Crowd Simulation, Motion Planning

CSE888.14X – Autumn 2008

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Motivation (Crowd)

- Entertainment (movies and games)
- Architecture
- Training
- Security
- Sociology (crowd behavior)
- Physics (crowd dynamics)

Approaches (Crowd)

- Particle systems
- Agent based models
- Probability networks
- Social force networks
- Flow and network model
- ……

Approaches (Cont.)

- Particle systems: the characters are attached to particle points that are then animated by vector fields.
  - Pros: inexpensive, can be done in most 3D software packages.
  - Cons: limitation of the behaviors
    not very realistic

Approaches (cont.)

- Agent based models:
- Two survey-papers:
  - THALMANN D., O'SULLIVAN C., CIECHOMSKI P., DOBBYN S., **Populating Virtual Environments with Crowds.** *Eurographics 2006 Tutorial* Notes.
  - SCHRECKENBERG M., SHARMA S. D., **Pedestrian and Evacuation Dynamics.** *Springer, 2001.*
- Pros: This system is much more realistic than particle Systems.
- Cons: expensive compared to the previous.

Key Issues

- Large-scale crowd in real time
- Richness of behaviors in a crowd
- control
- computational cost

Papers (crowd)

- REYNOLDS C. 1987, Flocks, herds, and schools: A distributed behavior model. In *Proceedings of ACM SIGGRAPH 87 (July 1987), Annual Conference* Series, ACM SIGGRAPH.
- REYNOLDS, C. 1999. Steering behaviors for autonomous characters. In *Proceedings of Game Developers Conference 1999,*763–782.
- MUSSE, S., AND THALMANN, D. 2001. Hierarchical model for real time simulation of virtual human crowds. *IEEE Transactions on Visualization and Computer Graphics 7, 2, 152–164*
- ULICNY, B., CIECHOMSKI, O., AND THALMANN, D. 2004. Crowdbrush: Interactive authoring of real-time crowd scenes. In *Proceedings of the 2004 ACM SIGGRAPH/Eurographics symposium on Computer animation, 243–252.*
- Anderson, M. McDaniel, E. and Chenney, S. 2003, *Constrained animation of Flocks. SCA*
- SUNG, M., GLEICHER, M., AND CHENNEY, S. 2004. Scalable behaviors for crowd simulation. *Computer Graphics Forum 23,* 3, 519–528.
- Mankyu Sung and Lucas Kovar and Michael Gleicher, 2005, Fast and accurate goal-directed motion synthesis for crowds, Proceedings of the 2005 ACM SIGGRAPH/Eurographics symposium on Computer animation
- Adriano Rinaldi, Alessio Malizia, Rick Parent, 2006, Modeling Behavior in a School of Fish by Fast Synthetic Distributed Vision
- Adrien Treuille, Seth Cooper, Zoran Popovic , 2006, Continuum Crowds, SIGGRAPH 2006
- R. McDonnell, S. Dobbyn and C. O'Sullivan, 2006, Crowd Creation Pipeline for Games
- Wei Shao and Demetri Terzopoulos, 2007, Autonomous pedestrians, Graph. Models, vol. 69.
- Xiaogang Jin*, X., Wang, C., Huang, S., Xu, J. 2007,* Interactive Control of Real-time Crowd Navigation in Virtual Environment, VRST '07: Proceedings of the 2007 ACM symposium on Virtual reality software and technology
- N. Pelechano, J.M. Allbeckand N.I. Badler, 2007, Controlling Individual Agents in High-Density Crowd Simulation

Composite Agents, SCA 08

Yeh, H., Curtis, S., Patil, S., Berg, J. Manocha, D., and Lin, M.

- A composite agent consists of a basic agent that is associated with one or more proxy agents.
- The idea is to inject intangible factors into the simulation by embodying them in "physical" form and relying on the simulator's pre-existing functionality for local collision avoidance.

Composite Agents (cont.)

Yeh, H., Curtis, S., Patil, S., Berg, J. Manocha, D., and Lin, M.

- Algorithm – agent based
- Navigation – global road map
- Collision avoidance – reciprocal velocity obstacles

Composite Agents, SCA 08

- Composite agent formulation

$$
\begin{aligned}
proxy(A_i) &= \begin{cases} \emptyset & \text{for basic agents} \\ \{P_{i,1}, P_{i,2}, \ldots, P_{i,m}\} & \text{for composite agents} \end{cases} \\
parent(P_{i,j}) &= A_i.
\end{aligned}
$$

Composite Agents (cont.)

