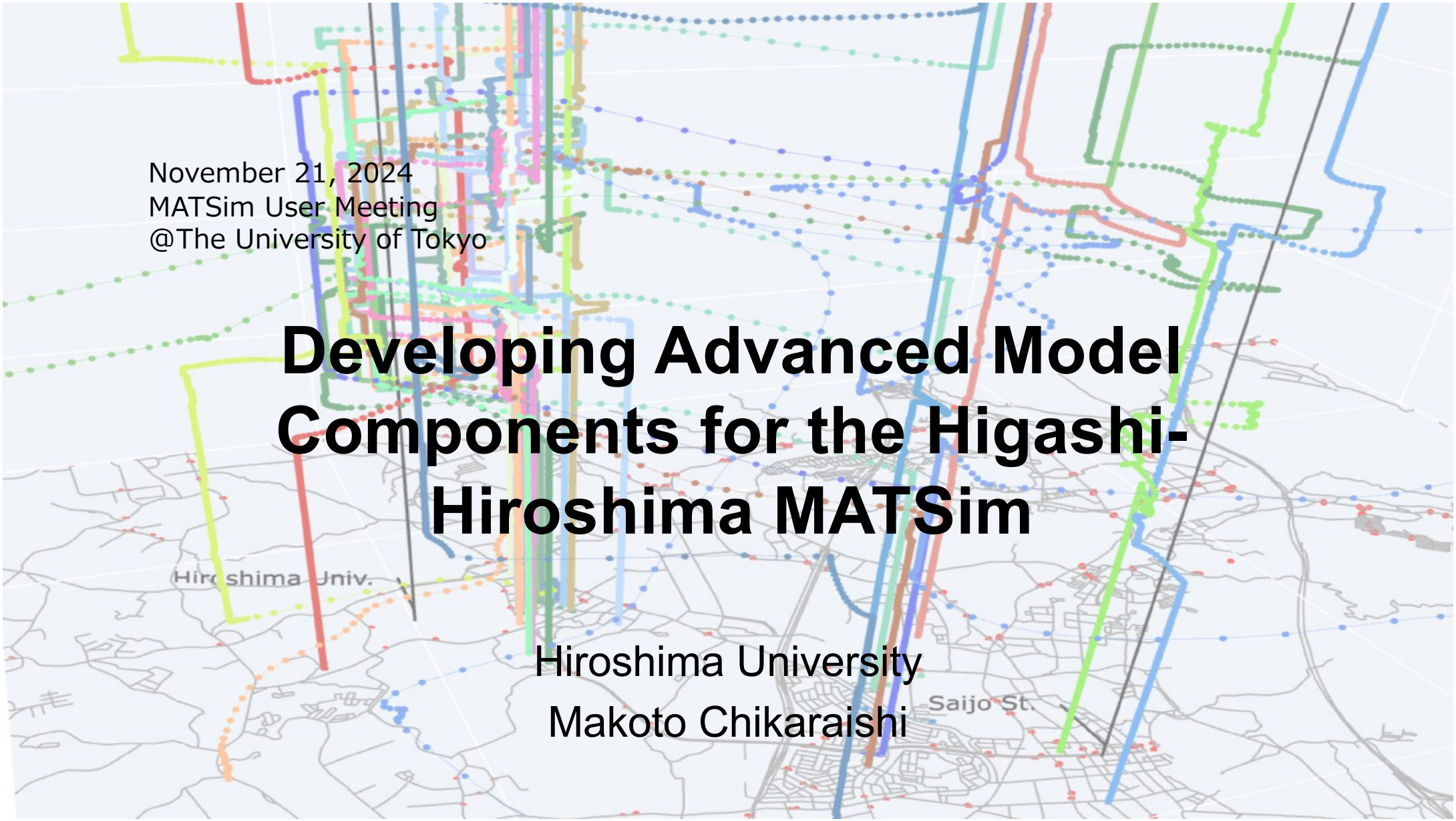


November 21, 2024
MATSim User Meeting
@The University of Tokyo

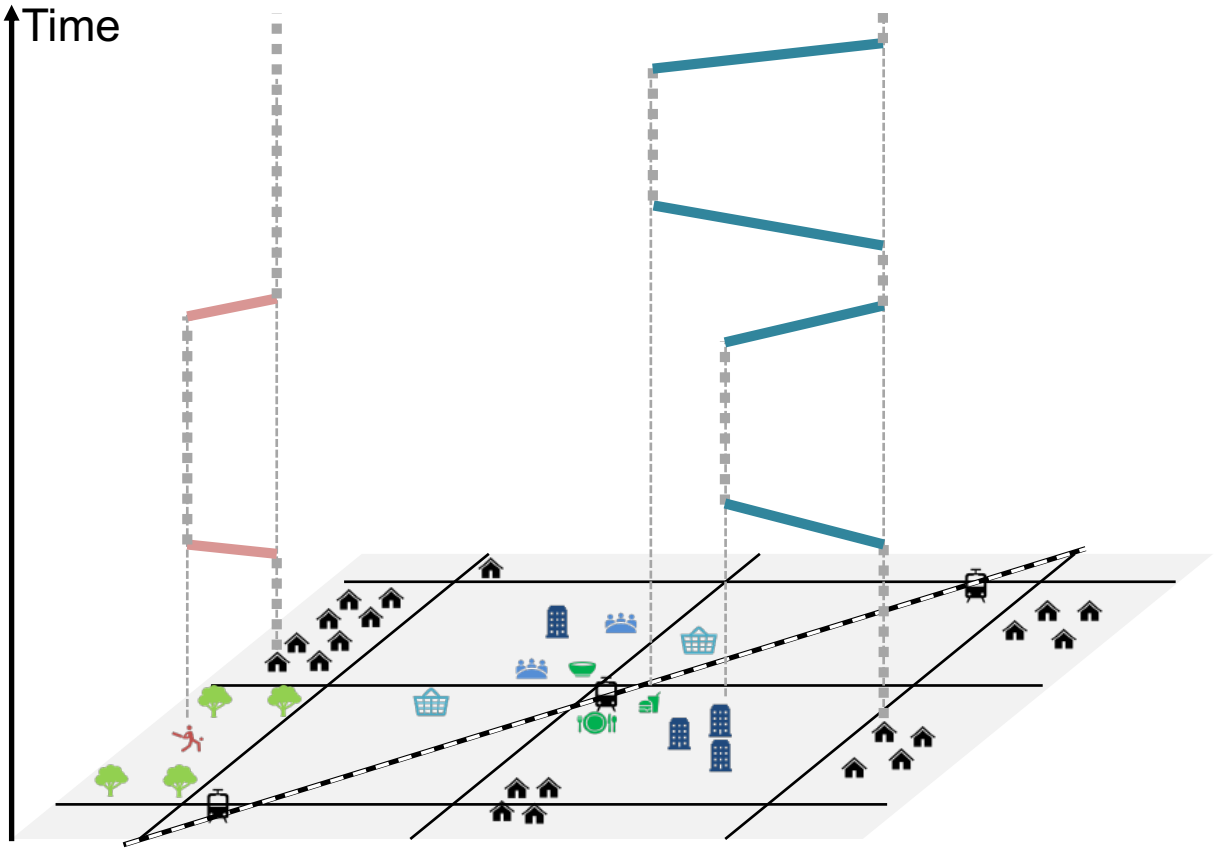
Developing Advanced Model Components for the Higashi-Hiroshima MATSim

Hiroshima University
Makoto Chikaraishi

Positive & Negative Impacts of Increased Mobility

- Hypermobility (Adams, 1999)
  - Increased environmental impacts, growing inequality, reduced children's freedom, decreased communication, cultural decline, reduced agglomeration effects, increased accident risks, etc.
- New Mobility Paradigm (Urry, 2007)
  - Global movement in physical/virtual space
  - Mobility as a key factor determining capability (network capital)
- Mobility Justice (Sheller, 2018)
  - Analysis of the Relationship between Mobility and Justice
  - Ethical Responsibility and the Importance of Fair Transportation Options

Trip-based approach

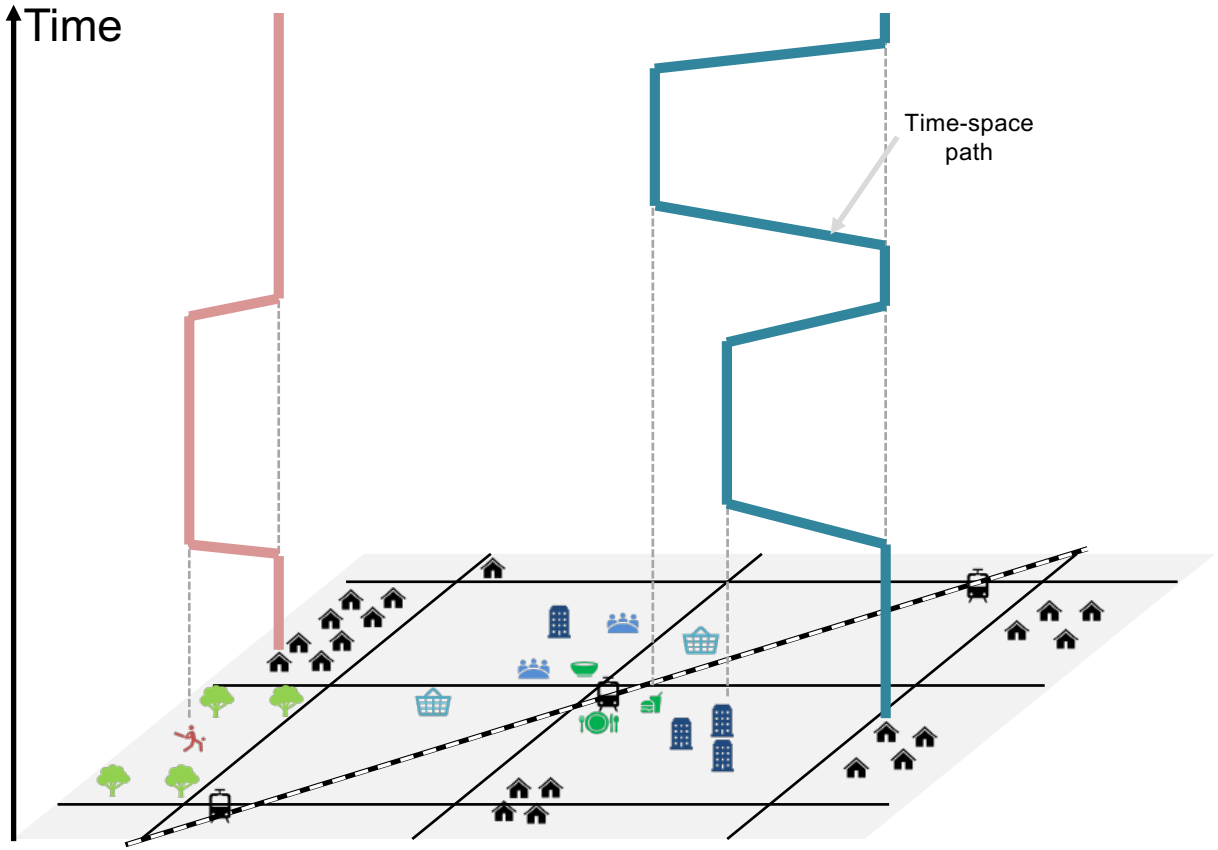


Urban and transport infrastructure

(When),
By which mode,
From where to where,
By which route

Model framework
✓ Four-step model
(or its variants)

