Robot collision avoidance in a supermarket environment

Project Robots Everywhere
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Why this subject?

- Designing robot store clerk as initial idea
- Difficult to design:
  - Product placement via FIFO principle
  - (Verbal) Interaction with customers
  - Analysing shelves
  - Robot navigation
    - Navigating from A to B
    - Recognising entities
    - Reactive collision avoidance (CA)

Look at environment & user requirements

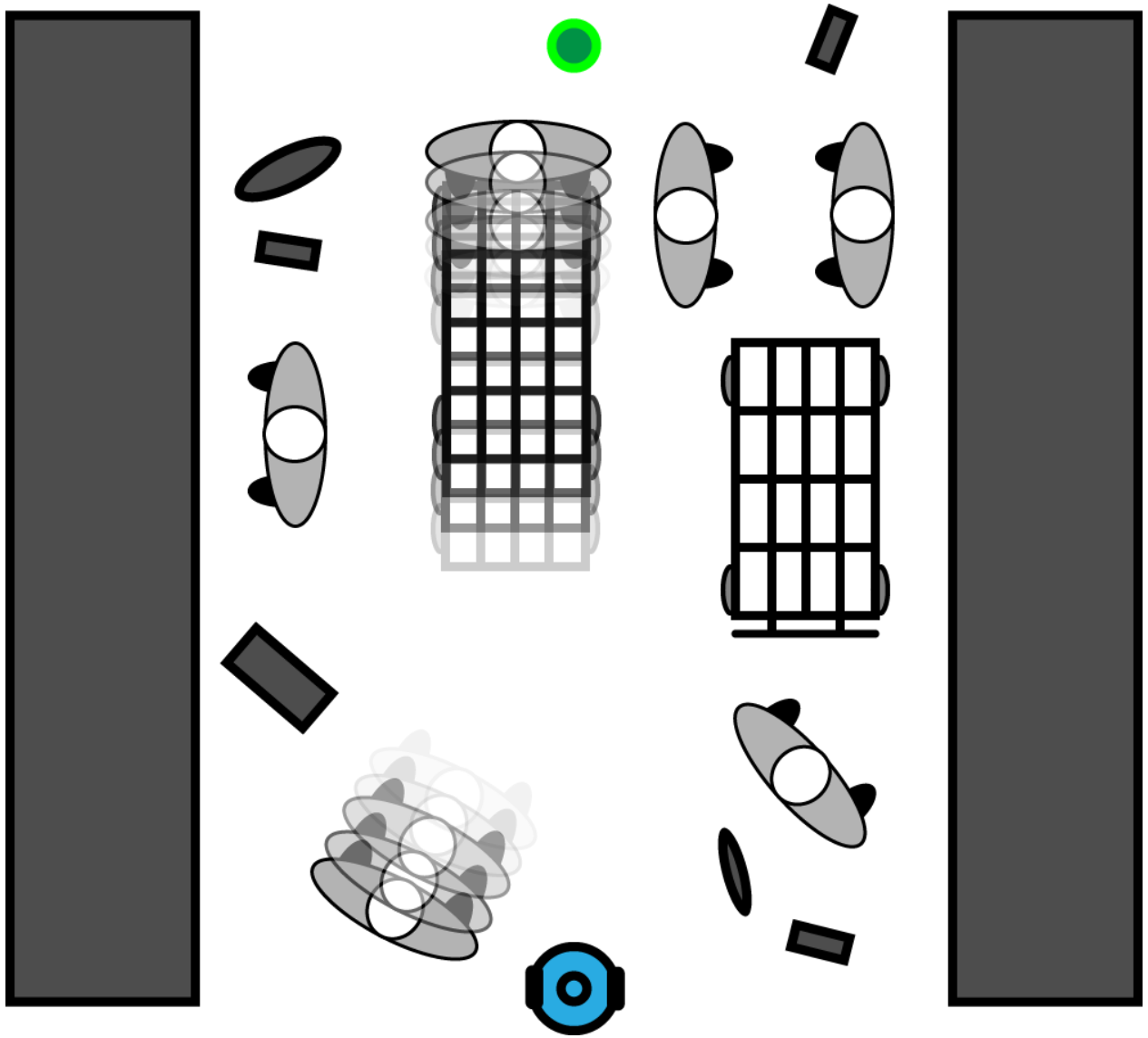
Incorporate them in a CA approach

Test the approach through simulations

Environment description

- Benefits
  - Cameras, top-down view possible
  - Static lay-out
- Difficulties
  - People walking around
  - Crowded situations
  - Shopping carts
  - Misc. items lying around

