Human Conceptions of Spaces: Implications for GIS
S. Freundschuh and M. Egenhofer
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Human Conceptions of Spaces: Implications for Geographic Information Systems[1]

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Abstract
The way people conceptualize space is an important consideration for the design of geographic information systems, because a better match with people's thinking is expected to lead to easier-to-use information systems. *Everyday space*, the basis to geographic information systems (GISs), has been characterized in the literature as being either small-scale (from table-top to room-size spaces) or large-scale (inside-of-building spaces to city-size space). While this dichotomy of space is grounded in the view from psychology that people's perception of space, spatial cognition, and spatial behavior are experience-based, it is in contrast to current GISs, which enable us to interact with large-scale spaces as though they were small-scale or manipulable. We analyze different approaches to characterizing spaces and propose a unified view in which space is based on the physical properties of manipulability, locomotion, and size of space. Within the structure of our framework, we distinguish six types of spaces: *manipulable object space* (smaller than the human body), *non-manipulable object space* (greater than the human body, but less than the size of a building), *environmental space* (from inside building spaces to city-size spaces), *geographic space* (state, country, and continent-size spaces), *panoramic space* (spaces perceived via scanning the landscape), and *map space*. Such a categorization is an important part of *Naive Geography*, a set of theories of how people intuitively or spontaneously conceptualize geographic space and time, because it has implications for various theoretical and methodological questions concerning the design and use of spatial information tools. Of particular concern is the design of effective spatial information tools that lead to better communication.

Keywords: Space-geographic, space-categories, cognition-spatial, GIS,

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1. Introduction

The way environmental or physical spaces have been modeled and manipulated in current geographic information systems (GISs) is contrary to how people experience and conceptualize this space (Couclelis 1992; Frank and Mark 1991). Psychologists (and some geographers) have characterized *everyday space* as being either small- or large-scale (Downs and Stea 1977; Ittelson 1973). In a *small-scale space* a person can see all places within that space from one vantage point. Typical examples are table-top spaces or room-size spaces (Ittelson 1973). In contrast are *large-scale spaces*, which cannot be perceived from a single view and, therefore, require locomotion through the spaces in order to experience them. By their nature, large-scale spaces are learned piecemeal, over time. These spaces include inside-of-building spaces, geographic neighborhoods, and city-size spaces (Downs and Stea 1977). This dichotomy of space has typically been associated with navigation and wayfinding behavior and is grounded in the view from psychology that people's perception of space, spatial cognition, and spatial behavior are scale-dependent and experience-based (Montello 1993).

This scale-dependent, experienced based view is in contrast to the space of vector GISs and maps (Newtonian space comprised of Euclidean objects) whose properties are typically treated as scale-independent:

> Objects in a vector GIS may be counted, moved about, stacked, rotated, colored, labeled, cut, split, sliced, stuck together, viewed from different angles, shaded, inflated, shrunk, stored, and retrieved, and in general, handled like a variety of everyday solid objects that bear no particular relationship to geography (Couclelis 1992, p. 66).

"There are difficulties with this view of the world, mainly that points, lines, and polygons that define vector objects do not have naturally occurring counterparts in the real world (Couclelis, 1992, p. 66)". At best, they are reasonable approximations of geographic phenomena when modeled at specific scales. Once the scale has been determined, then the spatial problem at hand is scale-independent. This inattention to different spatial conceptualizations has led to misrepresentations in today's GISs, which in turn may make it increasingly difficult to use such systems (Nyerges et al 1995).

Although human spatial cognition seems to operate differently in small- and large-scale spaces, maps and GISs enable us to interact with large-scale spaces as though they were small-scale or manipulable (Frank 1996). This unique property of spatial information tools has a rich history in the spatial sciences (Mark and Freundschuh 1995). These tools have long played a central role in reasoning about large-scale spaces. Because small- and large-scale spaces are cognitively different, maps and GISs are in a sense misrepresentations of large-scale spaces; therefore, how people perceive and comprehend the world at different scales is a relevant and important question, both conceptually and pedagogically.

Recent discussions in the geographic, linguistic, and cognitive science literature have focused on experientially based types of space, proposing models of space that go beyond this binary distinction of small- and large-scale (Couclelis 1992; Mark and Freundschuh 1995; Montello 1993; Talmy 1983; Zubin 1989). Some of these discussions have been encouraged by the works of Johnson (1987) and Lakoff (1987) on experiential realism, which assert that spatial cognition is structured by sensorimotor or bodily experience and influenced by cultural traditions. People learn about the environment through the senses—mainly via sight, touch, and sound—and it is these experiences that impel subsequent cognitive categories and concepts, or what Johnson (1987) refers to as image schemata. *Image schemata* are defined as recurrent patterns, shapes, and regularities in our actions, perceptions, and conceptions—recurrent experiences that serve as ongoing ordering activities. These activities result in meaningful structures for organizing our experience, and the application of current knowledge of schemas to new situations enables people to make sense, learn, and reason about our environment (Freundschuh and Sharma 1996). Image schemata can be described in terms of bodily experiences, structural elements, a basic logic, and metaphorical extensions. For example, consider the *surface* schema. Our experiences tell us that we walk, lay, and sit on surfaces, or that we place objects on surfaces (e.g., pictures on walls or books on tables). The structural elements of a surface include a region divided by a 2-dimensional plane. Logic indicates that if the surface is horizontal, objects are on/off or above/below, and if vertical, objects are off/on or in front/behind. Via metaphorical extensions the surface schema can apply to abstract concepts such as behavior, in that one can "tread on thin ice." Johnson (1987) argues that spatial and temporal image schemata are pervasive and constitutive of everyday bodily experience and language, suggesting that spatial image schemata are central to spatial cognition and to how humans perceive, categorize, and represent the world.

