Formal Concept Analysis

Welcome and Organizational Issues

Robert Jäschke
Asmelash Teka Hadgu

FG Wissensbasierte Systeme/L3S Research Center
Leibniz Universität Hannover

Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

Welcome & Socializing

- courses?
- semesters?
- prior knowledge?
- *goals & expectations*

Welcome & Socializing: Prior Knowledge

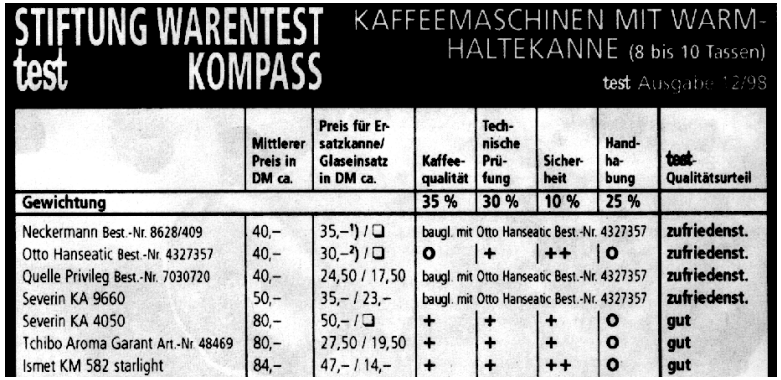
- Set
- Intersection
- Union
- Subset
- Superset
- Implication
- Partial Order
- Transitivity
- Lattice
- Isomorphism
- Apriori Algorithm

Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

History of Formal Concept Analysis

Formal Concept Analysis (FCA) originated in Darmstadt, Germany around 1980 as a mathematical theory that delivers a formalization of the concept of a "concept".



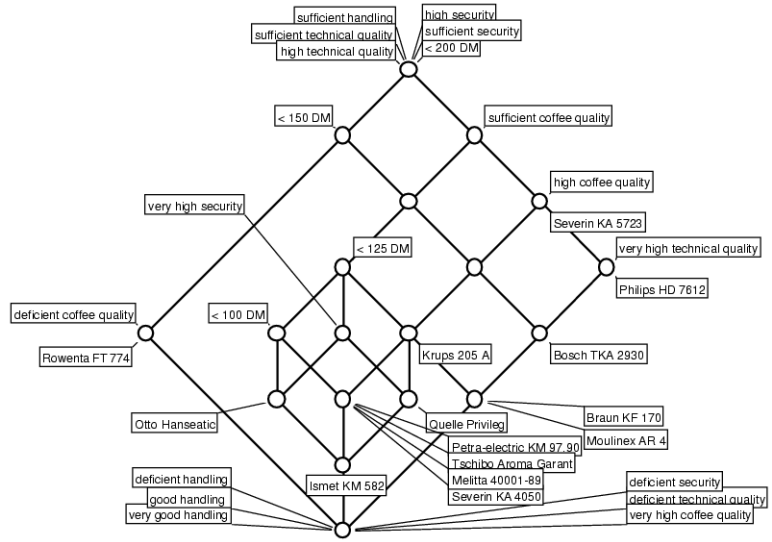
STIFTUNG WARENTEST test KOMPASS — KAFFEEMASCHINEN MIT WARMHALTEKANNE (8 bis 10 Tassen) — test Ausgabe 12/98

	Mittlerer Preis in DM ca.	Preis für Ersatzkanne/ Glaseinsatz in DM ca.	Kaffeequalität	Technische Prüfung	Sicherheit	Handhabung	test-Qualitätsurteil
Gewichtung			**35 %**	**30 %**	**10 %**	**25 %**	
Neckermann Best.-Nr. 8628/409	40,–	35,–¹) / ❑	baugl. mit Otto Hanseatic Best.-Nr. 4327357				**zufriedenst.**
Otto Hanseatic Best.-Nr. 4327357	40,–	30,–²) / ❑	o	+	++	o	**zufriedenst.**
Quelle Privileg Best.-Nr. 7030720	40,–	24,50 / 17,50	baugl. mit Otto Hanseatic Best.-Nr. 4327357				**zufriedenst.**
Severin KA 9660	50,–	35,– / 23,–	baugl. mit Otto Hanseatic Best.-Nr. 4327357				**zufriedenst.**
Severin KA 4050	80,–	50,– / ❑	+	+	+	o	**gut**
Tchibo Aroma Garant Art.-Nr. 48469	80,–	27,50 / 19,50	+	+	+	o	**gut**
Ismet KM 582 starlight	84,–	47,– / 14,–	+	+	++	o	**gut**

Since then, FCA spread into different areas of computer science, e.g.,

- data analysis
- knowledge discovery
- software engineering

Starting from datasets, FCA derives concept hierarchies. FCA allows you to create and visualize concept hierarchies based on well-grounded mathematical foundations.

