Road Network Metric Learning for Estimated Time of Arrival

Yiwen Sun[1], Kun Fu[2], Zheng Wang[2], Changshui Zhang[1], Jieping Ye[2]

[1]Institute for Artificial Intelligence, Tsinghua University (THUAI),
State Key Lab of Intelligent Technologies and Systems,
Beijing National Research Center for Information Science and Technology (BNRist),
Department of Automation, Tsinghua University, Beijing, P.R.China

[2]DiDi AI Labs, Beijing, P.R.China

Background of ETA & RNML-ETA

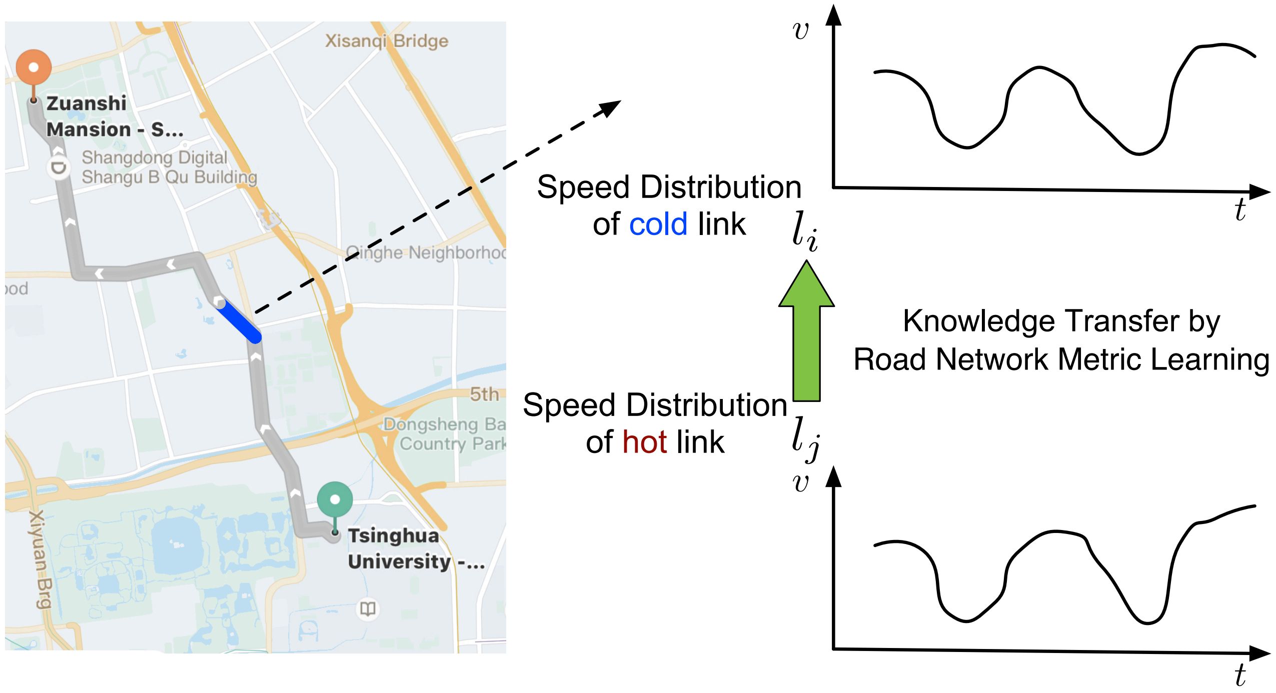

Fig.1. The conceptual demonstration of ETA & RNML-ETA.

- Estimated Time of Arrival (ETA): predicting the travel time from the origin to the destination along a given path.
- The route consists of a sequence of links → Embedding (key technique).
- The embedding suffers from the data sparsity problem of road network.
- RNML-ETA: Transfer the knowledge of hot links to the cold links by metric learning.
- The links' similarity is measured → speed distribution.

