12th INTERNATIONAL COMMAND AND CONTROL RESEARCH AND TECHNOLOGY SYMPOSIUM

"Adapting C2 to the 21st Century"

Developing a Horizon Scanning System for Early Warning

Topics: C2 technologies and system, sensemaking, collaboration

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Abstract

In Singapore, we have embarked on a Risk Assessment and Horizon Scanning (RAHS) Initiative, to provide conceptual, theory and technology enablers to help analysts make sense of the vast amount of available data for early warning. Our system is premised on three principles: (a) technologies are to augment the human in the sensemaking process, (b) need to move beyond data sharing, to perspective sharing, and (c) need to move beyond mere searches, towards data analytic and data structuring services.

Towards this end, we have completed the development of a Service Oriented Based Horizon Scanning Architecture (SOSA). SOSA enables collaboration across agencies, and allows data and tools in different agencies to be treated as web services that are discoverable, sharable and can be orchestrated for analyst consumption. Perspective sharing services in the system allow multiple analysts from various agencies to meta-tag and add comments to incoming and existing data sets, which could then be visualised, in order to amplify data outliers and help users avoid getting blind-sided through premature convergence. In addition, data structuring services enable building of system maps with associated consistency matrices, and to perform automated morphological analysis.

This paper will explain the imperatives of the RAHS System, SOSA, and the perspective sharing and data structuring services.

Introduction

The complexity of issues and tempo of activities handled by the Singapore Public Service has increased substantially over the past years, due to an increase in overall scale of activities and inter-connectivity, as well as the interplay of different components exhibiting emergent behaviour. Two recent examples stand out clearly. One is the declining birth rate of Singapore. To address this, a Government review panel had to look at issues handled by multiple departments, such as employer demands, workplace benefits and employee wages, family cohesion and values, manpower for national defence, and rising educational status of women. Another example is addressing the threat of Avian Flu spreading to Singapore, which involves the foreign affairs, human health, veterinary health, housing, and transport departments.

Operational Impetus for Early Warning

Given the complex, international and cross domain nature of the issues that we face, it is no longer feasible to focus on past trends and assume that the future will be similar, or to adopt an agency-specific, or worse still, purely reactionary approach to emerging issues. This is especially so given Singapore's inherent vulnerabilities: our small country-state of around 700 km^2 is home to several oil refineries, and provides highly developed infrastructure to maintain its status as a major air and sea transport hub. Demographically, its population comprises 4 main races and over 5 key religions. While Singapore stands as a symbol of stability and competent governance, it is also a prized target for terrorists, which if skilled, can exploit the vulnerabilities. The Risk Assessment and Horizon Scanning (RAHS) Initiative was thus started to enable the Public Service to leverage on the vast amounts of data and know-how, to provide early warning of arising strategic threats so that anticipatory action can be taken to remove or mitigate the impact.

The initiative will employ technology towards designing a system, to:

a) Augment human efforts in sensemaking processes, as we believe that no technology can yet fully replace the human in sense making.

b) Enable collaboration and information exchange across various Public Service departments, to meet the challenge of cross-sectoral issues and the increasing speed at which they arise.

Through this, the initiative will also ensure optimal allocation of limited Public Service resources, by allowing departments to focus efforts on identified low probability but high impact issues, otherwise termed as wildcards.

Survey of Organisations

Before we started developing our Risk Assessment and Horizon Scanning system, we studied various overseas organisations that carried out risk assessment and horizon scanning functions, and found that scenario planning and massive data analytics were the two main methods used in most of the organisations.

This traditional Scenario Planning method has been employed by Shell International Petroleum Company to allow the company to anticipate the rise and subsequent fall of oil prices. In the mid-1980s, Shell also created scenarios that focused on the future of the Soviet Union, as that country was a major competitor in the European gas market.[1]

Siemens AG has utilized a form of scenario planning as part of its technological forecasting technique, named "Pictures of the Future". This technique involves selecting a suitable time frame in the future, and generating comprehensive scenarios taking into account various aspects, such as socio-political environments and new customer needs.[2]

The Millennium Project, a global participatory futures research think tank for global issues, has employed scenario planning together with the Delphi participatory method, to produce a large range of scenario sets in various domains such as Demographics and Human Resources, Environmental Change and Biodiversity, Technological Capacity, Governance and Conflict, and International Economics and Wealth.[3]

In the public sector, the UK Horizon Scanning Centre, under the Department of Trade and Industry (DTI), helps identify future issues and trends relevant to the entire public policy spectrum, often employing scenarios and expert consultation in the process. Its aim in such work is to feed into cross-government priority setting and strategy formation.
Its work has been used by the Health and Safety Executive to inform scenarios on the future of workplace health and safety.[4]

The Global Public Health Intelligence Network (GPHIN) was developed for WHO through collaboration with Health Canada in 1996, and functions as a secure Internet-based early warning system that gathers information about potential public health threats on a 24/7 basis. It serves as a web crawler, conducting data mining from various sources, with a focus on infectious diseases and human safety issues. Acting on keywords assigned by Health Canada's Laboratory Centre for Disease control (LCDC) and keywords associated with public, environmental and animal health, it monitors over 10,000 online sources, such as newspapers and biomedical sources.[5]

The Australia and New Zealand Horizon Scanning Network (ANZHSN) is an initiative under the Australian Government Department of Health and Ageing (DoHA), that utilizes internet scanning and stakeholder consultation to provide advance notice of significant new and emerging technologies to health departments in Australia and New Zealand, and to exchange information and evaluate the potential impact of emerging technologies on their respective health systems.[6]

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[1] Details in Chp 13 "Scenarios", Futures Research Methodology CD-ROM v2.0 on, by the Millennium Project.
[2] Details at Siemens' website:
http://www.siemens.com/index.jsp?sdc_p=ft4mls3u20o1156534n1156534i1168864pFEcz2&sdc_sid=21842775797&
[3] Details at the AC/UNU Millennium Project website: http://www.acunu.org/millennium/environscen.html
[4] More info at the DTI website at:
http://www.gnn.gov.uk/environment/fullDetail.asp?ReleaseID=251912&NewsAreaID=2&NavigatedFromDepartment=False
[5] More background at the Carleton University website at: http://www.carleton.ca/jmc/cnews/12031999/f4.htm
[6] Details at the DoHA website at: http://www.horizonscanning.gov.au/

Principles of the RAHS System

The RAHS development team believes that all methodologies and technologies have their pros and cons. The Singapore RAHS System thus aims first to define the key principles and provide an inclusive architecture, which not only includes a comprehensive suite of methods and technologies based on existing work and concepts, but also is flexible enough to cater for future methods and technologies. The three key principles of our systems are:

a) Technologies are to augment the human and his/her team in the sensemaking process, as the team believes that the human remains as the ultimate sense maker.

b) The need to move beyond data sharing to perspective sharing, to deal with complexity and the common risk of being trapped by one's own perspective.

c) The need to move beyond mere search towards data analytic and data structuring services, as it is essential for analysts to have more time to analyse the input, and to augment their work in creating models to make sense of incoming data.

