Mapping Kinds in GIS and Cartography

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Rasmus Grønfeldt Winther
rgw@ucsc.edu
www.rgwinther.com
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“GIS provides a context, an information resource, and an environment for geographical thinking and research… [that] is open rather than closed [and] can accommodate pluralistic research styles”.

“All theory… is gray. In mapmaking, good results are more important than theoretical knowledge. A useful map can only be produced by a meticulously careful process of design and the most precise reproduction”.

“our most recent examples show that paradigms provide scientists not only with a map but also with some of the directions essential for map-making”.

Abstract
Geographic Information Science (GIS) is an interdisciplinary science aiming to detect and visually represent patterns in spatial data. GIS is used by businesses to determine where to open new stores and by conservation biologists to identify field study locations with relatively little anthropogenic influence. Products of GIS include topographic and thematic maps of the Earth’s surface, climate maps, and spatially referenced demographic graphs and charts. In addition to its social, political, and economic importance, GIS is of intrinsic philosophical interest due to its methodological richness and because it is an instructive analogue to other sciences. This chapter works towards a philosophy of GIS and cartography, or PGISC. In particular, it examines practices of classifying geographic space, objects, and relations. By focusing on the use of natural kinds in data modeling and map generalization practices, I show how the making and using of kinds is contextual, fallible, plural, and purposive.
0. Introduction

Geographic Information Science (GIS) is a scientific inter-discipline aiming to discover patterns in, and produce visual displays of, spatial data. Businesses use GIS to determine where to open new stores, and GIS helps conservation biologists identify field study locations with relatively little anthropogenic influence. GIS products include topographic and thematic maps of the Earth’s surface, climate maps, and spatially referenced demographic graphs and charts. The annual global GIS market (approx. $10 billion) is of the same order of magnitude as CERN’s total budget to date (approx. $13 billion), which it is only an order of magnitude less than the biotechnology global market. In addition to its social, political, and economic importance, GIS is worthwhile to explore in its own right due to its methodological richness, and because it is an instructive analogue to other sciences. The lack of attention to the sciences of GIS and cartography by the history and philosophy of science (HPS), science and technology studies (STS), and related fields—though not geography or sociology—clearly merits remedy. This chapter works towards a philosophy of GIS and cartography, or PGISC.

PGISC fits well in this volume on rethinking natural kinds in light of scientific practices. Collecting and collating geographical data, building geographical databases, and engaging in spatial analysis, visualization, and map-making all require organizing, typologizing, and classifying geographic space, objects, relations, and processes. I focus on the use of natural kinds in data modeling and map generalisation practices, showing how practices of making and using kinds are contextual, fallible, plural, and purposive. The rich family of kinds involved in these activities are here baptized mapping kinds.

Mapping kinds are only one aspect of PGISC. Philosophical concerns of realism, representation, explanation, reduction, and theory structure can also be expanded and reconstructed through an analysis of GIS. For instance, attention to GIS practices helps enrich and clarify ongoing philosophical debates about, e.g., (i) metrology and the nature of data, (ii) modeling, abstraction, and idealization in science, and (iii) the role of visualization in science. Moreover, products of these fields of inquiry, such as maps, are analogues to other scientific products, such as theories (e.g., “a scientific theory is a map of the world”). In short, PGISC can inform philosophy of science as well as GIS and cartography.
The epigraphs capture this chapter’s argumentative spread. The first makes explicit the functionality and promise of GIS as a science. Oppenshaw’s hope can be generalized to philosophical analysis, for which GIS can become an analytical exemplar. Imhof defends a practice-based and pragmatic view—rather than a theory-centric semantic or syntactic one—on cartography and science. Indeed, substituting “model” for “map” shows that results rather than knowledge are considered crucial; design and reproduction balance. Finally, the map analogy is used in perhaps the most influential philosophy of science book of the 20th century, Kuhn’s *The Structure of Scientific Revolutions*. This serves as one example of the map analogy’s ubiquity in philosophical analyses of science.7

The chapter is organized as follows. The first section reviews GIS, while the second turns to practices of data modeling and map generalisation, and to the plurality of mapping kinds. Other important practices and kinds involved in GIS and cartography are set aside. That is, surveying and census practices, visualization and spatial analysis, and so forth, must await future exploration from a PGISC perspective. Consonant with the themes of this anthology, the third section explores philosophical antecedents of natural kinds, consistent with mapping kinds: “plural” kinds (e.g., John Dupré, Nelson Goodman, and Muhammad Khalidi), “inferential” kinds (e.g., W.V.O. Quine, Ingo Brigandt, and Alan Love), and “reconstructing” kinds (e.g., John Dewey and Ian Hacking).

