# Mobile Robot Navigation Amidst Humans with Intents and Uncertainties:A Time Scaled Collision cone Approach

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# Outline

# Motivation

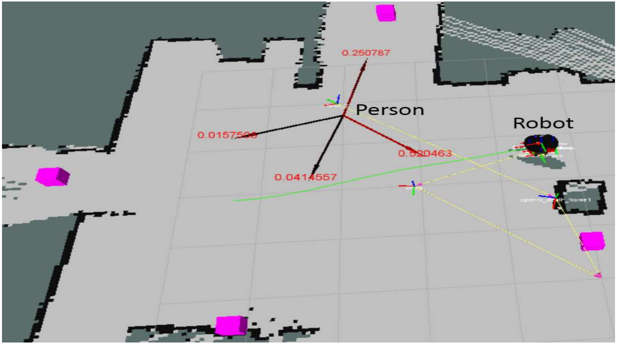
- Robots and humans are beginning to occupy the same work spaces
- Account for human intent in robot's navigation and avoidance Maneuver
- Uncertain and Haphazard local movements of human

# Outline

# Human Intention prediction

- Characterize intents as the final destinations a person might reach
- Let $D = \{\mathbf{d^1}, \mathbf{d^2}, ..., \mathbf{d^m}\}$ be the set of final destinations a person can go to in a given environment
- compute the probability of each of these intents Using Hidden Markov Model.
- Characterize local Haphazard movements as a gaussian $\mathcal{N}(\mu_i(\mathbf{x}^t), \sigma_t)$

# Human Intention prediction

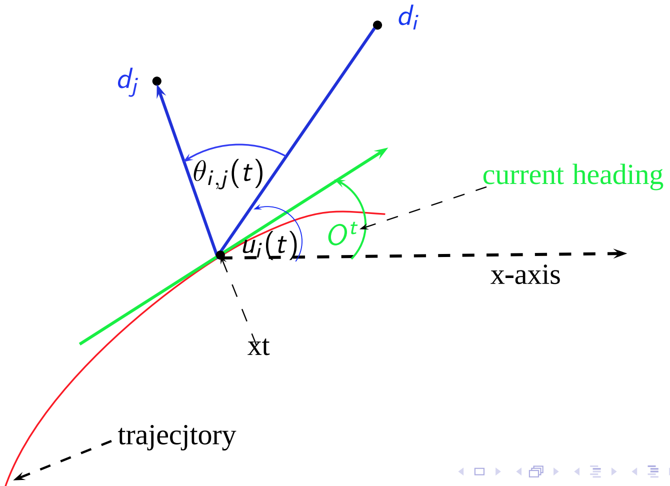


# HMM for Intention prediction

- Let $S^t \in D$ represent the intent of a person to reach destination $S^t$ at time $t$.
- $D$ represents set of states in HMM.
- Human trajectories are represented as $X(T) = \{\mathbf{x^1}, \mathbf{x^2}, ..., \mathbf{x^T}\}$

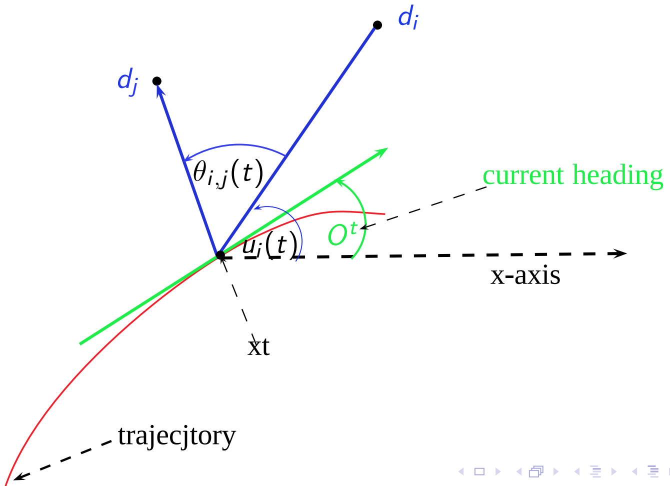
# HMM for Intention prediction

- $O^t$ is the angle defined by the first derivative of the trajectory at point $\mathbf{x^t}$
- Given the current position and orientation we compute the probability of reaching each of the destination $d^i \in D$



# HMM for Intention prediction

- $\mu_i(t)$ is the measure relative to the destination $\mathbf{d^i}$
- $O^t$ is the global measure of the target orientation
- $\theta_{ij}(t)$ is the measure between final destinations $\mathbf{d^i}$ and $\mathbf{d^j}$ relative to the current position $\mathbf{x^t}$



# HMM for Intention prediction

- $b_i(O^t)$ is the probability of observing heading $O^t$ given that the person is following the intent $\mathbf{d^i}$ at time $t$.

$$b_i(O^t) = p(O^t | S^t = \mathbf{d^i}) = \mathcal{N}(O^t | \mu_i(t), \sigma_o)$$

- $a_{ij}(t)$ is the probability that the human changes his intent from $\mathbf{d^i}$ to $\mathbf{d^j}$ at any discrete instant $t$

$$a_{ij}(t) = p(S^{t+1} = \mathbf{d^j} | S^t = \mathbf{d^i}) = \eta \mathcal{N}(\theta_{ij}(t) | 0, \sigma_a)$$

# HMM for Intention prediction

- Let $O^{1:T} = \{O^1, O^1, ..., O^T\}$ is the set of measurements obtained till time $T$.
- Our task is to calculate $p(S^t = \mathbf{d^i} | O^{1:T}, \lambda)$
- In HMM this term is usually referred to as $\gamma_t(i)$ To find this we use standard forward and backward algorithms.

# Proactive collision avoidance in intent space

# Summary

- The first main message of your talk in one or two lines.
- The second main message of your talk in one or two lines.
- Perhaps a third message, but not more than that.

- Outlook
  - Something you haven't solved.
  - Something else you haven't solved.

# For Further Reading I


A. Author.
*Handbook of Everything*.
Some Press, 1990.

S. Someone.
On this and that.
*Journal of This and That*, 2(1):50–100, 2000.