Household-level choice set generation and parameter estimation

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Overview

Introduction

- **Activity-based models (ABMs)**: Activity-based models portray how people plan their activities and travels over a period of time.
- Traditional ABMs treat individuals as **isolated entities**.
- Individuals do **not** plan their day in **isolation** from other members of the household.
- Various **interactions**, **time arrangements**, **constraints**, and **group decision-making** affect the activity schedules of individuals.

Hence, models dealing with individual choices need to be revisited to take into account the intra-household interactions.

Example intra-household interactions

- **Joint activities:**

Family night at cinema

A family dinner at home

- **Coordinate travels:**

Escorting children

Sharing a ride

- **Share responsibilities and resources:**

Sharing household maintenance

Sharing resources

Research question 1

- How to incorporate **in-home** and **out-of-home activity scheduling** in a **single** scheduling model with **intra-household interactions**? (Rezvany et al. 2023)
  - A framework for joint simulation of in- and out-of-home activities, capturing intra-household interactions.

Rezvany, N., Bierlaire, M. Hillel, T. (2023), 'Simulating intra-household interactions for in- and out-of-home activity scheduling', Transp. Res. Part C Emerg. Technol. 157.'

Background: Household-level OASIS with interactions

- Household-level daily schedule **simulation** framework, **explicitly** accommodating **multiple interactions**:
  - A mixed-integer utility optimisation approach.
  - Adopts the **Optimisation-based Activity Scheduling Integrating Simultaneous choice dimensions (OASIS)** framework (Pougala et al. 2021).
  - **Simultaneous simulation** of different choice dimensions.
  - **Group decision-making** paradigm.
  - **Explicit** interactions.
    - Ensures consistency of choices.
  - **Multiple interaction** dimensions.
  - High level of **flexibility**.

Motivation: Operationalisation considerations

- Econometric ABMs assume agents schedule activities to **maximise utility**, explained through **discrete choices**.
- Using discrete choice models implies the need for **calibration of maximum likelihood estimators of the parameters** of the utility functions.

$$\hat{\theta} = \arg\max L_n(\theta)$$

$$L_n = \prod_{n=1}^{N} \prod_{i \in C_n} P_n(i)^{y_{in}}$$

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- Full choice set in activity-based context is **combinatorial**.

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- Full choice set in activity-based context is **combinatorial**.
- Possible to estimate using only a **sample of alternatives**.

Research question 2

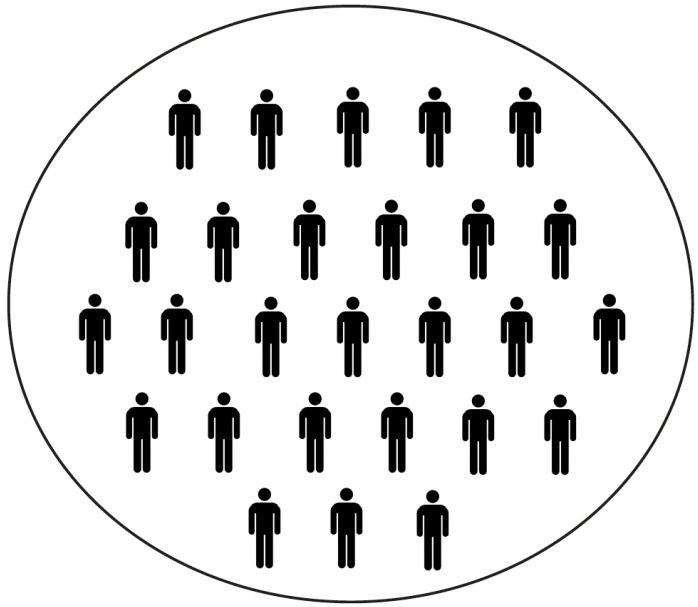
Gap: Defining a representative choice set for household activity pattern problem, necessary for operationalising household RUMs.

- Generate choice set of **considered** schedules to **estimate** significant and meaningful parameters.
- Efficient exploration of solution space:
  - High probability alternatives to ensure **robust parameters estimates**.
  - Low probability alternatives to **reduce parameter bias**.
- Aims to generate behaviourally sensible parameter estimates, estimated on ensemble of schedules with **consistent alternatives** for all household members. $\rightarrow$ enhance model realism in capturing household dynamics.

