Naive Geography

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Abstract

This paper defines the notion and concepts of *Naive Geography,* the field of study that is concerned with formal models of the common-sense geographic world. Naive Geography is the body of knowledge that people have about the surrounding geographic world. Naive Geography is envisioned to comprise a set of theories that provide the basis for designing future Geographic Information Systems that follow human intuition and are, therefore, easily accessible to a large range of users.

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1. Introduction

Naive Geography is the field of study that is concerned with formal models of the common-sense geographic world. It comprises a set of theories upon which next-generation Geographic Information Systems (GISs) can be built. In any case, Naive Geography is a necessary underpinning for the design of GISs that can be used without major training by new user communities such as average citizens, to solve day-to-day tasks. Such a scenario is currently a dream. Most GISs require extensive training, not only to familiarize the users with terminology of system designers, but also to educate them in formalizations used to represent geographic data and to derive geographic information. Naive Geography is also the basis for the design of intelligent GISs that will act and respond as a person would, therefore, empowering people to utilize GISs as reliable sources, without stunning surprises when using a system. This paper defines the notion[1] and concepts of Naive Geography.

Although various aspects of Naive Geography have been studied for at least 40 years in a piecemeal fashion, Naive Geography has never been addressed comprehensively as a theory of its own. Occasionally, different terms have been used to describe certain aspects of it—Spatial Theory (Frank 1987), Geographical Information Science (Goodchild 1992), Spatial Information Theory (Frank and Campari 1993), Environmental Psychology, or plain Artificial Intelligence. Aspects of Naive Geography have been also considered within academic geography, and can be found in books by Bunge (1962) or Abler *et al.* (1971). By labeling Naive Geography, and distinguishing it from related areas in spatial information theory, geographic information science, and Naive Physics, we intend to catalyze and focus work on some very central issues for these fields, and for artificial intelligence and GIS in general.

Central to Naive Geography is the area of spatial and temporal reasoning. Many concepts of spatial and temporal reasoning have become important research areas in a wide range of application domains such as Physics, Medicine, Biology, and Geography. Particularly the field of Naive Physics (Hayes 1979; 1985a) addresses concerns that appear at a first glance to be very similar to Naive Geography. We will, however, be more specific on the domain, and the types of representation and reasoning by focusing on common-sense reasoning about geographic space and time; subsequently called geographic reasoning. We argue that such a focus is necessary to treat appropriately the ontological and epistemological differences among the different application domains of spatio-temporal reasoning—their data and their reasoning methods, the way people use these data and interact with them.

Much of Naive Geography should employ *qualitative reasoning methods*. Note that this notion of qualitative reasoning is distinct from the notion of qualitativeness as it is occasionally used in geography to allude to descriptive rather than analytical methods. In qualitative reasoning a situation is characterized by variables that can only take a small, predetermined number of values (De Kleer and Brown 1984) and the inference rules use these values *in lieu* of numerical quantities approximating them. Qualitative reasoning enables one to deal with partial information, which is particularly important for spatial applications when only incomplete data sets are available. It is important to find representations that support partial information. Qualitative and quantitative approaches have significantly different characteristics. While quantitative models use absolute

[1] A poem by Waddington (1993) used the same term in a different context.

values, qualitative models deal with magnitudes, which can sometimes be seen as abstractions from the quantitative details; therefore, qualitative reasoning models can separate numerical analyses from the determination of magnitudes of events which may be assessed differently, depending on the context in which the particular situation is viewed. This is not to be confused with fuzzy reasoning, which is frequently applied to dealing with imprecise information (Zadeh 1974). Qualitative spatial reasoning is exact, as is its outcome; yet, the resulting qualitative spatial information may be underdetermined, i.e., there is a set of possible values, one of which is the correct result (Morrissey 1990). Qualitative information and qualitative reasoning are not seen as substitutions for quantitative approaches, they are rather complementary methods, which should be applied whenever appropriate. For many decision processes qualitative information is sufficient; however, occasionally quantitative measures, dealing with precise numerical values, may be necessary and that would require the integration of quantitative information into qualitative reasoning. Qualitative approaches allow the users to abstract from the myriad of details by establishing *landmarks* (Gelsey and McDermott 1990) when "something interesting happens"; therefore, they allow them to concentrate on a few but significant events or changes (De Kleer and Brown 1984).

