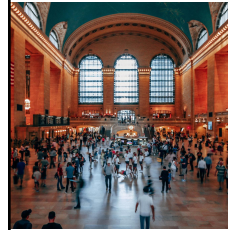


Don't be Rude! Learning Group-aware Policies for Robot Navigation

Yuxiang Gao¹, Kapil Katyal², Jared Markowitz², I-Jeng Wang², and Chien-Ming Huang¹

1. Intuitive Computing Laboratory, Department of Computer Science, Johns Hopkins University
2. JHU Applied Physics Laboratory

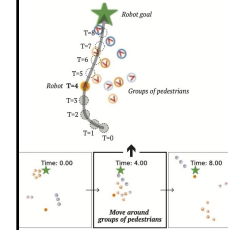


Navigating Crowded Human Environments

- Human movements are fast, dynamic, and following delicate social norms
- Pedestrians as individual, independent entities in robot navigation
- However, the majority of people (70%) walk in groups (Aveni, 1977)



A. F. Aveni, "The not-so-lonely crowd: Friendship groups in collective behavior," *Sociometry*, pp. 96-99, 1977



Dynamic Human Groups

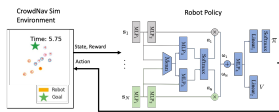
- Respect human grouping (e.g., not to cut through a social group)
- Measure discomfort caused by violating group social norms



3

Our Method

- Extended Social Force Model (Moussaid, 2010) for simulating pedestrian group dynamics
- Convex hull representation of "group space" as part of the reward to encourage group-aware policy
- An attention-based network trained using PPO, a leading model-free, actor-critic approach



M. Moussaid, N. Perrotti, S. Garnier, D. Helbing, and G. Theraulaz, "The walking behavior of pedestrian social groups and its impact on crowd dynamics," *Phys. Rev. E*, vol. 8, no. 4, p. 046117, 2010.

4

Evaluating Group-awareness

Method	Num. Groups	Num. Peds.	Group Intersections ↓	Individual Discomfort ↓	Ped. Social Force ↓	Robot Social Force ↓
Baseline	1	5	143	3.10 $t(498) = 3.48$	0.375 $t(498) = 3.43$	0.523 $t(498) = 1.95$
Group Aware	1	5	15	1.29 $p < .001$	0.351 $p < .001$	0.482 $p = .051$
Baseline	2,548	5	151	2.87 $t(498) = 0.49$	0.522 $t(498) = 3.95$	0.716 $t(498) = 2.78$
Group Aware	2,548	5	22	2.63 $p = .625$	0.485 $p < .001$	0.657 $p = .006$
Baseline	1	10	176	4.20 $t(498) = 2.92$	0.395 $t(498) = 3.99$	0.707 $t(498) = 3.85$
Group Aware	1	10	29	2.31 $p = .004$	0.366 $p < .001$	0.597 $p < .001$
Baseline	4,884	10	258	4.94 $t(498) = 4.99$	0.681 $t(498) = 7.32$	0.964 $t(498) = 4.80$
Group Aware	4,884	10	20	2.29 $p < .001$	0.599 $p < .001$	0.849 $p < .001$



5



Yuxiang Gao
yuxiang.gao@jhu.edu

INTUITIVE
COMPUTING
LABORATORY
Johns Hopkins University

Thank you!

For more information please read our paper
"Don't be Rude! Learning Group-aware Policies
for Robot Navigation"



6