Methodology

- **Parallel generation** for all agents.
- Ensures **inter-agent validity** of alternatives in the choice-set.
- Generates ensemble of **clusters** of schedules with **consistent alternatives** for all agents.
- Adopts a **Metropolis-Hastings** based sampling algorithm to explore the **solution space** (Pougala et al. 2021).

Household choice set generation: General scheme



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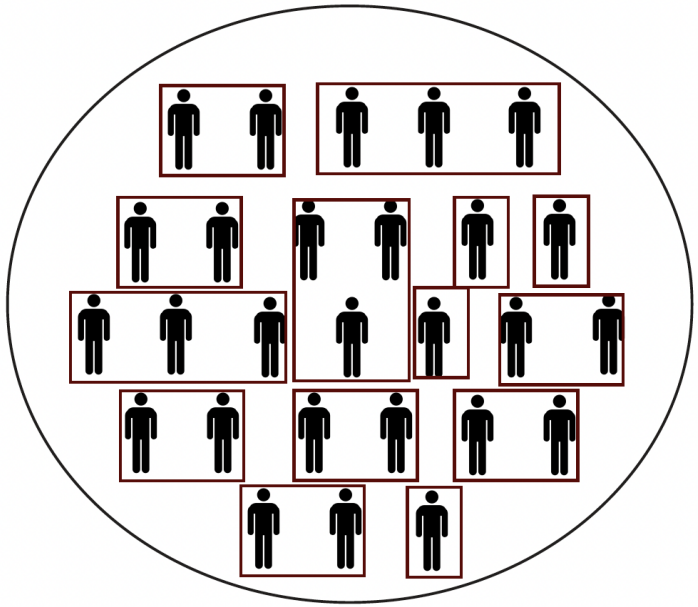

