

Local Model Semantics, Categories, and External Representation: Towards a Model for Geo-historical Context

Brian Tomaszewski¹

¹ The Pennsylvania State University, Department of Geography, 302 Walker Building
University Park, PA, USA 16802
bmt139@psu.edu

Abstract. Perspectives within social interaction situations are often shaped by geo-historical contexts derived from knowledge of indirectly experienceable phenomena such as geographic scale entities and past events that are communicated through external representations such as maps and historical accounts. Although geo-historical context is important for proving meaning to collaborative situations, no formal approach for modeling geo-historical context exists. This paper will provide a preliminary analysis of how select aspects of Local Model Semantics (LMS), used in conjunction with geographic and historic categories, can be used to theoretically inform the formal modeling of geo-historical context and how external representations affect geographical and historical categories. A brief case-study example will be given to show how geo-visual tools theoretically informed by LMS, geographical and historical categories, and external representation can support the development of geo-historical context from heterogeneous sources in a collaborative setting.

Keywords: Local Model Semantics, Categories, Geography, History, External Representation

1 Introduction

Situations of social interaction, such as collaborative problem solving, are inherently shaped by context. The context of the situation shapes and provides meaning to situations of social interaction by surrounding those situations with varying knowledge elements and varying degrees of knowledge detail, creating unique perspectives for those involved in the situation [3]. For certain social interaction situations, perspectives are developed from knowledge of phenomena that can not be directly experienced because of scale (i.e beyond the immediate field of vision) or time (such as historical knowledge of a phenomena derived from past events that can never be revisited) [10, 13].

The examination and representation of phenomena that can not be directly experienced is a cornerstone of Geographic inquiry. For example, a common use of a map is to provide geo-spatial context for a situation, such a traveling. When a map is coupled with a historic account, artifact, or temporal information on the map,

situations can then be contextualized from a *geo-historical* perspective. A geo-historical context allows a situation to be understood in relation to past events, as well as interactions and relationships of locations within those events that have operated across any number of space/time scales and thus can not be directly experienced. For example, in the domain of crisis management, preparedness and mitigation activities taken by disaster management officials in a hurricane-prone region in anticipation of a large hurricane hitting the region might create scenarios based on past events that specifically occurred in that location (for example, a locality was struck the previous year by a hurricane, or a major hurricane twenty years ago), or use spatially or temporally analogous facts (such a small city in one state that was not effected by a recent hurricane comparing its vulnerability and potential destruction to similar small city in another states that was effected by a recent hurricane)[12].

Although geo-historical context is of great importance for providing meaning to collaborative situations, no approach for formally modeling geo-historical context exists. The benefits of developing an approach to formally modeling geo-historical context is two fold. The first is that the processes of developing a model can lead to further insight into the nature, meaning, and representation of space/time phenomena by examining theoretical issues of geographical and historical knowledge conceptualization, categorization and external representation. Second, by understanding the theoretical and conceptual dimensions of geo-historical context, knowledge representation and reasoning systems designed to represent geo-historical context can be more effective for application domains such as collaborative problem solving activities and situation assessment in crisis management.

The focus of this paper will be to examine aspects of the theoretical issues of geographical and historical knowledge categorization and representation as means toward developing a formal model of geo-historical context. Specifically, a review will be made of Local Model Semantics (LMS) [7, 8] and a preliminary analysis made of how select aspects of LMS, in conjunction with geographic and historic categories, can be used to theoretically inform the development of geo-historical context. Next, a discussion will be given on how external representation affects geographical and historical categories. A brief case-study example will then be given to show how geo-visual tools theoretically informed by LMS, geographical and historical categories, and external representation can be designed to support the development of geo-historical context in a collaborative setting and what effect, if any, external representations have on categorizations, knowledge and reasoning within collaborative problem-solving. The paper will conclude with a summary and areas for future research.

2 Local Model Semantics

Local Model Semantics (LMS) is a semantic model for reasoning with contexts. LMS takes an approach that assumes localized, goal directed, domain specific theories of the world form the basis of what an agent knows, and that the sum of an agents knowledge is developed by composing local theories through rules that connect the theories into a comprehensive, yet partial representation of the world [4,

7]. Reasoning is local to a single given context that is seen as a partial state of the world derived from an individual perspective, drawn from a subset of knowledge, and relevant to the context or problem at hand [16].

