temporal database has to be scaled, and all

views (in German: Sichten) of interest have to be generated using the program CERNATO (developed by NAVICON, now obtainable from the Ernst-Schröder-Zentrum). Finally, the scaled temporal database together with all generated views has to be exported as an XML file and then imported into SIENA by clicking on *File\ Import Cernato XML*. The names of all views can be seen in the main menu of SIENA under the tab *Diagrams* in the top left. Clicking on the name of a view \mathbf{Q} a line diagram of the concept lattice of \mathbf{K}_Q as generated in CERNATO is shown. Often this diagram can be improved graphically in SIENA using five different *Movements*, a scalable *Grid* and an effective *Rescale* possibility.

2.1. The object-time key

The temporal database used in the TCA tool has to fulfill the following condition:

(OTK) There are two many-valued attributes, say object and time, together forming a key.

In some temporal databases a single many-valued attribute *time* forms a key. Then any further attribute together with *time* forms a key, hence OTK is satisfied.

In Table 1 an example of a temporal database satisfying OTK is shown. The first statement is interpreted as: Mary has been at time 0 in London.

Table 1. A temporal database with an object-time key

statement	object	time	town
1	Mary	0	London
2	Mary	1	Paris
3	Charly	1	Paris

To distinguish clearly between *objects* and *formal objects* we just remark that in Table 1 the statements 1,2,3 are the formal objects of this many-valued context and therefore also the formal objects of its derived context; the objects in Table 1 are the values *Mary* and *Charly* of the many-valued attribute *object*.

In the TCA tool in SIENA the column in the database containing the *temporal objects* can be *chosen* using the tab *DATA\Sequence Column*. In the same way the column containing the time values can be chosen using the tab *DATA\Timeline Column*.

To define the *trajectory* of an object \mathbf{o} in a view \mathbf{Q} we first need the notion of a *state of an object \mathbf{o} at a time \mathbf{t} in a view \mathbf{Q}* and then the definition of a *transition*.

2.2. The state of an object at a time in a view

Assume that we have chosen a view \mathbf{Q} and a temporal object \mathbf{o} , and we are interested where object \mathbf{o} has been at time \mathbf{t} in the concept lattice of $\mathbf{K}_{\mathbf{Q}}$ according to the given temporal database. By OTK, the pair (\mathbf{o}, \mathbf{t}) occurs in exactly one row g of the given database where g is a formal object of the derived context $\mathbf{K}_{\mathbf{Q}}$. Let $\gamma_{\mathbf{Q}}$ denote the object concept mapping of $\mathbf{K}_{\mathbf{Q}}$. Then the object concept $\gamma_{\mathbf{Q}}(g)$ is defined to be *the state of object \mathbf{o} at time \mathbf{t} in the view \mathbf{Q}* , denoted by $\gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{t})$; for further information see [3,4].

2.3. Transitions and trajectories

For introducing transitions in the TCA tool the values of the selected many-valued time attribute have to be *integers*. For each object \mathbf{o} its *\mathbf{o} -time* is the set of time values occurring together with \mathbf{o} in the same row, hence $\mathbf{o}\text{-time} := \{\mathbf{s} \mid \exists g \text{ object}(g) = \mathbf{o} \text{ and } \text{time}(g) = \mathbf{s}\}$. The partial mapping *next \mathbf{o} -time* assigns to each not maximal time value \mathbf{s} in \mathbf{o} -time the minimum of all \mathbf{o} -time values $\mathbf{t} > \mathbf{s}$. A pair (\mathbf{s}, \mathbf{t}) satisfying *next \mathbf{o} -time* $(\mathbf{s}) = \mathbf{t}$ is called a *base \mathbf{o} -transition* and the pair $(\gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{s}), \gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{t}))$ of states is called the *\mathbf{o} -transition* generated by the base \mathbf{o} -transition (\mathbf{s}, \mathbf{t}) in the view \mathbf{Q} .

