

The ATHENA Project: Using Formal Concept Analysis to Facilitate the Actions of Responders in a Crisis Situation

ANDREWS, Simon, YATES, Simeon, AKHGAR, Babak and FORTUNE, David

Available from Sheffield Hallam University Research Archive (SHURA) at:

<http://shura.shu.ac.uk/8601/>

This document is the author deposited version. You are advised to consult the publisher's version if you wish to cite from it.

Published version

ANDREWS, Simon, YATES, Simeon, AKHGAR, Babak and FORTUNE, David (2013). The ATHENA Project: Using Formal Concept Analysis to Facilitate the Actions of Responders in a Crisis Situation. In: AKHGAR, Babak and YATES, Simeon, (eds.) Strategic Intelligence Management. Amsterdam, Elsevier: Butterworth-Heinemann, 167-180.

Repository use policy

Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Users may download and/or print one copy of any article(s) in SHURA to facilitate their private study or for non-commercial research. You may not engage in further distribution of the material or use it for any profit-making activities or any commercial gain.

The ATHENA Project: Using Formal Concept Analysis to facilitate the actions of responders in a crisis situation

S. Andrews, S. Yates, B. Akhgar, D. Fortune

Centre of Excellence in Terrorism, Resilience, Intelligence & Organised Crime Research (CENTRIC)
Sheffield Hallam University, UK

Abstract

The ATHENA project brings together major user communities with world leading experts in crisis management and experts and technology developers of mobile and social media use and development. The goal of the ATHENA project is to deliver outputs that will enable and encourage users of new media to contribute to the security of citizens in crisis situations and for search and rescue actions. ATHENA is a system of software tools to enhance the ability of LEAs, police, first responders and citizens in their use of mobile and smart devices in crisis situations. An emerging semantic technology called Formal Concept Analysis will be used to capture meaning and key facts from the large amount of communication data created during a crisis.

Introduction

In recent years, a series of security events have occurred across the globe which serve to demonstrate the broad spectrum of crisis situations in which today's ordinary citizens are effectively utilizing their mobile communication devices. The prolific use of mobile communication devices and so-called smart phones during public disorder, terrorist attacks, extreme weather events, and public health scares are providing new challenges and opportunities for first responders responsible for securing public safety (1) (2). Hence, according to Edwards (3):

"Government, its agencies and emergency services should leverage the potential of social media for disaster management and emergency planning. Social media is important for building resilience due to its reach, usability, accessibility, and quick response time. It also opens channels of communication and allows individuals and communities to share and cooperate with one another outside the framework of traditional institutions and organisations."

Thus the goal of the ATHENA project is to enable and encourage users of new media to contribute to the security of citizens in crisis situations and for search and rescue actions. ATHENA will deliver a suite of software tools to enhance the ability of Law Enforcement Agencies (LEAs), police, first responders and citizens in their use of new media in crisis situations. This project will explore how the huge popularity of new communication media, particularly web-based social media such as Twitter and Facebook, and the prolific use of high-tech mobile devices, can be harnessed to provide

efficient and effective communication and enhanced situational awareness during a crisis. The project aims to produce guidelines for enabling and encouraging the users of social media and hi-tech mobile devices to contribute to the security of citizens in crisis situations as well as other contingencies demanding search and rescue activities.

By making use of high-tech mobile devices and social media for sourcing information, the project will develop the means of obtaining and delivering crisis information efficiently and effectively to and from crisis stakeholders: The emergency services command and control, emergency services first responders and the public as pre-first responders.

The ATHENA Vision

The public are under-utilized crisis responders; they are often first on the scene, vastly outnumber the emergency first responders and are creative and resourceful. In a crisis, the public self-organise into voluntary groups, adapt quickly to changing circumstances, emerge as leaders and experts and perform countless life-saving actions; and they are increasingly reliant upon the use of new communications media to do it. ATHENA will help them by joining their conversations and adding an enabling voice. ATHENA will give them the information they ask for, in a way they can understand. ATHENA will assist them in targeting their actions, by directing them to the places they need to be and away from danger. ATHENA will identify emergent behaviour that is beneficial and provide support with agency resources to develop that behaviour. The public have an extraordinary ability to adapt in a crisis, because it can mean the difference between life and death. ATHENA will help the public help themselves by empowering them with their own collective intelligence and the means by which they can exploit that intelligence. ATHENA will provide the emergency services with new real-time intelligence from crowd-sourced information, greatly assisting in their decision-making processes and making search and rescue more efficient. ATHENA will create a fundamental and permanent shift in the way crisis situations are managed; helping the public as victim to turn into the public as part of the crisis team. ATHENA will utilise social media and smart mobile devices as part of a shared and interoperable two-way communication platform. By developing an orchestrated cycle of data, information and knowledge, ATHENA will empower both the public and emergency services with the intelligence they need in dealing with a crisis.

Architecture Narrative

ATHENA System Overview

The ATHENA system is a crisis communication and management system that encourages and enables the public to participate, in an ethical way, in the process of emergency communication to contribute to the security of the citizen in crisis situations and for search and rescue actions. ATHENA makes use of new social media and high tech mobile devices to efficiently and effectively acquire, analyse and disseminate crisis information and intelligence that is appropriate and useful to LEAs/police/first responders and the public.

In the event of a crisis, such as a terrorist attack, extreme weather event or disease outbreak, the public will be encouraged to use an ATHENA Crisis Mobile "app" to report on crisis events and activities and to participate with crisis-related activities in the social media. These reports and social media activity will feed into a Command and Control Centre via an information processing centre. In

the information processing centre, feeds from the Crisis Mobile "app" and information scanned from social media will be analysed and aggregated in various ways to provide relevant, real-time, information to LEAs in Command and Control. In particular, an ATHENA crisis map will be created and populated from the information processing centre to visualise in real time such things as danger zones, safe routes, crisis events and activities, LEA resources and distress signals. Via the ATHENA Crisis Mobile "app" the public will be able to access the crisis map and important crisis information provided by Command and Control. The "app" will also provide the public with a means of requesting help in an emergency situation, even when the normal routes of communication have failed.

