Integrated Science of Movement: How to establish an interdisciplinary collaboration (A position paper)

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Abstract

This position paper presents a "how to" guide to establishing an interdisciplinary collaboration between GIScience and movement ecology, based on my experience. Such collaborations are crucial for establishment of the general discipline for movement analysis, the Integrated Science of Movement, yet are difficult to start and maintain. Other disciplines have more formalised protocols for interdisciplinary work, but GIScience has generally approached this relatively informally. This guide may therefore help GIScientists who are interested in connecting to other disciplines, but do not know how to approach this process and would like to understand better what interdisciplinary work entails. While focusing on movement ecology, this guide is also applicable for branching out to other disciplines.

1. Introduction

In recent years, researchers from various movement related disciplines started realising that concepts, data, problems and solutions in movement analysis are similar everywhere. GIScience has been at the forefront of this initiative, by calling for the establishment of the so-called Integrated Science of Movement (Miller et al. 2019, Demšar et al. 2021), which aims at bringing together the two main branches of movement research: animal movement ecology and human mobility analysis.

One of the main challenges of this process is the need for interdisciplinary collaborations, which bring together scientists studying movement and methodological researchers, who specialise in development of new methods for movement analysis. The benefits of such collaborations are mutual: movement scientists receive solutions to difficult data problems, which may lead to unexpected new insights. Methodology experts find unusual and interesting data problems, which, when solved, can provide a meaningful contribution to another discipline and lead to significant impact. This partnership is, however, not easy, as a meaningful collaboration requires significant effort on both sides and in particular requires initiative taking and a steep learning curve on the side of methodological researchers.

In this position paper I reflect on my experience (as a GIScientist who has been successfully collaborating with colleagues from movement ecology) to define a set of necessary steps for establishing interdisciplinary collaborations. While other methodological disciplines have made attempts to formalise this process (see a well-established protocol in information visualisation for user-centred design studies (Sedlmair et al. 2012)), GIScience has to date approached these collaborations informally. At the same time, as someone who is working across the boundary of two disciplines, over the last years I have often received questions on how this can be done. My perspective may therefore be useful to GIScientists who are looking for new opportunities in movement research. While this position paper is focused on connecting with movement ecology, the same process is applicable to branching out to other disciplines.

2. How to form an interdisciplinary collaboration between GIScience and movement ecology

2.1 Step 1. Learn the language of ecology

As in user-centred design (Sedlmair et al. 2012), the first step is to learn the requirements of your users, which in this case means learning both the language of ecology and how ecology research is conducted. Movement analysis in ecology is similar to human mobility analysis in GIScience and computer science (Demšar et al. 2021), but things are named differently. For example, analysis of human activity spaces is similar to utilisation distributions and home range analysis in ecology. Studying context of movement is done by including co-variates in movement models rather than through semantic annotation (Brum Bastos et al. 2021). The first step in this process is therefore to get acquainted with movement ecology terminology and literature. A good starting point are ecology journals which publish methodological advances (*Movement Ecology*, *Methods in Ecology and Evolution*) and interdisciplinary journals (*Journal of The Royal Society Interface*, *Nature Scientific Reports*, *PloS One*).

2.2 Step 2. Find ecologists who are open to data-inspired collaboration

Not all ecologists are interested in interdisciplinary collaborations. Therefore, to find partners in ecology you need to find those who are open to this possibility and willing to share their expertise and data. I found my collaborators through participating in interdisciplinary networks, such as the EU COST Action MOVE (Demšar et al. 2015), and by giving seminars to ecology groups. Moving activities online during COVID-19 pandemic (and also to some extent already previously, in the interest of open science) has perhaps made finding these scientists easier, either through their presence on social media, through attending relevant online seminars or through engagement with open data initiatives.

Ecology is at the forefront of open science, reproducibility and transparency (Powers and Hampton 2018) and providing data openly is increasingly common. One way to find ecologists who may be interested in methodological solutions is therefore to look at open data portals, such as Movebank.org and contact researchers in this way. In terms of social media, ecology twitter is very active, both in terms of people promoting their work, but also in terms of live-tweeting conferences or even organising twitter-specific conferences. For example, check the World Seabird Twitter conference hashtag #WSTC7 or follow the Movement Ecology Special Interest group of the British Ecological Society @BES_Move_SIG. Finally, one unexpected benefit of the COVID-19 pandemic is that there are now many online seminar series which are open to anyone – for ecological topics you could check Ecology Live series of the BES (https://www.britishecologicalsociety.org/event/ecology-live/).

Once you do find collaborators, it is important to respect their data policies. Even though many ecology data are open, they are not necessarily directly available to you to do whatever you want to do with them. This is reasonable, given the high costs and effort involved in collecting these data. Instead, typically, anyone wanting to collaborate with data collectors must sign a data sharing agreement, which sets out the conditions under which you can use their data. This will normally be co-authorship on any outcomes that use their data, but can also include other limitations, for example, in cases where geoprivacy is an issue (this is relevant even for animals – e.g., for anti-poacher protection of endangered species).

2.3 Step 3. Identify a biological problem which could be solved with a new data-driven approach

In my experience, ecologists are expert (spatial) statisticians and have established methodologies for solving standard data problems (which you already know from step 1,

since you have read all those ecology papers). To initiate a collaboration, it is therefore crucial that you can offer something different, such as an alternative rigorous solution to a biologically relevant, but potentially difficult and unsolved problem.

