Geo-Historical Context Support for Information Foraging and Sensemaking: Conceptual Model, Implementation, and Assessment

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Abstract

Information foraging and sensemaking with heterogeneous information are context-dependent activities. Thus visual analytics tools to support these activities must incorporate context. But, context is a difficult concept to define, model, and represent. Creating and representing context in support of visually-enabled reasoning about complex problems with complex information is a complementary but different challenge than that addressed in context-aware computing. In the latter, the goal is automated adaptation of the system to meet user needs for applications such as mobile location-based services where information about the location, the user, and the user goals filters what gets presented on a small mobile device. In contrast, for visual analytics-enabled information foraging and sensemaking, the user is likely to take an active role in foraging for the contextual information needed to support sensemaking in relation to some multifaceted problem.

In this paper, we address the challenges of constructing and representing context within visual interfaces that support analytical reasoning in crisis management and humanitarian relief. The challenges stem from the diverse forms of information that can provide context and difficulty in defining and operationalizing context itself. Here, we pay particular attention to document foraging to support construction of the geographic and historical context within which monitoring and sensemaking can be carried out. Specifically, we present the concept of geo-historical context (GHC) and outline an empirical assessment of both the concept and its implementation in the Context Discovery Application, a web-based tool that supports document foraging and sensemaking.

KEYWORDS: context, foraging, sensemaking, mapping, text analysis, geographic information retrieval.

INDEX TERMS: H.3.3 [Information Storage and Retrieval]: Information Search and Retrieval—Information filtering, relevance feedback; H.5.2 [Information Interfaces and Representation]: User Interfaces—Graphical user interfaces, Evaluation/methodology.

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1   Introduction

Context is an important concept for understanding the world. A common question is "what is the context?" For crisis management, context includes: where the crisis is occurring, what events have transpired, and who is involved. Although a ubiquitous concept, context is a difficult term to define and operationalize. Typically, it is thought of as a type of setting that gives meaning and describes the situation and circumstances of an entity [1]. Geography and history offer unique perspectives on context through study of the interconnectedness of phenomena, events, and places across multiple spatial and temporal scales through which situations are understood. The research we report here examines a fusion of these two epistemological perspectives, defined as Geo-Historical Context (GHC). From a visual analytics perspective, our emphasis is not on context as input to automated filtering (as in context-aware computing) but as a framework for sensemaking, with context actively assembled through analyst-system interaction. Our particular focus here is on the challenge of foraging for relevant information and using it to construct and represent GHC. Major contributions of the work presented here are that we have (a) developed a conceptual and computational model that is instantiated to represent context to support sense-making, (b) implemented a visual analytic system to produce context, and (c) evaluated the system with crisis management domain experts.

Often, knowledge and awareness of past associations, concepts, and places are critical to how situations are understood [2]. Thus, foraging for and integrating information that can contextualize situations from geographical and historical perspectives depends upon recognizing links across information fragments derived over extended time spans, geographic scales, and conceptual meaning. GHC creates a basis for creating these linkages. It supports understanding the interconnectedness of phenomena, events, and place across multiple spatial and temporal scales and it enables situations to be reasoned about, often through visual representations such as maps. The complex nature of GHC requires formalization to impose structure on the seemingly limitless parameters that must be related in order to make practical use of GHC for crisis management and similarly complex domains.

Here, we outline the conceptual framework for a GHC model, describe its implementation in the Context Discovery Application (CDA), and present the results of usability and utility evaluation. United Nations staff participated in the utility evaluation, providing input on the potential of the GHC framework and its instantiation in the CDA to support work in humanitarian crises management. More specifically, the GHC model and its implementation in the CDA were assessed for their potential to help analysts: (a) forage for, structure, and operate on heterogeneous information artifacts (documents, maps) that are (b) assembled, processed, interrelated, and interpreted in order to produce and represent

GHC, which in turn, (c) allows situations to be understood and reasoned within sensemaking and decision-making activities.

The paper is organized as follows. First, we present the theoretical foundations for our approach to context. Next, we outline a model of GHC developed and implemented on this foundation. This is followed by a brief overview of the CDA prototype, focusing on how its functionality reflects the GHC model. We then report on a usability study to refine the CDA. Finally, we report on a utility study, which offers insight into the GHC framework from the perspective of international crisis management practitioners, and of the CDA as an implementation of the model. We end the paper with a discussion and conclusions.

2 Theoretical foundations for GHC

2.1 Conceptualizing Context

Context as an object of research is conceptualized in diverse ways across different domains; Bradley and Dunlop [3] provide a useful review and synthesis of perspectives from linguistics, computer science, and psychology. Starting with a standard dictionary definition of context as "the interrelated conditions in which something exists or occurs," [4] we adopt Brezillon's [5] view that these conditions act as a filter or framework to support a human agent's reasoning in order to provide the correct meaning and interpretation for available information that is potentially relevant to a sensemaking or decision-making task at hand.

Following from this, we make a distinction between: (a) *contextual information*, information that creates, represents and provides context and thus implicitly provides a framework for problem solving, most often in the form of constraints and (b) *contextualized information*, information that is the focus of attention and that has been given meaning through the framework provided by contextual information. For example, contextual information providing a framework for crisis management in the recent Haiti earthquake might include a topographic map depicting terrain and infrastructure before the earthquake combined with information from news reports about building and infrastructure damage. This information framework helps to contextualize official information in situation reports about rescue team activities and distribution of relief supplies. At a later point in relief efforts, when an aftershock hits and situations change, the recently contextualized information about distribution of relief supplies becomes part of the overall framework of contextual information through which new situation reports are contextualized.

