Strava Data Disaggregation

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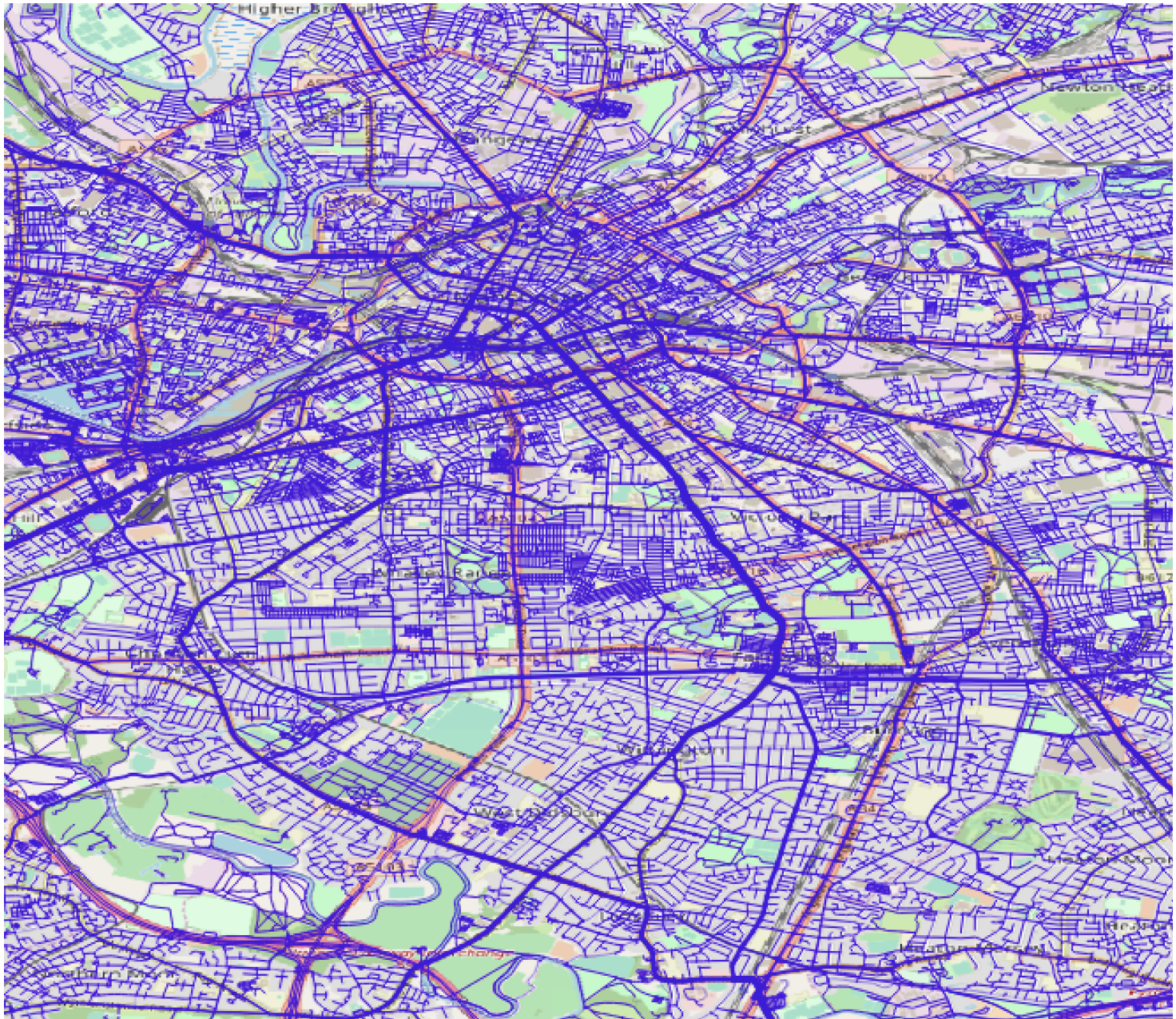
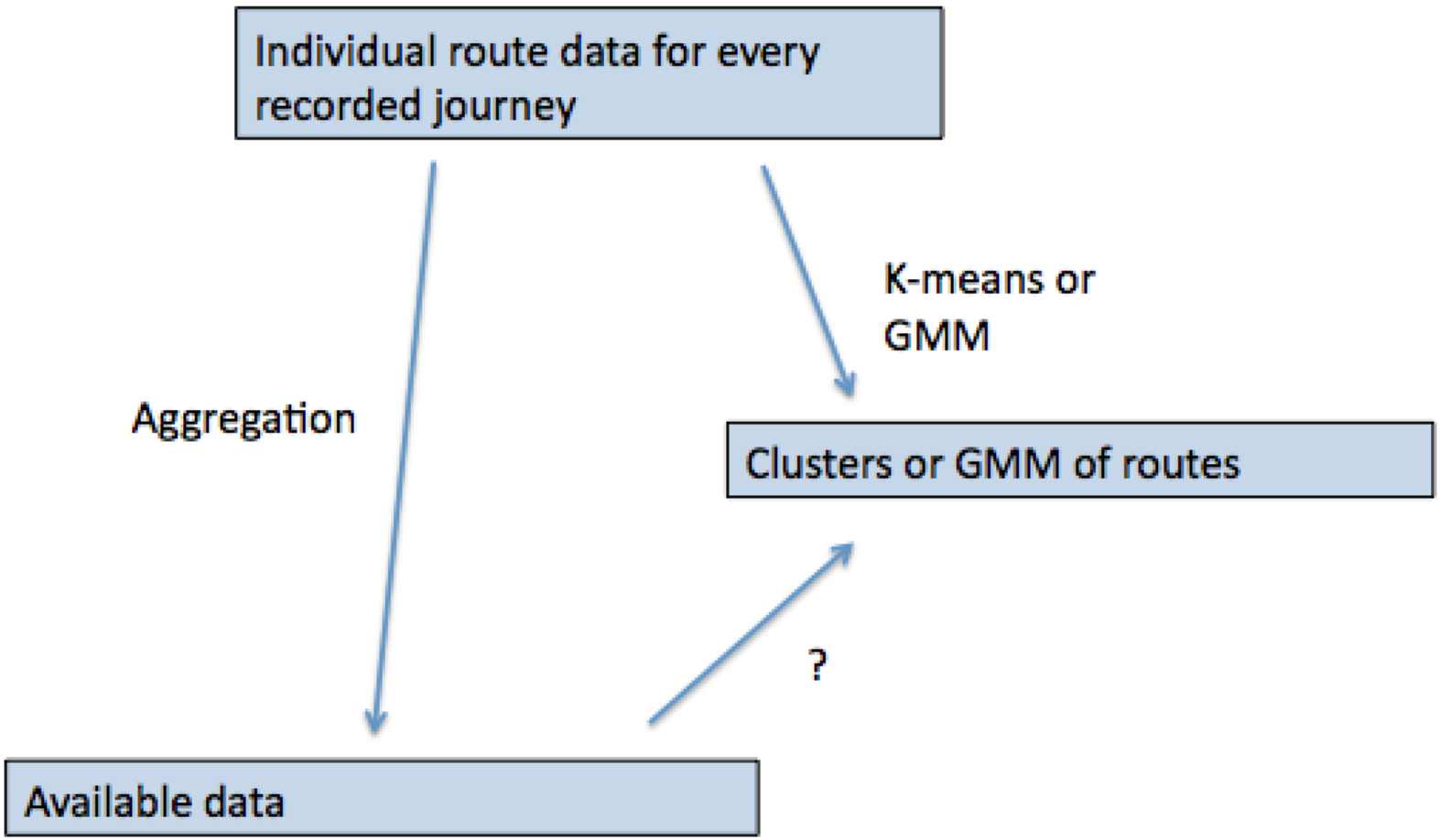
13th June 2018



