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Formal Concept Analysis

14th International Conference, ICFCA 2017 Rennes, France, June 13–16, 2017 Proceedings

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Preface

This volume features the accepted publications of the 14th International Conference on Formal Concept Analysis (ICFCA 2017), held during June 13–16, 2017, at IRISA, Rennes. The ICFCA conference series is one of the major venues for researchers from the field of formal concept analysis (FCA) and related areas to present and discuss their recent work with colleagues from all over the world. Since its first edition in 2003 in Darmstadt, the ICFCA conference series has been held in Europe, Australia, America, and Africa.

The field of FCA originated in the 1980s in Darmstadt as a subfield of mathematical order theory, with prior developments in other research groups. Its original motivation was to consider *complete lattices* as *lattices of concepts*, drawing motivation from philosophy and mathematics alike. FCA has since then developed into a wide research area with applications far beyond its original motivation, for example, in logic, data mining, learning, and psychology.

The FCA community is mourning the passing of Rudolf Wille on January 22, 2017, in Bickenbach, Germany. As one of the leading researchers throughout the history of FCA, he was responsible for inventing and shaping many of the fundamental notions in this area. Indeed, the publication of his article "Restructuring Lattice Theory: An Approach Based on Hierarchies of Concepts" is seen by many as the starting point of FCA as an independent direction of research. He was head of the FCA research group in Darmstadt from 1983 until his retirement in 2003, and remained an active researcher and contributor thereafter. In 2003, he was among the founding members of the ICFCA conference series. In memory of Rudolf Wille's contribution to the foundations of FCA, and in the tradition of previous conference proceedings, this volume contains a historical paper from the early days of FCA (1986), namely "Implikationen und Abhängigkeiten zwischen Merkmalen" by Bernhard Ganter and Rudolf Wille, together with a translation by Daniel Borchmann and Juliane Prochaska, authorized by Bernhard Ganter.

For the proceedings of this year's ICFCA, out of 37 submitted papers, 13 where chosen to be published in this volume, resulting in an acceptance rate of around 35%. Additionally, four papers were judged mature enough to be discussed at the conference and are included in a supplementary volume titled "Contributions to ICFCA 2017," published by the University of Rennes 1.

In addition to the regular contributions, this volume also contains the abstracts of the four invited talks at ICFCA 2017 as well as an invited contribution titled "An Invitation to Knowledge Space Theory." In this article, the authors again want to draw attention to the close links between FCA and *knowledge space theory*, a successful theory from psychology on how to learn.

This proceedings volume would not have been possible without the valuable work of the authors, the members of the Program Committee, and the members of the Editorial Board. Many thanks also go to the external reviewers, who provided valuable feedback across the board. We also want to express our gratitude to the team of local organizers, who made sure that the conference ran smoothly and was a pleasant experience for all its participants. We also thank Springer for sponsoring the Best Young Research Award. Finally, we would like to thank the EasyChair team for providing their system to organize the conference.

June 2017

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Invited Talks

Analogy Between Concepts

Laurent Miclet[1], Nelly Barbot[2], and Henri Prade[3]

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Analogical reasoning exploits parallels between situations. It enables us to state analogies for explanation purposes, to draw plausible conclusions, or to create new devices by transposing old ones in new contexts. As such, reasoning by analogy plays an important role in human thinking, as it is widely acknowledged. For this reason, it has been studied for a long time, in philosophy, linguistics, cognitive psychology and artificial intelligence, under various approaches.

The classical view of analogy describes the parallel between two situations, which are described in terms of objects, properties of the objects, and relations linking the objects.

An analogical situation may be also expressed by *proportions*. In that respect, a key pattern is a statement of the form '*A* is to *B* as *C* is to *D*', as in the examples "a calf is to a bull as a foal is to a stallion", or "gills are to fishes as lungs to mammals".

In the first example, the four items *A, B, C, D* belong to *the same* category, and we speak of *analogical proportion*. In the second example, the four items belong to two *different* categories, here *A* and *C* are organs and *B* and *D* classes of animals. In this second type of analogical statement, we speak of *relational analogy* or *relational proportion*.

It is only recently that these proportions have been systematically studied in terms of mathematic properties and of applications in AI tasks. As important examples, an exhaustive study of the "logical" proportions (in propositional logic) has been produced by H. Prade and G. Richard; proportions between formal structures, including words over finite alphabets, have been studied by Y. Lepage, N. Stroppa and F. Yvon; the use of proportions for Pattern Recognition has been proved useful by S. Bayoud and L. Miclet. In this spirit, we present in this talk our results on proportions in lattices, with a focus on concept lattices.

Hence, the goal of this talk is

- to give a formalization of the analogical proportion between four elements of a general lattice,
- to see how it applies in Formal Concept Lattices,
- and to give operational definitions of an analogical proportion between formal concepts and of a relational proportion in a formal context.

More precisely, concerning lattices of formal concepts, we will describe how an analogical proportion can be defined between concepts and how such proportions are deeply related to subcontexts of a special structure, that we call *analogical complexes*.

