# Generalized additive mixed models for spatial networks

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## What are GAMMs?

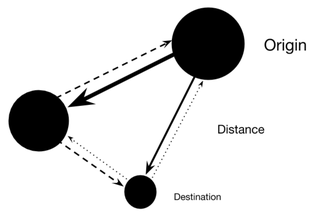
Generalized additive models (GAMs) and their variants Generalized additive *mixed* models (GAMMs) are a flexible family of regression models that capture the complexity of the archaeological record.

**Let's break it down:**

- *Generalized* – Model non-normal distributions such as counts or proportions
- *Additive* – Combine linear and non-linear relationships
- *Mixed* – Control for network, spatial, and temporal autocorrelation

## What can I do with them?

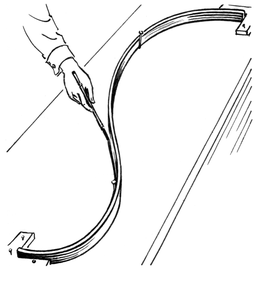
In archaeology, they're particularly useful for fitting so-called "maximum-entropy" spatial interaction models. These models estimate the *flow* of goods, information, or people between spatially-structured populations as a function of the origin site, destination site, and the space between them:




$$flow = f\,(origin) \times f\,(destination) \times f\,(distance)$$

The difficult part comes when we have to define the $f\,()$s. Economic geographers often use a generalized *linear* model (GLM), which requires them to definte $f\,()$ ahead of time. In a GAM, the $f\,()$s are estimated directly from the data using splines.

## How do they work?

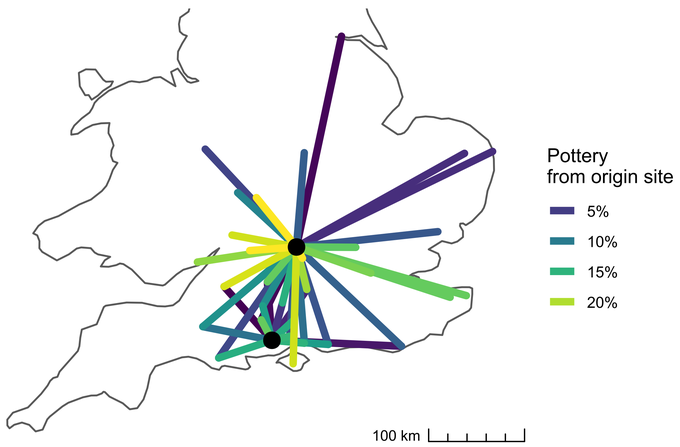


Real-world splines are flexible strips of metal or wood used to draw curves. Mathematical splines are complex curves made of many smaller, simpler curves. *Penalized* regression splines can estimate $f\,()$ from the data, limiting overfitting by penalizing the "wiggliness" of the function.

## Case Studies

Ceramic distribution in Roman Britain

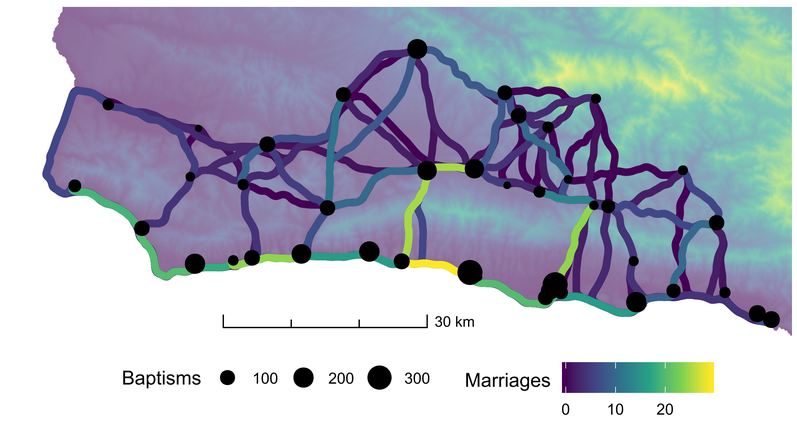
Percent late Romano-British pottery produced in Oxford and New Forest




The Oxford Pots dataset can be found in the R package `archdata`. *David L. Carlson and Georg Roth (2018). archdata: Example Datasets from Archaeological Research. R package version 1.2.*

Coastal Chumash marriages in southern California

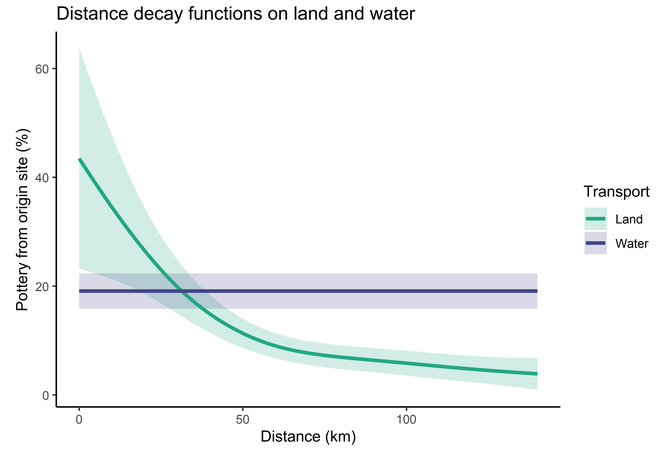
Marriages in mission registers, population estimated from baptisms




Chumash marriage data can be found in John Johnson's PhD thesis. *John R. Johnson, "Chumash social organization: An ethnohistorical perspective". PhD thesis. UC Santa Barbara, 1988.*

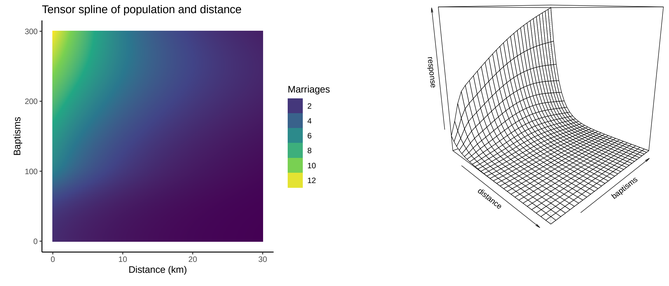
## Results

*Late Romano-British Pottery*




GAMs learn functions directly from data. Here we find that the amount of pottery moved over land decays logarithmically, but pottery moved by water does not.

*Mission-period Chumash*




Here we can use a "tensor" spline to model the nonlinear influence of distance and population size on Chumash marriage patterns.

## What's next?

Efficient estimation of GAMs and GAMMs is available in `R` with the package `mgcv`, and `brms` provides a Bayesian implementation. Scan this QR code or go to `https://github.com/nick-gauthier/gam-networks` for the code and data for this poster along with more detailed worked examples.