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Visualising movement

The Summer of V's of Data Science

St Andrews Institute for Data Intensive Research

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Individual-centric movement - trajectories

Measure the exact location of a moving object at certain times

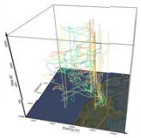
Polylines in 3D/4D space

Trajectories of individual objects

Temporal sequences of geographic locations of each moving object.

(x1,y1,z1,t1)
(x2,y2,z2,t2)
(x3,y3,z3,t3)
…

\+ **attribute information**



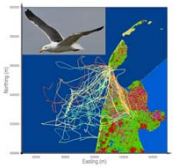
static (the same for entire trajectory, e.g. type of object)

dynamic (changes with time, e.g. speed, direction).

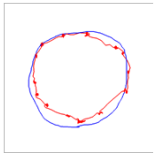
Movement as property of **objects.**

Visualising movement

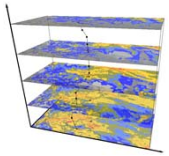
1. Volume
Case study: Movement ecology



2. Variety of movement
Case study: Human-Computer Interaction

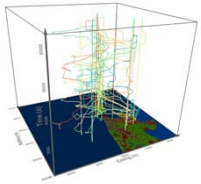


3. Variety of data
Case study: Integration of context for movement analysis

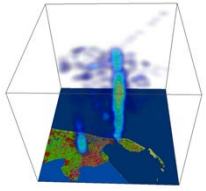


Concepts

Space-time cube



Space-time densities

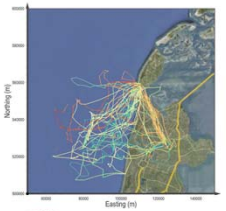


Volumetric visualisation, 3D map algebra, 3D interpolation, Space-time prisms

1. Volume: Basic trajectory mapping

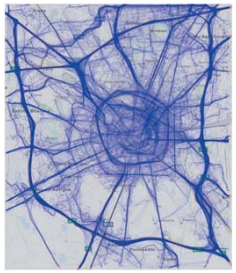
Volume

Spaghetti lines



Demšar et al., 2015

Sila-Nowicka et al. 2015



Andrienko & Andrienko, 2013

Space and time – 3D

Volume

Space-Time Cube / Space-Time Aquarium / Time Geography

Idea: space and time are inseparable

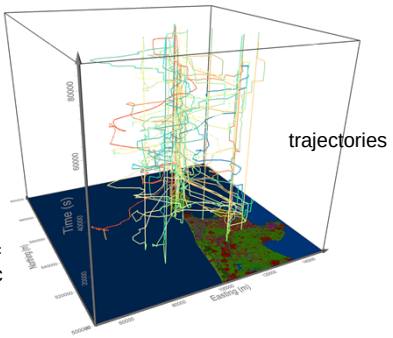
Hägerstrand 1970

Space-Time Cube (STC)

z axis – time t

trajectories

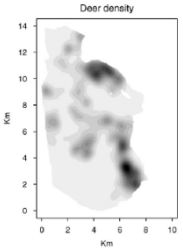
x-y plane = geographic map



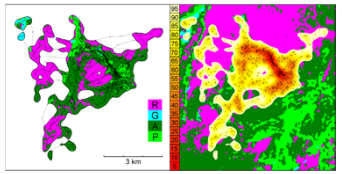
Aggregations

Volume

Kernel density surfaces of trajectory points / heatmaps



Brillinger et al. 2004, Journal of Statistical Planning and Inference



Benhamou, 2011, PlosOne

Utilisation distribution

probability surface over a 2D area, describing the intensity of usage of a particular location by an individual.

Kernel Density Estimation

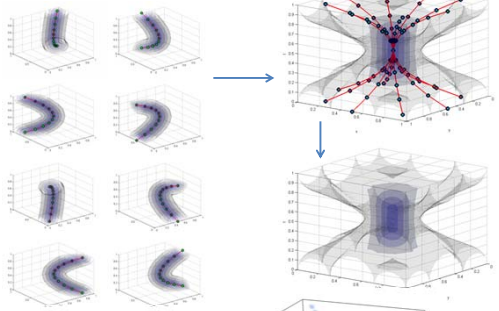
Home range

a set of bounded areas used by an animal in the course of its normal activities (foraging, mating).