The importance of spatial image schemata for GIS design has been raised before, particularly for data models and human-computer interaction (Mark 1989, Mark and Frank 1996). This paper extends the experiential-realism paradigm to drive a categorization of space that is based on people's perception of, and interaction with, the world. Such a categorization is part of *Naive Geography*, a set of theories of how people intuitively or spontaneously conceptualize geographic space and time (Egenhofer and Mark 1995). The way people conceptualize space is an important consideration for the design of geographic information systems, because a better match with people's thinking is expected to lead to easier-to-use information systems (Frank 1993; Mark 1993). It should be noted here that this paper does not pursue the meaning of space, and the causes of spatial patterns (Entrikin, 1991; Sack, 1980). Sack (1980) provided a foundation for discussion of the different meanings of space that are the result of various modes of thought, including what Sack referred to as "scientific, social-scientific, the aesthetic, the child's view, the practical, the mythical-magical, and the societal (p. 23)". These modes of thought suggest "that geographic space is seen and evaluated in different ways at different times and in different cultures (p. 3)", and that these modes carry different levels of objectivity and subjectivity in terms of the meaning and understanding of space.

Sack stated that no one mode was sufficient for describing multiple conceptions of space, and that these various conceptions may offer differing reasons to explain the *where*, *how* and *why* of various spatial patterns exhibited by features in the world. For example, science tells us that a circle is the most compact shape with regard to area, enclosing the greatest amount of area with the shortest perimeter. This compactness is then used to explain circular settlement patterns, pointing out that a circular pattern is efficient for both access to the area center, and for military defense. In contrast, the mythical-magical mode of thought might explain a circular settlement pattern based on beliefs of the cosmos. If the cosmos are believed to be round, constructing circular settlement patterns would "tap into the cosmic forces and be in sympathy with the heavens (p. 19)". Sack's (1980) resultant model of space included three components: Subjective Space, Objective Space and the space of Substance. The intent of this paper is not to thrash out the multiple meanings of space based on cultural, temporal, and philosophical differences. The intent here is to draw a link between how space is represented in a GIS, and how this representation compares to how people experience or perceive physical space.

In Section 2, we review existing models of space focusing on how each model parses space, drawing parallels between kinds of spaces (e.g., object space or neighborhoods), and we suggest a framework for a categorization of space based on the experiential notions of manipulability, locomotion, and size of space (Section 3). In Section 4 we introduce a categorization of space that is congruent with our conceptual framework and enables us to demonstrate formalized links between types of space. In Section 5 we discuss implications of these types of spaces on the design of next-generation GISs.

2. Cognitive Models of Space

The traditional approach used in the design of geometric data models goes back to Cartesian coordinate space (Egenhofer and Herring 1991; Frank 1992). These models start from the mathematical basis of points in an infinitely precise space and construct more meaningful concepts as sequences and enclosures of connections of points. Such space is static and of a single level of detail. While this model may be appropriate for constructing geometries, it does not necessarily reflect those concepts that are important when people think of geographic space. Geographic space, in this paper, refers to the physical spaces that humans experience on a daily basis. These are the types of spaces most often modeled with maps and other spatial tools such as GIS. This section summarizes the key concepts of alternative conceptualizations of space that emphasize people's experience with space.

2.1 Models of Small- and Large-Scale Spaces

One of the earliest works to distinguish between types of spaces was Lynch's (1960) *Image of the City*, where he discussed the role that environmental images play in social development, emotional security, and people's experiences, as well as their role with regard to movement within the environment. Based on interviews of residents of three American cities, Lynch dissected the city into its cognitive component parts, which include among others spatial nodes, districts and spatial regions (Lynch discussed spatial regions, but did not specifically label them as one of his five elements) A *spatial node* is a space that can be "scanned quickly" (p.105), inferring that it can be perceived from one position. Nodes are commonly intersections of paths, but they can also be large squares, linear shapes, central districts when the city is being considered at a large enough level, or at a national scale an entire city. *Districts*, on the other hand, are large subsections of cities that have a common defining characteristic such as ethnicity, class, building types, or topography. These defining characteristics create thematic units that can foster strong emotions of *place* in residents of a city. Unlike a spatial node, a district cannot be scanned, but must be experienced "as a patterned play of spatial changes, by a rather protracted journey through it" (p. 105). A *spatial region*, like a district, must be experienced over time from movement through the environment. In contrast though, a spatial region is characterized by "a structured continuum of spatial form" rather than by "a homogeneous spatial quality" inherent in districts (p. 105). This model stresses the importance of a city's legibility, structure, identity, and its imageability in terms of urban design, because it relies on the elemental spaces used by urban dwellers to organize their social and physical world—spatial nodes, spatial regions, and districts. Subsequent works that have considered different kinds of spaces have done so from different perspectives.

The relationships between scale, space, and people's experience was important in Ittelson's (1973) conceptualization of space, distinguishing between the space of *objects* and what he termed *environmental space*. Prior to that, most research concerning space perception had focused on distance, orientation, and movement of people and objects in space, rather than on space perception of the environment itself. The space of objects comprises primarily those objects smaller than the human body. In contrast to objects, environments surround, enfold, and engulf—people and objects cannot be outside of or apart from their environment. Environments necessitate movement within them in order to perceive and experience all parts of them. They extend from spaces of the size of a room to the whole universe and, therefore, scale plays a central role in this distinction between objects and environments.

Another model of space that is based on scale distinguishes between the *experimental laboratory space* of psychologists, called *object space*, and the *outside laboratory space* of geographers, called the *space of places* (Canter 1977). While geographers operate at a regional scale, psychologists operate at the scale of a buildings, and the links between these different levels (i.e., sizes) of place provide a continuum of the ranges of scales of places. Unlike object space, which has little emotional content, places foster emotional attachments that influence the perception of the environment.