Overall architecture

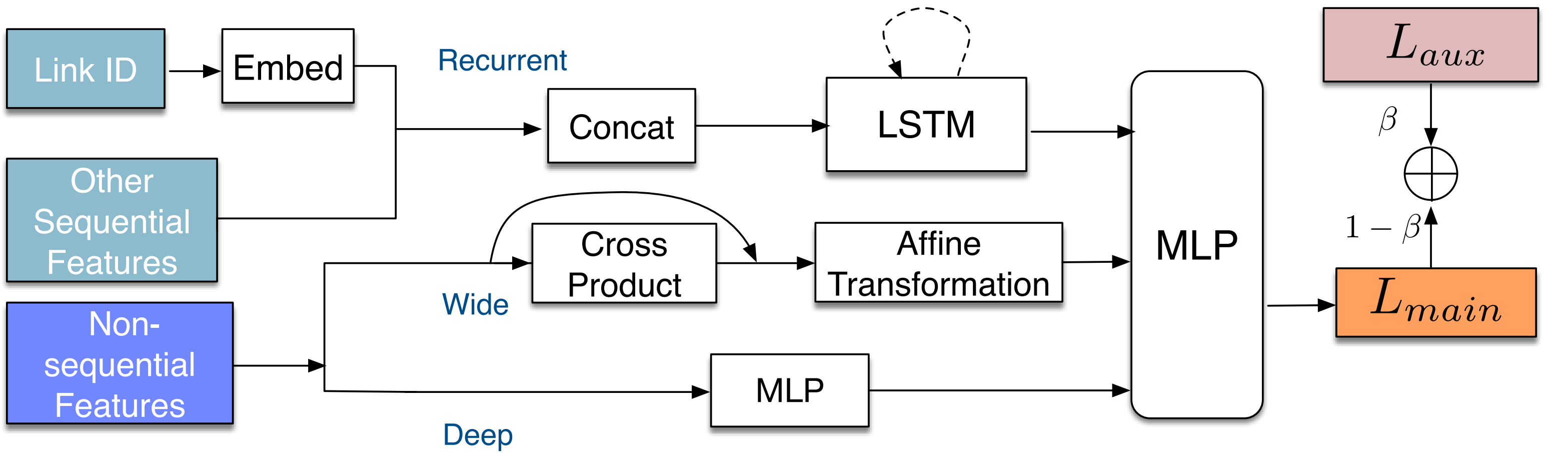

Fig.2. The overall architecture of RNML-ETA.

$$L = (1-\beta) \cdot L_{main} + \beta \cdot L_{aux}$$

(1) Main task: a Wide-Deep-Recurrent model to predict the travel time.

$$L_{main} = \frac{1}{N} \sum_{i=1}^{N} \frac{|y_i - y_i'|}{y_i}$$

(2) Auxiliary task: uses metric learning to transfer the knowledge from hot to cold links.

Link Similarity

- To statistic the average travel speed for link l and time bin τ_k

$$\bar{v}_k(l) = \frac{1}{Z} \sum_{i=1}^{N} \sum_{j=1}^{T_i} v_{ij} I_{s_i \in \tau_k} I_{l_{ij}=l},$$

$$Z = \sum_{i=1}^{N} \sum_{j=1}^{T_i} I_{s_i \in \tau_k} I_{l_{ij}=l},$$

- The normalized speed histogram of link l

$$\widetilde{\boldsymbol{v}}(l) = [\widetilde{v}_1(l),\ \widetilde{v}_2(l),\ \widetilde{v}_3(l)]^T$$

- The difference matrix for measuring the difference between links

$$Q_{ij} = Q_{ji} = \|\widetilde{\boldsymbol{v}}(i) - \widetilde{\boldsymbol{v}}(j)\|_2$$

Triangle Loss

- Without loss of generality, we assume the relationships among 3 difference matrices

$$Q_{l_i l_j} < Q_{l_j l_k} < Q_{l_i l_k}$$

- The Euclidean distances between the link embedding vectors

$$D_{l_i l_j} = \|\widetilde{\boldsymbol{E}}_L(:, l_i) - \widetilde{\boldsymbol{E}}_L(:, l_j)\|_2$$

- The triangle loss

$$L_{aux} = \frac{1}{U} \sum_{l_i, l_j, l_k} \Big(\gamma_1 \left[D^2_{l_i l_j} - D^2_{l_j l_k} + \alpha_1 \right]_+ + \gamma_2 \left[D^2_{l_i l_j} - D^2_{l_i l_k} + \alpha_2 \right]_+ + \gamma_3 \left[D^2_{l_j l_k} - D^2_{l_i l_k} + \alpha_3 \right]_+ \Big)$$

