R package:

leastcostpath

Modelling Pathways and Movement Potential Within a Landscape
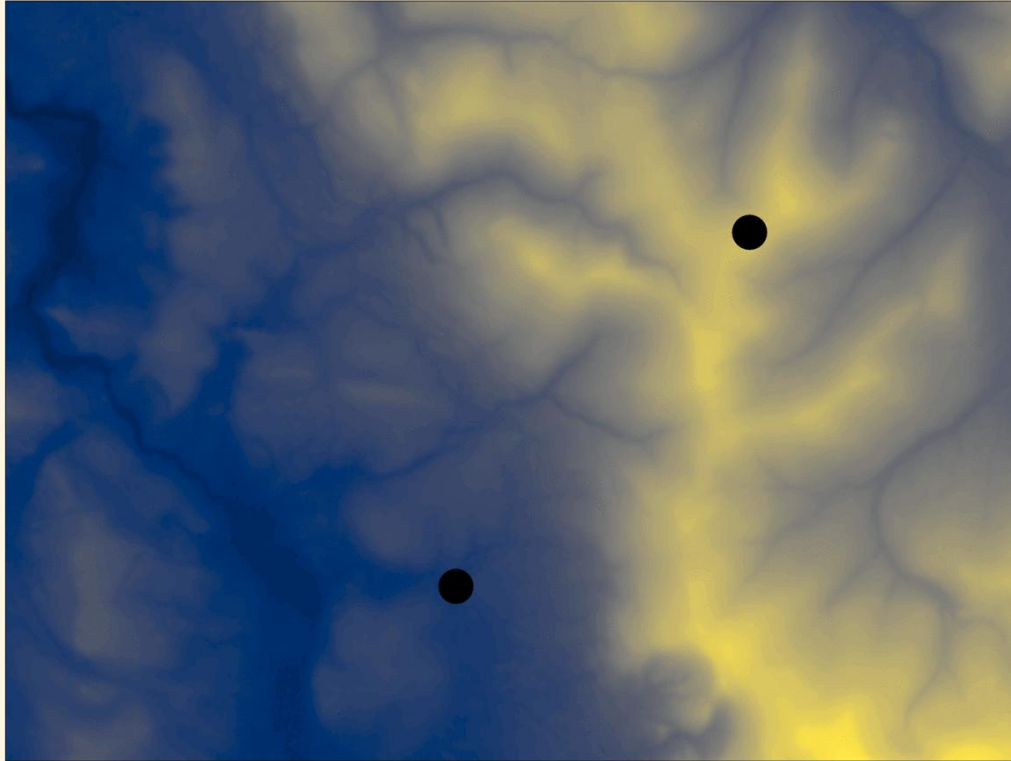
Joseph Lewis

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What is Least Cost Path (LCP) Analysis?

Elevation

Least costly path between two locations

Based on a cost Surface that expresses the ease / difficulty of moving between cells

Used to:

- **reconstruct pathways;**
- **identify factors that may have governed the location of pathways**

Bell and Lock, 2000; van Leusen, 1993; Orengo and Livarda, 2016; Verhagen and Jeneson, 2012

Why another LCP analysis software?

"Many Studies using default settings to calculate the LCP are unaware of alternatives and methodological issues" (Herzog, 2014)

- Moving across slope is often modelled isotropically (same irrespective of movement uphill/downhill)

- Least Cost Path can be significantly affected by the Digital Elevation Models resolution and accuracy

- Little work in evaluating which cost function best models real human movement

- Number of neighbouring cells used in Least Cost Path calculation is important

- New methods not readily accessible

Herzog, 2010; Herzog, 2014; Kantner, 2004; Kantner, 2012

R Package leastcostpath

Open-Source R package to Model Pathways and Movement Potential Within a Landscape

Aims to overcome methodological issues

Implement recently developed methods

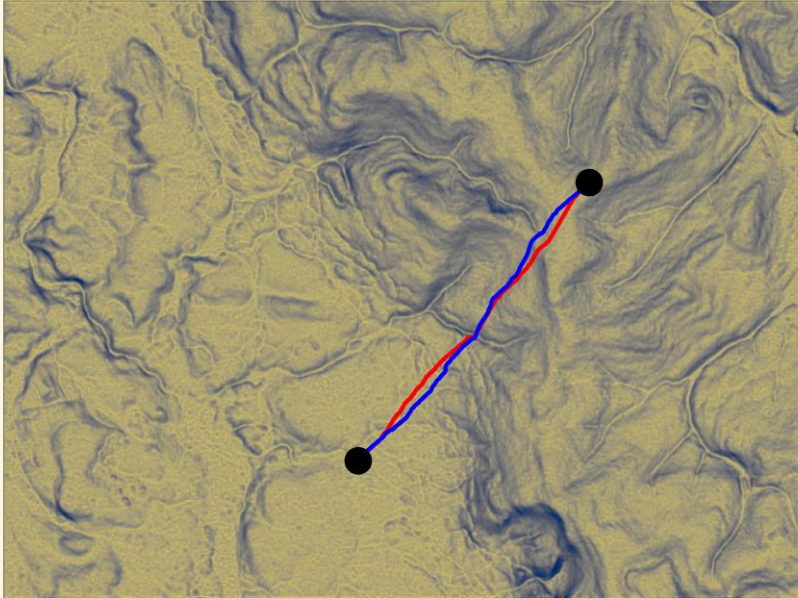**Leverages the iterative nature of Least Cost Path analysis**