Activity-based approach (Gen. 1)



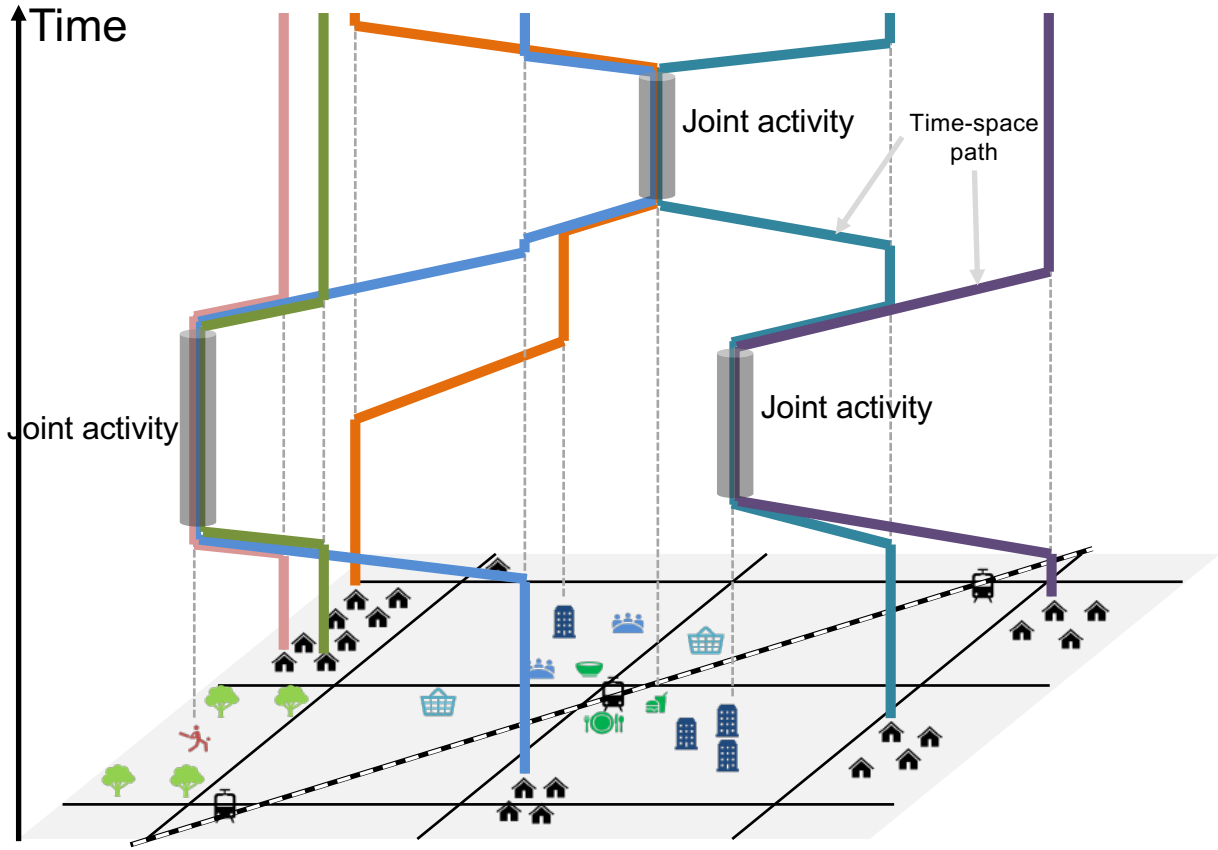
When,
By which mode,
From where to where
By which route

+ Scheduling constraints
  Activity utility
  Trip chain
  Lifestyle

(Focus on each individual's decisions)

Model framework:
- ✓ Constraints-based
- ✓ Utility-based
- ✓ Rule-based

Activity-based approach (Gen. 2)



When,
By which mode,
From where to where
By which route

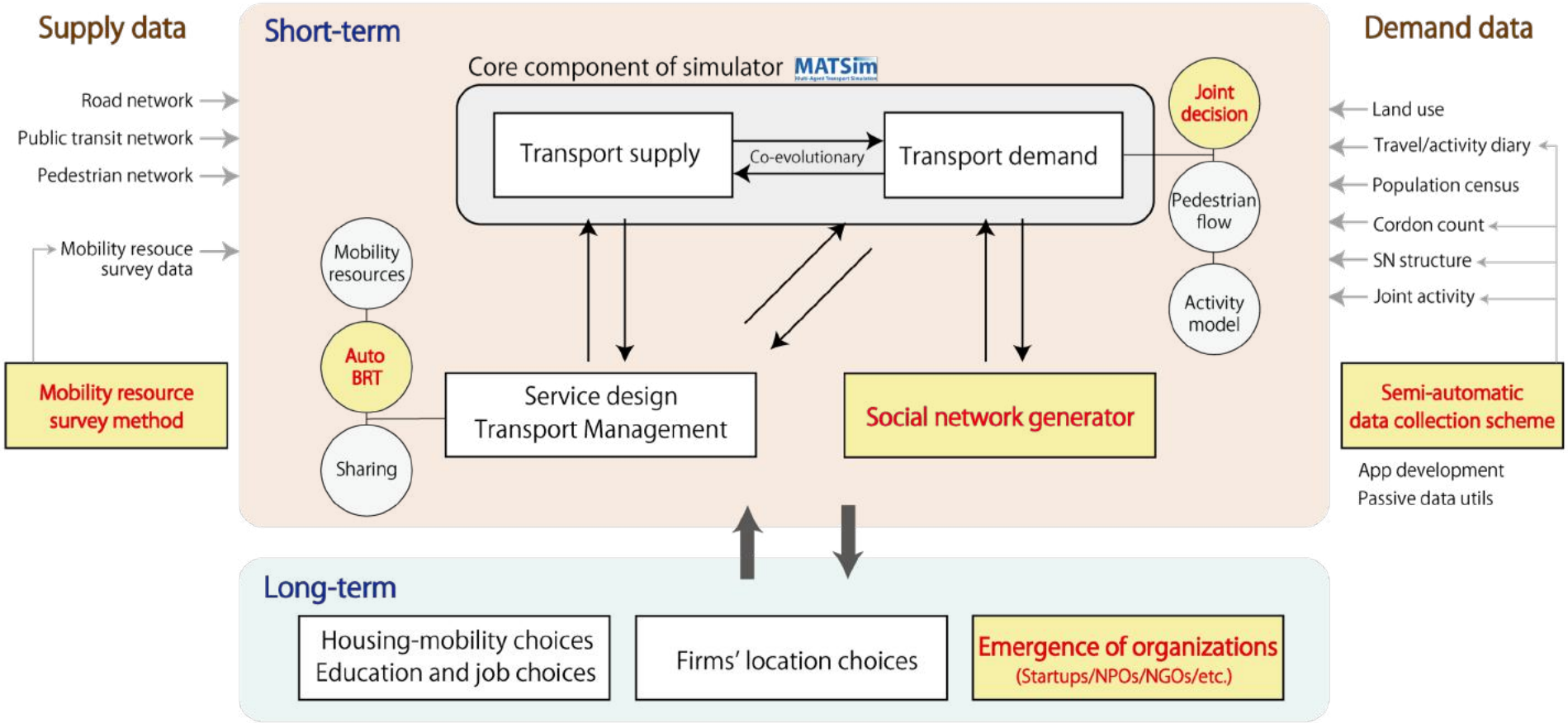
+ Scheduling Constraints
  Activity Utility
  Trip Chain
  Lifestyle

+ Social exchanges
  Forming social networks
  Emergence of
    collaborative behavior