1.0. Central Issues of GIS

In order to explain the content and methodology of GIS, an analysis of the central issues, a highly abbreviated history, a plurality of definitions, and the epistemic-technological structure of GIS are reviewed in what follows. GIS might be to HPS and STS fields what fruit flies were to the Morgan laboratory at Columbia University in the early 20th century. According to Ronald Abler’s report of the National Science Foundation’s National Center for Geographic Information and Analysis (NCGIA), the five “priority issues” of GIS are:

1. New modes and methods of spatial analysis
2. A general theory of spatial relationships
3. Artificial intelligence and expert systems
4. Visualization
5. Social, economic and institutional issues.8
A few years later, influential GIS researcher Michael F. Goodchild presented another list of “key issues” for GIS:

1. Data collection and measurement
2. Data capture
3. Spatial statistics
4. Data modeling and theories of spatial data
5. Data structures, algorithms, and processes
6. Display
7. Analytical tools
8. Institutional, managerial, and ethical issues.\(^9\)

These lists present snapshots of the empirical, computational, visual, cognitive, social, and ethical concerns of GIS researchers. The territory for PGISC is a rugged one, with a broad range of interdisciplinary issues.

1.1. An Abbreviated History

As Nicholas Chrisman observes, GIS is an outcome of WWII operations research that “helped bring the computer into nearly every part of modern life.” Chrisman takes the “systems concept” as a natural source for conceiving GIS “as a series of procedures… lead[ing] from input to output.” GIS was thus typically presented as a scientific process moving “from data sources through processing to displays”.\(^10\) As an inter-discipline or trading zone,\(^11\) GIS combines computer science with geography, cartography, cognitive science, statistics, and sociology. Thus, other historical influences must be incorporated. For instance, Chrisman’s analysis can be complemented in several ways: by the concept of “information,” pertinent to computer science and Shannon’s information theory, as well as to cartography;\(^12\) by recalling the quantitative revolution in geography during the 1960s and 1970s;\(^13\) and by not ignoring the cartographic communication paradigm, dominant particularly in the 1970s and 1980s.\(^14\) Undoubtedly, the quantitative revolution in geography and the communication paradigm of cartography—which today critiqued by Critical GIS\(^15\) and by semiotic and cognitive analyses of map symbolization and design\(^16\)—remain vital sources of GIS.

The 1991 publication of Maguire, Goodchild, and Rhind\(^17\) marked the appearance of “the first solid support for the claim that GIS is entering into a new phase and approaching the possibility of creating a separate discipline”.\(^18\) Whereas Openshaw\(^19\) defends GIS (see epigraph),
Pickles\textsuperscript{20} critiques GIS’s role in the “surveillant society.” The \textit{GIS wars} were afoot, with “empiricist,” “positivist,” and “technicist” GIS defenders on one side, and “critical theory,” “post-structuralist,” and “relativist” critics of GIS on the other\textsuperscript{21}. By the turn of the millennium, a reconstructed “critical GIS” emerged, aware of the benefits and wary of the risks of GIS. Even so, tensions between technoscientific and critical social theory perspectives remain alive.\textsuperscript{22}

The histories found in the work of Crampton, Chrisman, Goodchild, Pickles, Schuurman, and D.R. Fraser Taylor have tended to be linear and somewhat uncritical historiographies.\textsuperscript{23} Alternative narratives and pieces contributing to a fuller history of GIS may still be found. This is a promising avenue for younger historians interested in being among the first to detail the story of a socially, ethically, and economically relevant science. Given that many major players remain alive, an interview-based history is still possible.