2.2 Context: Static or Dynamic (or both)?

Given the shift and duality that can occur between information being contextual and contextualized, it is important to distinguish between (a) context as a static set of information categories that can be used like a cookie-cutter for constraining situational factors, and (b) context as ephemeral and evolving, with parameters and properties that change dynamically.

Static, pre-described categories or classes of information that can be used to represent context are often used in AI-based efforts to model context. For example, the Context-Web Ontology Language (C-OWL), an extension to descriptive capabilities of the Web Ontology Language (OWL), is designed to formally capture static concept contexts within a single ontology in order to support machine-based matching of concepts with other ontologies [6]. Gahegan and Pike [7], in work focusing on capturing, modeling, and representing how concepts are socially constructed in scientific processes, emphasize the static component of context, as a fixed set of concept properties that essentially serve as basic concept metadata (i.e., who created a concept and when, and how the concept was created). Static contextual information has also been used for schema matching and query matching in heterogeneous geospatial database integration [8] and in semantic similarity matching procedures [9]. The CYC project's knowledge base and common-sense reasoning engine, incorporates the notion of static context using pre-described categories. CYC includes 12 "mostly-independent dimensions along which contexts vary (Absolute Time, Type of Time, Absolute Place, Type of Place, Culture, Sophistication/Security, Granularity, Epistemology, Argument-Preference, Topic, Justification, and Anthropacity)" [10, p. 4].

A dynamic, shifting view of context is more prevalent in ubiquitous computing and distributed/situated cognition research where the focus is on human/machine/artifact interactions. In these domains, context and content are not separable entities, instead, context arises and is produced by activity [11]. More specifically, context can be interpreted as emerging from both activity and combinations of tools, settings, goals, and artifacts imbued with history [2]. A dynamic perspective of context creates challenges to modeling context or formally representing context information (whether visually, in a database, or an ontology) in that it is difficult, if not impossible, to imagine all possible contextual states, information needed to convey those states, and appropriate action within a given state [12].

Whether a conceptualization of context is based on a static set of pre-determined descriptive categories used for processing and integrating information, or as a dynamic state formulated from a complex series of interactions of artifacts, social interactions, environmental conditions, or their combination, contexts provide a mechanism for reasoning (both human and computer) with situational factors. Human reasoning, in particular, is critical to crisis management sensemaking and decision-making activities. A particular emphasis in research reported here is on understanding how the notion of context functions as a human reasoning framework and mechanism for such activities.

2.3 Theories of Contextual Reasoning

Formalization of context into logical theories for use as reasoning mechanisms has been an active area of inquiry in AI and knowledge representation/reasoning since the 1980s. A motivation behind formalizing context has been as input to models of human, context-based reasoning for understanding situational factors within automated, machine-based reasoning systems.

A concept addressed in these efforts is generality, related to the range of contexts across which assertions are true [13]. Stated simply, situations are unique, but unique systems are impractical and any knowledge representation or reasoning system that applies to all situations will be too general to be useful. The generality problem makes it difficult (if not impossible or desirable) to conceive of a universal knowledge representation and reasoning language based on a homogenous world [14]. An approach to deal with the generality problem is the use of contexts to localize knowledge and to then to find "compatibility" between localized contexts. Compatibility here is treated as the relations that can be defined between contexts that enable reasoning across contexts. Localized and compatible perspectives on context as a reasoning mechanism are the core ideas underlying local model semantics and multi-context systems, which are discussed in the following section and used as a theoretical principle underlying the GHC model presented in this work.

2.4 Local Model Semantics & Multi-context Systems

A multi-context system begins with the premise that context, as a formal structure for reasoning, is based on "local" facts derived from a global knowledge base and used for reasoning about a given goal [15]. Giunchiglia and Bouquet [15] argue that a local context of reasoning is based on a cognitive context, or an individual's cognitive representation of the world, as opposed to a

pragmatic context, or the external structure of the world. For example, in a conversation between two people, the pragmatic context might be composed of the speakers themselves, the time the conversation is taking place, and the location of the conversation. Reasoning with information that depends on the pragmatic context is utilized only as much as that information is represented or relevant within a given state of the cognitive context [15].

The utility of situating reasoning in a cognitive context is that it accounts for different and/or conflicting perspectives within an agent's cognitive view of the world [15]. Perspectives taken by different agents often differ in level of detail and interpretation will depend on what is implicitly assumed [16]. As a very simple example, the statement "The report is due on April 25th" could also be true if expressed as "The report is due today" with an implicit assumption that today is April 25th.

Despite potentially differing local reasoning contexts to describe a given domain, compatibility and overlap can and does exist. From the local model semantics perspective, compatibility between local reasoning contexts refers to mutually influential relationships between local reasoning contexts where similar perspectives can describe the same piece of the world, but with different details [16]. For example, two people looking at a globe may both see the Atlantic Ocean, but one person can only see North America (from his/her viewpoint), and the other can only see Europe. Thus, compatibility emerges from the fact that their reasoning is related (they are both seeing the ocean), but distinct as they are looking at different landmasses.

Ghidini and Giunchiglia [17:229] encapsulate these ideas in two basic principles for local model semantics:

Principle 1 (of Locality). Reasoning uses only part of what is potentially available (e.g., what is known, the available inference procedures). The part being used while reasoning is called the context (of reasoning);

Principle 2 (of Compatibility). There is compatibility among the kinds of reasoning performed in different contexts.

These local model semantics concepts have clear application to geographic problems such as a disaster relief, where context might differ on the basis of place, time, or concept/theme. Two local contexts could share a place but differ by theme (e.g., using a hydrological versus a transportation perspective) or time frame (based on the long history of a resident versus a short duration from an external emergency response manager brought in to help). Alternatively, local contexts might represent adjacent places that share only a border and common regional perspective. "Local" also can be defined at different geographic scales, such as the perspective of the county emergency manager whose local context is a single county and that of the state emergency manager whose local is the entire state. Furthermore, the compatibility relations among the different kinds of local contexts will be different. To summarize, local reasoning contexts that are derived from subsets of global knowledge and then paired into compatibility relationships with other local reasoning contexts are the essence of local model semantics and multi-context systems.