Partially Inverting Aggregation



Forwards Model

Manchester road network $G(V, E)$.

Set of all rides $R = \left\{ \boldsymbol{r}_\ell \in \{0,1\}^E \ : \ \ell = 1, \ldots, N \right\}$.

GMM with k-clusters $R \approx \sum_{i=1}^{k} \phi_i \mathcal{N}(\mu_i, \Sigma_i)$, where $\mu_i \in \mathbb{R}_+^E$.

Let $C \in \mathbb{N}^{k \times m}$ with $c_{ij} =$ number of rides from cluster i on day j.

Our data is given by $D \in \mathbb{N}^{E \times m} \sim \mathcal{N}(\mu_D, \Sigma_D)$, with

$$\mu_D = MC,$$

where $M = [\mu_1, \mu_2, \ldots, \mu_k]$.

Inverse Problem: Given aggregated data D determine the means/centres M.

Inverse Problem

Maximum Likelihood Estimate from Non-Negative Matrix Factorization

$$\min -\log\left(\mathbb{P}(D|M,C)\right) \propto \min_{M\in\mathbb{R}_+^{E\times k}, C\in\mathbb{R}_+^{k\times m}} \|D - MC\|_F.$$

Incorporating prior $p(M,C)$ results in Maximum A Posteriori problem

$$\min_{M\in\mathbb{R}_+^{E\times k}, C\in\mathbb{R}_+^{k\times m}} \|D - MC\|_F^2 - 2\sigma^2 \log\left(p(M,C)\right).$$

Prior should promote 'realistic' routes and route frequencies.

Route Length Prior

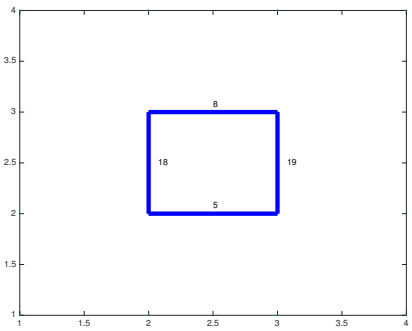
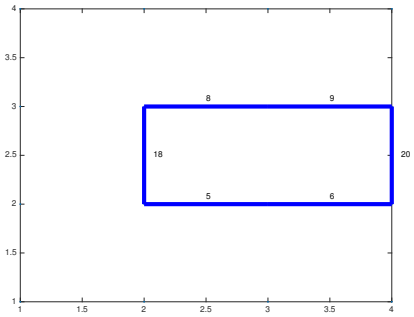
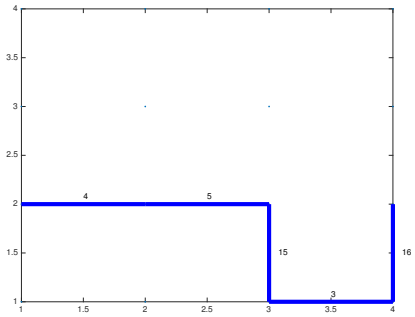
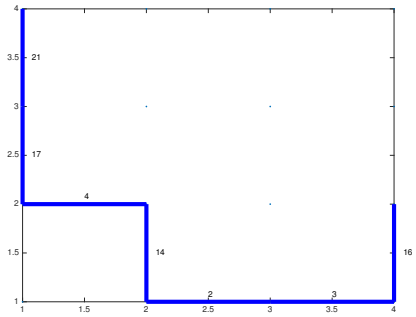
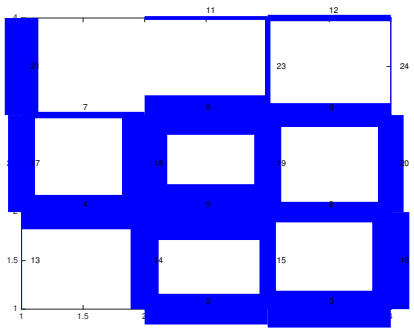
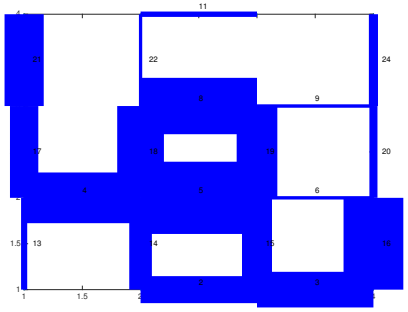
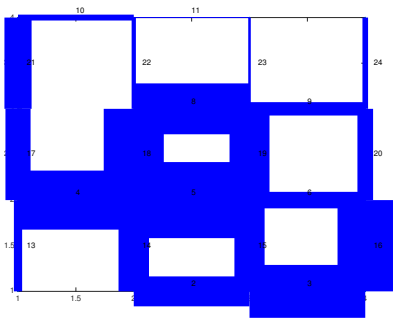
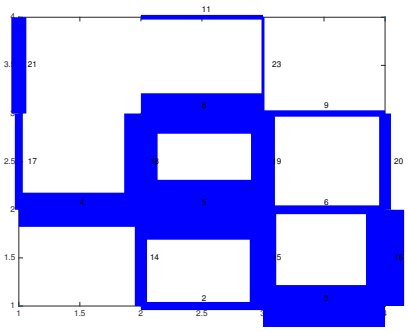
Ride till you crash model.