1.2. Definitions

Definitions involve background assumptions and a point of view. Chrisman\textsuperscript{24} identifies three approaches in which definitions of GIS are embedded: (i) the \textit{systems flow} approach of operations research and of information theory (e.g., senders and encoders, receivers and decoders), (ii) a \textit{content} approach emphasizing maps, and (iii) a \textit{toolkit} approach focusing on the specific technologies available (e.g., GIS versus CAD versus DBMS)\textsuperscript{25}. First, a paradigmatic systems flow definition mirrors the linearity of the information communication process:

$$\text{GIS is a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the Earth.}$$

This definition emphasises the flow of information. The data of GIS are intrinsically spatially referenced,\textsuperscript{27} which is required for other measured features (e.g., height, population density) to be meaningful. Second, a content approach “defines the GIS by what it contains, either as a special case of more general information systems or as an amalgamation of more specific uses.”\textsuperscript{28} Chrisman locates the following definition in a forestry journal:

$$\text{A form of MIS [Management Information System] that allows map display of the general information.}$$

Of course, many proponents of GIS in the early 1990s would have critiqued such map-centrism.\textsuperscript{30} A \textit{death of the map} was afoot.\textsuperscript{31} For instance, Waldo Tobler identifies the “flat earth syndrome”\textsuperscript{32} and calls for a “global spatial analysis.” He urges listeners and readers to “forget about working on maps”,\textsuperscript{33} admitting that “map projections, my specialty, are now obsolete”.\textsuperscript{34} Finally, a
contemporary characterization of GIS exemplifies the toolkit approach:

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.\(^{35}\)

Combined especially with the earlier (1997) definition of GIS presented in Chrisman,\(^{36}\) it becomes evident that the focus of the Environmental Systems Research Institute (ESRI) is on the various software packages and hardware devices constitutive of GIS activities. It is unsurprising that a firm developing and selling these products would characterize GIS in this way. While initially resisting definitions of GIS, Chrisman eventually produced his own reduced definition:

Geographic Information System (GIS) – Organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social structures.\(^{37}\)

This definition was developed in the context of a “nested ring” structure of GIS, where “each ring encapsulates the more technical decisions inside, mobilizing them in a more complex structure.”\(^{38}\) Accordingly, “measurement and representation” were prior to, and embedded in, “transformations and operations” of various sorts (e.g., spatial analysis, visualizations), which, in turn, were prior to, and embedded in, “social, cultural, and institutional context[s].” These definitions point to the trading zone of disciplines and research questions involved in GIS. Given intellectual differences among these definitions, and the breadth of concerns covered, the need for a PGISC seems evident.

1.3. The Epistemic-Technological Structure of GIS

Data collection and collation, database management, map generalisation, visualization, and spatial analysis are central inferential (and automated) processes of GIS. Questions regarding the relative roles of human and computer persist.\(^{39}\) In contrasting “artificial” and “amplified” intelligence, Weibel walks a middle path between analog and digital cartography.\(^{40}\) Weibel identifies advantages to amplified intelligence, including that “knowledge is contributed by human experts in a direct way,” and “it leaves creativity with the user to devote attention to interesting aspects of map production”.\(^{41}\) Two decades later we are still far from fully automated map production systems. AI continues, in many ways, to be a dream.\(^{42}\) But the symbiotic relation between humans and computers is clearly strong as indicated by the related fields of AI, machine learning, and Human-Computer Interaction (HCI), and any PGISC must address these.
GIS’s relation to cartography is complex. Nadine Schuurman plausibly detects a “switch” from “a map to model-oriented approach to generalization”. In North America, the “culture of cartography” had been dominant, while “Europeans had developed a landscape model [the database] that is based on derived data”. The key shift was from earlier work “with mental models of maps” to committing to “the database” as generative of “information and map objects”. Schuurman highlights Brassel and Weibel as instrumental to this shift. Brassel and Weibel characterized generalisation “as an intellectual process, [which] structures experienced reality into a number of individual entities, then selects important entities and represents them in a new form.” They distinguish two kinds of “objectives for spatial modeling” corresponding to two kinds of generalisation: (i) “spatial modeling for purposes of data compaction, spatial analysis and the like [i.e.,] statistical generalization” and (ii) “cartographic generalization,” which, “in contrast, aims to modify local structure and is non-statistical”. By identifying a broader set of generalisation types beyond mere visual display and map-making, Brassel and Weibel prompted the emerging GIS community to move past the map and cartography. Modeling, broadly construed, rather than map-making and map-use, became central to GIS.

GIS’s interdisciplinarity and rich epistemic-technological structure make it a promising land for philosophers exploring scientific modeling and visualization, cognition and HIC, and the social and ethical impact of science. As a case study of the philosophical quality of GIS, the next section turns to kind-making.

