

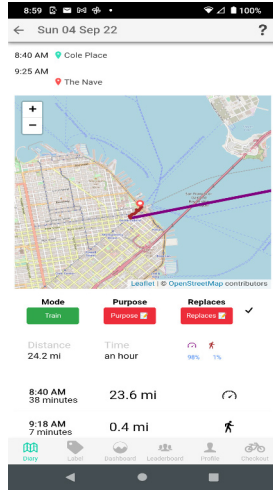
Count every trip: finding the uncertainty in energy estimates made from inferred travel modes

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Introduction

- Smartphones can record travel diaries
 - Users then label the mode and purpose
- Problem: People get tired of labeling
- Users only label ~38% of their trips
- Solution: guess (infer) trip modes using models
 - Need to know the uncertainty



OpenPATH app screenshot

“Count every trip” project goal: use all collected data with appropriate uncertainty

Methods

- Used existing OpenPATH mode inference model
- Used a public ground truth dataset (MobilityNet) to find uncertainty in:
 - Travel length
 - Inferred energy intensity
 - Get conditional mode probability from confusion matrix
 - Can use with other mode classifiers

- Energy consumption formula:
 - I is energy intensity
 - L is trip length in miles
 - D is the set of trips

$$E = \sum_{t \in D} I_t L_t$$

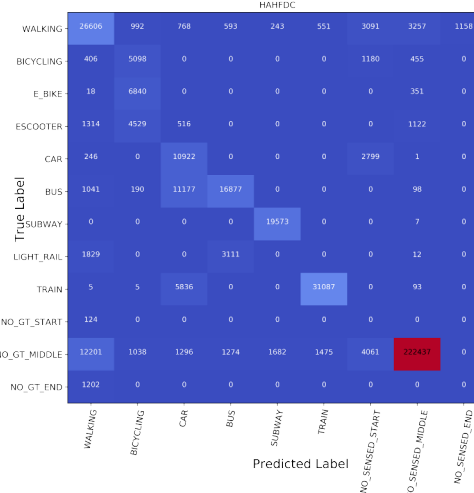
- Use variance propagation:
 - σ^2 represents variance
 - f is the energy consumption function

$$Var(E) \approx \sigma_I^2 \left(\frac{\partial f}{\partial I} \right) \mathbf{E}[(I, L)]^2 + \sigma_L^2 \left(\frac{\partial f}{\partial L} \right) \mathbf{E}[(I, L)]^2$$

Assumptions

- Mode error and length error independent
- Ignore energy model specification error
- Error in MobilityNet applies to other geographies
- Equal chances of drove alone and shared ride

Confusion Matrices for Inferred Output Data (GIS) on Phones Running ios



User Label	Proportion of labeled distance
shared_ride	0.4541
drove_alone	0.2452
pilot_ebike	0.1288
not_a_trip	0.0428
walk	0.0323
bus	0.0302
bike	0.0158
train_to_airplane	0.0107
train	0.0087
taxi	0.0064

Top 11 user labeled modes by distance proportion represented in CanBikeCO

Confusion matrix for the OpenPATH sensing algorithm on IOS using MobilityNet Data. Based on work by Kosmacher and Shankari.

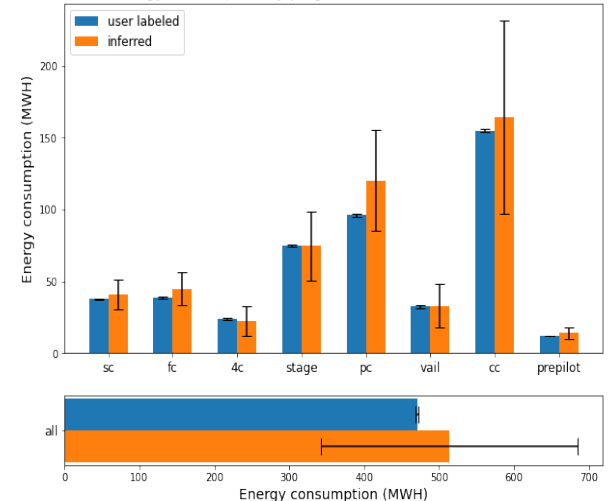
Evaluation

- Looked at 92k user labeled trips across multiple CanBikeCO programs and estimated energy consumption
- Estimated energy consumption for the same trips with *inferred mode labels*
- Estimated energy consumption variance
- Compared user labeled with inferred
 - 9% error overall
 - Each CanBikeCO program's total within 1 standard deviation (sd)
 - 85% of participant energy consumptions within 2 sd

Future Work and Relevance

- Apply methods to other mode inference models
- Find inferred mode proportion uncertainties
- Travel diary studies with less label burden
- Use data from updated travel patterns for behavior models

Cumulative energy consumption by program from user labels vs from inferred labels



Cumulative energy consumption by program with user labeled modes vs with inferred modes. Error bars show the estimated value plus or minus 1 standard deviation.