We will also illustrate the fact that the set of these complexes is itself structured as a lattice. In that way, we will demonstrate how analogical proportions between concepts can be constructed from the formal context, without the construction of the whole lattice of concepts.

We will also give a acceptable definition of what can be a relational proportion in terms of formal concept analysis, and illustrate it with some linguistic examples.

The talk will be mainly illustrative. No purely formal results nor demonstrations will be given, but mainly examples and illustrations of new notions and of the running of algorithms. An exhaustive article, which is the base of this talk, is presently under review for a journal.

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Facilitating Exploration of Knowledge Graphs Through Flexible Queries and Knowledge Anchors

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Semantic web and information extraction technologies are enabling the creation of vast information and knowledge repositories, in the form of knowledge graphs comprising entities and the relationships between them. As the volume of such graph-structured data continues to grow, it has the potential to enable users' knowledge expansion in application areas such as web information retrieval, formal and informal learning, scientific research, health informatics, entertainment, and cultural heritage. However, users are unlikely to be familiar with the complex structures and vast content of such datasets and hence need to be assisted by tools that support interactive exploration and flexible querying.

Recent work has proposed techniques for automatic approximation and relaxation of users' queries over knowledge graphs, allowing query answers to be incrementally returned in order of their distance from the original form of the query. In this context, approximating a query means applying an edit operation to the query so that it can return possibly different answers, while relaxing a query means applying a relaxation operation to it so that it can return possibly more answers. Edit operations include insertion, deletion or substitution of a property label, while relaxation operations include replacing a class by a superclass, or a property by a superproperty.

The benefits of supporting such flexible query processing over knowledge graphs include: (i) correcting users' erroneous queries; (ii) finding additional relevant answers that the user may be unaware of; and (iii) generating new queries which may return unexpected results and bring new insights. However, although this kind of flexible querying can increase a user's understanding of the knowledge graph and underlying knowledge domain, it can return a large number of query results, all at the same distance away from the user's original query. Therefore, a key challenge is how to facilitate users' meaning making from flexible query results.

Meaning making is related to users' domain knowledge and their ability to make sense of the entities that they encounter during their interactions with the knowledge graph. Empirical studies have suggested that paths which start with familiar entities (knowledge anchors) and then add new, possibly unfamiliar, entities can be beneficial for making sense of complex knowledge graphs. Recent work has proposed an approach to identifying knowledge anchors that adopts the cognitive science concept of basic-level objects in a domain taxonomy, with the development of a formal framework for deriving a set of knowledge anchors from a knowledge graph.

In this talk we discuss how a combination of these two directions of work - namely, flexible querying of graph-structured data, and identification of knowledge anchors in a knowledge graph - can be used to support users in incrementally querying, exploring and learning from large, complex knowledge graphs. Our hybrid approach combines flexible graph querying and knowledge anchors by including in the query results paths to the nearest knowledge anchor. This makes more evident the relationships between the entities returned within the query results, and allows the user to explore increasingly larger fragments of the domain taxonomy.

Patterns, Sets of Patterns, and Pattern Compositions

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The goal of exploratory data analysis – or, data mining – is making sense of data. We develop theory and algorithms that help you understand your data better, with the lofty goal that this helps formulating (better) hypotheses. More in particular, our methods give detailed insight in how data is structured: characterising distributions in easily understandable terms, showing the most informative patterns, associations, correlations, etc.

Patterns, such as formal concepts, can give valuable insight in data. Mining all potentially interesting patterns is a useless excercise, however: the result is cumbersome, sensitive to noise, and highly redundant. Mining a small set of patterns, that together describes the data well, leads to much more useful results. Databases, however, typically consist of different parts, or, components. Each such component is best characterised by a different set of patterns. Young parents, for example, exhibit different buying behaviour than elderly couples. Both, however, buy bread and milk. A pattern composition models exactly this. It jointly characterises the similarities and differences between such components of a database, without redundancy or noise, by including only patterns that are descriptive for the data, and assigning those patterns only to the relevant components of the data. Knowing what a pattern composition is, this leads to the question, how can we discover these from data?

Semantic Web: Big Data, Some Knowledge and a Bit of Reasoning

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Linked Data provides access to huge, continuously growing amounts of open data and ontologies in RDF format that describe entities, links and properties on those entities. Equipping Linked Data with reasoning paves the way to make the Semantic Web a reality. In this presentation, I will describe a unifying framework for RDF ontologies and databases that we call deductive RDF triplestores. It consists in equipping RDF triplestores with inference rules. This rule language allows to capture in a uniform manner OWL constraints that are useful in practice, such as property transitivity or symmetry, but also domain-specific rules with practical relevance for users in many domains of interest. I will illustrate the expressivity of this framework for Semantic Web applications and its genericity for developing inference algorithms with good behaviour in data complexity. In particular, we will show how it allows to model the problem of data linkage as a reasoning problem on possibly decentralized data. We will also explain how it makes possible to efficiently extract expressive modules from Semantic Web ontologies and databases with formal guarantees, whilst effectively controlling their succinctness.

Experiments conducted on real-world datasets have demonstrated the feasibility of this approach and its usefulness in practice for data integration and information extraction.

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