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Rethinking GIS teaching to bridge the gap between technical skills and geographic knowledge

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Abstract

Teaching GIS in universities, over the last few decades, has often been applied in focus. Yet academic research is much more than application: epistemology, representation, critical GIS have been gaining an increasing share of research. This trend is paralleled by increasing awareness and sophistication in the professional practice of GIS. Nonetheless, the increasing availability of spatial analytical techniques in commercial and freeware GIScience software, not paralleled by an increased knowledge in GIScience practitioners, raises questions about the maturity of the GIScience user community and the potential consequences of an incautious popularization. Appealing to the average GIScience user by means of friendly interfaces, most analytical functions fail to keep a standard promise of GIScience software: guiding the user through a safe path to a successful application. This lack of guidance is perceived as a gap, the consequences of which range from discouragement to naïve or incorrect applications. Future GIScience professionals should be prepared to look beyond their software interface, and the discipline should strive to maintain its own rules and make its own decisions when it comes to packaging their tools. A key role can and must by played by those who teach GIS in our universities, whose task id to form a generation of GIScientists, not simply of GIS technicians.

Keywords: GIS, Spatial Analysis, User, Software, Teaching, Practice

1. Introduction

Throughout the short history of GIS there has been a recurrent complaint about the lack of analytical applications: since its early days, GIS has been widely adopted in academic and professional settings, but mostly used for storing and mapping spatial data (Coppock and Rhind, 1991; Wright et al., 1997). Some went so far as to call the lack of GIS analysis a crime (Openshaw, 1993), but most would agree that analysis of spatial data was perhaps the greatest promise of GIS. Despite that complaint, a subdiscipline known as spatial analysis was growing: over a few decades, new techniques have been developed, older tools have been refined, the spectrum of applications has been broadened, and algorithms have grown better and faster (Berry et al., 2008). The term "advanced spatial analysis" has come to signify the distinct object of spatial analysis as a subdiscipline: a range of complex techniques and models, inherently different from the array of elementary spatial analytical operations commonly used in GIS.

Over the last few years, advanced spatial analysis has become increasingly available in standard commercial GIS packages and in user-friendly, GIS-oriented spatial analytical products, often freeware. This marks a radical change from a recent past, when spatial analysis was confined to specialized software, often user-unfriendly and GIS-unfriendly, owing to its requirement for command lines and scripts, and import-export of spatial data between analytical and GIS packages. In the current software packaging mode, spatial analytical techniques are presented, along with elementary GIS operations, via inviting icons, which in reality conceal complex procedures, whose inner workings are often unknown to the average GIS user. As a result, advanced spatial analysis has become not simply accessible, but even appealing to the broad GIS user community.

The objective of this paper is to analyse the growing gap between the potential of readily available analytical tools and user knowledge of those tools. Often GIS is still perceived – within and outside the discipline – as a highly technical set of tools. Consequently, users tend to have little awareness of the analytical potential of those tools and, worse, of the theories and concepts underpinning them. Up until now, emphasis has been on teaching how to use GIS software. In this paper we argue that GIS curricula and teaching practices are the best places where the gap can be bridged. It is in teaching GIS that emphasis can shift from "how to" to "why", so that users can keep the pace with the growing potential of GIS. Rethinking the teaching of GIS in this direction presents opportunities for GIS as well as for geography.

2. What is special about spatial analysis

For a long time spatial analysis has been perceive as a distinct subdiscipline, if already in 2000 one issue of the Journal of Geographical Systems was devoted to a discussion on the current status and future trends of spatial analysis, and to the relationship between spatial analysis and GIS (Getis, 2000). At the same time, spatial analysis is strongly rooted in quantitative geography (Baker, 2008). If the phrase "doing GIS" can be interpreted in different ways (Writght et al., 1997), likewise the phrase "doing spatial analysis" is prone to a multiplicity of interpretations; a major distinction is between elementary an advanced spatial analysis. Elementary spatial analysis in GIS refers to such operations as spatial queries, buffering, point-in-polygon, topological overlay, etc. (Burrough and McDonnell, 1998). Advanced spatial analysis or modelling refers to such operations as kriging, point pattern and cluster analysis, spatial and geographically weighted regression, etc. (Fotheringham et al., 2000).