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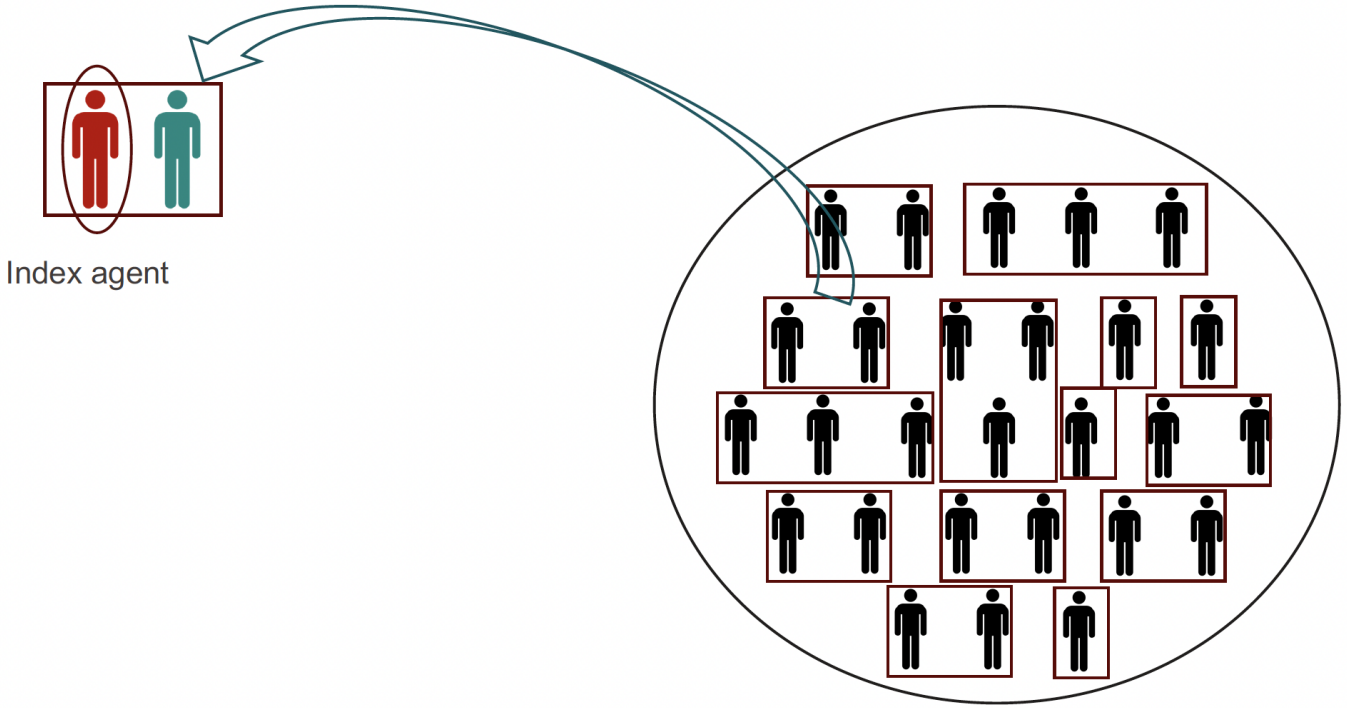
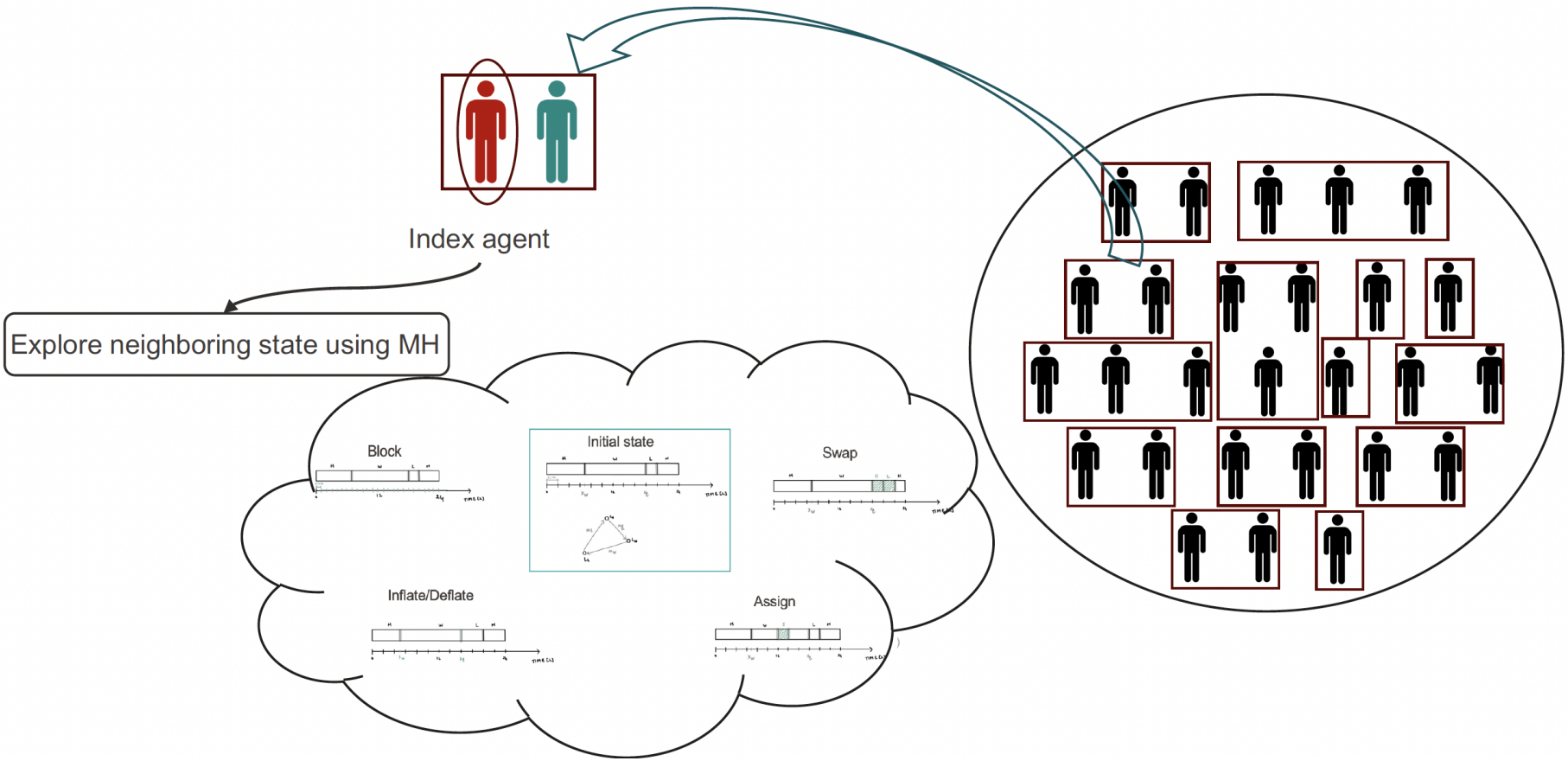