Assumptions:
Top-down view available
Moving objects treated as humans



User requirements

- For customers and staff members
- Looking at proxemics and HRI
  - *Comfort =* is the absence of annoyance and stress for humans in interaction with robots
  - *Naturalness =* is the similarity between robots and humans in low-level behaviour patterns
  - *Sociability =* is the adherence to explicit high-level cultural conventions

Personal space

- Adapt robot speed and distance to a human's personal space
- Increases comfort

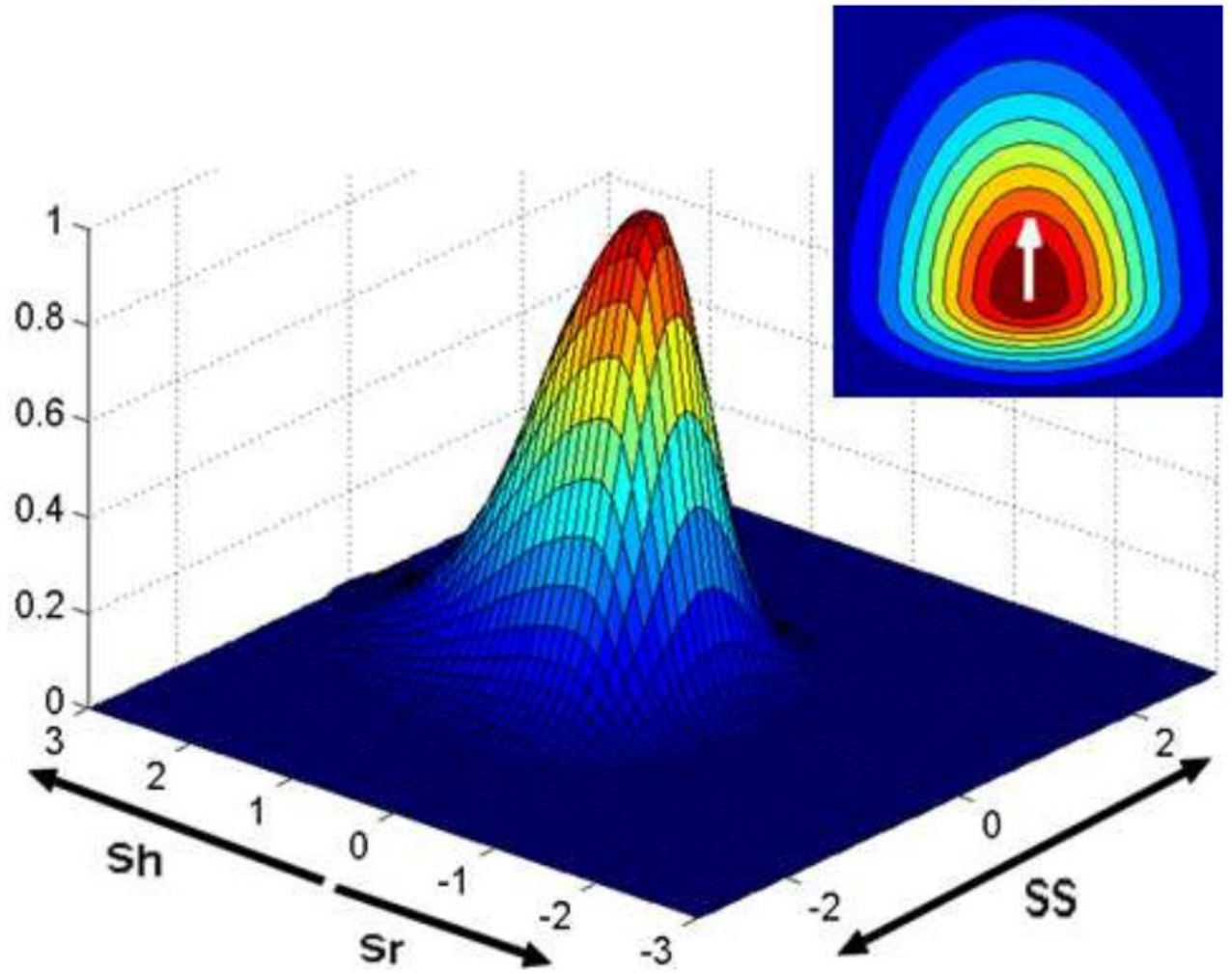
Designation	Specification	Reserved for ...
Intimate distance	0 - 45cm	Embracing, touching, whispering
Personal distance	45 - 120cm	Friends
Social distance	1.2 - 3.6m	Acquaintances and strangers
Public distance	> 3.6m	Public speaking