Ghidini and Giunchiglia [7:229] outline two principles underlying the intuitions for the use of context in LMS:

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 what (is called) context (of reasoning);

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

Locality can be seen as the set of facts an individual uses to develop a representation for reasoning about the world [16]. Compatibility refers to the possible mutually influential relationships between local reasoning where similar perspectives and contexts can describe the same piece of the world but with different details [4].

The following is a brief technical discussion of the notions local models, models and context in Local Model Semantics as discussed in Ghidini and Giunchiglia [7:226-230] and [8]

L_i - a family of formal languages defined over a set of indexes I , L_i is a representation language that describes what is true in a context

\overline{M}_i is the class of all models or interpretations of L_i so that each L_i in $\{ L_i \}$ is interpreted in its own, potentially different structure.

$m \in \overline{M}_i$ is a *local model* of L_i

Local models are paired into single structures through *compatibility sequences and relations*. Compatibility sequences pair local models that are mutually compatible and consistent with the situation being described. These pairings create *models* derived from sets of mutually compatible sequences of local models.

A compatibility sequence c for L_i is a sequence $c = \langle c_0, c_1, \dots, c_i, \dots \rangle$

Where for each $i \in I$, c_i is a subset of \overline{M}_i (or the model and interpretations of L_i)

A compatibility relation C (for a given language L_i) is a set C of compatibility sequences c

A model (for L_i) is defined as a compatibility relation with at least one sequence and does not contain a sequence of empty sets. These are conditions formally defined as

- (1) $C \neq \emptyset$;
- (2) $\langle \emptyset, \emptyset, \emptyset, \dots, \emptyset \rangle \notin C$;

Given a model $C < c_0, c_1, \dots, c_i, \dots >$, context is any c_i allowed in C within a particular compatibility sequence. A context consists of a set of models that exactly captures facts which are locally true within the constraints posed by local models of other contexts in the same compatibility sequence, as allowed by a given compatibility relation. Context is thus formed from a set of models and is partial object.

3 Categories and External Representation

One theoretical approach that could be used in parallel with LMS as a starting point for developing representation languages, local models, models and contexts relevant to geo-historical contexts derived from multi-scale phenomena is basic-level category theory [14]. In particular, the use of geographic categories [9, 17] and historical categories [20] can be used to understand geo-historical context at various scale and detail dependant levels.

Basic-level geographic categories (country, region, state, etc.) capture the hierarchical nature of how the world is categorized, often based on spatially contained regions [11]. The historic category state of experience, or where past things are present or can be remembered allows for a formal structuring of past events. When basic-level geographic categories and the historic category state of experience are combined, they can form the basis for defining local languages (L_i). Subordinate geographic categories (United States, Pennsylvania, etc) and specific past events can form the basis for local models (M_i) that are interpretations of L_i that can in turn form compatibility sequences.

The following is a discussion of how the geographic-historic situation “Waynesboro Bourough, located in Franklin County, Pennsylvania had a flood in 1980” could be modeled with LMS. In this example, three of the four propositional languages (L_s, L_c, L_b) are based, respectively, on basic geographic categories (county, borough, state). Each of these languages would utilize propositional constants derived from a set of toponyms (that are in fact subordinate level geographic categories) that fall within the administrative hierarchy of the category and/or are constrained topologically based on the situation being modeled (see [6] for a discussion of topological relationships relevant to geographic phenomena). Topological constraints in fact serve as a form of compatibility between local models as the sets of facts in one local model will structurally affect and/or influence other local models [8]. For example, $P_s = \{Alabama, Alaska, Arizona...Pennsylvania..n\}$ would define US states that in turn would effect $P_c = \{Adams, Allegheny, Armstrong, Beaver...n\}$ which would only be those counties within the state of Pennsylvania. P_b would be only those boroughs within a selected county that is within the state of Pennsylvania.

The propositional language for state of experience (L_h) could be based on an inventory of past disaster events¹. Facts within L_h , for this example, would be derived from a compatibility relationship defined as events that occurred within the geographic region of the situation (in this case, Pennsylvania). Subordinate level

¹ For example, an inventory such as that found at http://www.fema.gov/news/disasters_state.fema?id=42

categories (as defined by toponyms and events) serve as compatibility sequences within local models.

A compatibility relationship is then formed through a set of compatibility sequences subject to constraints (such as a borough must be in a county which must be in a state) needed to represent the situation. A model of the languages being used to describe the situation is then formed from the compatibility relationship.

