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Spatial Analysis

Trevor J. Barnes

Spatial analysis involves the use of a formal vocabulary to reduce complex geographical patterns to simpler relations, permitting identification of an underlying causal structure. Three separate but interlinked processes are entailed: *translation* of geographical patterns into a rigorous and precise lexicon, typically taken as mathematics; *decomposition* of the (now) formally defined geographical pattern into a set of parsimonious and precisely defined elemental relations; and *regression* to first principles that when grasped provide recognition and understanding of the essential spatial order.

While spatial analysis is most often thought of as a geographical pursuit that begins in the mid-twentieth century, associated with the discipline's 'quantitative revolution' (Barnes 2004), it is in fact a practice that goes back much farther, dating to the very beginnings of the subject. The early Greek (possibly Hellenised Egyptian) geographer, Claudius Ptolemy **(90–168 CE)**, for example, believed that to understand *geos*, the entire space of the world, required analysis. Examining *geos* necessitated its transformation into an arithmetical and geometrical language, its reduction to basic elements, and the identification of ruling principles.

After more than a thousand year gap or so, Ptolemy's spatial analytical interests resurfaced in the Enlightenment. A key contribution, explicitly drawing on Ptolemy, was *Geographia generalis* (1650) written by Bernhardus Varenius (1622–50), a young German geographer living in Amsterdam. His text was sufficiently analytical that it was used by Isaac Newton (1643–1727) in his teaching at Cambridge University. Newton, in fact, was so impressed that he produced two new Latin editions, the bases for multiple translations of Varenius's book into various European languages during the eighteenth century.

With the institutionalisation of academic geography in Europe and North America from the mid-nineteenth century, spatial analysis became part of the discipline's general curriculum, taking the form of instruction in cartography, surveying and geodesy. When the Department of Geography at the University of Toronto first opened in 1935, for example, one of the required courses was mathematical geography with its own dedicated lecturer (Sanderson 1988).[1] From the mid-1950s, however, spatial analysis began to be separated from the rest of geography, conceptually ratcheted up by adding new, often statistical and mathematical, techniques, and elevated in status, at least by some, to *the* disciplinary method. This was new, and justified by proponents grounding spatial analysis in the practice and philosophy of science, in particular, positivism.

That this change occurred when it did in the mid-1950s had everything to do with the larger post-Second World War context in which it unfolded, and which included: (1) a shift among many US social and environmental sciences, and in which geography was also caught up, towards a 'new rigorism' (Schorske 1997); (2) generous financial and institutional support from the military, the Cold War 'military–industrial–academic complex' (Leslie 1993), that in this case provided research funds for spatial analytic projects (Barnes and Farish 2006); (3) an energetic interventionist state concerned to fulfil instrumental planning ends, such as highway development or metropolitan growth, and made for the techniques of spatial analysis; and (4) the emergence and rapid refinement of the computer, the machine par excellence as it turned out for pursuing and elaborating spatial analysis. All areas of geography were subsequently affected by the swing to spatial analysis: human and physical geography as well as cartography. Narrowly dubbed at the time the 'quantitative revolution' (Burton 1963), it was always much more than about just numbers.

That this is true was revealed when the 'revolution' flagged in human geography during the 1970s, and attacked from a variety of competing perspectives. If spatial analysis had been just another of geography's internal philosophical paradigm changes it would likely not have survived, consigned like so many other of geography's post-war '-isms' to the intellectual dustbin. But it wasn't. Spatial analysis was historically part of the furniture of the discipline, and with resonances to other fields and worlds of practical accomplishment. Further, because of its link to the computer, as the latter developed, becoming the defining machine of the second half of the twentieth century, spatial analysis was pulled along with it, burgeoning into a vibrant new endeavour. Consequently, the computerised version of spatial analysis, geographical information systems/science (GIS) as dubbed by Goodchild and Haining (2004), has become increasingly a separate pursuit, different from human and physical geography. Further, because of its practical, instrumental uses (including profit-making potential), and connections to other intellectual pursuits (from electrical engineering to medicine), it has been strongly supported institutionally at universities. For example, Harvard University, which shut down its Department of Geography in 1948 because its Cold War warrior president, James Conant, believed geography was 'not a university subject' (quoted in Smith 1987: 159) re-opened a version of the Department in 2005 but based on GIS and spatial analysis. In this guise, the discipline was finally Harvard worthy.

