Current Trends in Geographic Information Systems (GIS) Science and Technology: Towards Free and Open Source Software and Public Participation GIS

Mary Straka

Department of Geography and Environmental Science: University of Colorado Denver

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Dr. Katharine Kelsey

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Abstract
There are four distinctive trends which have arisen within the field of GIS science and technology starting in the early 2000s-2010s. These trends include the movement towards Open GIS, the rise of Participatory or Public GIS frameworks, attempts to incorporate local and indigenous knowledge into GIS systems and analyses, and expansion of GIS systems to include qualitative data formats. While these four areas will be discussed in detail and examples of current or recent projects within each realm will be presented, it is important to note that these areas are all very closely related and are often practiced in tandem. In many of the case studies and research projects presented, most or all of these four trends can be seen in practice together.

Free and Open Source Software
The most broad of these trends is the movement for Free and Open Source Software for Geospatial (FOSS or FOSS4G). This movement is a field within GIS and a philosophy which holds that geospatial data, software, and ancillary programs should be free and available to everyone. Proprietary GIS systems (for example, ESRI's ArcGIS Pro, the "industry standard") require a paid subscription that often costs hundreds or thousands of dollars annually. As such they are inaccessible to a large proportion of society and are mainly used by professionals in academia, government, or the private sector. That is to say, it is very uncommon for a non-GIS professional to have access to or understand how to utilize proprietary software, which results in one main criticism: proprietary software is prohibitive, inaccessible, and as such is often an inappropriate tool to address problems which require incorporation of values, information, opinions, and experiences from local communities or social groups.

FOSS and Open GIS has risen as an alternative to proprietary GIS systems. FOSS and Open GIS are more accessible, appropriate, and effective in addressing issues pertaining to specific communities or social groups, largely because of the philosophy of openness which underpins these technologies (Ghose & Welcenbach, 2018; Moreno-Sanchez, 2012; Sui, 2014). The philosophy of openness can be summarized as a commitment to transparency, collaboration/cooperation, and free and open access to data, software, technology, information, and education (Moreno-Sanchez, 2012). Commitment to these principles has led to a suite of advanced FOSS products which rival proprietary GIS systems in analytical capabilities and often surpass proprietary systems in their capacity for modification and specification. Some areas of opportunity in the FOSS4G field include the potential to address challenges posed by an abundance of spatial data and the "curiosity-inspired, crowd-powered development of an open and geographic citizen science network" (Sui 2014, p. 1).

Public or Participatory GIS
Riding alongside the FOSS4G movement is the push to include members of the public in the planning and decision-making process. This is especially pertinent for issues related to community-led natural resource management and sustainable development. Public or Participatory GIS (PGIS) is the name given to GIS methodologies which incorporate knowledge, values, and participation of members of the public. When considering any environmental issue from a geographic lens, it is necessary to identify the stakeholders (people or groups involved in and impacted by the issue). Traditionally, GIS systems were used by one person or group and results were explained or applied to the area in question. This is particularly true when researchers "study" issues in developing countries and fail to solicit, incorporate, or involve any local or traditional knowledge. PGIS frameworks allow and encourage community involvement and as

such are a promising tool to increase public awareness of, involvement in, and trust in GIS approaches to problem-solving (Dunn, 2007; Elwood, 2008; Mekonnen & Gorsevski, 2015; Shay et al., 2016).

Dunn (2007) states: "Of fundamental importance to PGIS implementations are questions of access, control, and ownership of geographical information and outputs" (p. 620). There is a historical power imbalance between the people designing, analyzing, and implementing GIS/PGIS systems and the people or communities being studied or managed. PGIS provides a way to address this power imbalance and level the playing field. When PGIS systems are designed with a specific community in mind, and that community's needs and challenges are carefully considered, it is possible to design a PGIS which is appropriate, accessible, and effective. It is often assumed that PGIS are well-designed and meet the needs of end users, but this is not always the case. In one specific project designed to foster sustainable GIS programs for community-based management, Elwood (2008) describes the following statement from a community organizer describing their experience:

> "I don't know very much about what is happening in [our GIS lab], because when I came to work here, they told me nobody was allowed to touch those computers except for you and Juan. And besides, I don't know much about computers or maps anyhow." (p. 197)

This is exactly the type of problem that arises when PGIS systems are designed without carefully considering who will be using them and any limitations they may face. Elwood argues that improvement and advancement of PGIS systems will require identification of "key moments of inclusion and exclusion in the everyday negotiations of the research project" in order to develop appropriate and effective PGIS systems (p. 206).