The remainder of this paper continues with a brief review of Naive Physics (Section 2), and then defines Naive Geography in more detail (Section 3). Section 4 discusses an approach that promises progress toward the development of a Naive Geography. In Section 5, we lay out a sampling of ingredients of a Naive Geography. Section 6 presents our conclusions and points out some directions for further research.

2. Naive Physics

"Naive Physics is the body of knowledge that people have about the surrounding physical world. The main enterprises of Naive Physics are explaining, describing, and predicting changes to the physical world." (Hardt 1992, p. 1147). The term *Naive Physics* was coined by Patrick Hayes, and introduced in his *Naive Physics Manifesto* (Hayes 1978), a passionate and visionary statement that provided a catalyst for much research into qualitative methods for spatial and temporal problem solving. It was motivated by the recognition that Artificial Intelligence was—in the late 1970s—full of toy problems: "Small, artificial axiomatizations or puzzles designed to exercise the talents of various problem-solving programs or representational languages or systems" (Hayes 1978, p. 242). To overcome this limitation, Hayes proposed that researchers should concentrate on modeling common-sense knowledge.

Related terms and concepts include Intuitive Physics, Qualitative Physics, and Common-Sense Physics—some of these terms are more or less synonymous with Naive Physics, whereas others treat similar problems using different approaches. *Intuitive Physics* (McClosky 1983) addresses people's thinking about such tasks as dropping an object on a target while walking. Many people demonstrated poor performance in predicting when to release an object, which indicated that their intuitive models of physics may deviate from our current text-book examples of Newtonian Physics. Similarly, Naive Geography may follow Intuitive Physics as it may contradict many of our currently employed models for geographic space and time. *Qualitative Physics* (De Kleer and Brown 1984; De Kleer 1992) describes models of small-scale space in which objects undergo mechanical operations. A well-investigated example is the attempt to replicate the behavior of an analog clock (Forbus *et al*. 1991). While Qualitative Physics employs some methods that may be relevant to Naive Geography, it differs because Qualitative Physics usually focuses on the mechanics of a system and excludes human interaction.

Naive Physics by no means excludes geographic spaces. Indeed, Hayes's (1978) seminal paper on the topic contains examples of lakes and other geographic features; however, the great majority of the work in naive, common-sense, qualitative, and intuitive physics deals with spaces and objects manipulable by people, perceived from a single view point. There is strong evidence, from a variety of sources, that people conceptualize geographic spaces differently from manipulable, table-top spaces (Downs and Stea 1977; Kuipers 1978; Zubin 1989; Mark 1992a; Montello 1993; Pederson 1993; Mark and Freundschuh 1995). Thus, we think the new term, *Naive Geography*, is appropriate as part of an attempt to focus the research efforts of theoretical geographers and other spatial information theorists, on formal models of common-sense knowledge of geographic spaces.

3. Naive Geography: the Notion

In this paper, we are using the notion and concepts of *Naive Geography* to refer to what might otherwise have been called the *Naive Physics of Geographic Space*. Modifying Hardt's (1992) definition of Naive Physics:

> *Naive Geography is the body of knowledge that people have about the surrounding geographic world.*

Naive Geography captures and reflects the way people think and reason about geographic space and time, both consciously and subconsciously. *Naive* stands for instinctive or spontaneous.

Naive geographic reasoning is probably the most common and basic form of human intelligence. Spatio-temporal reasoning is so common in people's daily life that one rarely notices it as a particular concept of spatial analysis. People employ such methods of spatial reasoning almost constantly to infer information about their environment, how it evolves over time, and about the consequences of changing our locations in space. Naive geographic reasoning can be, and has to be, formalized so that it can be implemented on computers. As such Naive Geography will encompass sophisticated theories.