Elementary spatial analyses can be executed immediately and directly through the pull-down menu of standard GIS software: a single click opens up a window where the user must choose a number of parameters; once this choice is made, the software returns the results of the operation. Typically elementary analytical operations result in the definition of new geometric entities, the modification of existing ones, or the selection of subsets of entities; in all cases, the newly defined entities inherit the properties of the original ones, hence the validity of the analytical operation is guaranteed by prior choices. The user can choose within a range of parameters, which will define the characteristics of individual applications, such as buffer size or measurement units, but, normally, user's choices do not impact on the validity of the analytical results. Owing to their relative simplicity and limited choices, structuring these operations into a guided path through a software interface is generally a straightforward matter, and has become the norm in GIS packages.

Conversely, advanced spatial analytical operations are more complex tasks, conceptually and computationally; they require the formulation of hypotheses, the definition of models, and often the use of advanced mathematical and statistical tools. An advanced spatial analytical task can be broken down into a series of simpler operations, which are generally performed in a relatively standard sequence, and where typically each subsequent operation is determined by the results of the previous one(s). Only some of these operations are elementary. Consider, for example, a multivariate spatial regression analysis; a typical sequence of operations (assuming that all data have been gathered) includes: define the model's dependent independent variables; define the model's functional form; analyse each variable's distribution; test the correlation among variables; specify a spatial weight matrix; test the spatial autocorrelation in the variables; estimate the model's parameters; run diagnostic tests on the regression residuals; test the spatial autocorrelation in the model residuals; if any test yields unsatisfactory results, identify the problem and: restart from the appropriate step; repeat, until satisfactory results are obtained (Anselin, 1998).

A sequence of operations like this cannot simply be executed through a single click on the menu, no matter how complex the window that would be opened. Some of the analytical steps can be – and generally are – automated, but some of the most important steps, such as model definition, or implementation of specific corrections, require some judgment and the procedure capable of leading to valid results cannot always be automatically determined, prior to implementing the analysis. Therefore, the range of options facing the user cannot be structured in a screen window[1]. Unlike with elementary operations, some of the user's choices will impact the analytical results, their meaning, and their validity. Specifically, the choices made during the conceptual steps of model definition and model evaluation will determine the validity and meaning of any result (Getis and Aldstadt, 2004). The end product of a spatial analytical model is not a geometric entity, but a new piece of knowledge about one or more spatial phenomena, and this piece of knowledge does not simply inherit the properties of the entities analyzed throughout the procedure. It is the choices made by the user during the crucial analytical steps that will determine the validity and meaning of the analytical results (Anselin, 2002).

Irrespective of their fundamental difference, current software packages often present elementary and advanced spatial analytical operations on a single software toolbar, where all the operations are symbolized by kin icons, which conceal the diverse fate of their results. As a consequence, when a GIS user, who is accustomed to performing elementary GIS operations, is presented with an advanced spatial analysis via an icon like any other, he will expect to be able to perform the task as easily and immediately as any other familiar operation. He will expect to be guided safely, via structured windows, to valid results. But he will soon realize that this standard promise of GIS software is not going to be kept. He will also discover that help files and user manuals are not that helpful, because they too presuppose some knowledge of the technique, that the average GIS user is unlikely to have. Left alone, he can either drop the analysis, or proceed in the dark, and like a blind man bounce against the walls until he finds a door leading out, but there is no guarantee that that door opens to a valid solution, and he has no way to determine it for himself.