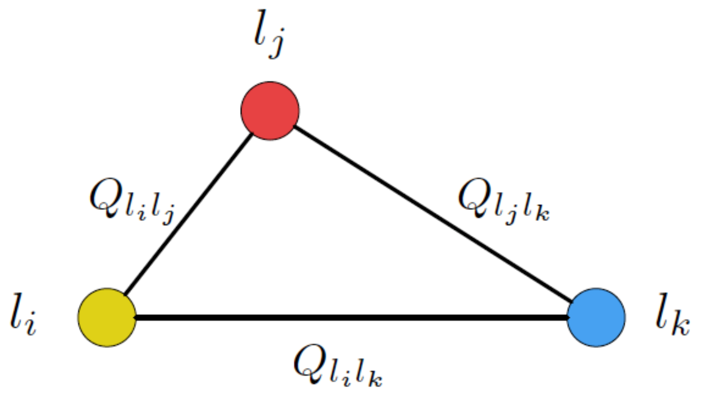

Fig.3. Visualized demonstration of distance triangle.

Dataset & Evaluation Metrics

TABLE I
STATISTICS OF DATASETS

	size	*pickup*	*trip*
training set	25 weeks	111.0M	105.5M
validation set	1 week	4.0M	4.5M
test set	1 week	4.1M	3.9M
# traversed link	-	1.2M	1.3M

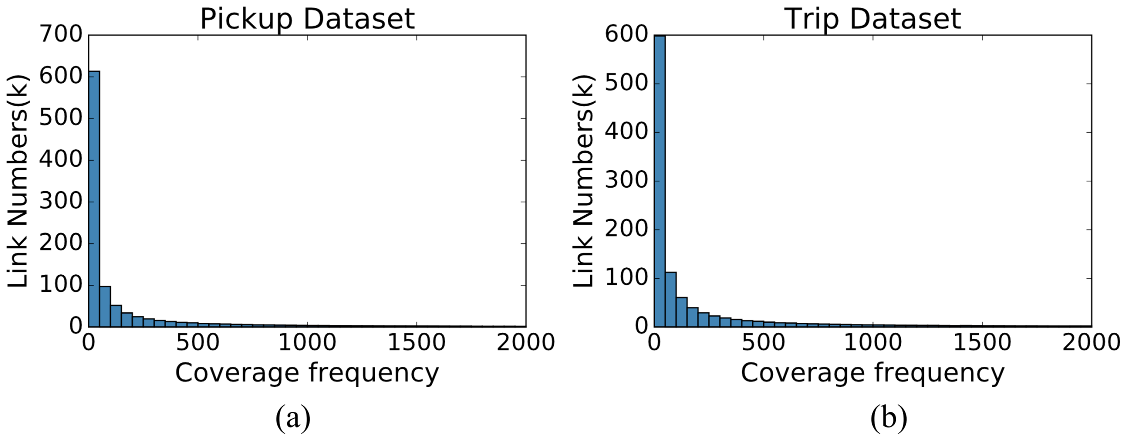

Fig.4. Statistics of link coverage frequency.

Mean Absolute Error

$$\mathrm{MAE} = \frac{1}{N}\sum_{i=1}^{N} |y_i - y_i'|$$

Rooted Mean Square Error

$$\mathrm{RMSE} = \left[\frac{1}{N}\sum_{i=1}^{N} (y_i - y_i')^2\right]^{1/2}$$

Experimental results

TABLE II
RESULTS OF THE PICKUP DATASET

	MAPE (%)	MAE (sec)	RMSE (sec)
Route-ETA	25.010	69.008	106.966
WDR-no-link-emb	20.845	59.018	95.876
WDR	19.386	54.686	89.976
RNML-ETA	**19.215**	**53.546**	**87.617**

TABLE III
RESULTS OF THE TRIP DATASET

	MAPE(%)	MAE (sec)	RMSE (sec)
Route-ETA	15.440	150.560	248.736
WDR-no-link-emb	12.742	117.337	197.652
WDR	11.737	108.919	186.083
RNML-ETA	**11.597**	**108.519**	**185.897**