ATHENA Components

Figure 1 gives a snapshot view of the system. The system consists of six main components (some with sub-components) as follows:

1. Crisis Mobile
 - a. Sending tools
 - b. Receiving tools
2. Crisis Information Processing Centre
 - a. Acquisition and Pre-processing tools
 - b. Aggregation and Analysis tools
3. Crisis Command and Control Intelligence Dashboard
 - a. Crisis Map
 - b. Mobile Communications Centre
 - c. Social Media Content Management tool
 - d. Crisis Summary and Query tools
4. Social Media
5. Interoperability
 - a. Crisis Management Language
 - b. Decentralised Intelligence Processing Framework
6. ATHENA Cloud Secure Information Centre

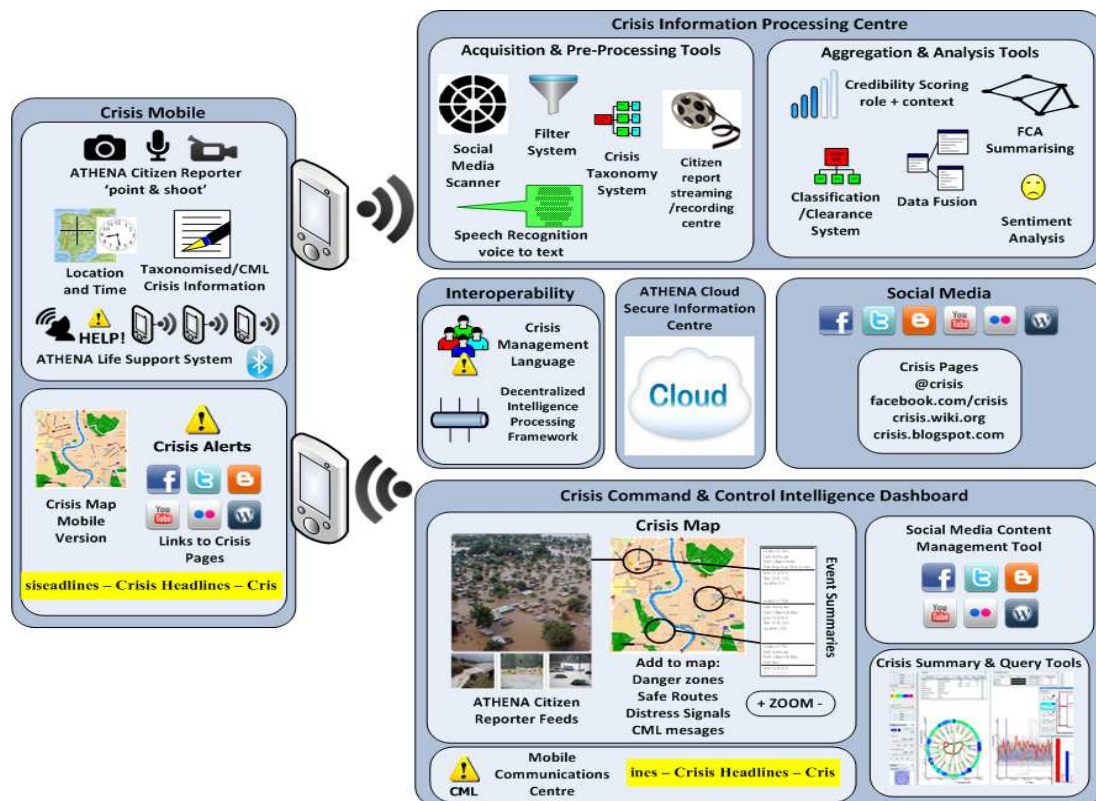


FIGURE 1: SNAPSHOT VIEW OF ATHENA

The following narrative describes the proposed operation of each of the components/sub-components in terms of the tools/systems they comprise.

1. Crisis Mobile. This is an application/web service for crisis pre-first responders comprising of a number of information sending tools and information receiving tools/systems.

a. Sending tools.

ATHENA Citizen Reporter ‘point & shoot’ system: A 'super simple' button interface to stream live photos or video as well as sound from a suitably equipped mobile device to the *Citizen report streaming/recording centre* of the ATHENA Crisis Information Processing Centre (CIPC). GPS and temporal information will be included in the data stream.

Location and Time: If permitted by the user, this will send GPS and temporal information with any information/messages sent to either the CIPC *Filter System* or the *Command and Control Centre Intelligence Dashboard (CCCID) Mobile Communications Centre*.

Taxonomised/CML Crisis Information tool: This is a text-based message sending interface, combined with a crisis taxonomy and/or Crisis Management Language (CML) selection/menu system for the user to compose and send crisis information/event report/requests for help/offers of help to the CIPC *Filter System* and/or the *Command and Control Centre Intelligence Dashboard (CCCID) Mobile Communications Centre*. The destination of the information will depend on the options chosen by the user and the protocols of the Decentralised Intelligence Processing Framework (DIPF).



The ‘ATHENA Life Support System’: Provides a new means of communication that enables emergency messaging when land lines and cell communications are disabled. If land lines or emergency numbers are disabled (e.g., overloaded), the cell/internet enabled communications will still allow geo-located, time stamped, requests for help to be sent to the *CCCID Mobile Communications Centre*. If the internet and cell systems are also disabled a mesh-connected communication system, using phone-to-phone Bluetooth and/or infrared transmission, will route a geo-located, time-stamped, distress signal to the *CCCID Mobile Communications Centre*.

b. Receiving Tools

Crisis Map (Mobile Version): This is a simplified mobile version of the crowd-sourced ATHENA crisis map (the full version is part of the CCCID). Crowd-sourced crisis information, combined with geo-spatial and temporal information, is used display event reports, automated summaries, danger zones, safe routes, and ATHENA Citizen Reporter feeds. A symbology will depict the level of a report’s credibility, cries for help, offers of



help, severity of event, type of event, type of report, etc., or aggregated versions where appropriate. A zoom facility in the interface will allow drill down to specific reports/areas when information has been aggregated in the display. The information available will depend on the ethics protocols, the clearance level of the user (generally the public will have a default 'public' level of clearance) and the protocols of the DIPP.

Crisis Alerts: An automated text message receiving system that will alert the user with targeted (by user/location/area) CML messages/warnings/instructions from the *CCCID Mobile Communications Centre*.

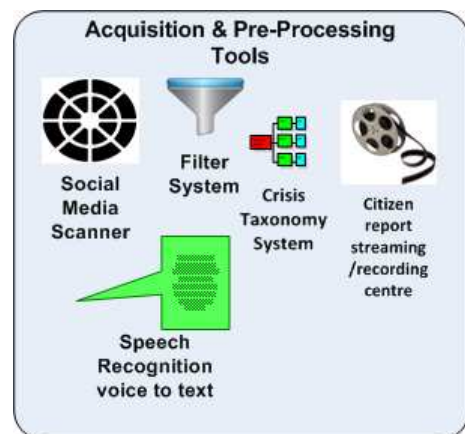
Crisis Headlines Display: A continuous moving-banner display of current crisis news and crisis progress information from the *CCCID Mobile Communications Centre*.