Central focus:
how the society forms

HH Simulator

Embedding social aspects into the simulator

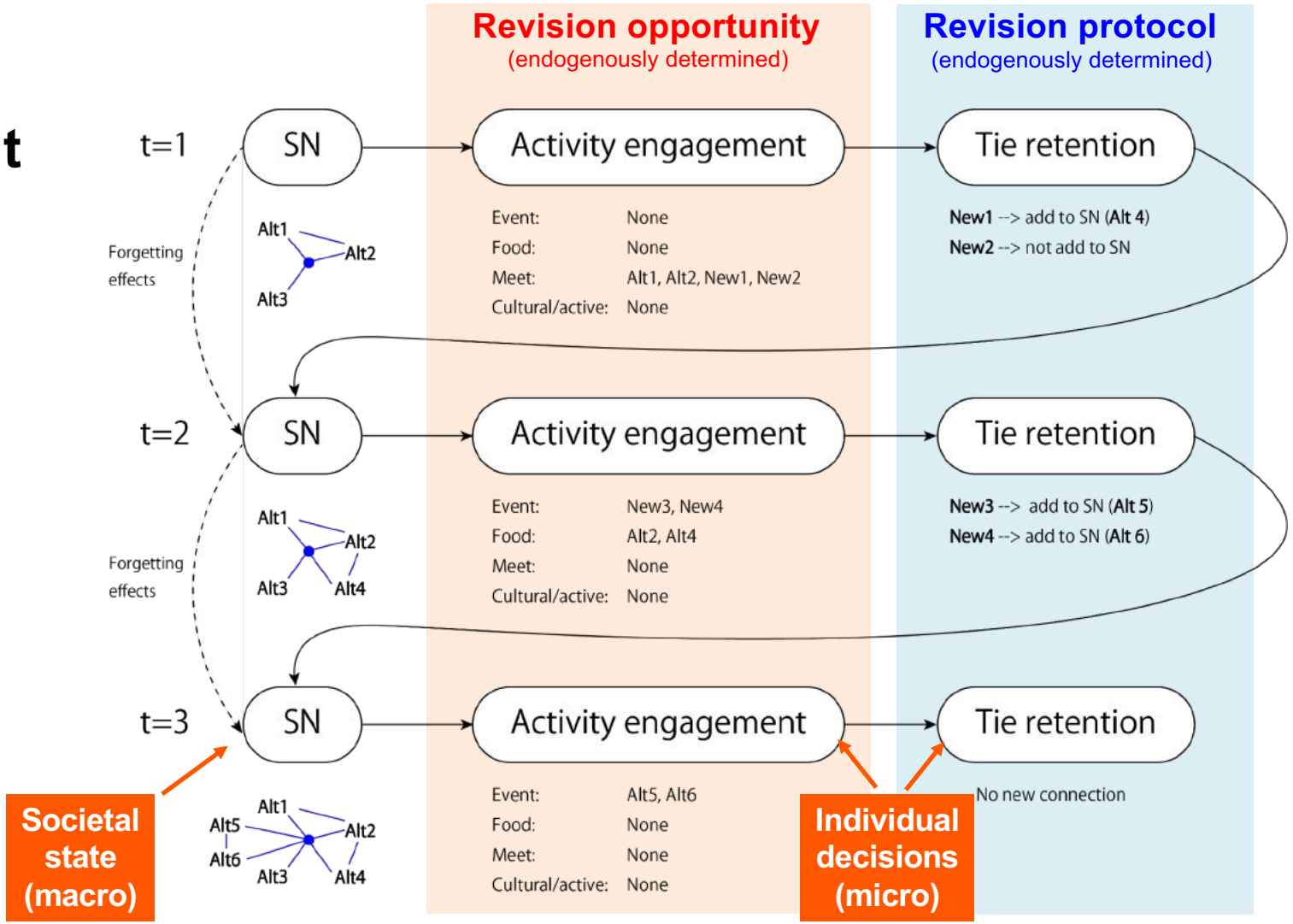


Co-evolutionary simulation of social network and activity engagement

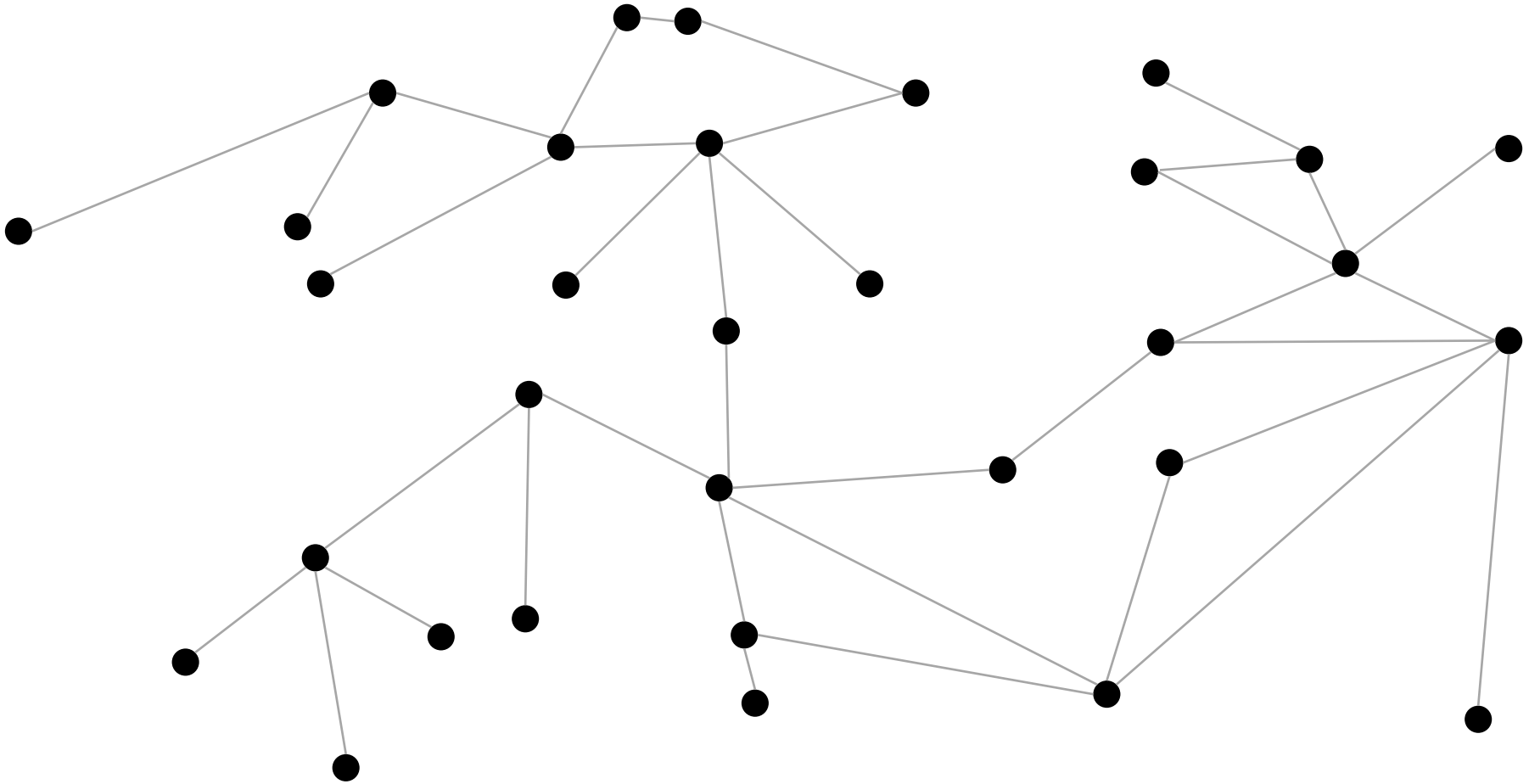
Makoto Chikaraishi,
Giancarlos Parady,
Noboru Harata, Swarnali Dihingia, Kiyoshi Takami

Submitted to Transportation
(IATBR special issue)

