Balancing Customer Interactions and Travelling Distance in Supermarket Design

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Relevance of the Problem

- Supermarkets maximise travelled distance[1]
- Not desirable in health crisis (like COVID-19)
- Why ABM?
  - Heterogeneous population
  - Interacting agents

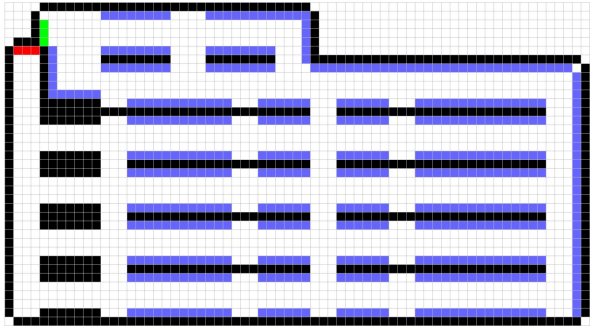
[1] Boros et al. (2016)

Description Model

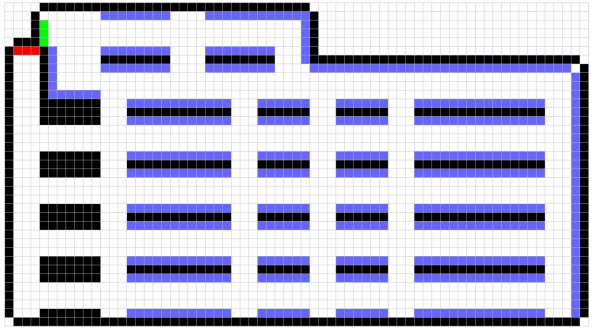
- Entity 1: Spatial Unit
  - Wall
  - Objective
- Entity 2: Agents
  - Heterogeneous
  - Walking speed, vision, familiarity

Supermarket Layouts

- Grid Layout [2]