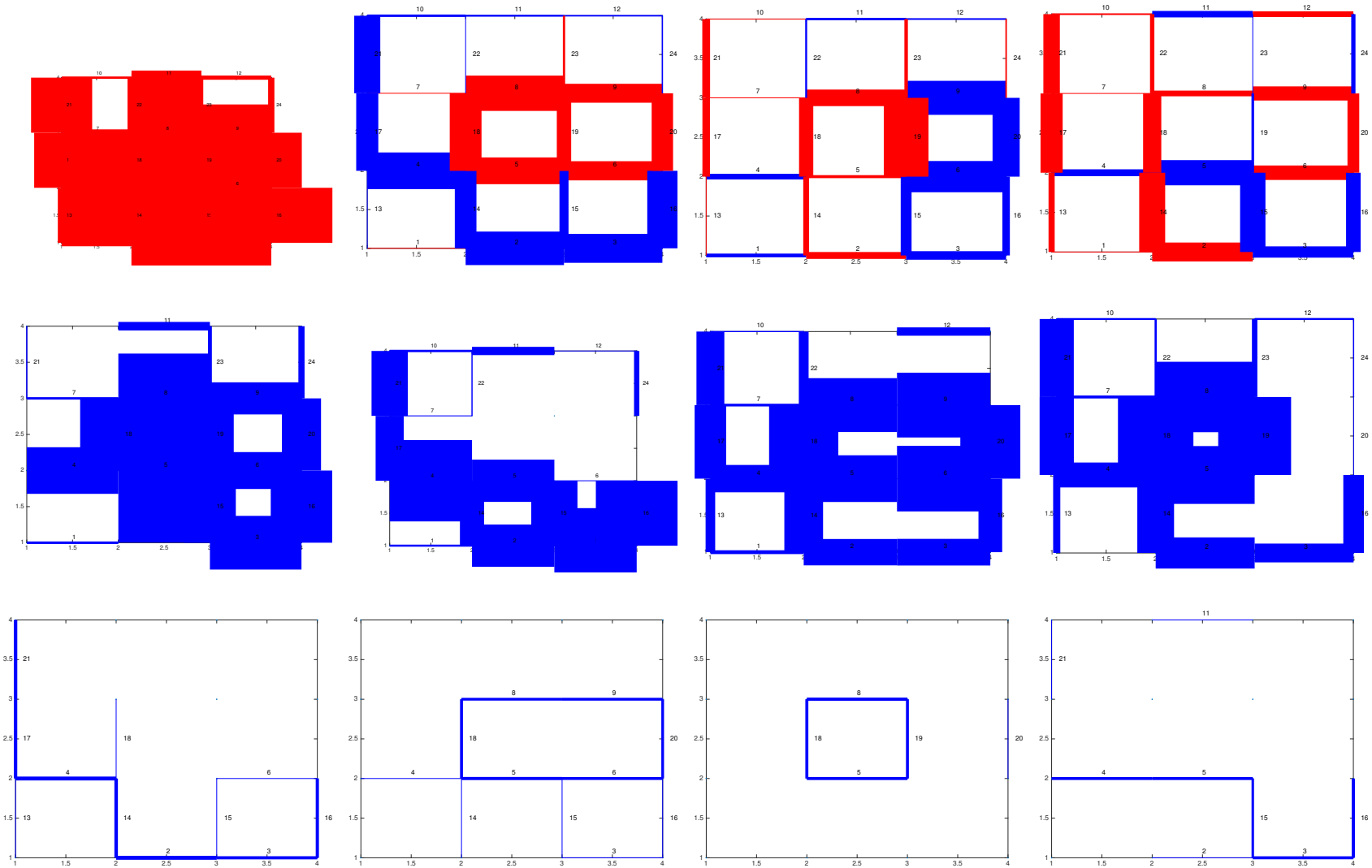
Rider crashes at rate λkm^{-1}, results in exponentially distributed route lengths.

We also know the total number of distinct activities per day $a \in \mathbb{R}^m$.