The chapter is divided into three unevenly sized sections. The first examines the early development of spatial analysis from Ptolemy to Varenius. The second recounts the rise of spatial analysis in the mid-twentieth century, and its failed bid for disciplinary hegemony within human geography. The final section examines the paradox of the toppling of spatial analysis within human geography, but its rise in another form, GIS, and which in certain respects now rivals human geography as a disciplinary sub-branch.

IN THE BEGINNING

Ptolemy

At the heart of Classical Greek geography was a triad of terms: *topos*, *choros* and *geos*. Traditionally *topos* was interpreted as the study of place, *choros* as the study of the region, and *geos* as the study of geography; that is, the entire face of the earth. While the difference among the three has been interpreted as one of geographical scale, Fred Lukermann (1961), and more recently

Michael Curry (2005: 681), suggest that a more appropriate differentiation is in their respective approaches to representation; that is, in their 'modes of geographical knowing'. *Topos* and *choros*, the earlier forms of Classical geography, emerged from an oral culture. Consequently, place and region were represented; that is, 'geographically known', through a narrative of words. They came into being from the telling of stories. *Geos*, in contrast, developed later, and was associated with quite a different form of representation, mathematics. Curry (2005: 695), in fact, argues that the very idea of space itself, 'invented rather late in the day', appeared with *geos* and its quantitative sensibility. From the beginning, space implied a different form of representation.

Ptolemy was perhaps the key contributor to understanding *geos*. While he was a geographer, author of the eight-volume *Geographia*, a summary of everything known about the second-century Greco-Roman world in which he lived, he was perhaps even better known as an astronomer. Using the geometry of epicycles he ingeniously tried to reconcile astronomical observations with the prevailing geocentric conception of the solar system. Similarly, he used a mathematical approach in his treatment of geography (*geos*). Defining *geos* as 'securing a likeness' of the earth's configuration, Ptolemy suggested such an end was possible only by first translating space into a mathematical vocabulary; in this case by imagining the earth 'as a surface divisible by a mathematical grid' (Curry 2005: 685).

As Ptolemy writes (quoted in Lukermann 1961: 208):

> Geography … is concerned with the quantitative rather than with qualitative matters, since it has regard in every case for the correct proportion of distances, but only in the case of the more general features does it concern itself with securing a likeness, and then only with respect to configuration … Geography by using mere lines and annotations shows positions and general outlines. For this reason, while chorography does not require the mathematical method, in geography this method plays the chief part.

While Ptolemy does not use the term 'spatial analysis', he clearly is gesturing towards it in his account of geography (*geos*). There is mathematical transformation; the identification of more basic elements like 'lines' and 'position'; and the recognition of an explainable spatial order, the world's 'configuration'. In addition, Curry (2005) argues that Ptolemy's mathematical, analytical form of representation contributed to the very development of the map, and which was absent in the earlier chorographic and topographic accounts based on only words.[2] Curry (2005: 685) writes, 'it is difficult … to see the geographic flourishing in the absence of the cartographic, and of a cartographic that uses a medium that is permanent, portable and reproducible'. It is precisely this link between the spatial analytical and the cartographic that continues to the present in GIS, making it so compelling.

Varenius and Newton

Ptolemy's *Geographia* was lost and re-found several times over the next thousand years or so before finally being translated into Latin in 1406, and published using engraved woodblock illustrations, including maps, in Bologna in 1477. It was this Latin edition that Bernhardus Varenius used in the late 1640s while living in Amsterdam, studying mathematics and medicine, to write in 1650 his own geographical text published by Elzevir press, *Geographia generalis*. The adjective in the title is critical, linking with Ptolemy's *geos*, and his incipient spatial analysis (Lukermann, nd.: 10).