Downs and Stea (1977) also distinguished between an object (i.e., small-scale) space and an environmental (i.e., large-scale) space. *Small-scale spaces*, or what they also referred to as *perceptual* spaces, contain three-dimensional objects that are manipulable (can be held, rotated, etc.). In contrast, *large-scale* or *transperceptual* spaces cannot be perceived from one perspective, but rather are pieced together through repeated direct experience within the environment.

The TOUR model included large-scale space explicitly and small-scale space implicitly (Kuipers 1978). Large-scale space cannot be observed from a single viewpoint, which includes road networks experienced during navigation, but excludes a variety of spatial tools such as maps and aerial photographs. On this basis, small-scale spaces are those that can be perceived from one perspective, suggesting that maps, in this instance, are representations of large-scale spaces in an object space. The distinction between small- and large-scale spaces is scale-dependent and relies on the position of the observer with respect to the perceived environment. In this regard, a city, which in the TOUR model would typically be considered a large-scale space, is a small-scale space when viewed from the window of an airplane or on a map.

2.2 Models of Small-, Medium-, and Large-Scale Spaces

Siegel (1981) recognized a continuum of spaces ranging from table-top spaces to countries and continents, distinguishing between three kinds of spaces, but like in the TOUR model, used only the terms small- and large-scale to classify them. In this model, *small-scale spaces* are of body size and smaller, while *large-scale spaces* range from house-size to city-size spaces—the primary distinction being that small-scale spaces can be perceived from one vantage point, whereas large-scale spaces are comprehended from the integration of spatial information learned via navigation (i.e., in parts) over an extended period of time. Siegel also included in small-scale space those spaces that were too large to experience via navigation, such as states, countries, and continents. These very large spaces are usually experienced from maps and other small-scale symbolic representations of a size smaller than the human body.

Another model with three kinds of spaces distinguishes between small-, medium-, and large-scale (Gärling and Golledge 1987). *Small-scale space* is the space at the level of a single room. *Medium-scale space* includes inside-of-building spaces and neighborhoods. Implicit in this definition is that unlike small-scale spaces, medium-scale spaces cannot be perceived from one perspective, but are comprehended from repeated exposure to the space. *Large-scale spaces* are similar to medium-scale spaces in that they require locomotion in order to perceive them, but the spaces are much larger and are learned in a more piecemeal fashion over a greater length of time. These spaces include city-size spaces and larger.

Although Mandler's (1983) model of space uses the same terminology as Gärling and Golledge—small, medium, and large—the meanings of the terms are different. Here, *small-scale space* consists of table tops or small-scale models of larger spaces. Spatial information about these spaces is gleaned from a single perspective. In addition, the perceiver stands outside of the space rather than in it. *Medium-scale spaces*, on the other hand, are room-size spaces that require movement to perceive objects in the space, but like small-scale spaces, spatial relationships can be deduced from one perspective. *Large-scale spaces*, which include houses, towns, and cities, are spaces where spatial relations cannot be perceived directly, but rather are induced from navigation experience. Although this model does not include very large-scale spaces (such as countries and continents), it is inappropriate to consider these as spaces that surround and enclose, as this spatial knowledge typically comes from maps and other vertical perspectives, rather than from direct experience (Montello 1993). This suggests a unique role for maps in the spatial cognition of large-scale places.

2.3 Maps as Representations of Space

Mandler's, Kuipers's, and Siegel's models were the earliest to suggest, or at least imply, that very large geographic spaces can be instances of a large-scale space in an *object* or *table-top space*—a notion that geographers had previously recognized and exploited. Cartographers (and geographers) have long defined the terms small- and large-scale as a reduction of space, rather than as a descriptor of the size of a space. Large-scale, in cartographic terminology, refers to little reduction in size from the real world to a map, whereas small-scale refers to a big reduction in size, relatively speaking, from the real world to a map. An example of a large-scale map could be a 1:10,000 map of the City of Chicago. In contrast, a small-scale map could be a 1:10,000,000 map of the United States.

Rather than using the terms large- and small-scale, Muehrcke and Muehrcke (1992) use terms that are tied intrinsically to geographic scope (in relation to how much of the world is shown on a map), rather than to what can be observed directly in the environment. They provided the terms global and local scope. There are no established boundaries of how much area comprises a global or local scope, because like small- and large-scale, they are relative terms. With regard to map scale, convention suggests that a *local scope* includes maps at a scale of 1:25,000 and larger (e.g., towns, parks, buildings) and a *global scope* includes maps at a scale of 1:100,000 or smaller (e.g., cities, states, countries). Due to the relative nature of these terms, it is difficult, if not impossible, to logically categorize maps ranging in scale from 1:25,000 to 1:100,000 as either local or global. It might be helpful to create a third category to describe this range, possibly called *regional scope*.

2.4 Models that Relate to Interactions

Kolars and Nystuen (1975) provide a hierarchy of geographic space that is defined by the level of interaction among people and between people and the environment surrounding them. Scale is an important consideration in this hierarchy as scale influences the spatial behavior of individuals and any interpretations made about specific behaviors. *Personal space* is within arm's reach where the primary modes of interaction are voice, touch, taste and smell and involve only a few people; *living/working space* involves one-to-one interactions among 50–400 people using audio or visual modes of communication; *house/neighborhood space* has many-to-one exchanges with 100–1000 people using amplified audio-visual communication; *proxemic space* is beyond face-to-face interactions, focusing on the geographic environment; *city-hinterland space* encompasses 50,000–1 million people who rely on local news media, TV, institutions, and commuter systems for interaction; *regional-national space*, the space of legal, economic and political systems, encompasses 200+ million people who interact via the national news media, national organizations, and a common language; and finally, *global space*, the space of 5+ billion people, restricts interactions by travel and trade barriers and agreements. This is the only model reviewed that speaks specifically to the relationship between size of space and the types and level of interaction among inhabitants of that space, suggesting again the link between how people experience space and how they subsequently might behave in that space.

