Optimizing automated radio tracking methods for high-throughput wildlife tracking

We have developed a new method and workflow for localizing radio tags in modern automated radio tracking systems (for details see [2]). Radio tracking is one of the oldest methods for tracking animals in the wild. While this method originally involved manually tracking tagged individuals using a small number of mobile receivers, modern radio tracking methods typically employ many automated receivers that continuously detect radio tags. Typically, these receivers detect the signal strength of a tag, which can be used to estimate the distance from the receiver to the tag. Conventional analytical methods to locate the position of the tagged animal, however, are not optimized to make full use of the information provided by modern automated radio tracking systems in which many receivers may simultaneously detect a tag.

Radio fingerprinting, a method commonly used for indoor positioning applications, is an alternative localization method that can use information from the large number of receivers within automated radio tracking systems. We conducted a large-scale field test of radio fingerprinting as a localization method for wildlife tracking and compared the results to the traditional localization method, multilateration. We show that while both methods yield similar localization accuracy under ideal circumstances, radio fingerprinting is more robust to a variety of situations that commonly occur in real-world tracking studies, such as missed detections and equipment failure (Output 1). We have created a template analytical workflow that is available for others interested in applying this localization method (Output 2).

In some cases, however, radio fingerprinting as localization method may be impractical to implement. In this case, multilateration can still provide valuable information, but ideally this method should account for the large location estimate errors that can occur due to the uncertainty in the relationship between signal strength and distance. Using a process of 'repeated multilateration' in which the relationship between signal strength and distance is estimated with uncertainty, we have developed a method to derive error ellipses around estimated locations. We have used this method to document space use and social interactions in free-living zebra finches (Output 3).

Tracking devices

Automated radio tracking systems

These tracking systems consist of a grid of autonomous receivers that detect radio tags and record some aspect of the tag's signal, such as strength or arrival time. Combining information from multiple receivers in the grid allows for the location of the tag to be estimated.

We used receivers (also called nodes) with an omni-directional whip antenna that records the received signal strength (decibels) of 434MHz radio tags. Receivers include an on-board GPS unit to maintain time synchronization with other receivers in the grid. Receivers are powered by lithium-ion batteries that are charged through an integrated solar panel which is coupled with an MPPT charge controller. Detections are transmitted to a central sensor station. The sensor station has four 430-440 MHz 10 element yagi beam antennas which can detect the nodes within a range of 2 km. More details about the system can be found at this link.

We used two types of 434MHz radio tags, LifeTags (0.45 g, solar only) and HybridTags (1.2 g, solar and battery). All tags have a 10 cm nylon-coated braided stainless-steel antenna. When sufficiently powered, tags signal every 5 seconds. Tags can be detected by the nodes within a range of approximately 300 m and by the sensor station within a range of several kilometres with line-of-sight.

Optimizing automated wildlife tracking methods

Raw data files generated by the automated radio tracking system consist of compressed comma-separated values tables with columns for date-time, tag identification code, receiver identification code, and received signal strength. Radio fingerprint localization makes use of this raw data in a two-step process.

The first step is the generation of the radio map, which consists of radio fingerprints at known locations throughout the receiver grid. These radio fingerprints are generated by placing tags at calibration points throughout the grid to characterize how the receivers detect the tag at known locations. Given features of the environment, such as distance to each receiver and sources of interference (vegetation, elevation, etc.), tags will be detected differently by each receiver within the grid. Once raw calibration data is collected, this data is processed to create a unique radio fingerprint at each calibration point. This radio fingerprint describes the mean signal strength of all tag detections registered by each receiver in the network and each calibration point has a unique radio fingerprint. Together, the collection of radio fingerprints constitutes the radio map.

In the second step, the radio map is used to predict the location of new radio fingerprints from a tagged animal. In this step, the detections from a tag are averaged within a discrete interval (e.g., a 5 second window) to create a radio fingerprint which describes how the tag is detected by each receiver within the grid. A machine learning classification algorithm (such as K-nearest neighbors or random forests) is then used to classify which radio fingerprint in the radio map most closely matches the new radio fingerprint in order to estimate the location of the tag. Ultimately, this process yields a location estimate for each tag at intervals corresponding to the window used to calculate the radio fingerprint.

Locations of scripts

https://github.com/cwtyson/radio_fingerprinting: Public repository with a template workflow to generate a radio map from calibration data and use radio fingerprint localization to estimate radio tag positions.

Lessons learned

- Traditional analytical methods to locate radio tags are not optimized for modern automated radio tracking systems. As such, even though technological advances have progressed rapidly in recent years, it remains a challenge to fully utilize these systems.
- The field of indoor positioning offers a variety of localization methods that are directly applicable to the localization challenge of wildlife tracking using automated radio tracking systems. The field of indoor positioning, however, is vast and is rapidly developing to incorporate advances in sensor technologies and machine learning. Incorporating these current practices benefits from working with a specialist in the field.
- There is often a disconnect between the manufacturers of products (such as wildlife tracking devices) and the users. As such, manufacturers may not appreciate how their products will perform in a real-world application. We experienced many surprising issues related to equipment failure, such as tag antennas breaking and receivers partially relaying detections, which complicated data collection.

Relatedly, the manufacturers of wildlife tracking devices typically have limited experience with the analysis of the data generated by their tools and do not provide workflows to even translate the raw data into something that is meaningful for the end user. Consequently, developing workflows and analytical methods is highly valued by the wildlife tracking community.

List of people involved and their role

Name	**Email address**	**Role in project**
Chris Tyson	chris.tyson@wur.nl	Researcher in Behavioural Ecology. Animal tracking and avian ecology expertise. Project lead.
Bruce Yu	bruce.yu@wur.nl	Postdoctoral researcher in Experimental Zoology. Animal tracking and machine learning expertise.
Marc Naguib	marc.naguib@wur.nl	Professor, Chair Holder in Behavioural Ecology. Animal tracking and avian ecology expertise.
Hugo Loning	hugo.loning@wur.nl	Postdoctoral researcher in Behavioural Ecology. Avian ecology expertise.

Output

Scientific output:

Thyson, C., R. Fragueira, E. Sansano-Sansano, H. Yu, and M. Naguib. 2024. Fingerprint localisation for fine-scale wildlife tracking using automated radio telemetry: https://doi.org/10.1101/2024.02.15.580447

Thyson, C., H. Loning, S.C. Griffith, M. Naguib. 2024. Constant companions: Wild zebra finch pairs display extreme spatial cohesion. BioRxiv. https://doi.org/10.1101/2024.03.21.586046

Presentations:

C. Tyson, S. Griffith, and M. Naguib. 2023. Zebra finch pairs display extreme spatial cohesion. Netherlands Society for Behavioural Biology. Egmond aan Zee, Netherlands. November 21-23. (oral presentation)

C. Tyson, S. Griffith, and M. Naguib. 2023. Zebra finch pairs display extreme spatial cohesion. Animal Behaviour Society. Portland, Oregon, USA. July 13-16. (oral presentation)

C. Tyson, R. Fragueria, S. Kingma, and M. Naguib. 2022. Optimizing location estimates using automated radio tracking systems. European Conference on Behavioural Biology. Groningen, Netherlands. July 20-23. (poster)

Popular press:

WUR Data Science / Artificial Intelligence coverage: https://www.youtube.com/watch?v=-GRehsGG6zY&list=PLpHeQy15q-08fbRHW6tnvpGr88e7Mt6YL&index=3