William Warntz (1989: 171), himself one of the twentieth century's most well-known spatial analysts, called Varenius's work 'the first modern textbook in geography' (see also Lukermann, nd.: 4). Following Ptolemy, Varenius envisaged both a 'general geography' (corresponding to *geos*), and a 'special geography' (corresponding to *topos* and *choros*).[3] Varenius's early death at age 28 prevented him writing the planned volume on 'special geography' (although he had written a monograph on Siam and Japan the previous year). But as he made clear in the preface to the *Generalis*, it was general geography that needed setting out and solidifying:

> [T]hose who have hitherto written on Geography have treated almost exclusively of Special Geography, and at tedious length. They have described very little which concerns General Geography, ignoring or completely omitting many necessary aspects of the subject. The result is that our young men while learning more and more Special Geography were largely ignorant of the foundations of study, and thus Geography scarcely vindicated her claims to be called a Science. I saw this state of affairs, and to remedy what was amiss, I began to bend my thoughts towards supplying the deficiency by composing a General Geography … according to such powers as God has granted me, cultivated by years spent in Mathematics.
> Varenius quoted in Lukermann, nd.: 7–8.

In particular, Varenius defined general geography as 'that part of mixed mathematics which one explains the state of the earth and its parts, which concerns quantities; its configuration, its position, its magnitude and its movement with the celestial appearances, etc' (quoted in Lukerman, nd.: 10). So, like Ptolemy's geography, Varenius's general geography required mathematising space using, in his case, geometry, trigonometry, and arithmetic; finding universal spatial elements; and recognising general principles of spatial order which are 'then appl[ied] within Special Geography to their respective areas' (Varenius quoted in Lukermann, nd.: 16).

One of the all time great analysers of space, Isaac Newton (1643–1727), recognised the analytical virtues of Varenius's book. In 1669 Newton was appointed to the Lucasian Professorship of Mathematics at Cambridge which included a stipulation that the Chair's holder provide instruction in geography (Warntz 1989: 177). It is not known if Newton ever did instruct geography, but it is known that he corrected and amended Varenius' text, arranging for its publication in 1672 and again in revised form in 1681. Newton did so, as the preface to the 1733 English translation of Varenius's book by Dugdale and Shaw put it, because 'he thought [Varenius] necessary to be read by his Audience, the Young Gentlemen of Cambridge, while he was delivering Lectures upon the same Subject from the Lucasian Chair' (quoted in Warntz 1989: 177).

The larger point is that elements of what now compose spatial analysis have existed not only for centuries, but for millennia. In making this argument, I am not suggesting that spatial analysis emerged fully formed, Athena-like, out of the head of Ptolemy. But Ptolemy was concerned with space, and was concerned with analysis through the philosophical tradition of Plato, Aristotle, and Euclid to which he was heir.[4] Not that Ptolemy would have called what he did spatial analysis. But there are elements in his ideas and practices that through mediators like Varenius and Newton were durable and potent, and eventually incorporated into what became contemporary spatial analysis. For spatial analysis to occur, though, took an enormous amount of work and effort. It didn't emerge simply because of its own rightness, shining by its own internal light. It occurred, as I will now suggest, because of an appropriate wider social, political and economic context that allowed a set of older ideas, practice technologies taken from people like Ptolemy, Varenius and Newton, to be combined, assembled and joined with a new set, and made to flourish in the second half of the twentieth century under the name of spatial analysis.

GEOGRAPHY'S QUANTITATIVE REVOLUTION AND ALL THAT

Spatial analysis gained its contemporary prominence from the title of an edited book published in 1968, *Spatial Analysis: a Reader in Statistical Geography*. Until that time, the term was rarely used, although synonyms were like 'regional analysis', or 'locational analysis', or 'network analysis'.[5] It was perhaps fitting that the book, edited by Brian

Berry and Duane Marble (1968), was a 'best of' collection of geography's quantitative revolution from the preceding ten years. The 37 previously published essays applied statistical and mathematical models to geographical problems, located key spatial axioms, elements, assumptions and behaviours, and above all pursued explanations of spatial order. None of the essays used the expression spatial analysis, but that is what they all did. Moreover, just as Newton said he had stood 'on the shoulders of Giants', so had the contributors, including in the case of the geographers standing on Newton's own shoulders.