"Success [of the dissemination of GIS techniques] can only be claimed when the majority of field and academic archaeologists have access to such techniques on a day to day basis"

(Gaffney and Stan, 1996, p.70)

Modelling movement anisotropically

Least Cost Paths

Red LCP – North to South; Blue LCP – South to North

- **Nearly all archaeological LCP studies are based on slope**

- **Slope traditionally measured as the maximum rate of change from a cell to its neighbour (isotropic)**

- **However, the effort of traversing slope depends on the direction (uphill more difficult than downhill) - anisotropy**

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leastcostpath incorporates this anisotropic property of slope by calculating slope in all directions, not just maximum rate of change

Herzog, 2010; Herzog, 2014

Testing Digital Elevation Models

Least Cost Path - 62m resolution
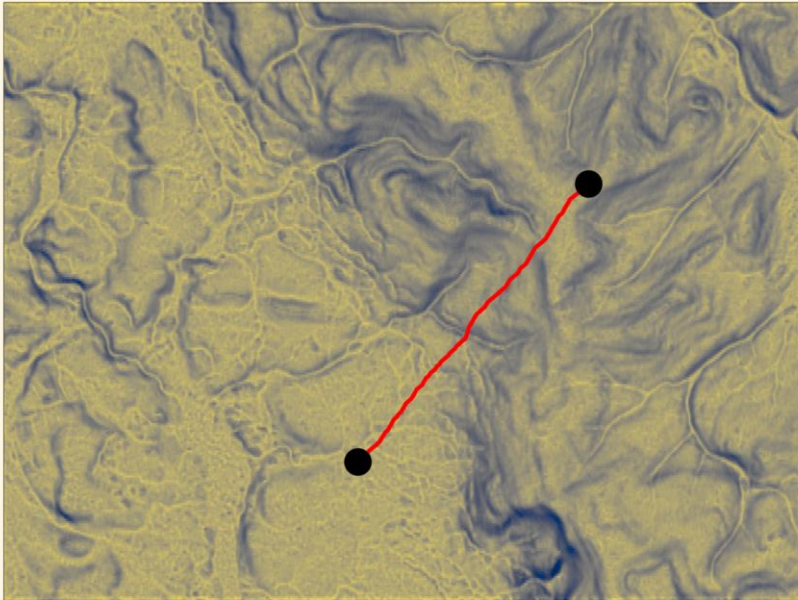
- **Least Cost Path can be significantly affected by Digital Elevation Model resolution and accuracy**
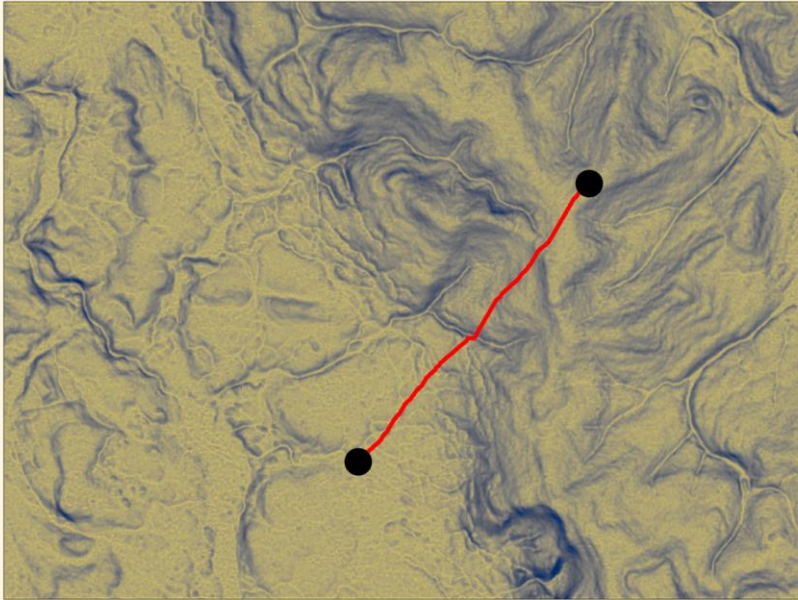
slope_cs <- create_slope_cs(dem = elev_data)

**lcp <- create_lcp(cost_surface = slope_cs,
origin = loc1, destination = loc2)**

leastcostpath allows for the flexible and easy testing of different elevation models when calculating Least Cost Paths

Branting, 2012

Comparing Cost Functions

Cost Surface - Cost Function = tobler

- Cost functions convert the change in elevation between raster cells to a cost (e.g. speed of movement, energy expenditure)

- Little work in evaluating which cost function best models real human movement

slope_cs <- create_slope_cs(dem = elev_data,

cost_function = "**tobler**")

lcp <- create_lcp(cost_surface = slope_cs,

origin = loc1, destination = loc2)

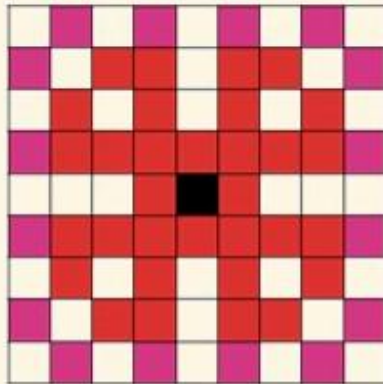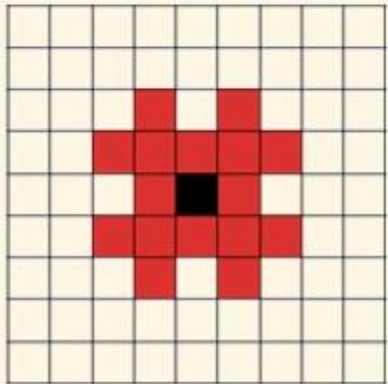
leastcostpath allows for the flexible and easy testing of different cost functions when calculating Least Cost Paths