In behavioral geography, there has been a long standing distinction between perceptual space and cognitive space. *Perceptual space* refers to what can be seen or observed through the senses at one time. *Cognitive spaces* include larger-scale spaces, which cannot be captured immediately with our sensors and, therefore, must be subsequently put together, much like a collage (Tversky 1993), in order to be understood. It is difficult to say precisely where perceptual space ends and cognitive space begins, as spaces that are within the sensory field can be mentally organized, stored, and recalled as can spaces outside of the sensory field. This confusion arises from the logical appeal to think of perceptual versus cognitive space as a distinction in scale. To clarify this fuzzy boundary between perceptual and cognitive space, Couclelis and Gale (1986) proposed a formalization of spaces based upon the algebraic structure of Abelian groups. They considered five axioms—the closure law [for all **a, b** that belong to **S**, **a*b** belong to **S**], the associative law [for all **a, b, c** that belong to **S**, **(a*b)*c=a*(b*c)**], the identity element [for all **a** that belongs to **S**, there exists an element **e** that belongs to **S** such that **a*e-e*a=a**], inverses [for every **a** that belongs to **S**, there exists and element **b** that belongs to **S** such that **a*b=b*a=e**], and the commutative law [for all **a, b** that belong to **s**, **a*b=b*a]**—for identifying different types of spaces. *Physical space*, which considers object displacement as mathematical vectors augmented by the concepts of physical mass and time, is defined by a marriage between the first four axioms. This type of space is one of existence, and it applies to all size spaces—from microscopic to astronomic. *Sensorimotor space* is a physical displacement augmented by sensory inputs, motility, and time irreversibility and is characterized by combining the first three axioms. It combines existence with physical interaction at the scale of the human body (i.e., within arm's length). *Perceptual space* is comprised of displacements (movements) linked to perceptual structures, such as views, which in turn are linked to sensory images of salient vantage points. Perceptual spaces, which can be described via the first two axioms, are the linking of existence and physical interaction to salient environmental cues. *Cognitive spaces* link salient sensory images to the cognitive factors of beliefs, knowledge, and memory. Due to the role of memory, cognitive space cannot be characterized by any of the five axioms—it is free of the constraints of physical space.

This freedom is the critical distinction between perceptual and cognitive space. *Symbolic space* represents the space of maps and other kinds of symbolic (both tangible and intangible) representations of space and involves the attachment of meaning with cognitive space.

An anthropomorphic or culturally-based classification of space stems from a study of Navajo concepts of space, distinguishing three kinds of spaces (Pinxten et al 1983). The first, *physical space*, was defined as smaller than body-size spaces comprised of manipulable objects. *Sociogeographic space* is larger than physical spaces and consists of things experienced through confrontation or from within. Finally, *cosmological space* is composed of phenomena of a still larger range of magnitude, such as the sun and stars.

A typology based on perception and spatial language differentiates four spaces (Zubin 1989). *A-spaces* comprise everyday manipulable objects that are smaller than the human body and are viewed from one perspective. Examples of A-space are pencils and other hand-sized artifacts, a cat, and parts of larger objects. *B-space* objects are larger than the human body and subsequently cannot be perceived from one perspective. Examples of these are an elephant, a car, and the outside of a house. Although these objects cannot be manipulated and handled as A-space objects, perception of B-space objects is similar to that for A-space objects as they possess the same basic physical properties of the latter in that all views of an object can be inferred from a single view. *C-spaces* comprise scenes of landscapes that can be seen from a single vantage point, such as within a large auditorium, at a scenic overlook, in a field or on a lake, or the horizon. They are perceived by turning one's head as if panning or scanning the landscape. *D-spaces* are regions beyond the range of direct experience. Locomotion through the space is required in order to experience it, from which the space is pieced together via inferences. Examples of D-spaces are the inside of a house, a forest, a town or city, and a country.

People's interaction with spaces and the mapping, or metaphorical extension, from one space to the next underlies Mark's (1992) classification of spaces. *Haptic spaces* are derived from touching and other bodily interactions. They are composed from generalizations over sensory experiences of touch and sensorimotor experiences (i.e., movement of the body and body parts through space). These spaces include manipulable objects and non-manipulable objects experienced via touch. *Pictorial spaces* are created predominantly via visual experiences and to some extent through sound and odors as well. People comprehend them through a combination of visual experiences and metaphorical extensions of concepts central to haptic space. A defining difference between haptic and pictorial spaces is that the former requires direct sensory experience, whereas the latter does not. Pictorial spaces, in principle, are scale-independent, because they can include all size spaces. This kind of space is similar in many aspects to Zubin's C-space. *Transperceptual spaces* are spaces that are learned via wayfinding experience over time. They are composed in the mind from several haptic or pictorial spaces or objects experienced over time. Consequently, transperceptual spaces can include complex inside building spaces, neighborhoods and cities, states, and possibly countries and continents.

A model of psychological spaces includes figural, vista, environmental, and geographic space (Montello 1993). *Figural spaces* are smaller than the body and are perceived from one vantage point. Montello further divides this space into pictorial and object space; pictorial meaning small flat spaces and object referring to small 3-D spaces. *Vista spaces* are larger than the body and again can be perceived from one vantage by turning one's head (i.e., scanning the space). Examples are single rooms, town squares, small valleys, and horizons. *Environmental spaces* surround or engulf and are too large to be perceived without moving through the space. These spaces are comprehended via integration of spatial information over extended periods of time. They include buildings, neighborhoods, and cities. *Geographic spaces* are much larger than environmental spaces—so large in fact that they cannot be perceived or experienced directly. Instead, these spaces are experienced from symbolic representations, such as maps and 3-D models, that reduce the space to manipulable or figural space. Examples include states, countries, and the solar system.

