Towards More Efficient Navigation for Robots and Humans

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Traditional Navigation Objectives

Don’t hit things

- plan paths that avoid obstacles

Take the shortest path

- travel close to obstacles without hitting them

Efficient algorithms

- heuristics and greedy algorithms

Don’t scare the humans

- subjective evaluations of friendliness

Social Navigation

People are not obstacles

- proxemics
- social norms

People react to robots

- robots navigate around people
- people navigate around robots

Our Goal

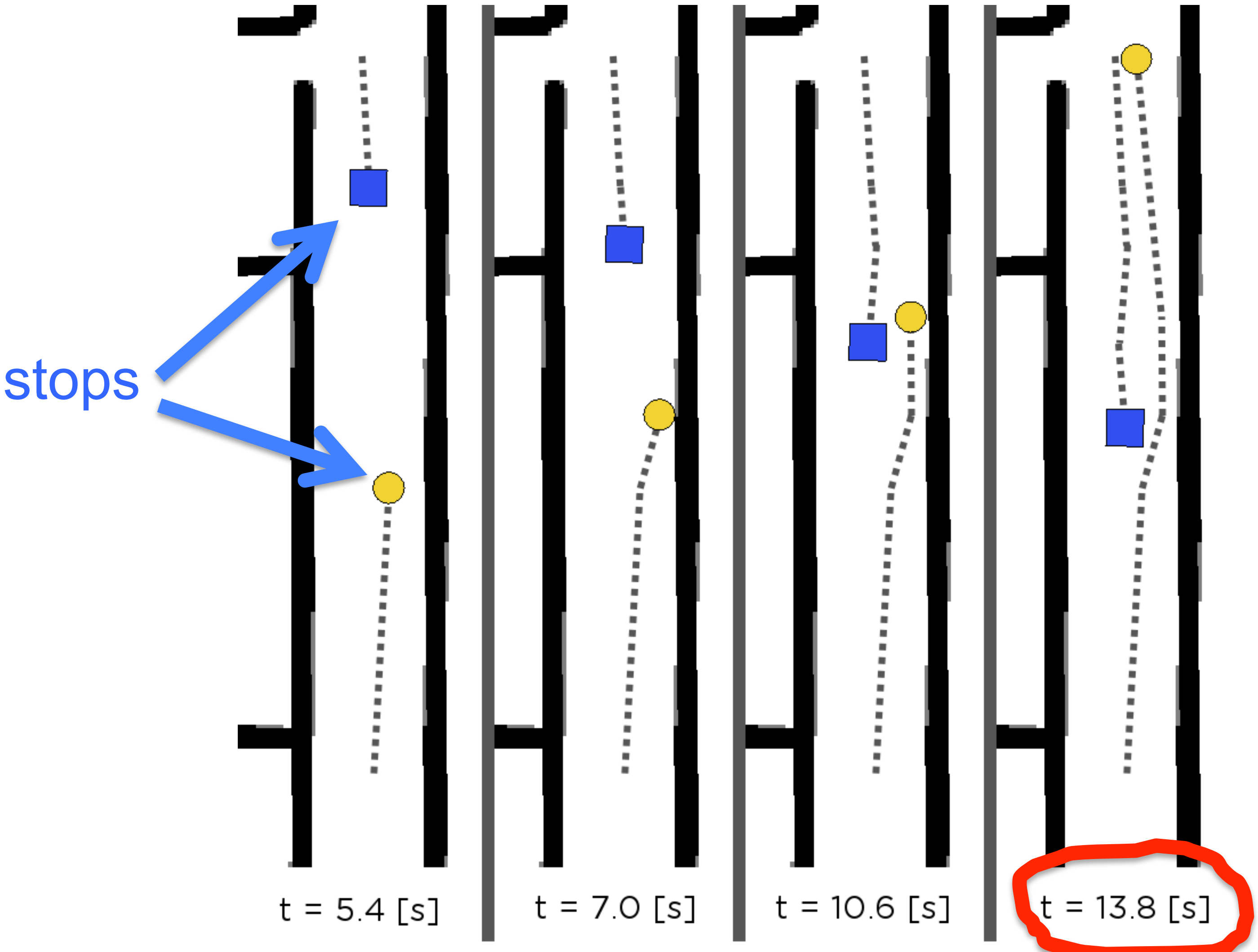
Effective navigation for *both* robot and human

- both get to their goal faster
- avoid awkward social moments
- understand how to prioritize when needed

Contextual navigation

- sometimes robot gets priority
- sometimes human gets priority
- navigation algorithm can adapt on-line

An Example: Passing in a Corridor



Can We Improve on This?