2.5 Context Modeling Challenges

From an information foraging and sensemaking perspective, static, descriptive context categories are used for integrating and relating heterogeneous information. From ubiquitous computing and distributed/situated cognition perspectives, context emerges from a complex mix of tools, artifacts, beliefs, and intentions imbued with history and existing within a social context of use where context is dynamic (subsumes static categories of context). Both static and dynamic contexts provide a mechanism for reasoning with situational factors. A context of reasoning is a localized, cognitive view of the world based on a subset of facts that retains

unique characteristics of a perspective. Compatibility needs to exist and be formalized for cross perspectives of local reasoning.

From this theoretical framework, two core challenges for developing a conceptual model and visual representation of GHC information can be defined. The first is that the sheer limitlessness of geography, the past, and other situational factors makes complete computational representation of geo-historical (or any other form of context [1]) unachievable. To address this challenge, it is necessary to establish static contextual categories to underpin a model of geo-historical context that can implicitly intervene in a task, provide constraints, and explicitly contextualize information when needed. The second challenge is that although geographical or historical information can be used to formulate a context, these and other information elements are not context, but rather, become parts of a broader dynamic geographic-social context that adjusts as situations evolve. Conceptual models and visual representation of and interfaces to GHC information must find a balance in meeting these two challenges. Static contextual categories must be able to operate within dynamic social contexts from which relevant GHC contexts emerge and are used to derive geo-historical meaning for supporting tasks and goals.

3   The GHC Model

Figure 1 is a high-level model representing the process of GHC production within a geographic-social context.
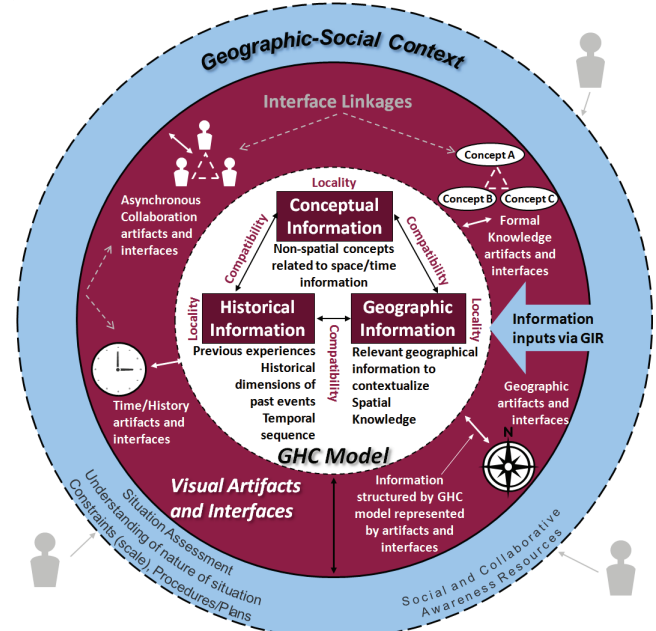

Fig. 1. The overall process by which GHC is produced.

The GHC model serves two purposes. First, it provides a formal structure for the theoretical and conceptual components of GHC; these include (a) events, places, and concepts as well as (b) relationships and constraints among these components such as scale, and spatial and temporal topological relationships. The GHC model is specifically structured using three sub-models - geographical, historical, and conceptual, which represent windows into locality of context, along with compatibility relations among the components. This structure is theoretically motivated by other data models that organize spatiotemporal phenomena into space/time/concept (or object) sub-models based on the intuition that these categories correspond with the way people think (cf.[18, 19]. Special characteristics of the GHC model when compared with other spatiotemporal models include the emphasis that the GHC model makes on (a) modeling context in particular, (b)

modeling derived knowledge and information rather than raw observational data, and (c) modeling reasoning contexts using local model semantics. For further discussion of the GHC model's geographical, historical, and concept sub-models, see [20].

Second, the model can be used as a conceptual template for structuring and representing specific information instances retrieved, compiled, developed, and ultimately used as part of foraging and sensemaking processes. Context information can then be applied to fulfill a task or achieve a goal requiring geographical, historical, and thematic interpretations of situational factors. The GHC model is represented formally through an OWL-DL computational ontological structure (one of several sublanguages of the Web Ontology Language) which is effective at representing, capturing and describing aspects of real-world contextual information in computer readable formats [21].

The GHC model has a simple structure. The three main sub-models (geographical, historical, and conceptual,) begin as sub-classes of the supreme OWL Thing class. The specific structures of each respective sub-model were defined using existing, established ontological definitions wherever possible. In particular, the GHC ontology uses two existing ontologies as a starting point for dealing with space and time. The Geonames Ontology (GO) is used for representing discrete, coordinate-based geographic entities as per the conceptual structure of the geographic sub-model of the overall GHC model (http://www.geonames.org/ontology/). The OWL Time Ontology (TO) [22] is used for representing discrete instances of historical events in linear time as per the conceptual structure of the historical GHC sub-model.

4   Context Discovery Application (CDA)

The GHC conceptual framework has been instantiated in the CDA, a prototype geovisual analytics environment focused on document foraging and sensemaking. In this section, we provide an overview of CDA functionality and outline a focused usability assessment designed to "proof" a version of CDA prior to conducting the utility study presented in the next section.