3. A Framework for a an Experiential Categorization of Geographic Spaces

Figure 1 summarizes the models reviewed in the previous section, plotting space types described in each model to examples of the spaces used in the literature to explain the respective model's space types. From this diagram, it is easy to compare each model and discover differences and, more importantly, similarities. Several of the models comprise only two types of space (Ittelson, Canter, Downs and Stea, Muehrcke and Muehrcke), whereas others include three (Lynch, Kuipers, Siegel, Mandler, Pinxten et al, Gärling and Golledge, and Mark), four (Zubin, Montello), five (Couclelis and Gale), and six (Kolars and Nystuen).

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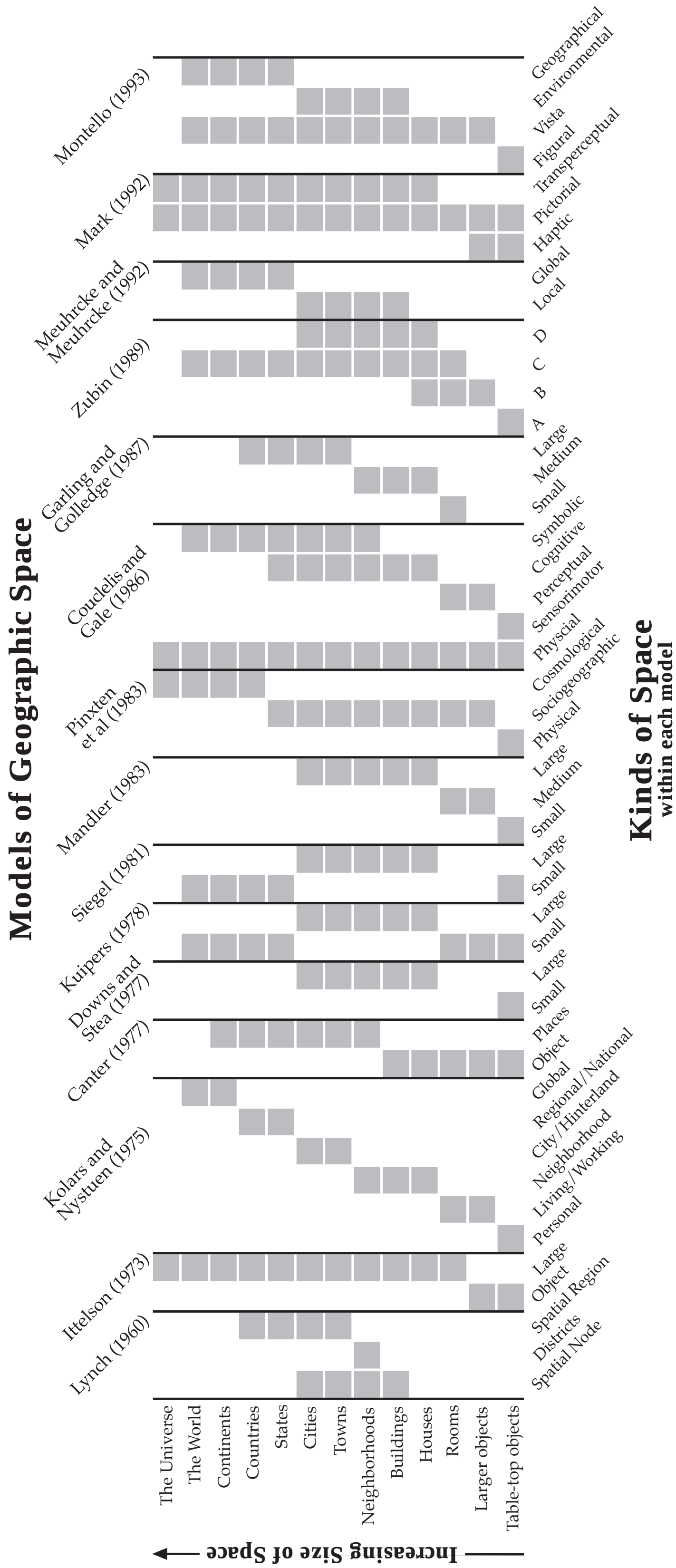

Figure 1: A graphical comparison of various models of geographic space.

These models provide a framework for understanding how users of GIS interact with objects in a GIS. They rely, either explicity or implicitly, on the properties of manipulability, locomotion, and size of space to describe, and therefore define types of space within each respective model. *Manipulability* refers to the ability to grasp, turn, and move objects in space. Spaces are comprised of objects (or features) that are either manipulable, or non-manipulable. In this sense, space is established by a configuration of objects that people interact with, or among. *Locomotion* refers to the necessity to travel through a space in order to perceive or experience, and subsequently learn the space. These spaces are viewed from many perspectives, i.e., they are orientation free. Spaces either require or do not require locomotion to perceive them. The property of *size* considers how spatial experience is constrained by size of space, and from the literature distinguishes between small (room-size or smaller) and large (inside-house-size and larger). The nature of, and relationships among these three properties is used as a basis for defining different types of geographic spaces. Two of the properties have binary, mutually exclusive values (manipulability and locomotion), while one property has binary, possibly inclusive values (size). A systematic and complete combination of these properties gives rise to different combinations of properties that may exist between manipulability, locomotion, and size (Figure 2).