Social navigation behavior

- obey social norms
- pass on right
- implement using standard costmap

Social cues from robot

- make eye contact with person
- confirm they have been seen

The Experiment

Robot and person pass in corridor

Two navigation conditions

- standard
- social

Two gaze conditions

- none
- looks at person

Social Navigation Condition

Uses standard navigation system

- only manipulates costmap

Costmap gradient reflects social norms

- slightly cheaper on right side of corridor
- linear gradient, not Gaussian as commonly used
- contextual and easier to design than social forces

Treat humans differently

- preserve social distances

Gaze Condition

Make “eye contact” with person

- look up from navigation
- point robot’s head at person’s head
- then look away after two seconds

Implementation

PR2 using ROS

- using new navigation stack
- layered costmaps
- code available in ROS Hydro release

Experiment

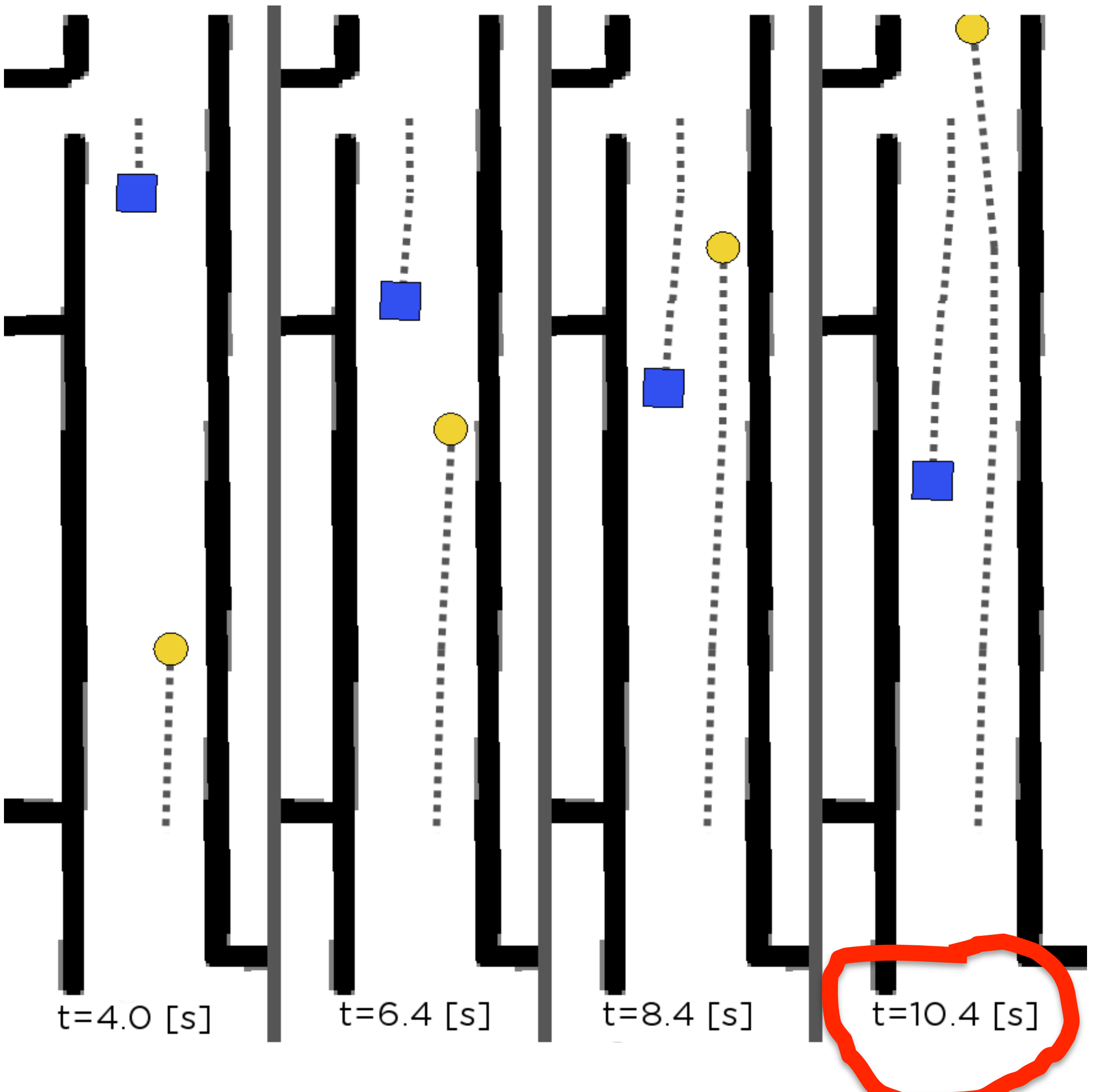
2x2 design

N = 30

180 individual trials

- 3 discarded due to failures

Results: Social Navigation Helps



Results: Social Navigation Helps

Signaling distance is higher

- human interprets robot’s intent earlier
- both get out of the way before they meet

Robot and human are both faster

- neither needs to slow down

Hypotheses

- faster with social navigation
- faster with gaze cues

Results: Gaze Doesn’t Help

People misinterpreted eye contact

- thought that robot as initiating an explicit interaction
- they stopped and waited for it to interact
- sometimes seemed confused when it didn’t

Might be novelty effect

- subjects knew they were in an HRI experiment
- were probably expecting an “interaction”
- might not think of passing in corridor as interaction

Final Thoughts

Robot behavior changes people's behavior

- not always in the ways you predict in advance

Social navigation makes navigation better

- for the combined human-robot system
- often for both individually

Interpretation of gaze is a subtle thing

- people react based on context
- context is also a subtle thing

Questions

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