Based on the above, our system aims to provide four enablers to users:

a) <u>Enable collaboration across agencies:</u> RAHS will link up various agencies, and enable people from different agencies to collaborate.

b) <u>Enable reduction of time spent on searches:</u> One of the ways to achieve this is through the use of tools that reduce the search time required by analysts, thus increasing the amount of analysis time spent on relevant information. Towards this end, the RAHS System implements a range of analytical tools, to reduce the amount of search and reading time required by the analysts, as well as software to automate the running of pre-determined workflow.

c) <u>Enable creation and use of models for sense making and monitoring:</u> According to the Naturalistic Decision Making framework developed by Dr Gary Klein[7], experts when dealing with complex situations and faced with high levels of uncertainty rely on mental models and pattern matching against these models, to allow them to discern subtle clues and choose the correct path of actions, in situations where novices fail. This hypothesis was further substantiated and popularized by subsequent publications from Dr Klein[8], as well as by Malcolm Gladwell[9]. Along this line, the RAHS System explores the use of various models as different means of data structuring, to help the user better make sense of incoming data and monitor the situation.

d) <u>Enable sharing of perspectives</u>: Knowledge management expert Dr Dave Snowden has argued for the need of perspectives sharing when operating in the complex domain, in order to gain new views on the situation, rather than rely on entrained patterns from past experience[10].

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[7] *Sources of Power: How People Make Decisions*
[8] *The Power of Intuition: How to Use Your Gut Feelings to Make Better Decisions at Work*
[9] *Blink: The Power of Thinking Without Thinking*
[10] *The new dynamics of strategy: Sense-making in a complex and complicated world*

System Overview

We have successfully completed the development of a Service Oriented Based Horizon Scanning Architecture (SOSA), which enables collaboration among human analysts in various agencies, and also enables data and tools in different agencies to be consumed as services, so that they are discoverable and can be orchestrated. The architecture sits on a physical network connecting the agencies involved in the pilot phase of our RAHS project. SOSA also has a generic, service-based flexible architecture referred to as SEFAR (Service-Oriented Flexible Architecture), and a wide range of services, such as data, application and visualisation services.

SEFAR allows service discovery and sharing of data, algorithms and visualization in a multi-agency environment, and provides the orchestration layer which enables workflow configuration on-the-fly. A key benefit of SEFAR is allowing system resources (data, tools and visualization) to be better managed and utilized. In addition, users are given greater flexibility to fine tune or create new workflows, to cater for changing requirements.

Overview of SEFAR Architecture

SEFAR is designed to be generic, extensible and conforming to industry support standards. Thus, besides use of such standards, its other architecture considerations include:

a) Interoperability
b) Reuse of existing applications
c) Scalability
d) Security

The basic elements in the SEFAR architecture are as follows:

1. <u>Workflow Man-Machine Interface (MMI)</u>: This allows the user to compose Web services; the output of this module will be in an XML format, termed as the workflow XML. The workflow XML describes the relationship between data, tools and visualization services, which is then passed to the orchestration layer for further processing. The workflow MMI display executes at the client-side.

2. <u>Orchestration Layer</u>: This module is divided into two separate modules: an XML Mapper and XML Actor. The XML Mapper is responsible for parsing the workflow XML into events, and this chain of events is then passed to the XML Actor for service initialization and invocation. The XML Actor is responsible for service synchronization and mediation. The orchestration module itself is a web service.

3. <u>Service Container</u>: This is a network node hosting web services, and resides at the server-side. Service Containers contain web services, such as data, tools and visualization services, and reside in a multi-agency environment.

4. <u>Visualisation Display</u>: This allows computed results to be displayed at the client-side within an Eclipse RCP (Rich Client Platform), for viewing and analysis work.

5. Utilities Servers: These comprise a UDDI Registry Server and Message-Queue Broker Server. The UDDI Registry Server keeps track of all registered Web services, while the Message-Queue Broker Server provides message exchange facilities between web services. The security module ensures SSL transaction between actor in orchestration layer and the web services. A Quartz Scheduler is used to schedule the workflow.

A simple scenario of a typical user's workflow is as follows (illustrated at Figure 1):

1. A user orchestrates a user workflow, using the workflow MMI display.
2. The workflow MMI converts the graphical workflow into an XML script.
3. The XML Mapper takes in the XML script, comprehends it, and breaks it down into individual events.
4. These events are then passed to the XML Actor for further processing.
5. The XML Actor takes in the events and performs service discovery via the UDDI Registry Server, to determine end-points of services (i.e. service access URLs).
6. The XML Actor initiates service synchronization. A Message Queue (JMS) is responsible for XML messages exchange between services.
7. All the web services are at the server-end, and servers that host the web services reside in a multi-agency environment; there are no data or web services at the client-end.

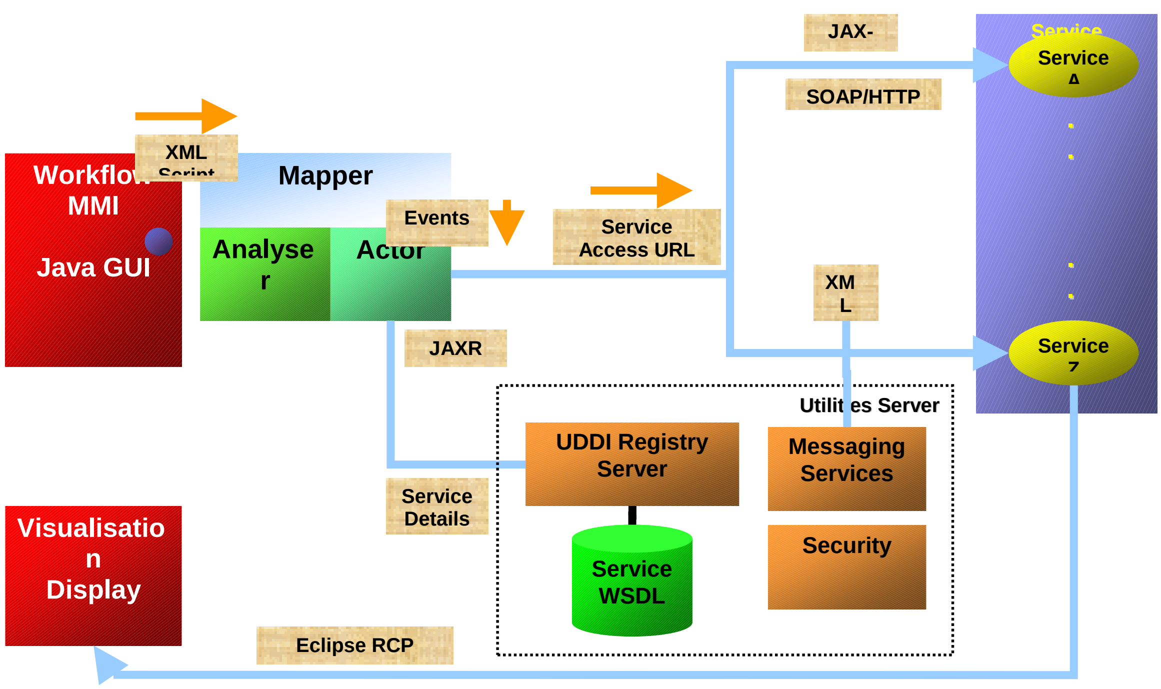

Figure 1: SEFAR Architecture

Results computed by the services are pushed back to a client via a message queue subscription, through the visualisation display on the client-end. The plug-in of the visualisation display sits within Eclipse RCP framework, also on the client-end.

Figure 2 illustrates how an end-user utilises the SEFAR workflow MMI. The workflow in Figure 2 automates the end user's work process of performing searches on the various data sources, moving the articles into project folders, and performing of entity, timeline and network analysis on the consolidated articles, resulting in various visualisations. The messages that pass between the different web services in the workflow are mediated by the SEFAR orchestration layer and utilities servers. Should the user analyst discover interesting information from the analytical visualizations, he/she can then choose to perform further analysis on the system.