3. Spatial analysis and GIS education

It is known that GIS developed rapidly, much as a technoscience, and since its early days it was trapped in the hindrance of its own success (Maguire, 1991). Soon after its birth GIS was big business, GIS literacy was in great demand, and many wanted a GIS education. In the early days, most GIS jobs required low level, technical skills. Consequently, colleges and universities began producing cohorts of GIS graduates, through certificate programs, undergraduate degrees, and eventually technical graduate degrees, such as course-based Masters degrees. Throughout the curricula, emphasis has ever since been placed on hands-on skills, courses had large lab components, and even lectures often had very technical contents. Even at the graduate level, the role of research has

[1] http://www.arcgis.com/home/item.html?id=71a65d35688a4502b123cbdfc99afdee (ArcGIS 2013); http://www10.giscafe.com/nbc/articles/1/1157925/Learn-Use-Regression-Analysis-Tools-Esri-ArcGIS (GISCafé, 2013).

been much lesser than in traditional academic degrees. Arguably, GIS academics have had fewer opportunities than their colleagues to develop as real academics, busy as they were teaching technically-oriented courses, keeping up with a fast-growing technology, and publishing in a discipline where technical advances were often seen more favourably than theoretical contributions (Coppock and Rhind, 1991). In a negative feed-back loop, university graduates inevitably have become more technically than intellectually prepared, and on their jobs they have been appreciated for their technical skills more than for their theoretical background, to the point that they even ended up thinking of themselves as technicians more than intellectuals.

These circumstances, and perhaps more, have shaped most current GIS programs. The GIS field is broad and complex: there are many things to learn and very little time to learn them. Should that little time be invested in studying concepts and theories or in learning practical, applicable skills? The choice is too simple to merit any discussion. No wonder GIS professionals know how to perform operations, much more than they know why they perform them, or what they mean. This implies that they possess know-how, more than knowledge: they know (have learned) how to calculate a buffer, but they do not know (have not learned) how to estimate a spatial regression model. It is only reasonable that, when they want to estimate a spatial regression model, they will think of it the same way as calculating a buffer, and they will seek a similar procedure. For this reason, presenting “spatial regression” via an icon exactly like the “buffer” icon is probably the best way of communicating with GIS professionals, the best way to make sure they will perceive it as a familiar and within-reach operation.

This approach to spatial analysis does not even take conceptual issues into consideration. Consistent with what they learned in school, GIS professionals will focus on the task; they may be aware that conceptual and theoretical issues exist, but they think of these issues as not part of their task. This appears to be the main problem of past and present GIS education. Not only has the technical focus deemphasized the theories, but the theories, confined to a very little space, are taught in a hurry, students get only the highlights. Performance evaluation is based on the student’s ability to achieve a solution, and, as a result, the theory is perceived as something other than the real doing GIS. This problem is not limited to advanced spatial analysis, but to all the GIS tasks that are non-trivial enough that concepts and theories matter.

There are two important consequences of the technical orientation of most GIS university and college programs: on one hand, there was little space in these technical programs to teach advanced spatial analysis; on the other hand, GIS professionals were raised and trained as software users . But there is yet another reason why GIS professionals are unprepared to resolve conceptual problems, accustomed as they are to find technical solutions to their daily technical problems, and this reason has its roots outside GIScience. Professionals across the map are increasingly unable to seek and elaborate original solutions to unfamiliar problems, and they are unprepared to revert to other than the usual resources. This tendency is not limited to the GIScience field, but pervades many disciplines and professional realms where user-friendly interfaces have replaced traditional environments, in which users were expected to possess a good knowledge of their tools. Indeed, today’s computing environment is pervaded by this philosophy, whereby the user is relieved of the burden of interpretation and the hardship of choice; he is told what to do and how to do it, in order to achieve, safely, valid results. Only marginal fringes within the discipline maintain their right to interpretation and choice, at their own risk. Paradoxically, the inner circle of spatial analysis professionals remains firmly anchored to this traditional way of computing and doing analysis: they develop, refine, and share their own tools; they even make their tools available, free-of-charge, to everyone. But as they know their tools and they know how to use them, they do not feel any need to enhance their user-friendliness: for this very reason, those tools, tantalizingly presented to the GIS community and beyond, remain effectively inaccessible to the average GIS user. Goodchild (2000) has identified as a “basic tension [in GIS] between the populist view, in which technology is easy to use and accessible to all, and the elitist view in which only those well versed in the principles of spatial theory and geographic information science are able to use it effectively".