Indigenous Knowledge

One notable application of PGIS frameworks is to incorporate traditional and indigenous knowledge into GIS systems. It was the norm for much of the twentieth century that researchers, academics, and professionals were the ones who would ask the question, design the research methodology, and interpret and share results. But starting around 2005-2010, we start to see efforts to expand the knowledge base by acknowledging the value of traditional and indigenous knowledge, specifically when it comes to environmental issues (Bishop, Oliver, & Aporta, 2021; Dunn, 2007; Eisner et al., 2012; Tripathi & Bhattara, 2017). Local and native communities are exceptionally qualified to understand their own unique geographical and ecological circumstances and possess a set of highly specialized knowledge, insight, and skills that pertain to their location and environment. GIS frameworks that supplement this knowledge with more recently developed technologies and forms of data collection show great promise as tools for tackling contemporary environmental issues.

One example of development of PGIS system which successfully incorporates indigenous knowledge can be seen in Eisner et al., 2012. This paper describes results of a five-year project where researchers collaborated with indigenous communities in Alaska to build a web-based GIS portal where members of the indigenous community, as well as the broader scientific community, could access user-friendly features like discussion boards, interviews, photos and videos, and interactive maps as a way to share indigenous knowledge and contemporary research. This project was successful largely because the indigenous community was involved throughout the entire process and thus the end result was an appropriate and useful web GIS system. But as with any technology, PGIS can suffer pitfalls when the technology is assumed to be appropriate and useful without careful consideration of the context in which it will be used. One important point when it comes to incorporation of indigenous knowledge into PGIS systems is that it is the participatory process itself, not the technology, that is truly invaluable. In other words, "the technology should not override the participatory process, rather it should complement it; else it can result in disempowerment of the local community" (Tripathi & Bhattarya, 2004, p. 9).

Qualitative GIS

Qualitative GIS is the name given to a methodological approach which attempts to leverage traditionally quantitative GIS systems for analyses of qualitative data. As mentioned in the previous section, there exists a wealth of knowledge and information in formats that are not traditionally considered to be "data." Qualitative GIS attempts to integrate data in the forms of verbal stories and histories, interviews, photographs, drawings, and the like into GIS systems in a way that allows them to be visualized and analyzed. Integration of diverse data types allows analyses from a wider variety of socio-political, historical, feminist, and other perspectives not traditionally considered within GIS frameworks (Bagheri 2014; Garnett & Kanaroglou, 2015; Muenchow & Kruher, 2019; Shay et al., 2016).

Qualitative GIS is especially promising in fields like critical physical geography which incorporate perspectives from social sciences into traditionally physical science areas. One example of this can be seen in the study by Bagheri (2014) in which qualitative data and feminist ideology is used as a lens to explore the "sociospatial behavior" of Iranian women in Tehran's public spaces. In this study, Bagheri draws on her primary research (mainly fieldwork) studying women in Tehran and much of her data is in qualitative format like interviews, photographs, and sketches. These qualitative data were linked to geographic data about the location and preference of women to occupy or travel through particular spaces. Through this analysis, Bagheri explores differences in the way we think about Western versus non-Western urban areas and identifies two main limitations in applying GIS methodologies to qualitative data: first, the potential data exclusion in "transforming rich, complex ethnographic data to GIS summaries, codes, and symbols," and second, scale incompatibility among multiple layers of GIS data (p. 175). Despite these limitations, this study provides an excellent example of the ways in which qualitative GIS can allow for further application of GIS beyond traditional realms and ways in which underrepresented voices and communities can be better understood.

Conclusion

The GIS field is evolving to include more FOSS/Open GIS systems and this trend will continue. Proprietary technologies will likely remain relevant for institutional/private sector use, but addressing complex environmental and social issues will require more flexible and accessible platforms which can only be provided by FOSS/Open GIS. In working towards sustainable development, proposed solutions must be ecologically viable, socially acceptable, and economically feasible. FOSS/Open GIS and PGIS provide frameworks in which historically excluded voices and perspectives can join these conversations and the decision-making process can be enriched by incorporation of diverse forms of qualitative data, which is critical in building resilient communities capable of working collaboratively to address contemporary environmental issues.

