Implementing a Social Joint Activity-Travel Multi-agent Simulation Tool: Method and First Results for Intrahousehold Ride Sharing

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Introduction

Agent's Coordination in MATSim

Results

Conclusions

Introduction

- informed policy making needs good forecasts about effects of new measures
- transportation system is a complex system
  - $\Rightarrow$ simulation seems to be the tool of choice for forecasting
- popular approach for forecasting the state of the transport system: activity-based multi-agent simulation
  - travel is a need *derived* from the desire to perform activities at different locations
- most travel simulation tools simulate behavior of *isolated* individuals
  - individuals make decisions independently, given traffic conditions influenced by others

Introduction

- in reality, individuals coordinate their travel behavior with social contacts
  - household: joint activities, limited number of cars, altruism
  - social contacts: joint activities
  - car-pools: pick-up and drop-off times and locations
- such coordinated behavior has a quite important empirical influence
  - joint trips
    - MZ2010: 18% daily traveled distance as "car passenger"
    - MZ2010: 32.5% all car stages done with 2+ persons in the car
  - leisure location choice

Aim of this presentation

- present an approach to integrate coordination mechanisms in the MATSim framework
- analyze the results of runs on scenarios for the Zurich area
- identify directions of future work

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MATSim in a Nutshell

- **M**ulti-**A**gent **T**ransport **Sim**ulation
- Open-source Activity-Based simulation framework
- implemented in Java
- developpers and users all around the world
  - Switzerland, Germany, Singapore, South Africa, Canada, Poland. . .
- www.matsim.org

The MATSim View of (Individual) Decision Making

- agents try to optimize their daily plan given their knowledge of the state of transport system
- this state depends on other agent's behavior
  - random from the agent's perspective
  - only *aggregate* behavior matters
- search for a good daily plan by a co-evolutionary algorithm: all agents perform an EA simultaneously
  - start with an initial plan
  - iteratively:
    - execute plan, score it
    - delete worst plan if more plans than allowed
    - select a past plan randomly based on score
    - (for some agents only) copy it and modify it

Introduction of Coordination

- *exact* behavior of *well identified* agents matters
- need to link plan choice for certain plans of certain agents
- no need to link plan choice for unrelated plans: risks on convergence (slow / toward a wrong state, see Braes Paradox)
- $\Rightarrow$ individual plans corresponding to *joint decision* are grouped in "joint plans": sets of individual plans to be selected together.
- $\Rightarrow$ "incompatibility" between (joint) plans
- redefine replanning:
    1. identify groups of agents to replan together
    2. remove plans part of the "worst" plan combination if needed
    3. select feasible combination of individual plans based on scores
    4. (optional) copy and modify those plans

Plan Selection

- not always possible to select the best plan for each agent
- "equilibrium" does not always exist
- need to represent group-level decision making
- classical solution in household decision models: group utility
- weighted selection: select the feasible combination which maximizes the sum of weights of individual plans
    - scores
    - Gumbel distributed (Logit-like)
    - random
- "utility transfers" in joint plans
- without contraints, same as selecting the plan of highest weight for each agent
- can be done efficiently (branch-and-bound)

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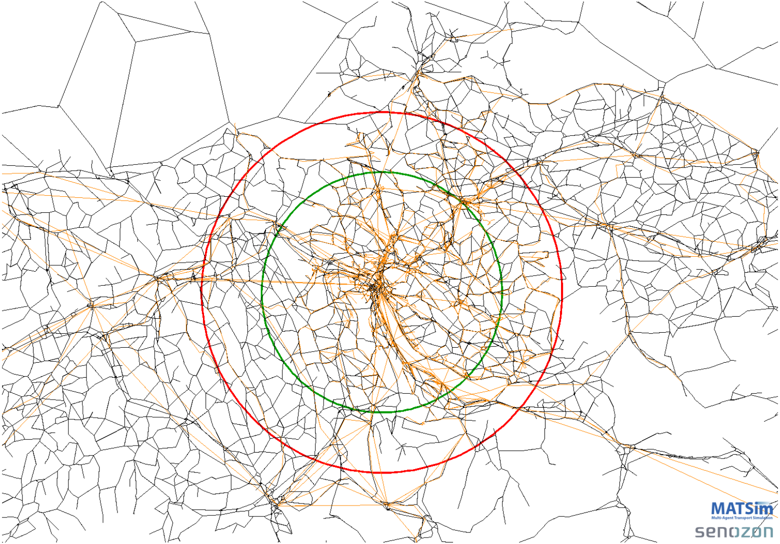
Aims