But how they got there is another story. Berry and Marble's (1968) account in their introduction has the spatial analytical approach hidden from the discipline during the first half of the twentieth century, but which is re-found, and once taken up allows geography in the post-war period to 'move back to the mainstream' in a 'flush of revolutionary change' (Berry and Marble 1968: 4). But what was the 'mainstream,' how had it been forged, and why was it congruent with spatial analysis? And why had geography taken so long to join, and what happened once it did? These two sets of questions organise the discussion that follows.

The 'mainstream'

'Mainstream' science which geography tried to join in the 1950s as spatial analysis was recent, and shaped very much by the Second World War and the success it had enjoyed there (science had won the war according to many). Exemplified by both the Manhattan Project responsible for the nuclear bomb, and the RadLab at MIT that developed the radar, science was defined in the post-war period by the same strategies found in these earlier ventures: team-based research; use of large sums of money; inter-institutional co-operation (usually private corporations, the state, the military, and universities); and fulfilment of specific, instrumental ends. Called also 'Big Science', dedicated labs (like Los Alamos or Lincoln) and research institutes were central, and organised around specific problems and their intellectual and material resolution. Further, the predilection was toward models rather than high theory. Models, of course, were no less mathematical or analytical than theories, but they were more grounded and tractable, more suited to the accomplishment of particular ends that became a guiding motif of Cold War science (Barnes 2008).

This post-war paradigm of science was additionally shaped by a machine produced by that very same paradigm, the computer. The computer's immediate origins were with Alan Turin's use of the 'Colossus' at Bletchley Park, England, during the Second World War to break the encrypted code used by German U-boats, Enigma. However, commercial development of the computer, and its dissemination to labs, institutes and universities did not occur until the early 1950s. Propelling the computer's development was precisely the 'Big Science' model. The computer was developed at MIT's Lincoln Labs, funded in large part by the US military, especially the Office of Naval Research (ONR), and constructed by IBM (at a cost of $30 million each, and at one point employing 20 percent of the corporation's workforce). Of course, early computers were lumbering dinosaurs compared with contemporary versions, but even then they could perform calculations with a speed, consistency and stamina that no human could match, and were vital to post-war science and, as we will see, to spatial analysis as well.

This 'mainstream' model did not stay only within science, however. It also moved into selected social sciences, and even some humanities like philosophy. Economics and psychology were early converts, and incursions were made into sociology, political science and even anthropology. Furthermore, institutes were inaugurated that did for social science what similar institutes did for the physical science; for example, the founding of RAND Corporation in 1947. As this occurred, social science was altered and became more team-based, problem-focused, instrumental, mathematical, and model- and machine-reliant. There was also a philosophical change that accompanied and justified the shift, initially taking the form of positivism and later a more general analytic philosophy, and which increasingly gained a hold at top US philosophy Departments such as Harvard, Princeton and Chicago, as well as in some research institutes. For example, the positivist philosopher, Hans Reichenbach, was *Time*'s coverboy for RAND in 1959 (Reisch 2005: 249–53; a reproduction of *Time*'s cover is on page 352). As a philosophy emphasising the centrality of formalism, logic, reductionism, analysis and generality, it was made for post-war mainstream science and social science, as well as the first modern forms of spatial analysis.

Spatial analysis and the 'mainstream'

It was within this larger context that spatial analysis in its modern guise emerged within geography. While spatial science possessed a longstanding disciplinary pedigree, Berry and Marble were right about its later diminishment. Spatial analysis was de-emphasised when geography became a university subject from the late nineteenth century, and instead it stressed *topos* and especially *choros*, or in Varenius's terms, a 'tedious' 'special geography'.

In 1939, Richard Hartshorne (1939) even wrote a dense, closely argued 400-page-plus book with the definitive title, *The Nature of Geography*, to make a philosophical case for 'tediousness.' His argument was that geography could never be on par with physical science because the stuff of geography's study, places and regions, were unique assemblages found no where else. Talk of general theories or principles was therefore a disciplinary non-starter. As Hartshorne (1939: 449) wrote, geography 'is essentially a descriptive science concerned with the description and interpretation of unique cases'. Ptolemy, Varenius and Newton would have rolled over in their graves.