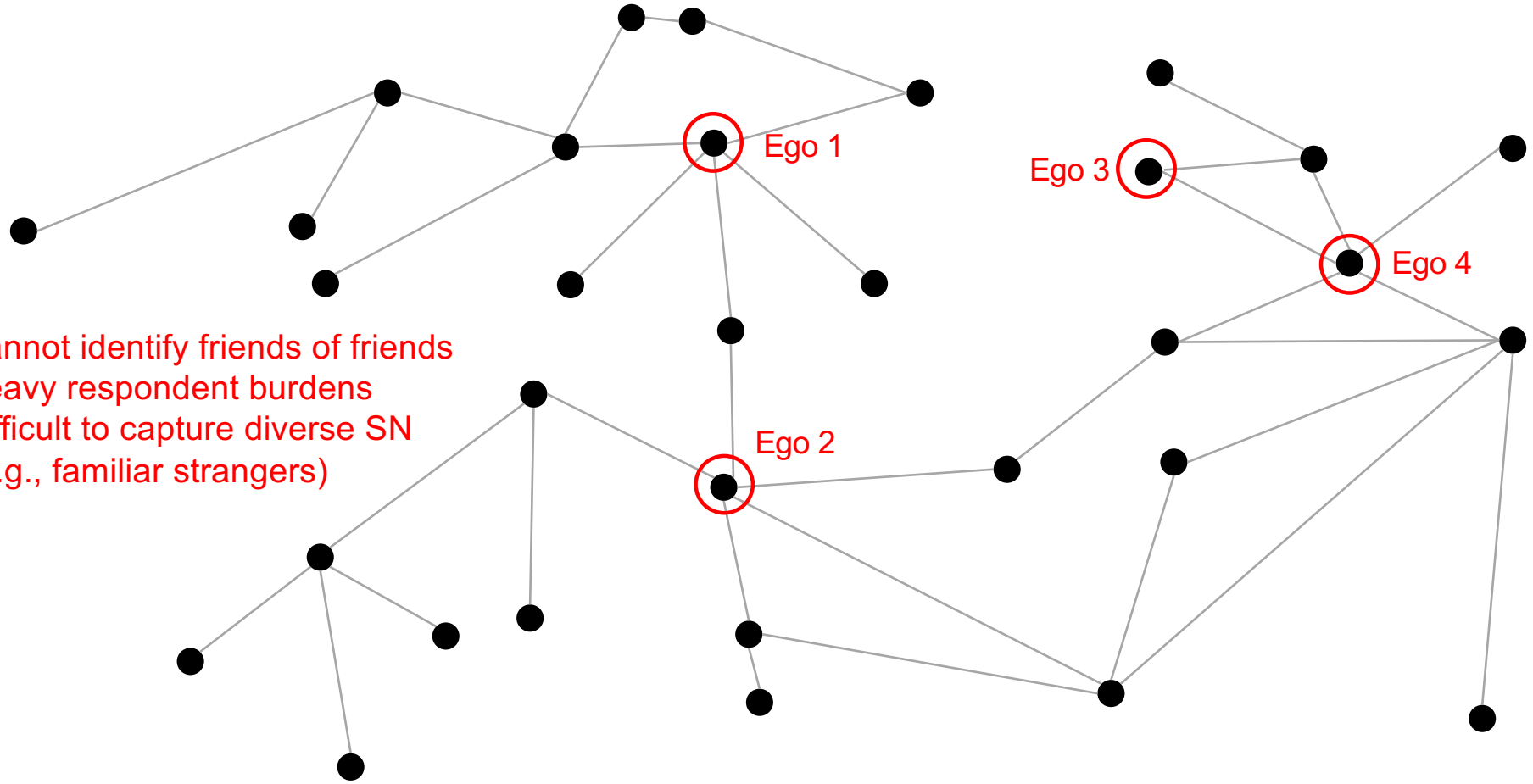
SN survey
+
Activity diary survey



Issues of ego-centric SN survey

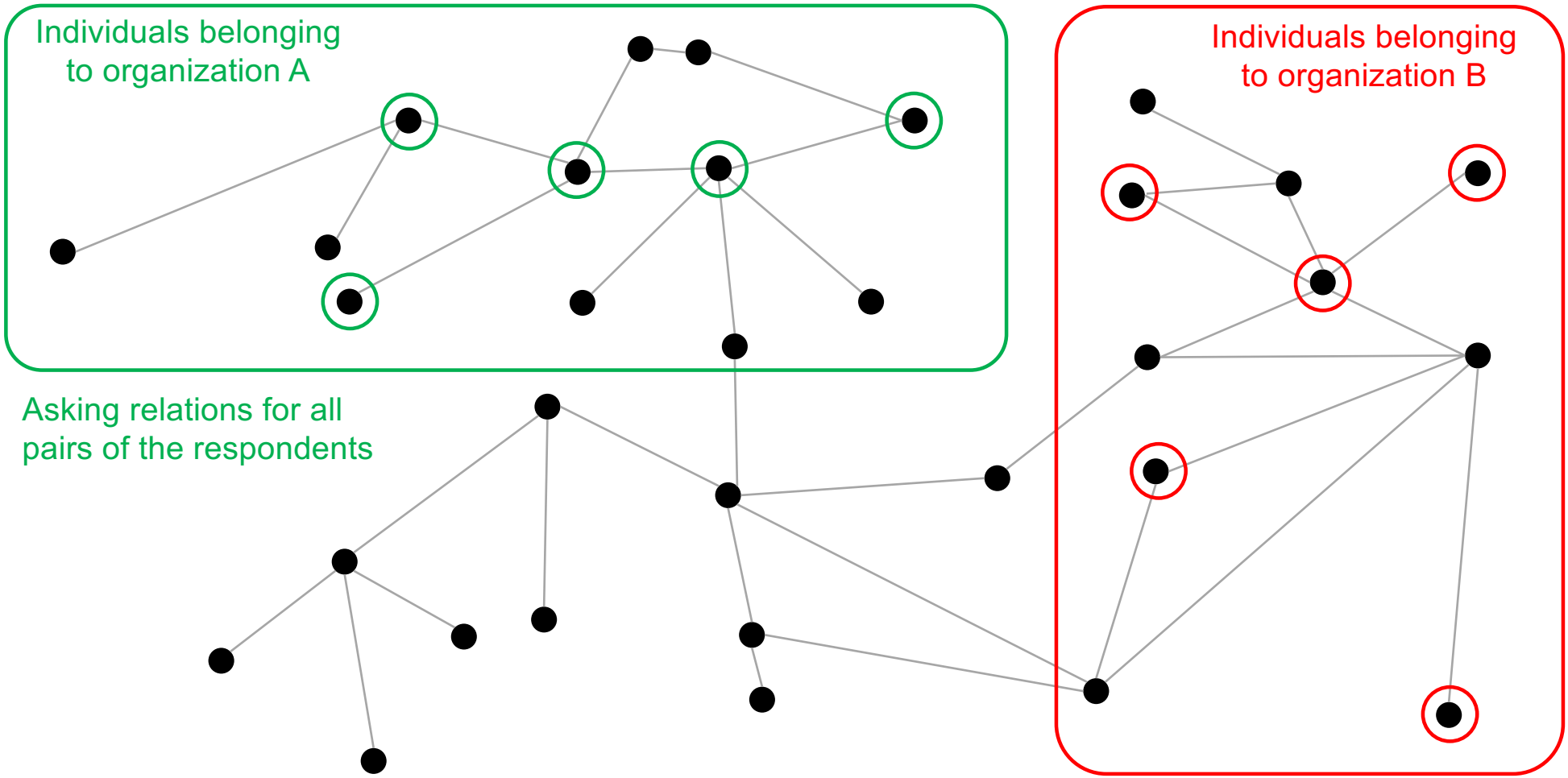


Issues of ego-centric SN survey



- ✓ Cannot identify friends of friends
- ✓ Heavy respondent burdens
- ✓ Difficult to capture diverse SN (e.g., familiar strangers)

Approach employed: cluster network-sampling



A TRIAL ESTIMATING SOCIAL RELATION STRUCTURE USING BEHAVIOR TRAJECTORY

Daisuke Kajiyama, Makoto Chikaraishi (Hiroshima University)

Observing various social relations

- **Social network: Social relation structure**
  - **Strong ties**: Trust, deep information exchange, long-term relationships
  - **Weak ties (Acquaintances)**: Diverse information exchange/diffusion
  - **Weak ties (Familiar strangers)**: Sense of belonging, feeling of security
- **Conventional SN observation methods**
  - **Focus on strong ties**
    - Observation of egocentric SN (Frei and Axhausen, 2007)
  - **Focus on weak ties**
    - Inference of SN using smart card data (Sun et al., 2013)
    - Observation of SN using mobile devices (Paulos and Goodman, 2003)

Little study has observed and inferred
diverse social networks ranging from weak ties to strong ties

Research objective

Propose a survey method to observe diverse social relations,
and a method to expand inference to populations using GPS data

1. Online survey to observe diverse social networks ranging from weak ties to strong ties
2. Method for estimating social network structure based on collocations (co-stay and co-move) obtained from GPS data

A method observing various social relations

- **Observe social networks between survey participants using online meeting tools:**
  - Participants report social relationships with other participants (from strangers to strong ties).
- **Advantages of proposed survey method**
  - Enables simple observation of diverse social networks including weak ties.
  - Allows observation of secondary connections by capturing social networks of all survey participants.
- **Challenges of proposed survey method**
  - As a sampling survey, requires careful consideration for inference to the entire population.
  - **Tentative Solution*:** Enable inference about social networks of large groups and entire regions from GPS trajectory data alone by developing algorithms to infer social networks from GPS movement trajectories.

* Currently assuming GPS data is available for all members of the target population. Planning to develop methods for expanding inference from sampling data to population in future studies.

SN survey using online meeting tools

Which of the following best describes your relationship with person X on the screen?

1. Strong tie / 2. Moderately strong tie / 3. Moderately weak tie / 4. Weak tie / 5. Stranger

Strength of relationship: Strong ⟷ Weak

	Strong tie	Moderately strong tie	Moderately weak tie	Weak tie	Stranger
Know their face	Yes	Yes	Yes	Yes	No
Know their name	Yes	Yes	Yes	No	No
Regularly communicate or engage in face-to-face activities together	Yes	Yes	No	Yes/No	No
Have at least one means of contact	Yes	No	Yes/No	Yes/No	No

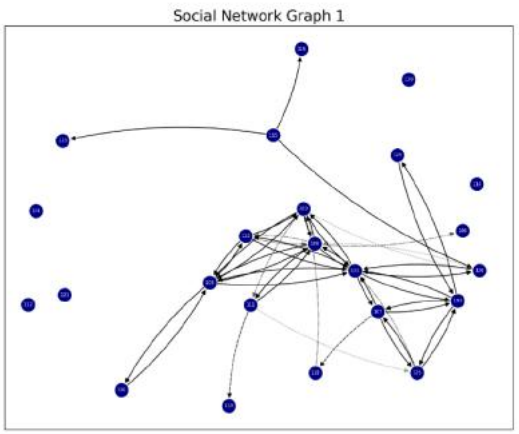
Survey summary

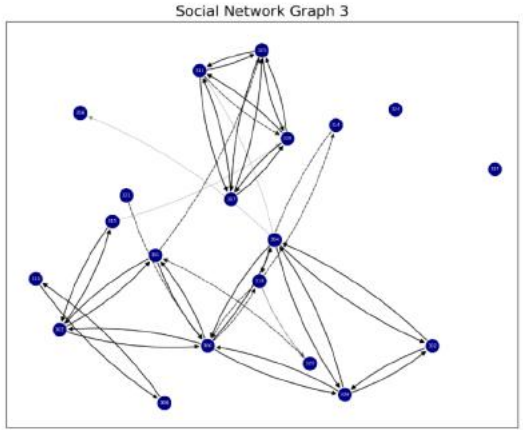
Target organization	Survey period (# of groups)	Collection of GPS trajectory data	Valid sample size
Hiroshima University	2023/11/1~2023/11/6 (7 groups)	From the online survey date to 2023/11/29 (minimum: 24 days)	154 persons
Fukken Co., Ltd.	2024/3/18~2024/3/21 (3 groups)	From the online survey date to 2023/4/19 (minimum: 30 days)	89 persons
Higashi-Hiroshima City	2024/3/19 (3 groups)	From the online survey date to 2023/4/19 (minimum: 32 days)	59 persons

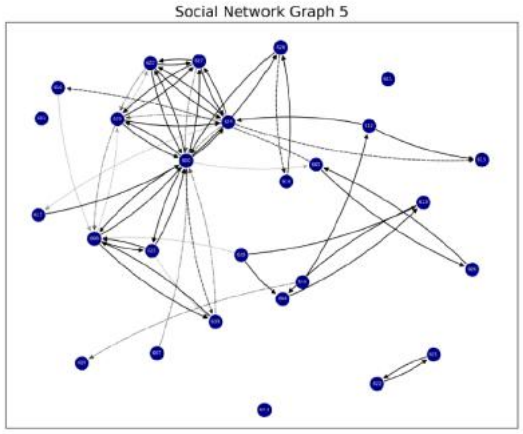
※ only present the results using data from Hiroshima University

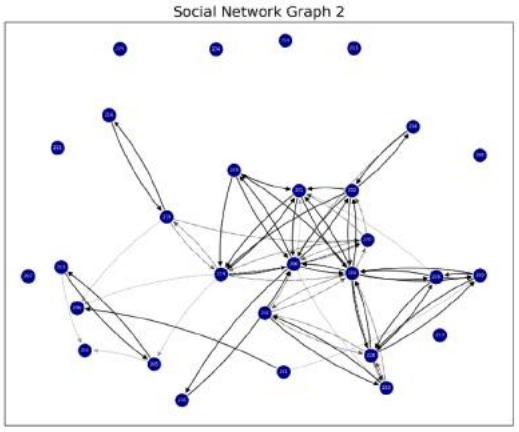
In each online SN survey, we had 17-29 participants (HU)