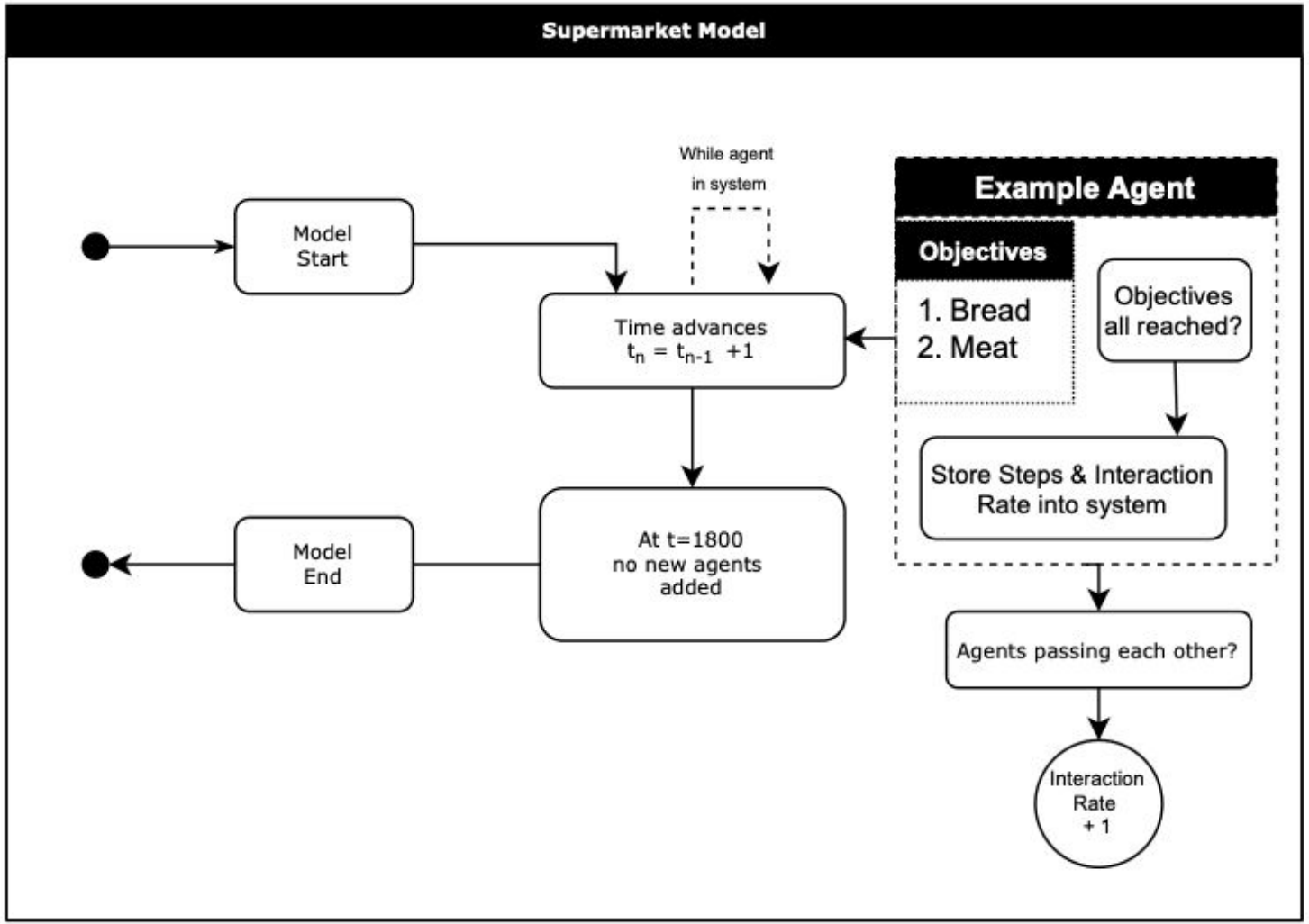


- Free Form Layout [2]



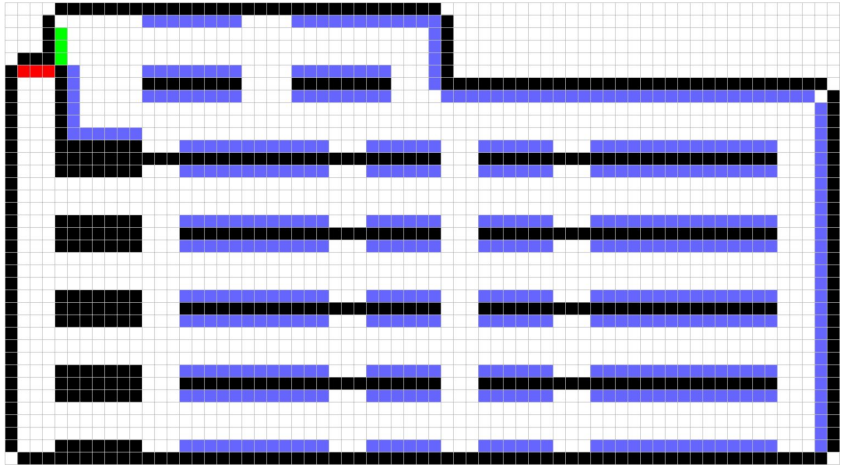
- Scale:
  - 1 cell = 0.5x0.5 metres
  - 67x35 cells eq. 33.5x18.5 metres
  - 1 time step = 2 seconds
  - Door closes after 1800 time steps eq. 1 hour

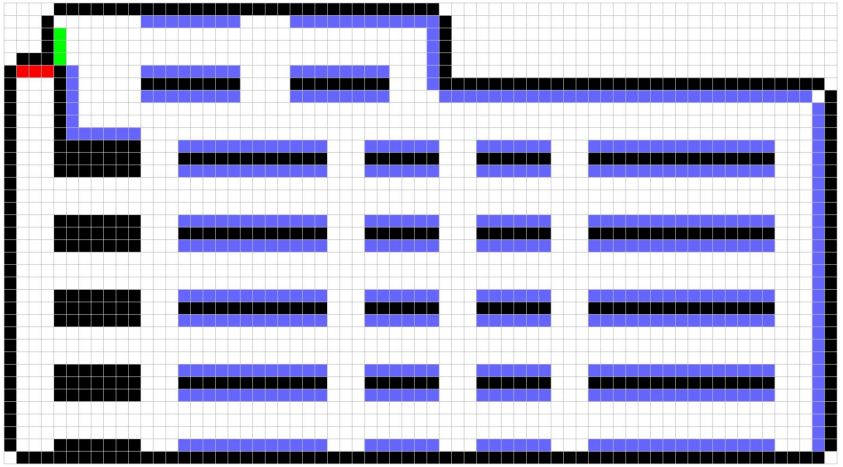
[2] Vrechopoulos et al. (2004)


Supermarket Model
While agent
in system
Example Agent
Objectives
1. Bread
2. Meat
Objectives all reached?
Model Start
Time advances
$t_n = t_{n-1} + 1$
Store Steps & Interaction Rate into system
Model End
At t=1800
no new agents
added
Agents passing each other?
Interaction Rate + 1

Research Question

How do the different supermarket layouts influence the mean number of agent interactions and agent travelled distance?