Herzog, 2010, p.374; Kantner, 2012

Increasing Number of Neighbours
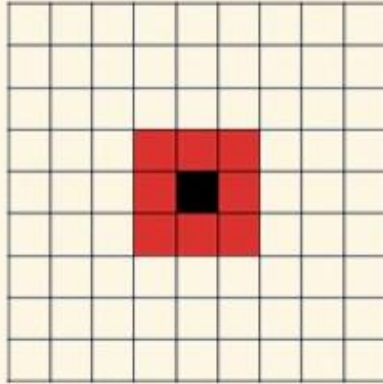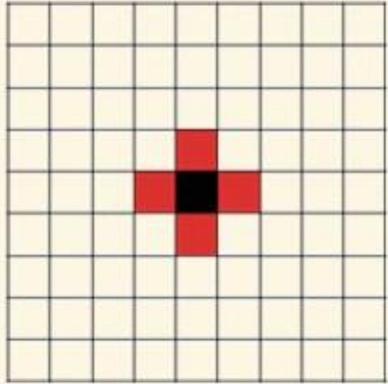
- **Number of neighbouring cells used in Least Cost Path calculation is important**

- **Number of neighbouring cells is often limited to a 4- or 8- neighbours**

slope_cs <- create_slope_cs(dem = elev_data, neighbours = 16)

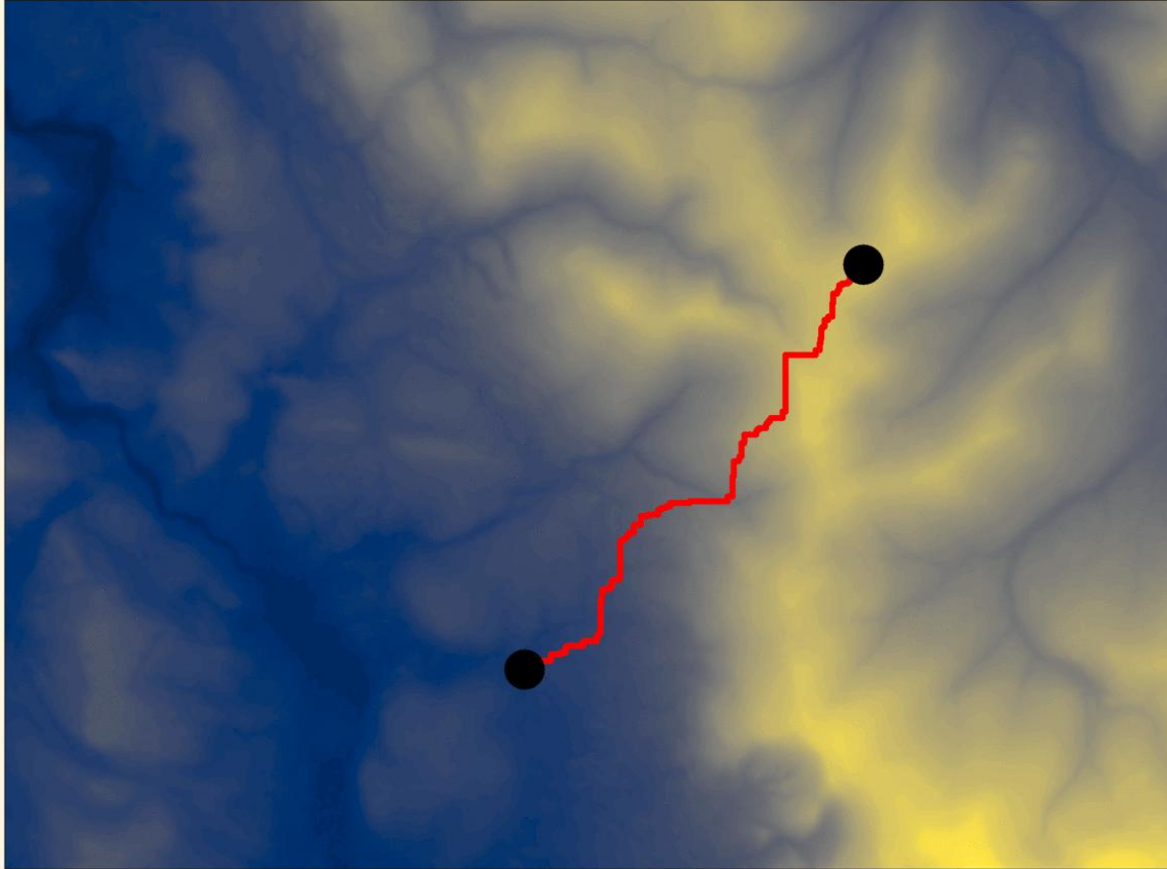**lcp <- create_lcp(cost_surface = slope_cs, origin = loc1, destination = loc2)**

leastcostpath allows for 4, 8, 16, 32, and 48 neighbours
More neighbours = More accurate least-cost distance