Household choice set generation: General scheme



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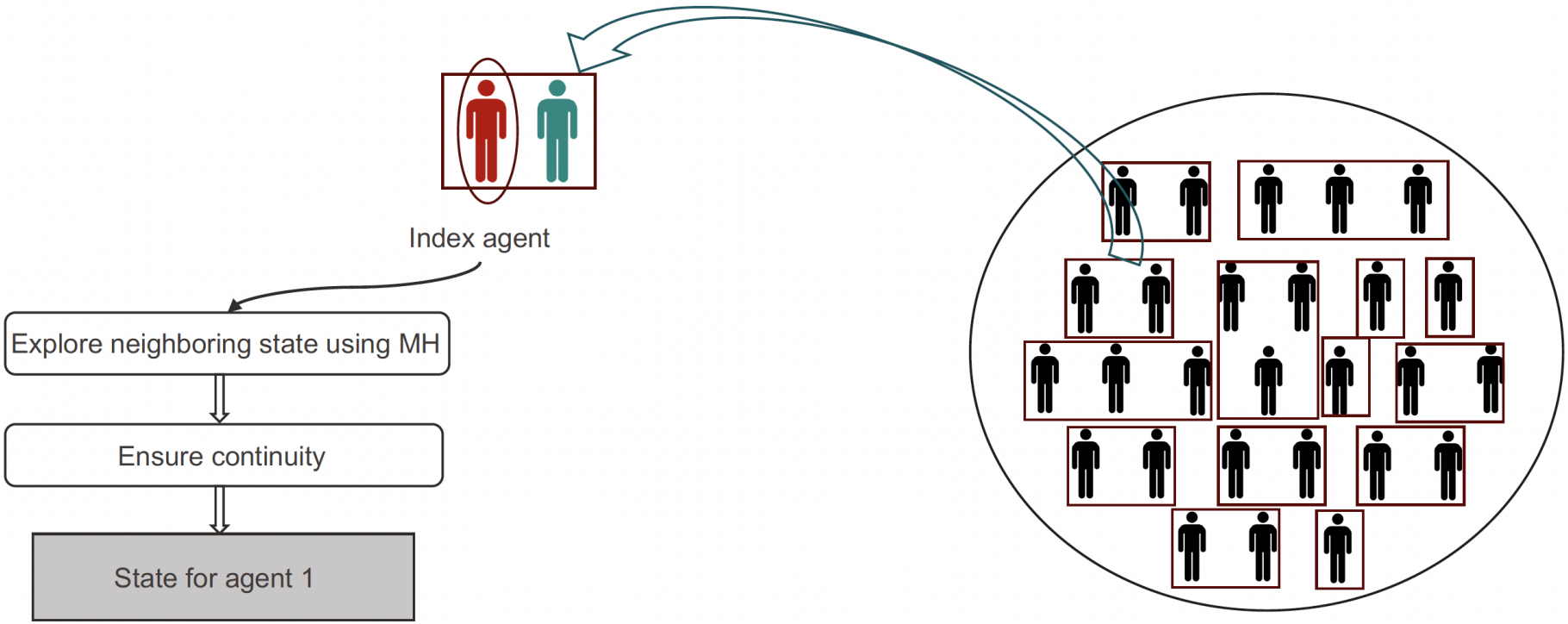