But Hartshorne was a powerful disciplinary gatekeeper, well-cited and connected, a past president of the Association of American Geographers, a man who literally wrote the book on geography. Bypassing him would be difficult. But the forces of change represented by mainstream science were also imposing and implacable. Slowly, but inexorably, a modern version of spatial analysis emerged in a process dubbed geography's 'quantitative revolution'. In the course of that revolution, geography increasingly joined the 'mainstream'.

An early example was at the Department of Geography, University of Washington. During the mid-1950s two catalytic professors, William Garrison[6] and Edward Ullman, drawing on funds from the Federal Government and the military, undertook team-based research with a group of graduate students who serendipitously had arrived at Seattle at the same time, and among whom included Brian Berry and Duane Marble. Making use of statistical methods that Garrison first taught in 1954 (Geog 426: Quantitative Methods in Geography), and a newly installed IBM 650 computer housed in the attic of the chemistry building, the group drew upon a series of spatial models to evaluate a proposed highway development for Seattle. The resulting volume, *Studies of Highway Development and Geographic Change* (Garrison *et al.* 1959), was in one way a remarkable volume, unlike anything else published in English up until that time in the name of academic geography. Crammed with calculations, data matrices, statistical techniques, cost curves and demand schedules, even the maps were subverted, overlaid with numbers, arrows, starburst lines, and balancing equations. But in another respect the book's spatial analysis was unremarkable, simply the recouping of the earlier tradition of spatial analysis, and following a road already heavily travelled since the end of the Second World War by a number of other sciences and social sciences.

The University of Washington along with the University of Iowa were the first of geography's centres of calculation to practice modern spatial analysis. Such centres quickly burgeoned elsewhere, often brought into being by the bodies of the young revolutionaries themselves as they took up new university appointments on various North American campuses: at Chicago, Northwestern University, Michigan, Ohio State, Illinois, Indiana, Buffalo, Toronto and McMaster. The quantitative revolution was less widespread in Europe, but the work of the iconoclast, Torsten Hägerstrand at Lund University (and visitor to the University of Washington in the late 1950s), was important. Similarly significant were contributions by the 'terrible twins' of British geography, Peter Haggett and Richard Chorley, who taught together at Cambridge in the late 1950s (Haggett later became professor at Bristol University in 1966 and also made it a key site for spatial analysis).

The spatial analysis that developed was found across the spectrum of geography. Perhaps the greatest discussions occurred within human geography though. Certainly, it was in human geography that the most intense philosophical debates occurred, drawing on the positivist philosophers already mentioned.[7] It wasn't a uniform disciplinary interest, however. Economic and urban geography grabbed most of the attention. In each case they traded heavily in borrowed mathematical models from both economics, such as location theory, and physics, such as the gravity model. Consequently, given their provenance, those models from the outset carried a sophisticated inbuilt analytic structure. Both sub-disciplines also increasingly drew on digitised socio-economic census data allowing computer-based statistical analyses, and, from the late 1960s, the use of pre-packaged statistical programmes (the Statistical Package for Social Sciences—SPSS—was launched in 1968). Brian Berry's arrival from Seattle in 1958 at the University of Chicago as a newly minted assistant professor therefore could have not been more propitious. Within three years Berry was director of the University of Chicago's Center of Urban Studies. And inside a decade he had made the Center the pre-eminent site for spatial analysis in urban and economic geography, developing spatial models of urban and economic structure, and testing them against an avalanche of numbers using ever-sophisticated statistical techniques, programmes, and computers.

Then there was physical geography, until the 1950s stuck in the William Morris Davis mould: largely descriptive, non-mathematical, and atheoretical. Partly because of greater availability of research funding by the military (the US earth sciences were the recipient of billions of dollars of funds in the post-war years (Cloud 2003)), and strong intellectual links to the physical sciences, physical geography was perhaps even more receptive to spatial analysis than human geography. The early career of geomorphologist Richard Chorley provides a useful illustration. A Cambridge geography undergraduate, Chorley went to the Geology Department, Columbia University in 1951 to do his PhD (and partly funded by an ONR grant). His research supervisor, Arthur Strahler (1992), had begun his own quantitative revolution in geology in the early 1950s (the 'quantitative/dynamic' approach (Strahler 1992)). Arriving at Columbia when he did Chorley realised later that he 'had stumbled into the control centre of a scholarly revolution' (quoted in Schumm 2004: 672). It was that revolution that Chorley, in turn, took back to the Cambridge Department of Geography in 1957 when he was hired as a demonstrator, and which later he brought more widely to own discipline: 'spatial analysis in geomorphology' (Chorley 1972).