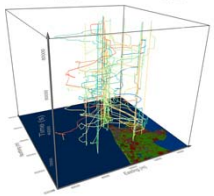
3D Space-Time Density of lines

Volume

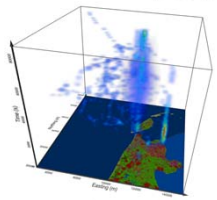
Generalise:
- from 2D to 3D in space-time display
- from points to lines



Space-time cube



Space-time density

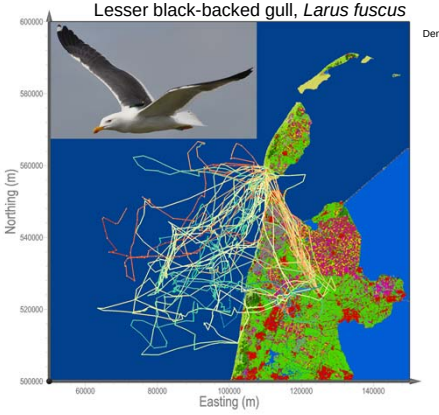


Case study: Movement Ecology

Volume

Revolution in animal tracking – device size, GPS/VHF

Lesser black-backed gull, *Larus fuscus*



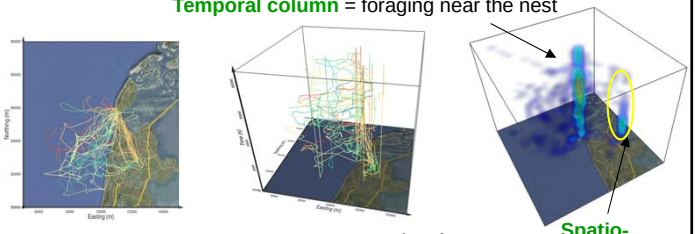
Demšar et al, 2015, Geoinformatica

http://www.move-cost.info

Bird 298, male

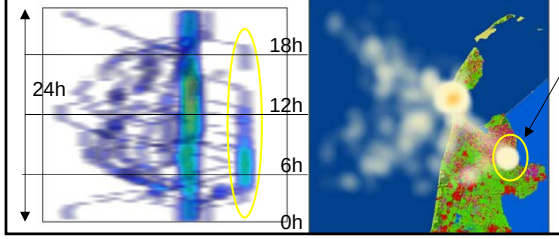
Volume

Temporal column = foraging near the nest



View from south

View from top



Spatio-temporal hotspot = Bird sat there mostly in the mornings, sometime in the afternoon, on several days this month

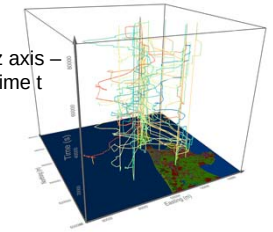
2. Variety of movement

Variety

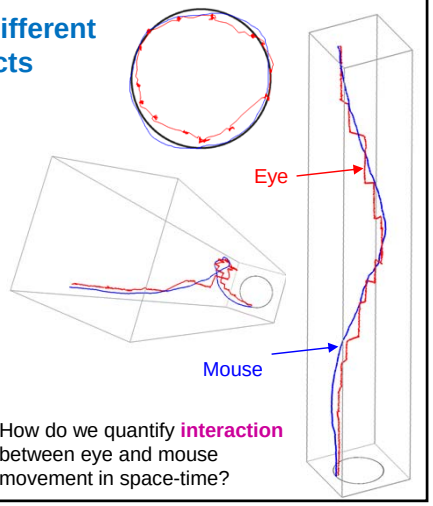
Interaction between different types of moving objects

Space-Time Cube (STC)

Trajectories = lines in 3D



x-y plane = geographic map



How do we quantify **interaction** between eye and mouse movement in space-time?

Case Study: Human-Computer Interaction

Variety

Investigating eye-mouse interaction in the use of spatial visual interfaces

Tracking eye movement

- Human-Computer Interaction
- Evaluation of visual displays
- Measuring the **gaze and eye movement** - where people pay attention to

?

