A Link-to-link Segment based Metamodel for Dynamic Network Loading

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Properties of DNL

- Purpose: calculate route travel times for a set of route departure rates.
- Requires Sequential Numerical Algorithm
- Little Parallelization Potential (Nava and Chiu, 2012)
- Bad Mathematical Properties (Szeto 2003, Song et al. 2016)
  - Discontinuity
  - No Closed Form Solution
  - Non-Differentiability
- Often Bottleneck of the TA Models

Kriging Type Metamodels

- Nonparametric, Interpolation Model
- Assumes Second Order Stationarity (Error is dependent on distance from data points and the decay relation is same all over problem domain)
- Assumes no fixed shape
- Operates with small dataset
- Smooth, continuous and infinitely differentiable

Objective

Explore a segment-based kriging type metamodel for dynamic network loading.

Sub-objectives:

- Increase efficiency
- Retain nice mathematical properties
- Design for low data availability

Link-to-Link Segment

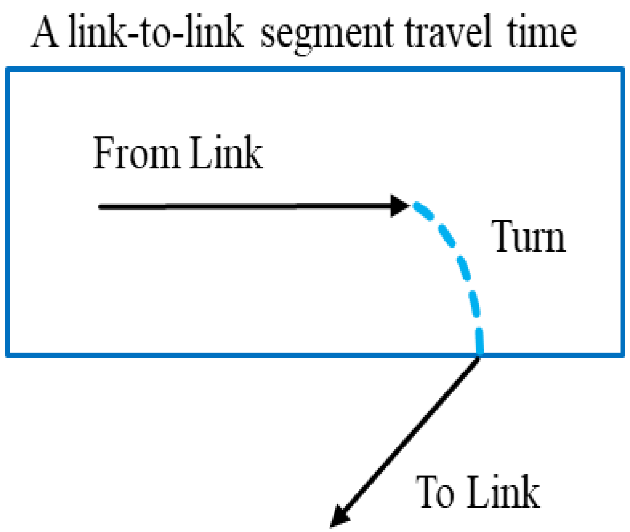


Fig: 1

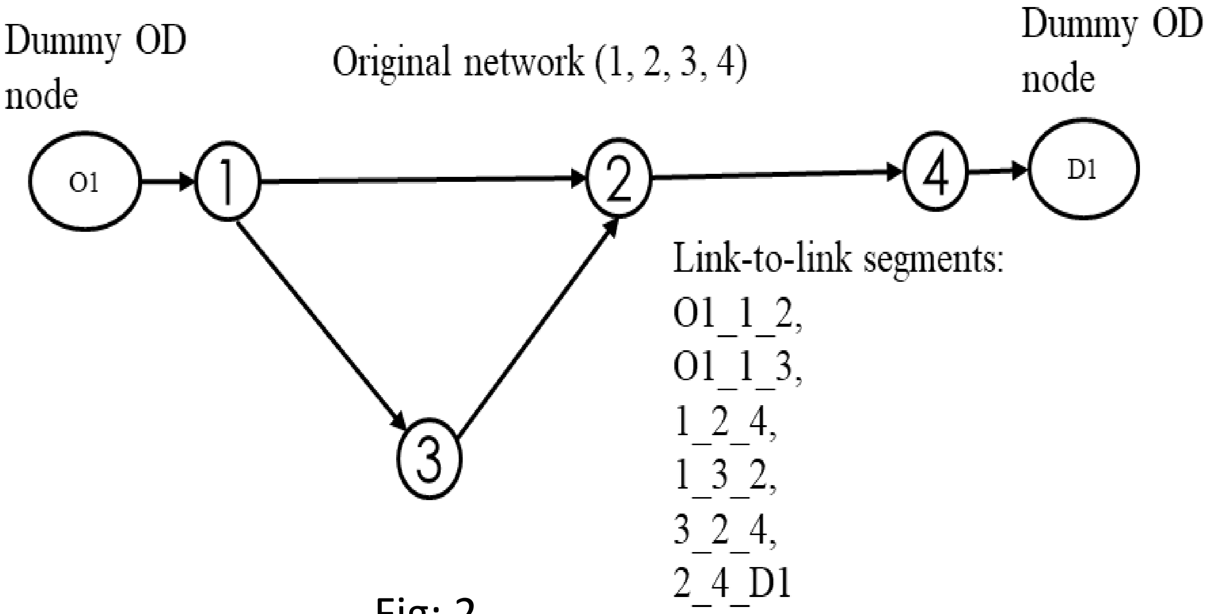
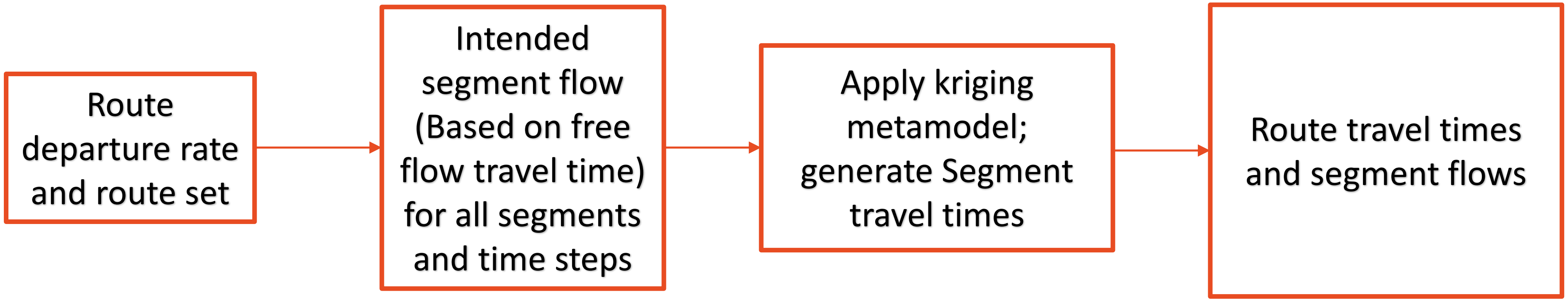