Links to Crisis Pages in the Social Media: A set of one-button links to the dedicated LEA/police/first responder social media crisis pages; Crisis Facebook page, YouTube channel, Crisis Wiki, follow Crisis on Twitter, Crisis Blog etc. Users will be encouraged to join the conversations and provide information.

2. Crisis Information Processing Centre (CIPC). This is a collection of information acquisition, pre-processing, aggregation and analysis tools. All crisis information is stored in the *ATHENA Cloud Secure Information Centre*.

a. Information Acquisition and Pre-processing tools.

Social Media Scanner: A powerful, real-time social media scanning/crawling system that uses the ATHENA crisis taxonomies and ATHENA crisis hash-tag syntax to detect and collect crisis information sources from the general social media. Citizen contributions are also collected by the scanner from the dedicated LEA/police/first responder social media crisis pages; Crisis Facebook page, Crisis Wiki, retweets of Crisis on Twitter, etc. Photographs, video and sound recordings are collected along with text-based sources. The acquired information sources are fed into the *CIPC Filter System* to remove irrelevant/unwanted sources.



Citizen Report Streaming/Recording Centre: This system will receive the streamed photo/video/sound output of *ATHENA Citizen Reporter Systems* of mobile devices and either stream them onwards as available feeds to the *Crisis Map: ATHENA Citizen Reporter System* or record them for pre-processing if band-width is not available for streaming.

Speech Recognition System: This tool will convert into text; streamed voice recordings from the *ATHENA Citizen Reporter System* and voice recordings from scanned social media sources. The text information is then fed into the *CIPC Filter System* to remove irrelevant/unwanted sources. The system will support multi-lingual conversion. The proposed demonstration will be dual-language; English and German.

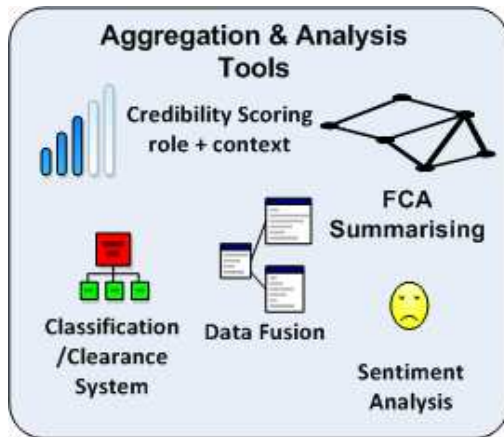
Filter System: Acquired information sources will be parsed by the filter system using sophisticated NLP (in the case of text) and image recognition software (in the case of photo/video) to remove irrelevant/unwanted material before information is stored in the *ATHENA Cloud*.

Crisis Taxonomy System: A set of dynamic/tailorable crisis taxonomies and Twitter hash-tag syntax with a separate interface for population, management etc. The crisis taxonomy system is used

extensively in the acquisition and recognition of crisis information and messages, and is also used by the *Aggregation & Analysis Tools* of the CIPC.

b. Aggregation & Analysis Tools

In all cases below, results of aggregation and results of analysis are stored in the *ATHENA Cloud* and may be available to the *Crisis Map System* if geo-located and/or the *CCCID Crisis Summary & Query Tools* in accordance with clearance, the ethics protocols and the protocols of the DIPF.



Classification/Clearance System: This system will use the crisis taxonomies/Twitter hash-tag syntax/CML, and other NLP and recognition techniques to classify information in terms of its type (e.g., offer of help, request for help, event information) and the clearance level required to use/obtain/process the information as determined by the DIPF.

FCA Summarising System: This system will use Formal Concept Analysis to aggregate and summarise textual crisis information sources when they contain similar information. This will cope with large volumes of

information to assist in giving a clear view of the crisis.

Data Fusion System: Outputs of the various classifiers of different types, text mining and clustering processes will be fused in order to identify and supply combined intelligence of critical situations by using a modular inference engine, supporting combination of weakly coupled distributed fusion processes to determine aspects of the crisis such as levels of danger, crisis timeline and progress, status of resources/hospitals, emerging volunteer groups and their actions etc.

Credibility Scoring System: This combines a role and context based systems of reliability assessment to produce credibility scores. Information from users with recognised roles will be scored according to role (e.g. no known role, trusted pre-first responder, social media 'brand leader' etc). Information will be context scored using NLP content assessment (e.g. writing age, sexual/profanity content) and sentiment-type analysis to gauge the user's intent and background. Thus a combined credibility score can be calculated to weight the merit of the information and determine its future use in accordance with the DIPF.

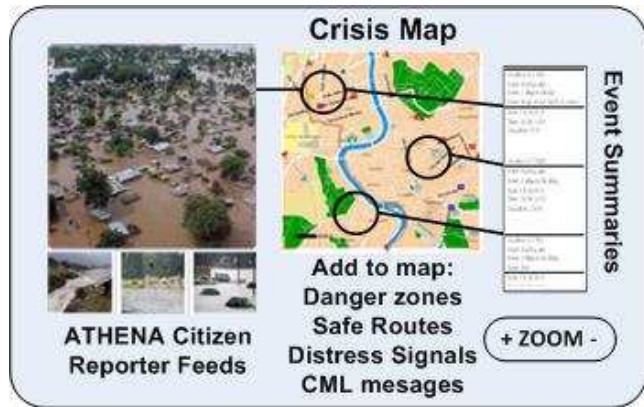
Sentiment Analysis Tool: This NLP/text mining analysis tool, based on the development of crisis-sentiment taxonomies, will be used to determine public opinion and emotion regarding the progress of the crisis, the perceived likely outcomes of the crisis/crisis events, the performance of the LEAs/police/first responders and feelings concerning fellow citizens in the crisis situation and their actions.

3. Crisis Command & Control Intelligence Dashboard (CCCID). This represents the main interface for the LEAs/police/first responders to the ATHENA system. It is assumed that the CCCID is an addition to, not a replacement of, current information systems. The sub-components are as follows:

a. Crisis Map (CCCID version)

This is a full PC-based version of the crowd-sourced ATHENA crisis map. The key difference will be in the size and configuration of the displays – particularly the ability to have *Citizen Reporter Feeds*, event summary information and the crisis map side-by-side.