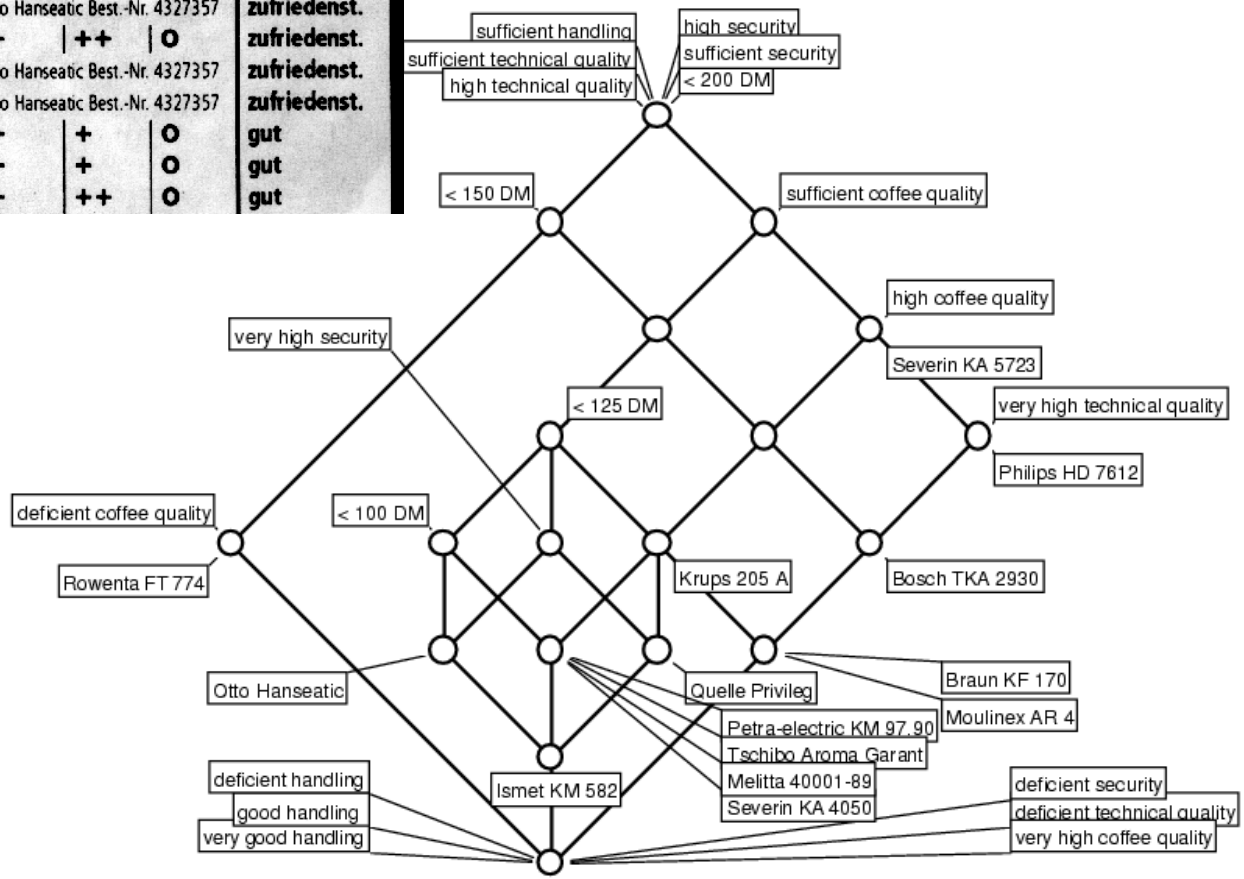


Example: Comparison of Coffee Machines

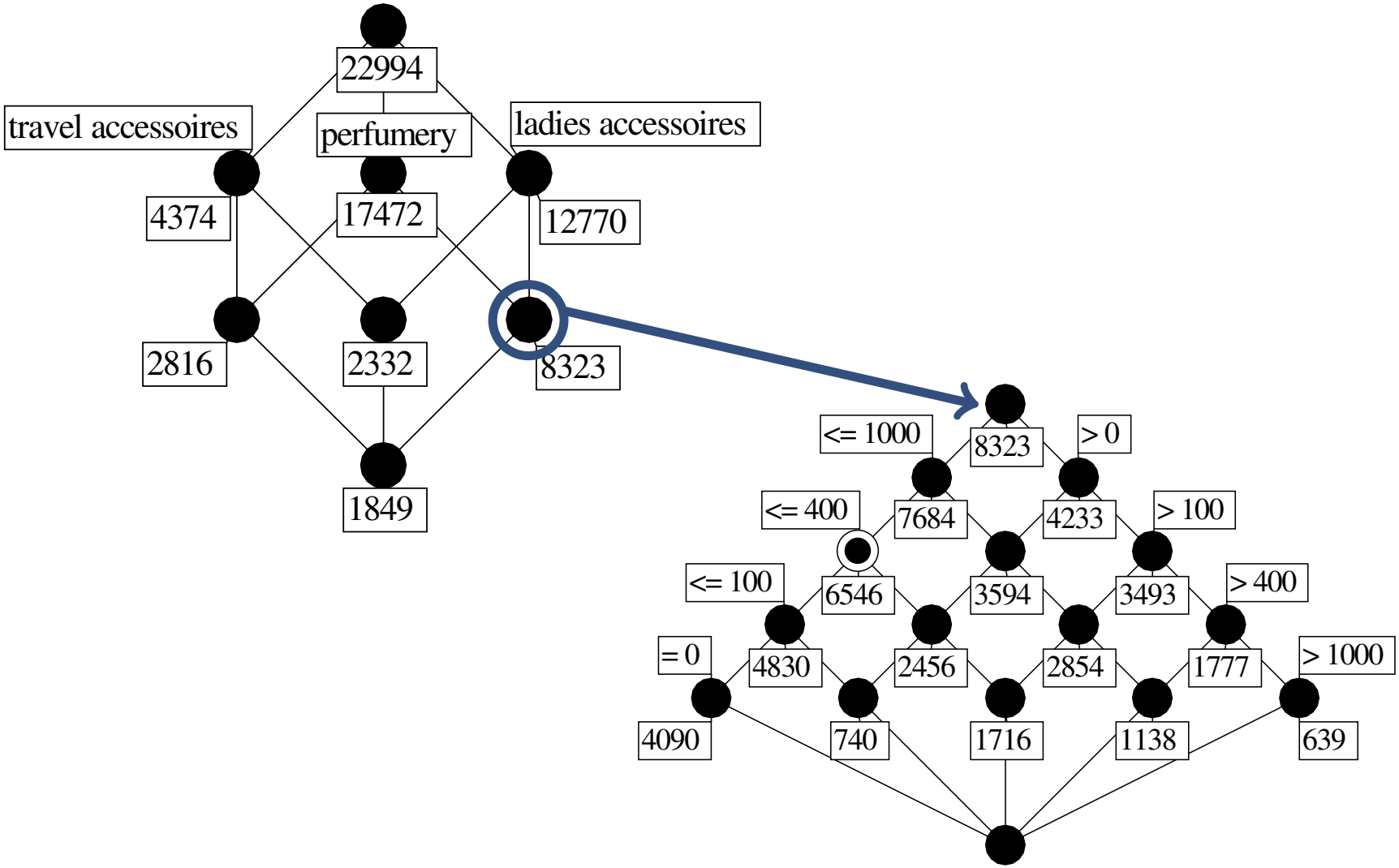
STIFTUNG WARENTEST test KOMPASS — KAFFEEMASCHINEN MIT WARMHALTEKANNE (8 bis 10 Tassen)

test Ausgabe 12/98

	Mittlerer Preis in DM ca.	Preis für Ersatzkanne/ Glaseinsatz in DM ca.	Kaffeequalität	Technische Prüfung	Sicherheit	Handhabung	test-Qualitätsurteil
Gewichtung			**35 %**	**30 %**	**10 %**	**25 %**	
Neckermann Best.-Nr. 8628/409	40,–	35,–[1]) / ❑	baugl. mit Otto Hanseatic Best.-Nr. 4327357				**zufriedenst.**
Otto Hanseatic Best.-Nr. 4327357	40,–	30,–[2]) / ❑	o	+	++	o	**zufriedenst.**
Quelle Privileg Best.-Nr. 7030720	40,–	24,50 / 17,50	baugl. mit Otto Hanseatic Best.-Nr. 4327357				**zufriedenst.**
Severin KA 9660	50,–	35,– / 23,–	baugl. mit Otto Hanseatic Best.-Nr. 4327357				**zufriedenst.**
Severin KA 4050	80,–	50,– / ❑	+	+	+	o	**gut**
Tchibo Aroma Garant Art.-Nr. 48469	80,–	27,50 / 19,50	+	+	+	o	**gut**
Ismet KM 582 starlight	84,–	47,– / 14,–	+	+	++	o	**gut**