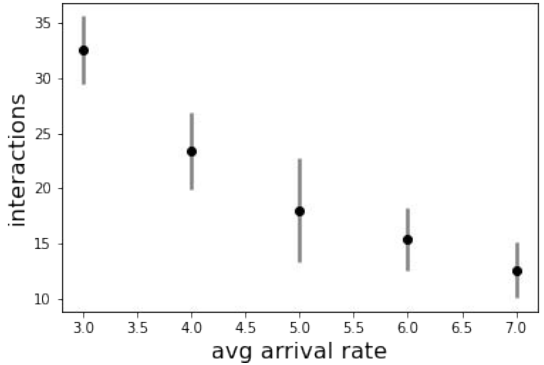


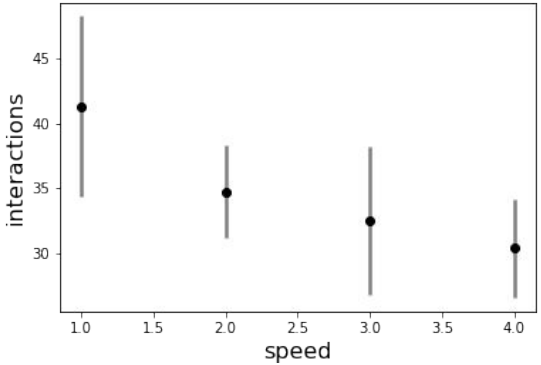
Outcome Measures & Input Parameters

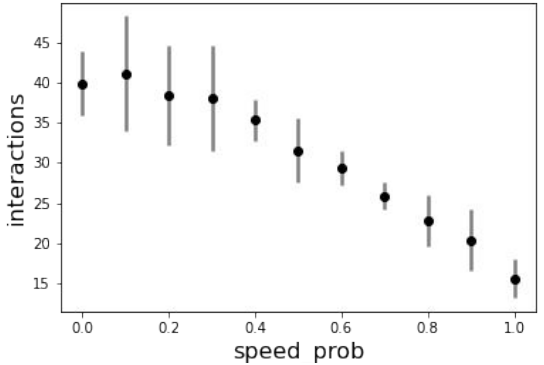
- Outcome Measures
  - Interactions: Other agents within two cells
  - Distance: The number of cells travelled

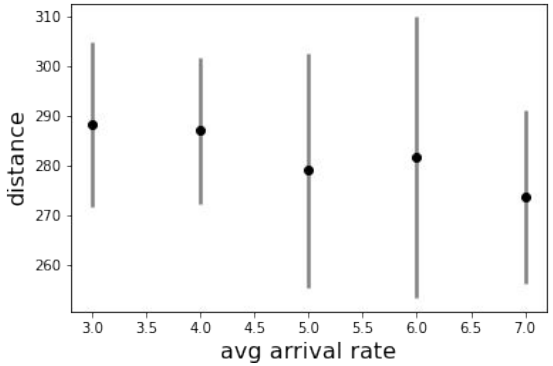
- Input Parameters
  - Average arrival time (Poisson)
  - Two familiarity values and their distribution
  - Two speed values and their distribution
  - Two vision values and their distribution