Harris, 2000; Herzog and Posluschny, 2011; Herzog, 2014
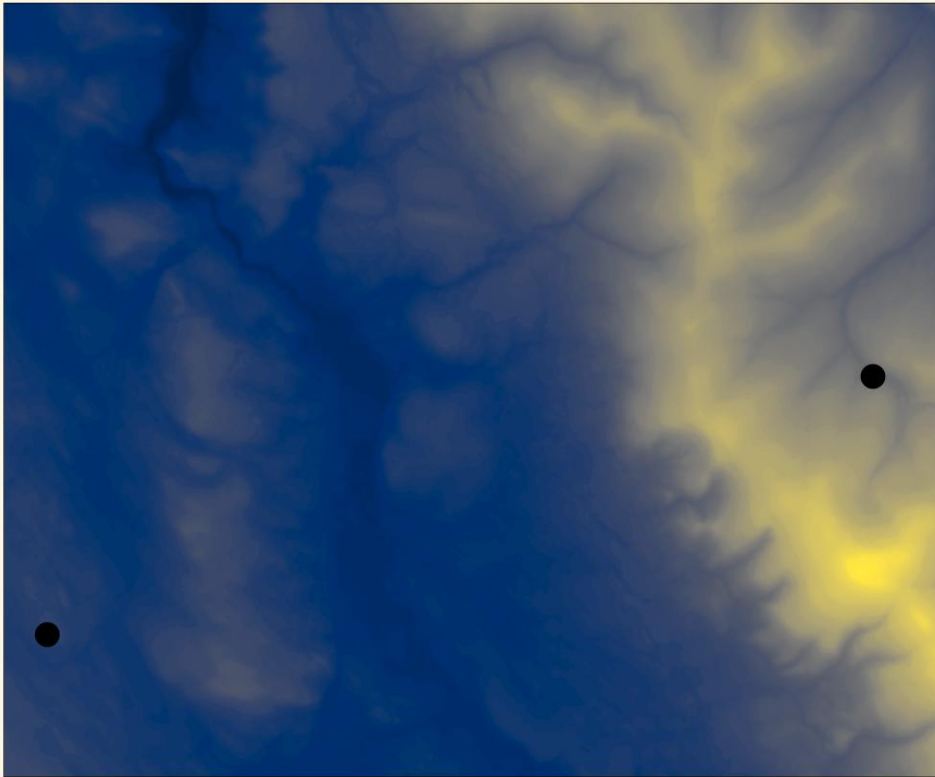
Increasing Number of Neighbours

Least Cost Path - Number of Neighbours = 4

leastcostpath allows for 4, 8, 16, 32, 48 neighbours

More neighbours = More accurate least-cost distance

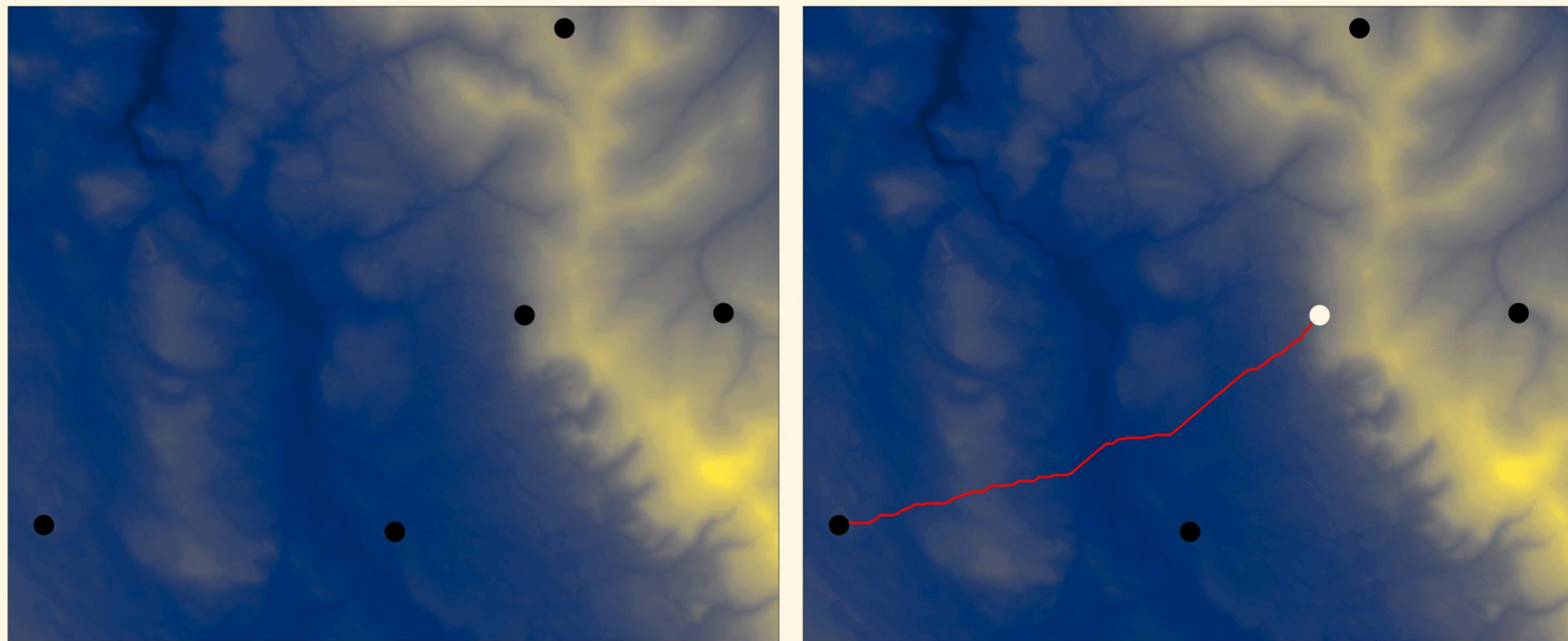Harris, 2000; Herzog and Posluschny, 2011; Herzog, 2014