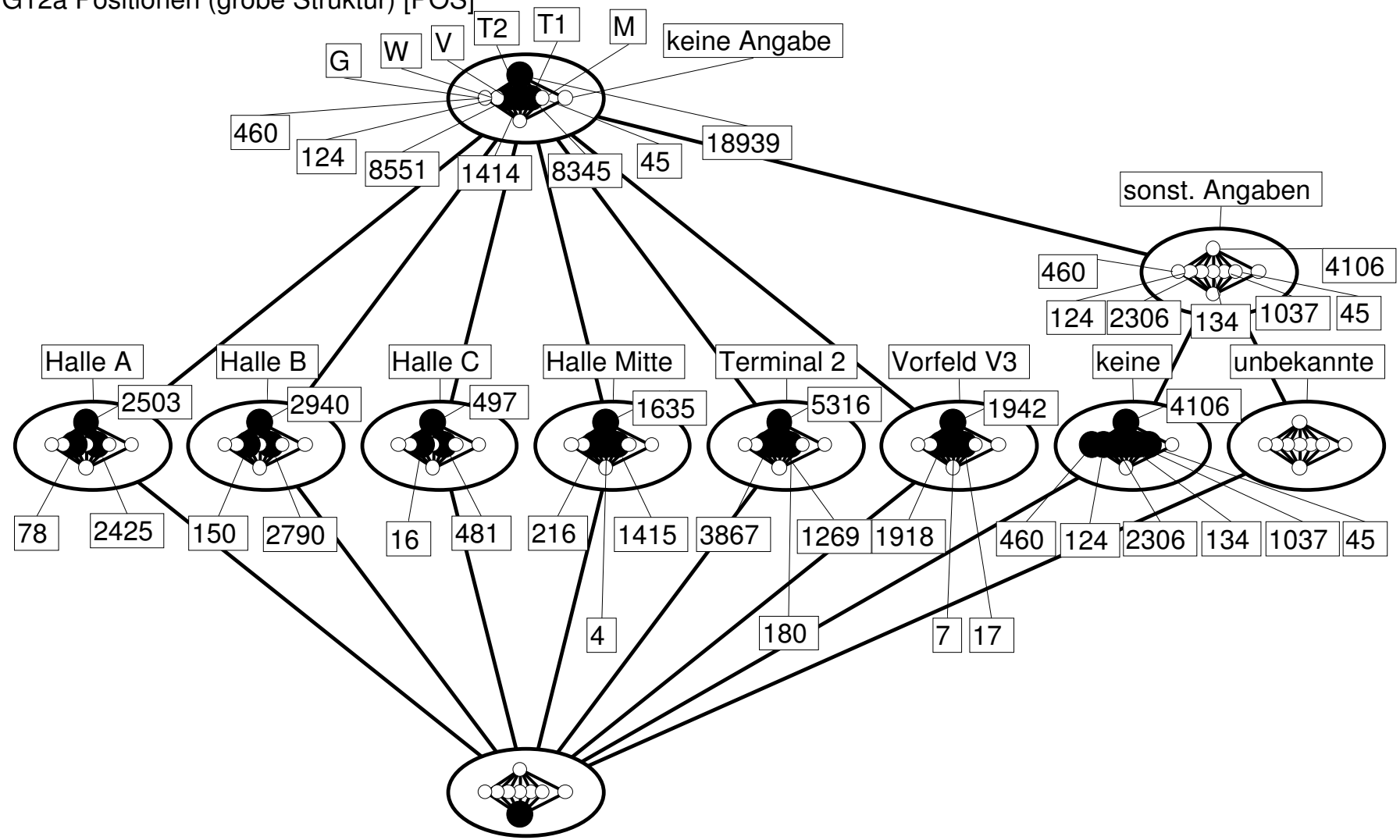
Database Marketing at Jelmoli AG, Zurich[1]



[1] J. Hereth, G. Stumme, R. Wille, and U. Wille. Conceptual knowledge discovery and data analysis. In *Proc. ICCS 2000*, volume 1867 of *LNCS*, pages 421–437. Springer, Berlin/Heidelberg, 2000.

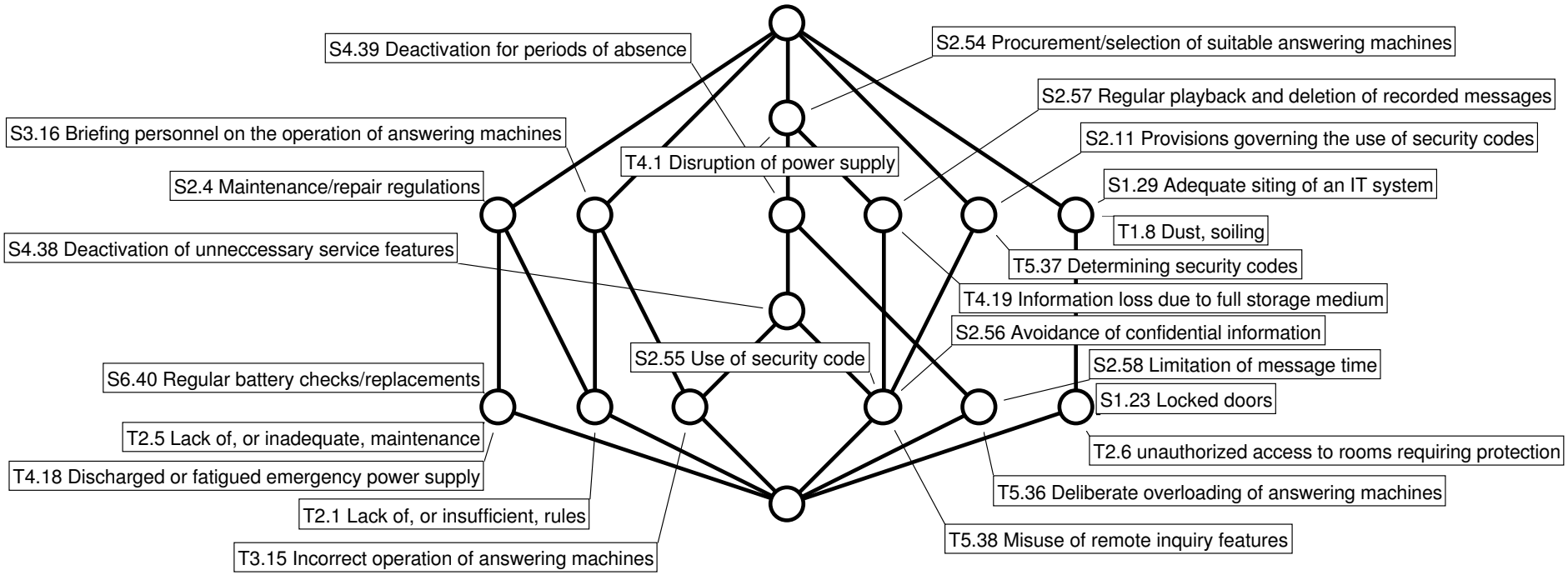
Analysis of Plane Movements at Frankfurt Airport[2]