Crowd-sourced crisis information, combined with geo-spatial and temporal information, is used to display event reports, automated summaries, danger zones, safe routes, and *ATHENA Citizen Reporter* feeds. A symbology will depict the level of a report's credibility, cries for help, offers of help, severity of event, type of event, type of report, etc., or aggregated versions where appropriate. A zoom facility in the interface will allow drill down to specific reports/areas when information has been aggregated in the display. The information available will depend on the ethics protocols, the clearance level of the user (generally the CCCID will have a default 'all information' level of clearance) and the protocols of the DIPF.



b. Mobile Communications Centre.

CML Messaging Tool: This is an interface for sending a receiving CML messages, communicating with other LEAs/police/first responders and with citizens who are using *Crisis Mobile*. CML requests for help and distress signals from the *ATHENA Life Support System* are received and alerted here.



Crisis Headlines Tool: This is a tool for populating and managing the *Crisis Headlines Display*.

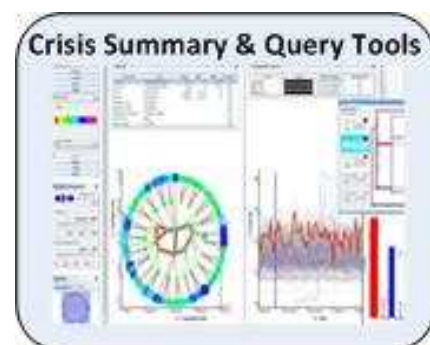
c. Social Media Content Management Tool.



This is a set of social media templates, web-interfaces and links to social media sites for the creation, population, management and maintenance of dedicated LEA/police/first responder social media pages, such as a Crisis Facebook page, YouTube crisis channel, Crisis Wiki, Twitter profile, Crisis Blog etc.

d. Crisis Summary & Query Tools.

This is a set of visual analytics tools for accessing the *ATHENA Cloud* and displaying crisis information such as casualty statistics, first responder resources, communications details, crisis progress and timeline information, sentiment analysis results etc. The tools will have corresponding query functionality for further, focussed, situation analysis and drill down. All crisis information that is used for annotating the crisis map is also available here in alternative views, e.g. summary/temporal/or other facets of interest. Non-geolocated information, not suitable for the crisis map, can also be accessed and included in analyses via these tools.



4. Social Media.

Although not strictly a component of the system, the social media, such as Facebook, Twitter, BlogSpot, Word press, Flickr, YouTube etc., are main sources of crisis information for the ATHENA system. The social media will also host a set of dedicated LEA/police/first responder social media pages, such as a Crisis Facebook page, YouTube crisis channel, Crisis Wiki, Twitter profile, Crisis Blog etc.

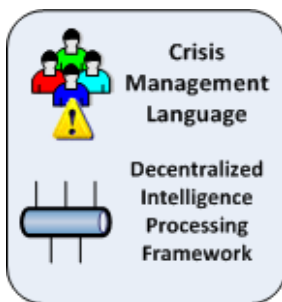


5. Interoperability.

The ATHENA system has heterogeneous and distributed tools, information and users. Interoperability is provided for these diverse human and technical elements via the Crisis Management Language and the Decentralised Intelligence Processing Framework.

a. Crisis Management Language (CML).

CML is a reduced, structured language for crisis management communications utilizing the underlying data models, ontologies and taxonomies of LEAs/police/first responders. CML will provide a means to communicate directives (assignments and requests) and reports in a formalized and unambiguous way with other LEAs/police/first responders and with the public via *Crisis Mobile*. In crisis operations, it can be assumed that each responder resource as well as the Command and Control Centre and the participating hospitals etc., and the public via Crisis Mobile are all part of a network. CML alerts and warnings can be directed to individual users, locations, areas etc. The connected systems should all contain a CML interface. The types of CML message and types of CML communication available to users will depend on their role, clearance level and the protocols of the DIPF.



b. Decentralised Intelligence Processing Framework (DIPF).

This is a framework supporting secure information flows and decentralized processing of data and intelligence. The framework will establish secure information/communication flows between providers of information and analysts, and between LEAs/police/first responders and the public in CML-based communication; channels are automatically established, such that the right information is delivered to the right analyst/process/user at the right moment in time; information sources and analysis resources are incorporated into distributed analysis processes on the fly, as they become available and on an as needed basis. This framework will be adapted to the operation in the *ATHENA Cloud Secure Information Centre*. The DIPF will control of the access to different information sources, provide an effective protection of the confidentiality and integrity of information over its whole lifetime, combining users and automated processing units from different roles and clearance levels and data with different classifications.

6. ATHENA Cloud Secure Information Centre.

Athena services will be made available in the *ATHENA Cloud Secure Information Centre*. This will be a robust environment in which the DIPF will be embedded. It will support robust operation by distributing (i) the CIPC aggregation and analysis processes and (ii) the secure information storage



including a knowledge repository for European LEAs. ATHENA will integrate with many existing cloud information channels through an extensible, flexible environment supporting diverse inputs and monitoring diverse channels. The environment will be configurable so that it will route specific types of information to a variety of community channels, some public, some protected and potentially some encrypted, depending on the requirements of the a particular service or community channel as defined by the protocols of the DIPF. Based on community/ channel requirements criteria the framework will aggregate and filter the incoming streams so as to provide relevant information to the community or service. The ATHENA client services will be available on a range of fixed and mobile devices.

Formal Concept Analysis

At the heart of ATHENA is a new data analysis method based on Formal Concept Analysis (FCA) to categorise, process and deliver relevant key information to crisis stakeholders. The method is based on semantics – capturing the meaning of information as it develops during a crisis situation, facilitating credibility assessment of such information and computing associations between key crisis facts in the form of formal concepts. Related information on crisis events and actions can then be usefully presented to selected stakeholders in an appropriate manner.