Visually, this situation, modeled with LMS, might appear like Figure 1.

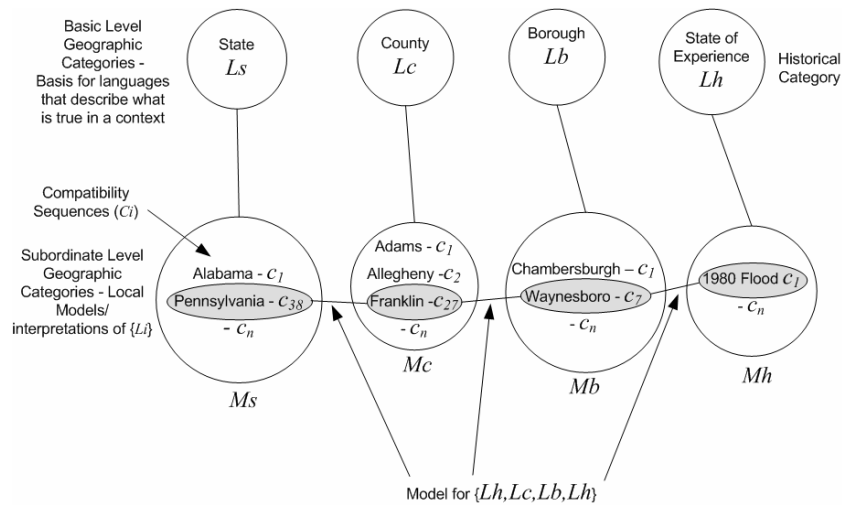


Figure 1: Modeling a Geographic-Historical Situation with LMS

For practical application and use, the previously discussed approach to modeling a geo-historical situation will need to rely on external, visual representations for sense-making and reasoning. External, visual representation can serve as one form of external cognition that can structure or restructure a given situation and the geo-historic categories used in that situation. Knowledge subsets and local context models are derived from reality through external representations and reflect localized effects that range any where from geographic data availability to implicit ontologies, or a persons world view on how they conceptualize a given domain or geographic space (Figure 2).

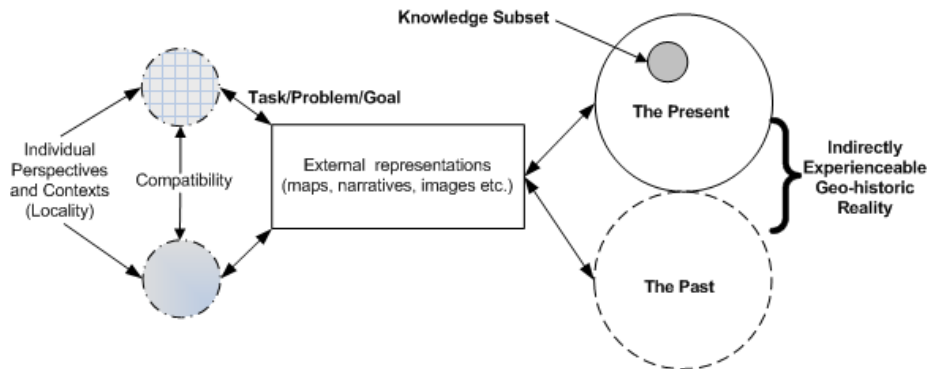


Figure 2: Knowledge subsets derived from reality through external representation that reflect localized effects; dashed lines represent individual perspectives/contexts drawn from subsets of knowledge of reality.

Structuring or restructuring a situation or the perspective on a situation through external representation may affect compatibility relationships between local models as reasoning about the situation maybe modified or influenced. For example, reasoning with a temporal/historical phenomena through a time line view versus a textual narrative or graphical constraining such as visually emphasizing one particular data source over another with modification to figure-ground relationships in order to draw attention to the source [15, 21].

3 Case Study

Ideally, collaborative development of geo-historical context from heterogeneous data sources can embrace the diversity of meaning, interpretations and perspectives on places and events contained in heterogeneous information sources and seek to find meaningful, compatible relationships between local contexts of the collaborators. Furthermore, variation in geographical and historical detail contained within individual information sources can be retained and not abstracted away (for example, ensuring that a category of Central Pennsylvania is not abstracted to Pennsylvania). Retaining heterogeneity may be critical for broader contextualization of situations that reflect varying perspectives and changes in opinions [5]. For example, two news media outlets covering the same story may have varying degrees of geographic detail about a story; the local news outlet where the event discussed in the story occurred may have much more detail than a national outlet reporting the story.