Cost Corridors

Identify areas of preferential movement between two locations

create_cost_corridor(cost_surface = slope_cs, origin = A, destination = B)

Lock et al. 2014; Palmisano, 2017; Slawisch and Wilkinson, 2018; Surface-Evans, 2012
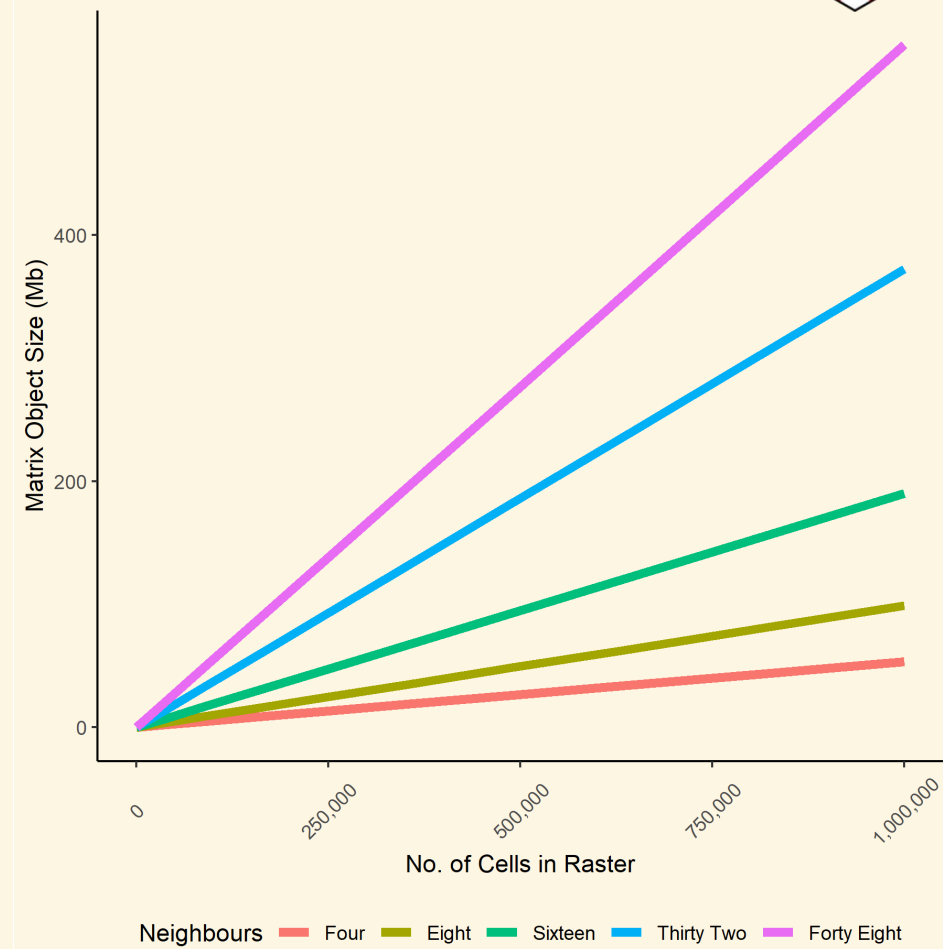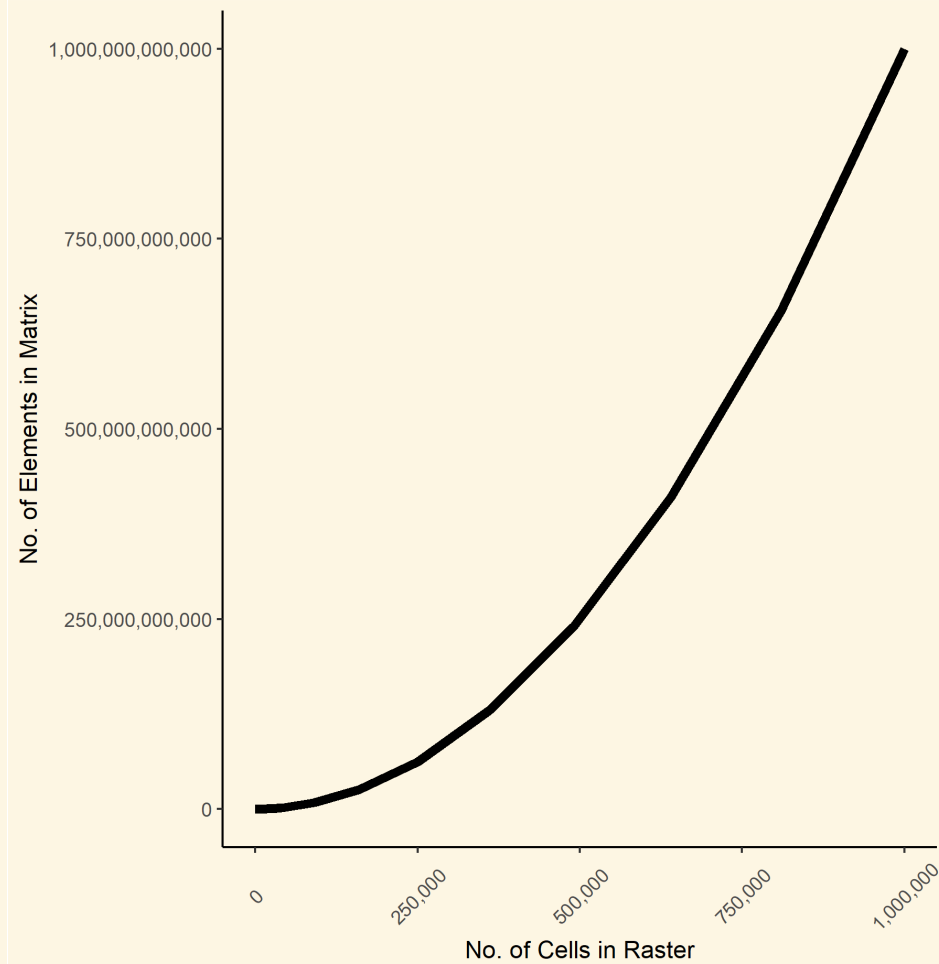
From Everywhere to Everywhere