2.0. Mapping Kinds: Data Modeling and Map Generalisation

Rich geographic features and processes that have been collected and collated through various technologies (e.g., theodolite, GPS) must be structured into databases for further analysis and map-making. That is, a physical ontology is discovered and constructed in practices of data modeling. Moreover, map-making itself involves (automated or conscious) inferential processes of abstraction and generalisation. It is to these purposive processes that I now turn.

2.1. Data Modeling

GIS models and maps rely on geographic information organized into kinds, captured in databases. Goodchild follows computer science in defining data models thus: “the set of rules used to create a representation of information, in the form of discrete entities and the relationships between them”. Up until the mid-1990s, two “models of the world”—i.e., two physical...
ontologies—dominated GIS data modeling: raster and vector. Whereas the first organizes the world into a Cartesian grid, the second carves up the world into mutually exclusive and collectively exhaustive irregular polygons, such as census or cadastral units. Each has advantages and disadvantages concerning ease of data collection, error proclivity (e.g. locational, ecological fallacy, and “modifiable areal unit problem”), computational efficiency, and appropriateness.\textsuperscript{53} As Tomlin quips, “Yes, raster is faster, but raster is vaster, and vector just seems more correcter”.\textsuperscript{54} Because of their fundamentality in space-carving, Cartesian pixels or vector polygons can be baptized \textit{calibrating kinds}.

These two inter-translatable geometry-based models of the world serve as the unifying matrix on which a complex array of geographic features is captured. That is, data of various sorts are linked to point locations (raster view) or to polygons (vector view).\textsuperscript{55} Geographic data can be stored in tables with location or polygons as rows and features as columns.\textsuperscript{56} Cartographically, the data can also be represented in distinct “map layers,” each of which is framed via pixels (or polygons). Each map layer captures a small number of predicates (e.g., population density, income – sometimes indicated at different time slices).\textsuperscript{57} The topographic (“general image of the Earth’s surface”\textsuperscript{58}) or thematic (population density, crime rate, etc.) features represented on each data table column or map layer, or both, can be termed \textit{feature kinds}. The map analogy comes to the fore here because every scientific paradigm, theory or model must take some stance towards the calibration (i.e., form) of its data, and the features (i.e., content) the paradigm, theory or model wishes to capture in data models. A physical ontology has to be articulated. Calibrating and feature kinds combined (i.e, calibrating/feature kinds) were the form and content of early GIS data models.

The concepts and language of GIS evolved in concert with technological innovations stemming from computer science. The calibrating kinds of the vector view (i.e., polygons) were sometimes referred to as “objects”.\textsuperscript{59} This manner of kind-ing space was associated with a discontinuous and individual-based perspective on the world, as opposed to the “field” view of continuous and homogenous rasters. But eventually it was recognized that both pixel and polygon calibrating kinds are “geometry-centric”\textsuperscript{60} and today both are often referred to as “fields”.\textsuperscript{61} In contrast, \textit{object kinds} constitute a fundamentally different manner of representing geographic information, and space. These are not spatial vectors such as census units or states or countries – the “objects” of yesteryear. They are individual kinds of things such as “oil wells, soil bodies, stream catchments, and aircraft flight paths”.\textsuperscript{62} Object kinds in GIS originated in object-oriented
In contrast to geometry-centric data modeling modes that permit neither empty space nor pixel nor polygon overlap, GIS data models based on object kinds insist on emptiness and overlap. Via encapsulation, inheritance, and polymorphism, object-oriented programming permits significant flexibility and structural capacity in working with object kind data models. Today, objects are distinguished from fields, and object kinds emerging from programming systems in the 1990s assist in making new data model types.

Further questions regarding path-dependency and the biases, heuristics, and judgments associated with practices of data encoding (e.g., which kind of data model—field or object—is chosen for a particular purpose?) and data management (e.g., inter-operability and translatability among data models and multiple representation databases), and practices of data collection and collation remain promising areas for future PGISC exploration.

