Visualizing Conceptual Structures Using FCA Tools Bundle

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Abstract. Formal Concept Analysis (FCA) is a prominent field of applied mathematics organising collections of knowledge - formal concepts - as conceptual landscapes of knowledge. FCA proved to be a promising theory to extract, analyse and visualise conceptual structures arising from various data structures. One of the strengths of FCA is the elegant, intuitive and powerful graphical representation of landscapes of knowledge as concept lattices. The purpose of this paper is to present FCA Tools Bundle and its various features, which is a bundle of tools for dyadic, many-valued, triadic and even polyadic FCA.

1 Introduction

Formal Concept Analysis (FCA) is dealing with collections of knowledge in order to detect, extract, process and represent patterns in various data sets. Following the Conceptual Landscapes of Knowledge paradigm [10], we present FCA Tools Bundle, a collection of tools covering the dyadic case, many-valued contexts, scale building and conceptual browsing. Polyadic data sets can be imported, the corresponding concept sets being calculated by using Answer Set Programming (ASP). In the triadic case, the visualization of the correspondent conceptual structures is based a local navigation paradigm in triadic data sets [8], while for higher-adic concept sets constraint based navigation is implemented [9]. FCA Tools Bundle can also be used to visualize conceptual structures arising from pattern structures [4] by an appropriate scale building. It also offers the possibility to compute analogical proportions in order to mine and represent analogies between formal concepts [6]. Moreover, following the ideas of R. Wille, we work on a separate feature, navigation in 3D landscapes of knowledge by a 3D visualization of concept lattices using some virtual reality hardware. Since this is work in progress, it has not been included in this short presentation. FCA Tools Bundle is a web based open access collaborative platform where users can share data, create public and private groups or can enter virtual conceptual exploration rooms.

2 Related work

There is a long list of software tools, developed in the last 30 years in order to support FCA based knowledge visualization.[1] Among them we briefly recall `Concept Explorer` which supports context processing, clarification and reduction of the context, computing the concept set and the conceptual hierarchy, the `ToscanaJ Suite` [2] which comprises three components: `Elba` (create the conceptual scales), `Toscana` (browse the conceptual schema) and `Siena` (display the result of conceptual scaling of the entire many-valued context and by that the entire conceptual structure of it). `FCABedrock`[2] handles many-valued contexts and supports discrete and progressive scaling for continuous attributes.

Most of the algorithms for computing dyadic formal concepts cannot be extended efficiently for the triadic case. R. Jäschke implemented Trias [3], one of the most popular algorithms, which offers the possibility to set the minimum support of the components in the input configuration file. `Lattice miner`[3] is an FCA software tool for the construction, visualization and manipulation of concept lattices, which allows the generation of formal concepts and association rules. Formal Concept Analysis Research Toolbox[4](`FCART`) is a software developed especially for the analysis of unstructured data [7] and is intended for knowledge discovery. `LatViz` is one of the newest tools developed within the FCA community which introduces interaction with expert, visualization of pattern Structures, AOC posets, concept annotations, filtering concept lattice based on several criteria and an intuitive visualization of implications. By this, the user can effectively perform an interactive exploration over a concept lattice which is a basis for a strong user interaction with WOD for data analysis [1].

3 `FCA Tools Bundle` - Description and Features

A first description of the `FCA Tools Bundle` features for dyadic and triadic FCA had been presented in [5]. The key features offered by the tool for a dyadic context are to compute and visualize the object, attribute and concept sets, the incidence relations and the corresponding concept lattice. For triadic contexts, one can compute first the concept list using ASP and then start a local visualization of parts of the triadic context which enables the navigation paradigm based on dyadic projections [8]. For polyadic data sets, one can narrow down the search space by using user defined constraints (on objects, attributes, conditions, states, etc.) and then compute the corresponding resulting concept sets. We proposed an ASP encoding for the membership constraint satisfiability problem and described an interactive search scenario [8]. As far as we know, this is the only

[1] An overview of this developing effort is maintained by Uta Priss on her page `http://www.upriss.org.uk/fca/fcasoftware.html`

[2] `https://sourceforge.net/projects/fcabedrock/`

[3] `https://sourceforge.net/projects/lattice-miner`

[4] `https://cs.hse.ru/en/ai/issa/proj_fcart`

software tool allowing navigation in polyadic concept sets and visualization of triconcept sets by using local navigation.

`ToscanaJ` was for many years the only tool to handle many-valued contexts. To overcome the difficulties and drawbacks of `ToscanaJ`, `FCA Tools Bundle` offers the possibility to build conceptual scales, either predefined or custom scales and by thus to browse and visualize the conceptual structures of knowledge of a many-valued context. Conceptual scaling is a process of transforming multi-valued contexts into unary-valued ones. A (conceptual) scale is a formal context that determines this procedure for a certain many-valued attribute. In order to create a scale in FCA Tools Bundle the following steps are required:

• **Select a source:** the tool supports two sources types from where one may build scales: database and csv.

• **Provide General Scale Data:** the tool request to fill in the name of the scale, select a table for your scale and then select the type of the scale. Currently the tool supports the nominal, ordinal, interordinal, grid or custom scales.

• **Provide Type Specific Data:** In order to build a nominal scale you need to select the column on which to build the scale. For an ordinal scale you need to define the column on which to build the scale, the order of the scale (increasing or decreasing), the bounds of the scale (include or exclude) and the actual values. For an interordinal scale you need to define the column on which to build the scale, which side includes the bounds and the actual values. For a grid scale you need to define the two columns on which to build the scale, the order for each of the two columns, the bounds for each of the two columns and the values for each of the two columns. In order to build a custom scale you need to create an incidence table defining the custom scale. Custom scales are used for advanced cases where the elementary scale types are not expressive enough.

`FCA Tools Bundle` is able to compute and display the concepts of a concept lattice which are in analogical complex relation by using the ASP based approach presented in [6]. Analogical complexes are formed by using analogy between four subsets of objects in place of the initial binary relation. They represent subsets of objects and attributes that share a maximal analogical relation. This feature can be very useful since it is interesting to find relations between concepts that are not directly linked in a concept lattice.

4 Conclusions and Future Work

In this paper, we presented `FCA Tools Bundle`, a platform that offers, for now, features of visualization and navigation for polyadic FCA. We have improved concept lattices generation using a detection collision algorithm, in order to avoid manually arranging the concept lattice for concept visibility. Moreover, we have shown how concept lattices can be used for a triadic navigation paradigm based on appropriately defined dyadic projections. We have implemented analogical proportions between formal concepts and have discussed various features of this tools bundle.

Further developments will include an AI assistant for navigation in large concept lattices, a Temporal Concept Analysis tool, as well as 3D navigation feature by using specific VR hardware.

In conclusion, we believe that the presented version of `FCA Tools Bundle` brings an important contribution to the collection of FCA tools, by implementing functionalities of visualization and navigation in a large variety of concept sets, which, to the best of our knowledge, are not present in any other tool.

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