Continuous Time Movement Models

Brownian Motion

About Brownian Motion

- Simple, random movement (diffusion)
- Parameters/Assumptions:
  - Does not feature continuous velocity nor a finite ranging area

When you would use it/not use it?

Appropriate for:

Coarsely/briefly sampled data:

- Too coarse to reveal velocity autocorrelation
- Too brief to show range residency

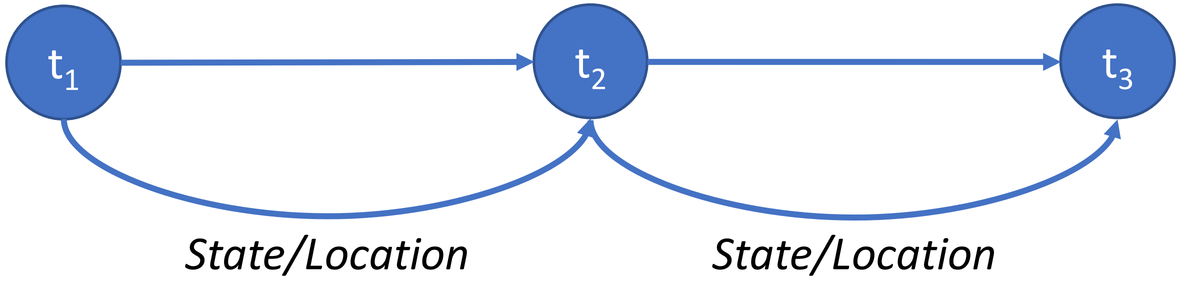
Not appropriate for:

Home ranges, as it is an endlessly diffusing process (perhaps better as an occurrence estimator – see Noonan et al. 2019)

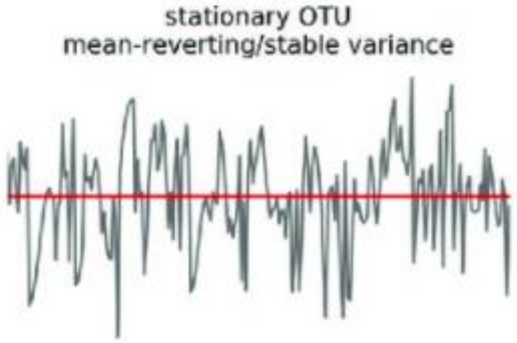
Ornstein-Uhlenbec (OU) Movement Model

(Uhlenbeck and Ornstein 1930)

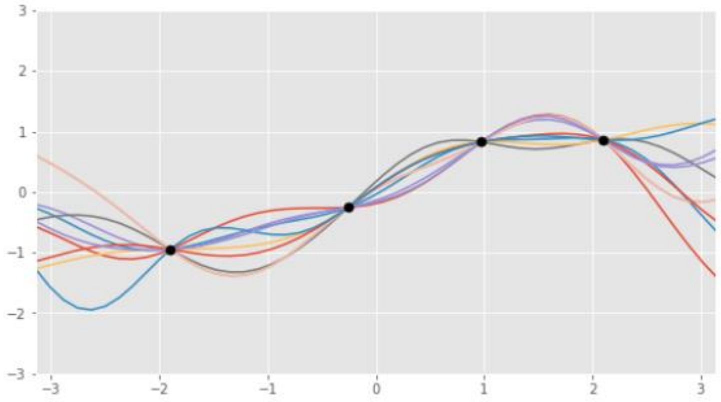
1. Markov process in continuous time with state given by the location of the animal