2.2. Map Generalisation, in General

Map generalisation in the broadest terms involves transforming and selecting kinds. For example, smoothing lines and aggregating buildings (represented either as calibrating/feature kinds or object kinds) are examples of transforming single kinds. Eliminating entire classes of kinds or dissolving out an area are examples of selecting different kinds. Töpfer and Pillewizer succinctly describe “cartographic generalisation” as “the reduction of the amount of information which can be shown on a map in relation to reduction of scale”. Perhaps the first to have framed map generalisation was Max Eckert in the early 20th century. Wright identified “simplification and amplification” as the key generalisation moves. While holding that “no rules can be given for generalization,” Raisz posited three aspects of generalisation called “combine,” “omit,” and “simplify.” Robinson and Sale influentially recognized four “elements of cartographic generalization,” viz. simplification, symbolization, classification and induction. These elements are subject to “controls” such as the objective, the scale, and the quality of data. Especially in the last 20 years, as we shall see further below, cartographic generalisation has become automated. Today, “elements” roughly correspond to “operators” of “spatial and attribute transformations” and “algorithms”, while “controls” map onto “geometric conditions” and “transformation controls”, and “constraints”. A more branching narrative of the development of map generalisation may be required.

2.3. Manual Map Generalisation
Similarly to any scientific abstraction, map generalisation must take functional context seriously. Indeed, the Swiss Society of Cartography’s classic analysis of cartographic generalization starts with the “need for a map.” The “aim” of the map grows out of this need. Only once scale, source, legibility conditions, and revision have been specified from the need and aim can the conceptual and graphical aspects of the map be determined and implemented. A functionalist top-down approach to map generalisation is here suggested. Map-making is made a function of map use, which itself involves descriptive and prescriptive purposes. The Swiss Society of Cartography writes:

Cartographic generalization requires prior knowledge of the essence and the function of the map. Consequently we first of all have to ask ourselves about the purpose of the map, the extent of its information contents and also about the requirements of the map user regarding the power of expression of a map type desired for a specific purpose.

Purpose and use play center stage here. Their verbatim citation from Imhof’s Kartographische Geländedarstellung bolsters the functionalist—rather than syntactic or formalist—vision:

The objective of generalization is the highest accuracy possible in accordance with the map scale, good geometric informative power, good characterisation of the elements and forms, the greatest possible similarity to nature in the forms and colours, clarity [of meaning] and good legibility, simplicity and explicitness of the graphical expression and coordination of the different elements.

The map must fit the purpose. Map generalisation must start from map need (compare epigraph). Following the map analogy, Imhof’s pragmatic view of cartographic representation could certainly be generalised to other forms of scientific representation, outside of cartography and GIS.

2.4. Digital Map Generalisation Pluralism in GIS

A significant interpretative problem presented by the history and pre-history of GIS is that it remains unclear whether digital cartography and digital generalization are continuous with earlier analog cartography and manual generalization. After all, earlier, pre-GIS cartography required significant human aesthetic and judgment components and was “labor-intensive,” “subjective,” and “holistic” in contrast to automated, “consistent,” and “much like the finite logic of a serial computer.” Thus, whether concepts such as “simplification” or “classification” share meanings, and imply the same consequences today and yesterday remains unclear.
Nevertheless, I explore digital map generalisation procedures, setting aside deeper matters regarding continuity of terms, periodization of history, and paradigm identification. Of interest is the sheer plurality of digital map generalisation procedures as well as map (and modeling) aims and audiences. There are multiple modes of selecting calibrating-feature kinds or object kinds, and transforming the ones that remain, given map purpose (Figure 3). Shea and McMaster’s classify twelve digital generalisation operators: simplification, smoothing, aggregation, amalgamation, merge, collapse, refinement, typification, exaggeration, enhancement, displacement, and classification. In their 1992 book, McMaster and Shea remove typification as a spatial transformation and add symbolization, classifying it with classification as attribute transformations.

Consider simplification and smoothing. Simplification is the retention of the fewest number of data points or features necessary to accurately represent a single kind of object. As an example, the Douglas-Peucker algorithm keeps only those coordinate points of a line exceeding a pre-defined tolerance, and thereby produces a piecewise “zig-zag” from a meandering line (e.g., representing a river or road). This zig-zag retains the essential properties of the original line. Smoothing involves diminishing deviations and perturbations from general trends, given a particular number of data points or features. For instance, consider transforming an irregular quadrilateral to a square. While McMaster and Shea’s classification is fairly comprehensive, important generalisation procedures are missing, including dissolution, segmentation, and selection. In fact, there is no single agreed-upon classification, or map generalisation model. Algorithmic implementation, conceptual model of map generalisation adhered to, and background knowledge and objectives influence each creator’s classification and model.