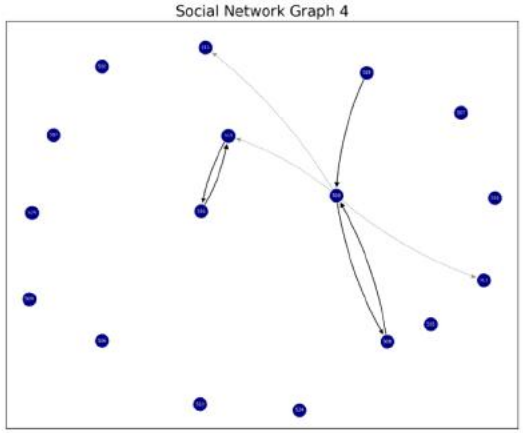
SN structure observed

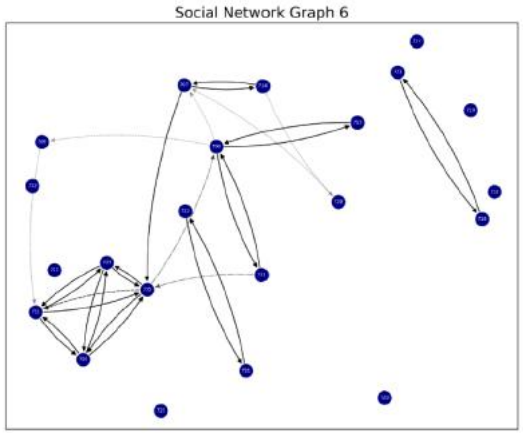












GPS trajectory（Moove Hiroshima）

調査参加者募集！

広島大学・交通工学研究室では，MaaS，スマートシティ，カーボンニュートラルの実現に向けた取り組みを加速するための解析プラットフォームの開発を進めています。開発に必要となるGPS移動履歴データを収集する調査にボランティアでご参加くださる方を募集しています。

調査への参加はこちらから：

https://forms.office.com/r/kVwtbRn3eX

リンク先の調査期間は10月10日からとなっております が，本チラシをお持ちの方は20日からご参加ください。

行動の観測期間は **2023年10月10日～11月9日**です。一部の期間のみでもご協力いただければ幸いです。

調査目的：本調査は，あいおいニッセイ同和損保と広島大学が共同で開発するアプリ「Moove HIROSHIMA」を用いて皆様のGPS移動履歴を取得させていただき，交通シミュレーションモデルの改善に役立てることを目的とした調査です。本交通シミュレーションモデルは，カーボンニュートラル達成に向けた種々の施策を検討するために利用することを想定しています。

調査内容：上記QRコードからフォームに回答いただいた後，アプリ「Moove HIROSHIMA」（iOS: https://apps.apple.com/us/app/moove-hiroshima/id6463923718; Android: https://play.google.com/store/apps/details?id=us.moove.MooveHiroshima）をインストールしていただき，日々の移動履歴を観測します。行動履歴の観測期間は2023年10月10日～11月9日ですが，一部の期間のみでもご協力いただければ幸いです。アプリをインストール後にしていただく操作は特段ございませんが，本アプリの位置情報の利用を常に許可してください。11月9日を過ぎましたら，アプリをアンインストールしていただき，調査終了となります。

注意事項：未成年（18歳未満）の方は本調査に参加できません。

調査実施期間中，いつでも同意を撤回し調査への協力を中止することができます。何かご不明な点やご質問がございましたら、問い合わせ先（E-mail: surveyhiroshima@ml.hiroshima-u.ac.jp 研究責任者:力石）までご連絡ください。

- # of unique users: **373** persons
- # of trip legs: **75,263** trip legs
- # of GPS points: **12,721,865** points

* Interval of GPS points: 30s

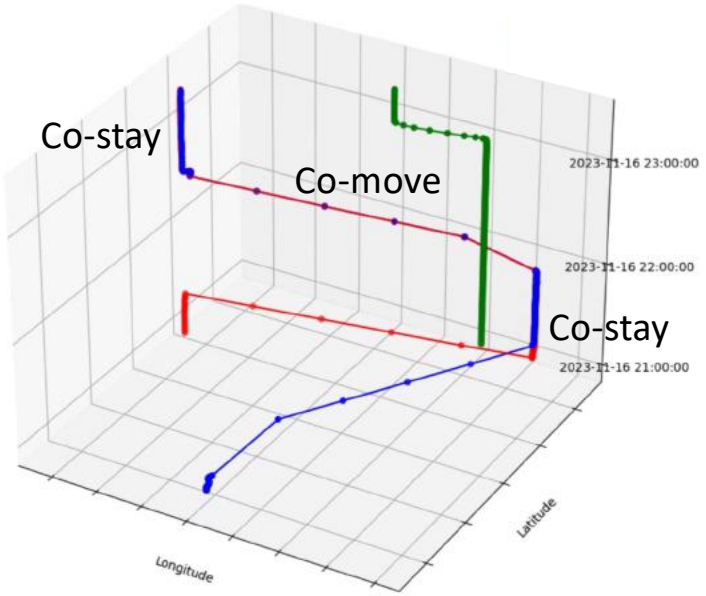
Estimating SN using co-move and co-stay

$$SN = f\ (co\text{-}move,\ co\text{-}stay)$$

- **Co-stay**: State where two people stay at the same place at the same time
- **Co-move**: State where two people move along the same space-time path
- f(): Decision tree (other model structures possible)

Example:

Red and **Blue** ⇒ Strong tie
Red and **Green** ⇒ Stranger
Blue and **Green** ⇒ Stranger



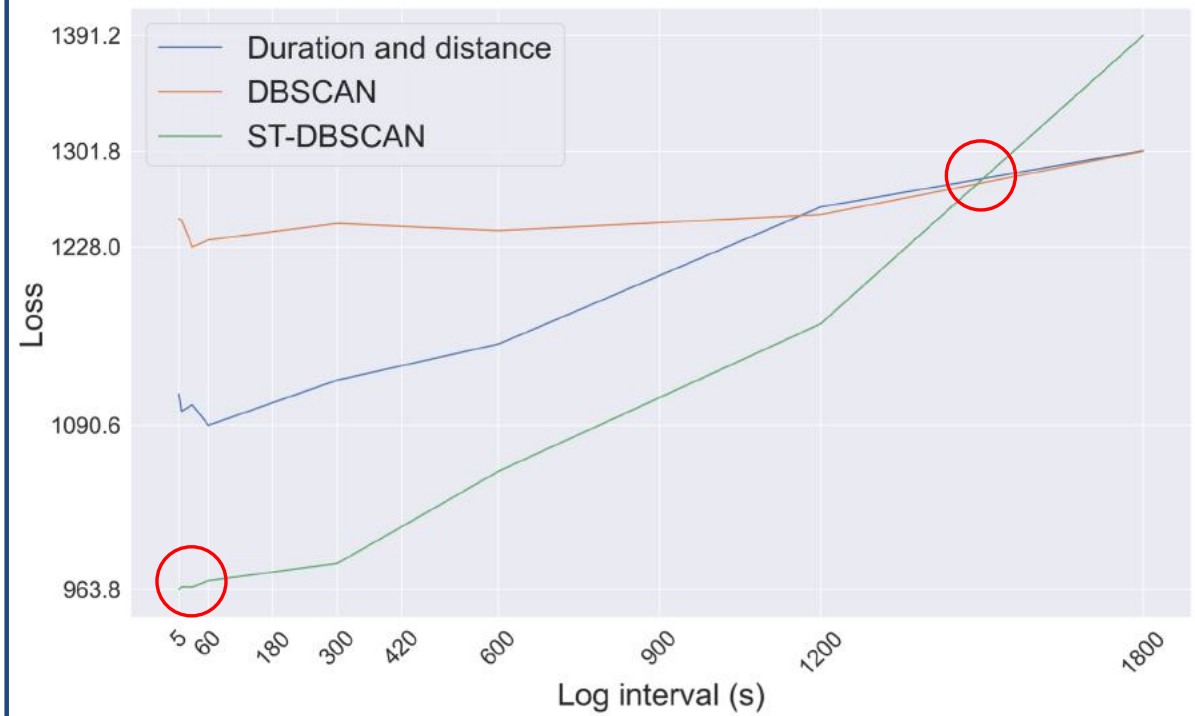
Process of estimating SN structure

- Step 1: Determine move/stay states from GPS trajectory data
  - Definition of movement/stay states need not follow the concept of “trip”
    → generate various move/stay states
    by tuning hyperparameters in ST-DBSCAN
- Step 2: Determine co-stay and co-move states
  - Co-stay and co-move states are algorithm-dependent
    → generate various co-move/co-stay states by tuning
    hyperparameters in the identification process
- Step 3: Estimate social network structure
  - Impact of co-stay and co-move on social network structure is likely nonlinear → use decision tree

Determine move/stay states

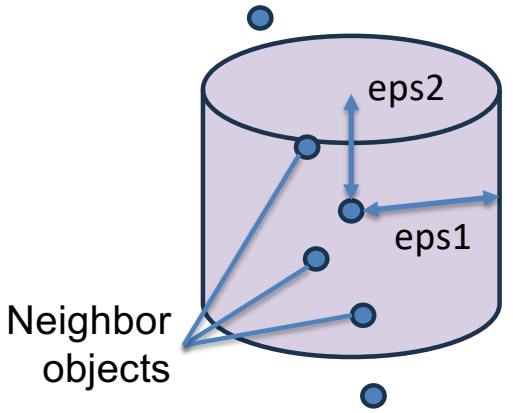
ST-DBSCAN: Spatial-Temporal Density-Based Spatial Clustering of Applications with Noise

Kato et al. (2024)



Step 1

ST-DBSCAN



1. Hyperparameters:

- Spatial distance threshold (**eps1**)
- Temporal distance threshold (**eps2**)
- Minimum number of samples required to identify a core object (**min_samples**)

2. Algorithm Steps:

- **Step 1**: Compute the spatial and temporal distances between each object. Define objects that satisfy both the spatial distance (eps1) and the temporal distance (eps2) thresholds as “neighbor objects.”
- **Step 2**: If the number of neighbor objects exceeds min_samples, designate the object as a core object.
- **Step 3**: Include all neighbor objects of core objects in the same cluster.
- **Step 4**: Objects that are not part of any cluster are considered noise.
- **Step 5**: If the neighborhood of a core object contains another core object, recursively include the neighbor objects of the latter in the same cluster.