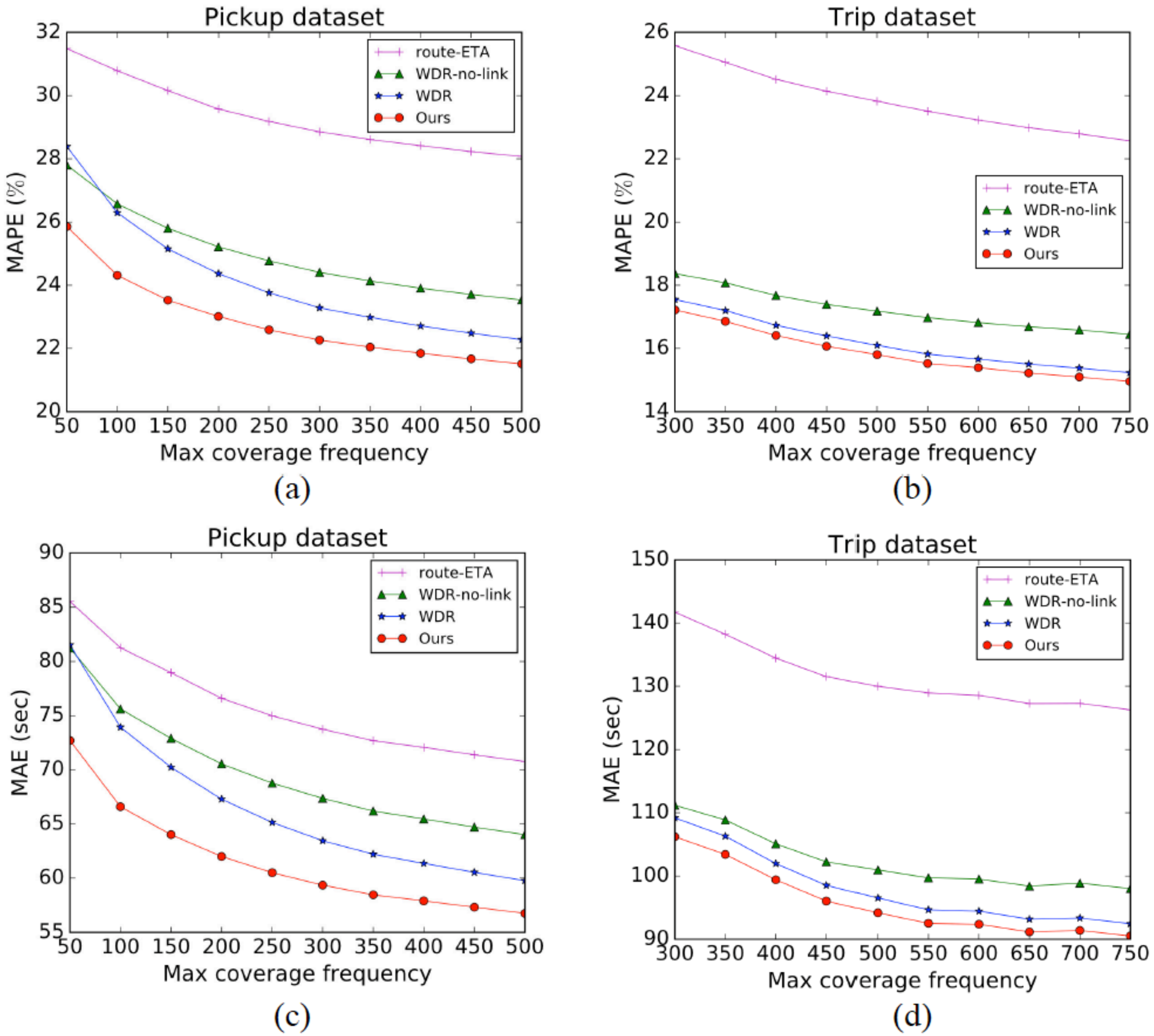

Fig.5. Results of the finer evaluation on subsets with different link coverage level.

Thank you for listening.