Naive geographic reasoning may actually contain "errors" and will occasionally be inconsistent. It may be contrary to objective observations in the real, physical world. These are properties that have been dismissed by the information systems and database communities. The principle of databases has been storage of non-redundant data to avoid potential inconsistencies. Information systems are supposed to provide one answer, one and only one. Naive Geography theories give up some of these restricted views of an information system.

3.1 The Essence of Naive Geography: Geographic Space

Geographic space is large-scale space, i.e., space that is beyond the human body and that may be represented by many different geometries at many different scales. Occasionally, geographic space has been defined as space that cannot be observed from a single viewpoint (Kuipers 1978; Kuipers and Levitt 1988). The intention of this definition was to describe the fact that geographic space comprises more than what a person sees. Of course, this definition falls short the moment one considers hills, towers, skyscrapers, hot-air balloons, airplanes, and satellites from which one can gain a view of much larger portions of space than by standing in a parking lot. A better definition of geographic space might be the space that contains objects that we humans do not think of being manipulable objects.

Geographic space is larger than a molecule, larger than a computer chip, larger than a table-top. Its objects are different from an atom, a microscopic bacterium, the pen in your hand, the engine that drives your car. Geographic space may be a hotel with its many rooms, hallways, floors, etc. Geographic space may be Vienna, with its streets, buildings, parks, and people. Geographic space may be Europe with mountains, lakes and rivers, transportation systems, political subdivisions, cultural variations, and so on. Within such spaces, we constantly move around. We explore geographic space by navigating in it, and we conceptualize it from multiple views, which are put together (mentally) like a jigsaw puzzle. This makes geographic space distinct from small-scale space, or table-top space, in which objects are thought of as being manipulable and whenever an observer lacks some information about these objects, he or she can get this information by moving the object into such a position that one can see, touch, or measure the relevant parts.

3.2 Naive Geography for GIS Design

In addition to the scientific motivation of trying to get a better understanding of how people handle their environments, there is the need to incorporate naive geographic knowledge and reasoning into GISs. The concepts and methods people use to infer information about geographic space and time become increasingly important for the interaction between users and computerized GISs. While many spatial inferences may appear trivial to us, they are extremely difficult to formalize so that they could be implemented on a computer system. Current methods to derive spatial and temporal information about geographic space are limited; therefore, we see a big gap between what a human user wants to do with a GIS, and the spatial concepts offered by the GIS. Today's GISs do not sufficiently support common-sense reasoning; however, in order to make them useful for a wider range of people, and in order to allow for prediction or forecasting, it will be necessary to incorporate people's concepts about space and time and to mimic human thinking; therefore, we will focus on common-sense geographic reasoning, reasoning as it is performed by people, reasoning whose outcome makes intuitive sense to people, reasoning that needs little explanation.

In the past, geographic reasoning has been limited to calculations in a Cartesian coordinate space; however, Euclidean geometry is not a good candidate for representing geographic information, since it relies on the existence of complete coordinate *n*-tuples. Likewise, pictorial representations are inadequate since they overdetermine certain situations, e.g., when drawing a picture representing a cardinal direction, a sketch also includes information about the sizes of the objects and some relative distances. Formalized spatial data models have been extensively discussed in the context of databases and GISs; however, to date there are, for instance, no models for a comprehensive treatment of different kinds of spatial concepts and their combinations that are cognitively sound and plausible. More flexible and advanced methods are needed to capture the results from cognitive scientists' studies, such as the fact that the nature of errors in people's cognitive maps is most often metrical and only rarely topological (Lynch 1960), or how topological structure (Stevens and Coupe 1978) or gestalt are used for spatial reasoning. Researchers have identified different types of spaces with related inference methods (Piaget and Inhelder 1967; Golledge 1978; Couclelis and Gale 1986).