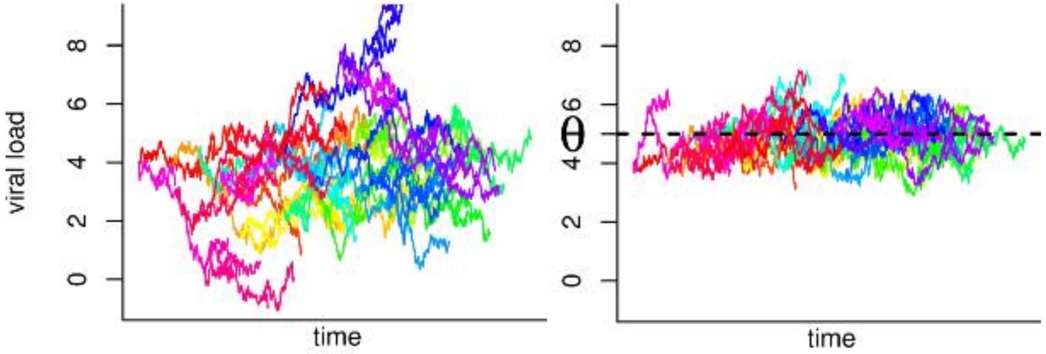


2. Process is stationary

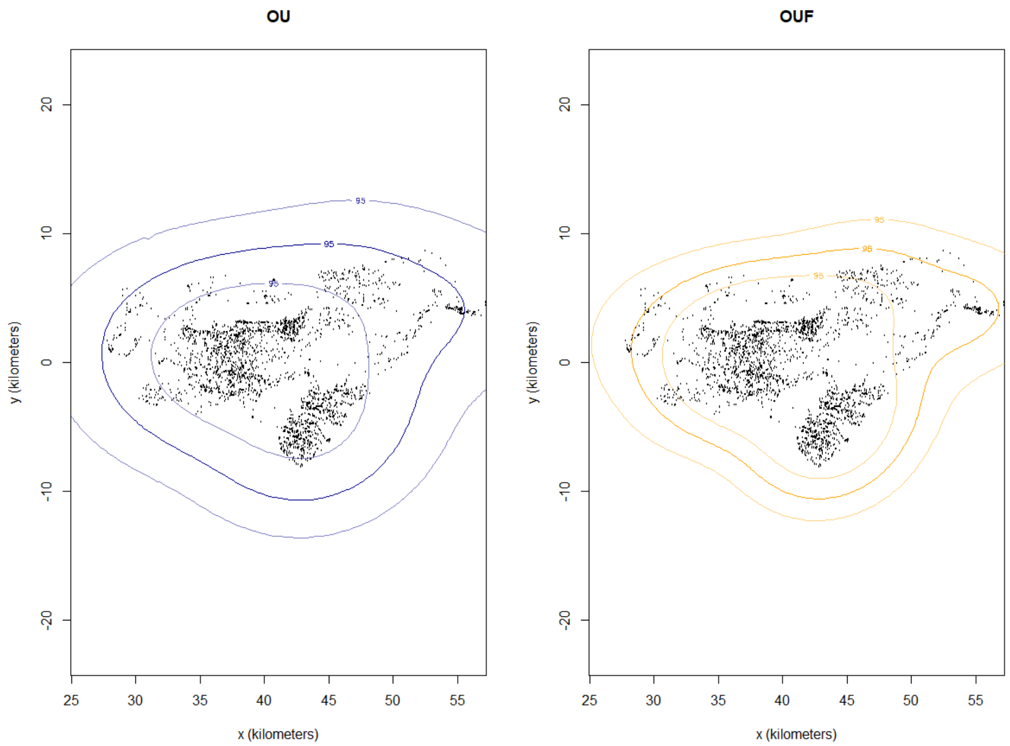


3. Process is Gaussian





	ΔAICc	ΔRMSPE (km)	DOF[area]
OUF anisotropic	0.0000	1.776673	18.135939
OUF isotropic	67.7508	1.912067	17.912922
OU anisotropic	1565.2907	2.203374	8.231783
OUf anisotropic	1863.8799	0.000000	345.919726



Combines Brownian motion with a tendency to drift to a central point/location(drag)

The OU process (Gardiner 2009) describes a random search within a defined area that grows more-and-more slowly in time and asymptotes to a finite value.

Movement Model	Pos. AC	Vel. AC	H. Range	Parameterization
Ind. Ident. Distr. (IID)	No	No	Yes	τ = NULL
Brownian Motion (BM)	Yes	No	No	$\tau = \infty$
Ornstein–Uhlenbeck (OU)	Yes	No	Yes	$\tau = \tau_r$
Integrated OU (IOU)	Yes	Yes	No	$\tau = \{\infty, \tau_v\}$
Ornstein-Uhlenbeck F (OUF)	Yes	Yes	Yes	$\tau = \{\tau_r, \tau_v\}$

Takes into account Markovian (positional) autocorrelation, but not velocity autocorrelation

Can be used for home range analysis

Can’t be used to estimate speeds or distances.

Appropriate for data that show restricted space use, but there is not directional persistence

35% of studies can be modelled using this movement model (Noonan et al. 2019).

https://www.youtube.com/watch?v=5S45TD4bnp8

INTEGRATED ORNSTEIN–UHLENBECK MOVEMENT MODEL

César Herrera

WHAT IS INTEGRATED ORNSTEIN–UHLENBECK (IOU)?

A case of Ornsteain-Uhlenbeck model (Uhlenbeck & Ornstein 1930, Physical Review)

- It is unbounded, so it diffuses
- Diffusion velocities are auto-correlated at short scales, and are continuous

Continuous-time movement model

- data can be non-uniformly sampled
  - it does not require interpolation or sub-sampling for achieving regularly space time locations.