- use the approach for the case of *intra-household ride sharing*, using a pre-existing scenario for the Zurich area
- see how the approach performs when "plugging" it in a pre-existing scenario, with a minimal amount of adaptation
  - Hope: structural constraints can explain important aspects of joint travel patterns
- identify limitations of scenario/approach

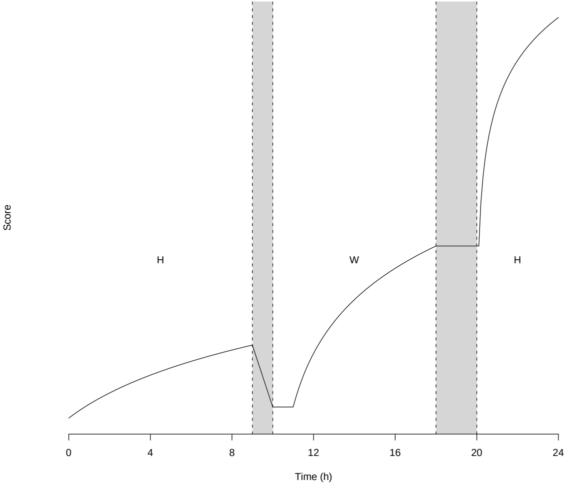
Scenario

- Zurich scenario:
  - planning network
  - schedule-based public transport
  - individuals grouped in households (Census 2000)
  - *working day* activity chains from National Travel Survey 2005
  - only households for which at least one member passes at least once closer than 30km to *Bellevue* Place are retained
  - 10% sample
- validation data:
  - National Travel Survey 2005
  - consider only trips with origin and destination closer than 20km to *Bellevue*

Network



Utility Function



Utility Function Parameters

- re-calibrated from existing scenario
- no explicit marginal disutility of traveling by car (*opportunity cost* only)
- "desired durations" differ from agent to agent
- opening times defined at the *facility* level

Replanning Modules

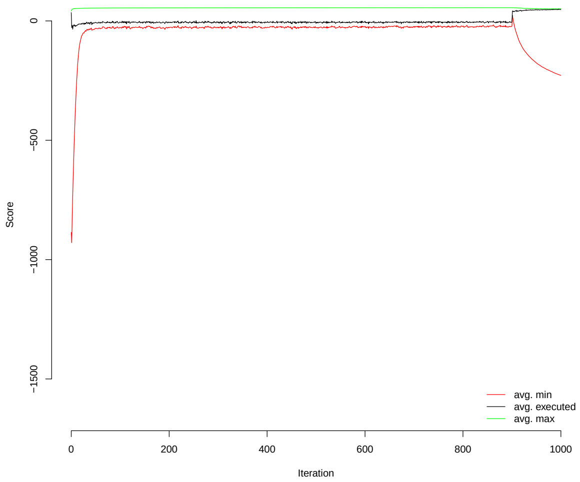
Module	Weight	Deactivated in Scenarios
Logit-like Selection	0.5	
Time Allocation Mutation	0.1	
Subtour Mode Mutation	0.1	
Re-routing	0.1	
Joint Trip Mutation	0.1	*base*
Joint Leisure Location Choice	0.1	*base*, *jt.nd*, *jt.d*

- full household always replanned together
- Joint Trip Mutation: *joins* a car and a public transport trip
- Joint Leisure Location Choice: allocates randomly a leisure location *from the set of leisure locations of the household*
- "innovations" deactivated after 900 iterations