A third leg of geography, cartography, was also transformed by spatial analysis, and prepared it for GIS. A central figure in that transformation was another of the students at the University of Washington in the mid-1950s, Waldo Tobler. In between his MA and PhD at Washington, Tobler worked in the belly of the beast, within the military–industrial complex, as a cartographer for a spin-off company of RAND charged with preparing plans for defending the country from a nuclear attack (Barnes 2008). Partly out of that work experience, he wrote in 1959 what became a celebrated paper, 'Automation and cartography' (Tobler 1959), the first in geography to think through the possibilities of bringing together computers and cartography. With that connection made, Tobler (1976) in the next decade developed what he called 'analytical cartography,' the correlative of 'spatial analysis'. It combined the computer, maps, and formal mathematical and statistical techniques. Analytical cartography, in turn, became 'the sub-discipline of cartography that l[ay] behind much of the development in geographic information science' (Clarke and Cloud 2000: 195), and discussed below.

By way of conclusion, and also as a transition to what has happened subsequently, let me discuss William Warntz. If any single person embodied spatial analysis it was him. (His last (posthumous) paper fittingly celebrated Newton and Varenius (Warntz 1989)). For a brief shining moment Warntz was even on the cusp of bringing back geography as spatial analysis to Harvard. Warntz had written his PhD in economics at Penn after the war. Unusually for an economist his dissertation was about space. He deployed Newton's gravity and potential models to present a geographical analysis of price, and empirically illustrated by commodity statistics from the US Department of Agriculture (Warntz 1959). If ever there was a geographical project requiring a computer given the inordinate number of calculations required it was Wartnz's, and to which he gravitated from the late 1950s. Appointed as research associate to the American Geographical Society in 1956, Warntz's big break came in 1966 when he was hired at Harvard to work in Howard Fisher's Harvard Lab for Graphical Design, and then an even bigger break in 1968 when he was made its director (Chrisman 2006).

The purpose of the lab was to develop computer mapping programmes, initially focused on Fisher's own, SYMAP (for details see Chrisman 2006: ch. 2). Warntz was hired in autumn 1966 to add 'factual information, its gathering, manipulation and analysis' (quoted in Chrisman 2006: 12). When he was made director two years later, Warntz insisted on adding 'and Spatial Analysis' to the Lab's title. That meant for him 'the study of surfaces and the mathematical structure of spatial distributions' (Chrisman 2006: 58). To that end, and supported by an ONR grant, Warntz established the series *Harvard Papers in Theoretical Geography* to disseminate results, and which consisted of mathematical analyses of both familiar geographical surfaces like drainage basins and urban systems, and unfamiliar ones like bovine livers and migratory paths of the artic tern (a full list of papers is given by Chrisman 2006). Warntz's promotion to director rather than being the crowning glory, however, was the beginning of the end of spatial analysis at Harvard, and in human geography more generally. In 1971 Warntz was forced to resign from his position and went to University of Western Ontario. By then, his colleagues at the Graduate School of Design were less keen on his kind of design; social science was becoming more social and less scientific; and even old reliable, ONR, and which paid for part of Warntz's Harvard salary, reined back its grants to human geographers. Larger changes were afoot.

Revolting against the revolution

Those changes were quickly seen in human geography, with spatial analysis increasingly criticised from the early 1970s. Spatial analysis, it was claimed, was: out of synch with the discipline's own intellectual past that emphasised grounded context and geographical singularity ('special geography'); out of synch with its own historical and political moment of, in particular, the late 1960s and early 1970s that reacted against the violence of abstraction, technology, formal ordering, and centralised authority, all of which critics said characterised spatial analysis; and even out of synch with scientific logic as detractors revealed in the assorted contradictions, inconsistencies and *aporias* they found within spatial analysis.