O12 Ort der benötigten Staubahn [SBE]
G12a Positionen (grobe Struktur) [POS]



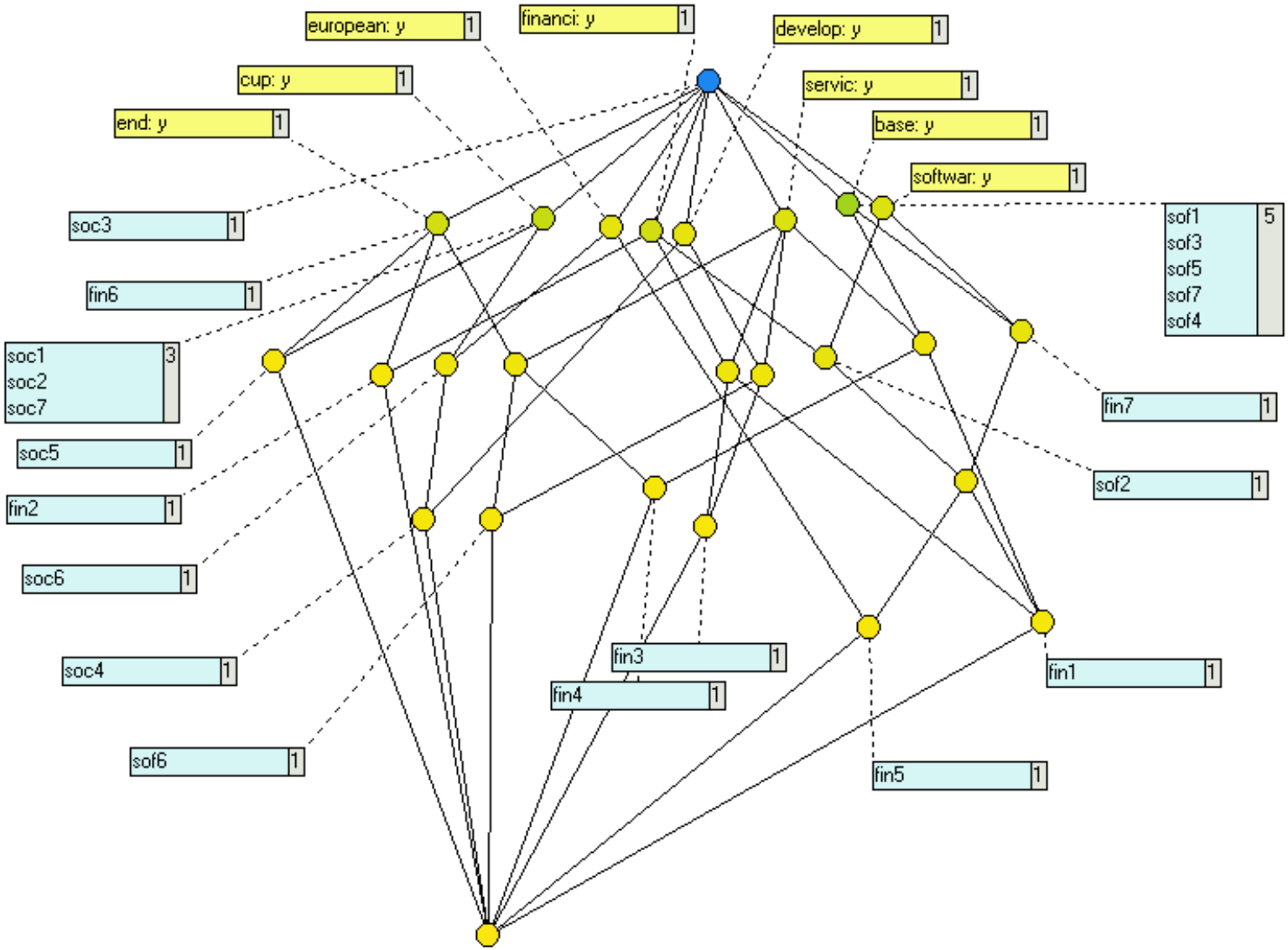
[2] G. Stumme, R. Wille, and U. Wille. Conceptual knowledge discovery in databases using formal concept analysis methods. In *Proc. PKDD*, volume 1510 of *LNCS*, pages 450–458. Springer, Berlin/Heidelberg, 1998.

IT Security Management[3]



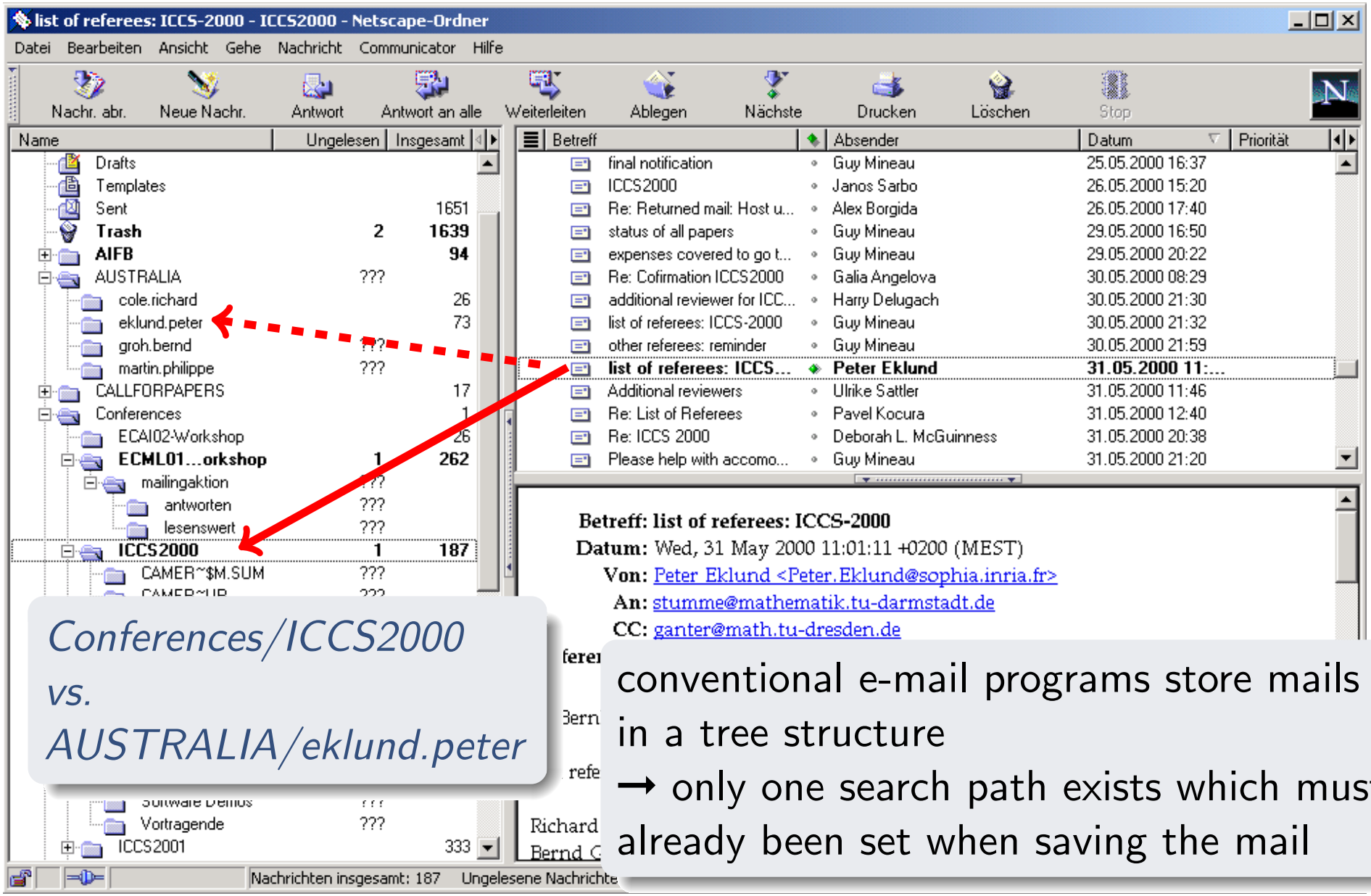
[3] K. Becker, G. Stumme, R. Wille, U. Wille, and M. Zickwolff. Conceptual information systems discussed through an it-security tool. In Rose Dieng and Olivier Corby, editors, *Knowledge Engineering and Knowledge Management Methods, Models, and Tools*, volume 1937 of *LNCS*, pages 352–365. Springer, Berlin/Heidelberg, 2000.