Fig: 2

The network is split into segments and time index

Schematics of the Kriging DNL



Kriging Model

Inputs :

- Intended segment flow for all segments and time indices
- Route segment weight
- Segment spatial proximity weight
- Time index proximity weight

Kriging Surface for each segment and time index (Gaussian Kernel)

Outputs :

- Segment travel time

Pass the total system information to each segment for parallel processing. Model is fitted using MLE.

$$T_{\lambda}^{t}(X) = m_{\lambda}^{t}(X)\beta_{\lambda}^{t} + \varepsilon_{\lambda}^{t}(X) \quad \text{----------------------(1)}$$

$$Cov\left(\varepsilon_{\lambda}^{t}(X_i), \varepsilon_{\lambda}^{t}(X_j)\right) = C\left(dist(X_i, X_j); \sigma_{\lambda,t}^{2}, \theta_{\lambda}^{t}\right) \quad \text{--------------(2)}$$

Numerical Analysis

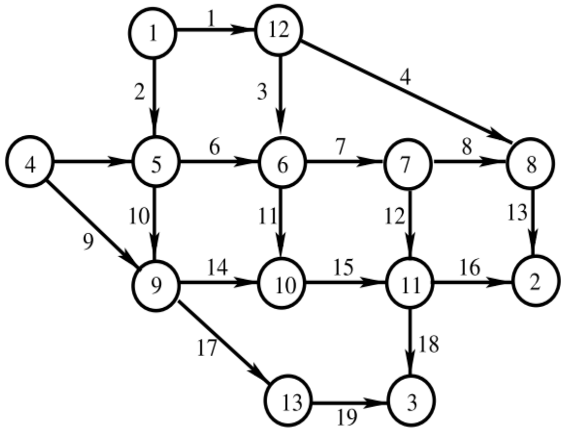


Fig: 1 ND network

33 Segments, 4 OD pairs

9 Time steps:

OD flows in 5 time-steps.

3 increasing, 2 decreasing, rest for flow dissipation

Dataset generated using MATSim (Horni et al, 2016)

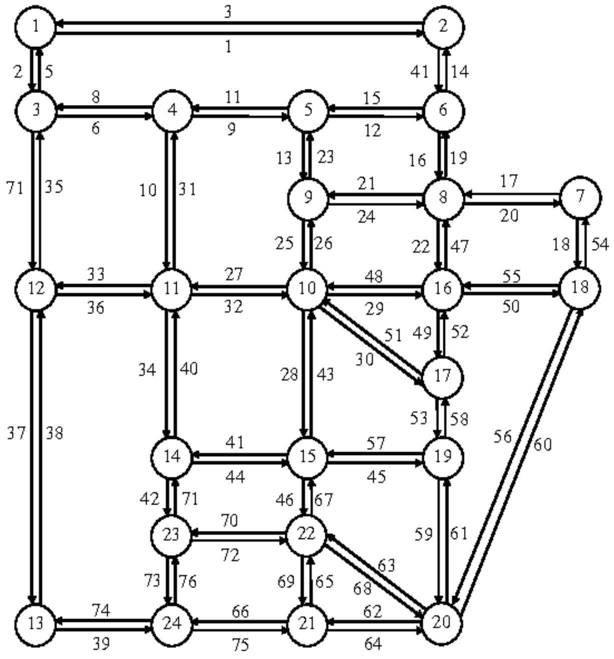


Fig: 2 Sioux Falls network

275 Segments, 12 OD pairs

Results

(ND Network) Method	Training Time sec	Testing Time sec (475 points)	Training Data Size	RMSE	MAPE	Speed Up Factor
NN	264.38	0.04	800	21.42	16.79	89786
Ordinary Kriging	517.31	8.22	800	6.68	1.64	404
BPR + Kriging	520.01	10.32	800	6.78	2.64	322