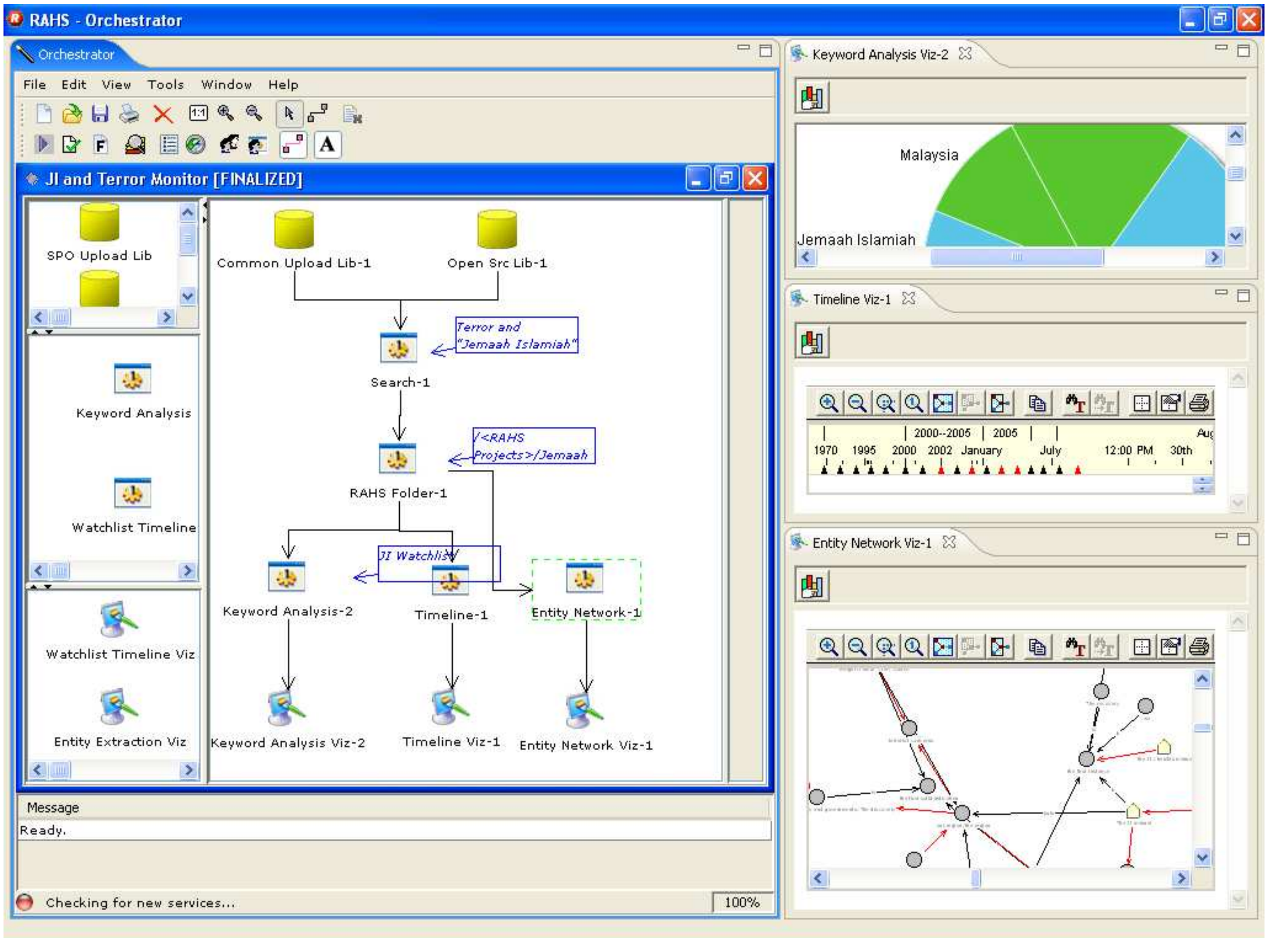

Figure 2: A typical service scenario

Advanced Data Analytics

The RAHS system empowers analysts with a suite of tools, to help them process large amount of data, which can either be unstructured text obtained from the Internet, or reports uploaded by the analysts. The system gives the user analyst the flexibility to apply these analytical tools in any order, in support of the analytic process. The following section describes various analytical tools:

Advanced Search Tool

The RAHS system allows analysts to search for articles within its repository (refer to Figure 3). The Advanced Search tool provides powerful features for fine-tuning text searches. Analysts can select different search modes, select specific libraries and filter search through fielded queries.

There are three primary search modes: **Concept**, **Pattern**, and **Boolean**. The **Concept** search enables finding of related words or concepts that may be relevant to a search query, utilising a knowledge base containing word meanings, syntax, word variations, and relationships between words. These defined relationships between words link them together in a "semantic network". In a **Pattern** search, query terms are expanded to include terms with similar spellings. A **Boolean** search produces exact matches, and is a fast way to look up articles without going through the majority of the semantic network. If an analyst enters multiple terms, he must use the appropriate operators (eg. AND, OR, NOT, etc.). The search engine also allows the analyst to mix the three search modes: **Concept** search, **Pattern** search and **Boolean** search, within a single search query.