4.1   CDA functionality

The following is a brief discussion of what a user might expect when working with a version of the CDA seeded with information relevant to humanitarian decision making (and thus has constraints over a "full", unconstrained version) to ground specific functionality in a usage context. When started via loading the CDA web-client, the CDA will (a) visually render a small domain ontology in a graph display, (b) load a list of predetermined humanitarian project names into a dropdown list for selection by the user, (c), load a predetermined list of relevant specific date or time span event references into a timeline interface (d) load a list of country names into a dropdown list for selection by the user to use with open text queries and (e) display a base map of the world. All other functions are driven by actions taken by the user. A user will formulate a query by either entering an open keyword search much like a Google search, or they can utilize a query string automatically generated from the pre-determined list of humanitarian project titles. Using either approach, the user will then submit the query as the basis for processing by other CDA functionalities. In particular, the CDA supports ontology-enhanced queries to information sources such as Google News. Small domain ontologies (e.g., based on entities and relations extracted from an existing reference document) are used to support query expansion that makes it possible for an analyst to retrieve multiple, relevant documents without precise keyword matches in documents, an approach similar to [23]. CDA uses open source text processing methods to extract entities from the documents (including people, places, organizations, and things)

and disambiguates and geocodes the places extracted. Technical details of the CDA were described previously in [24]; here we sketch core features to provide background for discussion of usability and utility assessments.

The CDA visually represents and allows users to explore implicit geographic information extracted from RSS feed-based sources. The information is represented in a set of linked views that included a 2D map, Google Earth™ view, concept graph, timeline, named-entity extraction window, and web browser. The concept graph, timeline, and 2D map views are linked using predetermined geographic coordinate and temporal references. The 2D map and Google Earth™ views are linked using a map synchronization algorithm discussed in [24].

Figure 2 shows one view in which the user has selected a news story about humanitarian action in Southern Sudan and how the user can browse through people, places, and organizations related to the story in the entity view (lower left). In this scenario, an analyst is cognitively gaining a contextual understanding of locations related to humanitarian events in the Sudan after doing a search. Locations involved in a complex crisis situation may have multiple conceptual and/or temporal dimensions that may be relevant for producing GHC. Conceptual and/or temporal dimensions can thus provide cognitive filtering capabilities that determine which locations are relevant based on relationships among concepts, events, and locations.
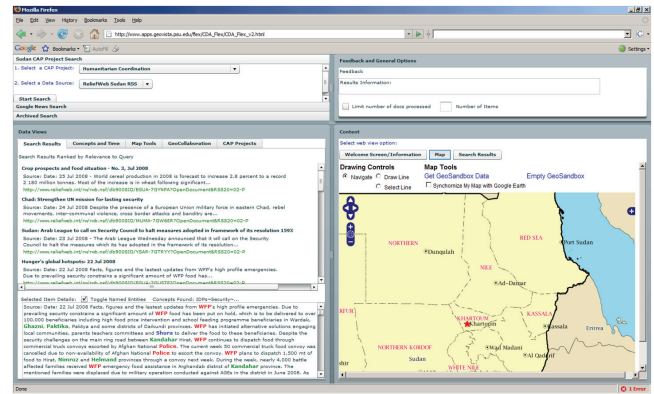

Figure. 2. Representative example of the CDA.

As a next step, the user has picked the timeline and concept map panel (Figure 3). A concept map depicting humanitarian relief activities is shown. Concepts that are extracted from a Sudan RSS feed and also found within the predetermined small domain ontology discussed previously in this section are highlighted in yellow to provide a high-level overview of the conceptual content of the document. The concept map may prompt the user to recognize unanticipated concepts as contextually relevant [25].
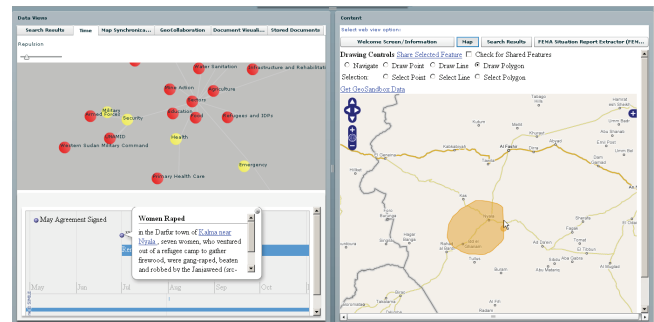

Figure 3. Concept map (top-left), timeline (bottom-left).

The scenario depicted illustrates: (a) selection of a concept, UNAMID by clicking (fig. 3, upper left); (b) identification of a UNAMID security event from 2005 that the concept is linked to, resulting in auto-scrolling of the timeline to highlight this event, or specific time reference, about atrocities (fig. 3, lower left); (c) mapping the event by clicking on a link to automatically re-center the map to the event (figure 3, right), and (d) drawing an annotation on the map; see [24] for a detailed account of this scenario. These interactions generate a set of linked artifacts that enable the analyst to construct GHC for interpreting events.. The overall process is iterative, and the user can conduct further searches to find out more about topics learned during the initial search.

As an analyst works, he or she can simultaneously view geographic components of information extracted from text documents on the 2D map view built into the CDA and on an independent 3D Google Earth™ view depicting origins of news stories as points plus lines that connect to places mentioned (fig. 4).
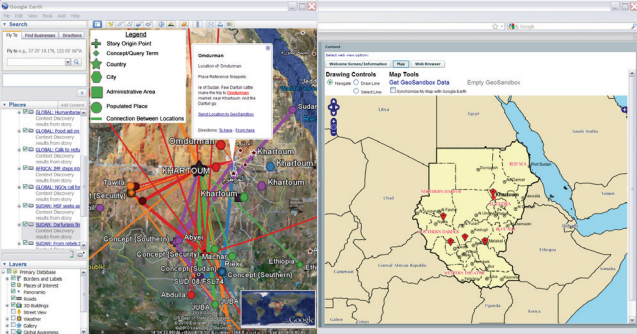

Fig. 4. The GeoSandbox view linked to Google Earth.