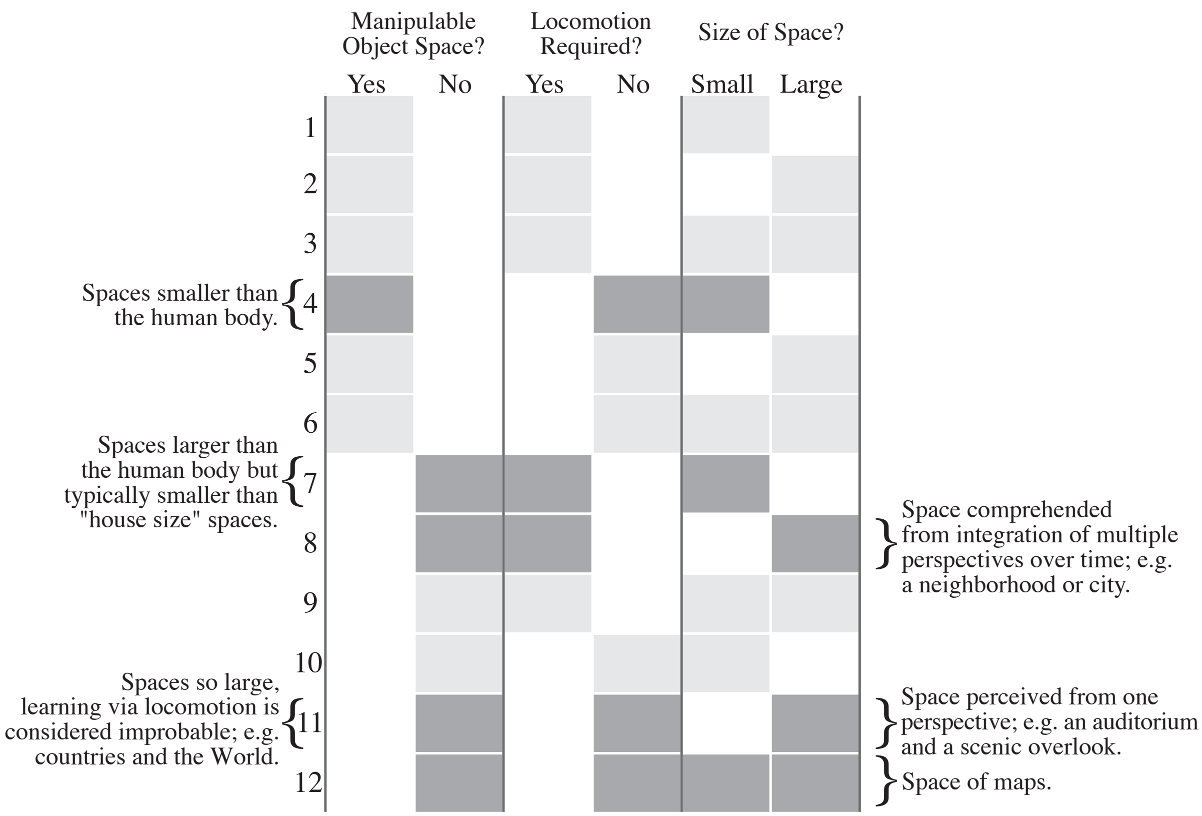

Figure 2: The properties of manipulability, locomotion, and size of space for defining types of space. Darker stippled rows indicate combinations of properties.

Of these twelve, five of the relationships are possible.

- Row 4 defines small, manipulable spaces not requiring locomotion to experience them. This encompasses spaces that are smaller than the human body, exclusive of microscopic space.
- Row 7 defines small, non-manipulable spaces that require locomotion to experience them. This includes spaces that are larger than the human body, but typically smaller than or equal to house-size objects.

- Row 8 defines large, non-manipulable spaces that require locomotion to experience them. This includes inside-of-house spaces, large buildings, neighborhoods, towns, and cities.
- Row 11 defines large, non-manipulable spaces that due to practical limitations cannot (usually) be experienced via locomotion. This encompasses very large spaces such as states, countries, continents, and the world. These spaces are unique, because they are normally too large to experience directly and, therefore, they are for all practical purposes only experienced via maps or other symbolic representations that are objects in a manipulable space. At the same time, this row also defines spaces that can be viewed from one position or perspective by panning or scanning the space. These include as examples views in an auditorium, the horizon, or views from a scenic overlook or from an airplane window.
- Row 12 defines small or large spaces that are not manipulable and do not require locomotion to experience them. Maps or photographs are examples thereof, because they can portray large spaces (e.g., as topographic maps or remotely sensed images) as well as small spaces (e.g., rooms and houses via floor plans). Although maps in and of themselves are manipulable, the spaces that they represent are not.

The remaining relationships shown in rows 1, 2, 3, 5, 6, 9, and 10 are not described in the literature as defining any space types. The relationships in rows 1 through 3 are not probable, because people can experience manipulable spaces without requiring locomotion. The relationships shown in rows 5 and 6 are impossible, because manipulable spaces that do not require locomotion to perceive them do not occur with large spaces. Similarly, the relationship shown in row 9 is improbable as non-manipulable spaces requiring locomotion cannot be size independent. Finally, the relationship shown in row 10 is not possible, because non-manipulable spaces without locomotion include other spaces than small spaces. Although microscopic spaces and spaces of planets and galaxies could in theory be considered very small and very large spaces, they are not included in this continuum as they are usually beyond the scope of geographic research.

4. A Model of Environmental Spaces

Building on the framework for identifying types of space, in conjunction with the models of space reviewed in the previous section, we have synthesized the following typology of space:

(1) *Manipulable object space* comprises very small, manipulable spaces that do not require locomotion to experience them. They comprise objects smaller than the human body. Models that include this kind of space refer to it as object (Canter, Ittelson), personal (Kolars and Nystuen), small-scale (Downs and Stea, Mandler), physical (Pinxten et al), *A* (Zubin), haptic (Mark), and figural (Montello) space.

(2) *Non-manipulable object space* consists of non-manipulable, small spaces requiring locomotion to experience them. These include objects larger than the human body and typically smaller than house-size spaces (e.g., cars, elephants, trees). Models that include this space refer to it as object (Ittelson, Canter), living/working (Kolars and Nystuen), small- (Gärling and Golledge, Siegel), and medium-scale (Mandler), as well as *B* (Zubin) space.

(3) *Environmental space* includes non-manipulable, large spaces that require locomotion to experience them. These include inside-of-house spaces, neighborhoods, to city-size spaces. All of the models reviewed include this space, referring to it as districts and spatial regions (Lynch), neighborhood and city/hinterland spaces (Kolars and Nystuen), medium- (Gärling and Golledge) and large-scale (Downs and Stea, Gärling and Golledge, Ittelson, Mandler, Siegel) spaces, places (Canter) and local scope (Muehrcke and Muehrcke), sociogeographic (Pinxten et al), *D* (Zubin), transperceptual (Mark), and environmental (Montello) spaces.