Structured by a hidden Markov model:

- stochastic
  - uncorrelated random process independent from previous conditions, only depends on current state

Parameterization often assumes a Gaussian process

- stochastic process for velocity in the movement dimension (v_x, v_y, v_z)

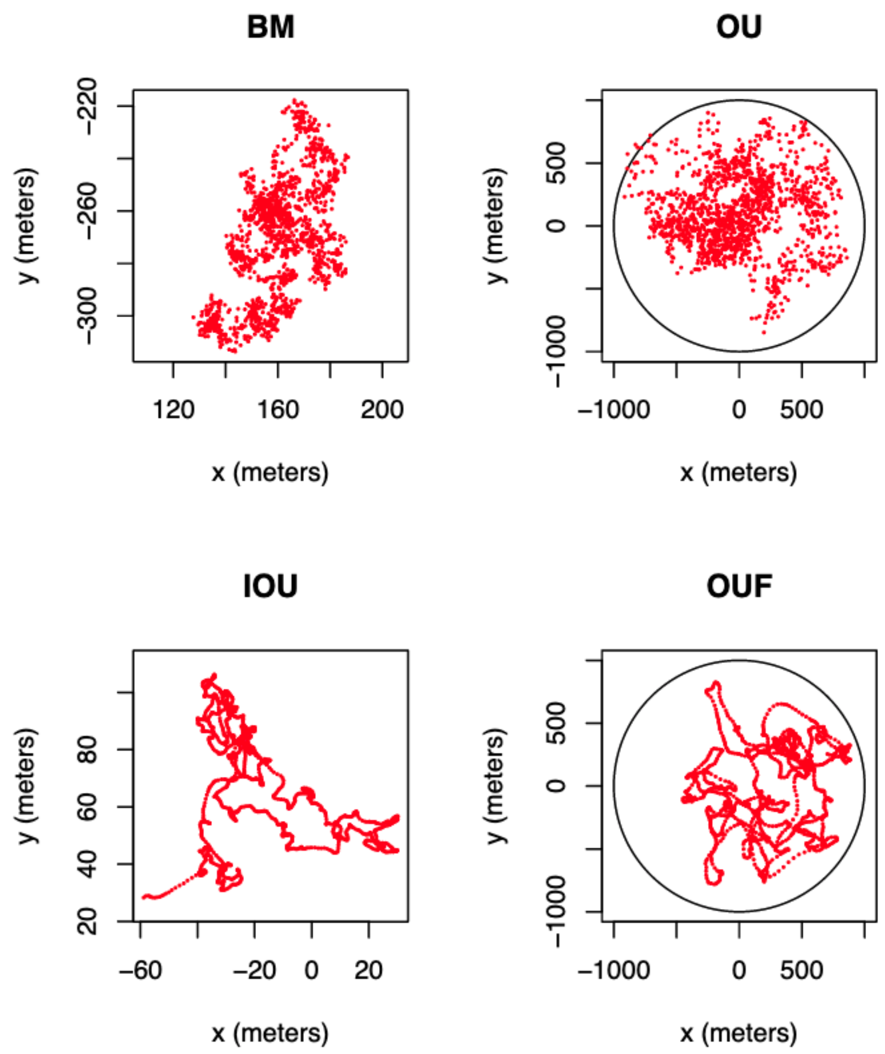
WHEN TO USE INTEGRATED ORNSTEIN–UHLENBECK (IOU)?

As it features diffusion, it is appropriate for individuals showing directional movement.

However, as diffusion is not bounded, it should not be used for datasets that show a residency pattern.

It must not be used for calculating home ranges (i.e. kernel densities).

As this model assumes continues velocities is good for high frequency data (i.e. high time resolution).



WHAT ARE THE ASSUMPTIONS OF THE INTEGRATED ORNSTEIN–UHLENBECK (IOU)?

It assumes position autocorrelation, but it does not feature a home range.

- Position autocorrelation continues for infinity time.
    - This mean, it assumes a “home range” with infinitely large area; and
    - infinitely long home-range crossing time

It assumes velocity autocorrelation.

Assumes Markovian dynamics if telemetry errors are absence or negligible.

It cannot be directly compared to range resident models, e.g. ctmm package comparison between IOU and range resident models is done by restricting IOU models as a case of OUF models for a specific state.

Ornstein-Uhlenbeck with foraging (OUF)

Basic concept:

- Adds a third parameter to OU models to account for foraging behavior
- Thus, it includes correlated positions (like OU) *and* correlated velocities

Advantages:

- Incorporates another component of animal behavior, thus improving model accuracy
- Deals well with lags in movement that are cause by animals foraging in one area for a long period
- Can be used to identify foraging behaviors within a movement data set

Key paper:

- Fleming et al. 2014. From Fine-Scale Foraging to Home Ranges: A Semivariance Approach to Identifying Movement Modes across Spatiotemporal Scales. American Naturalist 183: 154-167.