As one way of classifying map generalisation (abstraction, idealization) procedures, we can organize them into inferential processes that either transform or select among the kinds given by the data models (Figure 1). Intuitively complementary processes of REDUCE and AMPLIFY, JOIN and SEPARATE are part of an overarching framework of seven basic procession kinds within which the rich variety of easily 20 map generalisation procedures gleaned from multiple sources could be placed. Under my analysis, the kinds of map generalisation individuate inferential or automated processes, rather than objects or individuals. Even if the three-layer classification embodied in Figure 1 turns out to be neither collectively exhaustive nor mutually exclusive, the fundamental distinction between transforming single kinds and selecting among kinds, and the basic seven processual kinds of generalisation procedures, provide partial insight into the logic and
goals behind generalisation. Each processual kind can be implemented computationally in various ways. Moreover, the individuation criteria of the lowest-level processual kinds (e.g., smoothing and simplification) have to do with similarity of computational result rather than with static feature similarity. Finally, holistic cognitive, communicative, and aesthetic considerations of information visualization must also be addressed philosophically in trying to understand how and why these processual kinds can and should interact in producing visual maps. PGISC explores the pragmatics of modeling and visualization.

Figure 1. Map generalisation PROCESSUAL KINDS.

In summary, in digital map generalisation, the calibrating-feature kinds or object kinds present in data models are transformed or selected, or both, to produce a simplified and idealized map representing certain aspects of complex geographic reality, in light of map purposes. Philosophical considerations regarding kinds-in-practice (e.g., calibrating kinds and feature kinds) and kinds-of-practice (e.g., processual kinds) can be of benefit to GIS and philosophy alike. GIS is an exemplar whose pragmatic orientation can be extended, via the map analogy, to many other sciences.
3.0. Towards a Philosophy of Mapping Kinds

Recall that the overarching aim of this chapter is to motivate a PGISC, particularly an analytic PGISC (aPGISC). In this final section, a précis is provided of why GIS is a particularly instructive locus for exploring, and perhaps reconstructing, philosophy. Three overarching philosophical perspectives on kinds help place mapping kinds in perspective.

First, a number of philosophers of science analyze kind and classification pluralism. Under this view, there is no single, ideal, and eternal hierarchical classification of kinds of objects. For instance, Nelson Goodman prefers to speak of “relevant” rather than “natural” kinds in part because the latter “suggests some absolute categorical or psychological priority, while the kinds in question are rather habitual or traditional or devised for a new purpose.” Moreover, Dupré’s “promiscuous realism” argues for the interest-relativity of abstracting kinds. Dupré observes:

Is the kind of pluralism I have been advocating consistent with a realistic attitude to the various kinds, and even individuals, that I have discussed? There are a number of pluralistic possibilities that I have defended, but none, as far as I can see, forces one to abandon realism. … Provided realism is separated from certain essentialist theses, I see little more reason why the possibility of distinct and perhaps overlapping kinds should threaten the reality of those kinds.  

Similarly, Khaliči notes:

The idea that there are crosscutting taxonomies is closely related to the view that scientific classification is interest relative. If classification is always relative to certain interests, we would expect some taxonomies to reorganize some of the same entities in different ways without displacing existing ones.

As examples of this plural kinds argument, recall field vs. object views on geographic space. Depending on a variety of goals and technical realities, either of these two inter-translatable kindings of space can be adopted. Of course, the plurality of inferential processes of map generalisation—which may or may not be practiced together—can also be conceived within a plural kinds framework.