References

Bagheri, N. (2014). What qualitative GIS maps tell and don't tell: Insights from mapping women in Tehran's public spaces. *Journal of Cultural Geography, 31(4),* 166-178. https://doi-org.aurarialibrary.idm.oclc.org/10.1080/08873631.2014.906848

Bishop. B., Oliver, E. C., & Aporta, C. (2021). Co-producing maps as boundary objects: Bridging Labrador Inuit knowledge and oceanographic research. *Journal of Cultural Geography.* Advanced online publication. https://doi-org.aurarialibrary.idm.oclc.org/10.1080/08873631.2021.1998992

Dunn, C. E. (2007). Participatory GIS – a people's GIS? *Progress in Human Geography, 31(5),* 616-637. https://doi-org.aurarialibrary.idm.oclc.org/10.1177%2F0309132507081493

Eisner, W. R., Jelacic, J., Cuomo, C. J., Kim, C., Hinkel, K. M., Del Alba, D. (2012). Producing an indigenous knowledge web GIS for Arctic Alaska communities: Challenges, successes, and lessons learned. *Transactions in GIS, 16(1),* 17-37. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/j.1467-9671.2011.01291.x

Elwood, S. (2008). Negotiating knowledge production: The everyday inclusion, exclusions, and contradictions of participatory GIS research. *The Professional Geographer*, *58(2),* 197-208. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/j.1467-9272.2006.00526.x

Garnett, R. & Kanaroglou, P. (2015). Qualitative GIS: An open framework using SpatiaLite and open source GIS. *Transactions in GIS, 20(1),* 144-159. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/tgis.12163

Ghose, R. & Welcenbach, T. (2018). "Power to the people": Contesting urban poverty and power inequities through open GIS. *The Canadian Geographer, 62(1),* 67-80. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/cag.12442

Mekonnen, A. D. & Gorsevski, P. V. (2015). A web-based participatory GIS (PGIS) for offshore wind farm suitability within Lake, Erie, Ohio. *Renewable and Sustainable Energy Reviews, 41,* 162-177. https://doi-org.aurarialibrary.idm.oclc.org/10.1016/j.rser.2014.08.030

McCall, M. K. & Minang, P. A. (2005) Assessing participatory GIS for community-based natural resource management: Claiming community forests in Cameroon. *The Geographical Journal, 171(4),* 340-356. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/j.1475-4959.2005.00173.x

McCall, M. K. (2003). Seeking good governance in participatory-GIS: A Review of processes and governance dimensions in applying GIS to participatory spatial planning. *Habitat International, 27(4),* 549-573. https://doi-org.aurarialibrary.idm.oclc.org/10.1016/S0197-3975(03)00005-5

Moreno-Sanchez, R. Free and Open Source Software for Geospatial Applications (FOSS4G): A mature alternative in the geospatial technologies arena. *Transactions in GIS*, *16(2)*, 81-88. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/j.1467-9671.2012.01314.x

Muenchow, J., Schäfer, S., & Krüher, E. (2019). Reviewing qualitative GIS research – Toward a wider usage of open-source GIS and reproducible research practices. *Geography Compass, 13(6),* 1-17. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/gec3.12441

Sui, D. (2014). Opportunities and impediments for Open GIS. *Transactions in GIS, 18(1),* 1-24. https://doi-org.aurarialibrary.idm.oclc.org/10.1111/tgis.12075

Shay, E., Combs, T. S., Findley, D., Kolosna, C., Madeley, M., & Salvesen, D. (2016). Identifying transportation disadvantage: Mixed-methods analysis combining GIS mapping with qualitative data. *Transport Policy, 48,* 129-138. https://doi-org.aurarialibrary.idm.oclc.org/10.1016/j.tranpol.2016.03.002

Tripathi, N. & Bhattarya, S. (2017). Integrating indigenous knowledge and GIS for participatory natural resource management: State-of-the-Practice. *The Electronic Journal of Information Systems in Developing Countries, 17(1),* 1-13. https://doi-org.aurarialibrary.idm.oclc.org/10.1002/j.1681-4835.2004.tb00112.x