4. Conclusions

The popularization of spatial analysis, achieved by user-friendly software, has lead to increasing numbers of spatial analytical applications, yet not paralleled by improved quality of those applications. This may constitute a turning point that GIS and spatial analysis cannot miss. High quality applications of spatial analysis are in great demand, in important fields, ranging from environmental sciences to medical geography and regional planning. Failure to satisfy this demand can be of great detriment to the discipline of spatial analysis (and GIS) and its credibility. Effective solutions must recognize, for example, that statistical properties are only quantifiable manifestations of qualitative attributes, and poor analyses stems from the disconnection between data and geographic phenomena.

GIS software is a product of substantial commercial value; many GIS applications are equally valuable commodities, ranging from spatial databases to maps and analyses. The commercial value of GIS software is probably an important factor in the development of friendly interfaces, which can effectively expand that software market to spatial analysis practitioners. As said, the increased value of GIS software is not matched by increased value of applied spatial analyses. Several alternative strategies can help fill the gap between software potential and analytical applications. On the software side, a complete withdrawal of user-friendly interfaces is unthinkable, but measures can be undertaken to control the current risks, by discouraging an unwise use, for example by rating the difficulty of analytical tasks, like recipes in a cookbook or trails in a hiking guide. However, such measures can only produce technical improvements, but will not impact the quality of applied analysis, as long as users remain unaware of the meaning of their analysis, and a true geographic culture is still missing.

Arguably, the best strategy to improve spatial analytical results and to form better GIS professionals is to provide a more thorough GIS education in Universities. Achieving this goal will take a long time and conspicuous resources, but it would be a well-worth investment in the future of GIS, spatial analysis, and geography as a whole. As the disciplines of GIS and spatial analysis mature, research begins to move, beyond technical problems, to the profound questions revolving around their theoretical underpinnings: ontology, epistemology, critical GIS, representations of space (O'Sullivan, 2006; Schuurman, 2006). In this process, these disciplines (re)discover their deep roots in geography: geography, not software development or know-how, is the home where answers can be found to the fundamental questions that have started to surface once those disciplines have begun to emerge from their infancy. These disciplinary developments present a unique opportunity for the teaching of disciplines in a way that encompasses fundamentals along with technicalities: indeed, high-quality education cannot be achieved without high-quality academic research and professional practice. Therefore, here lies an opportunity also for geography to re-examine not only GIS, but geography itself through the development of GIS, GIScience, and spatial analysis. GIS and spatial analysis have a perhaps unique potential to improve communication across the social, environmental, health, and physical sciences. Recognizing this potential can lead to an integrated approach to quantitative analysis in the social sciences, where quantitative properties are, often, only the quantifiable manifestation of qualitative attributes.

A few simple changes could realize significant changes in GIS education: GIS programs should be expanded, to include a variety of courses on theory and fundamentals of the geographic discipline, and, most importantly, integrated within geography departments, where students can be immersed in environments pervaded by geographic culture. For example, experience shows that often courses on the foundations of geography or the philosophy of science are mandatory for masters and doctoral students, but not necessarily for GIS students. Extending such requirements to GIS students would reduce the noted gaps. GIS curricula should be taught not just by GIS and technical experts, but they should encompass contributions from a wide range of geographers, so that a new generation of GIS practitioners will possess not only the technical skills, but also the knowledge of geography and appreciation for the unique flavour of spatial phenomena. One important component of GIS education should be a training strategy aimed at exposing students to academic research, by involving them in relevant research projects. This strategy would provide rapid investment return, as those research projects could be enriched by GIS and spatial analytical components. Applying these directions can lead to a significant reduction of the gap between the technical field of GIS and the academic field of geography: teaching GIS can become the means to form a new generation of GIScientists, not simply of GIS technicians.

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