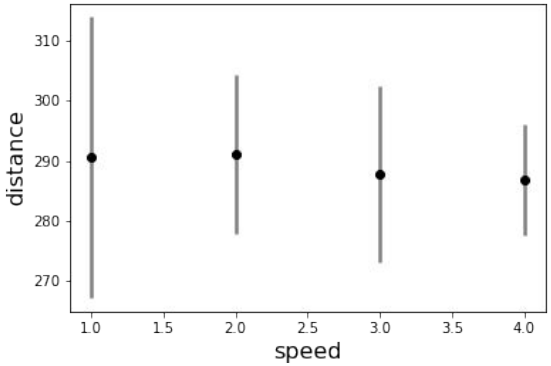
OFAT Sensitivity Analysis

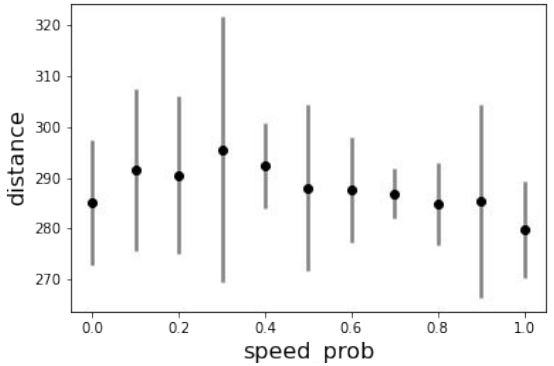






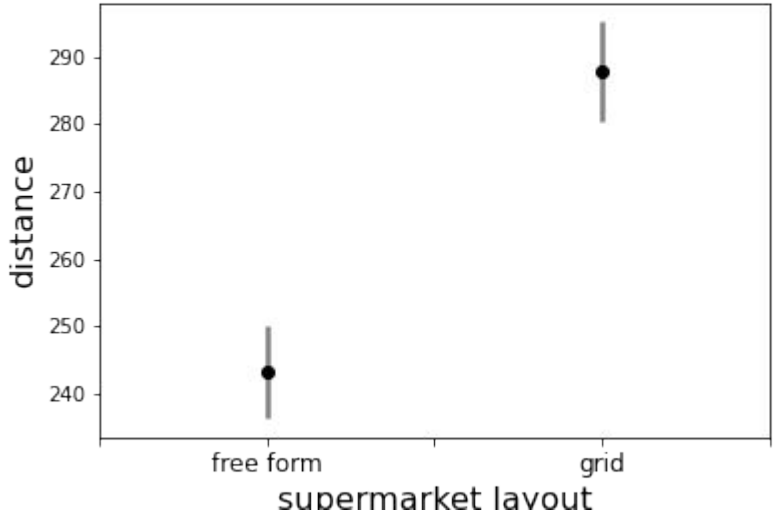




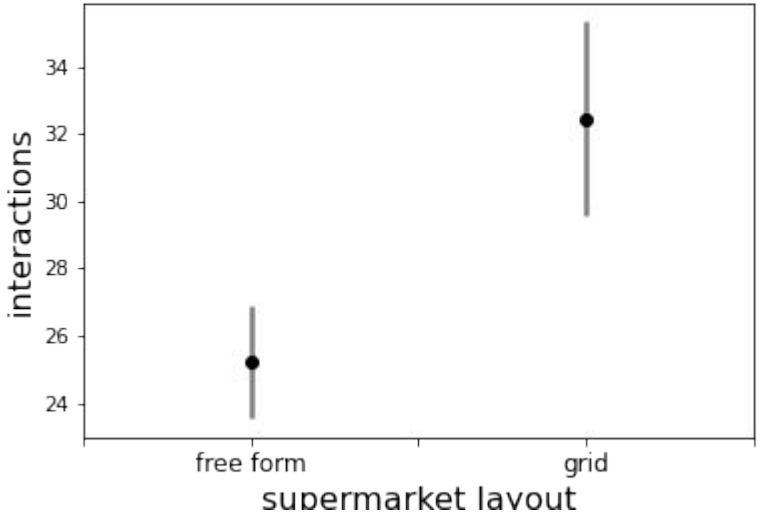


Results

- The free form layout has significantly lower distances and interactions compared to the grid layout



Welch: t(17) = -13.2, p = 1.05e-10

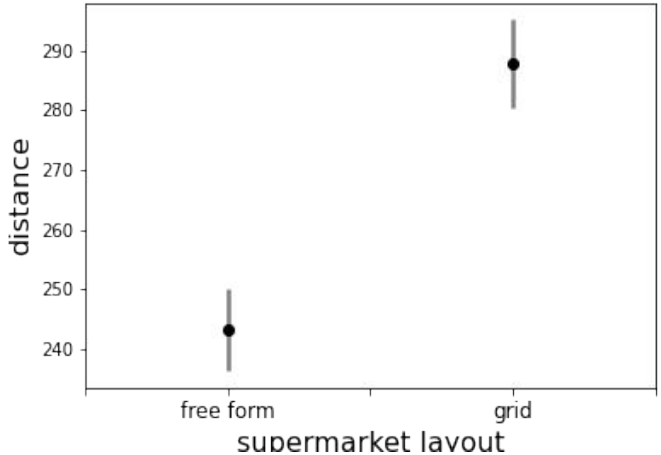


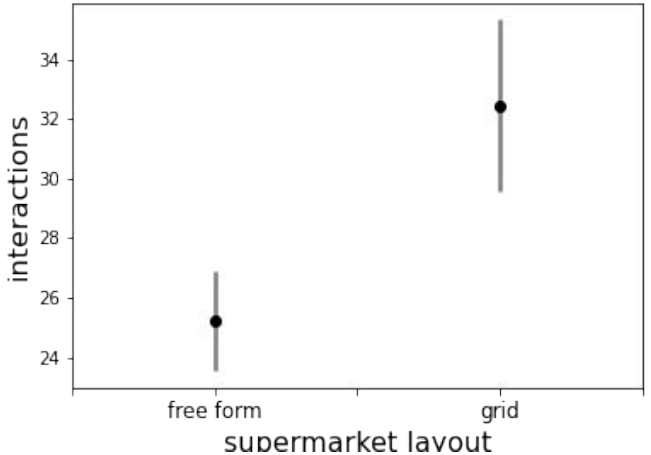
Welch: t(14) = -6.51, p = 1.16e-05

Conclusion

RQ: How do the different supermarket layouts influence the mean number of agent interactions and agent travelled distance?