(SF Network) Method	Training Time sec	Testing Time sec (221 points)	Training Data Size	RMSE	MAPE	Speed Up Factor
NN	745.34	0.11	800	92.95	60.26	27477
Ordinary Kriging	1436.91	64.18	800	104.36	5.32	46
BPR + Kriging	1515.82	110.12	800	104.78	5.56	27

Result in Congestion

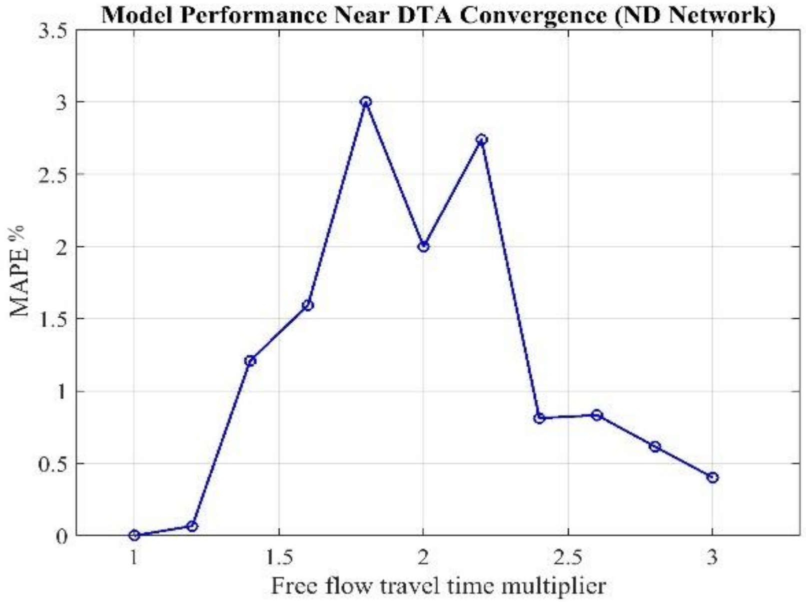


Fig: 1

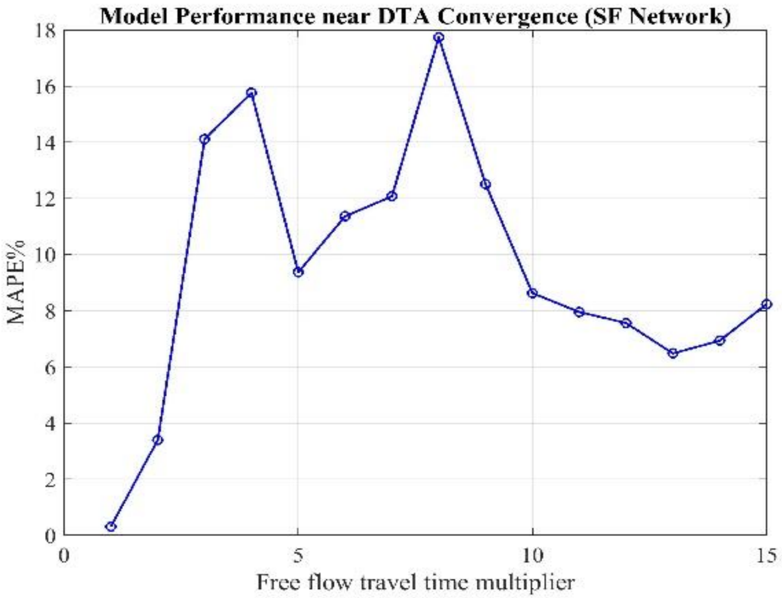


Fig: 2

Conclusion

- A link-to-link segment-based kriging metamodel for dynamic network loading was developed.
- Model was tested on ND and SF network.
- Perform better than neural network models.
- Model becomes expensive with large number of points.
- Congestion performance was reasonable in balanced network loading scenario.
- Future research includes addressing non-stationarity and developing a DNL specific kernel for improved prediction.

Selected References

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