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Producing Geo-historical Context from Implicit Sources: A Geovisual Analytics Approach

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Geo-historical context, or GHC, is a contextual setting based on the interconnectedness of phenomena, events, and place across multiple spatial and temporal scales. GHC allows for situations to be understood and reasoned with, often with aid of visual representations such as maps. This paper introduces a conceptual model of GHC that theoretically motivates a Geovisual Analytics application called the Context Discovery Application (CDA), which is also presented. The CDA is designed to aid in the production of geo-historical context by using computational processes to identify and extract potentially relevant context information from heterogeneous, implicit situation information. This information can then be explored through visual interfaces to help users explain and understand the information. A hypothetical humanitarian context analysis case study is used to show how the CDA can be applied to real world problems.

Keywords: Geo-historical context, Geovisual Analytics, open-source information, geographic information retrieval, crisis management, humanitarian information

INTRODUCTION

Context is a difficult concept to define. A dictionary definition of context is: 'the set of circumstances or facts that surround a particular event, situation etc.'[1] Geography and history are important components of a notion of context defined in this paper as geo-historical context, or GHC. GHC creates a contextual setting based on the interconnectedness of phenomena, events, and place across multiple spatial and temporal scales. These interconnections allow for present situations and possible insight into future situations to be understood and reasoned with, often with aid of visual representations such as maps. Although an important form of context, little research has been conducted on (a) formalising GHC into a model, (b) approaches to producing GHC from heterogeneous information, and (c) how GHC can be of practical use in application. These issues are investigated in this paper.

The need to geo-historically contextualise situations in application domains such as crisis management is greater than ever. GHC helps to support interpretations of and reasoning about varied geographic reactions to a disaster event, develop post-event intelligence about what happened during a crisis and why, and assess threats and vulnerabilities before disasters happen.

Information sources with the potential to be used in constructing geo-historical context for situations are vast and heterogeneous – ranging from GIS layers, email, and text messages to camera-enabled cell phone pictures, and online news reports. Therefore, the problem with producing geo-historical context is not a lack of information, but rather, how relevant information is made available, presented, accepted, and reasoned with by those who need it at the right time for the right reason (Tomaszewski *et al.*, 2007). Geovisual Analytics offers a new scientific framework for developing an approach to identifying relevant information that can produce geo-historical context. The significance of using a Geovisual Analytics framework centres on the specific emphasis made on supporting human analytical reasoning. Succinctly, analytical reasoning is the process by which human judgment is used to reach conclusions based on a range of evidence within a set of assumptions (Thomas and Cook, 2005). In a Geovisual Analytics framework, human analytical reasoning is meant to be supported by combining human vision and cognition with computer-based visualisation and computational tools and interfaces that support flexible connections to relevant data and supporting knowledge, (Thomas and Cook, 2005). Therefore, the goal of systems designed within the Geovisual Analytics paradigm is to aid user reasoning processes that are used to explain evidence and to make evidence-based decisions, especially when potentially relevant evidence is scattered across unstructured and differing

[1]http://dictionary.reference.com/browse/context, Last Accessed: 9 November 2007

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data formats. This differs from geovisualisation approaches that are meant to find patterns and relationships in well structured data through exploration and interactivity, but not necessarily to support human reasoning that explains and interprets those patterns and relationships (MacEachren, 2007).

Motivation

A particularly relevant and challenging use of a Geovisual Analytics framework is the production of geo-historical context from implicit geospatial and temporal references in text documents. Implicit geospatial and temporal references refers to largely unstructured information contained in text documents such as references to locations of towns, cities, or countries that can be combined with the largely numerical and structured information found in geospatial databases (Purves and Jones, 2006). Implicit geographical information contained in open-source channels such as the news media present important sources of information that can be used to construct geo-historical context (Mubareka *et al.*, 2005).

In application domains such as crisis management, implicit information sources such as the news media are used by organisations such as the Federal Emergency Management Agency (FEMA) and Reliefweb.int for geospatial intelligence analysis and situation monitoring/ reporting (ReliefWeb, 2007, Federal Emergency Management Agency (FEMA), 2007, Department of Homeland Security, 2007).

A primary challenge to producing geo-historical context from implicit sources using a Geovisual Analytics framework is that no conceptual model of GHC exists. A geo-historical context model can mediate human analytical reasoning when coupled to visual interfaces and data retrieval processes by conceptually and computationally structuring unstructured information that may be of relevance for producing context within a Geovisual Analytic or other context system (Strang and Linnhoff-Popien, 2004, Tomaszewski, 2007b).

This challenge for producing geo-historical context from implicit information is being addressed in a proof-of-concept system called the 'Context Discovery Application' (CDA) (Tomaszewski, 2007c). The CDA is a Geovisual Analytic environment intended to support the production of geographical and historical context from implicit sources for use in context analysis and situation assessment activities in humanitarian crisis management. The notion of the 'discovery' of context implies that users will be able to find information that produces geographical and historical context dimensions previously unknown through visually supported analytical reasoning processes.

The structure for the remainder of the paper is as follows. The following section provides a theoretical framework that underlies the motivations, design, and implementation of the CDA to addresses the challenges outlined above. Then, the computational processes, visual interfaces and general architecture of the CDA are described with a particular emphasis on visual interfaces to map-based and other geographic information. This is followed by a humanitarian context analysis case study used to illustrate the CDA. Finally, avenues for future work are explored and a research summary and conclusion are presented.

THEORETICAL FRAMEWORK

In this section, the theoretical framework of the CDA is discussed. Specifically, this section addresses: (a) definitions of context, situation, and other related concepts, (b) how these concepts are applied to a conceptual model of geo-historical context that structures specific data instances which are visually represented in various CDA interfaces, and (c) cartographic design approaches for representing computationally derived implicit geographic information used to aid analytical reasoning processes that determine the contextual relevancy of the information.

Context and situation

'Situation' and 'context' are concepts whose definitions as nouns, usages as verbs (such as ('to situate' or 'to contextualise'), and usages as adjectives (such as 'situated' and 'contextualised') can be easily intermixed. This paper differentiates the concepts of situation and context with the following definitions that are used to theoretically structure how the concepts are applied to the challenge of producing geo-historical context from implicit information. *Situation* is the complete set of geographic, historic, and other factors that can potentially provide information and act upon and influence the actions of a human agent or agent(s) working towards a goal (Brezillon, 1999a)[2]. *Context* then acts as a filter to a human agent's reasoning within the situation factors, providing the correct meaning and interpretations to situational factors for a given task and, ultimately, presenting the essential and minimal information needed for tasks through constraint of situation factors (Brezillon, 1999). The constraint and filtering capabilities of a context are represented through *context information*, or specific information that is used to represent the context such as specific layers on a map, or a particular map scale. Furthermore, an important distinction to make is between two descriptive categories of a given state of context information – *contextual* and *contextualised* information (Brezillon, 1999). Brezillon (1999:20) categorises these two descriptive categories as forms of context *knowledge*. Brezillon's categories are adopted and applied to ideas of context *information* discussed in this paper as context information allows for knowledge, but it is not knowledge unto itself, Brezillon distinguishes the two as:

- *Contextual* information intervenes implicitly in the problem solving, most often as constraints.
- *Contextualised* information is information that is explicitly considered in the problem solving.

The particular information category to which context may be assigned can shift quickly based on how the information is used. For example, when visiting a new city, a map may

[2] A dictionary definition of situation is: 'the total set of physical, social, and psychocultural factors that act upon an individual in orienting and conditioning his or her behavior' http://dictionary.reference.com/browse/situation, Last Accessed: 9 November 2007.

be of critical importance for *contextualising* the environment one has to interact and navigate in. Over time though, information from the map becomes *contextual* as one becomes familiar with the environment and establishes routines and patterns of travel. The map itself in fact may not even be needed anymore, except in cases when a task arises, such as visiting a location outside the familiar range of locations.

To summarise, when producing geo-historical context from implicit information, the *situation*, comprised of potentially numerous factors and represented by equally numerous forms of information such as text, images, and maps, is the setting that can potentially influence human activity. Geo-historical context then is produced from the situation by human reasoning processes that filter out and constrain situation information in order to develop correct meaning and interpretation of situation factors in order to accomplish particular goals. Geo-historical context is represented by geo-historical context information, such as maps, timelines, or concept graphs. In this paper, Geovisual Analytics approaches are used to aid the human reasoning processes that produce geo-historical context by using computational processes that can identify and extract potentially relevant context information in heterogeneous situation information and visual interfaces that help the user explain and understand the information.

Conceptual model of geo-historical context

The GHC model is used to model contexts that are beyond the realm of direct experience. GHC, as defined in this paper, can not be directly experienced because of multi-scale interconnections between geographical entities, abstract thematic concepts, and events that have happened in the past and can not be re-experienced again (Lowenthal, 1985, Peuquet, 2002). These distinctions differentiate the GHC conceptual model presented in this paper from models of context developed for context-aware computing environments that tend to focus on contexts within an immediate, directly experienced environment to support the automatic adjustment of devices to queries based on an estimate of context (Cai, 2007, Gartner *et al.*, 2007).

The GHC model is composed of three sub-models – geographic, historic, and concept. The natural separation of the GHC model into these categories begins with the intuition that space and time can be viewed as separate, yet interconnected phenomena that from various geographical, philosophical, scientific, and psychological perspectives, provide a basis for general understanding the world (Peuquet, 2002). Geo-historical understanding of the world, however, is not based on space and time alone. Concepts, themes and perspectives shape how space and time are interpreted and ascribe the level of knowledge needed to understand a situation (DeRose, 1992). Furthermore, space and time, respectively, can shape the concepts, themes and perspectives used to understand a situation, primarily through scale. From a representation perspective, a sub-model/separated approach is natural in that it allows each sub-model to be handled dynamically in relation to representation (Yuan, 1997).

