Metrics for describing dyadic joint movement

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Introduction

- How to assess joint movement in tracking data?
- Start simple: dyadic movement

Fishing vessels
(unpublished)

African lions
(Benhamou et al 2014)
Metrics

From animal ecology, sports, medicine, physics, psychology, music, etc.:

- **Prox**: proximity index (Bertrand et al. 1996)
- **Cs**: coefficient of sociality (Kenward et al. 1993)
- **HAI**: half-weight association index (Brotherton et al. 1997)
- **Lixn**: coefficient of interaction (Minta 1992)
- **jPPA**: joint potential path area (Long et al. 2015)
- **CSEM**: cross sampled entropy (Richard and Moorman 2000)
- **r**: correlation
- **$DI_d$, $DI_\theta$, $DI$**: dynamic interaction indices (Long and Nelson 2013)
Prox: proximity index

\[
Prox = \left( \sum_{t=1}^{T} K_\delta(t) \right) / T
\]

\[
K_\delta(t) = \mathbb{1}\{\|A_t - B_t\| < \delta\}
\]

- proportion of simultaneous fixes that are proximal
- min: 0 (no proximity)
- max: 1 (always close)
- Issue: \( \delta \)
Prox: proximity index

\[ \text{Prox} = \left( \sum_{t=1}^{T} K_\delta(t) \right) / T \]

\[ K_\delta(t) = \exp \left( -\| A_t - B_t \|^2 / (2\delta^2) \right) \]

- smoothed function of proximity
- min: 0 (no proximity)
- max: 1 (always close)
- Issue: \( \delta \)
Comparing $K_1^\delta(t) = \mathbb{1}_{\{\|A_t - B_t\| < \delta\}}$ and $K_2^\delta(t) = \exp\left(-\|A_t - B_t\|^2/(2\delta^2)\right)$ for $\delta = \{1, 3\}$

$K^1$ is easier to interpret; $K^2$ is continuous, monotonic and smoother

Other kernels are possible!
r: Pearson or Spearman correlation (e.g. speed, lon, lat)

- min: −1 (opposition)
- max: 1 (coordinated movement)
**DI, DI\(_d\) and DI\(_\theta\): dynamic interaction indices**

**DI: dynamic interaction**
- **Displacement:**
  \[
g_t = 1 - \left( \frac{|d_t^A - d_t^B|}{d_t^A + d_t^B} \right) ^ \delta
\]

**DI\(_d\): mean\((g_t)\)**
- min: 0 (no coord.)
- max: 1 (perf. coord.)

**Azimuth:**
- **Azimuth:**
  \[
f_t = \cos(\theta_t^A - \theta_t^B)
\]

**DI\(_\theta\): mean\((f_t)\)**
- min: −1 (opposed direct.)
- max: 1 (same orient.)

**DI: mean\((g_t \times f_t)\)**
- min: −1 (opposed mov.)
- max: 1 (cohesive mov.)
Evaluating contrasting case scenarios: e.g. generating arbitrary trajectories with

High proximity, high coordination in direction and speed

Some proximity, opposite directions, same speed
Evaluating 18 contrasting scenarios

Proximity

High

Different
Speed

18 13 14 15 16 17

Same
Speed

Low

Opposite

Medium

Different
Speed

12 7 8 9 10 11

Same
Speed

Independent
Direction

Different
Speed

5 4 3 2 1

Same
Speed

Independent

Same
Speed

Same
Case scenarios

For contrasting scenarios in proximity: high (green), medium (red), low (blue)
For contrasting scenarios in direction coordination: high (green), medium (red), low (blue)
Case scenarios

For contrasting scenarios in speed coordination: same (green), independent (red)
Not all metrics are sensitive to each component of joint movement.

Choice of metrics will depend on the component of interest, parameter tuning and assumptions.
Extensions

- Obtain **reference points** from metric values to distinguish between high or low joint-movement (manuscript in prep.)
- **Metrics interaction**: dyad characterization through **multivariate** analysis of metrics (manuscript in prep.)
- Use metrics to identify and assess interaction for larger groups
Thanks for your attention