MAP from $\ell 1$ regularized, linearly constrained NNMF

$$\min_{M \in \mathbb{R}_+^{E \times k},\ C \in \mathbb{R}_+^{k \times m}\ :\ C^\top \underline{1} = a} \|D - MC\|_F^2 - 2\sigma^2 \lambda \|M\|_{1,1}.$$

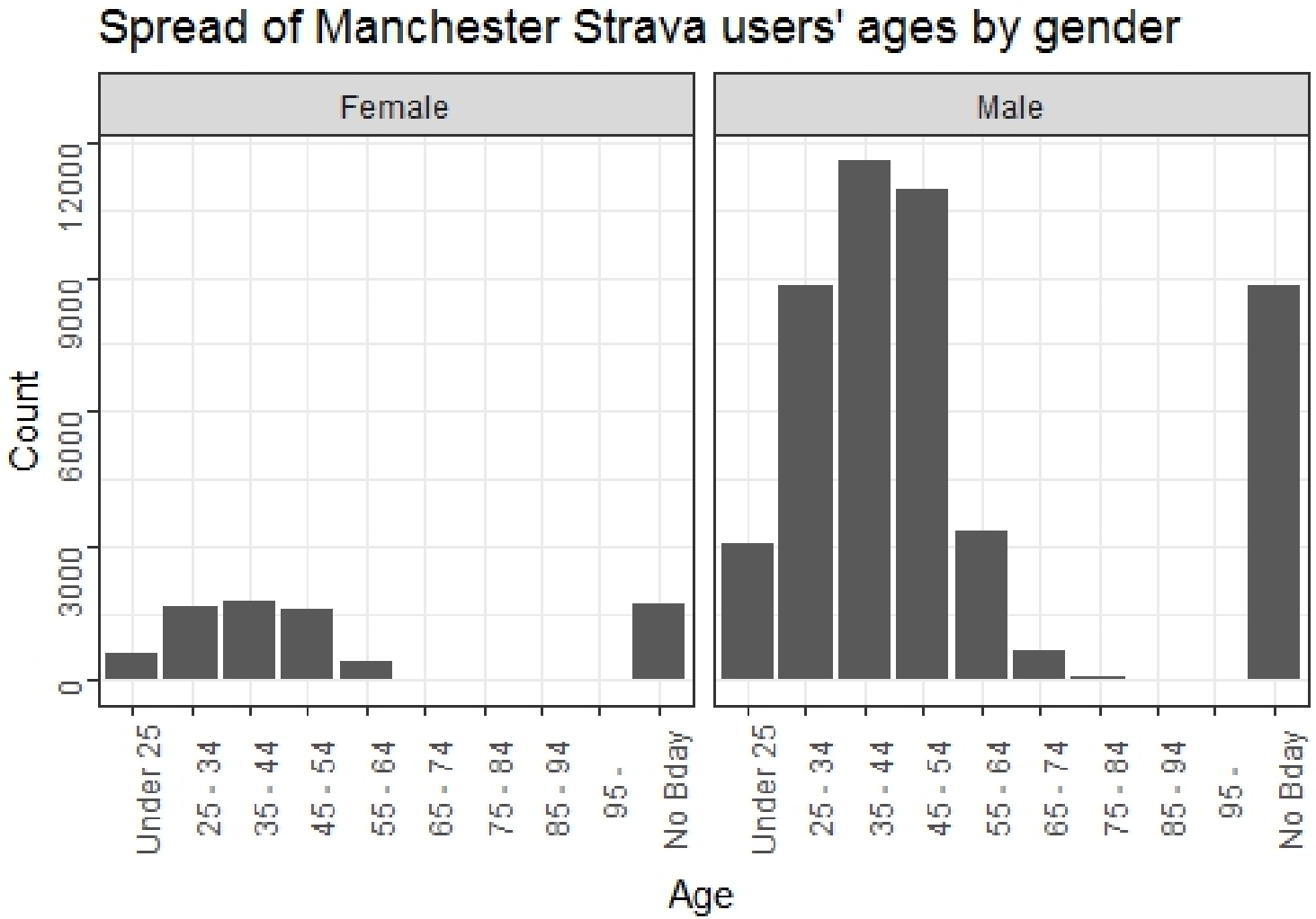











Stronger Prior

- Manchester Strava data has $\approx$ 100,000 roads and activity is only broken down into $\approx$ 100 time windows.
- We expect routes to be organized into $>>$ 100 clusters so need a strong prior for MAP problem to be well posed.
- Route length distribution worked well on smaller problem but won't be enough on full data set.
- Graph theoretic conditions: Basis vectors should be single connected components centred on a distinct path or cycle.
- Use known routes e.g. race routes and club rides to inform our choice of prior and validate our findings.

