

Preface

Formal Concept Analysis has been developed as a field of applied mathematics based on a mathematization of concept and concept hierarchy. It thereby allows us to mathematically represent, analyze and construct conceptual structures. That has been proven useful in a wide range of application areas such as medicine and psychology, sociology and linguistics, archaeology and anthropology, biology and chemistry, civil and electrical engineering, information and library sciences, information technology and software engineering, computer science and even mathematics itself.

More than 25 years of research have built up a rich mathematical theory and many application methods and procedures which are presented in more than 500 scientific publications. The basics of the mathematical theory were represented in the monograph “Formale Begriffsanalyse: Mathematische Grundlagen” (Springer 1996) and its English translation “Formal Concept Analysis: Mathematical Foundations” (Springer, 1999). Applications with the focus on conceptual knowledge processing are broadly discussed in the volumes “Begriffliche Wissensverarbeitung: Grundfragen und Aufgaben” (B.I.-Wissenschaftsverlag 1994) and “Begriffliche Wissensverarbeitung: Methoden und Anwendungen” (Springer, 2000). Applications of Formal Concept Analysis in text retrieval and mining were recently published by C. Carpineto and G. Romano in their book “Concept Data Analysis: Theory and Applications” (Wiley 2004). From the manifold developments of software for formal concept analysis applications we only mention the open source project ToscanaJ which is creating a large, flexible framework for conceptual knowledge processing and is documented in <http://www.tockit.org> and <http://sourceforge.net/project/toscanaj>.

A new field of research needs scientific communication and discourse which is stimulated best by scientific conferences. For the successful development of formal concept analysis such conferences have been above all the annual conferences of the German Classification Society in the 1980s and early 1990s, and since 1995 the International Conferences on Conceptual Structures (Springer LNAI 954, 1115, 1257, 1453, 1640, 1867, 2120, 2393, 2746, 3127). Since 2003, an International Conference on Formal Concept Analysis has been taking place every year: 2003 in Darmstadt, Germany, 2004 in Sydney, Australia (Springer LNAI 2961), 2005 Lens, France (Springer LNAI 3403) and 2006 in Dresden, Germany. Furthermore, in 2005, there will be already the 3rd International Workshop on Concept Lattices and Applications in the Czech Republic.

This volume is the outcome of a project inspired by the 1st International Conference on Formal Concept Analysis in Darmstadt. The idea was to use the expertise of the participating experts to elaborate a comprehensive presentation of the state of the art of formal concept analysis and its applications. Of course, it is clear that such a presentation could not completely cover all current developments in detail. Therefore the goal of this volume is rather to convey essential

information which gives readers an orientation and enough knowledge to use formal concept analysis for projects of interest. In any case, this volume should inspire further research and applications, even in directions completely different from the represented content.

The first part of this volume treats foundational themes of formal concept analysis. (1) R. Wille in his contribution shows the surprisingly rich correspondences between the multifarious aspects of concepts in the human mind and the structural properties and relationships of formal concepts in formal concept analysis. These correspondences make it understandable that – via formal concept analysis – mathematical thought may aggregate with other ways of thinking and thereby support human thought and action. (2) B. Vormbrock and R. Wille generalize in their paper from the Basic Theorem on Concept Lattices to basic theorems on algebras of semiconcepts and protoconcepts, extending the usefulness of the basic theorem on concept lattices to conceptual structures with negating operations. (3) T. Becker contributes with his paper to algebraic concept analysis by examining connections between formal concept analysis and algebraic geometry. He elaborates a theory of algebraically represented concept lattices based on notions such as algebraic varieties, coordinate algebras, and polynomial morphisms. (4) F. Dau and J. Klinger show in their contribution how formal concept analysis has been extended to “Contextual Logic,” a mathematization of the traditional philosophical logic with its doctrines of concepts, judgments, and conclusions. The basic idea of this extension is to mathematize concepts by formal concepts and judgments by concept graphs whose nodes and edges are formal concepts of suitable formal contexts. (5) B. Ganter extends in his paper the known attribute logic of formal contexts to a contextual attribute logic of many-valued attributes. This allows us, in particular, to generalize the well-known attribute exploration to an attribute exploration with background knowledge. (6) P. Burmeister and R. Holzer give a survey of what has been done so far in treating incomplete knowledge using methods of formal concept analysis. In particular, they compare different algorithms for attribute explorations based on incomplete knowledge. (7) K.E. Wolff reports on a temporal concept analysis which he develops as a temporal conceptual granularity theory for movements of general objects in abstract or “real” space and time such that the notions of states, transitions, and life tracks can be defined mathematically. Basic relations to theoretical physics, mathematical system theory, automata theory, and temporal logic are discussed.