Space/time/concept (or more accurately object) models have been used as a conceptual basis for various spatiotemporal data models in GIScience. None of these approaches, however, have specifically addressed the modelling of GHC. For example, the well-known Triad model of Peuquet (1994) is conceptual framework for structuring spatial–temporal queries and patterns expressed through combinations of relationships and referential bases between locations, times, and objects in a database. The Triad model is a spatiotemporal query language that answers space/time/object queries through combinations such as (1) when + where = what (2) when + what = where (3) where + what = when. The GHC model and the Triad model are similar to each other in that they both use sub-model referential bases and interconnections between those sub-models for understanding the phenomena they investigate from different perspectives.

The main difference between the GHC model and the Triad model is that the GHC model does not explicitly adopt objects as a sub-model. The GHC concept sub-model, instead of an object model, is meant to store concepts, themes and perspectives that interrelate with time (events) and space (locations) and may not necessarily be represented as database-storable objects (such as an abstract concept like human rights abuse), or rely solely on intrinsic object attributes (Perry *et al.*, 2007).

Furthermore, the GHC model is not a data model per se, but rather, is an information model. Production and subsequent representation of GHC does not come from raw observational data. Rather, it comes from derived information or knowledge by the virtue of the fact that context in general creates meaning/understanding based on the filtering and constraining of information that observational data alone can not create. Thus, the GHC model is theoretically more related to the Pyramid model, which is an expansion of the Triad approach where observational data are stored in a data component and information and knowledge derived from the data component are stored in a knowledge component in order to facilitate deeper understanding of observational data (Mennis *et al.*, 2000).

The GHC model also differs from other spatio–temporal models in that it is meant to model contexts of reasoning. By using separate sub-models, subsets of (or local) information based on the conceptual structure of each sub-model can be derived from global knowledge bases (such as all possible geographic locations or historical events that may be relevant contextually) and can be distinguished, described and locally reasoned with for a given goal (Ghidini and Giunchiglia, 2001). Finally, visual interfaces for context information instances based on each sub-model can be developed and related to one another to support contextual reasoning. For example, a geographic map for geospatial information, a time line for historical information, and a concept graph for conceptual information.

Although localised, compatibility relations exist between each sub model. Compatibility relations refers to mutually influential relationships between separate, local models where similar perspectives and reasoning contexts can describe the same piece of the world but with different details (Bouquet *et al.*, 2001). As a geographic example, a local model consisting of a single US state is compatible with another local model of all counties from that state by virtue of topological and political relationships.

The combinations and sum of relationships of specific data instances within and between each of the sub-models ultimately produce a GHC that can support a given task. Detailed discussions about the conceptual structure of each sub-model are beyond the scope of this paper, therefore brief synopses of each sub-model are provided.

The geographic sub-model is based on the idea of a parsimonious spatial data model as outlined in (Jones *et al.*, 2001) where minimal, coordinate-based representations of place are desirable as they are more closely related to geographical gazetteer models than traditional GIS models. An advantage of using a parsimonious spatial data model is that geographical gazetteers are a key component in geocoding tasks, provide simple representations of geographic locations that can be reasoned with by an analyst, and provide a starting point for developing deeper geographical meaning through combinations of geographical location information with historical and conceptual information.

The historic sub-model is based on the ideas of *occurrents*, or processes, activities and events that exist in successive temporal parts and phases with discrete beginnings and ends (Grenon and Smith, 2004). Like the parsimonious spatial data model, occurrents can be represented using simple visual interfaces such a 2D linear time line that is easily understood by analysts (André *et al.*, 2007, Aigner *et al.*, 2007). Occurrents are visually represented in the CDA using the SIMILE timeline interface (SIMILE project, n.d.).

Concepts, as a sub-model, are meant to capture non-spatiotemporal aspects of a GHC. The concept sub-model ultimately serves in a filtering or sub-contextualisation role within the overall GHC model. This sub-contextualisation effect comes from non-spatiotemporal concepts providing themes, perspectives, and viewpoints on the historical and geospatial sub-models through compatibility relationships between the sub-models such as spatial properties of theme entities not explicitly recorded or thematic relationships that indirectly provide spatial properties (Perry *et al.*, 2006). Concepts are visually represented in CDA using a node-link graph interface.

As implemented in the Geovisual Analytic system discussed below, the GHC model supports simple 1-to-1 relationships between specific information instances in each model such as a specific event at a specific location, or a specific concept associated with a specific event and/or location. Conceptually, compatibility relations between the sub-models are generally based on scale, topological, and subsumption relationships The GHC model components and their compatibility relationships are visually summarised in Figure 1 and use information instances from the Sudan as examples.

Table 1 outlines seven compatibility relationships between the three sub-models shown in Figure 1. Note that in most cases the relationships provide constraint in the form of spatial topologies, or the effect of spatial, temporal, and conceptual/attribute scale.

Design framework

As the focus of this paper is on producing geo-historical context from implicit information (geographic information

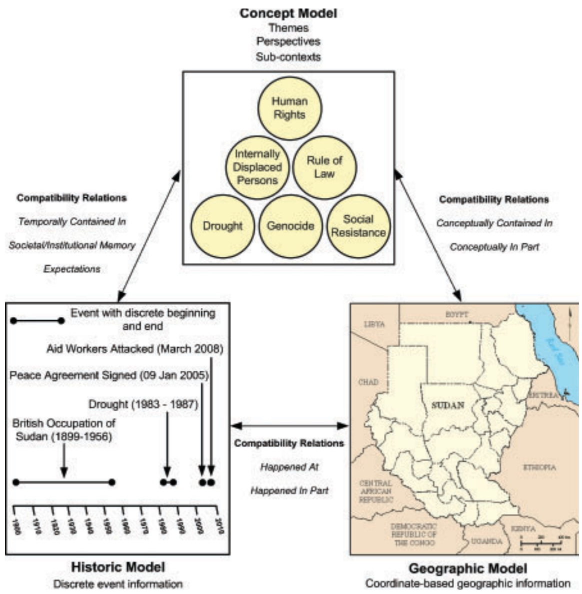

Figure 1. The GHC conceptual model. Sub-models use data instance examples from Sudan

from text in particular), it is necessary to discuss design approaches to representing geographies that are computationally derived from text. Limited discussion on cartographic design for geographic information derived from text has been made (see (Purves *et al.*, 2005) for a discussion on visually representing and exploring document footprints derived from spatial information retrieval procedures). Both representation and computational extraction procedures, in general, tend to focus on generating point-based representations of phenomena due to current lack of sophistication and difficulty in determining areal focus and document footprints (Leidner, 2007).

In particular, maps created from implicit sources through text extraction procedures have the challenge of displaying multiple scales of administrative units found in text and imprecise regions (such as 'northeast' or 'north of') (Tomaszewski, 2007a). For example, in this text:

> The National Weather Service is warning about possible flooding on the North Fork of the Elkhorn River in **Pierce County**. The service also has extended a flood warning for **Cedar County** in **northeast Nebraska** until 10:30 Sunday morning. The sheriff's department says there is lowland flooding in **rural parts of the county**, mostly **north of Hartington**. Floodwater has closed several **Cedar County** roads.

geographical entities at multiple scales (towns, counties, and states; shown **in bold**) can be found. The challenge of displaying multiple scales of administrative units found in text as point phenomena is compounded when the locations returned from the procedures are rapidly shown to the user at an initial, fixed viewing scale, and/or large volumes of data must be examined.

Furthermore, visual representation of multi-scale interconnections between places, such as conceptual connections between the origin point of a document based on a summary description of the document and the locations

Table 1. GHC model compatibility relationships

Sub-model Interactions	Compatibility Relationship Name	Comments	Example
Geographic Concept	*Conceptually Contained In*	Concepts/locations have explicit connections (or space is a property of concept) by virtue of scale, and/or topology	Concept: Human Rights Abuse. Geospatial: Rapes near Nyala, Sudan
	Conceptually In Part	Specific concepts subsume locations at scale thresholds because of broad or implicit scale dimensions	Concept: Internally Displaced Persons (IDPs). Geospatial: Darfur region
Concept Historical	*Temporally Contained In*	Discrete beginning/end of events within the scope of a concept	Concept: Rule of Law. Historical: Comprehensive Peace Agreement signed, 09 Jan 2005
	Societal/Institutional Memory	Concepts do not match to particular discrete events, interpretation/memory of events contestable	Concept: Social Resistance. Historical: Southern Sudan Conflict. Contested Interpretation: Sudan People's Liberation Army – revolutionaries or terrorists?
	Expectations	Concepts and events combined create expectations for the future	Concept: Drought. Historical: Sudan Droughts of the 1980s. Expectation: Future droughts will create famine/social upheaval, refugee situation
Historical Geospatial	*Happened At*	Specific event(s) at specific location(s)	Historical: Aid workers attacked (March 2008). Geospatial: Julud, Southern Sudan

mentioned in the document, can aid in producing GHC. Visually representing such connections has the potential to reveal relationships between places that may not be readily apparent when the place references are text-based and contained within web documents from different sources.

Information categories will also have a variety of attributes, most notably temporal attributes such as when a data source was created. Visually representing temporal attributes is important for indicating the relevance of a given piece of information in relation to understanding the present context of a situation or how a situation has evolved over time (Kapler and Wright., 2004).

