Introduction

Johannes Signer & Brian Smith

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Welcome!

- Welcome to this online course on animal movement.
- We are Brian and Johannes.
- Who are you? *Pair up and introduce your partner*
- Ask your partner:
  - What is your background?
  - Where do you come from?
  - Where do you study/work?
  - What is your study organism?
  - Why do you attend this course?

Outline of the course

Day 1:

- Introduction and exploratory data analysis for movement data (J)
- Data cleaning (B)

Day 2:

- Quantifying space use of animals with home ranges (B)
- Multiple instances (J)

Day 3:

- Introduction to habitat selection (B)
- Integrated step selection functions 1 (J)

Day 4:

- Integrated step selection functions 2 (B)
- Simulations from fitted iSSF (J)

Day 5:

- Advanced (i)SSF topics (J)
- Validation of models for habitat selection (B)
- Time to discuss questions related to **your** projects.

Some logistics

- The course is scheduled from Monday (22nd of January) to Friday (26th of January) from 2pm to 6pm Berlin time.
- We split these 4h block into two chunks, each roughly structured like this:
    - Lecture $\sim$ 45 min
    - R walkthrough $\sim$ 45 min
    - Introduction of exercises $\sim$ 5 min
- A 20 min break between the two chunks.
- Lectures will be held via zoom.
- During the whole workshop we have a slack channel where you ask questions (we will monitor the channel during the course, feel free to ask questions there also outside the course hours).

Analysis of movement data in R

- The statistical software package R has become a widely used tool for data analysis in ecology and evolution and also in movement ecology.
- Also visit R task view for tracking data: https://cran.r-project.org/web/views/Tracking.html

- A typical analysis usually undergoes a few steps (all of which can be performed in R), this was reviewed by Joo et al. 2020.

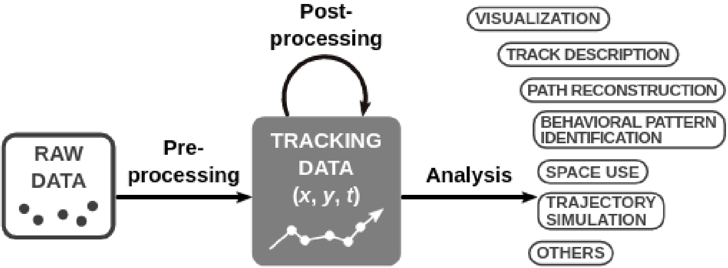

Figure 1: Figure from Joo et al 2020

Packages that we will use

- We will mainly use the `amt` package, but also occasionally other packages for movement analysis.
- See also `required_packages.R` for a list of all packages that we need and to get the latest version of all packages.

Some conventions in R

- `%>%` or `|>`: Pipes the output of one function to a next function. We will discuss this further later on.
- `::` to access a name space form a package.
- use of ‘a‘.
- `.` means this directory
- `..` refers to the parent directory
- `data.frame` or `tibble`?

- We often use `here::here("path to a file")`, when reading in a file.
- The first `here` calls the function `here()` from the package `here`.
- The function `here()` dynamically creates the absolute path to the project root.

```
here::here()
```

```
[1] "/Users/jsigner/git/movement_workshop"
```

This means, that we save all our data in the root directory data (even though my scripts are in different sub directories).

Brackets ((, [, {)

- round brackets or parentheses (() usually indicate functions or are used in arithmetic calculations.

```
sqrt(3)
```

```
[1] 1.732051
```

or

```
2 * (3 + 1)
```

```
[1] 8
```

- square brackets (`[`, `[[`) are used to subset data structures.

```
letters[1:3]
```

```
[1] "a" "b" "c"
```

or

```
head(iris[["Species"]])
```

```
[1] setosa setosa setosa setosa setosa setosa
Levels: setosa versicolor virginica
```

- curly brackets or braces ({) are used to form code blocks (e.g., inside a function or control structure).

```r
for (i in 1:10) {
  i^2
}
```

Functions

- Functions *do* something. For example function `sqrt()` takes the square root for a number.
- It is easy to recognize functions, because they usually have a name (e.g., `sqrt`) followed by round brackets `()`.
- Within these round brackets arguments are passed to a function. This arguments can be named or unnamed (as long as they are in the correct order).

Recommended setup

- We would recommend to download the whole repository from GitHub (`https://github.com/jmsigner/movement_workshop_winter_2024`)[1].
- Then use the RStudio project (together with RStudio).
- Following these guides, you should have all paths correct.

