Planning, Execution & Learning: Social Navigation Planning

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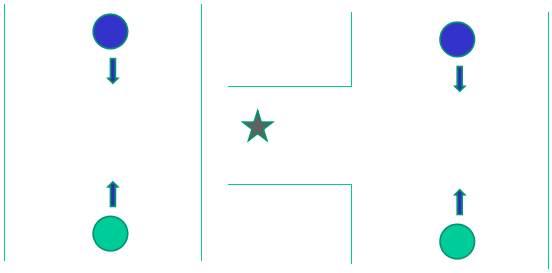
Socially Acceptable Navigation (Kirby)

- Adhere to Social Conventions
  - Respect personal space
  - Tend to one side of hallways
  - Yield right-of-way

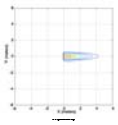
- Such social conventions for movement can be represented as a set of mathematical cost functions
  - Need to consider both immediate (social) situation and ultimate goal
  - Need to replan frequently due to uncertainty (in particular, uncertainty as to people's intentions)

Why Global Planning?



Constraint-Based Planning

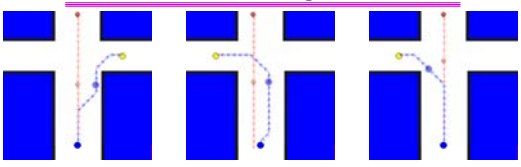
- Constraint: limit the allowable range of a variable
  - Hard constraint: absolute limit
  - Soft constraint: cost to passing a limit
- Objective function
  - "Cost": $\text{cost}(s_1, s_2, a) = \sum_i w_i \cdot c_i(s_1, s_2, a)$
  - Can be *optimized* (maximized or minimized)
- Mathematical equivalence between soft constraints and objectives
- Examples:
  - Minimize distance; Obstacle avoidance; People avoidance; Personal space; Pass on right; Face direction of travel; Inertia; …



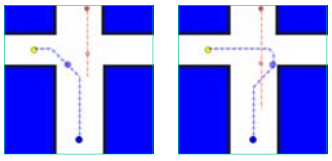
Efficient Social Planning

- A* on 8-connected grid
  - Include people (positions and velocities) in the state space: Very high dimensional space
  - RRT, even with smoothing, produced paths that were too random looking
  - Uses variable-level-of-detail (increasing grid-cell sizes) to deal with computational issues
  - "Forgets" people who have passed and cannot perceive those who are too far away
- Replan continuously
  - Cannot use current incremental planning methods, since they rely on planning backwards from the goal

Corridor Navigation

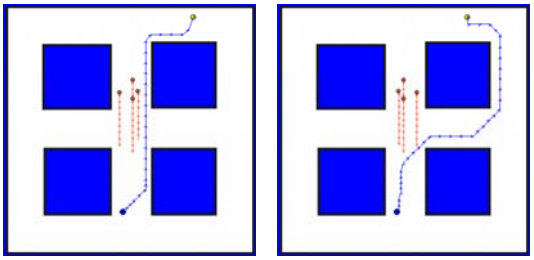


Changing weights:



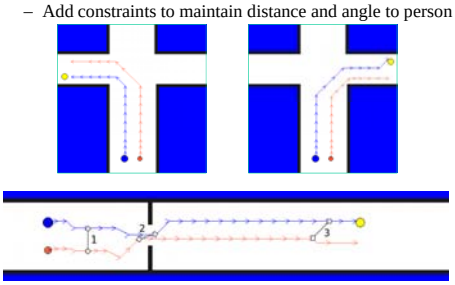
Building Navigation

- Whole route may be affected by presence and distribution of people



Side-By-Side Navigation

- Consider joint actions, joint goals, joint costs
  - Add constraints to maintain distance and angle to person



Human Study

- **Determine User Attitudes Towards Social Navigation**
  - "Social" robot seen as significantly more respectful of human's personal space and robot did better in getting out of person's way
  - Despite that, "social" robot ***not*** seen as significantly more human-like or social