David Harvey was a central figure in this subsequent unravelling. In 1969 he had published *Explanation in Geography*, a lengthy and detailed philosophical justification of spatial analysis based on a close reading of various venerated positivist and analytic philosophers. Even before he finished his tome, however, Harvey had doubts, and which then erupted at the 1971 Annual Meeting of the Association of American Geographers in Boston. He announced there that:

> [Geography's] quantitative revolution has run its course and diminishing marginal returns are apparently setting in as … [it] serve[s] to tell us less and less about anything of great relevance … There is a clear disparity between the sophisticated theoretical and methodological framework which we are using and our ability to say anything really meaningful about events as they unfold around us … In short, our paradigm is not coping well. Harvey 1972: 6.

The rest of the 1970s was a decade in which various elements of spatial analysis in human geography were in turn held up for scrutiny, and found wanting. Harvey (1972) began by attacking the usefulness of theory, models and statistical techniques, portraying them as at best irrelevant and at worst politically regressive ('counter-revolutionary'). Gunnar Olsson (1975) pitilessly unpicked the logic of Warntz's cherished gravity model, arguing that its formal reasoning undid any claim to empirical veracity, and when applied it made bad worlds not good ones, worsening the lot of humans not improving it. In a similar vein, Robert Sack (1980) argued that the very idea of a separate analysis of space was logically inconsistent with the scientific principals it invoked. Humanistic geographers (Ley and Samuels 1978) berated the spartan, clinical, de-contextualised, and amoral model of humans and places spatial analysts erected. Derek Gregory (1978: 49) drew on the full force of critical theory to 'kill the Gods' of positivism. And in case there was still doubt, with forensic precision Andrew Sayer (1979) declared the body well and truly dead right at decade's end. Drawing on critical realism, Sayer argued that spatial analysis failed to recognise the importance of causal mechanisms, and instead was content with the sop of mere association, and manifest as an endless stream of correlation and regression studies that looked impressive but explained nothing.

For some, however, the announcement of the death of spatial analysis was greatly exaggerated. They were not willing to let it shuffle off to the other side, at least not yet. Just as well because there was still a pulse.

SPATIAL ANALYSIS REDUX: GIS

Spatial analysis did not so much die as it was reincarnated in the new body of GIS. Of course, GIS did not need to happen. There was no ineluctable force that produced its emergence as some Whig historians of GIS have suggested (see Curry (1998: ch. 4) for references and the counterargument). It was a consequence of contingent factors that while context-specific, and existing in embryonic form since the end of the Second World War, were no less potent. They included many of factors already discussed including the quantitative revolution, the increasing power and user-friendliness of computers, large gobs of Cold War military and later corporate research money, the instrumental ends of government, and increasing academic institutional capacity. The Harvard Lab which embodied so many of these features was the exemplary case, and repeated later in different guises in other places.

The move from spatial analysis to GIS occurred almost seamlessly. Certainly, Warntz did not make a distinction, with the two pursuits converging in his renamed laboratory. In addition, several of the Washington 'space cadets' wore both hats: Art Getis and Duane Marble, the co-editor of the *Spatial* *analysis* volume, are now just as well-known for their contributions to GIS as to spatial analysis.

Moreover, there are good reasons for the convergence. GIS permits greater extension of existing forms of spatial analysis. It isn't either/or. Instead, it is a case of having your cake and eating it. GIS does not embody spatial analysis as such. At its most basic, GIS is the cartographical representation of digital geocoded data. But in that form, data is easily manipulated by spatial analysis. As Longley and Batty (1996: 1) write, GIS 'is part of the wider move to a digital world … and within that digital environment … quantitative geographical methods and techniques can be used … thus enabling the development of rigorous models of spatial distributions, the analysis of locational patterns, and the investigation of forecasting of space-time dynamics.' In this sense, 'GIS becomes the new context for spatial analysis' (Longley and Batty 1996: 2).

Goodchild and Haining (2004) go even further, anointing a new discipline, geographical information science (GISci), as a vehicle for combining spatial analysis and GIS. They write: 'Although GIS and spatial data analysis started out as two more less separate areas of research and application, they have grown closer together over time. We argue that the two areas meet in the field of geographic information science, with each supporting and adding value to the other' (Goodchild and Haining 2004: 363).