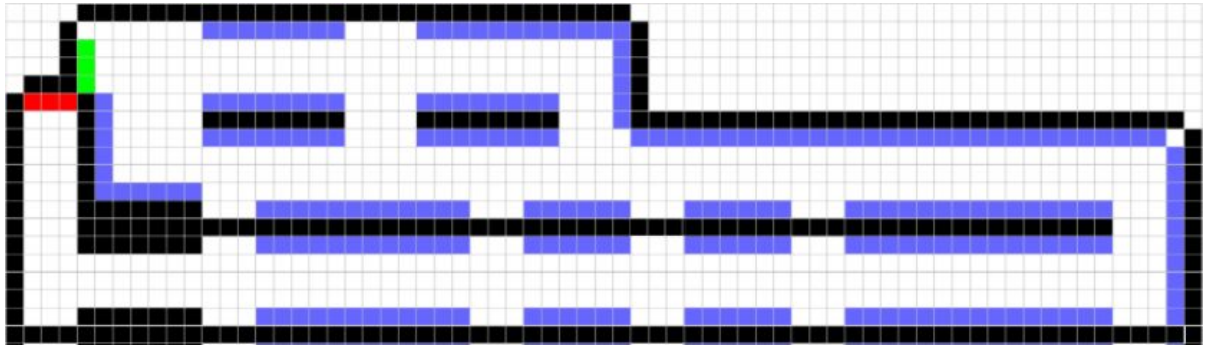
The grid layout has higher travelled distance for agents and higher mean agent interactions compared to the free form layout.





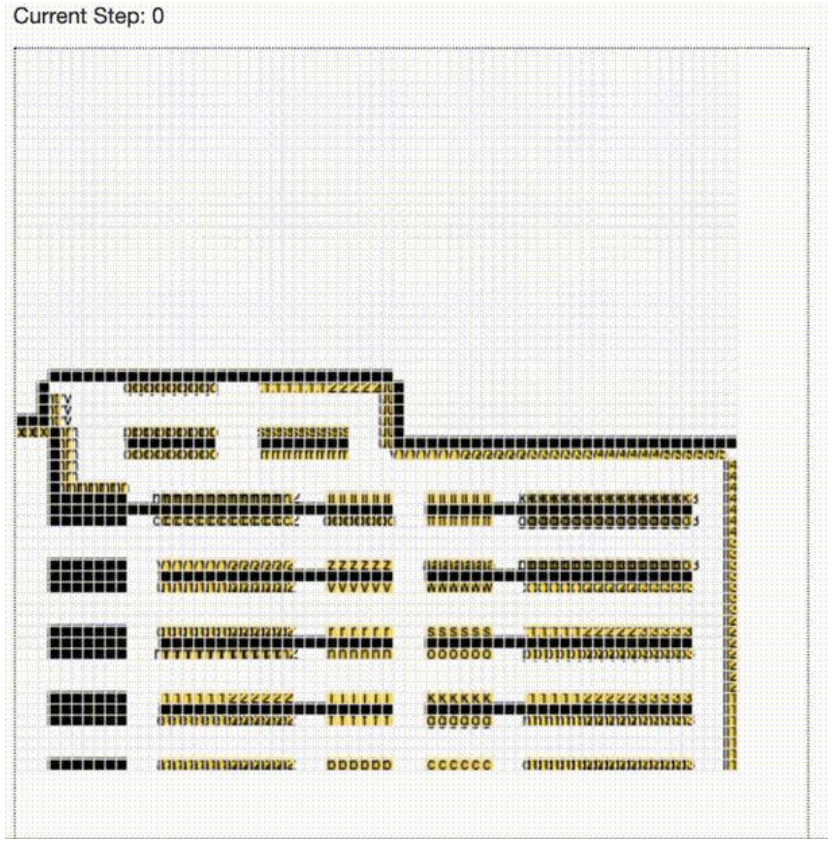
Future Work

- Validation, comparing to observed data
- What chance to get diseased from an interaction
- More supermarket layouts (e.g. Loop/racetrack layout[2])