Non-spatiotemporal concepts found in text can be visually indicated to the user in order to impose structure on thematic dimensions of potential interest to user within an information space (Gahegan and Pike, 2006). Concepts found can be anchored to a cartographic display in order to visually represent a concept's relationship to the underlying geography (MacEachren, 2007).

Effective information display design (i.e., that maps data to the visual variables of the display in logical ways) can aid the user in making relevancy assessments of harvested information by helping the user quickly distinguish features or attributes of information that may or may not be of contextual relevance importance (Keim *et al*., 2004). Table 2 specifies how visual variables apply to GHC sub-models to represent point, line, and area features. Figure 2 shows how some of these design principles have been applied using the CDA to create geovisual outputs from a text extraction process.

CONTEXT DISCOVERY APPLICATION

Features and overview

Current Geovisual Analytical functionality of the CDA includes automated retrieval of text-based information from Real Simple Syndication (RSS) feeds and computational processing, geocoding and visualisation of geographic place names and possible relationships between places across geographic scales over time from retrieved content.

RSS feeds were selected as a primary information source since they are commonly used for publishing web content that is easily accessible due to the XML structure of an RSS[4] feed (Grossnickle *et al*., 2005). The disadvantage of RSS is that their contents are not always representative of the entire content a web site may contain, and thus may only provide a partial view of content that is available.

The CDA also supports concept map integration to find potentially relevant non-spatial dimensions within information retrieved. Concept maps can help to conceptually structure information being found in searches (which is usually loosely structured) and by making concepts of a given domain accessible to a non-expert user by highlighting those concepts when they are found in the search and thus indicating which terms may be of relevance to the user (Tergan, 2005). Geographic information presentation and synthesis functionality is supported using a 'Geographic Sandbox'. The Geographic Sandbox uses tightly coupled map displays to allow users to simultaneously view geographical locations in a virtual globe and standard 2D cartographic perspectives for geographical orientation analysis. Theoretically, the linked 2D/3D map display approach provides the user with multiple external geographic views of areas that can enhance users' working memory and subsequent reasoning capabilities by increased duration and capacity of stored information (Keller and Tergan, 2005) Practically, the Geographic Sandbox serves as a visual space for placing location deemed contextually relevant by the user. Further technical details are discussed later in the 'Geographic Sandbox' subsection.

[4]For more information on RSS, see http://en.wikipedia.org/wiki/RSS_(file_format) (Last Retrieved 23 March 2008)

Table 2. Design matrix for implicit information derived from computational and representational procedures. Items in *italics* are proposed design ideas and not shown in Figure 2

	GHC Sub-Models		
Symbol type	Geographic[3]	Historic	Concept
Point	Size – Variation in size based on administrative scale (visual hierarchy); variation in size based on place frequency reference (graduated symbol)	Transparency – Can be used to show temporal decay of a data source (for example, the older a document is, it will appear to be fading away)	Perspective/Height – Can be used to anchor non-spatial concepts above related locations, height can signify importance of concept such as frequency of mention in a data source or for concepts derived from graph-based ontologies, number of connections the concept has, thus indicating potential importance (see Figure 7)
	Shape – Variation in shape based on administrative scale, useful for when data is first presented to the user at one display scale		Shape – Variation in shape based on type of concept
	Hue – Can make objects of potential interest more discernable, especially in cluttered displays (Kroft and Wickens, 2003)	Hue – Can be used to show temporal decay of a data source. For example, a newer or 'hot' document might be shown in red. This can be useful when the temporal scale of data sources is short, such as breaking news story for a situation coming out every hour.	
Linear	Connections between places –	Hue– Can be used to distinguish between different data sources	
	Size– Can be used to frequency of connections between places		
	Spacing – Can be used to show certainty of connections Example – dashed line to show uncertainty in a relationship		
Areal	Shape – Can be used to generalise patterns such as point clusters		

System architecture

The CDA uses a client-server architecture and is implemented using Java™, Google™ and Flex™ technologies. The client tier uses both an online interface and a desktop client in the form of Google™ Earth (GE). The server tier hosts a gazetteer database, supports connections to outside web services for specialised text processing, provides geographic information retrieval, extraction, geocoding, and GeoRSS web services, and constructs and serves the output visualisation that is rendered in the GE client. Figure 3 shows the general architectural components of the CDA.

The CDA was built to use as much using stable, open-source web technologies as possible and was designed using a web 'mashup' approach. A web mashup refers to loosely coupled software components and data combined into a unified interface to create a unique application[5]. The CDA web client can therefore easily swap visual components such as map interfaces, time lines and concept graphs in and out as new components are developed and can work across technological formats and programming languages.

Adobe Flex™ (hereafter referred to as 'Flex') was chosen to develop the client component as the Flex development environment is a Free Open Source Software (FOSS) environment[6], and web interfaces developed in Flex can be run using the AdobeFlash Player which is free and used by 98% percent of Internet enabled desktops[7]. Disadvantages of using Flex are that despite the widespread presence of the Flash Player plugin, a web browser plug in is none the less still required to run the web client.

The open-source Open Layers[8] mapping client was used as the 2D mapping client in the CDA due to the fact that map interaction is very similar to the map interaction of Google Maps, a widely used (but proprietary) mapping tool that is familiar to many users. Open Layers can easily incorporate Open Geospatial Consortium (OGC)[9]-compliant data, and is a pure-javascript library, making it possible to integrate into the mashup approach used by the CDA. Other open-source 2D map clients exist that also could be viable candidates for use as the 2D mapping client in the CDA, but these other alternate options were not explored as Open Layers was deemed

[3]A or P Feature Class Entities (first-order administrative division, populated places etc), feature codes and classes are based on the GeoNames.org Feature Code list at http://www.geonames.org/export/codes.html (Last Retrieved 9 January 2008)

[5]http://en.wikipedia.org/wiki/Mashup_(web_application_hybrid) (Last Retrieved 23 March 2008)

[6]http://labs.adobe.com/wiki/index.php/Flex:Open_Source (Last Retrieved 23 March 2008)

[7]http://www.adobe.com/products/player_census/flashplayer/ (Last Retrieved 23 March 2008)

[8]http://www.openlayers.org/ (Last Retrieved 23 March 2008)

[9]http://www.opengeospatial.org/standards (Last Retrieved 30 March 2008)

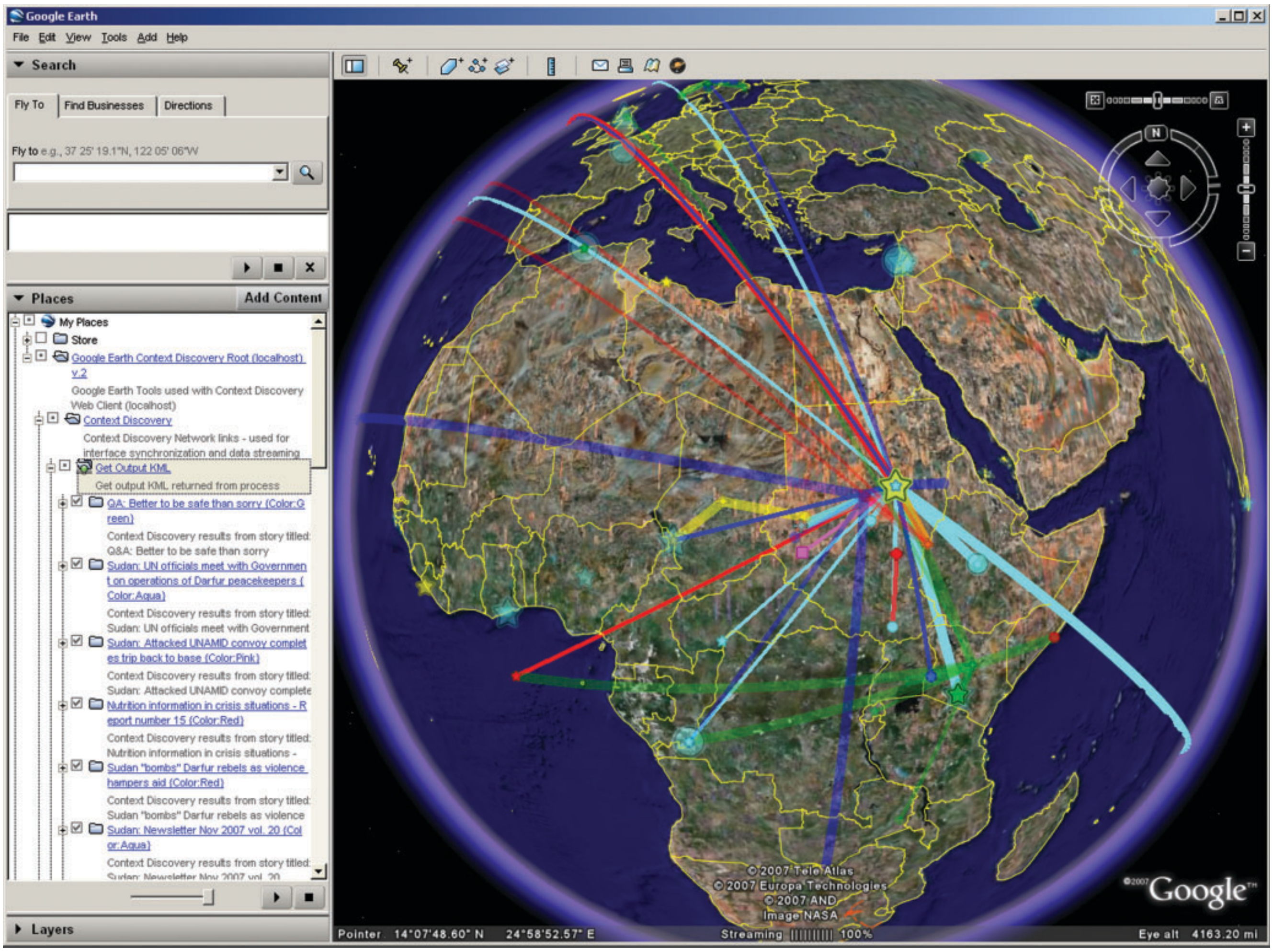

Figure 2. Visual examples of selected Table 1 design matrix principles created by the CDA

sufficient in terms of functionality and scalability for the CDA.