Whatever its new mantle might be now called, spatial analysis has clearly survived its near-death experience and is prospering (literally and figuratively). GIS is now a distinct field of inquiry generating its own journals, conferences, academic pecking order, lines of funding, centres and institutions. It is connected to a multi-billion-dollar industry, the products of which now seep into everyday practices. This does not necessarily contribute to the intellectual standing of GIS/spatial analysis, but within increasingly corporatised universities it certainly attracts their financial attention. Harvard recently has followed the money, but whether this will be a backdoor strategy to bring back geography to that university is unclear. If anything, GIS and spatial analysis appear to be going on their own, increasingly detaching from the discipline as a whole. As a model it could be the end of geography as we knew it.

CONCLUSION

Spatial analysis as I tried to suggest has been part of the subject almost as long as geography has been a subject. It is bound up with mathematisation, identifying fundamental spatial elements, and explaining spatial order from general principles. Because of these features it has constantly been linked to science, whether that of Ancient Greece, the Enlightenment, or the post-Second World War 'Big' kind. Most recently, its tie is to computer science through GIS. Given the commercial possibilities of these connections, spatial analysis may well take off on a life of its own, leaving even its original subject base behind. Of course, spatial analysis and GIS will still be found in geography (especially physical geography), but it will have become too important (and lucrative) to be left only to geographers.

However, knowledge does not belong to any one group, a fact geographers should readily appreciate given that they have been one of the great borrowing disciplines since their incorporation into the academy. Neither is knowledge in any sense pure but is always muddied by its historical and geographical context. It is always 'mangled', to use Andrew Pickering's (1995) metaphor, by social ends, or bureaucratic ones, or internal university politics, or by military and commercial imperatives, or even by new material environments such as those given by machines like the computer. Here is the irony: spatial analysis aspires to purity of knowledge, but historically it has been corrupted from the beginning. If it hadn't there would have been no beginning. Like the other concepts written about in this section of this volume, spatial analysis remains vibrant, with a future, because it is messy not because it is pure.

NOTES

1 Clout (2003: 5) also reports that the University College London's Department of Geography course listings for 1924 included 'mathematical geography,' albeit taught by surveyors from engineering.

2 Maps existed long before Ptolemy wrote, but Curry's (2005) point is that they were not connected to earlier forms of geographical inquiry, *topos* and *choros*. They were joined to geographical study only once there was movement away from the 'technology' of writing to the 'technology' of mathematics and which occurred with the examination of earth's spaces (*geos*) as opposed to its places and regions.

3 The terms 'general' and 'special' were used earlier by Bartholomäus Keckermann in his *Systema Geographicum* (1611) (Livingstone 1992: 83–4). Lukermann (nd.: fn. 5: 49) argues, though, that Keckermann should not be given credit for inventing these terms because their origins lay 'well back into Hellenistic times,' and they are 'the common property of numerous geographers and logicians of the sixteenth and seventeenth centuries.'

4 The word analysis derives from the Greek term *analusis* meaning loosening up or dissolution, and associated with writings by Plato and Aristotle (Beaney 2007).

5 Using JSTOR which has digitised the contents of ten long-standing geographical journals from their first publication, I carried out a search for the terms 'spatial' and 'analysis'. There is increasing use made of both terms separately from the early 1950s, but they are not used together jointly until William Garrison's (1959) paper, but even then it is done in passing. The first sustained discussion of spatial analysis as spatial analysis is with Berry and Marble's edited book. A statistically based content analysis of JSTOR journals is carried out by Jackson *et al*. (2006). They did not search for the term 'spatial analysis' per se, but found that kindred terms like 'laws', 'theories', 'correlation' and 'regression' were most prominent within human geography during the 1970s. See also Chrisman's (2006: 58) pertinent discussion.

6 Berry and Marble (1968: v) dedicate *Spatial Analysis* to Garrison, 'the spark that set us all in motion'.

7 The first battle cry in the quantitative revolution came as a philosophical attack on Richard Hartshorne by Fred Schaefer (1953) who avowed a strict positivist position.

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