Move/stay with different hyperparameters

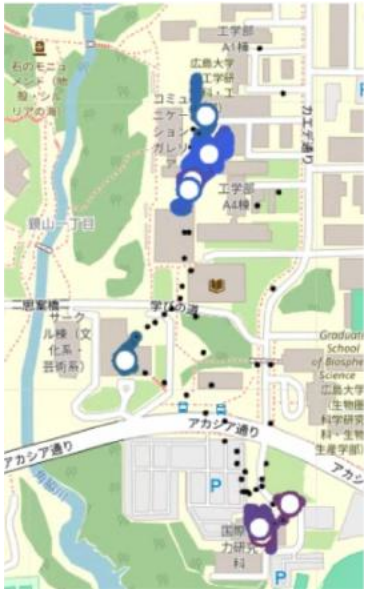
Move/stay algo.1 :
eps1: 0.005
eps2: 600
min_samples: 36

Ignore building-level stays

Move/stay algo.2 :
eps1: 0.00069
eps2: 1100
min_samples: 18

Identify building-level stays

Move/stay algo.3 :
eps1: 0.00012
eps2: 300
min_samples: 8



Identify moves in the same building (1)

Move/stay algo.4 :
eps1: 0.00001
eps2: 300
min_samples: 4

Identify moves in the same building (2)

Move/stay algo.5 :
eps1: 0.00001
eps2: 400
min_samples: 2

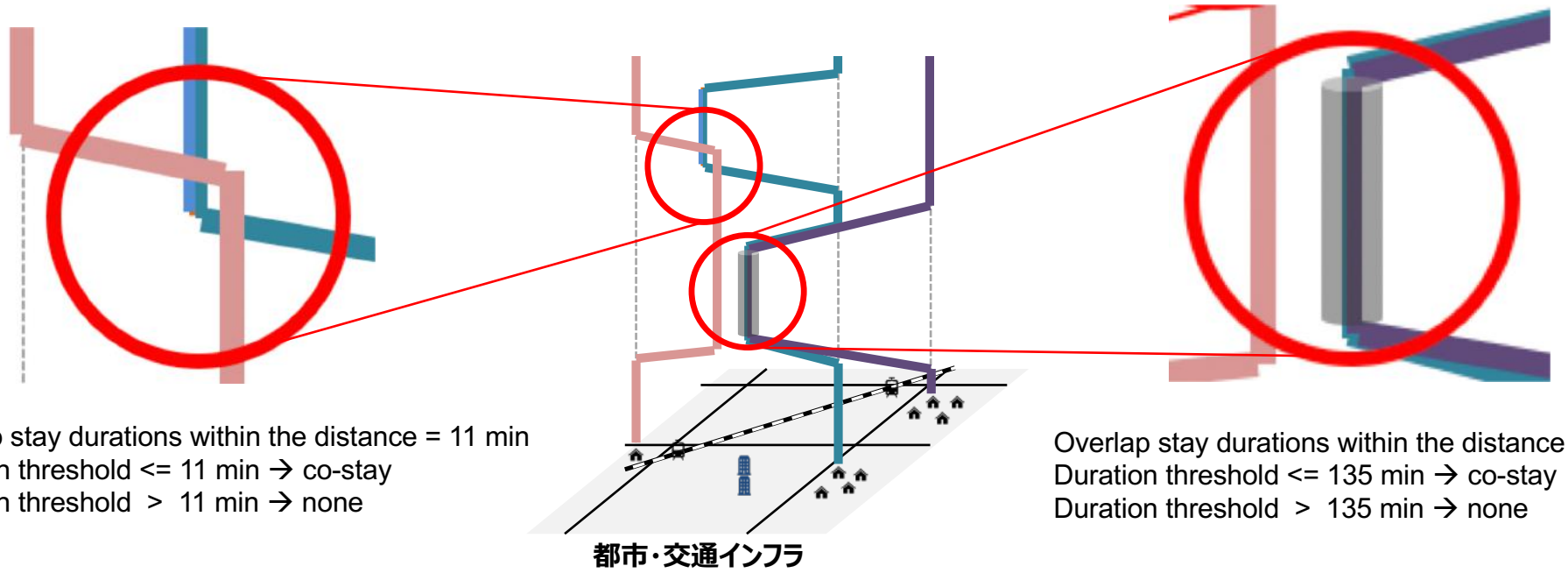
Identify moves in the same building (3)

Move/stay identification results

	Av. # of stays per day	Av. stay duration (min)	Av. # of moves per day	Av. travel time per move (min)
Move/stay algo.1	3.45	384.05	3.16	12.41
Move/stay algo.2	5.64	230.13	5.15	11.74
Move/stay algo.3	9.66	130.79	8.76	10.32
Move/stay algo.4	39.22	29.07	41.58	5.52
Move/stay algo.5	90.93	14.67	46.54	3.47

Identification of co-stay

- Co-stay is determined when two individuals' stay durations overlap for more than the duration threshold (1 min, 5 min, 10 min, 30 min, 60 min, 360 min) and their stay locations are within the distance threshold (30m)



Overlap stay durations within the distance = 11 min
Duration threshold <= 11 min → co-stay
Duration threshold > 11 min → none

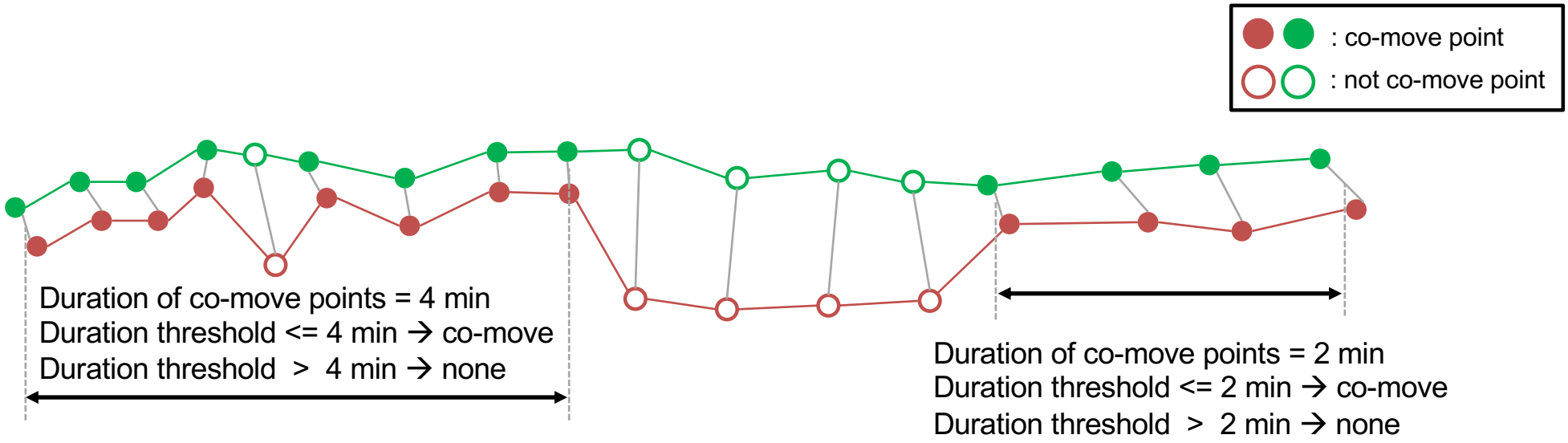
Overlap stay durations within the distance = 135 min
Duration threshold <= 135 min → co-stay
Duration threshold > 135 min → none

Step 2

Identification of co-move

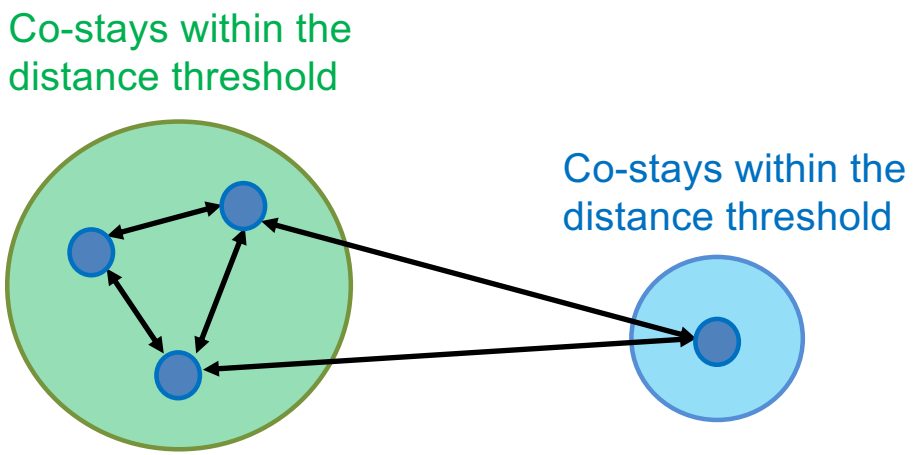
- When GPS points of two individuals are recorded at the same time and within 30m of each other, their centroid is defined as a co-move point. Co-move is determined when the continuous duration of co-move points (movement time) exceeds the threshold (1 min, 5 min, 10 min, 30 min, 60 min, 360 min).

*1 Time points are considered simultaneous when rounded observation times (to 30-second intervals) of two individuals exactly match.
*2 Continuity is determined when the next co-move point appears within 1 minute of the previous point.