[1]

[1] E. Hall. The hidden dimension. Anchor Books, 1966.

Personal space model

- Better representation
- Validated with real-life experiments with robots
- Can be used to test CA approach (numerically)



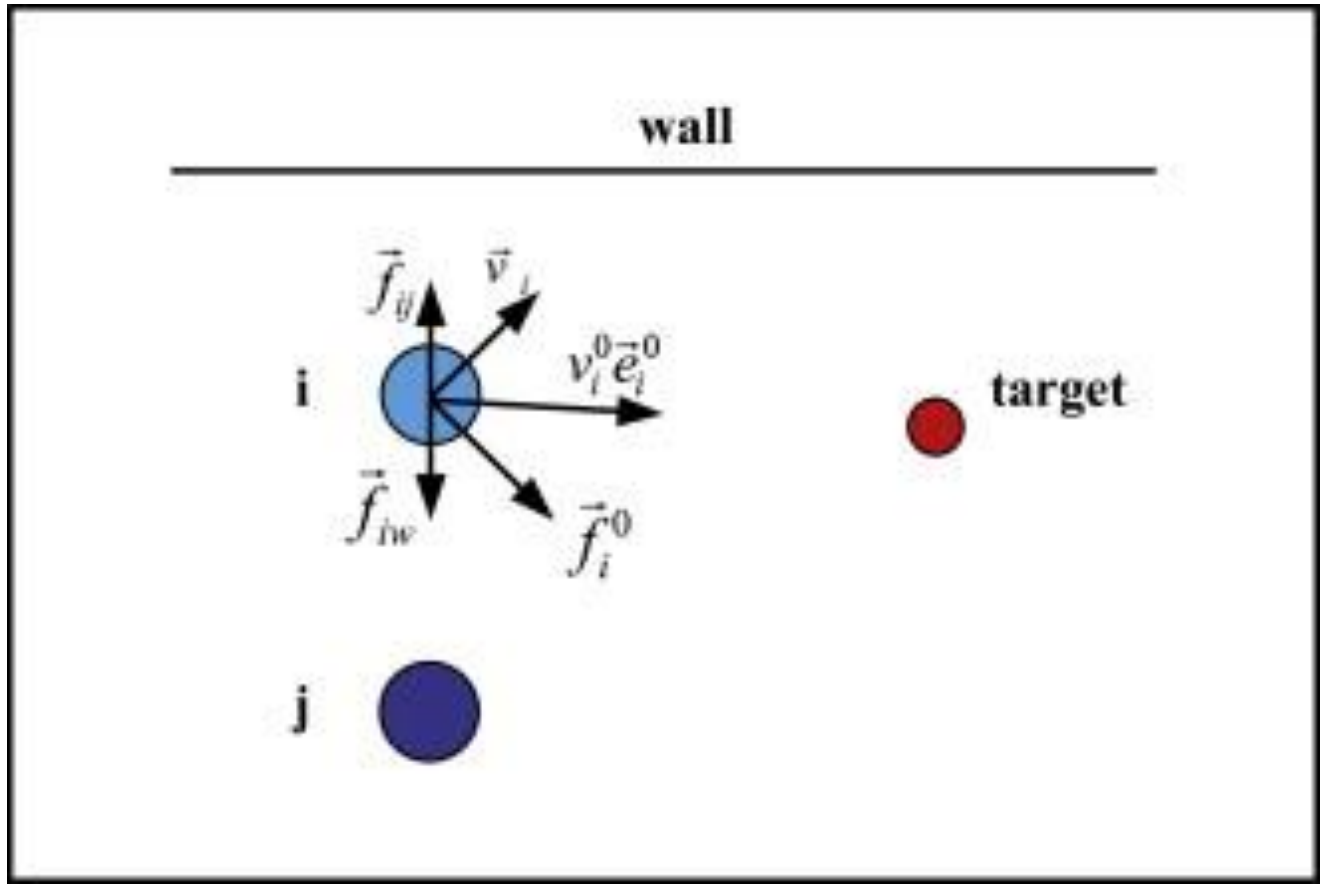
[2] Barnaud, M.-L., Morgado, N., Palluel-Germain, R., Diard, J., & Spalanzani, A. (2014, September 14). Proxemics models for human-aware navigation in robotics: Grounding interaction and personal space models in experimental data from psychology. Retrieved from https://hal.archives-ouvertes.fr/hal-01082517