Google Earth (GE) is used to present CDA search results in a virtual globe environment as it is a tool that is highly interactive and relatively easy to use through exploration, characteristics that are important for Geovisual Analytics tools (Allendoerfer *et al.*, 2005). GE was also used because its scripting environment offers flexible visual encoding and data processing (Wood *et al.*, 2007). The CDA creates custom views and renderings and integrates custom functionality through the Keyhole Markup Language (KML), an XML-based structure used to define customisations in GE. KML was also used as it is currently under review for becoming an Open Geospatial Consortium (OGC) standard and, thus, has potential to provide greater interoperability between web mapping systems (Open Geospatial Consortium, 2007). Disadvantages of GE is that it a closed, proprietary system. NASA's World Wind system[10] is an open source, alternative virtual globe that will be examined in the future for incorporation into the CDA.

[10]http://worldwind.arc.nasa.gov/ (Last Retrieved 23 March 2008)

Text capture and geocoding functionality

This section discusses specific functionality used by the CDA for capturing, extracting and geocoding textual content may provide potentially relevant context information.

Capturing content from RSS feeds

Upon retrieving an RSS feed, the CDA opens each web page referenced in the RSS feed and extracts relevant text content from the web page. Figure 4 shows the basic process of how the CDA extracts relevant text content from a web page referenced from an RSS feed.

After the relevant content is extracted from a web page, the contents are then sent to the CDA's geocoding process.

Geocoding process

The CDA performs geocoding using a pattern matching algorithm combined with the Generic Architecture for Text Engineering (GATE) toolkit (Cunningham, 2002). GATE is used to perform textual annotation of named-entities (i.e. locations, people, organisations) and parts-of-speech annotation (verbs, nouns) within the input text. For locations in particular, GATE uses a gazetteer approach for annotating locations. A gazetteer approach refers to using predefined location lists that serve as references when attempting to

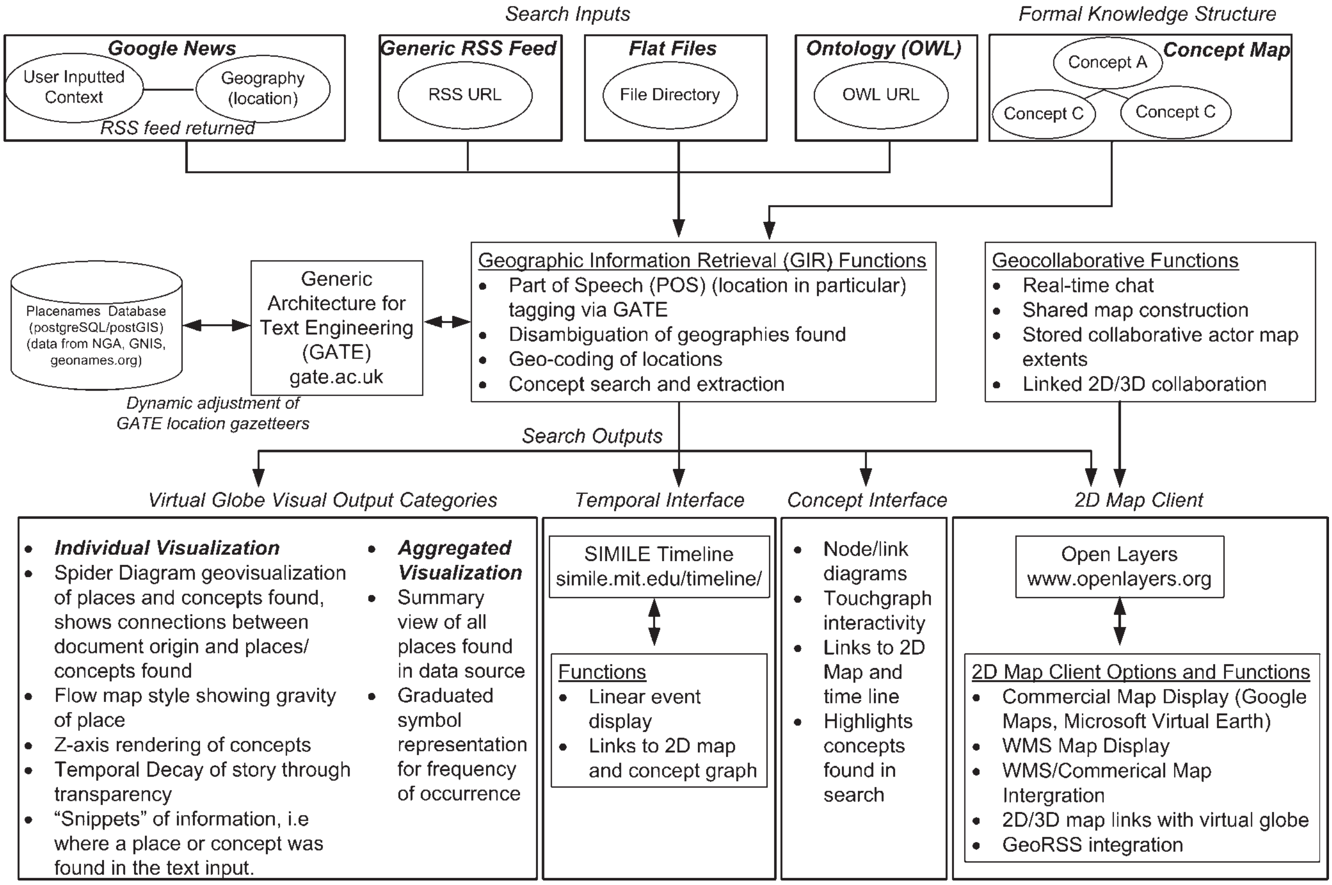

Figure 3. CDA Architecture Overview; the section entitled 'Using the CDA – a walkthrough' includes a detailed discussion of some of these components

determine if a word being examined is in fact a location. As the default gazetteers of GATE do not provide effective geographic granularity for Geographic Information Retrieval (GIR) at scales beyond large cities, the CDA dynamically adjusts GATE's location gazetteers based on a default 'sense of place' for a search. For example, if documents are being retrieved from an RSS feed related to the Sudan (as determined by examining the title tag of the document in the RSS feed), the CDA will automatically update GATE's location gazetteers to include place names from the Sudan. The CDA establishes a default sense of place and origin point for a document by examining the contents of the RSS feed's title tag. Often, a place reference will be found in the title tag. If a place reference is not found in the title tag, broader scale gazetteers such as country names or cities with populations over 50 000 are used in the search.

The benefit of using a default sense of place approach is that irrelevant place names are not included for matching, thus potentially preventing false positives. The limitation of this approach is that it requires there to be a default or user-provided sense of place for a document in order to adjust the gazetteers, or a sense of place that is reasonably bounded in scale (such as a state or country).

Using the annotation provided by GATE, the CDA then attempts to construct 'geophrases' that capture near-context word information around location words found, an approach similar to that discussed in (Li *et al.*, 2003). The purpose of this step is to help with disambiguating locations found. For example, in the sentence:

The flood will effect Springfield County.

The word 'Springfield' will be tagged as a location, but given the many possible Springfield's that exist (cities, towns, counties, businesses, etc.), it is difficult to determine which one to geo-code the word to. By identifying the term 'County' after the explicit reference of a location, the geophrase 'Springfield County' can be used to guide the geo-coding as the term 'County' provides meta-information about the scale of the entity that was found.

If a document has a default sense of place, this meta-information can help pinpoint a location within the extent of the default sense of place (i.e. a state). If no default sense of place for a document exists, this information is still of use, but the location will be more difficult to determine and may need to be compared with other locations found in a document, such as a city that is potentially in the same state as the place that is to be geo-coded.

USING THE CDA – A WALKTHROUGH

This section discusses a case study of how the CDA can be used for humanitarian context analysis using open source media.