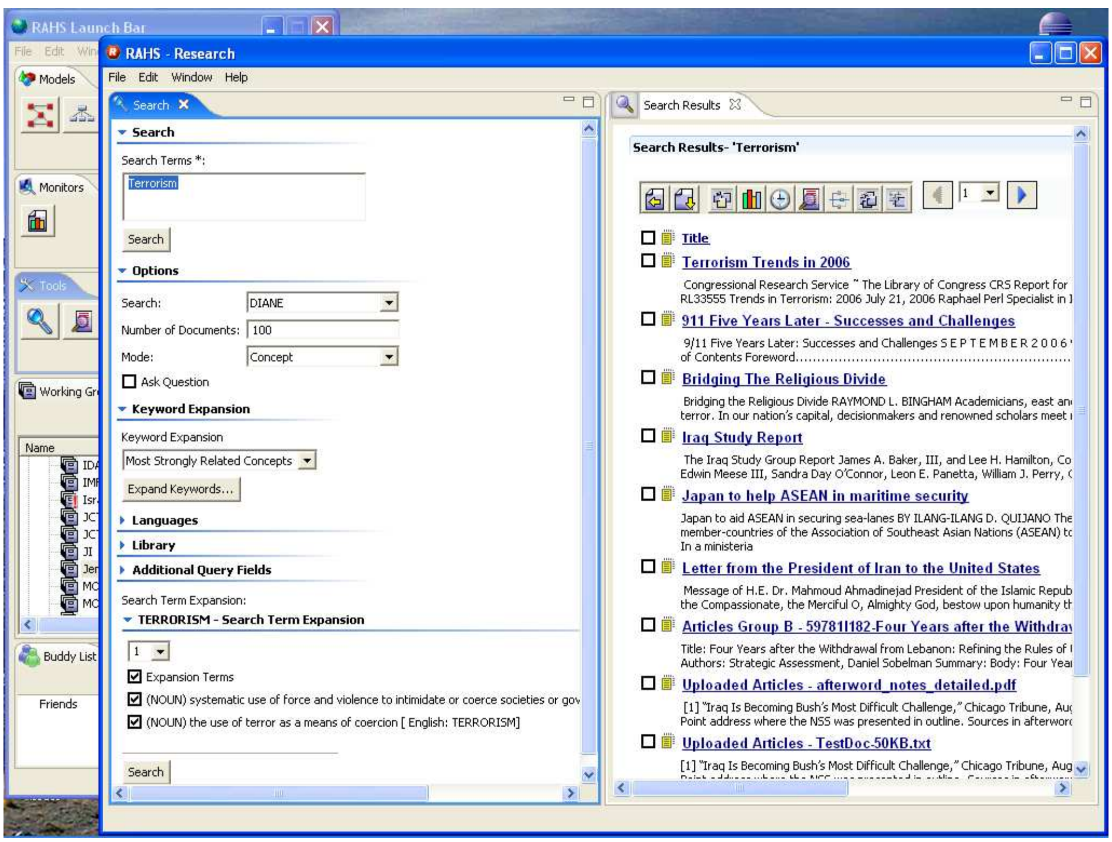

Figure 3: Screen Shot of the Advanced Search Tool

Summary Tool

A common problem faced by analysts today, is having to read through a collection of articles, after which realising that only a handful are relevant to the topic of research; on hindsight, the analyst's time could have better utilized for more meaningful analysis and findings. The RAHS multiple document summarizer will thus be useful in reducing the amount of analyst reading required, by picking up key sentences that best summarize a single article or a collection of articles (refer to Figure 4).

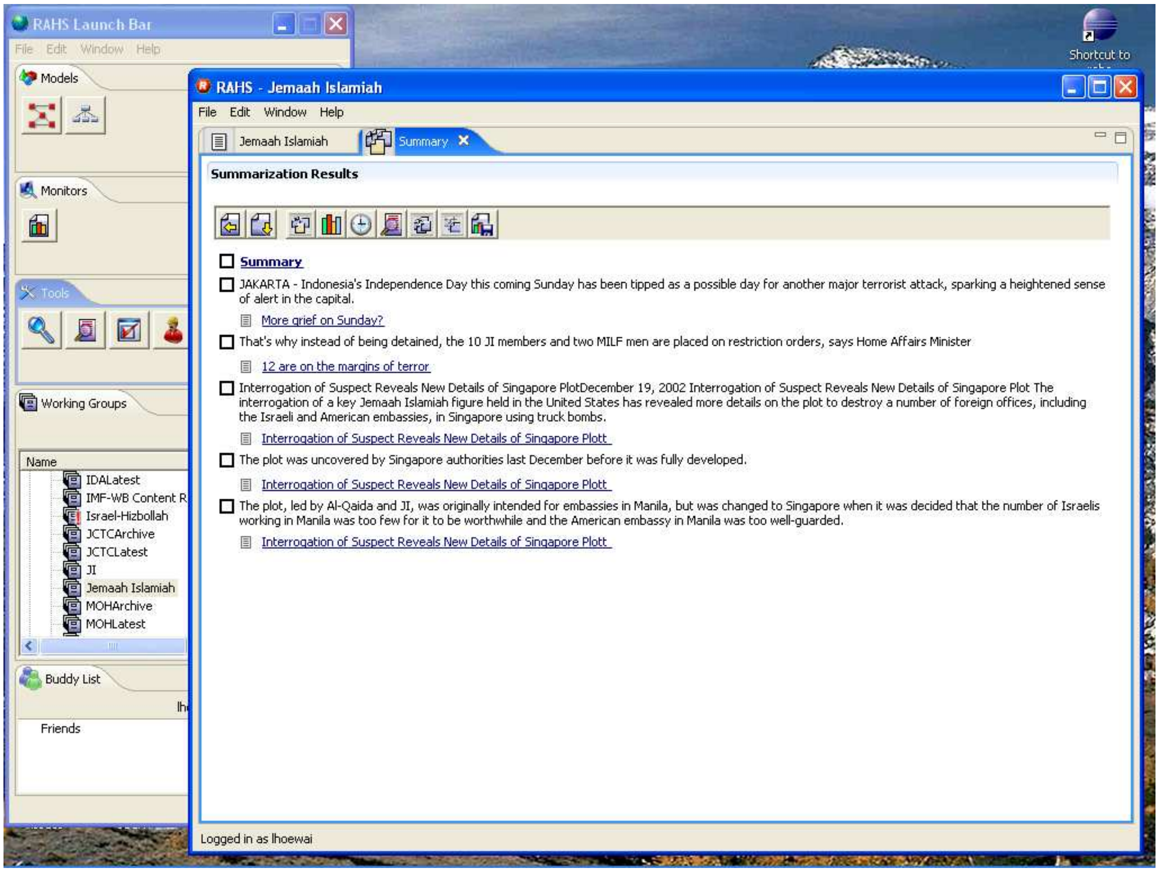

Figure 4: Screen Shot of the Summary Tool

Entity Analysis Tool

An entity is an object that can be a human, a location, an organization, dates and times, monetary amount or percentage; Entity Analysis thus is the process of extracting such objects from raw data. This is based on automatic word alignment of speech recognition output, through natural language processing of the English grammar and language. The RAHS system includes an entity analysis tool, as well as other variants (also see Figures 5 and 6).

The Temporal Analysis Tool is one variation of entity analysis, which shows references to entities extracted from the entity analysis tool over time. The time is associated with the publication dates of the document if it exists; otherwise the date the article entered the RAHS system is adapted.

The Cross-sectional Analysis Tool is another variation, which shows the entities that are mentioned in the same article, as the entity currently being held constant by the analyst.

The Keyword Analysis Tool is similar to entity analysis in that it counts the occurrences of "entities" on a set of documents. However, the major differences of keyword analysis, as compared with entity analysis, are that:

a) Keyword analysis is a process whereby user-defined "terms" or "phrases", as specified in a watch list, are extracted from the set of documents.

b) Keyword analysis includes the ability to process "terms" in their native languages. This assumes that the English "terms" have corresponding synonyms defined in native language in the watch list.

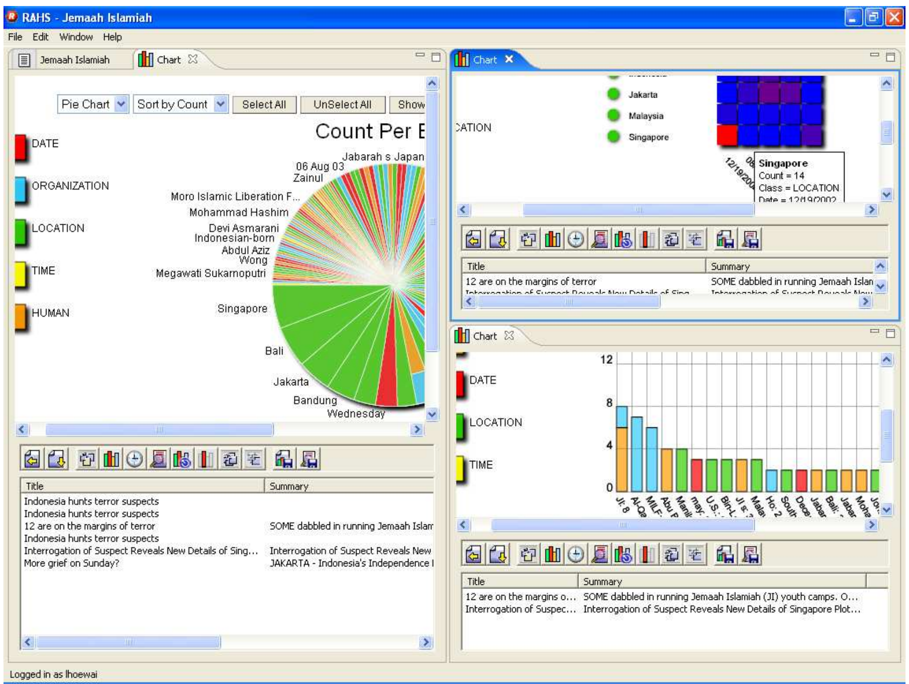

Figure 5: Screen Shot of the (clockwise from left) Entity Analysis Tool (with pie chart illustration), Temporal Analysis Tool, and Cross-sectional Analysis Tool, all based within an Eclipse RCP