The contributions of the second part demonstrate how formal concept analysis might be applied outside mathematics. (8) U. Priss discusses in her article linguistic applications of formal concept analysis: the identification and analysis of linguistic features, the support of the automated or semi-automated construction of lexical databases for corpora, and the representation and analysis of hierarchies and classifications in lexical databases. (9) C. Carpineto and G. Romano focus in their paper on the features of formal concept analysis used to build contextual information retrieval applications as well as on its most critical aspects. The development of a formal concept analysis procedure for mining

Web results, returned by a major search engine, is envisaged as the next big challenge. (10) L. Lakhali and G. Stumme give a survey on association rule mining based on formal concept analysis. Basic ideas of applying formal concept analysis are explained by using the notion of an “iceberg concept lattice” and the specific algorithm TITANIC. (11) S.O. Kuznetsov offers a retrospective survey of the application of Galois connections in data analysis elaborated at the All-Soviet (now All-Russia) Institute for Scientific and Technical Information since 1970. He shows the connections with formal concept analysis, in particular, for the JSM method of inductive plausible reasoning. (12) R. Wille explains in his contribution how conceptual knowledge processing (based on formal concept analysis) enables effects in economic practice. This explanation is guided by the key processes of organizational knowledge management: knowledge identification, knowledge acquisition, knowledge development, knowledge distribution and sharing, knowledge usage and knowledge preservation.

The third part is concerned with applications of formal concept analysis in software engineering, including also software development for formal concept analysis. (13) T. Tilley, R. Cole, P. Becker, and P. Eklund offer a survey on formal concept analysis support for software engineering activities. This survey is based on academic papers that report the application of formal concept analysis to software engineering. The papers are classified using a framework based on the activities defined in the ISO 12207 Software Engineering standard. (14) G. Snelting gives an overview that summarizes important papers on applications of concept lattices in software analysis. He presents three methods in some detail: methods to extract classes and modules, to re-factor class hierarchies, and to infer dynamic dominators and control flow regions from program traces. (15) W. Hesse and T. Tilley focus on the use of formal concept analysis during the early phase of software development, in particular in object-oriented modelling. As a typical application, the task of finding or deriving class candidates from a given use description is considered in more detail. (16) R. Godin and P. Valtchev present an overview of work on formal concept analysis-based class hierarchy design in object-oriented software development. In particular, they discuss how to derive a concept lattice from a given class hierarchy and from the class methods and associations; and how to then turn the lattice into an improved class hierarchy. (17) P. Becker and J. Hereth Correia explain in their paper the features of the TOSCANAJ tool suite and their use in implementing conceptual information systems. TOSCANAJ as an open source project (embedded into the larger Tockit project) is offered as a starting point for creating a common base for software development for formal concept analysis.

For the basics of formal concept analysis the reader is referred to the monograph “Formal Concept Analysis: Mathematical Foundations” (Springer, 1999). The elementary definitions of a formal context and its concept lattice up to the notions used in the Basic Theorem on Concept Lattices are also presented at the beginning of the second section of the first paper in this volume.

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