More user requirements

- Humans should not be blocked (irritation)
  - Cooperation in CA necessary
- Robot should provide environmental cues (sociability, predictability)
  - In crowded situations use low controlling language to alert people
- Approaching speed (naturalness, predictability)
  - Preferred velocities: 0.5 – 1.4 [m/s]
- Avoid erratic motions (naturalness, predictability)
  - Max. acceleration: 0.68 [m/s^2]
- Robot should not be too noisy (comfort, predictability)
  - Preferred: noise volume that scales with velocity
- Avoid behaviour disliked by society/culture (naturalness)
  - E.g. Prefer to walk on right hand side, politely interact with humans

Social Force Model (SFM)

- Physics based
  - Desired forces & velocities
  - Interaction forces
- Benefits for CA
  - Motion prediction
  - Static objects avoided
- Limitations
  - Particle-based
  - No heading
  - No groups



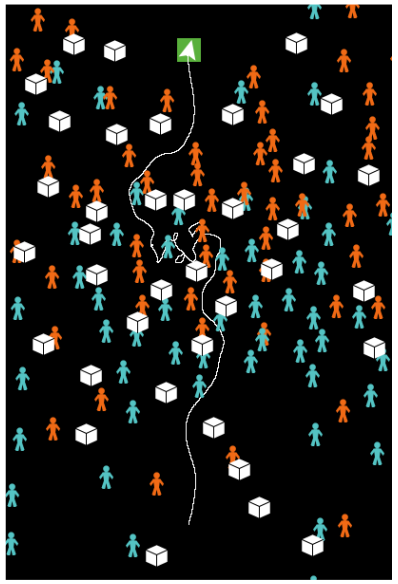
[3] Yang, X., Dong, H., Wang, Q., Chen, Y., & Hu, X. (2014). Guided crowd dynamics via modified social force model. Physica A, 411, 63–73. doi: 10.1016/j.physa.2014.05.068