[1] If you are familiar with git, feel free to clone the repository

Geographic data in brief

- Movement data is inherently spatial.
- Thus we will have to deal with tools to work with spatial data (R has a rich set of tools to deal with spatial data; e.g. https://geocompr.robinlovelace.net/).
- We will work frequently with raster data (spatial covariates) and possibly with vector data (i.e., home ranges).
- One of the challenges is to ensure that both – tracking data and covariates – have a matching coordinate reference system (CRS).

- The CRS defines the reference system that is being used to explicitly reference a feature in space.
- There are two classes of CRS: **geographic** (e.g., WGS84) and **projected** (e.g., UTM) CRS.
- Projected CRS flatten the three dimensional data to the a two-dimensional plane (and introduce some distortion).

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- EPSG codes are four to five digits number that refer to different CRS. See for example www.epsg.io.
- Which CRS is best to use? It depends on the range of the study species. I usually prefer projected CRS, because their units are meters and not degrees.

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Take-home messages 1

1. Do not get confused by `::`, this is just explicitly calls a function from a package.
2. Consider using RStudio projects to have everything in one place.

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1. Do not get confused by `::`, this is just explicitly calls a function from a package.
2. Consider using RStudio projects to have everything in one place.
3. Coordinate reference system (CRS) are used to describe where our animals are.
4. EPSG-Codes can be used to refer to CRS.

Movement data

- Often times the data we receive is just a time series of coordinates (longitude, latitude and time stamp).
- Depending on the sensors we use, other (meta) information may also be stored (this could include temperature, coordinates in a different [projected] CRS, . . .).

```
No;CollarID;UTC_Date;UTC_Time;LMT_Date;LMT_Time;Origin;SCTS_Date;SCTS_Time;ECEF_X [m];ECEF_Y [m];ECEF_Z
13563;9977;30.03.2020;10:01:01;30.03.2020;10:01:01;Collar;11.05.2021;09:15:07;4040415;851181;4845535;49,
13562;9977;30.03.2020;09:01:06;30.03.2020;09:01:06;Collar;11.05.2021;09:15:07;4040398;851190;4845551;49,
13561;9977;30.03.2020;08:02:12;30.03.2020;08:02:12;Collar;11.05.2021;09:15:07;4040451;851194;4845498;49,
13560;9977;30.03.2020;07:01:18;30.03.2020;07:01:18;Collar;11.05.2021;09:15:07;4040383;851193;4845554;49,
13559;9977;30.03.2020;06:01:56;30.03.2020;06:01:56;Collar;11.05.2021;09:15:07;4040403;851166;4845550;49,
13558;9977;30.03.2020;05:01:04;30.03.2020;05:01:04;Collar;11.05.2021;09:15:07;4040452;851209;4845535;49,
13557;9977;30.03.2020;04:00:31;30.03.2020;04:00:31;Collar;11.05.2021;09:15:07;4040388;851194;4845495;49,
13556;9977;30.03.2020;03:01:09;30.03.2020;03:01:09;Collar;11.05.2021;09:15:07;4040401;851191;4845489;49,
13555;9977;30.03.2020;02:01:04;30.03.2020;02:01:04;Collar;11.05.2021;09:15:07;4040394;851198;4845524;49,
13554;9977;30.03.2020;01:01:07;30.03.2020;01:01:07;Collar;11.05.2021;09:15:07;4040417;851185;4845543;49,
13553;9977;30.03.2020;00:01:07;30.03.2020;00:01:07;Collar;11.05.2021;09:15:07;4040472;851176;4845521;49,
```

Environmental covariates

- Vector layers (e.g., road networks, rivers, protected areas)
- Raster layers (e.g., land use, remotely sensed data such as NDVI, climatic variables)

Tracks and bursts: the basic building block

- For movement data, we usually read a text file into R (`.csv`, `.txt`, `...`) as a data frame and then create a analysis-specific object.
- When working with the `amt` package the function `make_track()` takes a sequence of coordinates (with or without timestamps) and creates a track. Note, at this point multiple individuals can be mixed and sampling rates can be heterogeneous.

- **Bursts** can be created from tracks.
- A burst is a sequence of (re)locations from the **same** individual at **equal** time intervals (with some tolerance).
- Options to change from tracks to bursts are:
    1. Use the function `amt::track_resample()`.

Sampling rates, and resampling

- The function `summarize_sampling_rate()` takes an track as input and gives a summary of the sampling rate.
- If there are multiple animals present, there is also the function `summarize_sampling_rate_many()`, which will do the same thing, but for many animals.