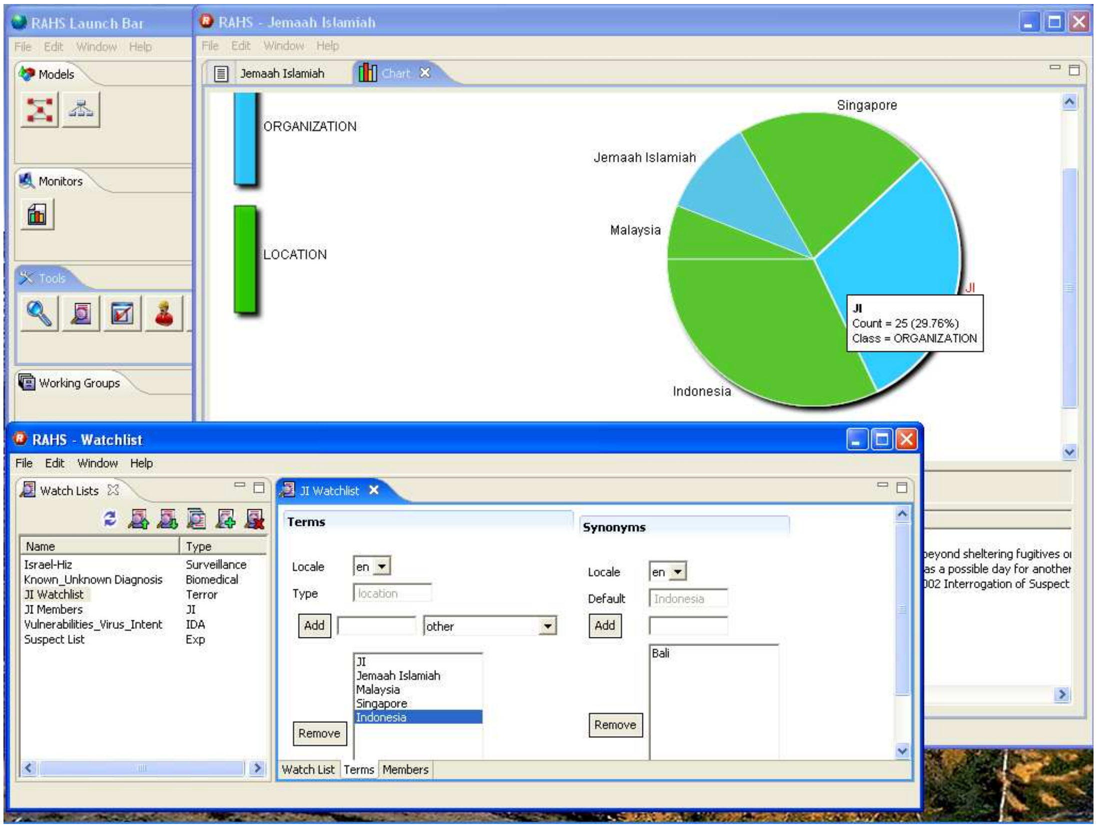

Figure 6: Screen Shot of the Keyword Analysis Tool, and Watch List

Timeline Analysis Tool

Timeline analysis is the extraction of events (with a best estimate of when these events had occurred) from a set of articles, using a set of user-supplied query terms. The Timeline Analysis tool in the RAHS system performs this function, and also assigns ranking scores to these events, based on how significant these events are to the query terms (refer to Figure 7). Rules are used to detect date expressions in sentences and resolve them to absolute dates using the creation dates as references[11]. Such dates may be a single day, a whole month or a whole year.

In the case where no date expression is detected in the entire sentence, the date is taken to be the date of creation of the article. However, such rules within the tool only apply well to news articles where the reported events in the document source are happenings that occurred recently; the assumptions these rules make do not apply well to certain article types such as biographies, literary writings or historical texts.

[11] For example, "Today" will be resolved to the article creation date, "September" to mean the last month of September before the article's date, and "Sunday" to be the last Sunday before the article's date.

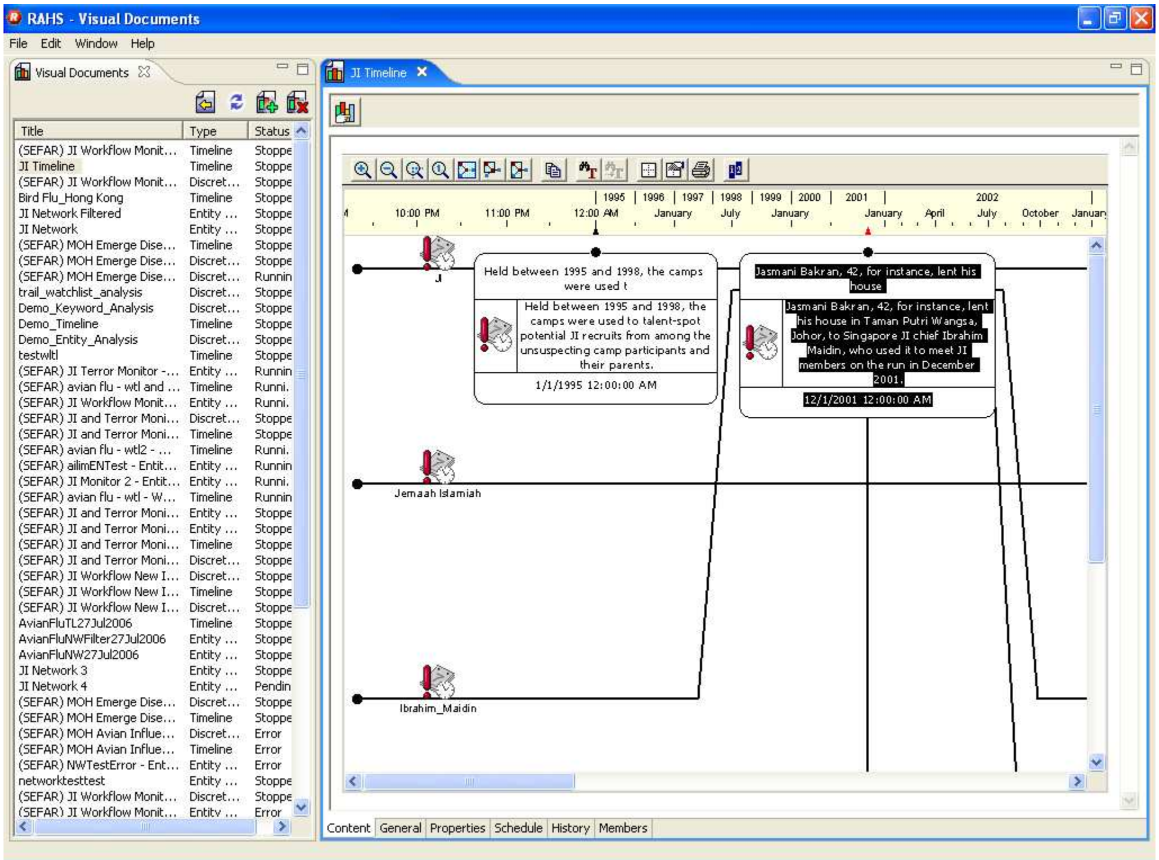

Figure 7: Screen Shot of the Timeline Analysis Tool

<u>Network Analysis Tool</u>

A link between two entities is the relationship between them; an analyst reading an article forms a mental map of how the entities mentioned in the article relate to each other. An entity network tool captures this relationship map in the form of a graph, and the RAHS system has integrated a highly sophisticated entity and link extraction engine, to linguistically process and present the captured information in a visually appealing format (refer to Figure 8). This allows analysts to then analyse the links and discover knowledge, which would otherwise be obscured by thousands of words in the voluminous data.