What affects the usage of these routes?



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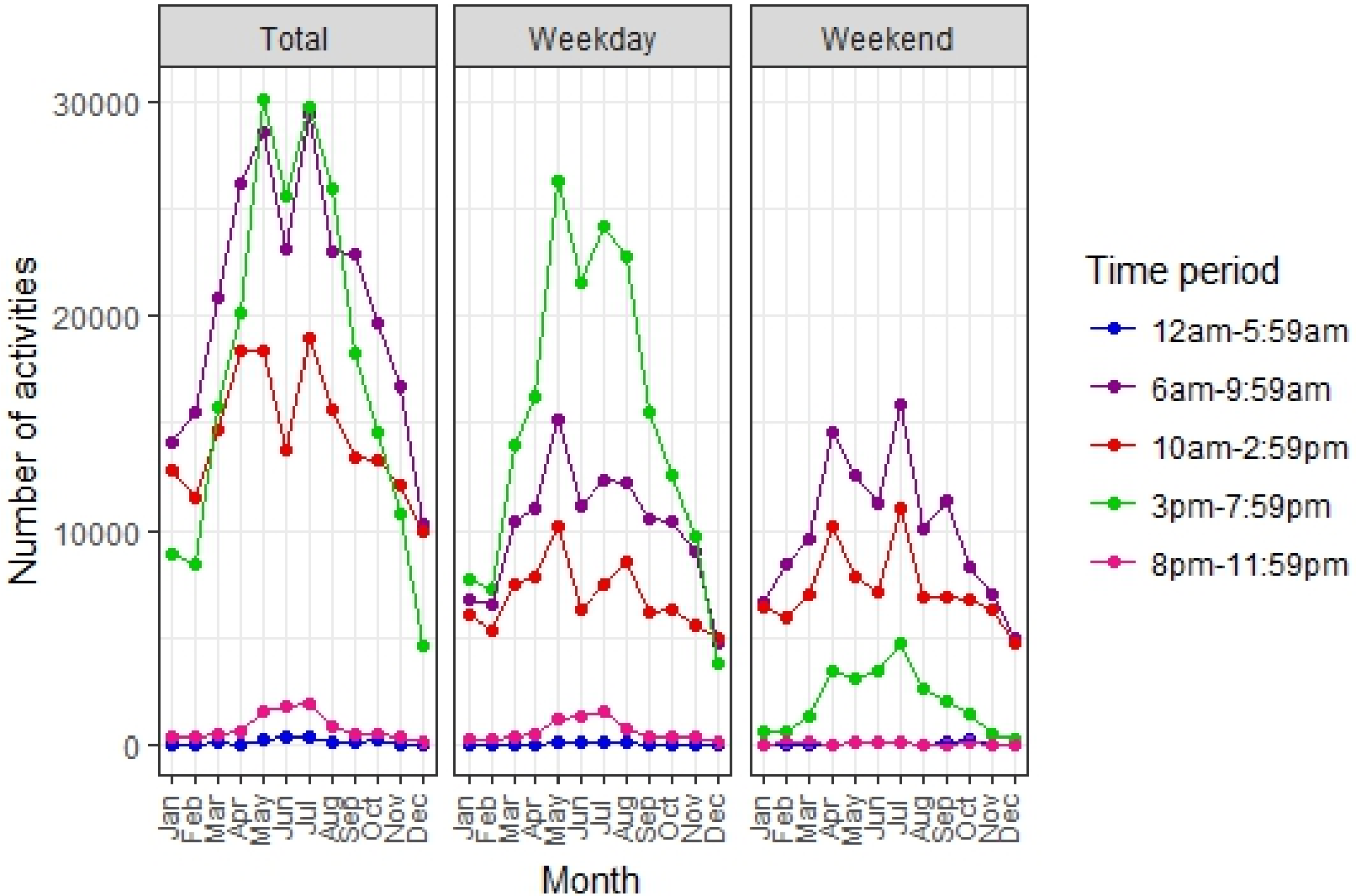

Conclusion

- Methodology works on toy problem.
- Could be applied to Strava data with a stronger prior.
- GIS software required to visualise routes.
- Could be applied to other problems with aggregated data.

Thanks!

Thanks for listening!
Any questions?