GISs need to include such intelligent mechanisms to deal with often complex spatial concepts. If GISs can achieve geographic reasoning in a manner similar to a human expert, these systems will be much more valuable tools for a large range of users—family members who are planning their upcoming vacation trip, scientists who want to analyze their data collections, or business people who want to investigate how they performed in various geographic markets.

3.3 What Naive Geography is Not

Naive Geography is neither arm-chair science, nor does it employ Mickey-Mouse research. Likewise, Naive Geography is neither childish nor stupid geography, nor is it the geography of ignorant or simple-minded people. It is not geography by the uneducated nor for the uneducated. Despite the attempts to capture human performance, naive geographic reasoning does not aim at being descriptive, neither in its methodologies nor in its results and interpretations. And it is not just another term for fuzzy reasoning, nor is fuzzy reasoning a substitute for Naive Geography—it might have its value as one of several methods for naive geographic reasoning, though. Finally, Naive Geography is not a replacement for GIS.

3.4 Naive Geography and Related Disciplines

Naive Geography is not a completely new discipline. Quite the opposite, it is closely related to several of our current scientific and engineering disciplines, and builds upon them. Geography is the most obvious discipline—it is part of the name Naive Geography. Geography is the science concerned with relationships, processes, and patterns of our surrounding world, and as such it addresses at a coarse level the kind of issues we are concerned with. At a more detailed level, the domain-specific fields contribute to Naive Geography. They include geology, archeology, economics, and transportation as they describe particular domain knowledge that shapes the users' and analysts' mental models and therefore, often enable inference that is otherwise impossible.

These geographic disciplines are not the only relevant fields for Naive Geography. Naive Geography has to employ concepts and principles of cognitive science and linguistics to ensure a linkage with the way people perceive geographic space and time, and the ways they communicate about them. Naive Geography is associated with anthropology as it has to accommodate regional and cultural particularities in how people deal with geographic space and time. There is the field of psychology upon which Naive Geography builds. And philosophy may contribute to Naive Geography as Aristotle's, Kant's, or Leibnitz's views of space frame many of the discussions about the nature of Naive Geography.

Finally, there are the fields that provide us the tools to express and formalize naive geographic knowledge: engineering as it pertains to the modeling of geographic information, from measurements about the Earth to GIS user interface design, as well as computer science and mathematics.

This scanning of relevant fields is certainly incomplete, and there may be many others whose findings and influences may be even more dramatic than those listed here. There are many who contribute—as there are many who will benefit.

4. Towards the Development of Naive Geography

Naive Geography has to bridge between different scientific perspectives; therefore, in order to investigate naive geographic concepts, researchers have to combine different research methodologies. It will be the *interplay* between the different approaches that will provide the exciting and useful results.

The framework for developing Naive Geography consists of two different research methodologies: (1) the *development of formalisms* of naive geographic models for particular tasks or sub-problems so that programmers can implement simulations on computers; and (2) the *testing and analyzing of formal models* to assess how closely the formalizations match human performance. For Naive Geography, the two research methods are only useful if they are closely integrated and embedded in a *feedback loop* to ensure that (1) mathematically sound models are tested (bridging between formalism and testing) and (2) results from tests are brought back to refine the formal models (bridging between testing and implementable formalisms). The outcome of such a complete loop leads to refined models, which in turn should be subjected to new, focused evaluations. In an ideal scenario, this leads to formal models that ultimately match closely with human perception and thinking. From the refinement process we may gain new insight into common-sense reasoning and we may actually derive certain reasoning patterns. The latter—the generic rules—would manifest *naive geographic knowledge*.

Research in the area of spatial relations provides an example in which the combination and interplay of different methods generates useful results. The treatment of spatial relations within Naive Geography must consider two complementary sources: (1) the cognitive and linguistic approach, investigating the terminology people use for spatial concepts (Talmy 1983; Herskovits 1986; Retz-Schmidt 1988) and human spatial behavior, judgments, and learning in general; and (2) the formal approach concentrating on mathematically based models, which can be implemented on a computer (Egenhofer and Franzosa 1991; Papadias and Sellis 1994; Hernández 1994). The formalisms serve as hypotheses that may be evaluated with human-subject testing (Mark *et al.* 1995).