Simulation with standard SFM

- Not viable for this application
  - PS compromised
  - Inefficient paths taken
  - Physical collisions occur

$$\vec{f}_{i,j}^{int} = -A \exp\left((\ell - s_{i,j})/D\right)\mathbf{e}_{i,j}$$

1



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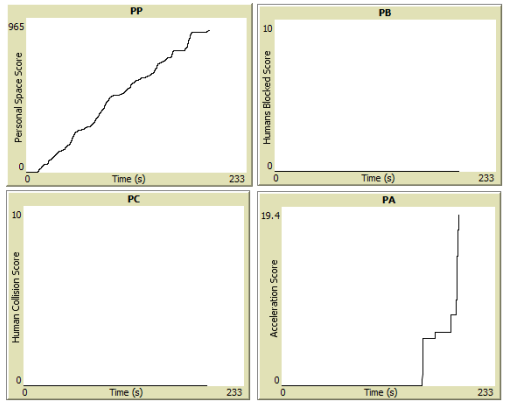
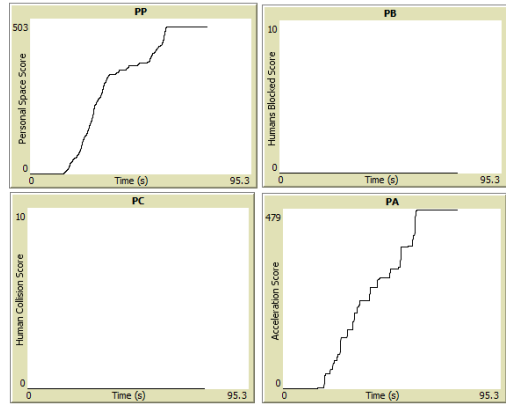


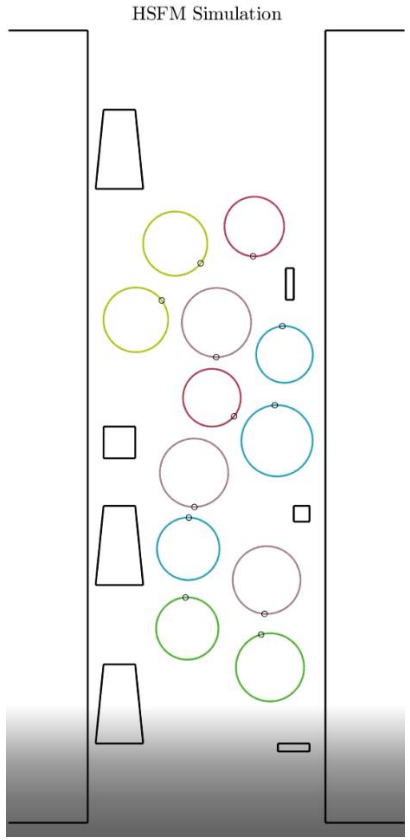


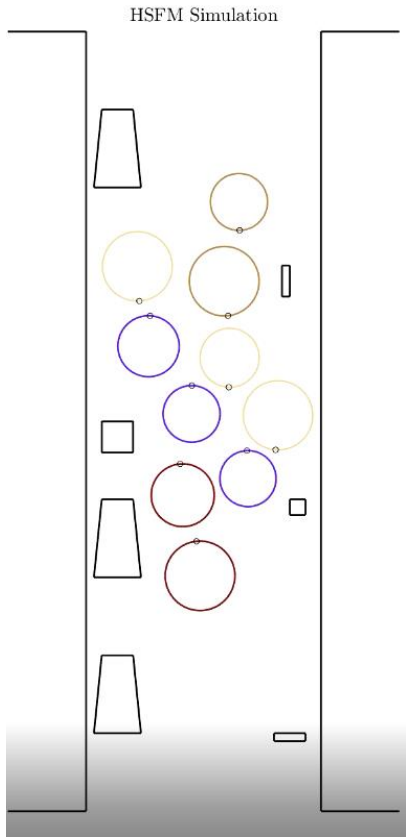
Extended Social Force Model

- Extensions needed
  - Adding physical radii to agents
  - Define agent's heading
  - Adding agent groups with cohesion forces