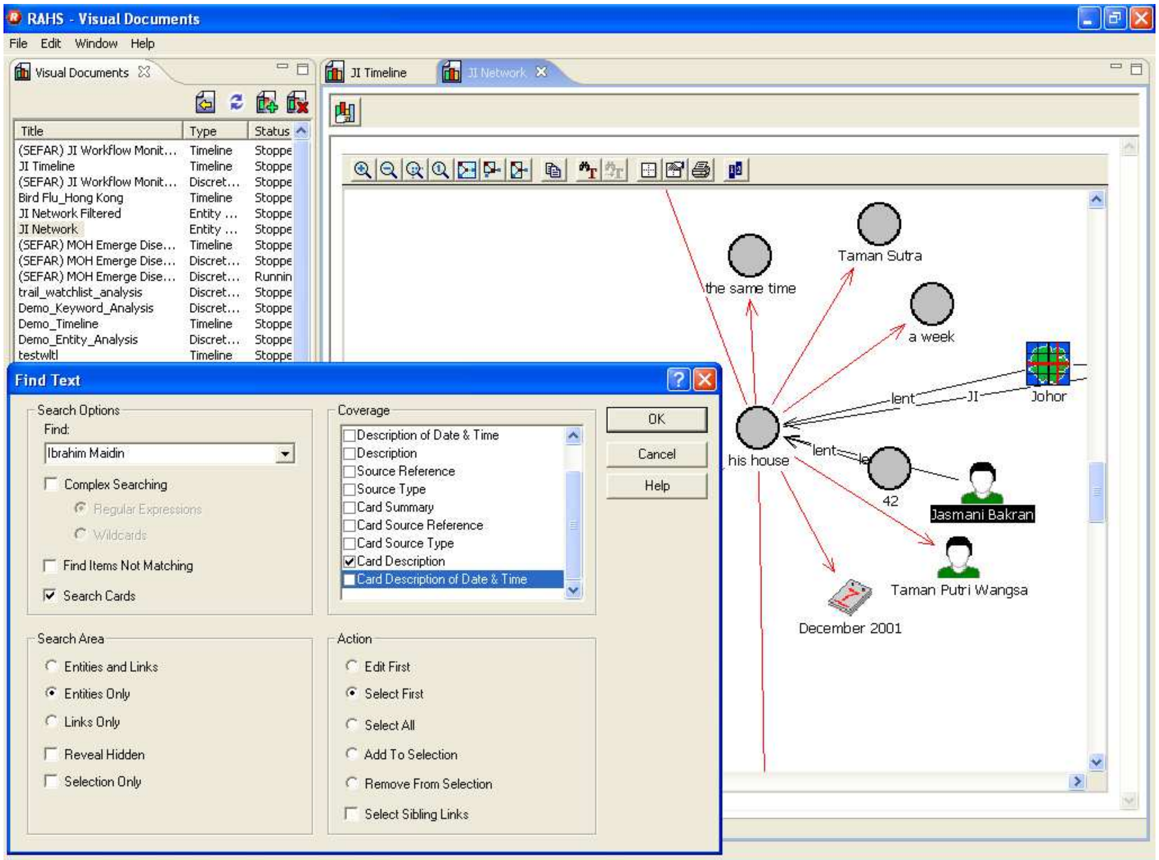

Figure 8: Screen Shot of the Network Analysis Tool

<u>Automatic Categorization Tool</u>

Analysts, when working on a project, may find it increasingly time consuming to route articles into the appropriate folders, especially as the frequency of such routing as well as number of folders increase, as the project progresses. To ease this process, The RAHS system provides a personalized categorizer, which can automatically route articles into the relevant folders. The RAHS system will keep track of movement of articles in and out of categorization-enabled folders, and will try to deduce the analyst preference for sorting of articles into the folders. In future, it will then automatically route documents into the appropriate folders. Figure 9 illustrates this tool.

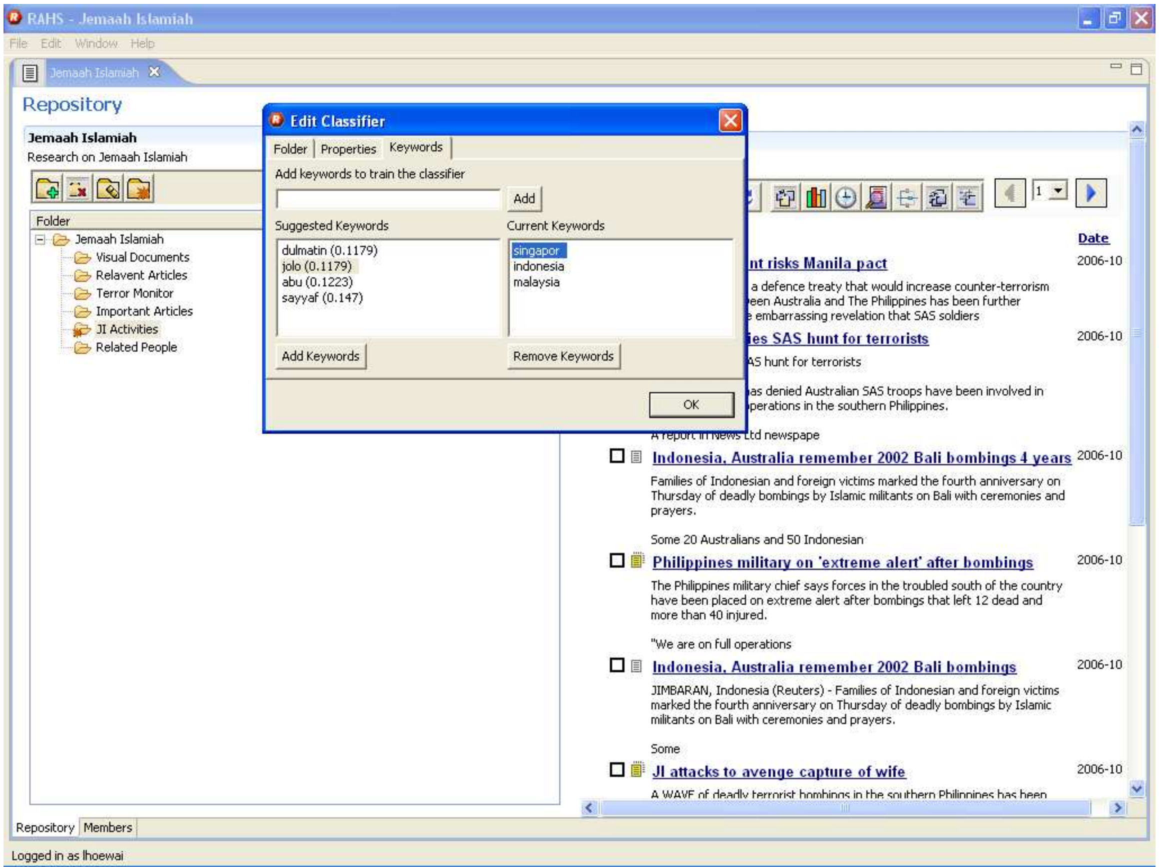

Figure 9: Screen Shot of the Automatic Categorization Tool

<u>Clustering Tool</u>

Clustering is an analytic process, where a collection of articles are arranged such that similar articles are grouped together. This process, which can be done automatically or manually, can be used to:

a) <u>Identify hidden relationships between groups of objects</u> which arise from a search result, to help the analyst better refine his/her search query.

b) <u>Ease the process of browsing</u>, to find similar or related information from a search result, helping the analyst to obtain information.

c) <u>Find unique topics within a collection of articles</u>. The unique topics might draw the attention of the analyst to new trends or patterns, which have not yet been mentioned in other articles.