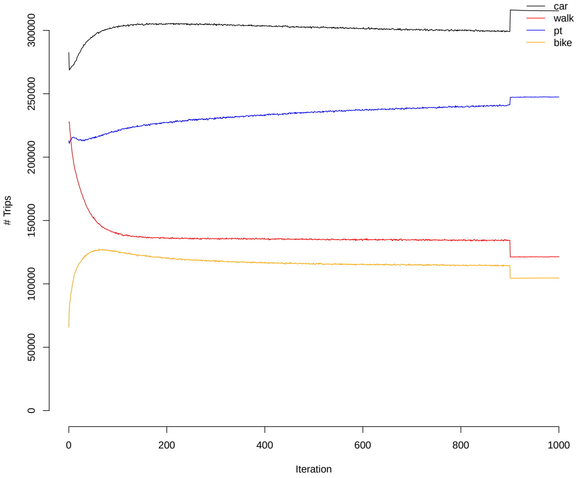
Variants of the Scenario

1. *base*: no joint travel
2. *jt.nd*: joint trips are randomly included, no penalty of detour
3. *jt.d*: joint trips are randomly included, penalty of detour
4. *jt.d.l*: joint trips are randomly included, leisure location choice
5. *jt.d.l.s*: joint trips are randomly included, leisure location choice, score logarithmically time passed with household members in leisure activities

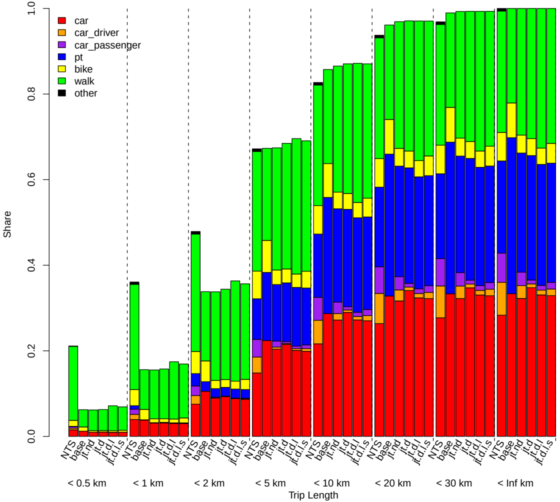
Score Evolution (Base Scenario)



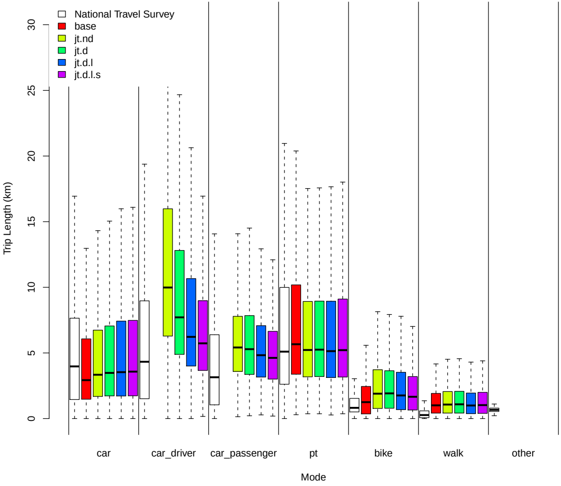
Mode Evolution (Base Scenario)