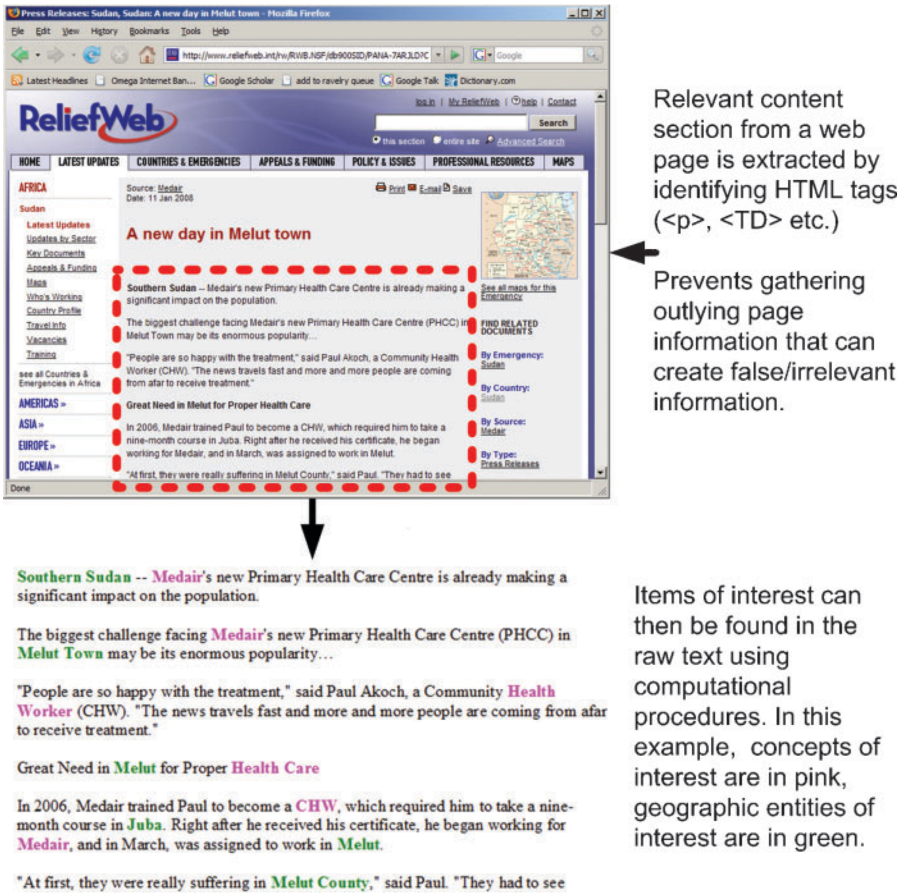

Figure 4. Extracting relevant web page content for text processing

Scenario – Humanitarian context analysis

Projects that address humanitarian issues such as building schools, hospitals, and sanitation facilities often seek funding from aid agencies such as the World Bank, the European Union, or governments of specific countries. Project details such as the motivation behind the project, work that will be conducted, and the amounts requested to complete the project are documented in reports generated in the *Consolidated Appeals Process* (CAP) [Office for the Coordination of Humanitarian Affairs (OCHA), 2007a]. Context analysis is the starting point in the CAP (Figure 5).

Context analysis is meant to 'outline the root cause of the crisis and its evolution, including any regional or historical dimensions' [Office for the Coordination of Humanitarian Affairs (OCHA), 2007b:3].

Thus, GHC can be produced by gathering and reasoning with subsets of varied geographical, historical, and conceptual situation information as structured by the GHC model in order to understand and establish the context of a crisis to begin the process of developing a formal appeal plan. During development of the appeal report, context may implicitly frame report generation activities by filtering and constraining information that is under consideration or by being explicitly considered. Explicit or implicit context information can aid in answering specific questions that may arise during generation of the report such as:

- What are the locations that have been affected by the crisis over a given time period?
- How do locations relate to events and thematic/conceptual aspects of the mission or focus of a group developing a CAP? For example, an NGO that focuses on women's rights and security issues examining where instances of rape have occurred over time.

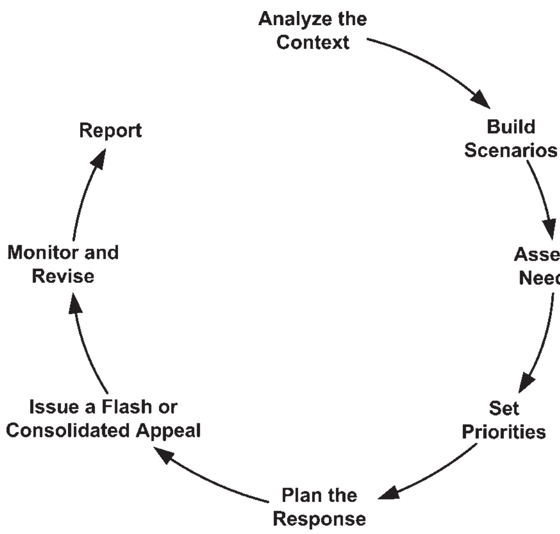

Figure 5. The Consolidated Appeals Process (CAP) Cycle, figure based on [Office for the Coordination of Humanitarian Affairs (OCHA), 2007(a)]

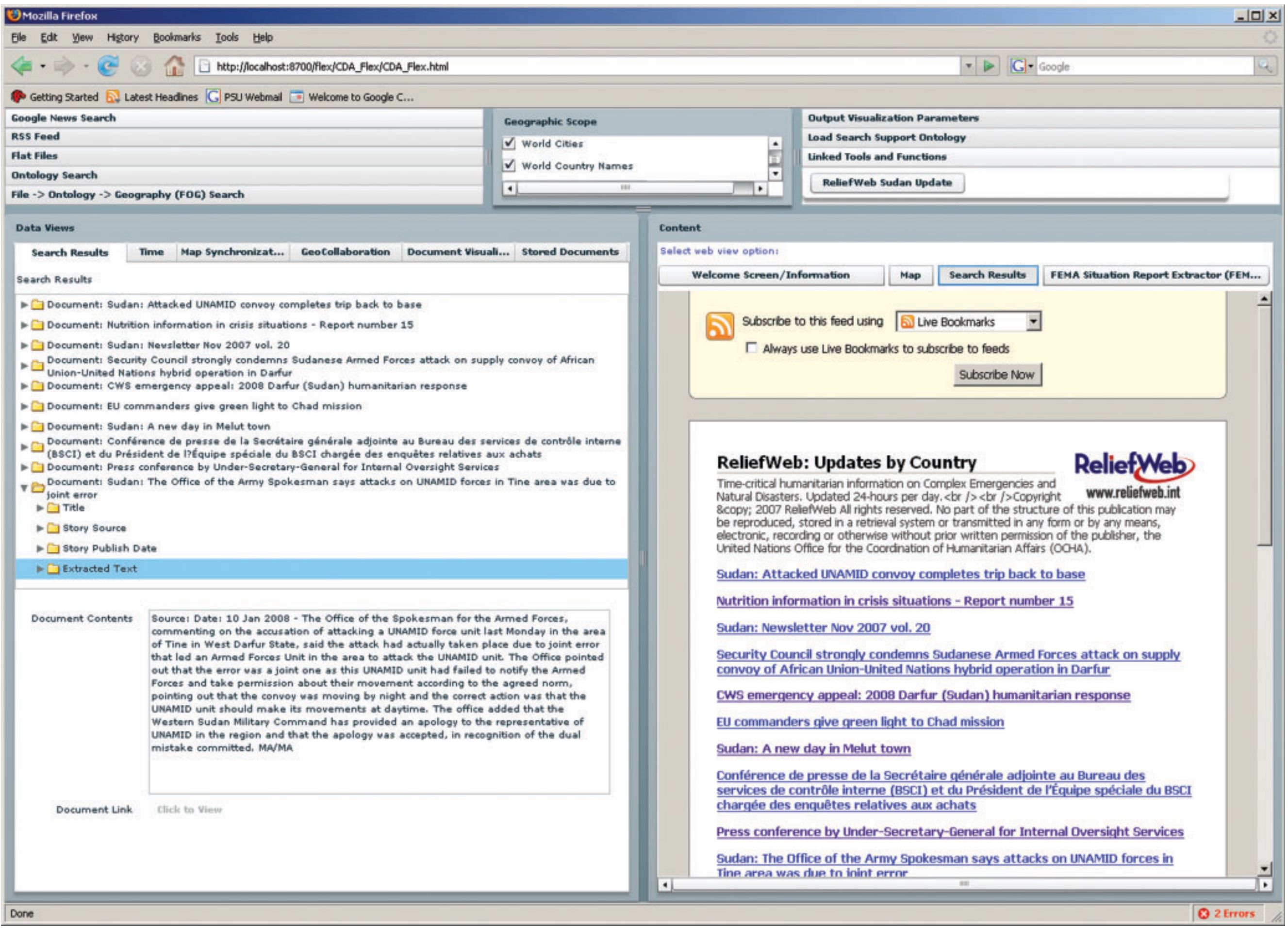

Figure 6. ReliefWeb Sudan RSS feed (right) and extracted feed contents (left) in the CDA

In this case study, a fictional analyst working for a hypothetical non-governmental organisation (NGO) is doing a context analysis of the long-term humanitarian crisis situation in the Sudan using open source media. The analyst uses the CDA to produce a GHC based on integrated representations of geographical information extracted from text combined with existing maps and geographic databases, and visual representations of stored temporal and conceptual information in order to establish the geographical, temporal, and thematic contextual dimensions of the crisis.

Capturing information – RSS data extraction

The analyst starts by using the CDA's Real Simple Syndication (RSS) feed extraction tool discussed above in the subsection 'Capturing Content from RSS Feeds'. In particular, the analyst wishes to extract content from the ReliefWeb Sudan RSS feed (ReliefWeb, 2008). The analyst starts the context analysis with ReliefWeb because ReliefWeb is an authoritative world repository for humanitarian information, and is often seen as providing the context for humanitarian crisis situations (Wolz and Namho Park, 2006). The analyst also incorporates a concept map of humanitarian terms into the search so that formal knowledge about non-geographical concepts can be tagged during CDA document processing and visually represented in the concept model interface. Figure 6 shows the Sudan RSS feed inside the CDA web client interface.

Relevant text content from each web page referenced by the Sudan RSS feed is retrieved and geocoded using the process as discussed above in the 'Geocoding Process' subsection. After the text extraction and geocoding processes are complete, the analyst then reviews the extracted and geocoded information using a CDA-generated Google Earth visualisation to begin making determinations about the potential contextual relevancy of the information.