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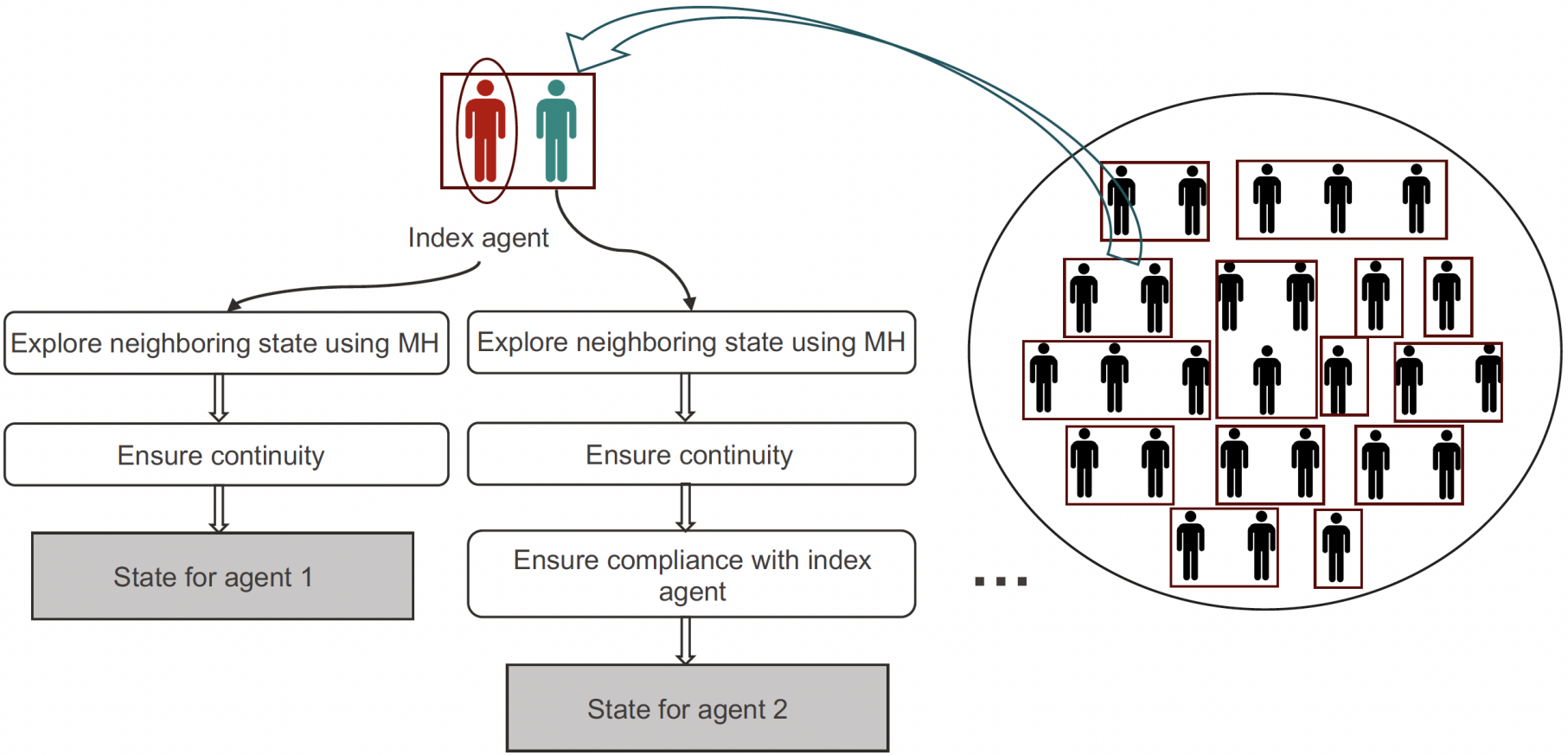