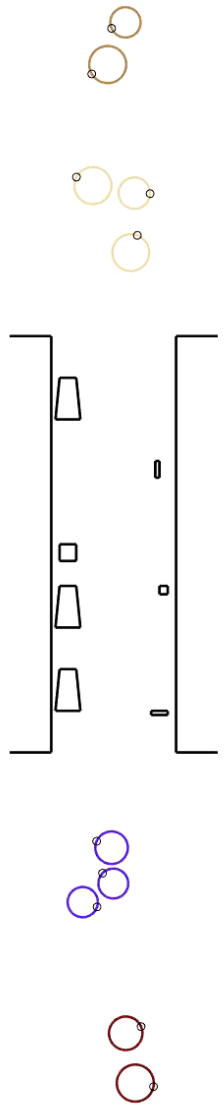
} Headed Social Force Model (HSFM)

Simulation with HSFM

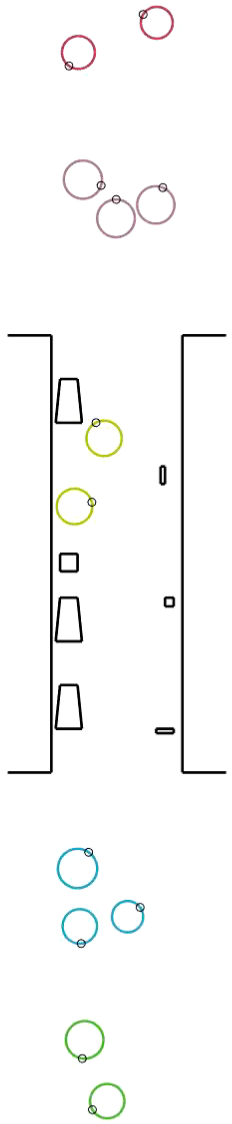




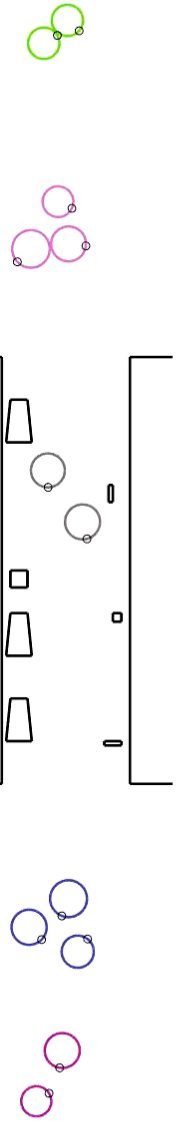
HSFM Simulation



HSFM Simulation



HSFM Simulation

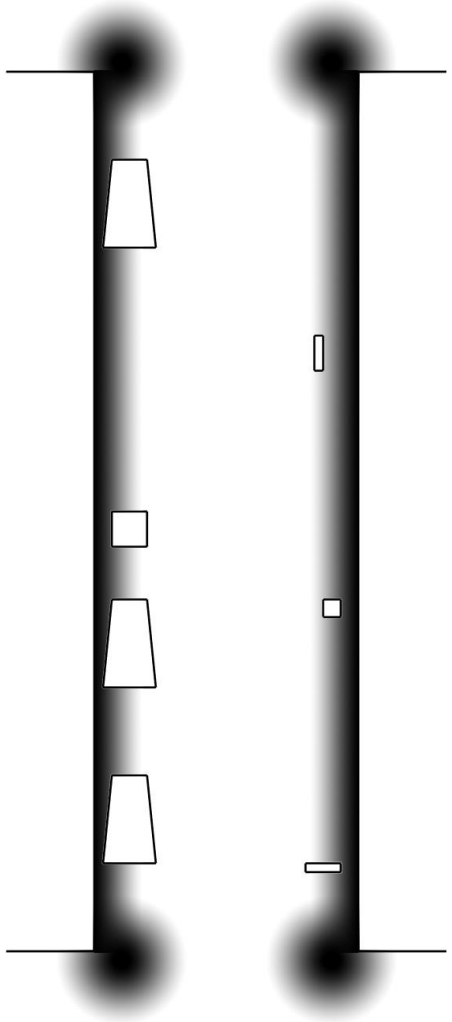


Further extensions

- Environment cost functions influencing velocity
  - Safer movement in critical regions of static environment
- Adding $F^{facepose}$ to repulsive forces
  - Increases predictability