In my case, I identified a gap in animal migration research for which I saw a potential data science solution: how to study how animals navigate during migration with real contemporaneous environmental and tracking data. I connected over this topic to my collaborators at the Max Planck Institute for Animal Behaviour by taking the initiative to jointly co-organise a workshop on movement analytics (the Lorentz workshop 2017). This lead to a larger joint project on data science for animal navigation, which is currently on-going. As part of this project, my team developed a new tool for data fusion of animal movement data with satellite data on Earth's magnetic field (Benitez Paez et al. 2021), an unusual type of remote sensing data. Remote sensing is increasingly used in ecology, but it is limited to satellite imagery and related products (Pettorelli 2019), while we were able to provide, for the first time, linkage to different and complex satellite data – a problem that required a spatio-temporal data science solution going beyond traditional remote sensing used in ecology.

At this stage it is important that the gap you identified and to which you can imagine a data-driven solution, is biologically meaningful. Recently, there have been many attempts where GIScientists take some popular new method (typically deep learning or some other AI method) and apply it to random online movement data, mostly in human mobility (e.g., taxi trajectories from New York or GeoLife or similar), but sometimes to animal data as well. This is often done without any real understanding of the biological relevance or even a need for using a machine learning or AI. This kind of work is unlikely to lead to a successful collaboration and critically assessing your ideas (Brunsdon and Comber 2020) prior to initiating communication with ecologists is therefore needed. Step 1 is a necessary pre-condition for this stage, as is thinking outside of the mainstream way ("let's throw some machine learning on some random data" is not going to get you anywhere).

2.4 Step 4. Develop your new method

You have a great idea, you have started talking to your new collaborators and they are intrigued by the possibilities you offer, so now it is time to design your new method. Have fun with your experiments! But do talk to your collaborators as you progress and regularly check with them that your results make sense biologically.

2.5 Step 5. Learn traditional statistics

GIScientists are often not trained in traditional statistics. If you want to work with ecologists, however, you will need to know your statistics very well (see next step).

2.6 Step 6. Convince ecologists that your method is a good solution to their biological problem

Ecologists are expert statisticians, and their data analysis and interpretation of results is mostly based on traditional statistics (as you already know from step 1). If you want to convince your new collaborators that your method is useful for a specific biological problem, you will need to do two things. (1) You will need to be able to explain it in ecological language (step 1) and (2) you will need to confirm its validity through statistical analysis of some kind. For example, for our new MagGeo tool, we ran accuracy analysis by statistically modelling the error based on method parameters and geographical locations (Benitez Paez et al. 2021). Further, we linked results of this statistical analysis to biology by showing that our average error of geomagnetic intensity is smaller than the threshold that some animals can sense. In my experience, you really do need rigorous statistics to convince your collaborators

about the usefulness of your new method. The first test if you have succeeded is if your collaborators are excited about your results. The second test is if you are able to publish your method in an ecology journal (where reviewers are often sceptical about alternative methods, such as those coming from another discipline, and your statistics to convince them to the opposite, needs to be rigorous, logical and relevant).

2.7 Step 7. Make your tool easy to use

Running data analysis is not the primary interest of most ecologists. Instead, what they enjoy doing is to catch and tag sometimes dangerous animals, from eagles to sharks. If you therefore want your method to be used, you need to provide a tool that will be easy to use as well as accessible (Free and Open Source Software is a given expectation these days). Most ecologists use R for movement analysis – a recent review found 58 R packages for analysis of animal movement (Joo et al. 2019). Writing your tool as an R package, preferably compatible with other packages already in use (e.g. *move* package for Movebank.org data, Kranstauber et al. 2020) is therefore your best bet to having your methods disseminated to a wider community. This does not preclude you from using Python, as the more common language in human mobility (Graser 2019), but if you do, the advice is to package your tool as something easy to use for non-data-experts who are not familiar with Python (for example, our MagGeo tool is implemented as a Jupyter Notebook, Benitez Paez et al. 2021).

3. Conclusions

New developments in tracking technologies are bringing exciting new challenges. In ecology, miniaturisation of sensors and new satellite tracking systems with small tags (e.g., ICARUS), are starting to allow tracking of new small species. This will expand the field of potential opportunities and collaborators immensely, since most animal species are small (for example, songbirds are one of the largest groups of migratory birds, yet we still know very little about their movements, as it was almost impossible to track them until now). There are also new sensors that allow real-time monitoring of physiological state of the individual (Hawkes et al. 2021) or environmental conditions around the individual (Williams et al. 2020). Environment can also be studied with increasingly open and available data from remote sensing and other sources. Taking a data-driven approach to movement ecology therefore invariably means that multi-source complex data sets need to be linked across space and time and analysed jointly, with new methods developed for this purpose. GIScientists are well-placed to address these issues through our focus on space, time, scale, autocorrelation, and other characteristics of geographical data. Taking the steps outlined in this paper to connect to ecologists can therefore help us find a way to contribute to upcoming discoveries in animal movement research.

Further, while this position paper focused on one particular discipline (since this is where my experience comes from), a similar set of steps would be required to work with any other disciplines. For example, recently we have seen many attempts of methodological researchers linking with public health researchers to work on COVID-19 related modelling, often using data on human mobility and some kind of machine learning or AI methods. Again, groundwork through steps as presented here is important there as well, otherwise this can lead to unreliable results and useless methods (see e.g. Roberts et al. 2021).

Finally, while establishing an interdisciplinary collaboration requires a lot of effort, it is also inherently rewarding when your new methods are being used for real exploration. Helping to discover something noone in the world has ever seen or known before is an immense thrill and it is hugely satisfying to know that through collaborating outside of GIScience disciplinary silo, you are contributing to increase the knowledge about the natural world.

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