FCA was introduced in the 1990s by Rudolf Wille and Bernhard Ganter (4), building on applied lattice and order theory developed by Birkhoff and others in the 1930s. It was initially developed as a subsection of Applied Mathematics based on the mathematisation of concepts and concepts hierarchy, where a concept is constituted by its *extension*, comprising of all objects which belong to the concept, and its *intension*, comprising of all attributes (properties, meanings) which apply to all objects of the extension (5). The set of objects and attributes, together with their relation to each other, form a *formal context*, which can be represented by a cross table (Figure 2)

Airlines	Latin America	Europe	Canada	Asia Pacific	Middle east	Africa	Mexico	Caribbean	USA
Air Canada	x	x	x	x	x		x	x	x
Air New Zealand		x		x					x
Nippon Airways		x		x					x
Ansett Australia				x					
Austrian Airlines		x	x	x	x	x			x

FIGURE 2: AIRLINES FORMAL CONTEXT

The cross-table above is a formal context representing destinations for five airlines. The elements on the left side are formal objects; the elements at the top are formal attributes. If an object has a specific property (formal attribute), it is indicated by placing a cross in the corresponding cell of the table. An empty cell indicates that the corresponding object does not have the corresponding attribute. In the Airlines context above, Air Canada flies to Latin America (since the corresponding cell contains a cross) but does not fly to Africa (since the corresponding cell is empty).

In mathematical terms, a formal context is defined as a triple $K := (G, M, I)$, with G being a set of objects, M a set of attributes and I a relation defined between G and M . The relation I is understood to be a subset of the cross product between the sets it relates, so $I \subseteq G \times M$. If an object g has an attribute m , then $g \in G$ relates to m by I , so we write $(g, m) \in I$, or gIm . For a subset of objects $A \subseteq G$, a derivation operator $'$ is defined to obtain the set of attributes, common to the objects in A , as follows:

$$A' = \{m \in M \mid \forall g \in A: gIm\}$$

Similarly, for a subset of attributes $B \subseteq M$, the derivation operator $'$ is defined to obtain the set of objects, common to the attributes in B , as follows:

$$B' = \{g \in G \mid \forall m \in B: gIm\}$$

Now, a pair (A, B) is a formal concept in a given formal context (G, M, I) only if $A \subseteq G$, $B \subseteq M$, $A' = B$ and $B' = A$. The set A is the extent of the concept and the set B is the intent of the concept. A formal concept is, therefore, a closed set of object/attribute relations, in that its extension contains all objects that have the attributes in its intension, and the intension contains all attributes shared by the objects in its extension. In the Airlines example, it can be seen from the cross-table that Air Canada and Austrian Airlines fly to both USA and Europe. However, this does not constitute a formal concept because both airlines also fly to Asia Pacific, Canada and the Middle East. Adding these destinations completes (closes) the formal concept:

$(\{Air\ Canada, Austrian\ Airlines\}, \{Europe, USA, Asia\ Pacific, Canada, Middle\ East\})$.

Another central notion of FCA is a duality called a 'Galois connection', which is often observed between items that relate to each other in a given domain, such as objects and attributes. A Galois connection implies that "if one makes the sets of one type larger, they correspond to smaller sets of the other type, and vice versa" (6). Using the formal concept above as an example, if Africa is added to the list of destinations, the set of airlines reduces to $\{Austrian\ Airlines\}$.

The Galois connections between the formal concepts of a formal context can be visualized in a concept lattice (Figure 3), which is an intuitive way of discovering hitherto undiscovered information in data and portraying the natural hierarchy of concepts that exist in a formal context.

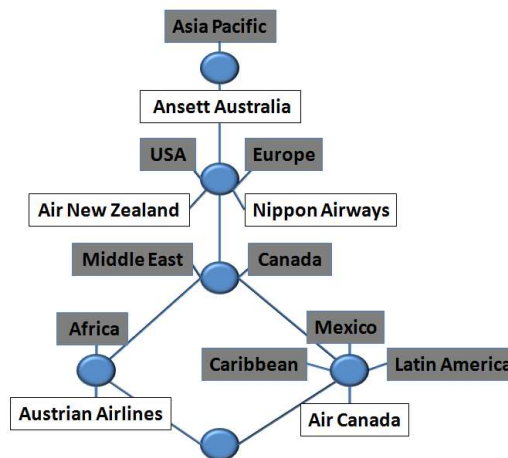


FIGURE 3: AIRLINES CONCEPT LATTICE

A concept lattice consists of the set of concepts of a formal context and the subconcept-superconcept relation between the concepts (6). The nodes in Figure 3 represent formal concepts. Formal objects are noted slightly below and formal attributes slightly above the nodes, which they label.

A concept lattice can provide valuable information when one knows how to read it. As an example, the node which is labelled with the formal attribute 'Asia Pacific' shall be referred to as Concept A. To retrieve the extension of Concept A (the objects which feature the attribute 'Asia Pacific'), one begins from the node where the attribute is labelled and traces all paths which lead down from the node. Any objects one meets along the way are the objects which have that particular attribute. Looking at the lattice in Figure 3, if one takes the attribute 'Asia Pacific' and traces all paths which lead down from the node, one will collect all the objects. Thus Concept A can be interpreted as 'All airlines fly to Asia Pacific'.

Similarly, the node which is labelled with the formal object 'Air New Zealand' shall be referred to as Concept B. To retrieve the intension of Concept B (the attributes of 'Air New Zealand'), one begins by the node where the object is labelled and traces all paths which lead up from the node. Any attributes one meets along the way, are the attributes of that particular object. Looking at the lattice once again, if one takes the object 'Air New Zealand' and traces all paths which lead up from the node, one will collect the attributes USA, Europe, and Asia Pacific. This can be interpreted as 'The Air New Zealand airline flies to USA, Europe and Asia Pacific'. As a further example, the formal concept involving Air Canada and Austrian Airlines, from above, can be clearly seen in the concept lattice as the third node down from the top of the lattice.

Although the Airline context is a small example of FCA, visualising the formal context clearly shows that concept lattices provide richer information than by looking at the cross-table alone. However, concept lattices are not suitable visualisations for pre and first responders in crisis situations; they require some expertise and time to analyse. Thus ATHENA will develop new FCA visualisations appropriate to the Crisis Summary and Query Tools in the Command Centre and use the FCA derived crisis summary information to populate the ATHENA Crisis Map.