Identify areas of preferential movement by calculating LCPs to- and from- all locations

create_FETE_lcps(cost_surface = slope_cs, locations = locs)

White and Barber, 2012

So what's the catch?

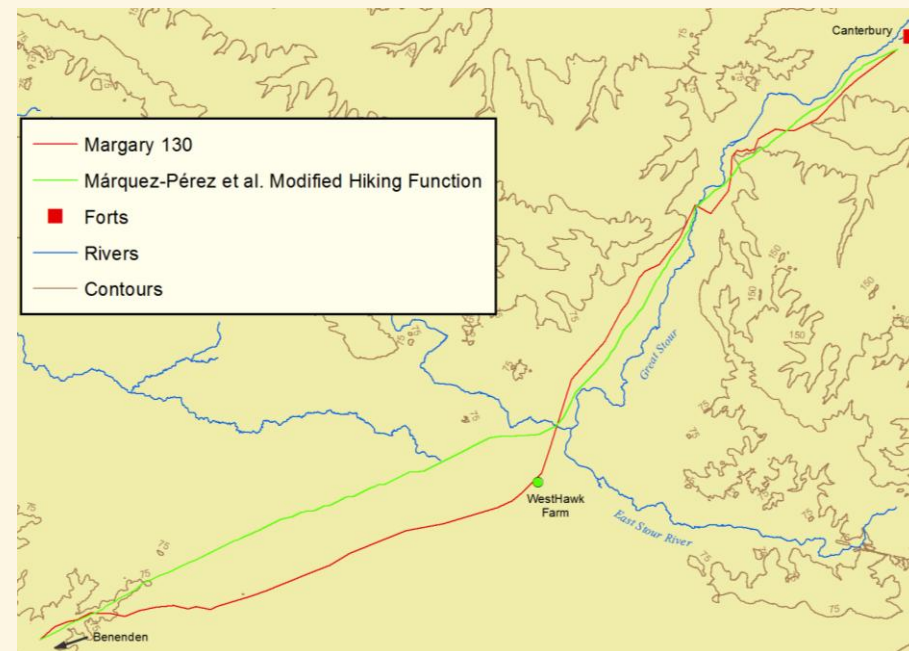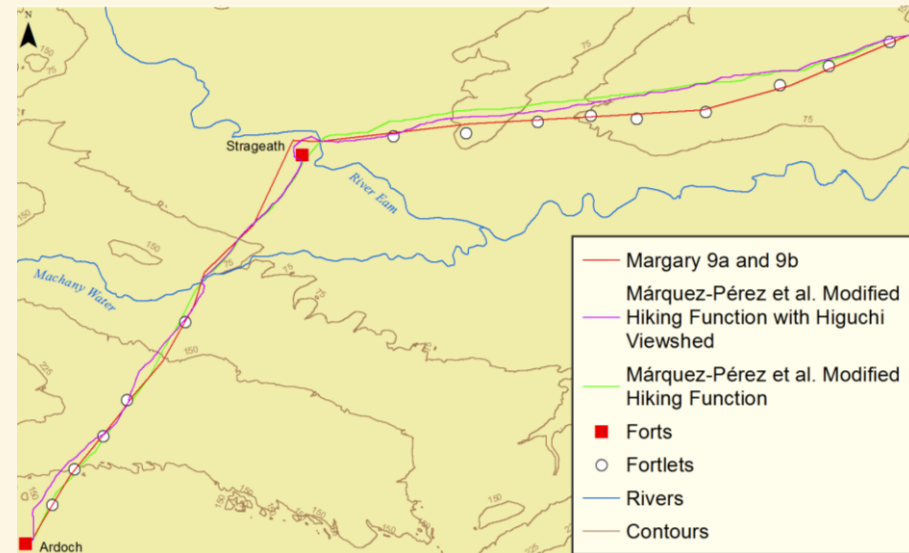- **leastcostpath can consume large amounts of memory (RAM)**
- **Computation time increases with Raster size**

In practice:
Modelling Roman Roads in Roman Britain

Multiple cost functions compared to assess which best models the Roman roads

Impact of number of neighbouring cells on Least Cost Path results assessed
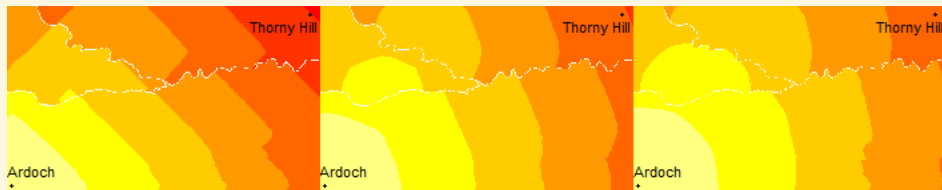
josephlewis.github.io/Dissertation.pdf
josephlewis.github.io/GISRUK2018_presentation.pdf