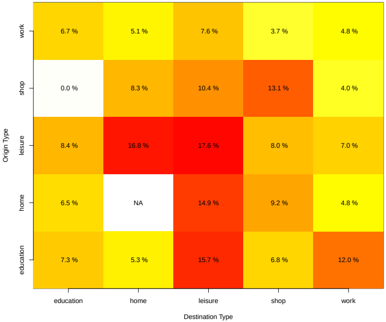
Mode Share Comparison

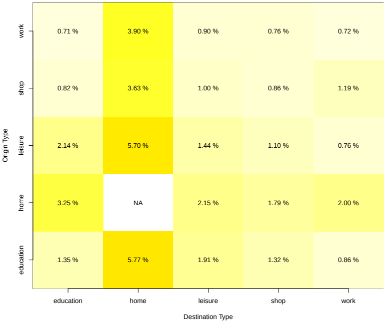


Distance Distribution per Mode

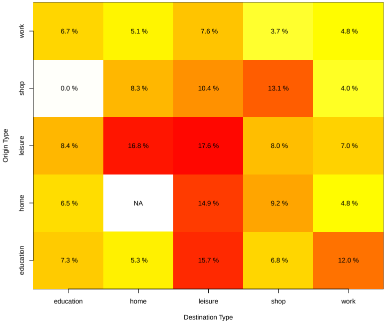


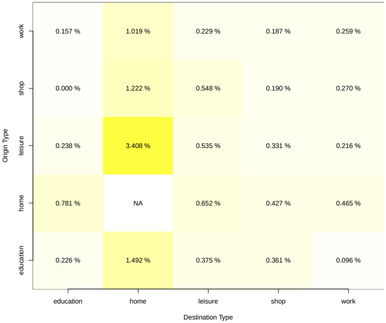
Passenger Share per Purpose: NTS vs jt.nd





Passenger Share per Purpose: NTS vs jt.d.l.ns





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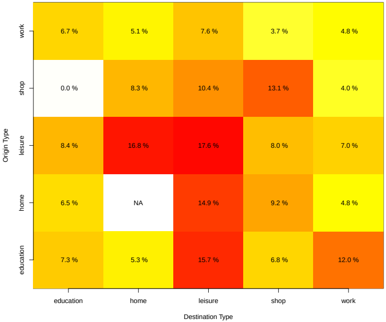

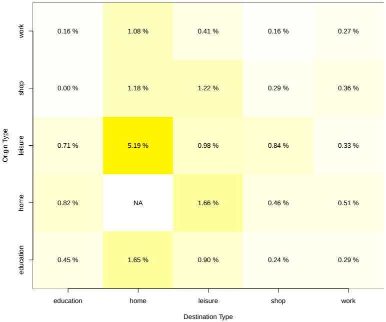

Summary

- "utility transfers" seems a too strong hypothesis
  - over-estimation of driver detours, even when penalizing
  - but *under*-estimation of joint travel!
    - vehicle ressources?
- "drive to work/school" trips quite well predicted, the rest underestimated
- associating a positive utility to joint presence at leisure activity *did not* improve the share of joint modes to leisure activities
  - no joint generation of schedules
  - no generation of pure serve passenger tours
  - only intra-household ride-sharing

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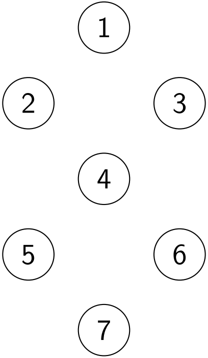
- most travel simulation tools do not include joint travel
- an approach applicable with general social network topologies was implemented in MATSim
- comparison of the results with travel diary data allows to identify limitations of the approach and plan the next steps

Next Steps

- improve accuracy of driver detours
  - relax utility transfer hypothesis
  - joint activities w/ location choice?
    - not a significant impact for the approach used here
- improve overall passenger share
  - household-level correlation of plan construction / co-adaptation of plan structures
  - consider limited vehicle resources
  - generate pure *serve-passenger* tours?
    - purpose "service" represents only 10% of the driver trips in the National Travel Survey
  - include friendship relationships?
- improve specificity of leisure purpose
  - consider friendship relationships?
  - co-adaptation of plan structure

Questions?

Group Identification



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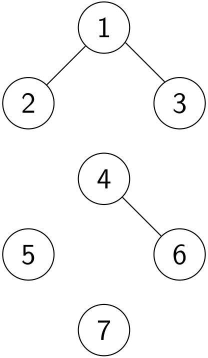

- some agents have joint plans

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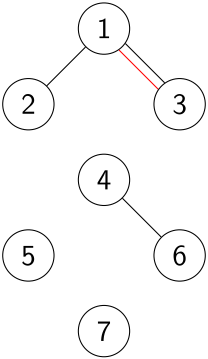