From a human Geography perspective, it may be argued that relative, localized approaches to developing and understanding geo-historical context are ideal as these relative approaches embrace the richness, diversity, complexity, and interrelationships found within an “ecology of place” where understanding of place emerges from the interlacing of relationships and not from preset descriptive categories and essentialist approaches that see the world in an objective, conformist manner [1, 18].

The following is a hypothetical case study of how the basic concepts of Locality and Compatibility from LMS and geo-historical categories can inform how geo-historical context can be developed through external, visual representations. This case study uses an online prototype collaborative tool called the Context Discovery Application (CDA) that allows collaborators to develop geo-historical context from heterogeneous data sources such as news stories and shared geospatial data [19].

In this example, two officials from adjoining counties in the gulf coast region of the United States are examining ongoing relief efforts to hurricane Katrina using the CDA. In LMS terms, since both collaborators share a common geographic area (the counties share a common border), they will have compatibility in their reasoning, but each will have different locality as a result of implicit ontologies that create differing local contexts based on different levels of detail available (such geo-spatial datasets and jurisdictions), needed or perceived.

In this example, the first hypothetical user (Brian, from Harrison County, Mississippi) has a local model of context that is derived from the basic-level geographic category of town, and subordinate categories of local streets within that town that form compatibility sequences as visually represented in the streets web map service (WMS²) layer (Figure 3).

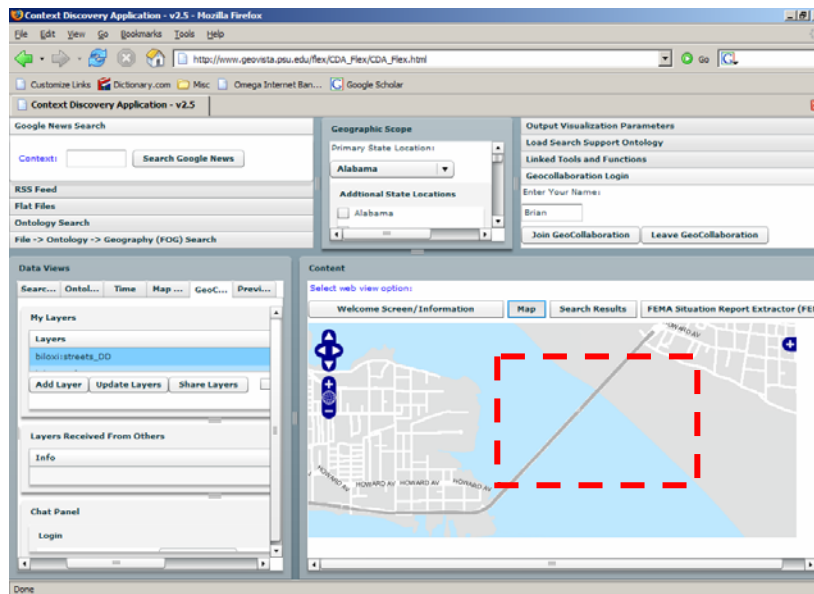


Figure 3: Visual representation of a local model (Brian). The dashed-line box represents the approximate common geographic areas between Brian and Donna.

The second hypothetical user (Donna, from Jackson County, Mississippi) has a local model of context that is derived from the basic geographic category of county and subordinate categories of streets only from that county at the county level (i.e. no local streets) (Figure 4).