A related strategy for understanding kinds philosophically is an approach that focuses on the role of kinds in scientific inference. While he thinks that mature science can and will do without natural kind terms, WVO Quine also believes that “some such notion [of kind], some similarity sense, was seen to be crucial to all learning, and central in particular to the processes of inductive generalization and prediction which are the very life of science”. Indeed, Quine holds that kinds are “functionally relevant groupings in nature” whose recognition permits our inductions to “tend
to come out right.” That is, kinds help ground fallible inductive inferences and predictions, so essential to scientific projects including those of GIS and cartography. Brigandt and Love take this epistemic understanding of kind terms further. Brigandt wishes to bracket the search for “a unique metaphysical account of ‘natural’ kind,” calling instead for “the epistemological study of how and for what purposes various natural kind concepts are employed in scientific reasoning.” Love interprets typology and natural kinds as involved in “representational reasoning” and “explanatory reasoning.” The move from a metaphysical to an epistemic analysis of kinds—already instituted by Quine (and Goodman)—is welcome in a philosophical field otherwise emphasizing essences, rigid designators, counterfactually-supported universal non-ceteris paribus laws, and other elements of the abstract, theory-centric “book of the world.” Certainly PGISC requires understanding how a variety of mapping kinds are involved in scientific inference.

Finally, a rather different approach is to leave the concept behind altogether, either via utter rejection or systematic reconstruction. Upon providing an erudite discussion of the natural kind tradition, Hacking concludes with this paragraph:

Although one may judge that some classifications are more natural than others, there is neither a precise nor a vague class of classifications that may usefully be called the class of natural kinds. A stipulative definition, that picks out some precise or fuzzy class and defines it as the class of natural kinds, serves no purpose, given that there are so many competing visions of what the natural kinds are. In short, despite the honourable tradition of kinds and natural kinds that reaches back to 1840, there is no such thing as a natural kind.

Wishing less to banish kinds from science and more to reconstruct them, John Dewey elucidates the standard view of species thus:

Just as we naturally arrange plants and animals into series, ranks and grades, from the lowest to the highest, so with all things in the universe. The distinct classes to which things belong by their very nature form a hierarchical order. There are castes in nature. The universe is constituted on an aristocratic, one can truly say a feudal, plan.

Dewey resisted the standard view of natural kinds, inherited from the Greeks, and itself inflected by Greek socio-political context. Instead, Dewey presents an analysis of kinds (and classes and universals) as fallible and context-specific hypotheses permitting us to address problematic situations effectively. Consider this passage from Quest for Certainty:

The object is an abstraction, but unless it is hypostasized it is not a vicious abstraction. It designates selected relations of things which, with respect to their mode of
operation, are constant within the limits practically important. … It marks an ordering and organizing of responses in a single focused way in virtue of which the original blur is definitized and rendered significant.\textsuperscript{107}

Depending on the project or inquiry, a certain object will be classed and individuated as a kind. Dewey is applying his “reconstruction of philosophy” program of (i) understanding concepts and kinds as tools, (ii) insisting that the function of philosophy is criticism, and (iii) viewing abstraction and analysis as embedded in larger wholes of social, communicative, and material needs.\textsuperscript{108} GIS and cartography provide excellent scenarios of reconstructed kinds negotiating theory and practice, and realism and constructivism.

Mapping kinds can be understood from various philosophical perspectives, including “pluralism kinds,” “scientific inference kinds,” and “reconstructive kinds.” These are not mutually exclusive. Moreover, the analysis of mapping kinds presented here encourages their adoption, and the concomitant bracketing (or rejection?) of more standard essentialist perspectives on natural kinds.

4.0. Conclusion

GIS and cartography suggest that kinds are simultaneously discovered and constructed. Geographic features, processes, and objects are of course real. Yet, we must structure them in our data models and, subsequently, select and transform them in our maps. Realism and (social) constructivism are hence not exclusive in this field.\textsuperscript{109} Moreover, kind-ing inferential processes—mediated by technology, cognition, and communication—force the questioning of a strong theory vs. practice distinction. Kinds are no longer purely theoretical concepts serving as small mirrors of nature. Instead, they are shaped by design principles, communicative context, and local aims and norms. Kinds are as much about process as objects. Not just individuals with static essences, kinds emerge from processes in the world, in our minds, and in our technologies and society. PGISC suggests the possibility that realism vs. constructivism and theory vs. practice should not be deemed two absolute binaries. Further development of PGISC will permit reflection on natural kinds, as well as other standard philosophical concerns, from a Pragmatic View perspective.\textsuperscript{110} Such a practice-turn view is detail-based and relevance-oriented, with a deflationary and reconstructive approach to metaphysics.