- some agents have joint plans
- or use common resources

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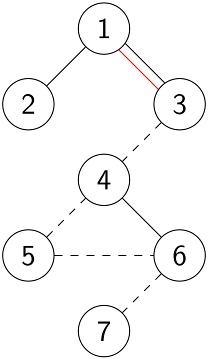

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- "social ties" along which coordination behavior can be created

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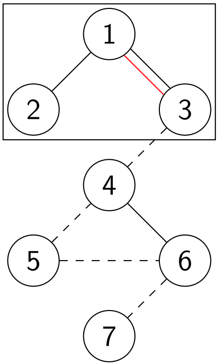

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- agents with coordination must be in the same group

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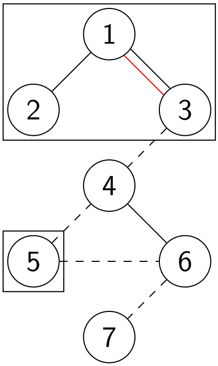

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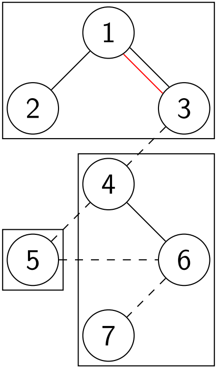

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Plan Selection

1 2 3 4 5

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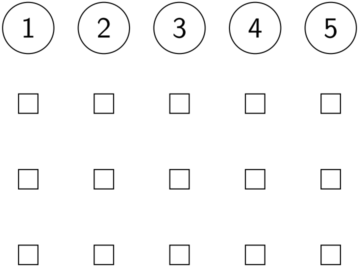

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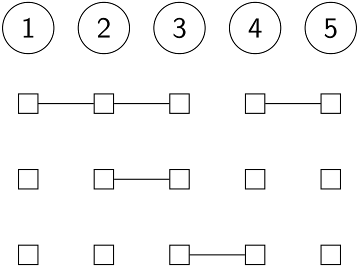

- agents have plans
- joint plans constraints

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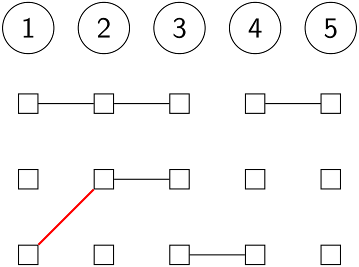

- agents have plans
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- incompatibility constraints

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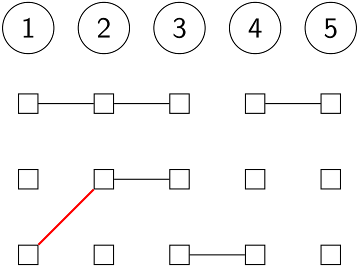

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- aim: model the choice of individual plans, given the constraints

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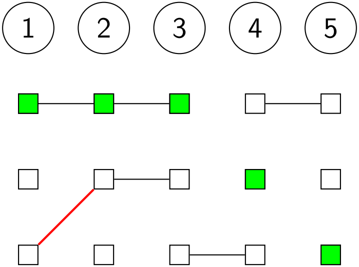

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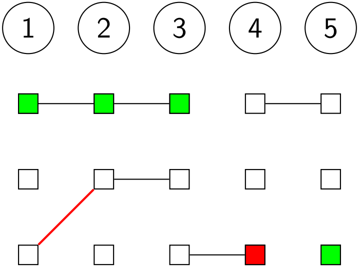

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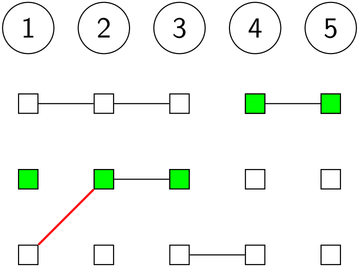

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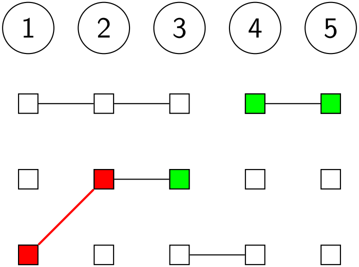