5. Some Elements of Naive Geography

The mere identification of a comprehensive set of elements of Naive Geography comprises a major research task, and its completion would provide a big step towards the successful manifestation of Naive Geography. As a starting point, we present an *ad hoc* collection of elements that would contribute to a Naive Geography. The list is by no means exhaustive, and some of the following may turn out to be false, or at least uncommon and/or limited to specific cultures, primarily those of the authors. We present these elements to give the reader a flavor of what we intend should be included in Naive Geography.

5.1 Naive Geographic Space is Two-Dimensional

Manipulable objects on a table-top are essentially three-dimensional. Even a sheet of paper has a thickness. Furthermore, in everyday-object (manipulable) space, the three dimensions are all about equal. Objects are easily rotated about any axis, or obliquely. When an object is moved, we expect its properties, spatial and non-spatial, to remain unchanged.

Geographic space under Naive Geography is, in contrast, essentially two-dimensional. There is considerable evidence that the horizontal and vertical dimensions are decoupled in geographic space. For example, people often grossly over-estimate the steepness of slopes, and the depths of canyons compared to their widths. So, instead of parsing a three-dimensional space into three independent one-dimensional axes, geographic space seems to be interpreted as a horizontal, two-dimensional space, with the third dimension reduced more to an attribute (of position) rather than an equal dimension. This is very much like the 2 1/2-D representations used in computational vision (Marr 1982). That GISs have succeeded in the marketplace with little or no capabilities to do three-dimensional analysis is testimony to the nature of geographic space. A two-dimensional system for CAD (computer-aided design) would not likely be successful.

5.2 The Earth is Flat

This is a different point than the one about two-dimensionality. In most of our large-scale reasoning tasks, this is a common simplification. It is not a discussion as to whether it is admissible, or not. People do it. When traveling from Boston to New York, one disregards the Earth's curvature. This is independent of the mode of transportation. Trans-Atlantic air travelers often ask why the flight path goes all the way up over Greenland, rather than going straight across—the great circle, shortest path between two points across the surface of a sphere, is not part of common-sense knowledge for most people.

5.3 Maps are More Real Than Experience

Perhaps this point should be, "Maps are more faithful to the reality of geographic space than are our direct experiences of such spaces." Many times, we hear statements like, "When I get home, I want to look at the route on a map, to see where I went." This seems to be based on a naive assumption that the truth about where one is in geographic space is better represented by a map-based, map-like, or configurational view of geographic space, than it is by our memories of our experiences with that space from within.

5.4 Geographic Entities are Ontologically Different from Enlarged Table-Top Objects

As geographic space differs from table-top space, so are the properties and the behavior of many entities in geographic space different from those on a table top. The issue is not just mere size. In his paper *Ontology of Liquids*, Hayes (1985b) gave an excellent example with a detailed discussion of how the ontology of lakes is different from that of many other objects composed of liquids. He showed how a phenomenon/entity in geographic space has an ontology that is not simply an enlarged version of the table-top manipulable world.

5.5 Geographic Space and Time are Tightly Coupled

The linkage between space and time is an aspect of Naive Geography that deserves special attention. The term *geographic space and time* is understood such that *geographic* distributes over *space and time*—formalists would tend to write `geographic (space and time)`. As there is geographic space, we want to argue that there is geographic time, i.e., time that is inherently linked to geographic concepts (Egenhofer and Golledge 1994). We select one of several examples to underline this claim:

Many cultures have pre-metric units of area that are based on effort over time (Kula 1983). The English *acre* (Jones 1963; Zupko 1968; 1977), the German *morgen* (Kennelly 1928), and the French *arpent* (Zupko 1978) all are based on the amount of land that a person with a yoke of oxen or a horse can plow in one day or one morning. There have been similar measures for distance, such as how far a person can walk in an hour, or how far an army can march in a day. We know of no such "effort-based" units of measure for manipulable (table-top) space.