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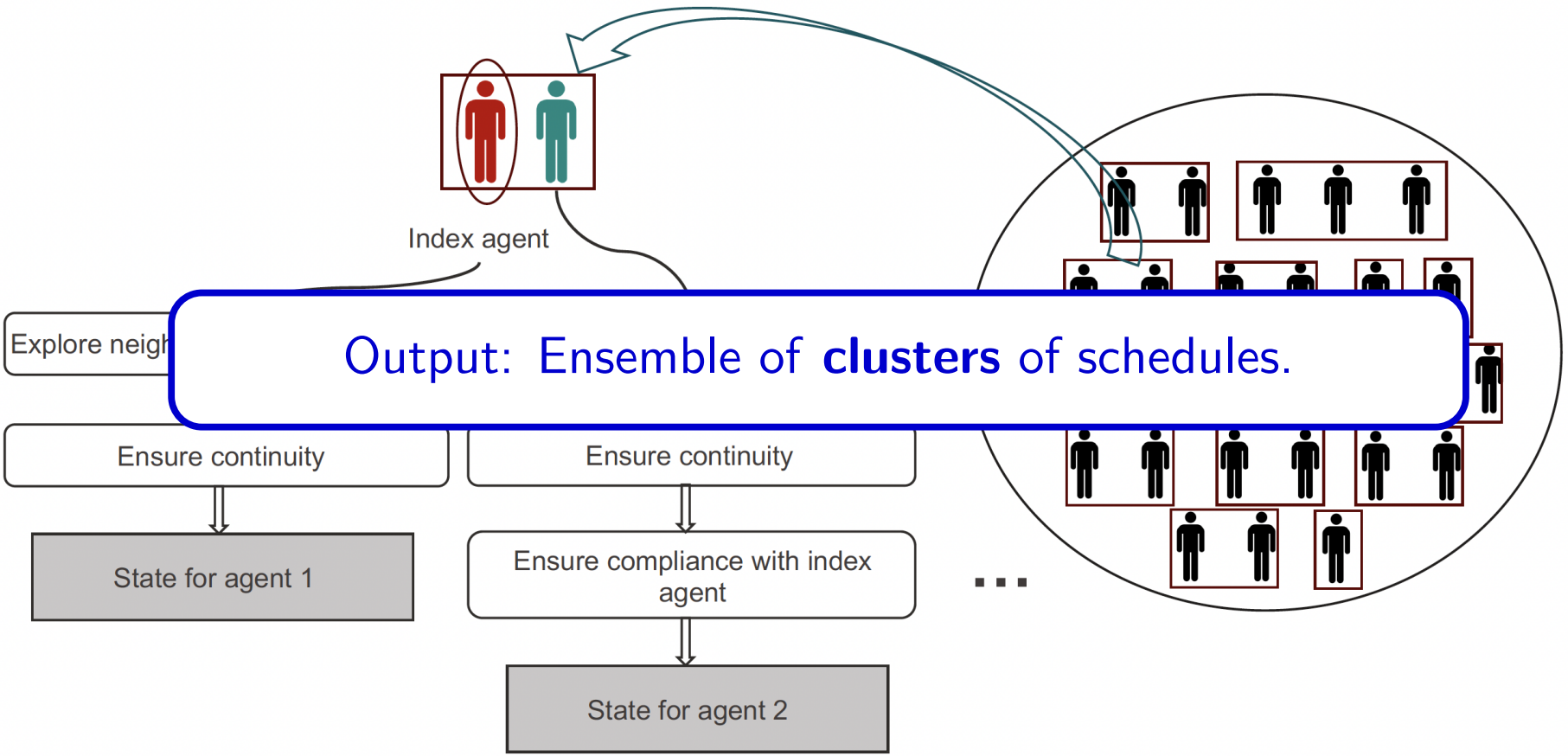


Household choice set generation

1. The **choice set** of **all agents** in a **household** generated **in parallel**.
   - The **relation** between **individuals** and **their household** is **lost** in **individual-level** choice-set formations, leading to **separate choice set formation** procedures with **no feedback** between them.

Household choice set generation

2. Move from individual utility function to **household utility function**.

$$\text{HUF} = \sum_{n=1}^{n=N_m} w_n \; U_n$$

Household choice set generation

3. Ensure possible interaction aspects are captured in **utility function**.
   - Utility of a schedule:

$$U_n = \sum_{a_n \in A^n} \omega_{a_n} U_{a_n}$$

   - For agent n, considering activity a_n:

Utility purely associated with participation in activity, irrespective of timing and trips

Duration deviations

$$U_{a_n} = U_{a_n}^{partic} + U_{a_n}^{start} + U_{a_n}^{duration} + \sum_{b_n \in A^n} U_{a_n,b_n}^{travel} + \varepsilon_{a_n}$$