Formal Concept Analysis for Deriving Crisis Information

Central to ATHENA is the use of Formal Concept Analysis to aggregate and summarise textual crisis information sources when they contain similar information (see Figure 4). High performance FCA software, based on fast concept mining algorithms (7) (8) will cope with large volumes of information to assist in giving a clear view of the crisis. This high-performance data capability will enable FCA to be applied in a dynamic fashion. ATHENA will develop a new facet to FCA: Dynamic FCA (D-FCA). Parallel processing and bit-wise optimisation (formal contexts are implemented as bit-arrays enabling 64-way computation) will be combined with FCA-based aggregation, noise-filtering and simplification techniques to supply crisis stakeholders with real-time information and analytics. 'Super-simple' mobile visualisations and interfaces will be provided to present important information in a clear manner via the ATHENA crisis map and to allow pre and first responders to scan and drill down through FCA derived crisis summary information, from social media such as Tweets and Facebook posts.

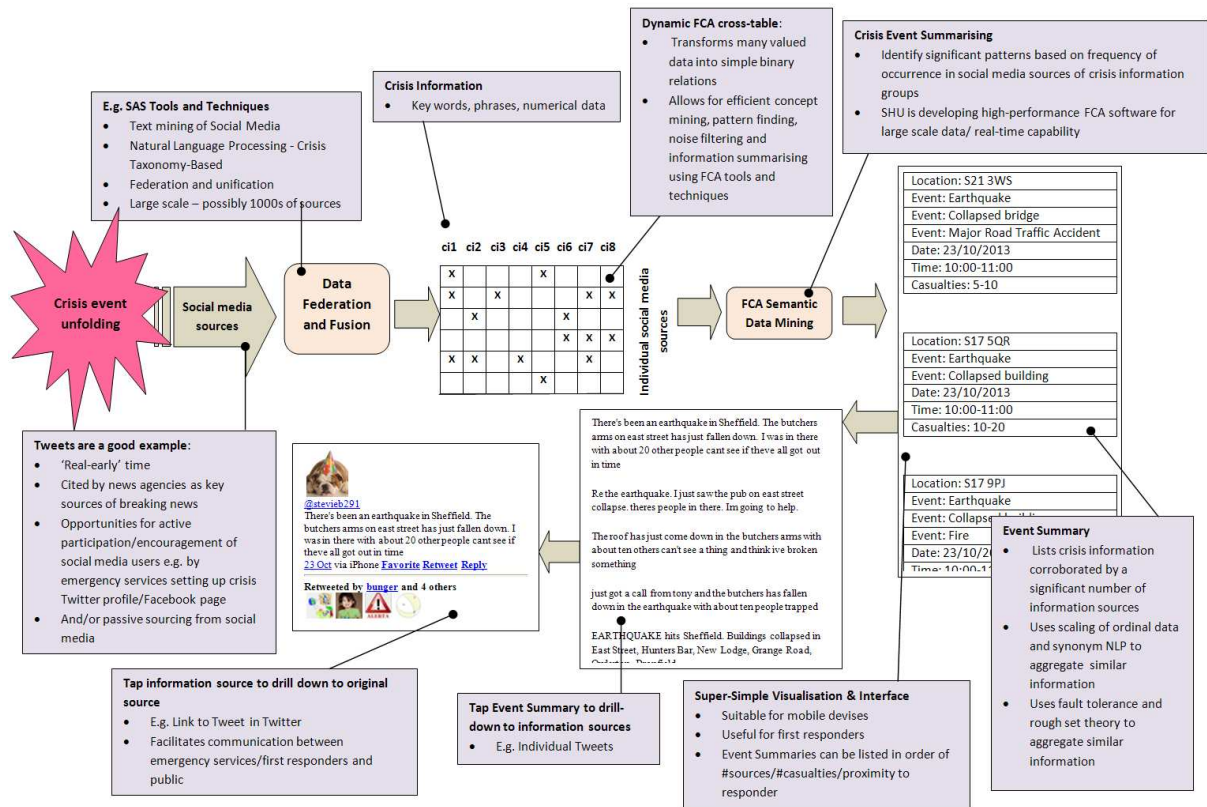


FIGURE 4: USING FCA TO DERIVE CRISIS INFORMATION

London Bombing Example

To provide a demonstration of use, a simple example is taken from the July 2005 London bombings. As social media was in its infancy eyewitness accounts are taken from on-line media available at the time. A total of 66 accounts were used in the analysis. ATHENA will adapt and develop new crisis taxonomy-based text mining techniques and tools but for the purposes of this example simple well-known techniques were used. The text of all the accounts was aggregated into a single document. This was fed into tag-cloud software to extract key-words to be formal attributes. The 66 accounts were then used as the formal objects thus creating a formal context. FCA software was then used to extract the largest (most significant) concepts [ref] and visualise them as a concept lattice (Figure 5).

The lattice in Figure 5 appears to indicate an incident on a train and another on a bus. A high proportion (48%) of the eyewitness accounts include both “smoke” and “train” (Figure 6). When the analysis is repeated using this 48% of accounts, a finer level of granularity appears; the single train-related incident appears actually to be two incidents on the tube: one near Edgware Road and another near Russell Square (Figure 7). The drill-down also reveals how serious the incidents appear to be with the common use of words such as “explosion” and “bodies”.