² <http://www.opengeospatial.org/standards/wms>

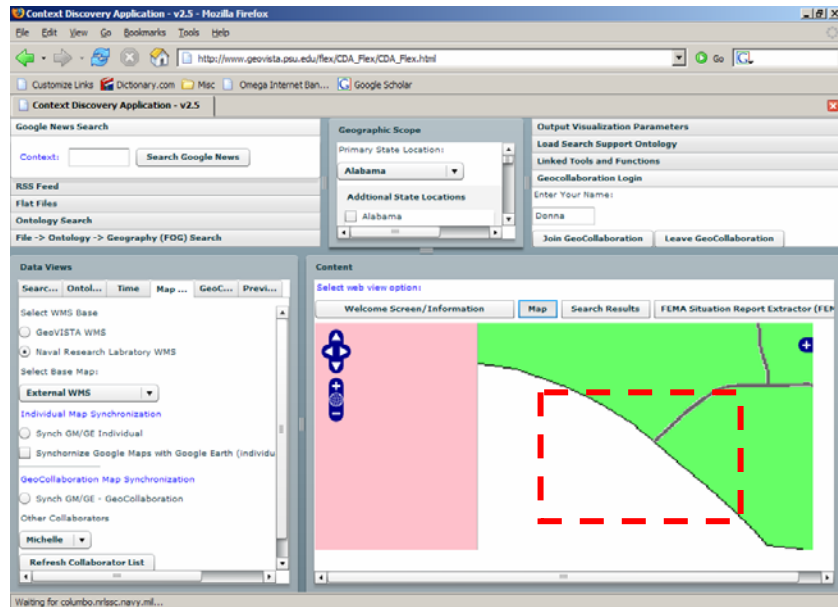


Figure 4: Visual representation of a local model (Donna). The solid area (pink) on the left is the area of Brian's local model, and is the limit of Donna's available data. The dashed-line box represents the approximate common geographic areas between Brian and Donna.

Because the local model of Donna is developed from visual representations that effect geographic categories Donna uses to reason with the local model, the level of detail and possible compatibility sequences within Donna's local model(s), in this case, is less than that of Brian since Donna has less visual representation available because of lack of data.

In Figures 3 and 4, the dashed-line boxes figuratively represent one possible form of geographic compatibility between Brian and Donna's reasoning. For example, the presence of a bridge in this area represents an object both users may need to reason with in shared problem solving. The bridge is likely to be part of the local reasoning of both users that will mutually influence, constrain and shape each users individual localized reasoning and possibly make their individual localized reasoning agree [8].

Using the CDA's search capabilities, Brian queries for news stories related to Harrison county Mississippi and Katrina. The news stories develop a local historical model for Brian as he can review recent past events related to recovery efforts (Figure 5).

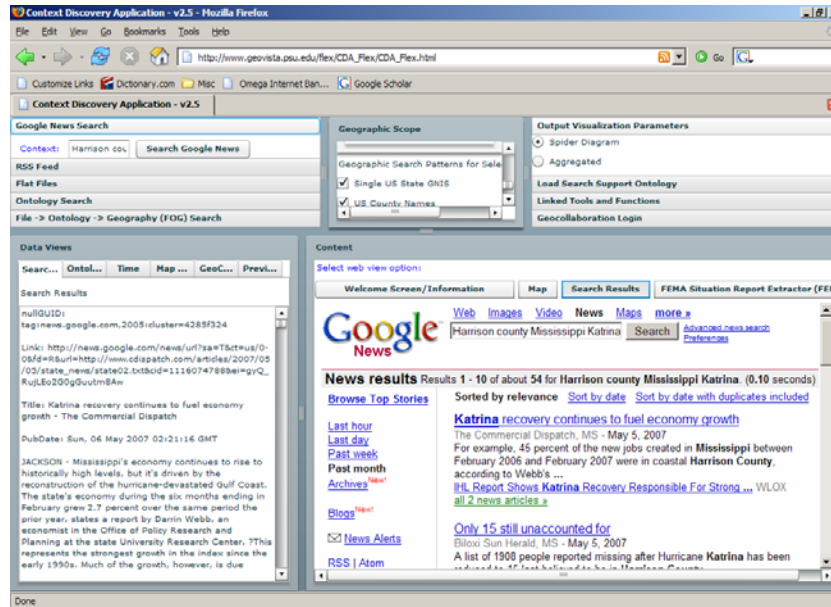


Figure 5: News stories related to ‘Harrison county Mississippi Katrina’ queried by Brian

Also using the CDA’s search capabilities, Donna queries for news stories related to Jackson county Mississippi and Katrina. Like Brian, the returned news stories develop a local historical model for Donna as she can also review recent past events related to recovery efforts (Figure 6). The terms “Mississippi” and “Katrina” act as a compatible relation between Donna and Brian as these terms will constrain and influence what information they will mutually view, and thus locally reason with.