Start time deviations

Travel from activity a_n to b_n

$$U_{a_n}^{partic} = U_{a_n}^{const} + U_{a_n}^{joint} + U_{a_n}^{escort}$$

Joint activity participation

Escort

Household choice set generation

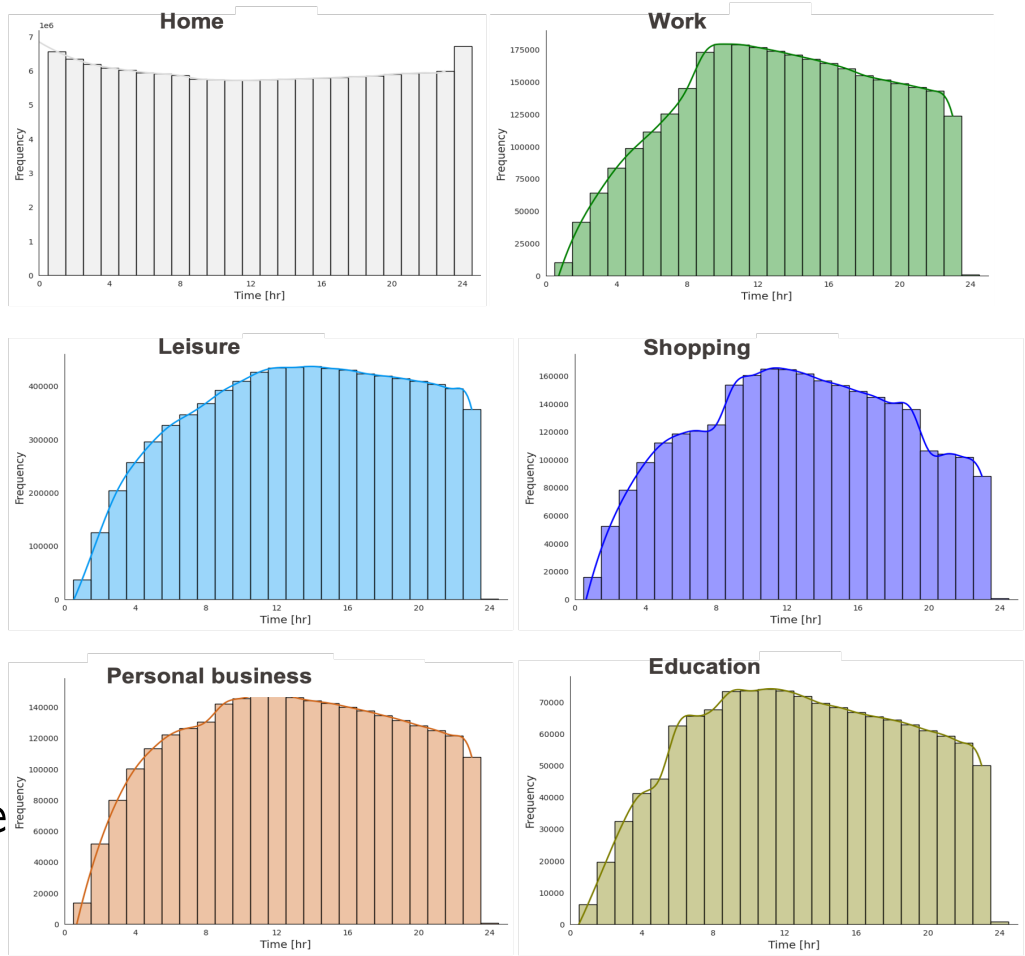
4. **Operators** to **modify choice dimension aspects** related to **household scheduling**, such as **activity participation mode (solo/joint)**.
5. Individual and household **socio-demographic** characteristics are preserved and reported in the generated choice-set.
    - Enables testing model specifications containing socio-demographic variables.

Case study

- **Sample data**:
  - 2018 – 2019 UK National Travel Survey (NTS).
  - Sample of 2-membered households of 2 adults: 3126 households.
  - Activity participation modes (solo/joint) extracted from the data, using set of rules inspired by Ho & Mulley (2013).
- **MH setup**:
  - 1′000 iterations
  - Choice set size = 10 alternatives
- **Model specification**:
  - Model with interaction of socio-economic attributes.
  - Activity-specific constants.
  - Activity-specific penalties.

Results: Distribution of Activity Participation Across Different Hours of the Day in Generated Sample

- **Distinct peak** activity times for **work**.
- **Leisure**: more spread-out pattern.
  - Reflect more scheduling flexibility.
- **Home**:
  - **Peak** at **midnight** (common resting period).
  - **Decline** (begin of day, participate in out-of-home activities).
  - **Gradual increase** towards the **evening** (return home after daily activities).