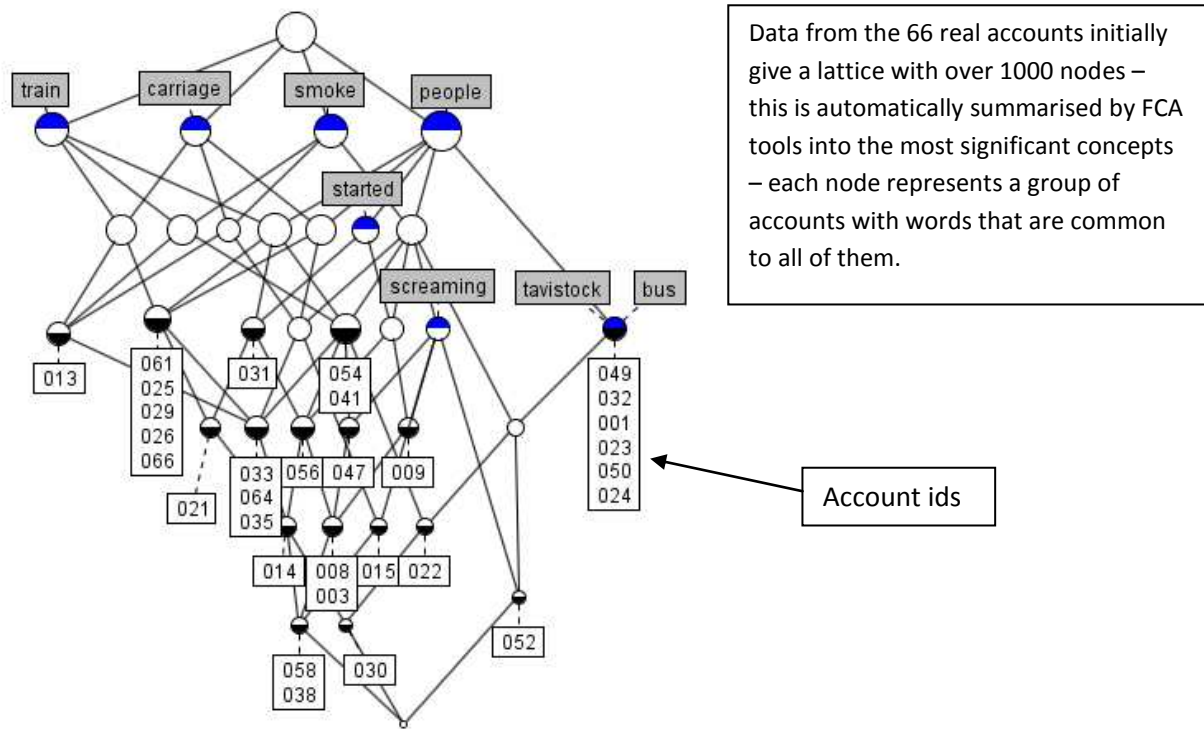


FIGURE 5: CONCEPT LATTICE OF LONDON BOMBING EYEWITNESS ACCOUNTS

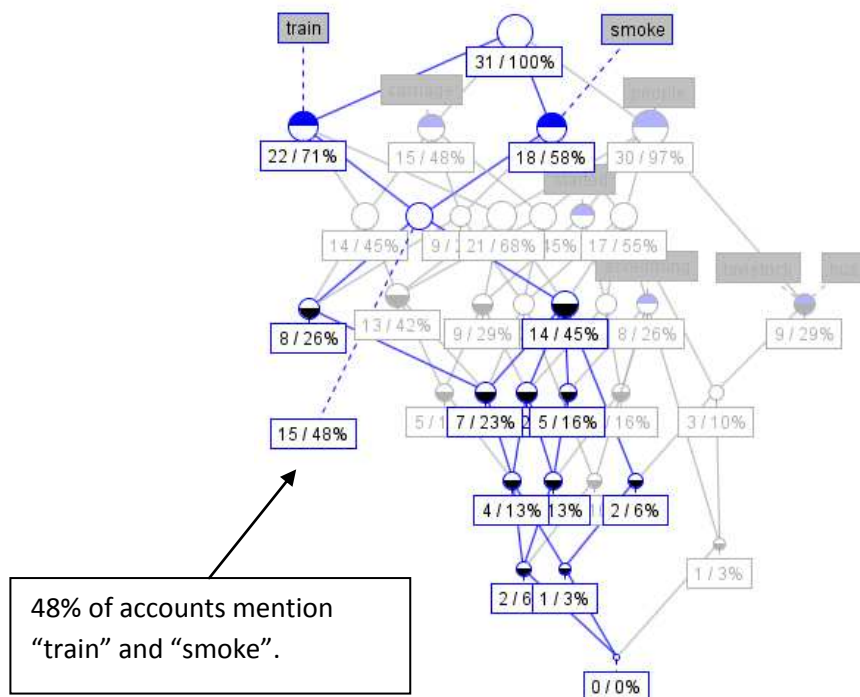


FIGURE 6: HIGHLIGHTING A KEY PIECE OF INFORMATION USING FCA

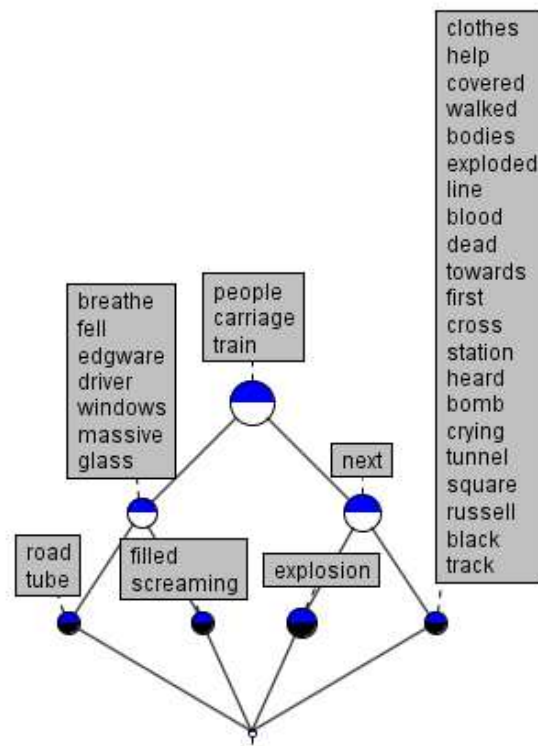


FIGURE 7: DRILL-DOWN TO REVEAL FINER DETAIL

One account in particular (no. 052) links the tube and bus incidents by the words "smoke", "people" and "screaming" (see Figure 8). It may be worth examining the account to see if any insight can be gained on a possible connection.

Account 052: "I'm in Tavistock Square. There was a big bang. After the smoke went away I realised there was a double decker bus exploded. People were running towards me screaming and crying. I saw at least five people jump from the top deck of the bus. Half of it was blown away. They were jumping onto the street to escape. It was such a big explosion and the bus was packed because the tube was closed. People were covered with dust and debris. I didn't see any blood."

Account 052 raises the question that if the tube wasn't closed, could this have been another tube incident? It is possible that someone with a bomb was unable to deliver it to its tube target and perhaps improvised an alternative public transport target. The analysis is beginning to suggest that this might be a co-ordinated multi-targeted terrorist attack on London's tube system.