GIS and its related disciplines of geography and cartography provides a model system for philosophy of science as well as for HPS, STS, history of science, and sociology of science. GIS is
a young field, approximately 25 years old, and relatively small in size.\textsuperscript{111} It is clearly interdisciplinary, involving a broad range of expertise, technologies, practices, aims and norms, and a variety of styles, paradigms, and models.\textsuperscript{112} Interestingly, many GIS and cartography scholars are already philosophically reflective about conceptual, methodological, and theoretical matters. It would be a pity, if not socially and intellectually irresponsible, \textit{not} to further develop PGISC, in both its analytic and “continental” varieties.

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\textsuperscript{5} While non-trivial to determine, one report by Global Industry Analysts, Inc. predicts that the global GIS market will reach $10.6 billion by 2015 (\url{http://www.harrisburgu.edu/news/article.php?id=913} [accessed 11 November 2014], with another report by TechNavio calculating and forecasting a compound annual growth rate (CAGR) of roughly 10\% (\url{http://www.businesswire.com/news/home/20110318005466/en/Research-Markets-Global-Geographic-Information-Systems-Market#UuVIJGTTk18} [accessed 11 November 2014]. It remains unclear how and whether these reports incorporate lost revenue via illegal pirating, or unreported revenue via clandestine purchases (e.g., by the CIA, NSA), of GIS software and hardware.


45. Ibid.
46. Schuurman, GIS: A Short Introduction, pp. 48-49; and, Figure 1.
48. Ibid., pp. 230-1.
49. Ibid., p. 232; also see Figure 2, p. 233.
55. More precisely, the term “vector” stems from the fact that geographic polygons consist of a series of lines each of which has magnitude and direction. Vector geometrisation in general involves categorizing two-dimensional space in irregular ways, classifying points, lines or areas (Goodchild, ‘Modeling Error in Objects and Fields’, p. 107; M. Monmonier and R. B. McMaster, ‘The Sequential Effects of Geometric Operators in Cartographic Line Generalization’, International Yearbook of Cartography, 30 (1992), pp. 93-108, Figure 1 p. 94; Longley, Goodchild, Maguire, and Rhind, Geographic Information Systems & Science, p. 214 and p. 221).
57. The map layer perspective on storing cartographic information leads to “club sandwich” (Couclelis, ‘People Manipulate Objects (but Cultivate Fields)’, p. 65) or “layer-cake” (Schuurman, GIS: A Short Introduction, p. 36) caricatures of GIS.
60. Longley, Goodchild, Maguire, and Rhind, Geographic Information Systems & Science, p. 221.
64. Telegraphically: “Encapsulation describes the fact that each object packages together a description of its state and behavior.” “Inheritance is the ability to reuse some or all of the characteristics of one object in another object.” “Polymorphism describes the process where each object has its own specific implementations for operations like draw, create, and delete.” (Longley, Goodchild, Maguire, and Rhind, Geographic Information Systems & Science, p. 222.)
66. Tomlin, GIS and Cartographic Modeling.
Winther

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68. On the biological distinction between transformation of individuals (qua single kinds) and selection of individuals (qua distinct kinds) within populations, see R. Levins and R. Lewontin, The Dialectical Biologist (Cambridge, MA: Harvard University Press, 1985), pp. 85-86.


76. McMaster and Shea, Generalization in Digital Cartography.


82. Imhof cited in Swiss Society of Cartography, Cartographic Generalisation: Topographic Maps, p. 12. Imhof, Kartographische Geländedarstellung, p. 100. Brackets are added from the English translation: Imhof, Cartographic Relief Presentation, p. 86. The Swiss Society of Cartography cut out the last phrase: “and finally, summarizing all these qualities, a beauty peculiar to the map itself.” Imhof, Cartographic Relief Presentation, p. 86.


84. Robinson, Morrison, Muehrcke, Kimerling, and Guptill, Elements of Cartography.

85. McMaster and Shea, Generalization in Digital Cartography.


88. McMaster and Shea, Generalization in Digital Cartography, p. 2.

89. Shea and McMaster, ‘Cartographic Generalization in a Digital Environment: When and How to Generalize’. See also, Winther, When Maps Become the World.


96 Kuhn, *The Structure of Scientific Revolutions*.


101 Ibid., p. 126.


110 Winther, ‘The Structure of Scientific Theories’.

111 One of the most important conferences GIScience (Michael Goodchild in personal communication, 20 January 2014 “regularly brings together more than 200 international participants from academia, industry, and government organizations.” http://www.giscience.org/ [accessed 10 February 2014].


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