The <u>Duplicate Document Detection tool</u> is a variation of the Clustering Tool. This tool enables a process to detect near-duplicate documents, based on the correlation of a group of words, which appear frequently in a document collection. It provides a user-defined parameter called "Similarity Threshold" to refine the results (refer to Figure 10).

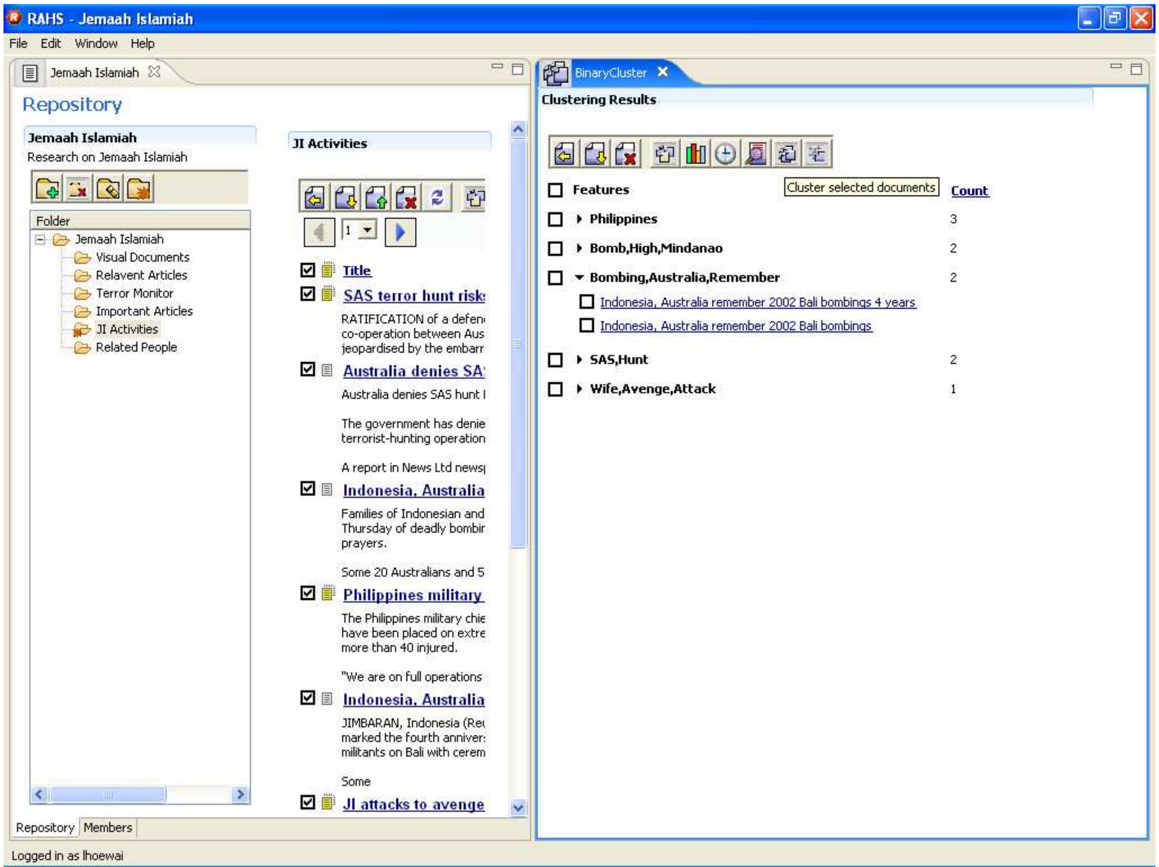

Figure 10: Screen Shot of the Clustering/Duplicate Document Detection Tools

In addition to these tools, others to provide a) data structuring and b) perspective sharing capabilities are also currently being integrated into SOSA.

Model creation and monitoring

Data structuring capabilities to enable the analyst to build models and enable collaborative modelling efforts are being incorporated into the RAHS system, thus allowing analysts to connect across silos and challenge previous thinking assumptions. Capabilities for model monitoring will also be provided, to enable matching of models with incoming data streams, and to allow the human team to explore the interpretations and implications of these data.

Model Creation Tool

The RAHS system provides a Scenario Builder tool, which is based on Systems Thinking, to enable the analyst to create a system model (referred to as a System Map). This depicts the analyst's understanding of the factors/components of the system or situation being studied, as well as the relationships between these factors.

In a System Map, the factors/components are represented as nodes, and the relationships are depicted as links. The RAHS system allows the System Map to be created either individually or collaboratively. The System Map helps the analysts clarify their understanding of the system, and serves as a basis for in-depth discussion and sense making.

A set of supportive tools, such as that to help find out the most influenced and most influential factors, are also provided to help derive more insights from the System Map. A sample System Map and its Influenced/Influential Map is illustrated at Figure 11.

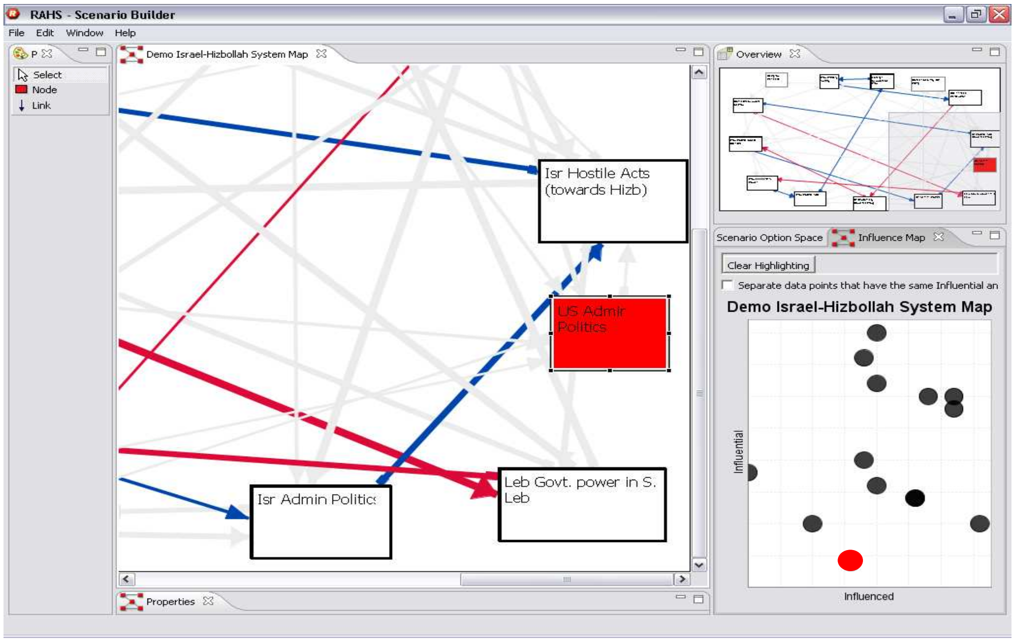

Figure 11: A System Map on the left, with its Influenced/Influential Map in the lower right.