The maps are dynamically linked and the 2D map includes a GeoSandbox feature enabling the analyst to save information extracted from GE as deemed contextually relevant. Here, the user saves information from a news story mentioning Omdurman (see snippet in GE view, left) to the GeoSandbox within the CDA (markers indicate other saved information). The GeoSandbox is related to the idea by Wright et al. [26]of an analysts' Sandbox; their Sandbox offers a more general purpose concept-focused rather than geographic focused organizational "space" for evidence fragments to support intelligence analysis.

In addition to the above features, the CDA contains support for remote collaboration. One objective is to help analysts share analytical insights related to production of GHC and subsequent sensemaking activities as per the ideas of situated cognition and dynamic context discussed in section 2.2. This objective is addressed through the idea of a geomessage (fig. 5).

A geomessage uses a standard email message as a metaphor to support a spatiotemporally-enabled message for asynchronous geocollaboration. Conceptually, the body of a geomessage is a map extent linked to a text note like an email message.

Geomessages include an attachment mechanism designed explicitly to support geospatial artifacts. In its current form, the geomessage supports attachments of map annotations and shared web map service (WMS) layers. WMS layers allow users to collaboratively create maps by sharing any individual and external geospatial resources from OGC-compliant servers. Map layers from a given server can be loaded into the CDA by parsing the XML-based results from a GetCapabilities request made to the server. Users can then select available layers and attach them to the geomessage. The benefits of this approach are that it (a) allows users to maintain a private view of their own data but share components as needed, (b) provides users with the flexibility to use multiple spatial data providers, (c) overcomes technical chal-

lenges to data sharing, such as for example, when a novice user with geospatial technologies needs a layer for decision making from a geospatial expert, and (d) supports user dialog through annotation tools that link formal geographic data to user knowledge, enabling holistic geographic awareness about a situation [27].
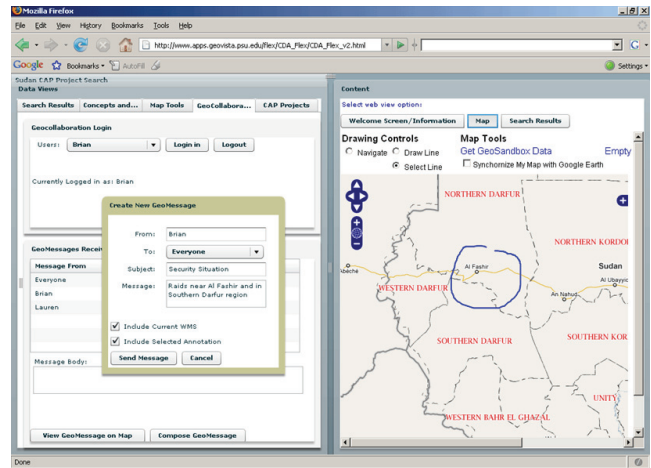

Figure 5. Example *Geomessage* with map and annotation.

4.2 CDA Usability Assessment and Refinement

A targeted usability assessment of the CDA has been carried out. The primary goal was to develop a limited but robust version of the CDA through which to assess utility of the GHC conceptual framework (see section 5), not to do a comprehensive user study. We summarize the methods and outcomes here, briefly.

Participants included two post-doctoral and three graduate students from the Penn State GeoVISTA Center; all were experienced with Geographic Information Systems (GIS) and geovisual analytic technologies, enabling them to provide expert review from a tool design perspective. Five additional participants were from UN groups within the Office for the Coordination of Humanitarian Affairs (OCHA); all but one of the latter had some experience with GIS (and the one who did not was familiar with using Google Earth); all were experts in humanitarian relief activities. The usability assessment had three components: a task analysis, a survey, and a focus group with the first two done individually by each participant and the last as a group.

Tasks: Each participant carried out tasks with representative features of the CDA such as extracting text from news articles and viewing the results in a map. Before the session, participants received instructions on how to use basic CDA features and on concepts such as the Consolidated Appeals Process (CAP). During the session, participants were asked to "talk aloud" while they worked and the work was observed and recorded. "Talk aloud" is slightly different than "think aloud" as in the talk aloud protocol, subjects describe but do not explain their actions [28]. The following 6 tasks were completed: (1) select (from a list) a CAP project to run a query against the Relief Web Sudan RSS feed, (2) review documents found in the search results interface (left half, fig. 2), (3) use the space/time/concept interface (fig. 3) to review concepts, locations, and events that were potentially contextually relevant, (4) review search results in Google Earth, (5) use the GeoSandbox to save and select contextually relevant places, and (6) send a Geomessage. Tasks were conducted in 30 minute sessions.

Focus group: Given time constraints of UN personnel, only a focus group with Penn State participants was conducted. The goal was to leverage expertise of these individuals in design of geo-

graphic information technologies and visual interfaces focused on geographic analysis.

Surveys: Ten confidential survey forms were returned. The survey included Likert scale rankings (assessing understandability of the interface and of the displays, consistency of design, acceptability of response time, and overall usability) and 3 questions allowing written response (focused on best features, worst features, and suggestions for improvement).

The Likert ratings were summarized using descriptive statistics (mean, medium, mode). Data from talk aloud and observations during task completion, the focus group results, and the written responses to surveys were coded based on Nielsen's usability heuristics categories [29]. The combined analysis resulted in three primary changes to the CDA.