In practice:
Probabilistic Least Cost Paths

Incorporating and propagating the effects of Digital Elevation Model error on Least Cost Path results
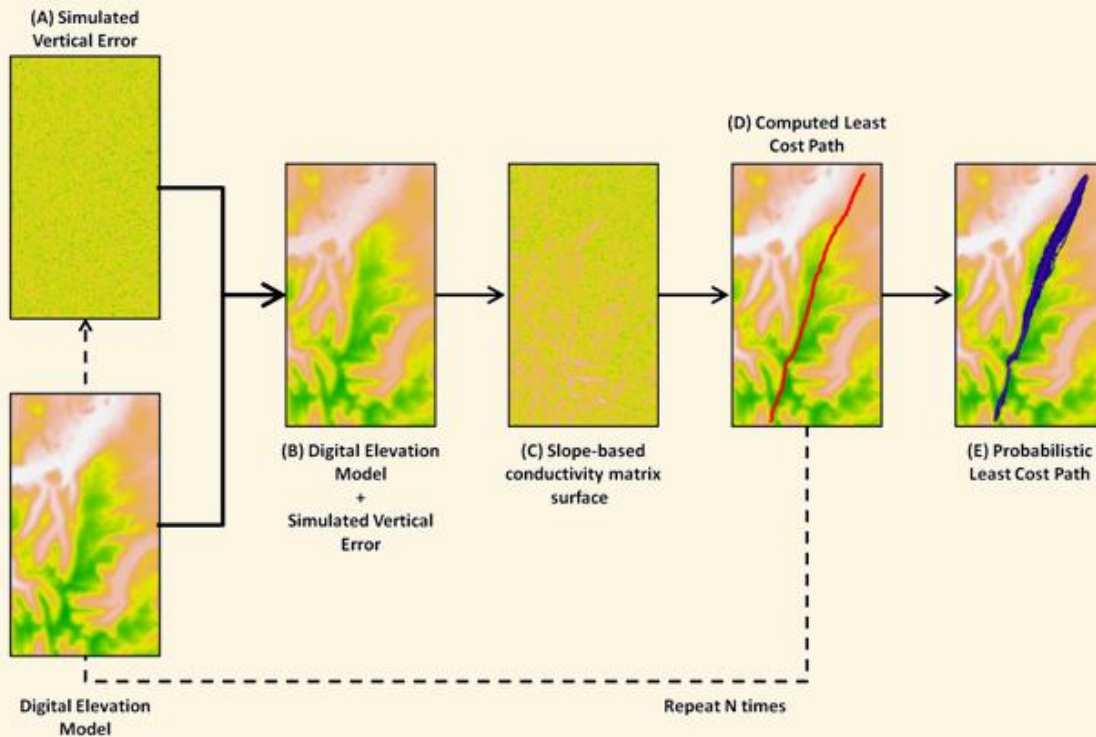
Conclusions

- **leastcostpath provides an Open-source; Flexible; Reproducible and Easy to use software for creating cost surfaces, least cost paths and other recently developed methods**
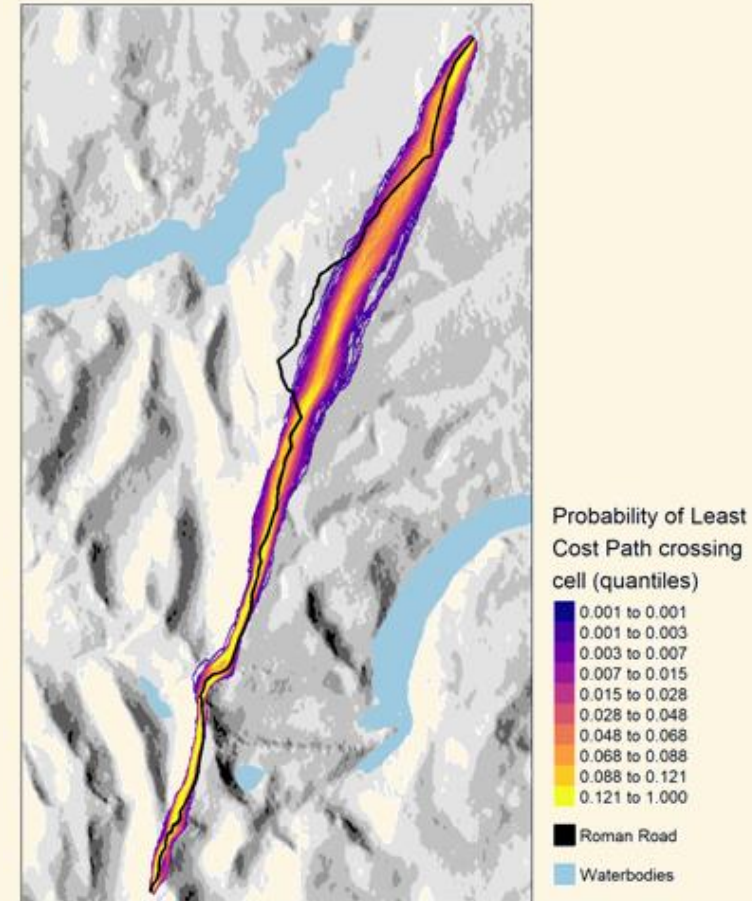
twitter.com/josephlewis1992
#leastcostpath

github.com/josephlewis/leastcostpath

cran.r-project.org/web/packages/leastcostpath/index.html

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"**Success [of the dissemination of GIS techniques] can only be claimed when the majority of field and academic archaeologists have access to such techniques on a day to day basis**"
(Gaffney and Stan, 1996, 70)