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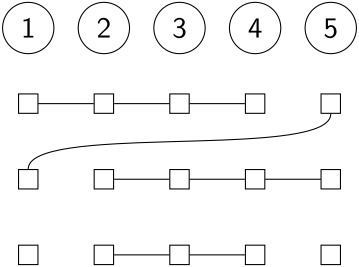
Plan Selection for Removal



- when removing plans, there must remain feasible combinations

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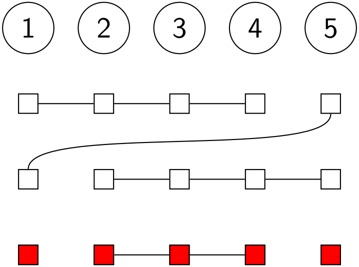

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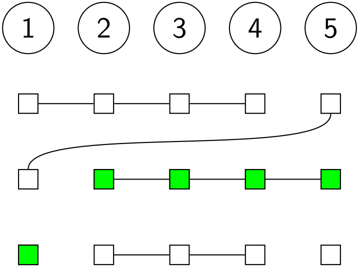

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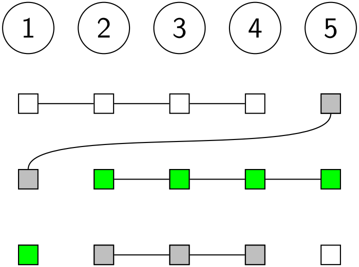

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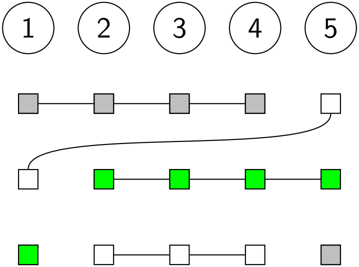

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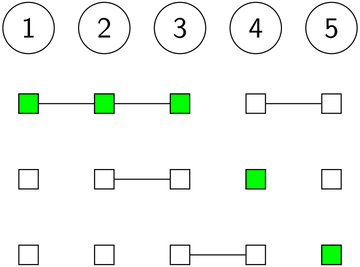
Plan Mutation



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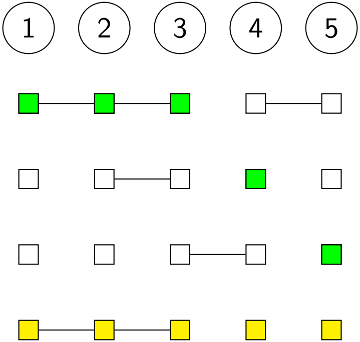

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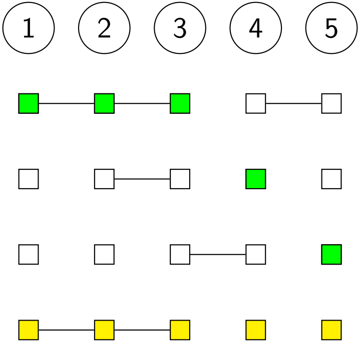
Plan Mutation



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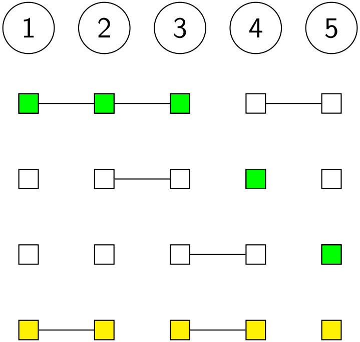
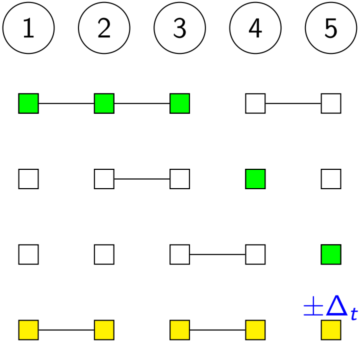
Plan Mutation



- copy
- modify:
  - agents interations

Plan Mutation



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- modify:
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  - other dimensions