(4) *Geographic space* covers very large, non-manipulable spaces that due to practical limitations cannot be experienced via locomotion. These include larger than city-size spaces, states, countries, and the universe. Models that include these spaces refer to them as small- (Siegel) and large-scale (Ittelson) space, regional/national space (Kolars and Nystuen), global scope

(Muehrcke and Muehrcke, Kolars and Nystuen), cosmological (Pinxten et al), and geographic (Montello) space.

(5) *Panoramic space* encompasses non-manipulable, small- to large-size spaces that do not require locomotion to experience them. These include views in a room, an auditorium, a field, and from a scenic overlook. Models that include this kind of space refer to them as spatial nodes (Lynch), C-space (Zubin), pictorial space (Mark), and vistas (Montello).

(6) *Map space* represents non-manipulable, small- and large-size spaces that do not require locomotion to experience them. Maps are a symbolic representation, whose general intent is to reduce and simplify spatial information and present it in a manageable form. Maps are the result of the cartographic generalization process. Although several of the reviewed models make mention of maps and point out their unique space-in-space property, none have an explicit type of space equivalent to how map space has been defined here.

Using the properties of manipulability, locomotion, and size of space, it is possible to demonstrate links between the six space types defined above. Figure 3 illustrates graphically how various relationships between the three properties can define types of space. For example, the linkage from manipulable space (MP) to a small-size space (SM) that does not require locomotion (NLO) describes manipulable object space. Another example might link non-manipulable space (NMP) to large size spaces (LA) that require locomotion (LO) to experience them, thus identifying environmental spaces. The six space types can be characterized by triangular relationships , one of them (map space) having two triangular relationships.

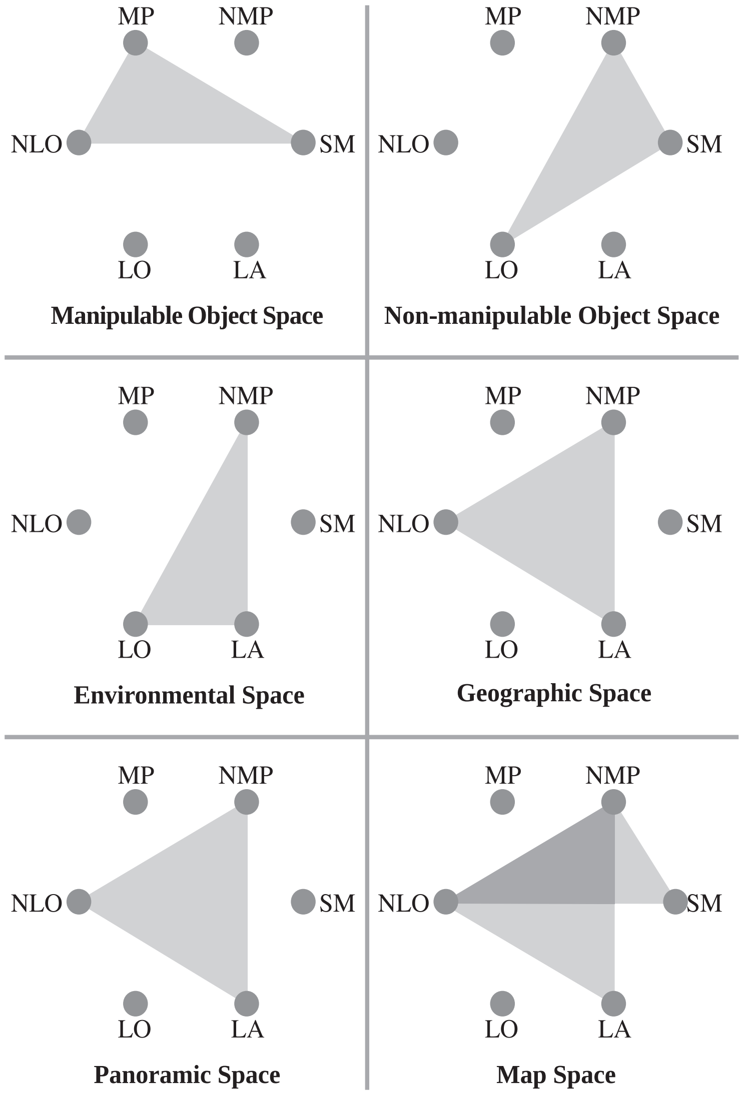

Figure 3: The relationship between space types and manipulability, locomotion, and size of space. MP represents manipulable; NMP represents non-manipulable; SM represents small-scale; LA represents large-scale; LO represents locomotion; NLO represents no locomotion.

Note that each of space types shares a common vertice of it's triangle with a triangle from at least one other space type. For example, the triangles representing Environmental Space and Geographic Space have the same NMP—LA vertice, and the triangles for Panoramic Space and Map Space have the same NLO-NMP vertice. These common vertices illustrate how these different space types are linked, and which property (of manipulability, locomotion and size) is changed to move conceptually from one space type to another. Figure 4 shows the relationships among space types, suggesting how these space types might be linked cognitively via multiple representations. For all links between space types, at least two properties (i.e., manipulability, locomotion, or size) are held constant, while movement along any one axis results in changes in the property associated with that axis. Movement along the X axis results in a change in locomotion (e.g., moving from map space to non-manipulable object). Movement along the Y axis results in a shift in size of space (e.g., moving from environmental space to non-manipulable object space) and movement along the Z axis results in a change in manipulability (e.g., moving from a manipulable object space to a map space). Shifts along two axes result in changes in the two properties associated with those axes. For example, shifts along the X and Y axes result in changes in both locomotion and size of space, a phenomena experienced when moving from a map space to environmental space. Shifts along the Y and Z axes result in changes in both size and manipulability, such as when moving from a panoramic space to a manipulable object space.