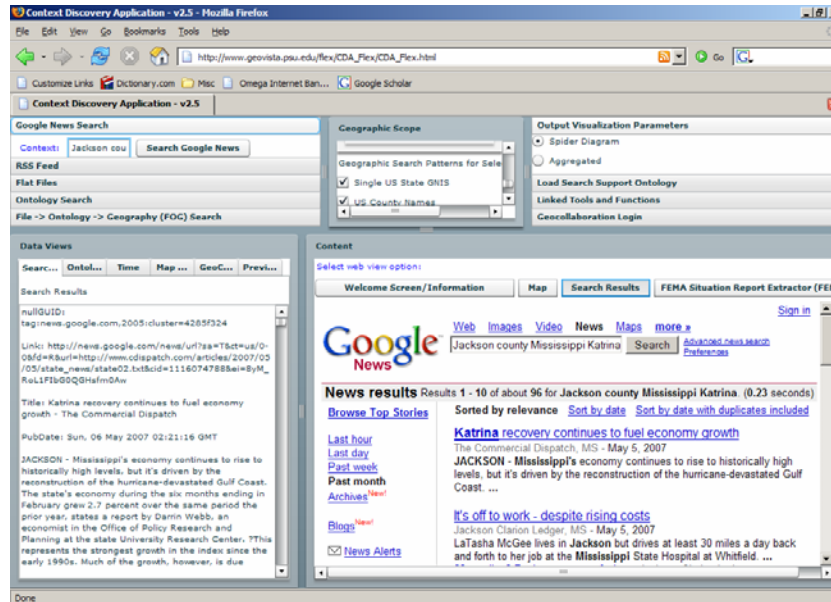


Figure 6: News stories related to 'Jackson county Mississippi Katrina' queried by Donna

Using a real time chat tool, both collaborators note the news story about Katrina recovery fueling economic growth. The story provides commonality for both collaborators, and represents a shift in context that requires more factual detail (such as increased geo-spatial data representation to understand geographical dimensions of the economic growth such as the effects on neighborhoods or civil infrastructure) so that shared problem solving and investigation into the situation can continue. Using the geocollaborative tools of the CDA, Brian has his local streets layer drawn on Donna's map, thereby adding more detail to Donna's local contextual model through visual representation (Figure 7).

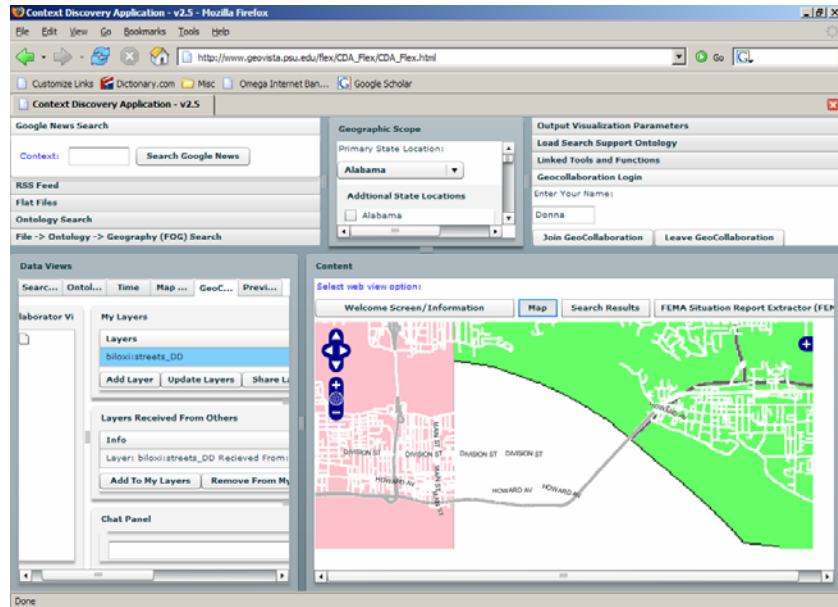


Figure 7: Level of detail in Donna's local model increased by the addition of visual representations from Brian.

3 Conclusions and Future Work

LMS and basic-level categories show promise for providing a theoretical and conceptual basis for informing the design of visual representations and virtual collaboration environments that model and represent geo-historical context. Future work on refined models and formal language definitions of specific geographic and historical categories and the effects that ad-hoc categories, or categories that do not have a regular, correlational environmental structure or are not well established in memory [2] may have on contextual models can lead to enhanced knowledge representation and reasoning and external representation procedures that can be used to develop geo-historical context from heterogeneous data sources.

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