The first change was simplification of the overall user interface; from an interface with five main frames that each included many sub-controls to an interface with only two main frames and fewer controls. The second change was a modification of the search results interface, shifting from a tree view of retrieved documents with text fragments visible for the selected document to a view modeled on a Google Search results display at the top matched with a tagged document view below (as shown in fig. 2). The third change involved addition of a legend to the Google Earth display.

5   Evaluating Utility of GHC Framework

Utility of the GHC theoretical framework was evaluated through a study conducted at the New York offices of the United Nations (UN). The emphasis was on evaluating the GHC conceptual framework and the general strategy for instantiating it in the CDA, not to do a comprehensive evaluation of the CDA as production software. Thus, a limited version of the CDA was used that contained features relevant to humanitarian relief. The particular focus for the evaluation was on the problem of making humanitarian funding decisions. The scenario required contextualizing humanitarian crisis situations via analysis of implicit geographic information derived from open source documents. More specifically, while using CDA, study participants conducted tasks focused on contextualizing and reasoning with open source information about humanitarian disaster relief projects in the Sudan.

Four UN staff members participated in the study, each from groups within of the UN's OCHA, including the Field Information Services bureau and ReliefWeb. Having access to UN staff provided a key opportunity for examining a use of the GHC conceptual framework for application to real problems and not hypothetical scenarios. However, since UN OCHA personnel are constantly dealing with ever present world-wide disasters, the evaluation was necessarily much less controlled with fewer participants than the typical laboratory study with student or similar participants.

To provide a comparable experience during task completion so that a follow up focus group would be productive, the CDA was loaded with pre-complied datasets for the task analysis sessions. Specifically, datasets from the ReliefWeb Sudan RSS feed and IRIN Sudan RSS feed were used. Each contained (a) documents that were processed by the CDA automated reasoning document classification and (b) a KML representation of the RSS feed derived using the CDA..

Specific tasks were developed to assess the GHC model; these tasks incorporated geographic, thematic/conceptual, and historical components and the interrelations among them. Tasks were motivated by the following prototypical scenario that was also presented to participants at the beginning of each individual session.

Scenario: *OCHA financial decision makers want an executive summary report on the evolving context of a select CAP project in the Sudan. They want to know how food security at local, regional, and international scales is playing out in the Sudan and how this may or may not relate to the efforts of the CAP project.*

Two categories of cross-cutting tasks were developed to address this scenario. These tasks are targeted at establishing a preliminary context of a CAP project, thus to constrain/shape/ contextualize a CAP project from geographic, historical, and thematic dimensions. One task sub-category includes tasks to produce context needed to answer a question (e.g., selecting the map in order to review basic CAP project information). The second sub-category includes tasks targeted at determining the contextual relevancy of a given piece of information (e.g., viewing a documents' geographical footprint in Google Earth).

Within these broad categories, distinct tasks were developed to utilize information from each of the GHC sub-models (geographic, historical, and conceptual/thematic) in different forms as per the ideas of locality (different view on the same world), and compatibility (interconnections existing with varying degrees of detail). The following are examples of GHC sub-model components related to sub-tasks that were developed to assess the GHC model in terms of locality:

- *Geographic sub-model:* View the documents' geographical dimension in Google Earth (as seen in fig. 4).
- *Concept sub-model:* Review thematic information of potential relevance to a selected document that seems potentially useful (as partly seen in fig. 2 and also using the concept and timeline view of the CDA as in fig. 3).
- *Historical sub-model:* Review historical information of potential relevance to a selected document using the CDA concept and timeline view (see fig. 3).

The following are examples of tasks developed to assess the GHC model in terms of compatibility:

- Compile/synthesize your findings (a finding is something you think is potentially relevant that you would record/add to your report).
- Repeat (previous steps) as needed to support your analysis. For example, review several documents from different sources.

The intent of these tasks, in relation to evaluating compatibility in the GHC model, was to see how GHC sub-model information could be combined in order to represent the context of a humanitarian project. Each participant worked for approximately one hour and was asked to talk aloud during task completion.

Lots of linkages with neighboring countires, similar (food security) problems likely; most links shown are to donor countries.

Many of the found topics are referring to Darfur.

Lots of sudan (Kartoum) to South Sudan links, bot no clear links between Darfur and South ..

Fig. 6. Example report section from one participant.

In addition to the specific detailed tasks outlined above, the participants were asked to create an executive summary report that outlined geographical, historical, and thematic dimensions of the CAP project's context. Figure 6 shows a map and the related ex-

cerpt from a report generated by one participant. The report fragment and map shows multiple geographic dimensions of humanitarian projects in the Sudan in order to contextualize the project. On the map, colors represent individual news stories and lines represent locations computationally extracted from RSS feed to reveal potential geographic relationships between news stories. The ideas of locality and compatibility are reflected in this graphic in terms of how the study participant reports countries (locality) that share similar but not identical food security problems (compatibility).

Following completion of the tasks, a focus group was used to prompt discussion targeted at key aspects of the GHC framework, its implementation in CDA, its applicability to the kind of task presented, and the general utility of the tools and the overall framework for supporting humanitarian relief activities.

Data from the utility assessment included notes taken while observing participants, transcription of the talk-aloud during portions of the task analysis sessions that focused on carrying out the task, and full transcriptions of the focus group session. Comments made in the transcriptions were analyzed using an approach outlined in Krueger [30] which has been utilized by cartographic/Geography researchers such as Kessler [31]. In this approach, comments made during discussions are analyzed in terms of (a) frequency (or the number of times an individual or the group raises a specific comment), (b) extensiveness (which can be indicative of objection or support to a given topic), (c) intensity (potentially revealing feelings/emotions connected to a topic), and (d) what was not said (indicating participants did not mention anything about a given issue). Using an approach outlined by Kessler [31], comments derived from the transcriptions were then matched to the specific research questions outlined above. Space permits only highlight from results.