References

Bell, T., Lock, G.R., 2000. Topographic and cultural influences on walking the Ridgeway in later prehistoric times, in: Lock, G.R. (Ed.), Beyond the Map: Archaeology and Spatial Technologies, NATO Science Series. IOS Press ; Ohmsha [distributor], Amsterdam ; Washington, DC : Tokyo, pp. 85–100.

Branting, S., 2012. Seven Solutions for Seven Problems with Least Cost Pathways, in: White, D.A., Surface-Evans, S.L. (Eds.), Least Cost Analysis of Social Landscapes: Archaeological Case Studies. University of Utah Press, Salt Lake City, pp. 209–224.

Gaffney, V.L., Stančič, Z., 1996. GIS approaches to regional analysis: a case study of the island of Hvar, Razprave Filosofske fakultete. Znanstveni inštitut Filozofske fakultete, Ljubljana.

Harris, T., 2000. Moving GIS: exploring movements within prehistoric cultural landscapes using GIS, in: Lock, G.R. (Ed.), Beyond the Map: Archaeology and Spatial Technologies. IOS Press, Amsterdam, pp. 116–123.

Herzog, I., 2010. Theory and practice of cost functions, in: Fusion of Cultures: Abstracts of the XXXVIII Conference on Computer Applications and Quantitative Methods in Archaeology. CAA 2010, Granada, pp. 431–434.

Herzog, I., 2014. Least-cost Paths – Some Methodological Issues. IA. https://doi.org/10.11141/ia.36.5

Herzog, I., Posluschny, A., 2011. Tilt – slope-dependent least cost path calculations revisited, in: Jerem, E., Redő, F., Szevérenyi, V. (Eds.), On the Road to Reconstructing the Past: Computer Applications and Quantitative Methods in Archaeology (CAA): Proceedings of the 36th International Conference, Budapest, April 2-6, 2008. Archaeolingua, Budapest, pp. 212–218.

Kantner, J., 2004. Geographical Approaches for Reconstructing Past Human Behaviour from Prehistoric Roadways, in: Goodchild, M.F., Janelle, D.G. (Eds.), Spatially Integrated Social Science: Examples in Best Practice. Oxford University Press, Oxford, pp. 323–244.

Kantner, J., 2012. Realism, Reality, and Routes: Evaluating Cost-Surface and Cost-Path Algorithms, in: White, D.A., Surface-Evans, S.L. (Eds.), Least Cost Analysis of Social Landscapes: Archaeological Case Studies. University of Utah Press, Salt Lake City, pp. 225–238.

Lock, G., Kormann, M., Pouncett, J., 2014. Visibility and movement: towards a GIS-based integrated approach, in: Polla, S., Verhagen, P. (Eds.), Computational Approaches to the Study of Movement in Archaeology. DE GRUYTER, Berlin, Boston. https://doi.org/10.1515/9783110288384.23

Orengo, H.A., Livarda, A., 2016. The seeds of commerce: A network analysis-based approach to the Romano-British transport system. Journal of Archaeological Science 66, 21–35. https://doi.org/10.1016/j.jas.2015.12.003

Palmisano, A., 2017. Drawing Pathways from the Past: the Trade Routes of the Old Assyrian Caravans Across Upper Mesopotamia and Central Anatolia, in: Kulakoğlu, F., Barjamovic, G., Veenhof, K.R. (Eds.), Movement, Resources, Interaction: Proceedings of the 2nd Kültepe International Meeting, Kültepe, 26-30 July 2015: Studies Dedicated to Klaas Veenhof, Subartu. Brepols, Turnhout, Belgium, pp. 29–48.

Slawisch, A., Wilkinson, T.C., 2018. Processions, Propaganda, and Pixels: Reconstructing the Sacred Way Between Miletos and Didyma. American Journal of Archaeology 122, 101. https://doi.org/10.3764/aja.122.1.0101

Surface-Evans, Sarah L, 2014. Cost Catchments, in: White, D.A., Surface-Evans, S.L. (Eds.), Least Cost Analysis of Social Landscapes: Archaeological Case Studies. University of Utah Press, Salt Lake City, pp. 128–151.

van Leusen, P., 2002. Pattern to process. Methodological investigations into the formation and interpretation of spatial patterns in archaeological landscapes. Rijksuniversiteit Groningen, Universiteitsbibliotheek.

Verhagen, P., Jeneson, K., 2012. A Roman Puzzle: Trying to find the Via Belgica with GIS, in: Chrysanthi, A., Murrieta-Flores, P., Papadopoulos, C., Huggett, J. (Eds.), Thinking beyond the Tool: Archaeological Computing and the Interpretive Process, BAR International Series. Archaeopress, Oxford, pp. 123–130.

White, D.A., Barber, S.B., 2012. Geospatial modeling of pedestrian transportation networks: a case study from precolumbian Oaxaca, Mexico. Journal of Archaeological Science 39, 2684–2696. https://doi.org/10.1016/j.jas.2012.04.017