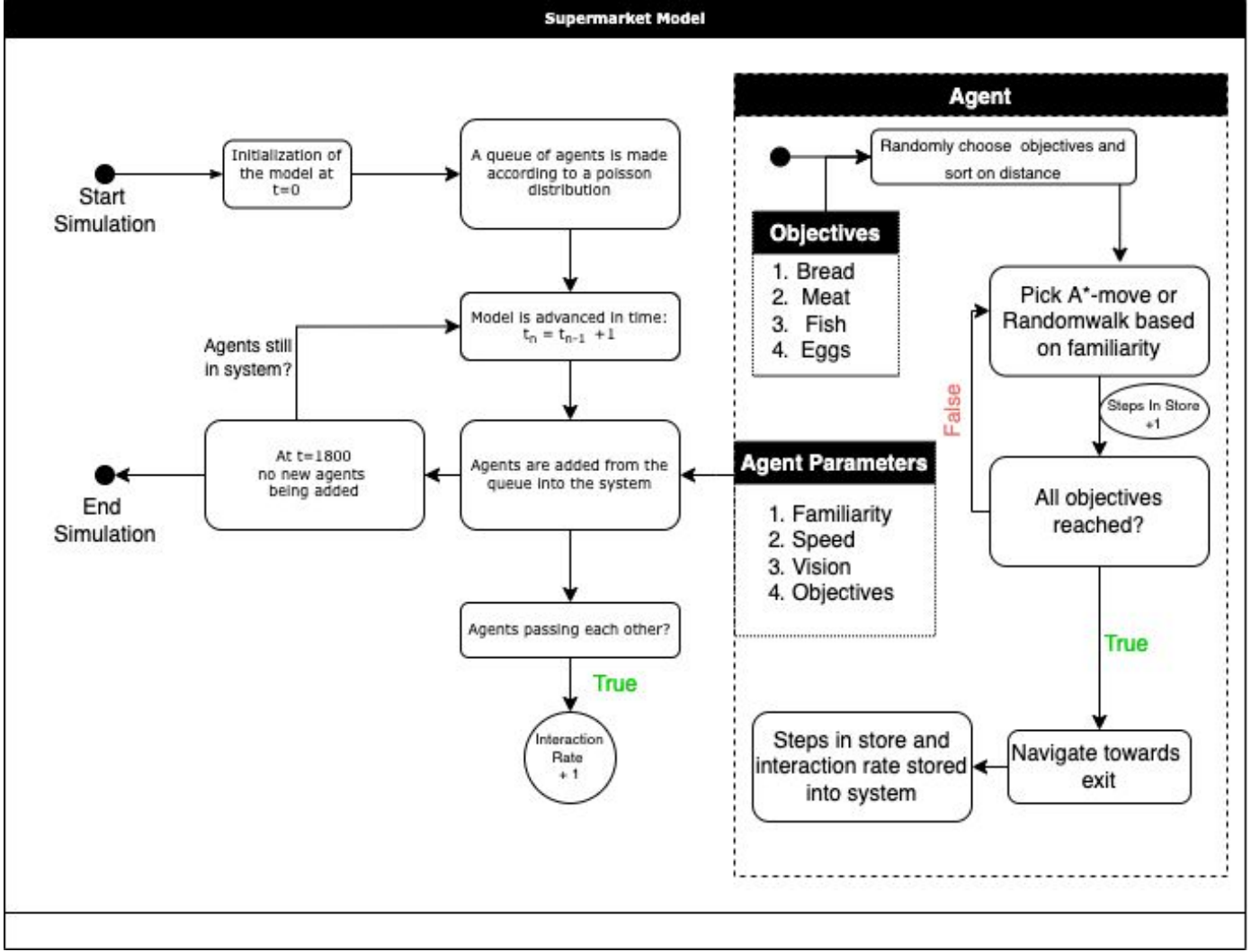


[2] Vrechopoulos et al. (2004)

Questions?