5.6 Geographic Information is Frequently Incomplete

Another setting for geographic reasoning is given by the constraint that reasoning in geographic space must typically deal with incomplete information. Nevertheless, people can draw sufficiently precise conclusions, e.g., by completing information intelligently or by applying default rules, frequently based on common sense. A number of cognitive studies have provided evidence that people may employ hierarchically organized schemes to reason in geographic space and to compensate for missing information (Hirtle and Jonides 1985; McNamara *et al*. 1989).

5.7 People use Multiple Conceptualizations of Geographic Space

When thinking about geographic space, people typically employ several different concepts, and change between them frequently. Such conceptualizations of space may reflect the differences between perceptual and cognitive space (Couclelis and Gale 1986), or may be based on different geometrical properties, such as continuous vs. discrete (Egenhofer and Herring 1991; Frank and Mark 1991). The dependency on scale, or difference in the types of operations people would typically employ, has been raised as another motivation for distinguishing different types of spaces (Zubin 1989).

5.8 Geographic Space has Multiple Levels of Detail

This aspect of representing geographic space is orthogonal to multiple conceptualizations of geographic space. A conceptualization of geographic space may have several levels of granularity, each of which will be appropriate for problem solving at different levels of detail. In cartographic applications, this aspect has been considered to be part of *scale* (Buttenfield 1989). The naive view of geographic space implies that processing a query against a more detailed representation would not provide a more precise query result.

5.9 Boundaries are Sometimes Entities, Sometimes Not

The fact that Naive Geography models geographic space as it is perceived by people, is strongly reflected in the way boundaries are represented. There is no uniform view of what a boundary is and how it is established—even if one could agree on a model for the physical entities. Such simple configurations as national boundaries may have diverse interpretations, even if the countries involved agree over the extent of their territories. Conventionally, political subdivisions are modeled as a partition of space in which a boundary separates one nation’s land from its neighbor. Each of the neighbors may actually have a different perspective, namely that the boundary belongs to their country. As such, the boundary between two neighboring countries may be considered a pair of boundaries. Smith (1994) argues, from a philosophical point of view, that there may be geographic situations in which the boundary between two adjacent areas is even asymmetric. As examples he cites situations in which one country did not recognize the existence of a national boundary with its neighbor, while the other country considered it a valid boundary. Political subdivisions are certainly not the only cases in which such multiple views of boundaries may occur. The same case could be made for land parcels and the question as to who owns the boundary between two adjacent parcels.

5.10 Topology Matters, Metric Refines

In geographic space, topology is considered to be first-class information, whereas metric properties, such as distances and shapes, are used as refinements that are frequently less exactly captured. There is ample evidence that people organize geographic space such that topological information is retained fairly precisely, capturing such relationships as inclusion, coincidence, and left/right (Lynch 1960; Stevens and Coupe 1978; Riesbeck 1980).

5.11 People have Biases Toward North-South and East-West Directions

People's mental maps of directions and distances are frequently quite gross simplifications, with particular preferences for alignments in North-South and East-West directions. Despite exposure to maps and satellite images, we often ignore *geographic reality*. For instance, at a global scale, South America often is considered to be due south of North America. Likewise, most people misjudge latitudes when trying to compare cities in North America and Europe (Tversky 1981). While such misconceptions are similar to those found by Stevens and Coupe (1978), they cannot be explained with a hierarchical conceptualization of geographic space. A potential source for some of these errors are climate comparisons, and the equation (for the Northern hemisphere) that colder means further North, and warmer equates to further South, may indicate that factors other than geographic location may influence estimations of directions.