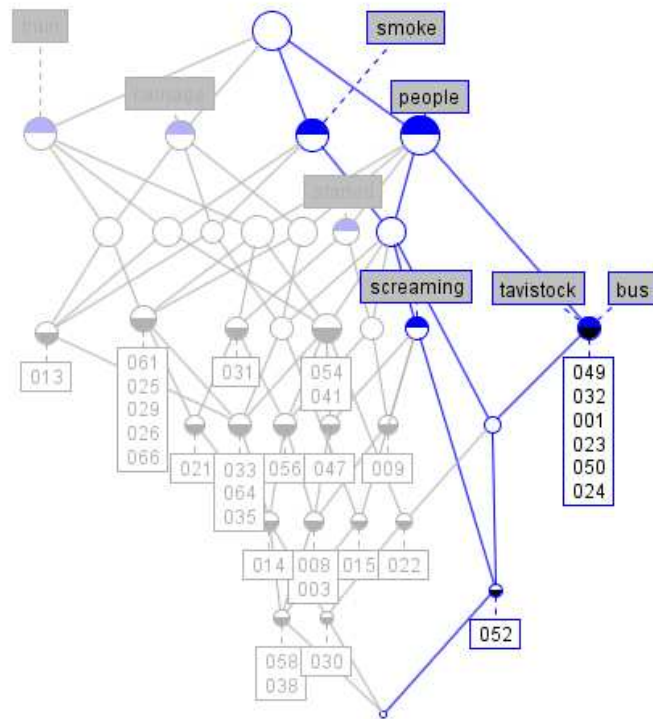


FIGURE 8: ACCOUNT 052 LINKS TUBE AND BUS INCIDENTS

Building on Prior Projects

To maximise the benefit from prior EU investment Project ATHENA will build upon prior work under PASR and FP7. Key partner projects whose outcomes will be used in the ATHENA project include the FP7 projects Odyssey, CUBIST, DIADEM, and INDIGO and other security agency funded projects such as, C-BML (NATO), 'Communicating in Crisis' (FBI), 'Community Resilience/Shielding for the National Capital Region' (U.S. Department of Defence) and 'Advice in Crisis' (Federal Emergency Management Agency). Other prior EU projects to be drawn on include: SGL for USaR; ESS; G-MOSAIC; SAFER; and CrisComScore. The SGL for USaR project addressed problems facing rescue teams following massive destruction and large structural collapses. This project focused mainly on the location of entrapped victims using chemical and physical sensors. The ESS project relied heavily on the use of multiple sources of information in order to build a picture of the situation on the ground and a real time synchronisation of information, with commanders able to communicate via group 'text' (SMS) message and recorded voicemails. GMES services such as the G-MOSAIC and SAFER projects are still relevant to crisis management as they provide details of a situation on the ground within 6 hours of a request from crisis management agencies. CrisComScore developed guides for crisis communication strategies in order to make authorities better prepared to communicate with the public in crisis situations. ATHENA will build on these projects in a number of ways. The proposed platform could provide live updates from nearby members of the public, as well as potential victims, with regards to location of collapses, condition of structures and possible entry/exit points to urban areas where the rescue teams may be needed. ATHENA in the hands of search and rescue teams would provide an effective and detailed platform for ensuring the flow of important information from the field to the command and control centres (C&Cs). The applications provided by ATHENA

would provide the opportunity for pre-first and first responders to immediately send geolocated messages and mini-blogs, or provide pictures and/or live stream video to C&Cs, as well as using the information being shared indirectly between members of the public via social media, providing decision makers with critical and constantly updating information regarding layout of crisis scenes. Whilst the public acting as pre-first responders often provide crucial help and assistance in the immediate aftermath of a crisis situation, their presence can often hinder further efforts by blue light responders. A more constant discourse coupled with the ability of mapping crowds based on geolocation information during the crisis can ensure able-bodied members of the public are provided advice on moving out of emergency areas (including safe routes, areas to avoid and modes of transport which may still be available to them) in a timely fashion.

ATHENA Concepts in Related Domains

It is expected that the outcomes and deliverables from ATHENA will have applicability in other security and safety domains where the involvement of the public as a key resource can be enhanced and facilitated. Inherent in ATHENA is the notion of terrorist activities as crisis situations and it is envisaged that the system can be adapted to focus more on the detection and prevention of terrorism, with the public acting as a new, more co-ordinated and organised role, as the eyes and ears of counter-terrorism LEAs. It is a small step from this to broaden the use of the system to dealing with organised crime and radical groups.

Conclusion

It is important to note that the FCA in the London bombing example is based on corroborative information – the key facts are revealed through the common use of words and combinations of words in information sources. Provided in real time, this analysis will give added clarity, insight and corroboration to the information flowing into Emergency Services telephone and Command and Control operations centers. The example is limited in that it is only simulating social media scanning and does not use more sophisticated taxonomy-based text mining techniques that will be used in ATHENA. Nevertheless, the use of FCA demonstrates how key facts can be revealed and corroborated in a methodological manner. The analysis presented here was ‘open’ in that in the criteria for key words in the text mining was limited to frequency of occurrence and the omission of stop words. In ATHENA, a crisis taxonomy will allow differentiation of information into categories such as damage assessment, causality numbers and severity and search and rescue operations. In addition, geo-spatial and temporal information will be acquired in real time to provide further levels of analysis and to populate the ATHENA crisis map. Automation of this analysis and tailored visualisations in ATHENA will provide crisis stakeholders, including the public as pre-first responders, with reliable, relevant and timely information to help safeguard and rescue citizens in crisis situations.

References

1. **Lindsay, B.** *Social Media and Disasters: Current Uses, Future Options and Policy Considerations*. s.l. : Analyst in American National Government, 2011.
2. *The social media manifesto: A comprehensive review of the impact of social media on emergency management*. **Crowe, A.** 1, s.l. : Journal of Business Continuity and Emergency Planning, 2010, Vol. 5.

3. **Edwards, C.** *Resilient Nation*. s.l. : DEMOS, 2009.
4. **Ganter, B., Wille, R.** *Formal Concept Analysis: Mathematical Foundations*. s.l. : Springer-Verlag, Berlin, 1998.
5. **Wille, R.** Formal Concept Analysis as Mathematical Theory of Concepts. [book auth.] B., Stumme, G., Wille, R. Ganter. *Formal Concept Analysis: Foundations and Applications*. s.l. : Springer-Verlag, Berlin, 2005.
6. **Priss, U.** Formal Concept Analysis in Information Science. [book auth.] B. Cronon. *ASIST*. s.l. : ASIST, 2008, Vol. 40.
7. *In-Close2, a High Performance Concept Miner*. **Andrews, S.** s.l. : Springer, 2011. 19th International Conference on Conceptual Structures. pp. 63-76.
8. *Parallel Recursive Algorithm for FCA*. **Krajca, P., Outrata, J., Vychodil, V.** s.l. : Palacky University, Olomouc, 2008. Proceedings of the Sixth International Conference on Concept Lattices and their Applications. pp. 71-82.