Google Earth visualisation

KML is used to render the results found by the CDA's geographic text extraction and geocoding process in GE. Using a network link connection, the analyst can easily take the KML-based output renderings from the CDA server component for addition into GE. Figure 7 is a screen shot of a CDA rendering of documents based on the analyst's query of the ReliefWeb Sudan RSS feed and formatted as per the design guidelines outlined in Table 2

Each place found in the search is connected to the established origin point (as determined by examining the title tag of the document in the RSS feed) using a line. In

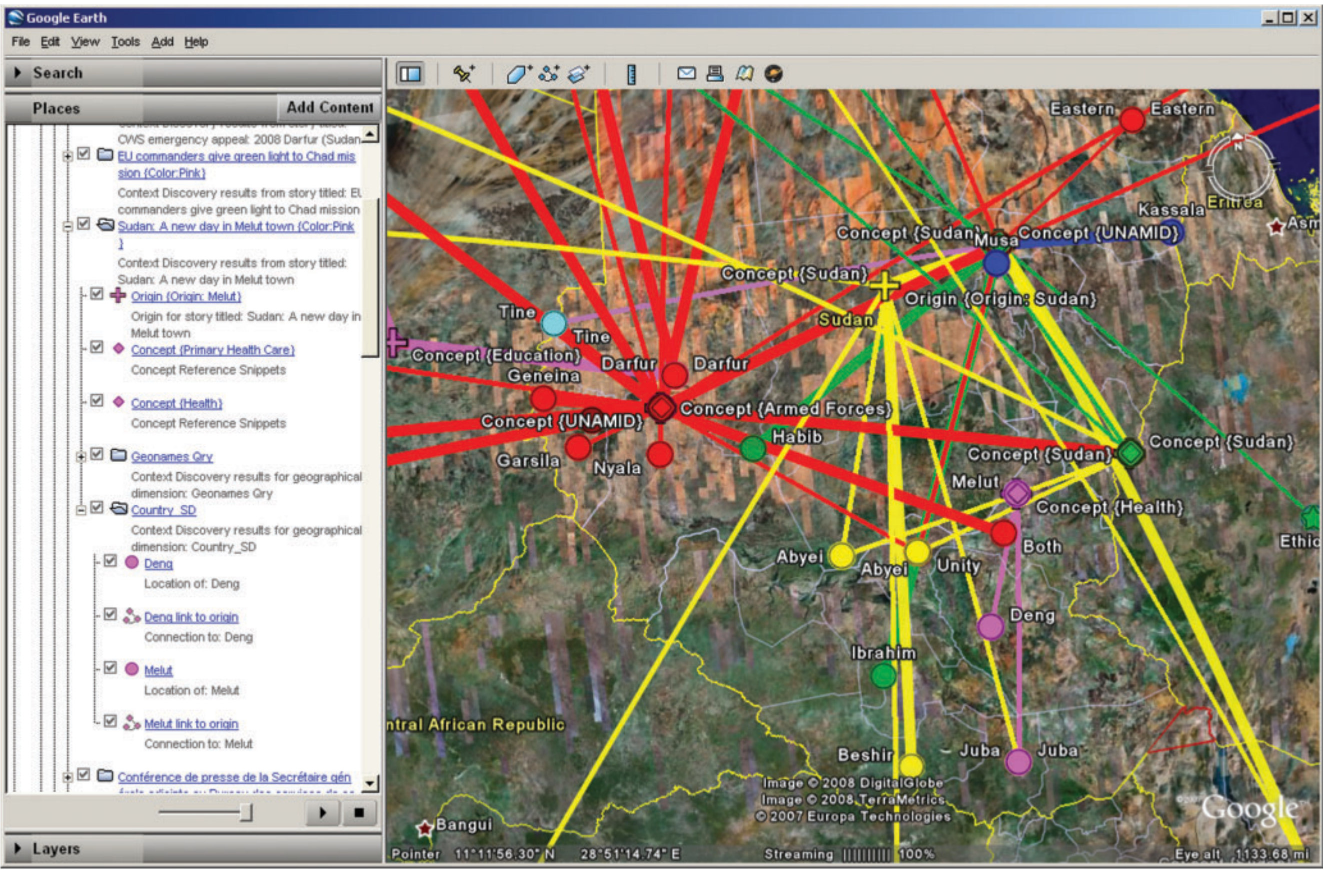

Figure 7. CDA Output rendered in Google Earth

the present implementation, if an origin point was not established for the document, connection lines are not created, and locations are rendered as a graduated symbol based on frequency of occurrence in the document.

As seen in Figure 7, when an origin point is established, the thickness of the line indicates the number of times a place was referenced in the news story, point symbols represent the geographic scale of the entity found (town, country etc.). Transparency of lines and points indicate how old the story is relative to the time when the geovisualisation was created. These approaches are used to give a quick overview of the information returned before the analyst decides to potentially removing unneeded or irrelevant information.

Each document processed by the CDA is listed in the Google Earth legend. Legend items contain folders for geographic and non-geographic concepts found. Structuring information retrieved from the CDA search in this way provides the analyst with interactivity over geographic scale and concepts and can aid in determining which items may be of contextual relevance.

Automated geocoding procedures often make incorrect assignments of terms to locations. Therefore, it is critical that the analyst is allowed to review how a given term was geocoded. Furthermore, concepts identified during the search may be unfamiliar to the analyst. To address these issues, the CDA provides the analyst with visual 'snippets' of extracted entities in order to review how extracted locations or concepts were used in the context of the source document (Figure 8).

For concepts in particular, a link to a Google search on the term (not shown) is provided to help the analyst with understanding potentially unfamiliar concepts. Furthermore, concepts are visually displayed in 3D space to indicate possible importance of the concept. The number of times a concept is mentioned within a given document will determine the height the concept is drawn in 3D space (Figure 9).

Once the search is complete, the analyst now begins a process of reasoning to determine which pieces of geographic and conceptual information extracted are relevant to the context analysis task. In addition to the GE visual encoding strategies previously discussed, the CDA provides the analyst with two visual interface methods to aid in reasoning with information returned – the Geographic Sandbox and a linked space/time/concept interface.

The Geographic Sandbox

The intent of the Geographic Sandbox is to provide the analyst with a map space into which he/she can place pieces of information pulled out from GE as deemed relevant. The tool is based on the idea of the analysts' Sandbox presented in (Wright *et al.*, 2005), a general purpose (concept-oriented rather than geographic oriented) 'space' for