Biases toward strict cardinal directions appear also in judgments about coastlines—the U.S. East coast is frequently believed to be due North-South (Mark 1992b). Such misconceptions may have surprising consequences when people interact with information systems. For example, most people requesting the satellite image South of the State of Maine from an image archive, would expect to receive an image that covers parts of New Hampshire and Massachusetts (Frank 1992). They would be puzzled to get nothing but water!

People tend to have similar biases towards North-South directions and right angles in navigation, where they may be irritated by slight deviations from the norm and consequently perform poorly in wayfinding.

5.12 Distances are Asymmetric

Euclidean geometry includes the axiom that a distance from point *A* to point *B* is equal to the distance from *B* to *A*. In naive geographic space, this premise is frequently violated. Distances are not only thought of as lengths of paths on the Earth's surface, but frequently seen as a measure for how long it takes to get from one place to another (Kosslyn *et al.* 1978). The *shortest* path may have multiple interpretations, e.g., in terms of distance, time, fuel consumption, or toll. Even if the same path, in opposite directions, is chosen between two points, the *distance* as people perceive it may not be the same (Golledge *et al.* 1969): terrain may influence how fast one can travel or traffic during rush hours may slow down travel in one direction.

While distance applies as a measure between positions in geographic space, it extends to abstract concepts where it captures *conceptual closeness*. For example, among water bodies, a pond is conceptually closer to a lake than to the sea, because one can find more conceptual differences between a pond and the ocean than between a pond and a lake. The shorter the distance is, the more similar the instances are. Again, such distances among concepts are frequently asymmetric, implying that the induced similarity is asymmetric as well (Papadias 1995), i.e., if *A* is similar to *B*, then *B* is not necessarily similar to *A*.

5.13 Distance Inferences are Local, Not Global

Geographic distances are thought of as local, i.e., covering the neighborhood between the two points of interest, without involving locations remote to both objects. Common coordinate systems, however, have their origins at the equator, and distance differences are calculated as differences of lengths from the equator and from Greenwich. How far it is from Bangor, Maine to Orono, Maine is based on how distant Bangor and Orono are from the equator, and how remote Bangor and Orono are from Greenwich, U.K. (Goodchild 1994). In a similar way, any distinction about North, South, East, and West is related on the reference frame's (remote) origin. Despite the convenience of such coordinate calculations, alternative spatial reference systems are needed in support of Naive Geography. Such reference systems should pay attention to neighborhood relations, as demonstrated in measurement-based systems (Buyong *et al*. 1991), or use coordinate-based calculations as a last resort of inference, as supported by deductive geographic databases (Sharma *et al*. 1994).

5.14 Distances Don't Add Up Easily

Reasoning about distances along networks in geographic space underlies formalisms that differ considerably from standard calculus. Usually, one adds up lengths of segments along a path, irrespective of their values, to obtain the length of the entire path. This method provides unreasonable results in cases where the values to be added differ by large amounts. For instance, the distance between the airports in Bangor, Maine and Santa Barbara, California is approximately 5,000 kilometers. When computing the travel distance from the University of Maine to UC Santa Barbara, it would make little sense to add the relatively short legs between the campuses and the respective airports—10 kilometers and 1.5 kilometers—to the overall distance and claim that it took 5,011.5 kilometers to get from one campus to the other.

6. Conclusions

This paper described the notion and concepts of Naive Geography. Naive Geography establishes the link between how people think about geographic space and how to develop formal models of such reasoning that can be incorporated into software systems. Such intelligent GISs—one or two generations down the road—would be intuitive to use and would provide powerful reasoning capabilities and some limited methods to make predications of human behavior. Like Patrick Hayes in his *Naive Physics Manifesto*, we consider our framework as a start of a discussion, to be revised in the future.

Common-sense reasoning is difficult, and if there are formalizations that appear to be common-sensical, then they are excellent results. Unfortunately, our scientific communities frequently consider such formalizations as "too simplistic"—because everyone understands them, and science should have some complexity to be considered science. We disagree with this attitude at the level of common-sense reasoning. *If it is simple and solves the problem, then it is good.*

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