Text Clustering[4]



[4] A. Hotho, S. Staab, G. Stumme. Ontologies improve text document clustering. In *Proc. ICDM*, pages 541–544, 2003.

Concept Email Manager

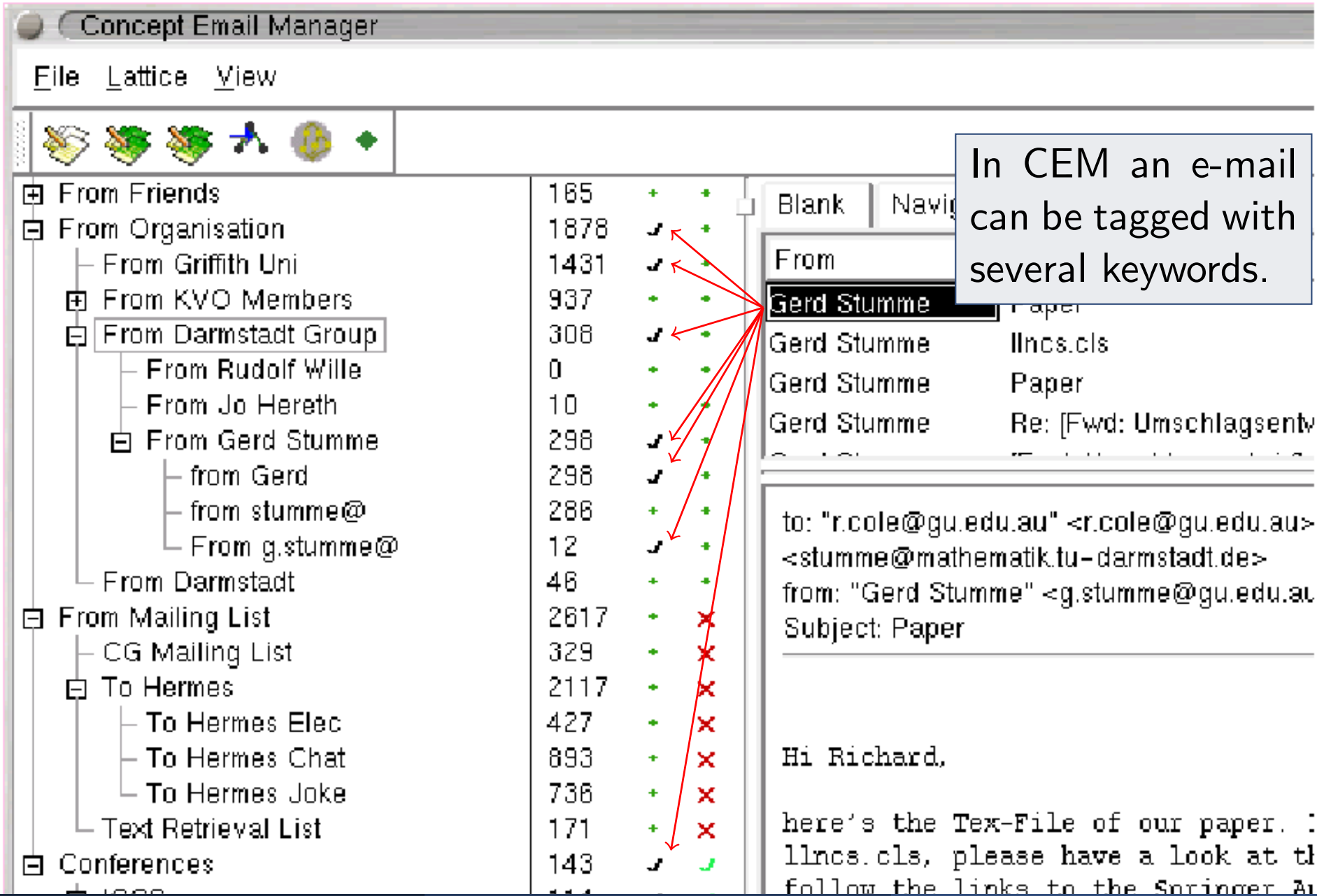


Conferences/ICCS2000 vs. AUSTRALIA/eklund.peter

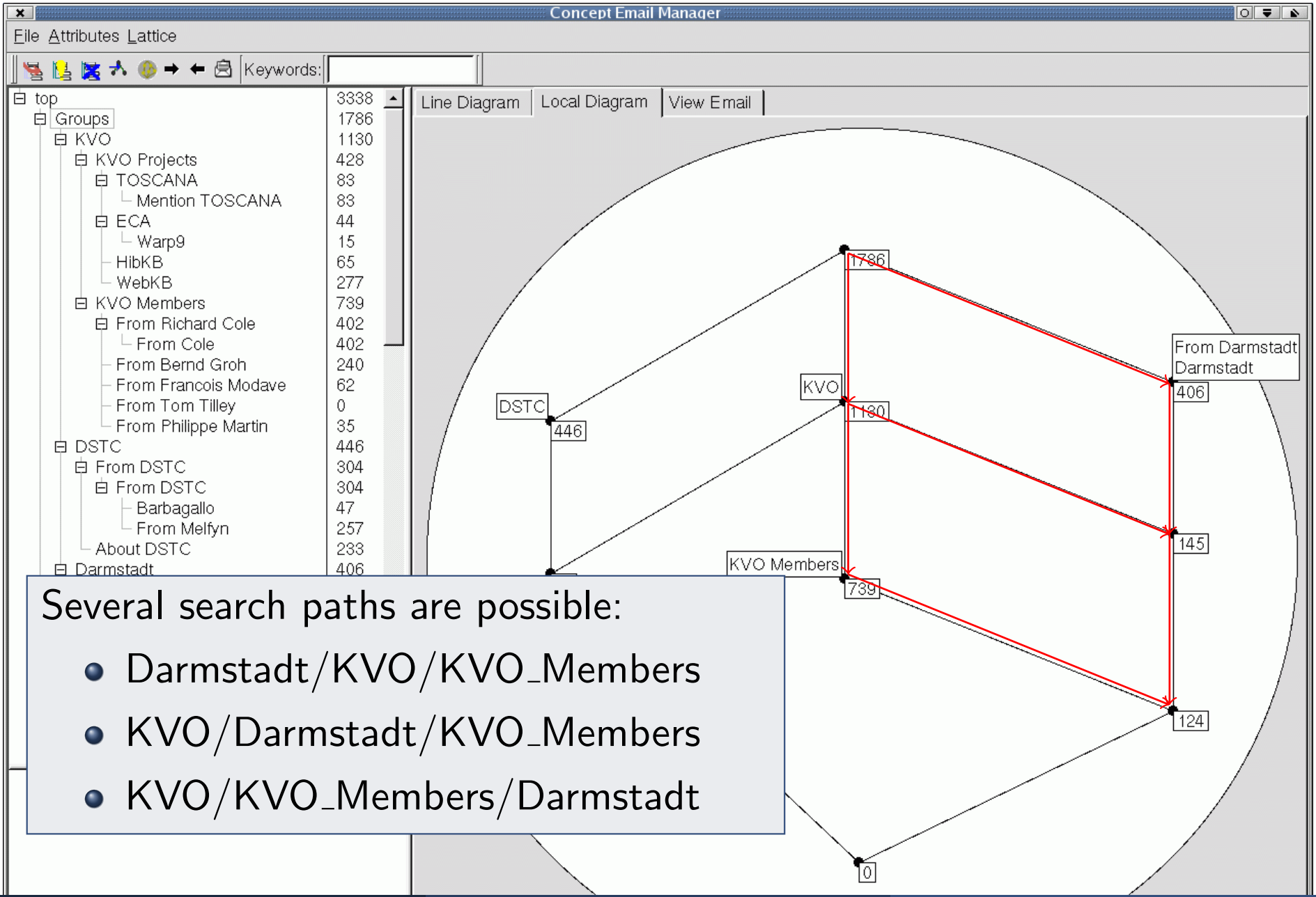