A sub-goal of the overall study was to examine whether the participants felt it was useful to consider context as a concept with geographic, historical, and conceptual components. The following are excerpts from the focus group transcriptions where the participants answered questions about utility of the GHC theoretical framework to support answering strategic level questions.

As a prelude to examining GHC specifically, participants were first asked what the term "context" meant. P1 and P2 responded to the question that context was a series of relationships between information components. This view matches closely with the theoretical perspective grounded in local model semantics outlined above. P1 even noted an idea discussed above that context acts like a framework – "it's also a very complex relationship let's say, because you're looking at some info and how it connects or relates to a ton of other information may be around that subject, so that's, what I, I would consider a context of something." P4 made a comment that context was "the environment and situation", demonstrating how the terms context and situation can often be intermixed. As a follow up to the basic question about a general definition of context, a question was then posed to the group about the notion of "analyzing a context" as per the language of the humanitarian case study the participants were conducting. P1 and P2 said that analyzing the context was in essence looking at the background to a specific situation. P4 however restated that analyzing the context was in fact analyzing the situation.

Finally, probes directed discussion to whether it is useful to consider context to have geographical, historical, and conceptual components. All participants agreed that it is useful to consider context (and context for humanitarian projects in particular) to have geographical, historical, and thematic components. In agreeing with this, P4 related the notions of geographical, historical, and thematic components to humanitarian profile maps developed by ReliefWeb, as illustrated in the quote – "yes because otherwise we couldn't, if we don't know the situation of one country …

provide funding so that's why we also decided to put together a profile map. We can provide the situation of country, therefore they will learn of the situation and then they can provide some funding, so the situation, . . . the awareness of the situation is very important. It's key." Beyond the geographic dimensions mentioned explicitly, historical and thematic dimensions of context are implied in P4's quote implicitly. Humanitarian profile maps contain numerous references to thematic and historical information that is essential for understanding the situation. Also of note in the previous quote from P4 is the sentiment that the GHC helps provide a context in which decisions about funding can be made (although P4 didn't use the term context specifically). P1 and P2 also echoed this sentiment, and P3 agreed.

Reports produced by participants were also reviewed. With the exception of Report 3, each of the four reports provided some indication of geographical, historical, and/or conceptual dimensions of the CAP projects contexts. The level of detail and means to represent and describe the GHC dimensions varied based on the form of information used by the report author. For example, participants 1 and 2 relied on Google Earth images with minimal accompanying text to describe contextual information. The author of Report 3 used numerous screen captures of web pages and the named entity view to describe geographical, historical, and thematic/conceptual dimensions, but did not include any map, concept, or timeline views. With the exception of Report 3, all participants used the geomessage tool to share findings. What was interesting to note was that two participants used the geomessage tool to develop messages with expressive annotations.

Three observations can be made from the focus group results. First, in spite of earlier usability assessments with UN personnel (who also participated in the utility study) and subsequent CDA revision, several usability issues were identified that were sufficiently serious to impede use for the tasks posed; one of the four participants needed to spend a substantial proportion of the hour session re-learning CDA functionality before starting on the tasks. This suggests that simpler interfaces and perhaps training in tool use will be necessary to put tools like these into practice. More positively, although participants could not agree on an exact definition of what context was, they all generally agreed that it was useful for context to be composed of geographic, historical, and thematic components for humanitarian information work. Finally, all participants, in different ways, saw the future value of specific components of the CDA (with an improved interface), for use in humanitarian information management.

6   Conclusions

Context is a difficult term to define and has many usages and meanings in different research and application domains. This research has formalized a particular type of context, called Geo-Historical Context (GHC), through the development of a GHC model that is based on relevant theoretical perspectives and computational representation strategies. The GHC model was the basis for developing a geovisual analytics environment designed to produce GHC from unstructured information sources within a challenging application domain – namely context analysis activities that underlie information foraging and sensemaking in humanitarian crisis management.

While the evaluation of GHC as a conceptual framework presented here is a limited one, the limits are countered by the ecological validity of obtaining focused input from experts in international humanitarian relief. Evidence presented suggests that GHC is a viable framework for structuring situational reasoning tasks related to the production of GHC. In particular, outcomes of the evaluation revealed that study participants thinking about the general notion of context matched closely with the local model semantics theoretical perspective as reflected in evaluation task

outcomes and focus group discussions. Furthermore, participants were able to use the computational text processing and visual interface tools of the CDA to find relevant information and focus more of their attention on developing CAP reports.

Future research can incorporate the notion and evaluations of GHC promoted in this research to develop more robust geovisual analytics tools that are well suited to the information foraging and sensemaking tasks of finding and interpreting information, identifying relationships, monitoring changes, and making decisions. Ideally, such efforts will lead to the development of visual anlaytics and other information systems that can effectively contextualize crisis situations from geographic, historical or any other dimension of interest [32] . Properly contextualizing crisis situations can lead to improved crisis mitigation, response, and coordination, and ultimately improve or save lives.

7   Acknowledgement

Larger sized versions of graphic found in this paper can be viewed at: http://people.rit.edu/bmtski/docs/vast2010/

8   References

[1] A. K. Dey, "Understanding and Using Context," Personal Ubiquitous Computing, vol. 5, pp. 4-7, 2001.

[2] M. Cole and Y. Engeström, "A cultural-historical approach to distributed cognition," in Distributed cognitions. Psychological and educational considerations, G. Salomon, Ed. New York: Cambridge University Press, 1993, pp. 1-46.

[3] N. Bradley and M. Dunlop, "Toward a multidisciplinary model of context to support context-aware computing," Human-Computer Interaction, vol. 20, pp. 403-446, 2005.