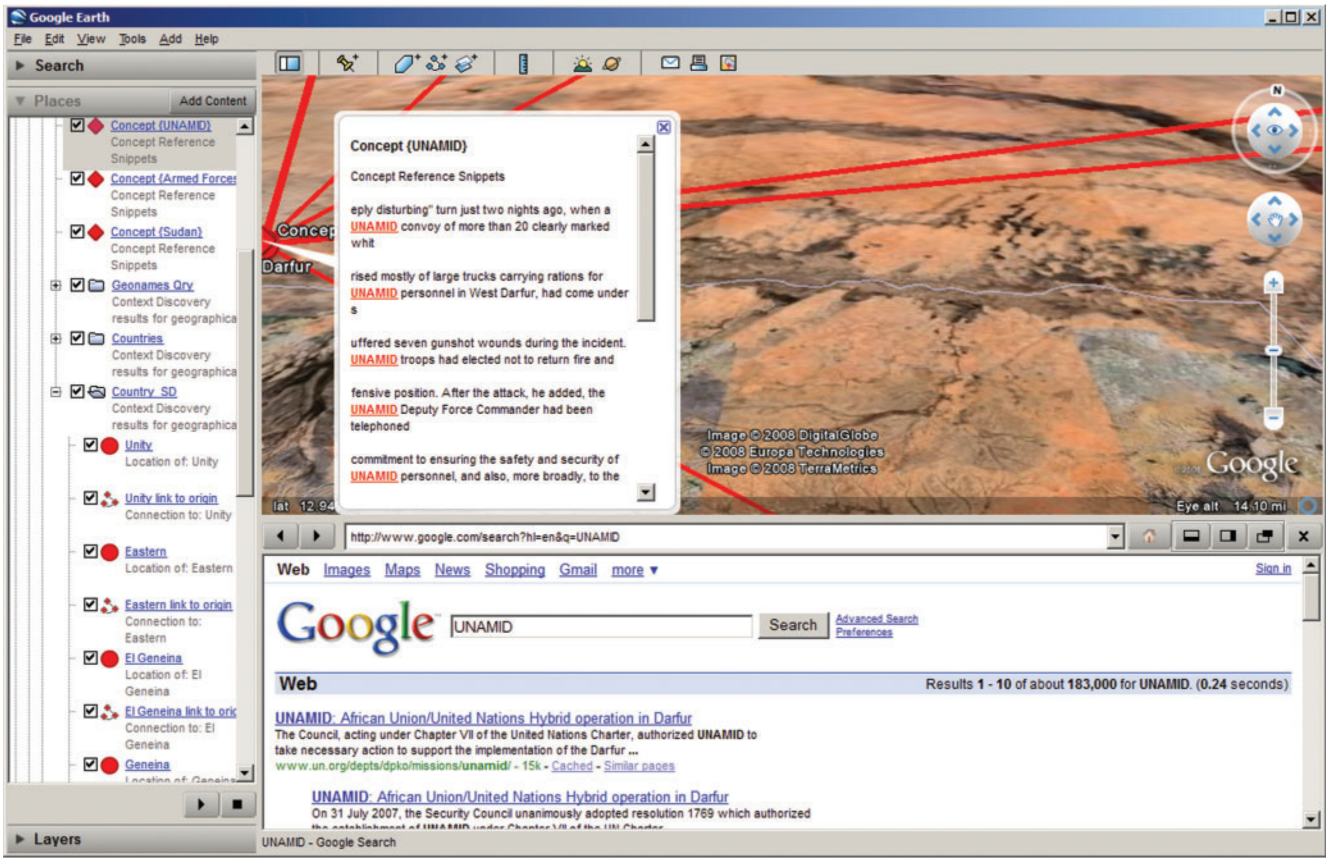

Figure 8. Reviewing extracted entities snippets

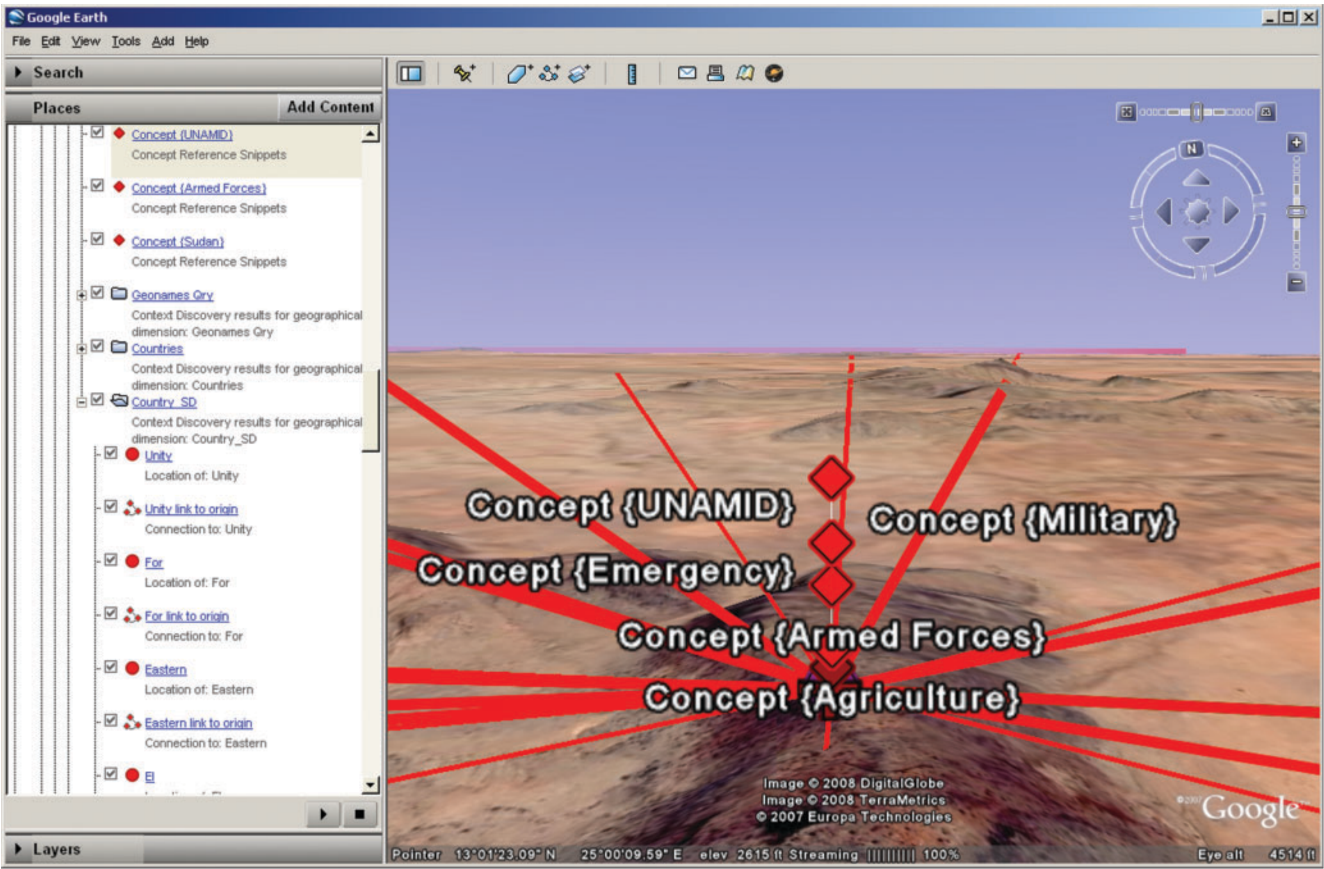

Figure 9. Reviewing concepts in 3D space

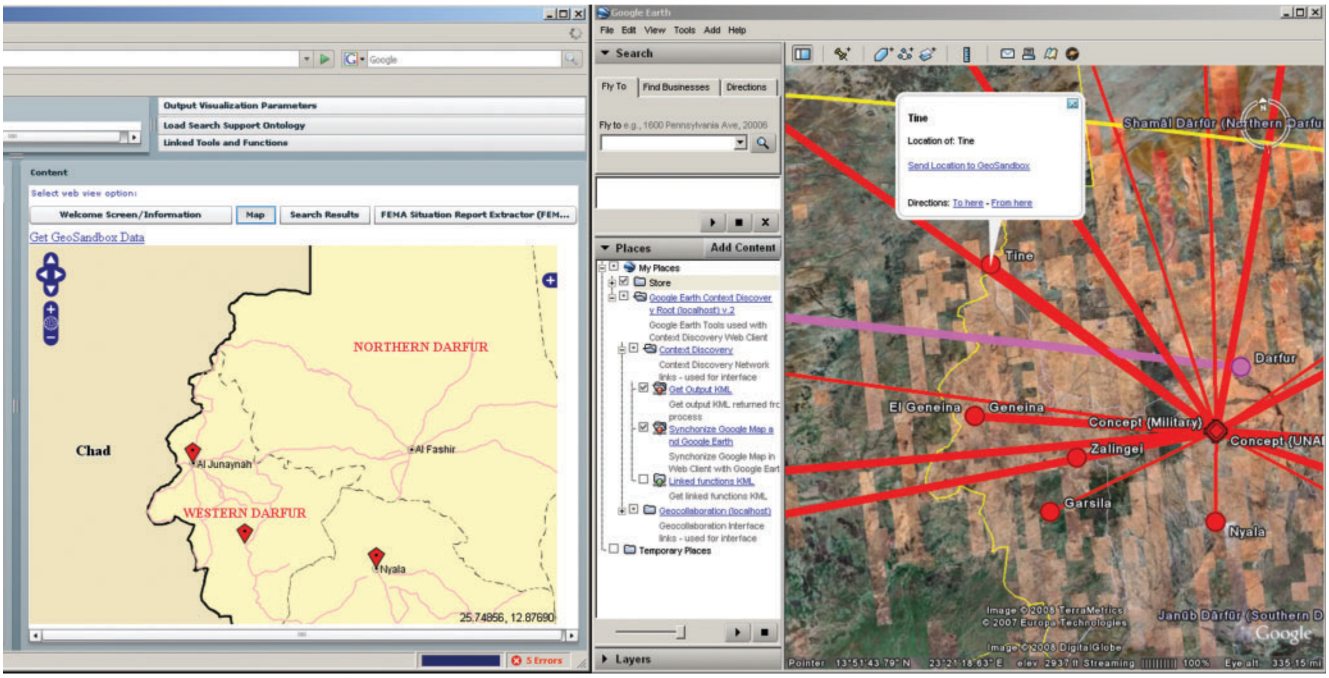

Figure 10. The geographic sandbox – Linking GE with a 2D WMS map

organising fragments of evidence in support of intelligence analysis.

Another goal of the Geographic Sandbox is to provide the analyst with multiple views of the geography being investigated. These multiple views come in the form of linked map representations and overview and zoomed perspectives of geographic and other data being examined. The CDA accomplishes this goal by using a novel approach that links the virtual globe views of GE with 2D Web Map Services (WMS) maps contained within the Open Layers web mapping client software. By using this approach, the analyst can (a) seamlessly use GE for exploration with a standard 2D cartographic display that may be better suited to their work, such as incorporating organisational map symbols or other relevant styling, (b) maintain geographic orientation, for example having the 2D display indicate where in map space a user is when in the 3D view of GE, and (c) and manipulate perspectives where the flexible scaling between GE and Open Layers allows either to easily serve as the overview or detail due to ease of scale manipulation and/or the map data used in the 2D client (Figure 10).

The basic process of using the Geographic Sandbox is as follows. The analyst can send a location of interest from the GE view into the Geographic Sandbox by clicking on a link that sends the location's coordinates and info into a GeoRSS feed. The CDA 2D map client reads the GeoRSS feed and renders the locations in the 2D WMS map. In the example above, the locations Nyala and Al Juniah have already been added to the Geographic Sandbox and the user is in the process of adding the location Tine.

Space/Time/Concept Interface

Another visual interface available to the analyst for producing GHC is the Space/Time/Concept Interface. This feature provides the visual interface to the three sub-models of GHC outlined in the subsection 'Conceptual Model of Geo-historical Context' above. The intent of the Space/Time/Concept Interface is to enable reasoning about local information through visual representations of information structures by each of the GHC sub-models and through compatibly relationships between the sub-models.

For example, locations involved in a complex crisis situation may have multiple conceptual and/or temporal dimensions that may be of relevance for producing GHC. Conceptual and/or temporal dimensions can thus provide filtering capabilities that determine which locations are relevant based on relationships among concepts, events, and locations (Figure 11).

In Figure 11, concepts that were found during the search and extraction of the Sudan RSS feed based on the user inputted humanitarian concept map are highlighted in yellow. Highlighting concepts that were found helps the analyst to understand what conceptual elements are contained within the document space that was searched and to suggest concepts that the user may not have considered as contextually relevant (Leake *et al.*, 2003). Furthermore, neighbour concepts to those extracted can be revealed to indicate connections between concepts not previously considered.