In the TCA tool the \mathbf{o} -transition $(\gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{s}), \gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{t}))$ is graphically represented in a line diagram of the concept lattice of $\mathbf{K}_{\mathbf{Q}}$ by an arrow leading from the circle of $\gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{s})$ to the circle of $\gamma_{\mathbf{Q}}(\mathbf{o}, \mathbf{t})$. The sequence of all \mathbf{o} -transitions in the view \mathbf{Q} forms the *trajectory of the object \mathbf{o} in the view \mathbf{Q}* .

2.4. Using the TCA tool: Controls, Data, Arrows, Options

To show a line diagram of a view \mathbf{Q} one has to click on \mathbf{Q} in the list of *Diagrams*. To show in the line diagram of \mathbf{Q} the trajectories of all temporal objects click in the menu of the TCA tool on *Controls\Show all transitions*. To show the trajectories for only a few temporal objects these objects can be selected using *Data\Sequence*. The selected trajectories can be animated using *Controls\Animate transitions*. The speed of the animation can be chosen using *Options\Speed (ms/step)*. Using *Controls\Repeat Animations* the chosen animation is repeated until stopped.

To study several trajectories simultaneously step by step the user should first click on *Controls\Start stepping* and then use *Step Controls*.

The arrows of a trajectory can be modified: click on *Arrows* to see 10 arrows in different colors. Move the mouse to an arrow to see the name of the temporal object assigned to it. Double click on an arrow opens a new window where the *Color*, the *Shape* and the *Label* of the arrow can be modified.

Using *drag and drop* each arrow and each label in the line diagram can be moved. These changes are not saved in SIENA. Hence, use *File\Export Diagram* to store good diagrams in jpg- or png-format. To generate nested line diagrams click with the *right mouse* on a second view and then click on *Nest Diagram*.

2.5. An example: Three gymnasts

There is a well-known demonstration for three gymnasts, say Tobias (t), Konstantin (k), and Florian (f), moving between the places 1,2,3 in the following way:

In the beginning they are standing in a line, Tobias at place 1 facing Konstantin at place 2 and Florian at place 3. At time 0 Konstantin rolls forward to place 1 while Tobias jumps straddling over him to place 2 and Florian is standing on place 3. At time 1 Tobias rolls forward to place 3 while Florian jumps straddling over him to place 2 and Konstantin is turning (T) on place 1. At each time the gymnast in the middle (at place 2) rolls to the gymnast jumping over him (see Fig.1). At time 6 the starting position is reached again. That can be easily represented in a temporal database satisfying (OTK) as shown in Table 2.

Table 2 . A temporal database for three gymnasts

statement	gymnast	time	exercise	place
1	Tobias	0	jump	1
...
8	Konstantin	0	roll	2
...
21	Florian	6	turn	3

Choosing ordinal scales for *place* and *time*, the *view* of the place-time attributes, the *gymnasts* as temporal objects, the *time* as the Timeline Column we generate Fig.1 with arrows, its colors, shapes and labels as shown.

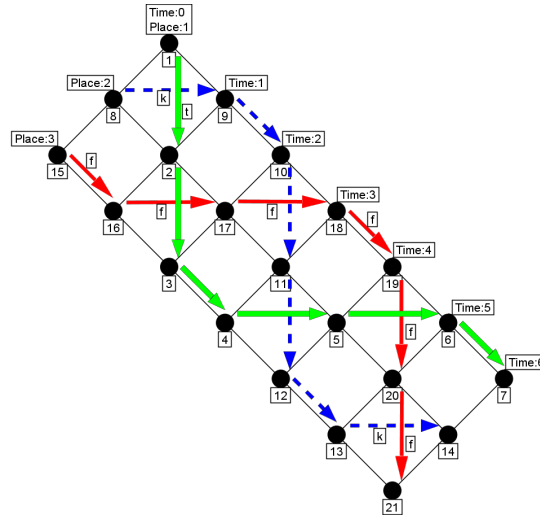


Fig. 1. A transition diagram for the movement of three gymnasts t, k, f in some *space-time* view generated using CERNATO and SIENA from the temporal database in Table 2.

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