Example generated alternative with joint participation

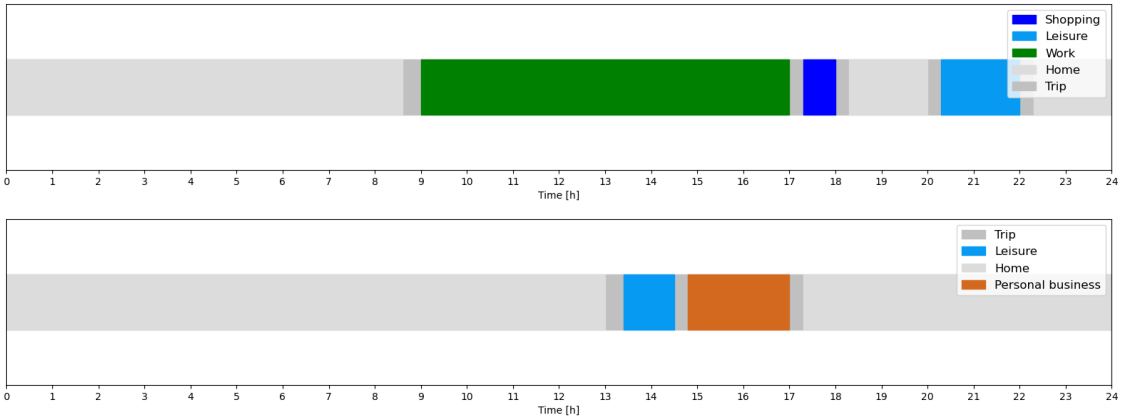


Figure: Initial schedules for agents in a household

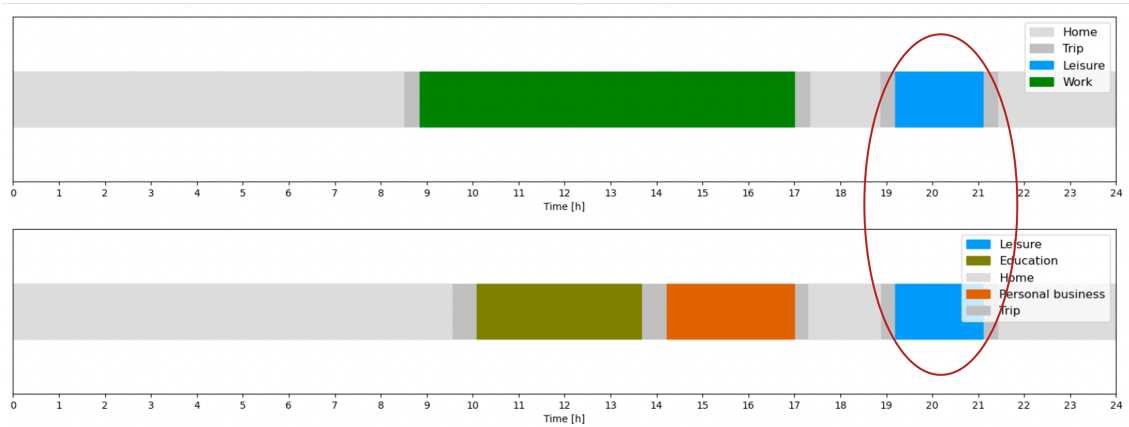


Figure: Example generated schedules for the agents in the household

Estimation

Name	Value	Rob. Std Err	Rob. t-test	p-value
Leisure:joint_partic_noCar	-0.364	0.214	-1.7	0.0885
Leisure:joint_partic_twomoreCar	-0.262	0.123	-2.13	0.0328
Education:constant	2.35	0.617	3.81	0.000139
Education:early	-2.13	0.645	-3.3	0.000979
Education:late	-0.457	0.166	-2.86	0.00422
Education:long	-1.21	0.224	-5.41	6.14e-08
Education:short	-0.728	0.133	-5.47	4.54e-08
Leisure:constant	3.22	0.146	22	0
Leisure:early	-0.459	0.0324	-14.2	0
Leisure:joint_partic	0.244	0.109	2.25	0.0246
Leisure:late	-0.176	0.0169	-10.4	0
Leisure:long	-0.322	0.0188	-17.2	0
Leisure:short	-0.486	0.0607	-8	1.33e-15
Personal business:constant	3.77	0.239	15.8	0
Personal business:early	-0.75	0.107	-7.03	2.06e-12
Personal business:late	-0.326	0.0492	-6.62	3.51e-11
Personal business:long	-0.533	0.0497	-10.7	0
Personal business:short	-3.6	0.853	-4.22	2.44e-05
Shopping:constant	5.61	0.207	27.1	0
Shopping:early	-1.32	0.13	-10.2	0
Shopping:late	-0.237	0.0395	-6	2.02e-09
Shopping:long	-0.634	0.0438	-14.5	0
Shopping:short	-4.67	0.654	-7.14	9.34e-13
Work:constant	5.67	0.231	24.5	0
Work:early	-0.738	0.0839	-8.8	0
Work:late	-0.423	0.0559	-7.56	4.04e-14
Work:long	-0.747	0.0501	-14.9	0
Work:short	-0.576	0.0426	-13.5	0

To conclude

Summary:

- Household-level choice set formation.
- Estimate household-level OASIS using sampled choice set.

Future work:

- Embed parameters in simulation framework.
- Investigate other household structures.
- Non-homogenous scheduling preferences across individuals.
- Travel related interaction dimensions, travel parameter estimates.
- Validation techniques.

Bibliography I

Ho, C. & Mulley, C. (2013), 'Tour-based mode choice of joint household travel patterns on weekend and weekday', *Transportation (Amst).* **40**(4), 789–811.

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Thank You!