conventional e-mail programs store mails in a tree structure

→ only one search path exists which must already been set when saving the mail

Concept Email Manager



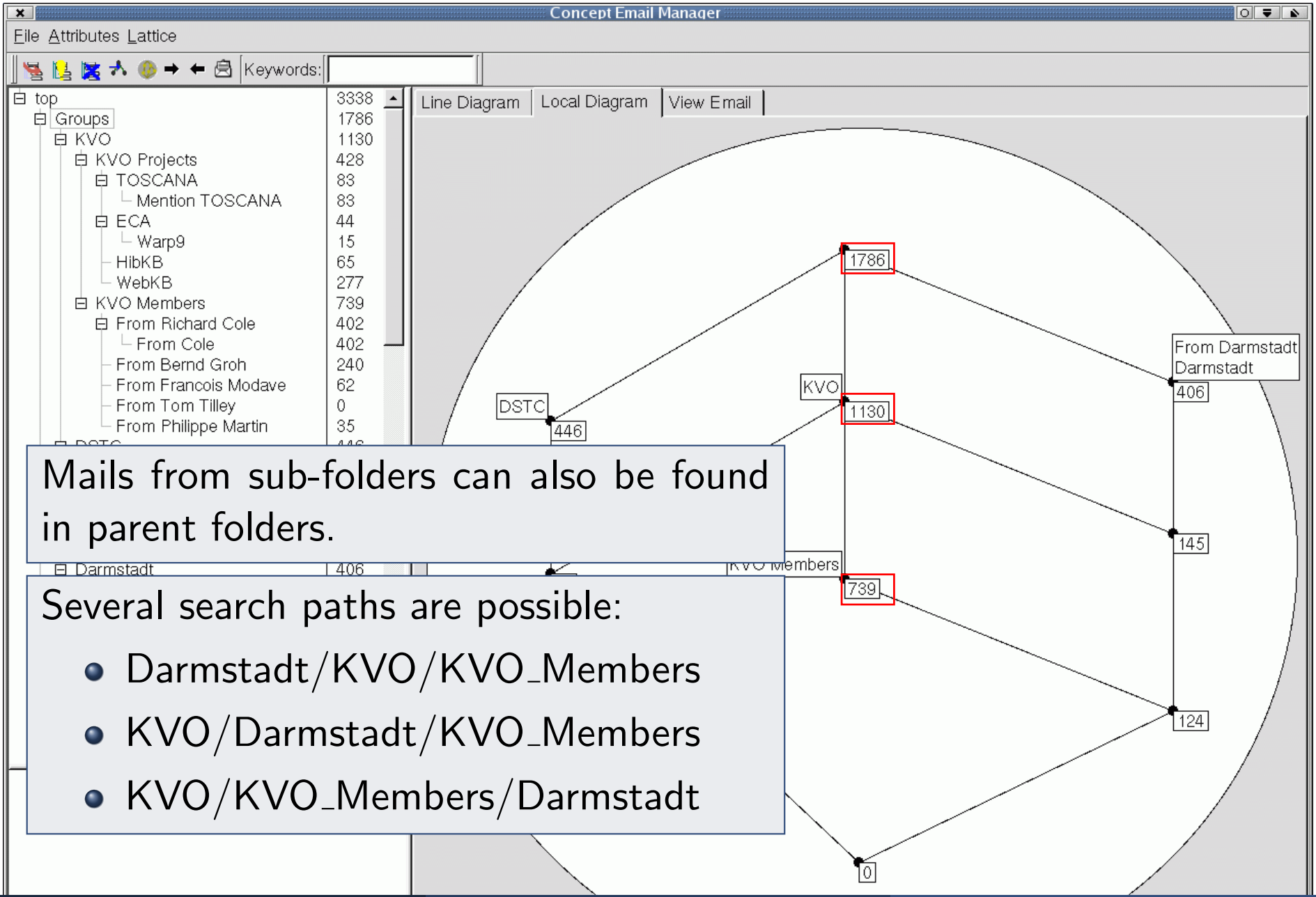
Concept Email Manager



Several search paths are possible:

- Darmstadt/KVO/KVO_Members
- KVO/Darmstadt/KVO_Members
- KVO/KVO_Members/Darmstadt

Concept Email Manager

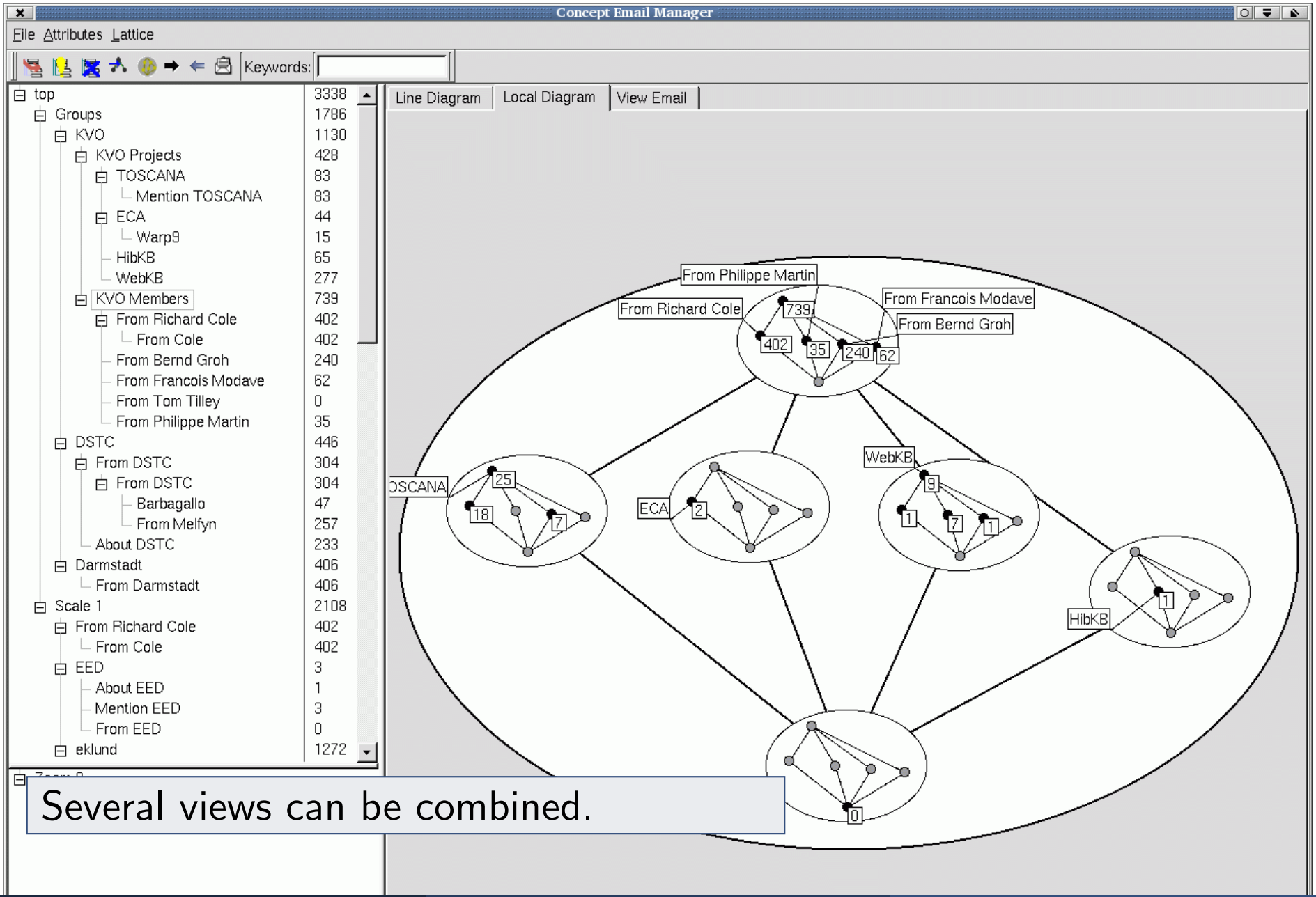


Mails from sub-folders can also be found in parent folders.

Several search paths are possible:

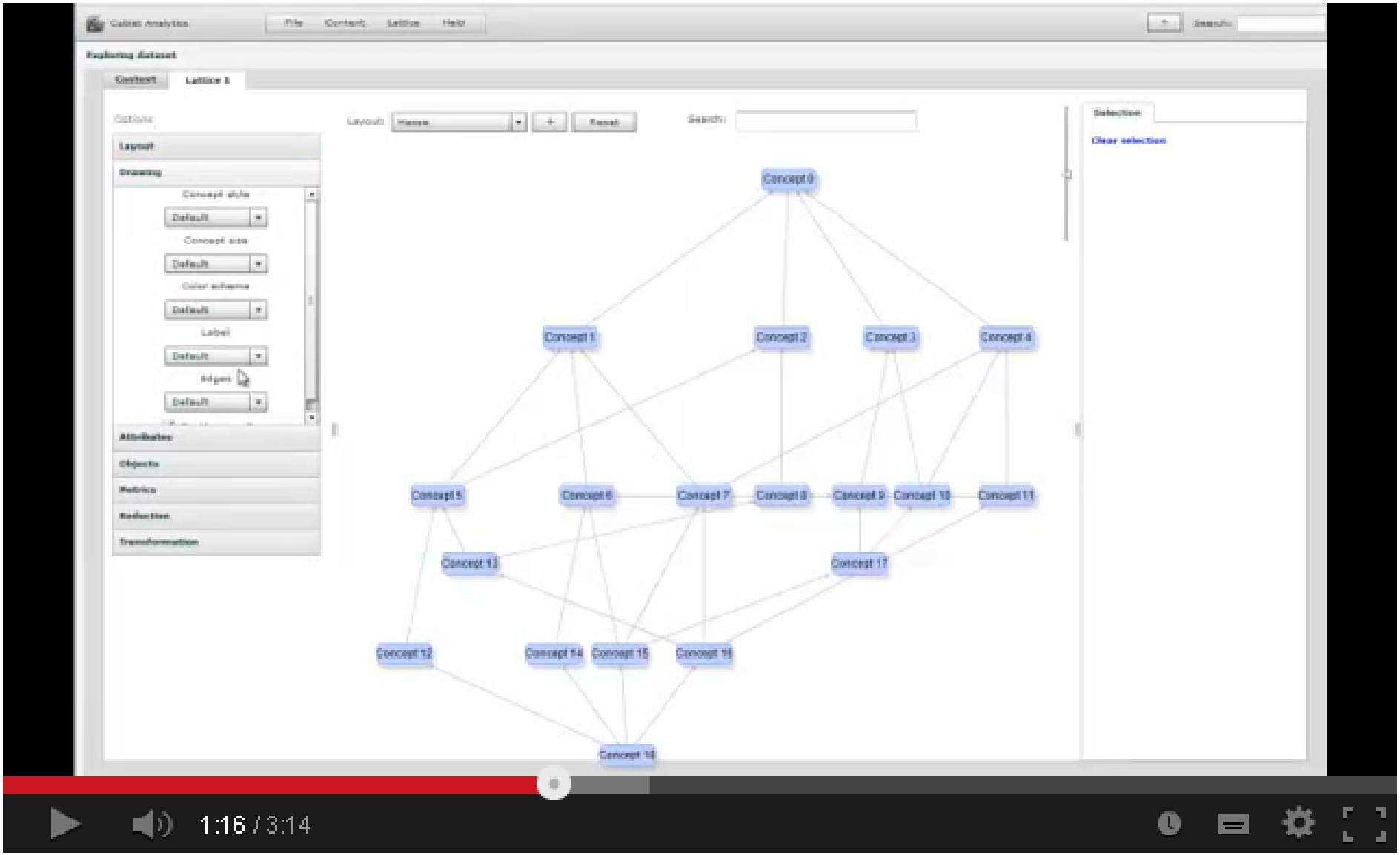
- Darmstadt/KVO/KVO_Members
- KVO/Darmstadt/KVO_Members
- KVO/KVO_Members/Darmstadt