Tracking mouse movement

- Collecting **mouse positions**
- Mouse clicks – measure of interaction
- Mouse movement – often assumed as proxy for attention

Demšar & Çöltekin, 2014, 2015 paper in preparation

Trajectories of eye and mouse – geometric tracing

Variety

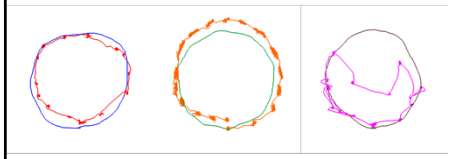
Two different types of trajectories:

Eye

- Discrete movement between saccades
- Irregular trajectory, jumps

Mouse

- Continuous smooth movement
- Regular sampling

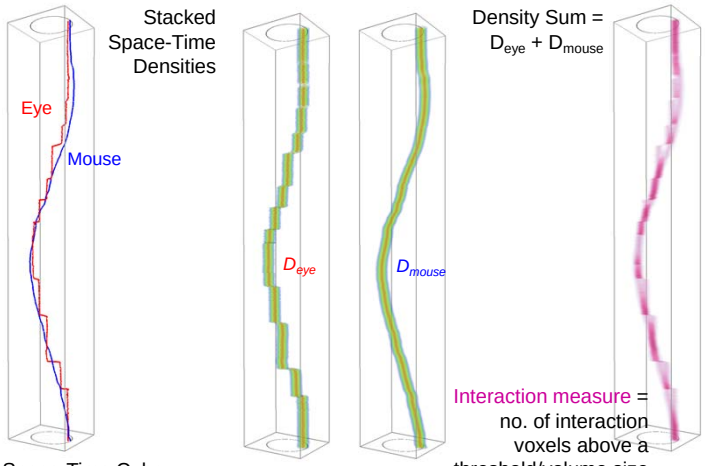


But, both trajectories are:
1) generated by the **same process**: visual exploration of the screen; and
2) **co-located** in space-time

Assumption: we can develop new **spatio-temporal trajectory analysis** methods to compare the two movement types.

Space-time densities + voxel-based change detection

Variety



Space-Time Cube

Interaction measure = no. of interaction voxels above a threshold/volume size

3. Variety of data

Variety

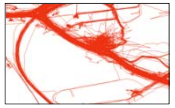
Integration of context for movement analysis

… often linked to spatial and temporal variability in environmental conditions

Dodge et al. (2013)

Movement is a change in spatial location over time…

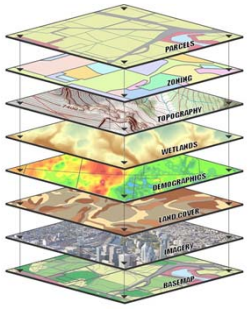
Nathan et al. (2008)



Trajectories

?

Scale/ Granularity



Environmental data sources

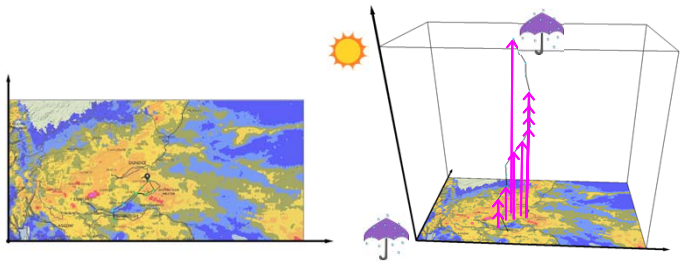
Case Study: Integration of context

Variety

Vanessa da Silva Brum Bastos

Context semantically enriches trajectories adding, through trajectory annotation, environmental and sensor information at each location and time.

Safi et al. (2013)



Driving in the rain?

?

Same values assigned to different points, large temporal differences of trajectory points to actual state of environment.

Thank you for your attention.

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Demšar U, Buchin K, van Loon EE and Shamoun-Baranes J, 2015, Stacked space-time densities: a geovisualisation approach to explore dynamics of space use over time. *GeoInformatica*, 19(1): 85-115

Demšar U, Buchin K, Cagnacci F, Safi K, Speckmann B, Van de Weghe N, Weiskopf D and Weibel R, 2015, Analysis and visualisation of movement: an interdisciplinary review. *Movement Ecology, 3:5*

da Silva Brum Bastos V, Long JA and Demšar U, 2015, New methodological approaches for cross-scale integration of environmental remotely sensed data with spatio-temporal movement data. *Evolving GIScience workshop*, 14-15 July 2015 (upcoming), Leicester, UK.

Demšar U and Çöltekin A, 2014, Quantifying the interactions between eye and mouse movements on spatial visual interfaces through trajectory visualisations. *Workshop on Analysis of Movement Data* at GIScience 2014, Vienna, Austria, 23 Sept 2014.

Çöltekin A, Demšar U, Brychtova A and Vandrol J, 2014, Eye-hand coordination during visual search on geographic displays. In: Kiefer P, Giannopoulos I, Raubal M and Krüger A (eds), *ET4S 2014 - Eye Tracking for Spatial Research*, Vienna, Austria, 23 Sept 2014.

http://www.move-cost.info