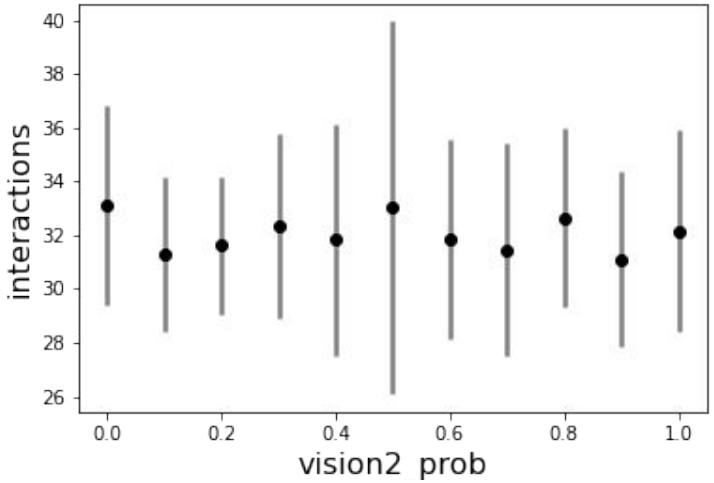

Current Step: 0

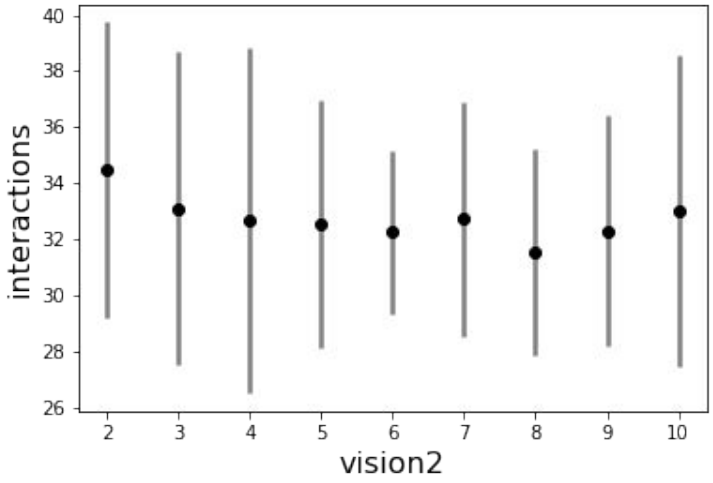

n_persons
n_done
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
0
standing_still
waiting_to_enter
mean_interactions_done
interactions
total_switches

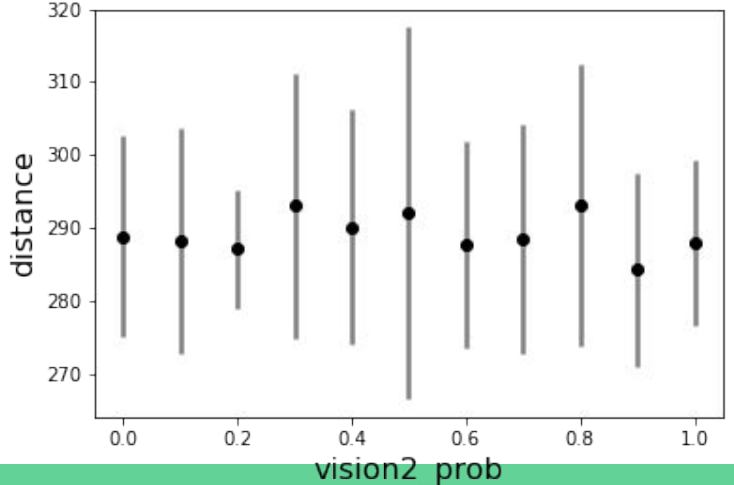

Supermarket Model
Start Simulation
Initialization of the model at t=0
A queue of agents is made according to a poisson distribution
Model is advanced in time: $t_n = t_{n-1} + 1$
Agents still in system?
Agents are added from the queue into the system
At t=1800 no new agents being added
End Simulation
Agents passing each other?
True
Interaction Rate + 1
Agent
Randomly choose objectives and sort on distance
Objectives
1. Bread
2. Meat
3. Fish
4. Eggs
Agent Parameters
1. Familiarity
2. Speed
3. Vision
4. Objectives
Pick A*-move or Randomwalk based on familiarity
False
Steps In Store +1
All objectives reached?
True
Navigate towards exit
Steps in store and interaction rate stored into system

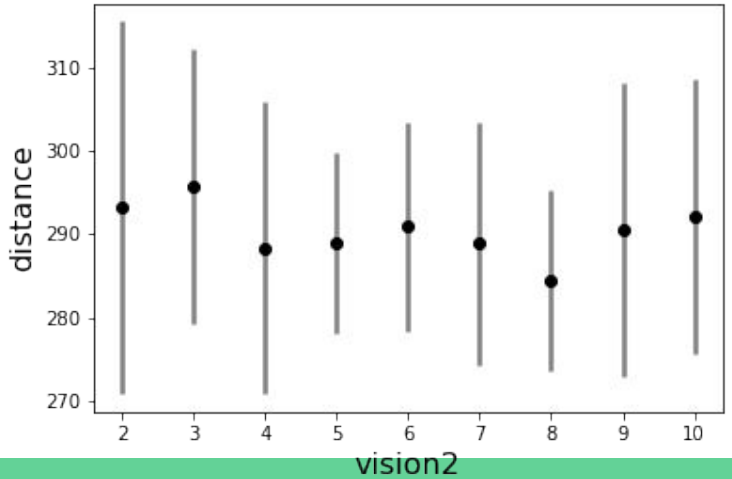
Standard Parameter Values

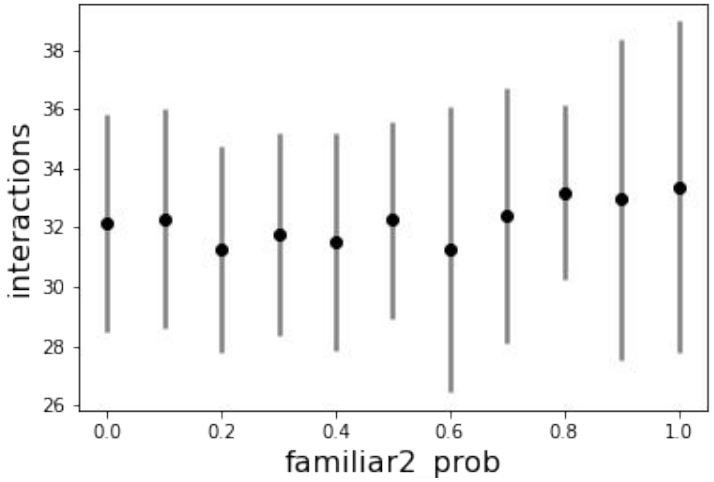
- Average arrival time (Poisson) = 3
- Two familiarity values = 0.6, 1
- familiarity distribution = 0.5
- Two speed values = 3, 1
- speed distribution = 0.5
- Maximum vision = 6, 3
- vision distribution = 0.5