Concept Email Manager



Several views can be combined.

CUBIST Visual Analytics



Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

Organization

Lectures and Exercises

lecture	Tuesday, 14:00 – 15:30, room 235
hands-on exercise	Tuesday, 10:00 – 11:30, room 235

Material

overview	`http://www2.kbs.uni-hannover.de/fca.html`
slides & exercises	`http://www.kbs.uni-hannover.de/~jaeschke/teaching/2015w/fca/`
Stud.IP	`https://elearning.uni-hannover.de/`

Contact

Robert Jäschke	jaeschke@l3s.de, room 203, afternoon or scheduled individually
Asmelash Teka Hadgu	asmelashtk@gmail.com, scheduled individually

Organization: Lectures

- we experiment with new forms of teaching, learning, and cooperation
- (occasionally) highly interactive lecture
- framework:
  - assuming responsibility
  - lecture is a process, participating actively
  - doing something on your own
- my goal is good teaching which (necessarily) is interactive

How did you understand this?

Organization: Exercises

hands-on exercise means

- *autonomous work* on the practice sheet in small teams of 3-4 students, under supervision
- *no general repetition* of lecture material
- *no general demonstration* of the solution (will be provided later)

necessary for that is

- making notes during the lecture
- performing autonomous follow-up course work *before* the exercise
- bringing the script and your notes to the exercise
- developing own activity

Organization: Exercises

Why this exercise concept?

- active development of the lecture material is more effective
- discovering relationships in the material
- learning structured thinking and autonomous working
- learning team work
- learning to explain things
- exercise for the exams ;-)
- *You have finished your study of . . . Your personal strengths include pro-activity and team work, you are communicative and willing to cooperate.* (typical job advertisement)

Organization: Exams

- oral exam at the end of the semester
- you can choose a topic to start with
- you are generating exam questions:
  - after every lecture each of you devises two questions
  - ask yourself *"Which question should I ask my fellow students to see if they really understood what today's lecture was about?"*
  - answer the two questions by yourself
  - write down the answer+question
  - at the beginning of the next lecture, one question+answer is presented and all other questions are collected
  - promise: we will take some of the questions for the exam

Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

Literature


Bernhard Ganter.
Diskrete Mathematik: Geordnete Mengen.
Spinger, Berlin/Heidelberg, 2013.


Bernhard Ganter and Rudolf Wille.
Formal Concept Analysis: Mathematical Foundations.
Springer, Berlin/Heidelberg, 1999.


Robert Jäschke, Andreas Hotho, Christoph Schmitz, Bernhard Ganter, and Gerd Stumme.
Discovering shared conceptualizations in folksonomies.
Web Semantics: Science, Services and Agents on the World Wide Web, 6(1):38–53, February 2008.


Gerd Stumme, Rafik Taouil, Yves Bastide, Nicolas Pasquier, and Lotfi Lakhal.
Computing iceberg concept lattices with TITANIC.
Data & Knowledge Engineering, 42(2):189–222, August 2002.

Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

Overview

Organization

I Contexts, Concepts, and Concept Lattices
1. Concept Lattices
2. Multi-valued Contexts and Conceptual Scales

II Closure Systems and Implications
3. Closure Systems
4. Implications

III Knowledge Discovery
5. Attribute Exploration
6. Rule Exploration
7. Attribute Exploration with Background Knowledge

IV Extensions of FCA
8. Triadic Formal Concept Analysis

Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

Homework

The next lecture

- will be highly interactive
- requires careful preparation by each one of you

Prepare for the next lecture

Read the following works about concepts and conceptual modelling

- `http://www.alleydog.com/glossary/definition.php?term=Concept`
- `http://general-psychology.weebly.com/how-are-concepts-formed.html`
- Walter Edelmann *Lernpsychologie*, 6. Auflage, 2000. Kapitel 4.2 (Seiten 116-130, insbesondere Kapitel 4.2.1 zu "Eigenschaftsbegriffen" und "klassischer Theorie")

Identify the most important and common ideas and concepts and write them down. You need them in the next lecture, where we will try to mathematically formalize the concept of "concept".

Agenda

1. Welcome & Socializing
2. Applications of FCA
3. Organization
4. Literature
5. Overview
6. Homework
7. Mathematical Basics

Mathematical Basics: Ordered Sets

On the blackboard:

- definition of partial order
- definition of total order
- examples

Mathematical Basics: Infimum & Supremum

On the blackboard:

- lower bound, upper bound
- infimum (join, $\bigwedge$), supremum (meet, $\bigvee$)
- Def. (complete) lattice $(V, \leqslant)$
- $\mathbf{0}_V$, $\mathbf{1}_V$

Mathematical Basics: Vacuous Truth

Logic: a statement about elements of the empty set

Example

- $P :=$ all cell phones in the room are turned off
- $Q :=$ all cell phones in the room are turned on
- $P \wedge Q$

What if there are no cell phones in the room?

A statement $P \Rightarrow Q$ is *vacuously true*, if P is known to be false.

- $\forall g : P(g) \Rightarrow Q(g)$ is always true when $\forall g : \neg P(g)$
- $\forall g \in A : Q(a)$ is always true when . . . ?
- $\forall g \in A : (g, m) \in I$ is always true when . . . ?
- $\{m \in M \mid \forall g \in A : (g, m) \in I\}$ for $A = \varnothing$ is equal to . . . ?