Having built the System Map, the analyst can further input the states for each factor, along with the pair-wise consistency between each pair of states of two different factors. After the options for the factors and the consistencies are provided, the RAHS system will then be able to carry out Morphological Analysis, and generate a spread of all possible scenarios.

<u>Monitoring Tool</u>

To monitor the situation, the analyst can create filters for each of the factors, so that incoming data streams can be extracted and matched to each factor. The analyst can then take note if the incoming data implies a situation different from the model currently depicted by the System Map and its associated consistencies, and revise his/her existing model. The data input can also help the analyst to monitor development of the situation, and to narrow down the possible scenarios that are likely to unfold in the near future.

Perspective Sharing

The RAHS system further allows the analyst to provide his/her perspectives, and to share them across the entire network. The analyst can provide his/her perspective of a data item by meta-tagging the articles. The meta-tag not only facilitates easy retrieval of individual data, but also helps reveal outliers when meta-tags of various data are viewed together.

In addition, the meta-tags of the other analysts working on the same project will provide alternative perspectives to the first analyst, thus avoiding the danger of being blind-sided through premature convergence. Two tools to enable perspective sharing, namely the Indexing and Perspective Visualisation Tools, will be elaborated upon.

Indexing Tool

The RAHS system provides an indexing software to allow analysts to meta-tag articles. Four types of meta-tags are provided: Filters, Questions, Comments and Keywords. Filters and Questions are meta-tags whose meanings are understood by all RAHS network users; Comment and Keywords are freeform meta-tags that are user-specific.

The analyst can select from a range of Filters, and specify the extent to which each Filter best describe a piece of data, by selecting from a range of values in each Filter. Each Question has a set of predefined options, for the analyst to decide which option best describes the data. Comment meta-tags allow the analyst to enter freeform text, while Keyword meta-tags allow entry of multiple user-specific words or sentences relating to a particular piece of data.

Perspective Visualisation Tools

The meta-tags entered are representations of the analyst perspective, and the RAHS system provides a set of visualisation tools specially designed to help analysis of such perspectives and accompanying data. Six types of visualization tools are provided to the users: Web-like reporting, Text Panels, Jumping Indicators, Sliding Panels, Clusters in Space, and Multiple Indexing.

1. Web-like reporting provides a web based user interface, which shows the number of data indexed by each Filter, and each option in the Questions.

2. Text Panels allows the analysts to concurrently compare multiple pieces of data.

3. Jumping Indicators allows analysts to view the number of data indexed against the different ranges of the Filters.

4. Sliding Panels enable the analyst to view the meta-tags, based on combinations of any two Filters.

5. Clusters in Space enables the viewing of meta-tags relating to multiple Filters and Questions.

6. Multiple Indexing compares the number of data indexed by each analyst, according to each Filter and each option in the Questions.

Experience Gained

A spiral development approach was adopted for the development of the RAHS system, and a test bed environment was created for users to try out new software and concepts. In addition, training and exercises were also carried out to familarise the users with the new tools and processes, and to encourage the formation of informal networks across various agencies. Key experience pointers gained during the system development are as listed:

1. Bridging the Gap between Conceptual and Operational issues: The RAHS system is built upon a suite of concepts and methodologies - at present, based on a) a synthesis between Systems Thinking and Morphological Analysis, and b) methodologies from the Cynefin framework. It was a challenge translating these concepts and methodologies into software functions. This is as many of them had shown success when applied in workshop settings, but were difficult to translate into tools that can be easily used by the analyst in daily operations.

The initial approach was to design the system such that it could be used without an expert knowledge of the underlying theories and concepts. However, it was gradually realised that at least a basic understanding of the methods was required, in order to derive best results from the RAHS System. Therefore, the National Security Coordination Centre will be taking up the role of providing such method expertise in the interim, and will explore the long-term possibility of each agency on the network developing their own method expertise.

2. Common Language - Broad-based vs Agency Specific: A common language across the various agencies was necessary for Perspective Sharing to work. The experience was that implementing such a language was extremely challenging. The approach adopted was to conduct a workshop with the different agencies, to determine a set of common indices which the agencies could use in the context of national security. This approach would however require the regeneration of the common indices, whenever new agencies join the network.

Preliminary research on collaborative tagging on the web[12] has shown that individual tags could converge over time into a set of stable, consensus tags which can be use on a large scale. However, for this convergent effect to take place, it will require a large amount of users to perform the tagging activities. Furthermore, in engagement of agencies so far, the experience is that use of agency-specific indices would bear more resonance with the users and encourage the tagging of their perspectives.

3. Building a 'Balanced' System for the Human: There is a distinct difference between functionality and usability, and implementing a rich interface is just as important as delivering functional capabilities to the users. Hence, the development focus of the RAHS system should be properly communicated to, and discussed with users. The RAHS system development team has focused primarily on capability development in the early stages of the system, and also paid attention towards involving the eventual users at an early stage, which was helpful in creating ownership and buy-in.

[12] Scott A. Golder and Bernardo A. Huberman (Information Dynamics Lab, HP Labs) The Structure of Collaborative Tagging Systems: http://www.hpl.hp.com/research/idl/papers/tags/tags.pdf

After initial deployment of the fully operational RAHS System scheduled by end of 2007, the development team will derive an initial version of the operational workflow, to lower the learning curve for novice users. This workflow will be influenced by both the RAHS system's functionality at that time, as well as the current workflow of the agency.

Moving beyond usability of the tools, the RAHS system will have to support the cognitive tasks of the users, when performing operational workflows (or the Macrocognition[13] aspect). There will also be need to manage user expectations from the various agencies, on the turn-around time to incorporate other human-centred computing enhancements, as well as on requests for additional agency-specific functionality in the RAHS system.

4. Intelligence Dilemma - Security vs Functionality: There was an ongoing tradeoff between security and functionality throughout development, as a successfully RAHS system would require the information richness of open sources, while also catering to security concerns of specific agencies. Hence, the need for operational security resulted in the development team building the RAHS system into a secured intranet, equipped with a one-way channel for input of open source information. Future efforts in development would include establishing a RAHS system in an open and non-sensitive network, so that collaboration with the private sector, universities, think tanks and foreign governments can take place.

Conclusion

The RAHS system is a network of people, tools and data, and adopts a wide range of methodologies to cater for different situations. Its open architecture enables it to evolve continuously, to connect with new agencies and to incorporate new RAHS-related concepts and technologies. The system will be fully deployed by end of 2007 within a secure intranet. However, the same architecture can also be applied in an open network, to leverage on a wider source of people, expertise and data, both locally and internationally, towards enhancing Singapore's early warning capabilities with regard to threats to our National Security.

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[13] Gary Klein, Karol G. Ross, and Brian M. Moon, Devorah E. Klein, Robert R. Hoffman, Erik Hollnagel (2003) Macrocognition: http://www.coginst.uwf.edu/research/CognitiveSystemsEngineering/Macrocognition.pdf