The analyst clicks on the UNAMID concept found during the search to see if there are any events related to the concept. The concept is linked to a UNAMID security event from 2005 and the timeline moves accordingly to this event about women being raped. The event on the timeline is linked to the map. The analyst can see where the event took place by clicking on the link associated with event making the map automatically re-centre at the location of the event. Together, the linked map, timeline, and concept map tools and information retrieved by the CDA provide

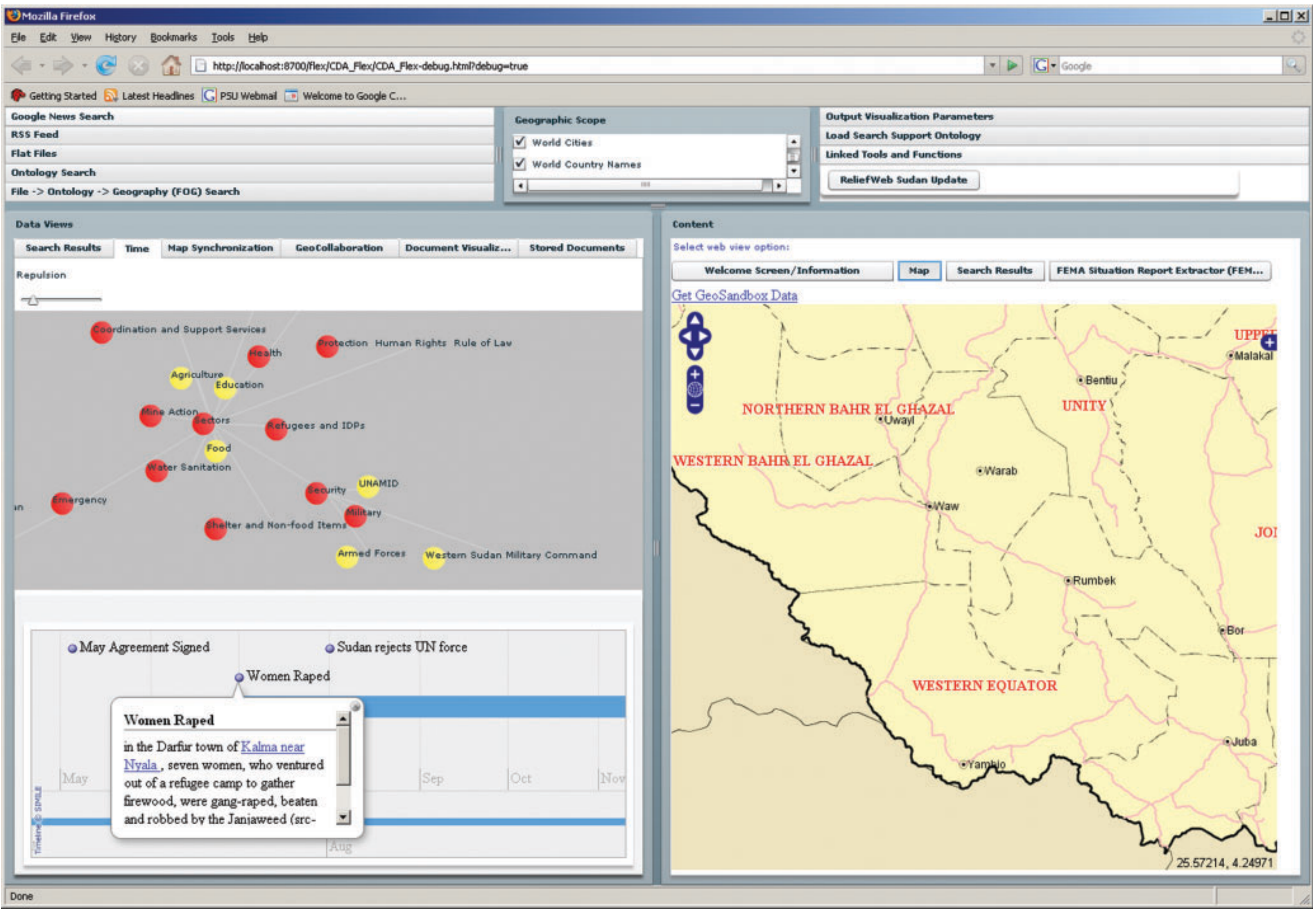

Figure 11. Space/Time/Concept Interface

the analyst with the GHC for interpreting events that UNAMID has been involved with.

FUTURE RESEARCH

Numerous avenues for future research exist for both conceptual and technological aspects of and application areas for the CDA. The two main conceptual and technological areas that will be pursued in future work are collaborative geovisual analytics and automated reasoning integration.

Supporting collaborative Geovisual Analytics

Since most of the humanitarian issues to which the CDA may be applied involve different place collaboration, an important next step is to support collaborative Geovisual Analytics. Analytical reasoning end products, such as situation reports for decision makers, are rarely created by individual analysts. Therefore, research is needed to understand how human analytical reasoning processes operate and how they can be visually supported within the inherent collaborative and team-oriented nature of work within domains like crisis management. Visual artefacts and interfaces help provide awareness of many factors within dynamic systems such as the activity of collaborators and external events. They are critical for representing situational states of these systems that allow humans to interpret, reason about and understand these systems (Garbis and Artman, 2004, Keel, 2006). Ongoing development of the CDA to address these issues includes functionality to support real-time and asynchronous geocollaboration (Tomaszewski and MacEachren, 2006).

Furthermore, collaborative Geovisual Analytics adds the conceptual challenge of how to account for spatially and temporally fragmented or overlapping social processes that produce GHC for a given task, and how the GHC model can account for these processes.

Automated reasoning integration

Another planned research direction is the incorporation of automated reasoning procedures to aid in producing GHC. Automated reasoning procedures refer to computational algorithms that can automatically reason about relationships within conceptual structures, which are most often formally encoded as ontologies. From the perspectives of this research, automated reasoning can be used to aid in producing relevant GHC by referencing extracted information instances to stored contextual concepts structured in the GHC model that may have implicit relationships through the use of realisation and subsumption (Turhan *et al.*, 2006). Succinctly, realisation is an automated reasoning technique that determines which concept an individual most closely belongs to (i.e. a Labrador Retriever is a type of dog), subsumption is used to determine concept/sub concept relationships (i.e. dogs are a sub-concept of animals) (Baader and Nutt, 2003). For example, an analyst interested in understanding the GHC of the treatment of refugees in a humanitarian crisis might conduct a search of documents where automated reasoning techniques realise that the term school is a type of building and that buildings are a sub-concept of shelters. Thus, the incorporation of automated reasoning can help to initially identify possible contextually relevant information, such as in the example given, the possible use of schools as shelters in the past. The human analyst can then use visual interfaces that support human analytical reasoning to make the final judgments of contextual relevancy of information returned.

Future applications areas

The application area of the CDA discussed in this paper was context analysis in the Consolidated Appeals Process (CAP). The applications areas of the CDA for humanitarian information analysis, however, are numerous. One particular area that future CDA research can be applied to is the analysis of slow onset disasters such as droughts, disease, famine, and conflicts. Analysis of slow onset disasters can aid decision making processes on when (or when not) to intervene in such situations. In particular, the CDA and related research can aid in understanding and identifying implicit factors within such situations using automated and human reasoning. For example, CDA could be used to examine how instances of malnutrition may reflect wider situation factors such as the social environment and public health (Hedlund, 2007).

SUMMARY AND CONCLUSION

How geo-historical context can be modelled, produced, represented, and applied using a prototype Geovisual Analytic environment called the Context Discovery Application (CDA) has been discussed. The GHC model underlying the CDA provides the first formalisation of the essentially abstract notion of GHC. By formalising GHC into a model, Geovisual Analytic software environments can use the model as a theoretical basis and motivation for the design of visual artifacts and interfaces that aid human reasoning about the contextual relevancy of information and computational procedures for retrieving potentially relevant contextual information.

The current focus of the CDA is to produce geo-historical context by mining locations and concepts of interest from text that are combined with stored geographical, temporal and conceptual information. The CDA primarily extracts data contained within and referenced from RSS feeds. The increasing use of RSS as means to publish web content make the techniques used by the CDA a valuable first step in developing methods for acquiring, processing, analysing and transforming non-spatio–temporal information into spatio–temporal formats based on widely available, yet heterogeneous and unstructured data formats.

The CDA also provides the analyst with various visual strategies to aid the reasoning processes that determine the contextual relevancy of retrieved information. Using visual representations and interfaces, an analyst can determine connections among locations, and interrelations between locations, discrete temporal events and concepts. Although the emphasis has been on supporting human reasoning about the contextual relevancy of retrieved information, the visual strategies used by the CDA could also be used for general reasoning about the relevancy of information for other purposes such as situation assessment and awareness tasks where the current state of the environment (as opposed to longer term past states in GHC) is analyzed to support decision making (Endsley, 1995).

The applied purpose of the Geovisual Analytic approaches used by the CDA are to show, in part, the geo-historical contextual dimensions for a humanitarian situation of interest. Properly contextualising humanitarian crisis situations can lead to improved crisis mitigation, response, and coordination and ultimately save lives.

BIOGRAPHICAL NOTES

Brian Tomaszewski is currently pursuing a Ph.D in Geography at the Pennsylvania State University under the advisement of Dr. Alan MacEachren. Brian's particular research focus in the Ph.D. program centers on model and representing geo-historical context, and the development of Geovisual Analytic tools for use in humanitarian information activities. Brian's past degree's include a BA in Anthropology with a concentration in Archeology that he received in 1994 from State University of New York (SUNY) Albany and an MA in Geography with a concentration in GIS he received in 2005 from SUNY Buffalo.

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