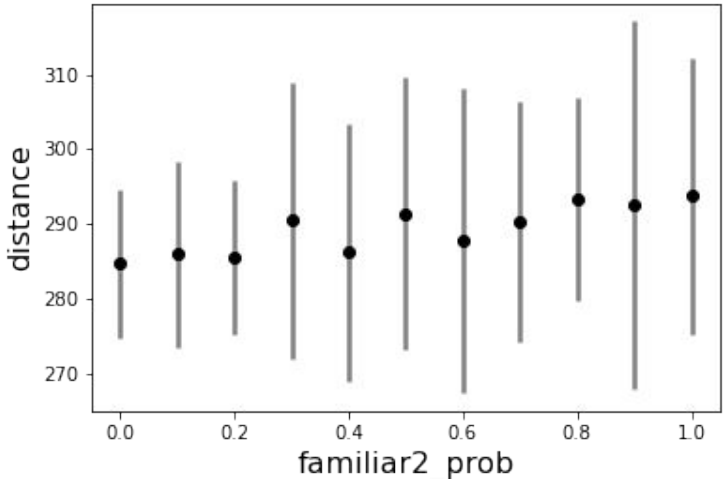

interactions
vision2_prob

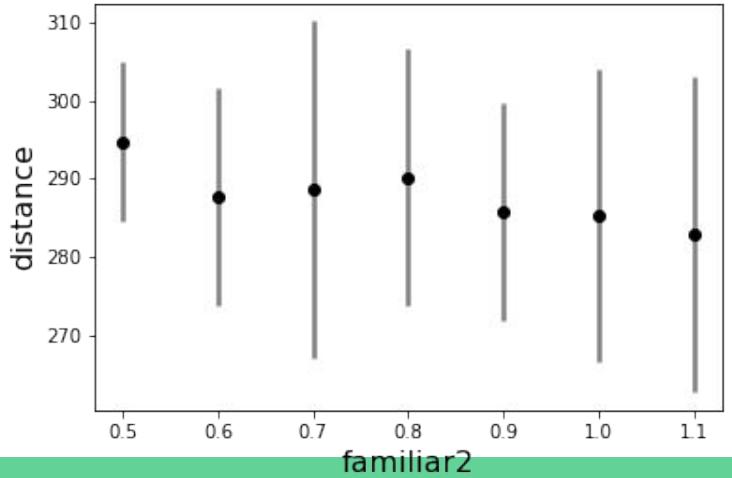

interactions
vision2

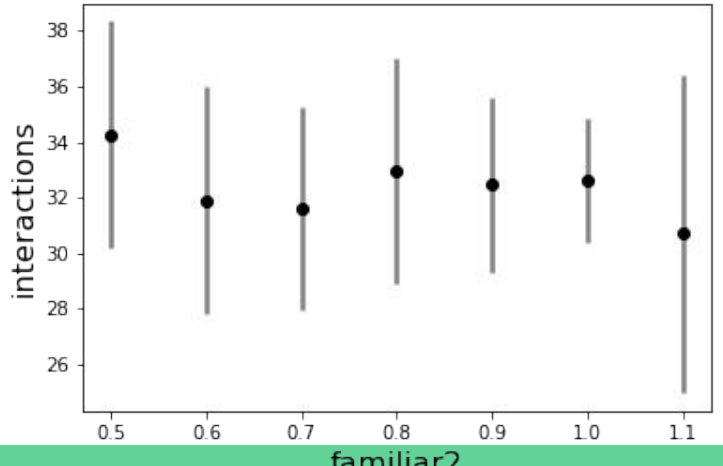

distance
vision2_prob


distance
vision2


interactions
38
36
34
32
30
28
26
0.0
0.2
0.4
0.6
0.8
1.0
familiar2 prob


distance
310
300
290
280
270
0.0
0.2
0.4
0.6
0.8
1.0
familiar2 prob


distance
310
300
290
280
270
0.5
0.6
0.7
0.8
0.9
1.0
1.1
familiar2


interactions
38
36
34
32
30
28
26
0.5
0.6
0.7
0.8
0.9
1.0
1.1
familiar2