- Once a suitable sampling rate is determined, the function `track_resample()` can be used to take a relocation every predefined time interval (e.g., 30 minutes, 2 hours, . . .) within a tolerance.
- The result of `track_resample()` is again a track with one additional column called `burst_`.

Take-home messages

- Movement data are often 'just' text files.
- The `amt` package uses tracks as the basic building block.
- A burst is a track (or a part of a track) with a regular sampling rate.
- Use `track_resample()` create tracks with equal sampling rates.

If you have gaps and/or different sampling rates, interpolation with continuous time movement models may be an option.

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APPLICATION | Open Access

aniMotum, an R package for animal movement data: Rapid quality control, behavioural estimation and simulation

Ian D. Jonsen, W. James Grecian, Lachlan Phillips, Gemma Carroll, Clive McMahon, Robert G. Harcourt, Mark A. Hindell, Toby A. Patterson

First published: 26 January 2023 | https://doi.org/10.1111/2041-210X.14060

Handling Editor Edward Codling

Movement characteristics (`sl_`, `ta_`)

Tracks are still *just* the points as they were collected. If we want to get insights, we have can look at different characteristics of steps (i.e., two consecutive relocations).
This include:

- step length
- turn angle
- speed
- Net squared displacement

Note, unless you take care of different instances or bursts, they are ignored.

Net Squared displacement (NSD)

- The NSD is the squared distance between the first relocation of a track and the every relocation that follows.
- Bunnefeld et al. 2011 described different forms of the NSD that resemble different migratory behaviors.
- The different models can fit to the data (e.g., using nonlinear least square with the function `nls()` in R).

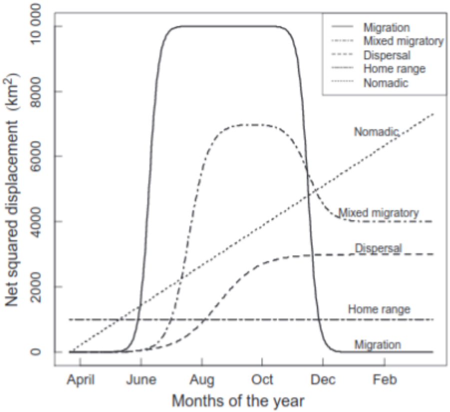


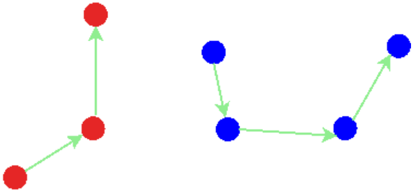
Figure 2: Figure taken from Bunnefeld et al. 2011

Time of the day

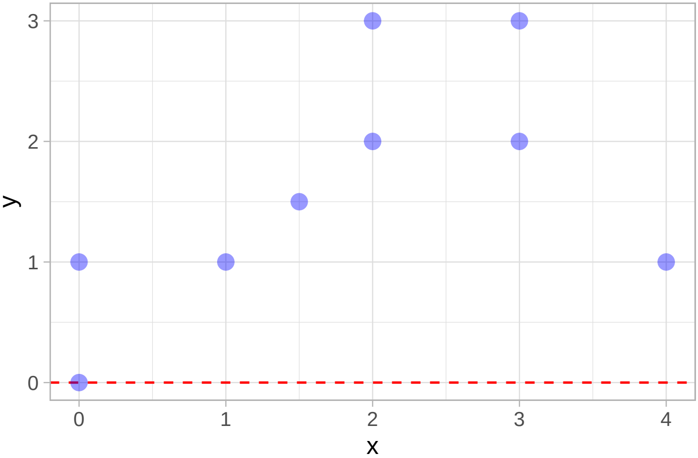
- Time of day can be annotated to steps with the function `amt::time_of_day()`. This will add an additional column to the data frame of steps `tod_end` or `tod_start` depending on the argument `when`.
- If the data is of sufficient temporal resolution, it is also possible to annotate twilight (dawn and dusk).