[4] context, Dictionary.com Unabridged (v 1.1),. Last Accessed: 8 November 2007,<http://dictionary.reference.com/browse/context>, 2007.

[5] P. Brezillon, "Context in Artificial Intelligence: II. Key Elements of Contexts," Computer & Artificial Intelligence, vol. 18, pp. 425-446, 1999.

[6] P. Bouquet, F. Giunchiglia, F. van Harmelen, L. Serafini, and H. Stuckenschmidt, "C-OWL: Contextualizing ontologies," Proceedings of the Second International Semantic Web Conference, pp. 164–179, 2003.

[7] M. Gahegan and W. Pike, "A Situated Knowledge Representation of Geographical Information," Transactions in GIS, vol. 10, pp. 727–749, 2006.

[8] D. Souza, A. C. Salgado, and P. Tedesco, "Towards a Context Ontology for Geospatial Data Integration," presented at Workshop on Reliability in Decentralized Distributed Systems (RDDS), Montpellier, France, 2006.

[9] K. Janowicz, "Kinds of Contexts and their Impact on Semantic Similarity Measurement," presented at 5th IEEE Workshop on Context Modeling and Reasoning (CoMoRea) at the 6th IEEE International Conference on Pervasive Computing and Communication (PerCom'08), Hong Kong 17 – 21 March 2008, 2008.

[10] D. Lenat, "The Dimensions of Context-Space," Austin, TX 1998.

[11] P. Dourish, "What we talk about when we talk about context," Personal and Ubiquitous Computing, vol. 8, pp. 19-30, 2004.

[12] S. Greenberg, "Context as a dynamic construct," Human-Computer Interaction, vol. 16, pp. 257-268, 2001.

[13] J. McCarthy, "Generality in artificial intelligence," Communications of the ACM, vol. 30, pp. 1030-1035, 1987.

[14] F. Giunchiglia, "Contextual reasoning," Epistemologia - Special Issue on I Linguaggi e le Macchine, vol. XVI, pp. 345-364, 1993.

[15] F. Giunchiglia and P. Bouquet, "Introduction to contextual reasoning. An Artificial Intelligence perspective," Perspectives on Cognitive Science, vol. 3, pp. 138-159, 1997.

[16] P. Bouquet, C. Ghidini, F. Giunchiglia, and E. Blanzieri, "Theories and uses of context in knowledge representation and reasoning," Istituto Trentino di Cultura 2001.

[17] C. Ghidini and F. Giunchiglia, "Local Models Semantics, or contextual reasoning= locality+ compatibility," Artificial Intelligence, vol. 127, pp. 221-259, 2001.

[18] D. Peuquet, Representations of Space and Time: Guilford Press, 2002.

[19] M. Yuan, "Modelling Semantical, Spatial and Temporal Information in a GIS," in Geographic Information Research: Bridging the Atlantic, M. Craglia and H. Couclelis, Eds.: CRC Press, 1997, pp. 334-347.

[20] B. Tomaszewski, "A geovisual analytics approach for producing geohistorical context," Penn State University, University Park, PA 2009.

[21] T. Strang and C. Linnhoff-Popien, "A context modeling survey," Workshop on Advanced Context Modelling, Reasoning and Management associated with the Sixth International Conference on Ubiquitous Computing (UbiComp 2004), pp. 1-8, 2004.

[22] J. Hobbs and F. Pan, Time Ontology in OWL. Last Accessed: 28 August 2008,<http://www.w3.org/TR/owl-time/>, 2006.

[23] P. Smart, A. Russell, and N. Shadbolt, "AKTiveSA: A Technical Demonstrator System For Enhanced Situation Awareness," The Computer Journal, vol. 50, pp. 703, 2007.

[24] B. Tomaszewski, "Producing geo-historical context from implicit sources: a geovisual analytics approach," The Cartographic Journal, vol. 45, pp. 165-181, 2008.

[25] D. Leake, A. Maguitman, T. Reichherzer, C. J., M. Carvalho, M. Arguedas, and T. Eskridge, ""Googling" from a concept map: Towards automatic concept-map-based query formation.," presented at Concept Maps: Theory, Methodology, Technology: Proc. of the First Int. Conference on Concept Mapping, Pamplona, Spain, 2004.

[26] W. Wright, D. Schroh, P. Proulx, A. Skaburskis, and B. Cort, "Advances in nSpace – The Sandbox for Analysis," presented at 2005 International Conference on Intelligence Analysis, McLean, VA, 2005.

[27] B. Tomaszewski and A. M. MacEachren, "A Distributed Spatiotemporal Cognition Approach to Visualization in Support of Coordinated Group Activity," presented at Proceedings of the 3rd International Information Systems for Crisis Response and Management (ISCRAM) Conference, Newark, NJ (USA), 2006.

[28] K. Ericsson and H. Simon, Protocol analysis: Verbal reports as data (rev. ed.): Cambridge, MA: MIT Press, 1993.

[29] J. Nielsen, Ten Usability Heuristics. Last Accessed: 25 August 2008,<http://www.useit.com/papers/heuristic/heuristic_list.html>, 2005.

[30] R. Krueger, D. Morgan, and J. King, Focus Group Kit: Sage, 1998.

[31] F. Kessler, "Focus Groups as a Means of Qualitatively Assessing the U-Boat Narrative," Cartographica: The International Journal for Geographic Information and Geovisualization, vol. 37, pp. 33-60, 2000.

[32] B. Tomaszewski, A. C. Robinson, C. Weaver, M. Stryker, and A. M. MacEachren, "Geovisual Analytics and Crisis Management," presented at Proceedings of the 4th International Information Systems for Crisis Response and Management (ISCRAM) Conference, Delft, the Netherlands, 2007.