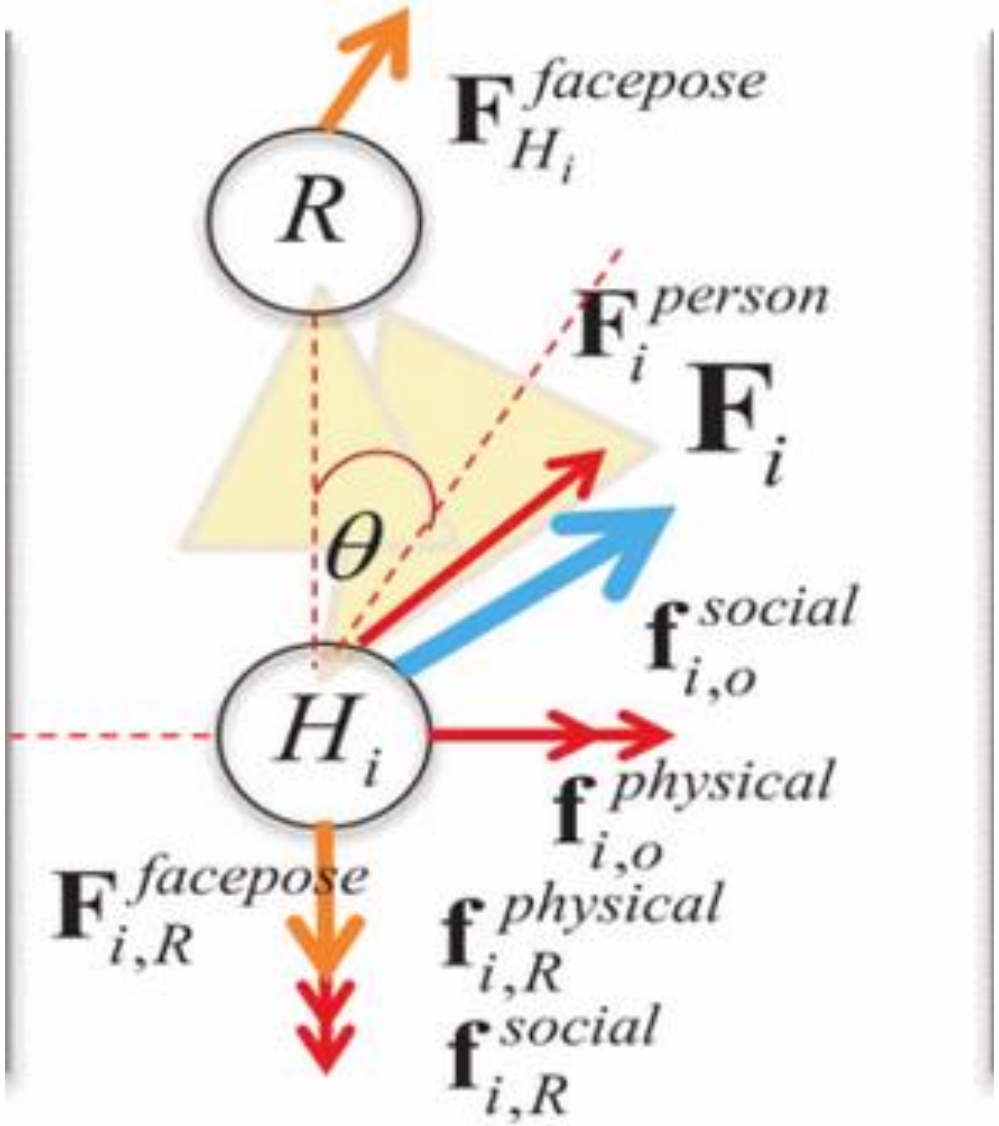
Adding environment cost functions

- Influences velocity directly
- Safer movement
  - Near shelves & corners



Adding $F^{facepose}$

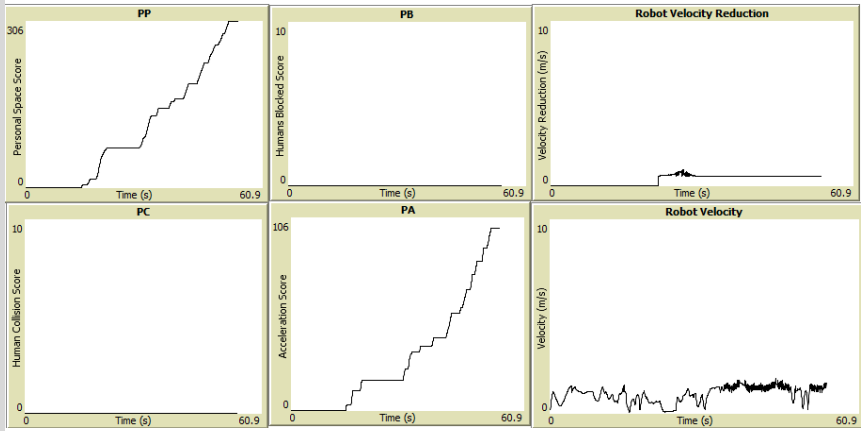
- Respect personal space
- More efficient avoidances
- Predictable trajectories



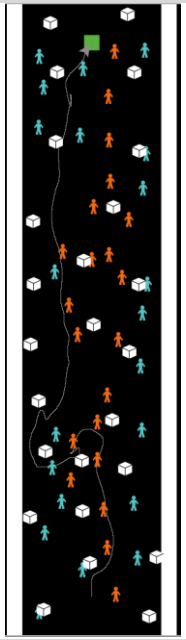
[4] Ratsamee, P., Mae, Y., Ohara, K., Takubo, T., & Arai, T. (2012). Modified social force model with face pose for human collision avoidance. 2012 7th ACM/IEEE International Conference on Human-Robot Interaction (HRI), 215–216. doi: 10.1145/2157689.2157762

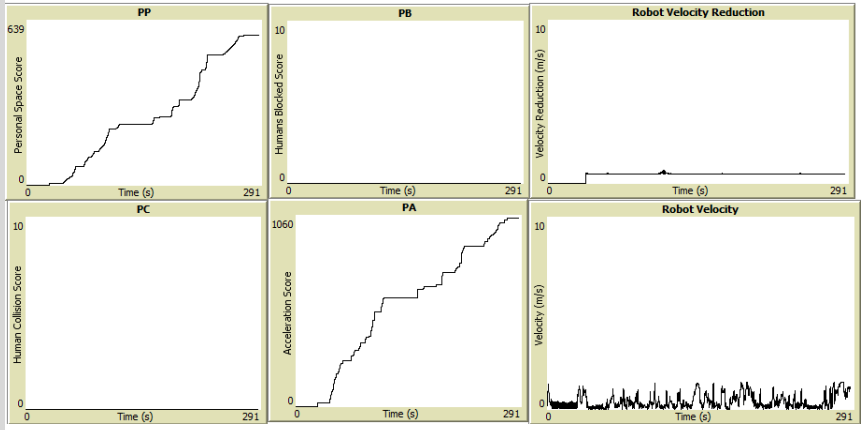
Extended SFM simulation

- $F^{facepose}$ and cost function added
- Benefits
  - Personal space score better
  - Acceleration score better
- Limitations
  - No heading, groups or physical radii added
  - Velocities have to be scaled down

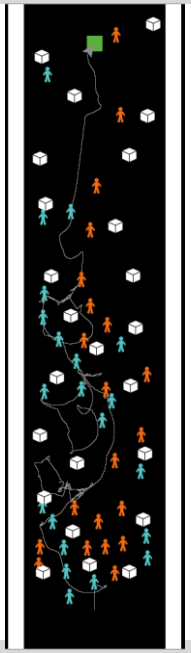


Extended SFM





Standard SFM



Conclusion

- SFM is promising, but needs adaptations
- More simulations with extended HSFM necessary
  - Validation & calibration
  - Look into more extensions
    - Adding navigational forces
    - Better ways to limit unwanted velocities
- Real-life experiments necessary

Questions?