Steps

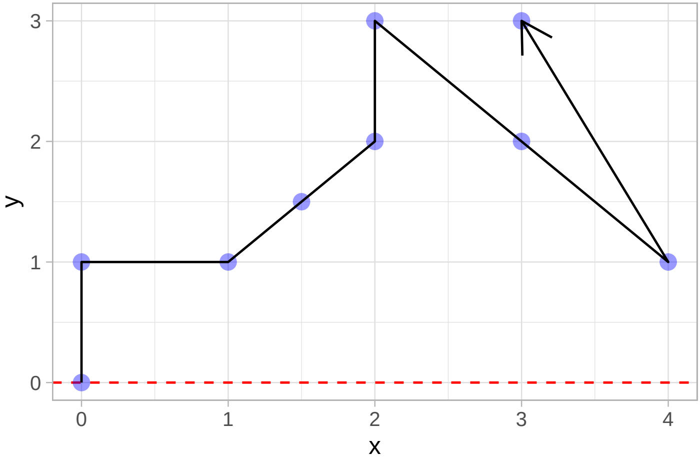
We can start to create a `steps`-representation.



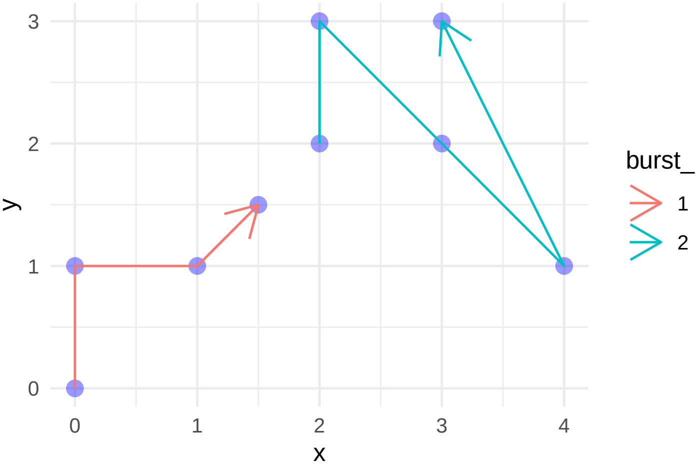
This can be achieved with the function `amt::steps()`. If we resampled the data previously, we can even use `amt::steps_by_burst()`.



3
2
1
0
y
0
1
2
3
4
x



3
2
1
0
y
0
1
2
3
4
x



3
2
1
0
y
0
1
2
3
4
x
burst_
1
2

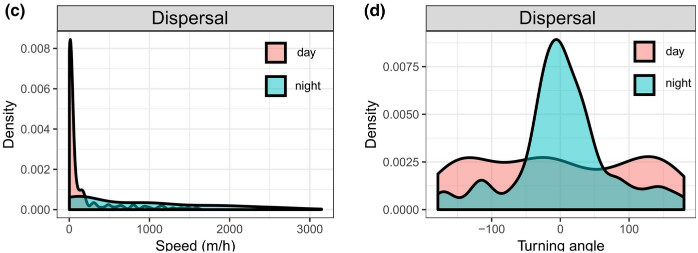
This automatically calculates several step attributes:

- Start and end point
- Step length
- Absolute and relative turn angles
- Duration

This allows already calculate some step characteristics. It becomes even more informative, if we pair this for example with the whether a step was in the night, day or twilight.

Example

Remington Moll observed a (rare) long distance dispersal for White Tail deer[3] and looked at the turn angle and step distribution for day and night.



[3] Moll et. al Ecology and Evolution; https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.7354.

Take-home message

1. Movement characteristics (e.g., step length or turn angle) are fundamental to many analyses in discrete time.
2. We often compare movement characteristics for different times of day.
3. The Net Squared Displacement (NSD) can be used to infer different migratory modes.

Data sets that we use

- We will use several data sets during this course including a data set on fishers, elephants and deer.
- Feel free to use your own data during the exercises, we are happy to help to get it into shape.
- For the R walkthrough we often simulate data. We believe if understand how data is generated it is much easier to understand how a specific method works.

Key resources/publications

Movement ecology

- Bunnefeld, N., Börger, L., van Moorter, B., Rolandsen, C. M., Dettki, H., Solberg, E. J., & Ericsson, G. (2011). A model-driven approach to quantify migration patterns: individual, regional and yearly differences. Journal of Animal Ecology, 80(2), 466-476.
- Bjorneraas et al. 2010: Screening Global Positioning System Location Data for Errors Using Animal Movement Characteristics. https://doi.org/10.1111/j.1937-2817.2010.tb01258.x
- Joo, R., Boone, M. E., Clay, T. A., Patrick, S. C., Clusella-Trullas, S., & Basille, M. (2020). Navigating through the R packages for movement. Journal of Animal Ecology, 89(1), 248-267.

R resource

- Lovlace, R. et al. (2019). Geocomputation with R: https://geocompr.robinlovelace.net/.
- Wickham, H. R for data science: https://r4ds.had.co.nz/