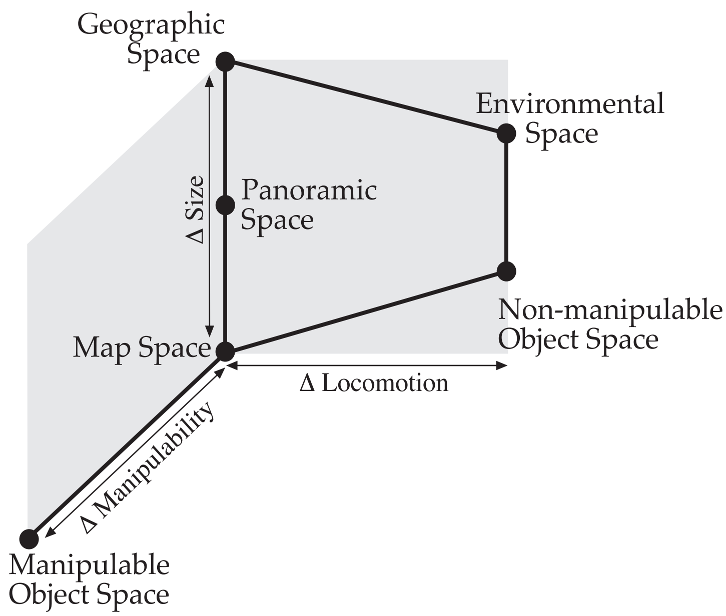

Figure 4: Links between space types. For all relationships, at least two of the properties of manipulability, locomotion and size are held constant, while movement along any one axis is associated with changes in the property associated with that axis. For example, shifts along the X axis result in changes (Δ) in locomotion. Shifts along two axes result in changes in the two properties associated with those axes. For example, shifts along the X and Y axes result in changes in both locomotion and size of space.

5. Implications for GIS Design

One goal of GIS design is the design of tools that would lead to better communication between users and GISs. The existence of different space types has implications for various theoretical and methodological questions concerning the design and use of geographic information systems. Since the different properties of each type of space lead to multiple conceptualizations of space, it may be necessary to integrate into GISs multiple models, presentations, and interaction styles. In order to enable GIS users to interact with these simulated spaces as if they were interacting with the actual space, the GIS must present a world of spatial concepts that is as close as possible to the concepts used when reasoning about real world spaces (Frank 1993; Mark and Freundschuh 1995).

The types of space may be a rationale for different types of user interfaces that afford multiple types of interactions. Current desktop GISs are good at manipulating small-scale objects that do not require locomotion, but they offer only a very limited set of operations for locomotion (e.g., panning) and change in size (e.g., zooming). Bier (1991) suggested editing operations that follow Zubin's four spaces. Type -A editing—when all objects are of approximately the same size and fit well on a single screen—are commonly supported with current desktop systems; however, when panning is required to move through B-space, such concepts as *pockets* may be useful to carry things from one end to the other. Type-C tasks require walking through a scene and, therefore, need support by changing the resolution of a representation. Finally, Type-D editing requires navigational tools to navigate very large objects while simultaneously keeping track of multiple, much smaller objects. The present categorization of spaces, with the distinction of manipulable and non-manipulable object space, may identify further interaction needs. Further guidance for interface design may apply to alternatives of desktop GISs, such as WallBoards (Florence et al 1996), Smart Rooms (Pentland 1996), and Virtual Worlds (Jacobson 1995), which enable new types of interactions that may be better suited to the exploration and understanding of large spaces. For example, a wall-sized display unit offers users to work collaboratively from different spaces, referring to different interaction modes for contact manipulations within an arm's length, empty-handed gestures within spitting distance, and passively viewing within sight (Florence et al 1996).

The discussion of space types also brings into question the use of artificial or simulated testing environments in geographic and psychological research. A number of studies exploring environmental spaces have utilized manipulable object representations of these spaces, such as maps (Lloyd 1989), slides (Golledge et al 1993), 3D models (Blades and Cooke 1994), and computer simulations (Golledge 1992), drawing conclusions and making general statements about spatial learning and cognitive spatial representations. Using manipulable object space to study spatial learning, behavior, and representation of large environmental spaces may be questionable (Montello 1993). Understanding the various links between space types can help to clarify what the implications are for research that explores spatial learning in one space, but is conducted in a different space.

6. Conclusions

In this paper, we have suggested a framework for a typology of geographic space based on people's experience. Its elements are manipulability, locomotion, and size of space. We illustrated that links between these properties were sufficient for defining types of space and for exploring how space types might be associated. In addition, we demonstrated that these properties could be used to gain insight into models of space discussed previously in the literature and to identify unique characteristics of space types.

Experiential realism offers us a new perspective on people's understanding of space and on spatial behavior. Considering how people interact with space, and in space, as a means of identifying space types seems particularly attractive from a geographic perspective. The framework, and subsequent classification of space put forward in this paper, offers new insights into the kinds of spaces within which we live and possible links between spaces. It also provides a theoretical basis for how different spaces might shape and mold the spatial cognitive representations that we create. Lastly, it helps to further our understanding of the unique role that maps and other spatial tools play in spatial cognition.

An arena for further investigations is to explore what kinds of spatial knowledge people acquire in each space. There have been a number of studies that have explored spatial knowledge from map space (Freundschuh 1992; Lloyd 1989; MacEachren 1992), from environmental space (Freundschuh 1992; Lloyd 1989; Thorndyke and Hayes-Roth 1982), and from manipulable object space (Blades and Cooke 1994; Blades and Spencer 1994; DeLoache 1989). Studies designed to measure and compare spatial knowledge acquired from a variety of spaces would help to clarify the present space classification.

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