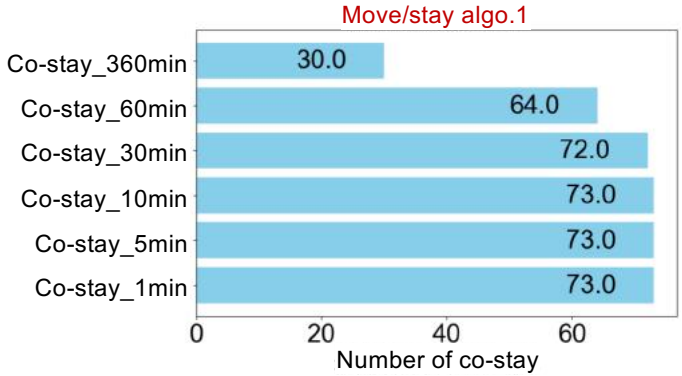
Counting # of co-stays at different places

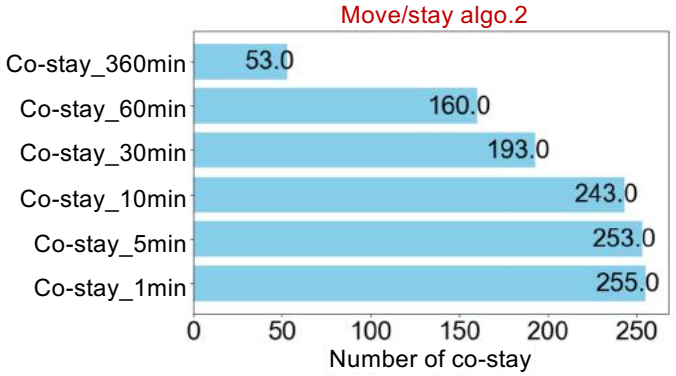
- Count # of locations where co-stay occurred between two individuals.
  - Locations are considered the same co-stay place when the distance between points is within the distance threshold (10m, 100m, 1000m, 10000m).

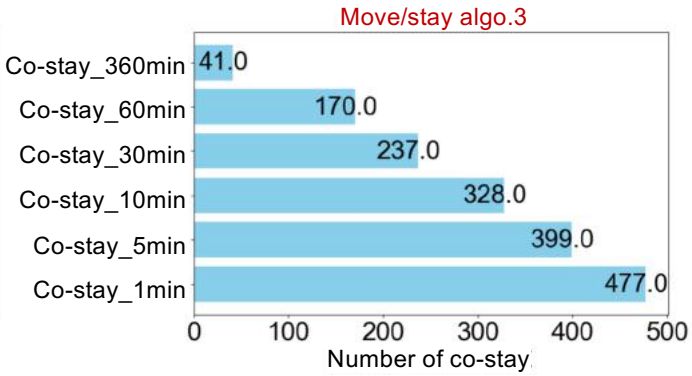


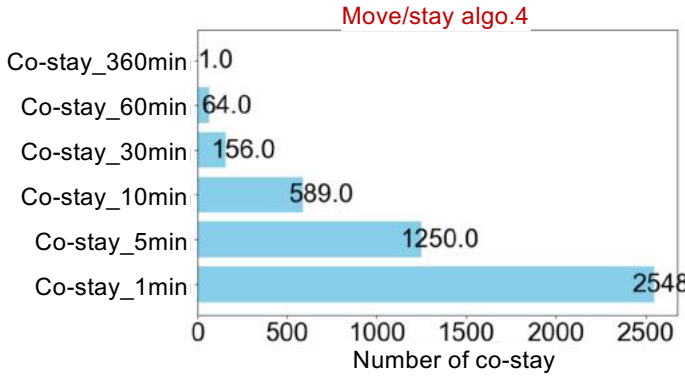
# of co-stays: **4 times**
# of co-stays at different places: **2 locations**

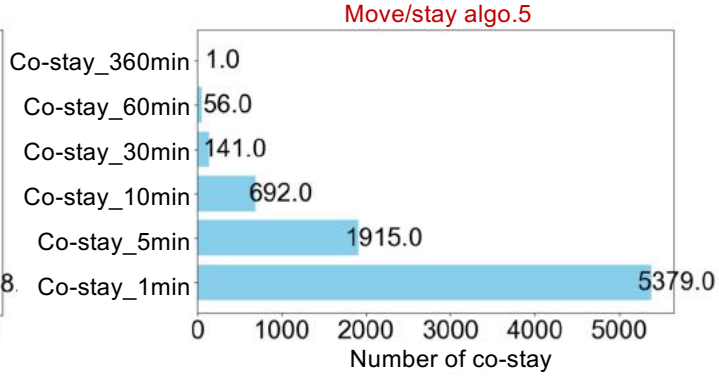
Results: # of co-stays



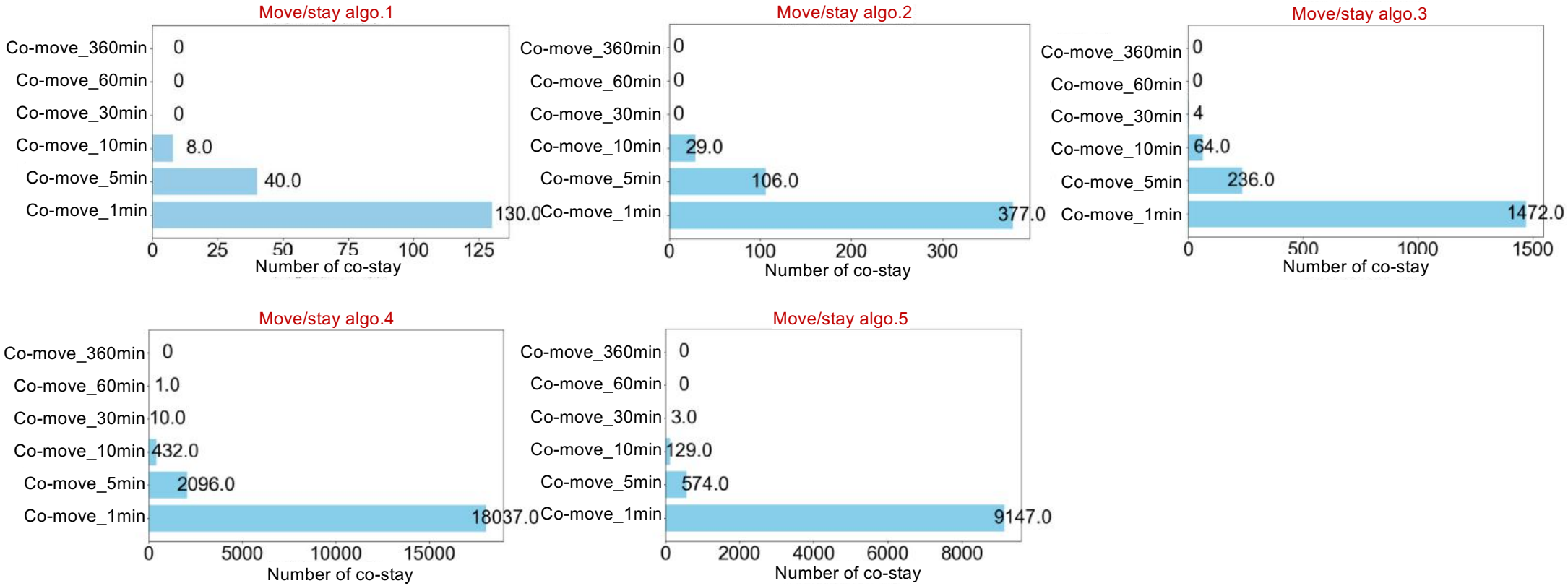








Results: # of co-moves



Estimation of SN structure

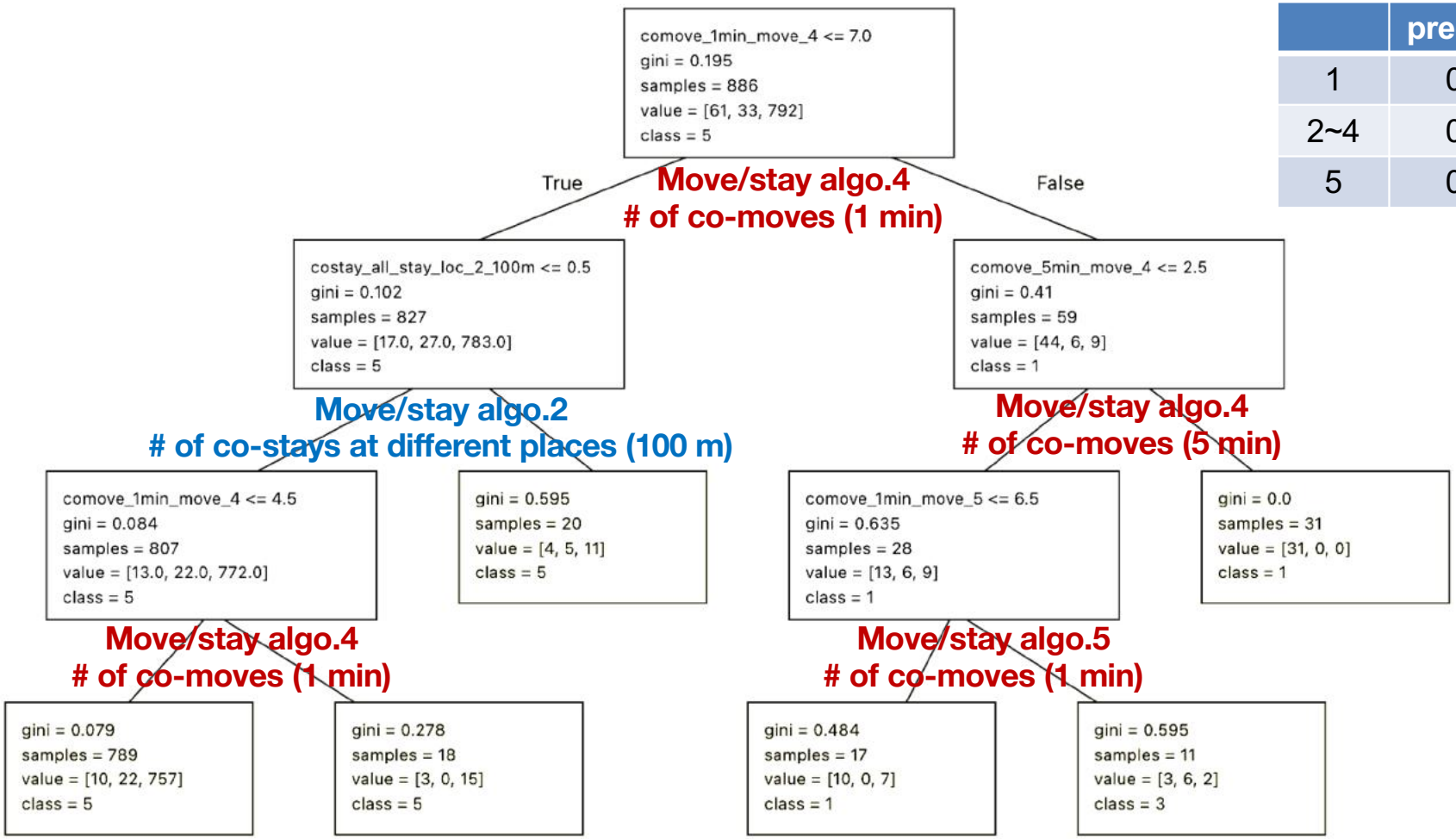
- **Model used**
  - Conventional decision tree analysis (CART)
- **Variables used**
  - # of co-moves (30 different definitions: 5 different move/stay hyperparameter settings × 6 duration threshold in co-move identification)
  - # of co-stays (30 different definitions: 5 different move/stay hyperparameter settings × 6 duration threshold in co-stay identification)
  - # of co-stays at different places (20 different definitions: 5 different move/stay hyperparameter settings × 4 distance threshold)

Estimation results

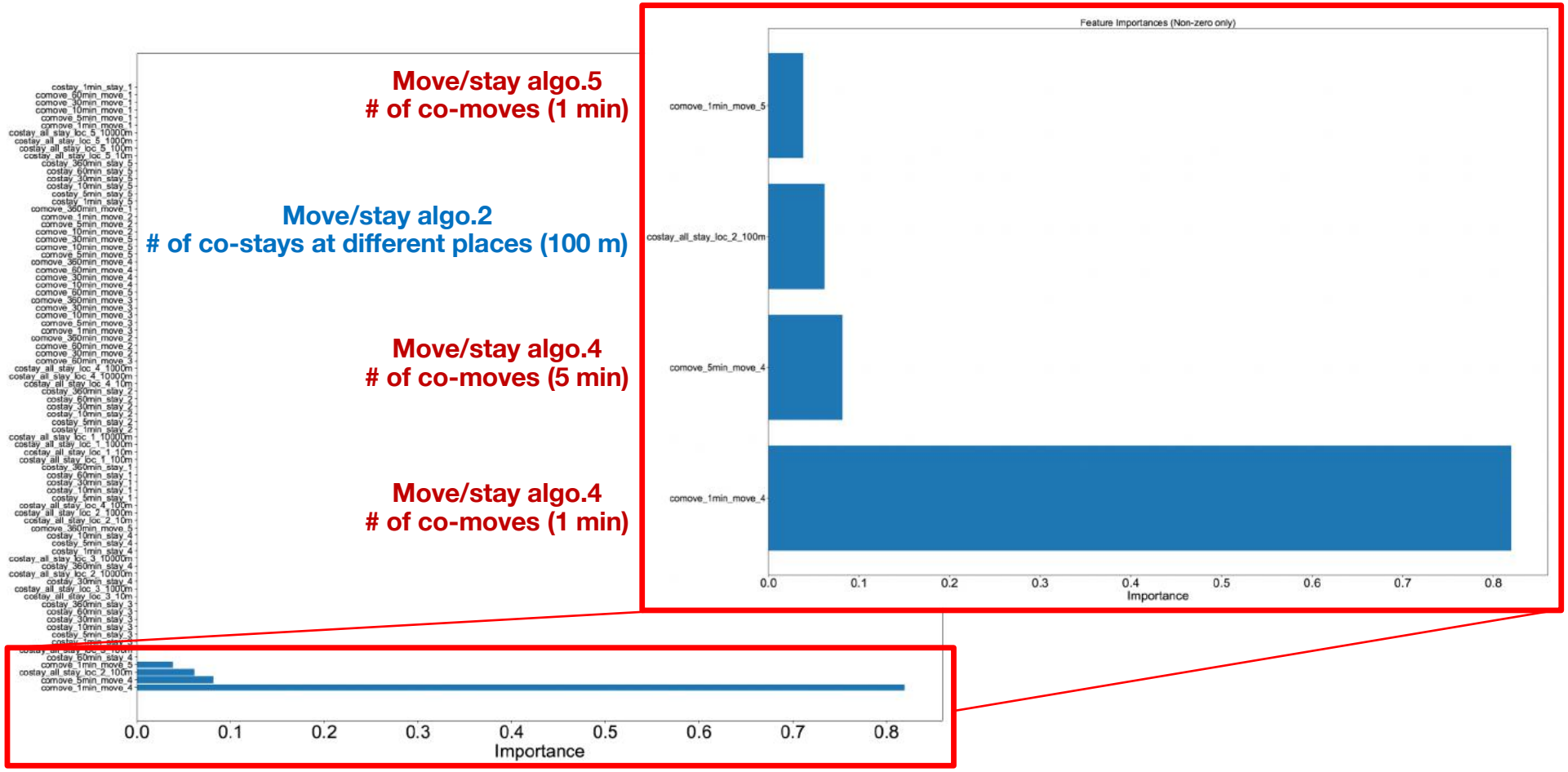
Sample size: 1,266 pairs
(886 for training)

	precision	F1-score
1	0.86	0.65
2~4	0.33	0.17
5	0.95	0.97

accuracy: 0.94



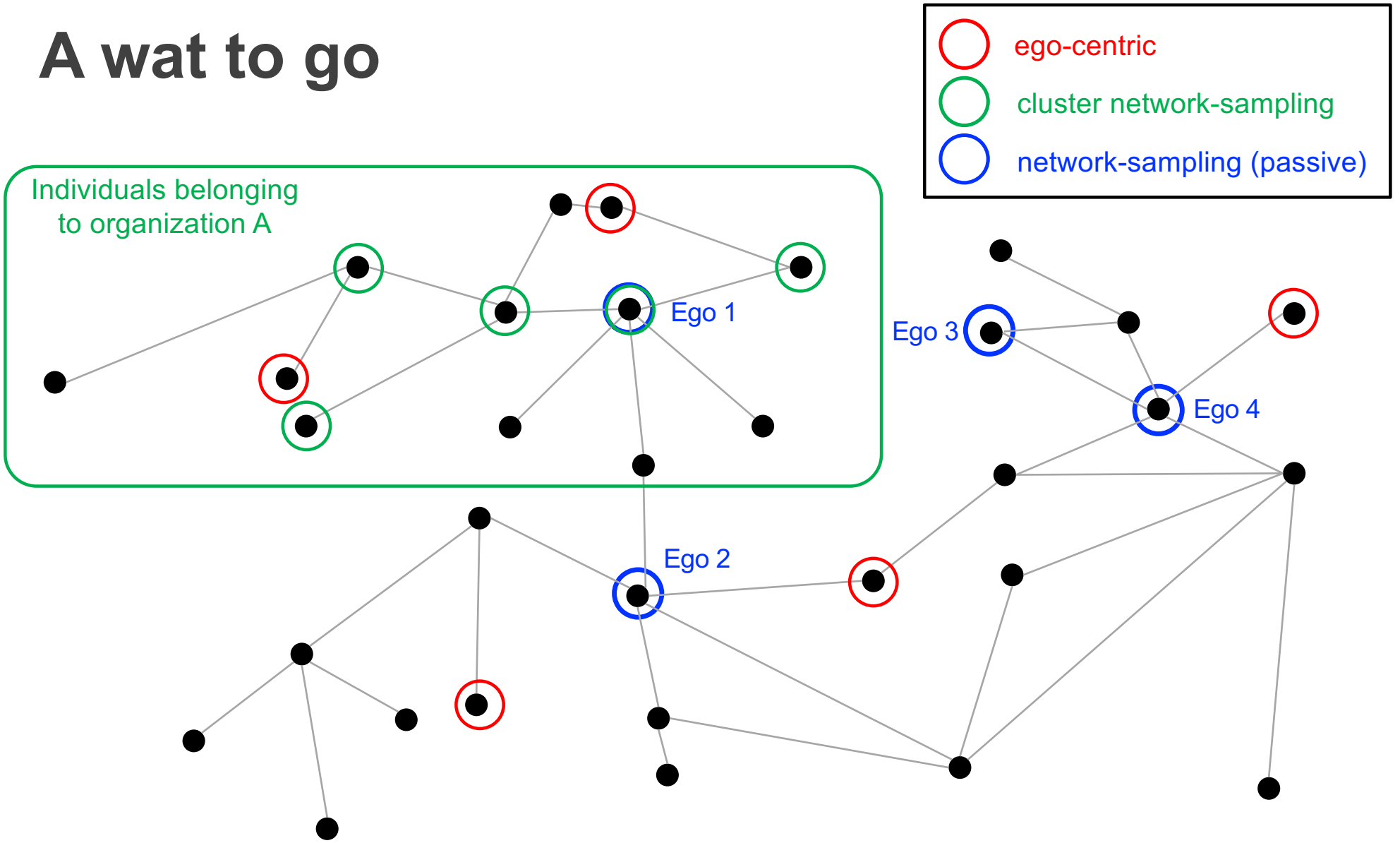
Importance of variables



Conclusions (tentative)

- **Research outcomes**
  - Proposal of simple online survey methods to observe diverse social networks and methods to expand inference to populations using GPS data
  - Conducted surveys on three groups (Hiroshima University faculty/students, Higashi-Hiroshima City staff, Fukken Co. Ltd. employees)
- **Key findings**
  - Estimation results indicate that for social network structure estimation, detailed move-stay identification is preferable, instead of using a conventional move-stay identification for conventional travel analysis
  - Confirmed that all 31 individuals had strong ties when co-move (1 min) occurred at 7 or more locations and co-move (5 min) occurred at 3 or more locations, using stay point detection method 4
- **Future challenges**
  - Development of methodology to estimate population-level social network characteristics from sampling data, etc. etc.

A wat to go


ego-centric
cluster network-sampling
network-sampling (passive)
Individuals belonging
to organization A
Ego 1
Ego 2
Ego 3
Ego 4

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THANK YOU VERY MUCH