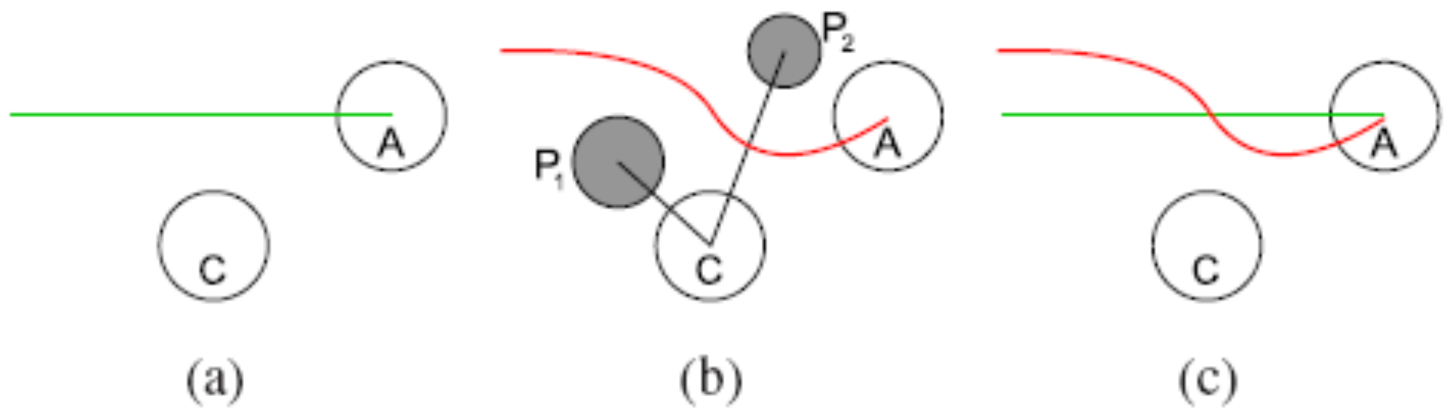


Figure 1: *Responses of an agent A encountering a composite agent C. (a)The green line shows the original planned path taken by A. (b) In the presence of the proxy agent of C, A takes the red path and avoids collision with P_1 and P_2. (c)Comparison of the paths.*

Composite Agents (cont.)

- Limitation:
  - behaviors complicated communication or group coordination.
  - composite agents rely on the mechanism provided by the underlying planning system (e.g. collision avoidance), this level of indirection disallows precise control over the exact nature of the agent interactions.

Group Motion Editing

SIGGRAPH 08

Taesoo Kwon, Kang Hoon Lee, Jehee Lee, Shigeo Takahashi

- A real-time approach to editing group motion as a whole while maintaining its neighborhood formation and individual moving trajectories in the original animation as much as possible.

Group Motion Editing (cont.)

- The graph structure - vertices represent positions of individuals at specific frames and edges encode neighborhood formations and moving trajectories.
- Editing operations
  - Deform group motion by pinning or dragging individuals.
  - Stitch or merge multi-group motions to form a longer or larger group motion while avoiding collisions.

Group Motion Editing (cont.)

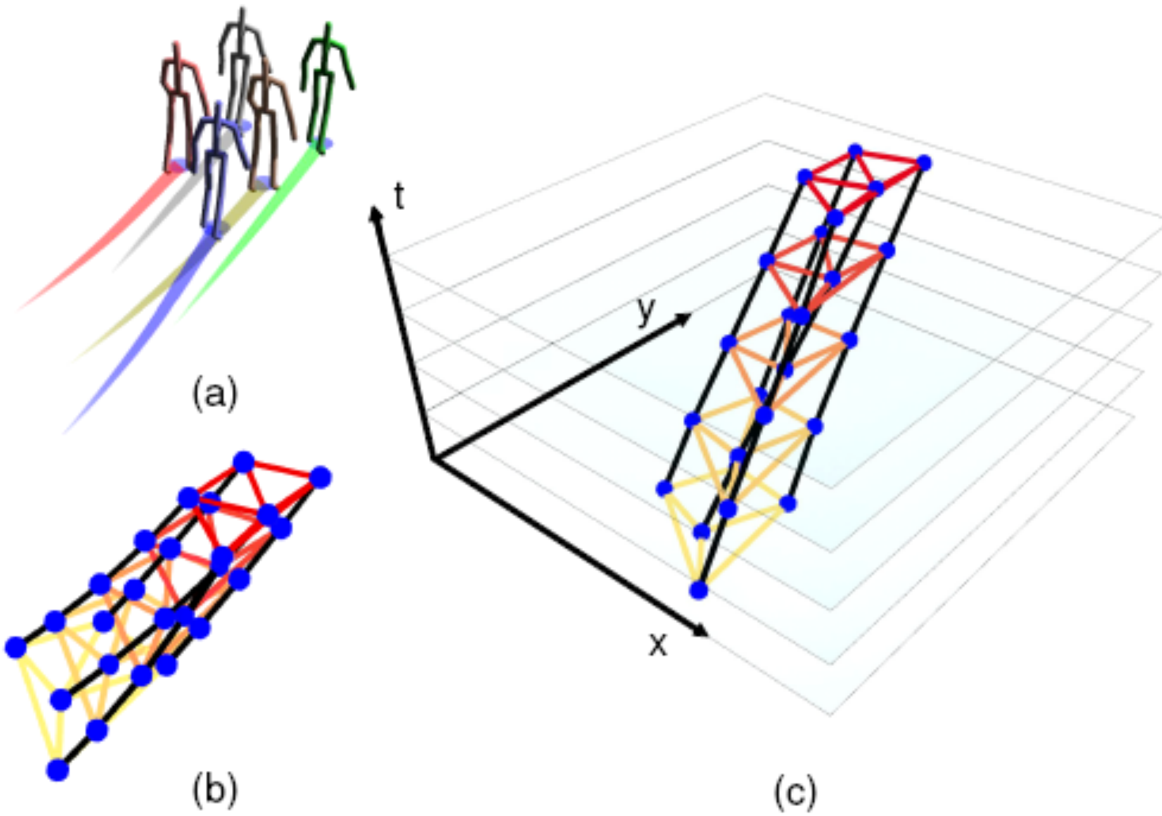


Figure 2: *Graph representation of a group motion clip. (a) A short group motion clip. (b) A graph constructed from the clip. (c) Conceptual view of the graph. The graph encodes time-varying group formations.*

Group Motion Editing (cont.)

- Advantage - a user can interactively manipulate multiple character motions as a whole and still have direct, precise control over individual trajectories.
- Limitation - A large deformation of a group motion can lead to unnatural speedup/ slowdown of individual motions.

Clone Attack! Perception of Crowd Variety

SIGGRAPH 08

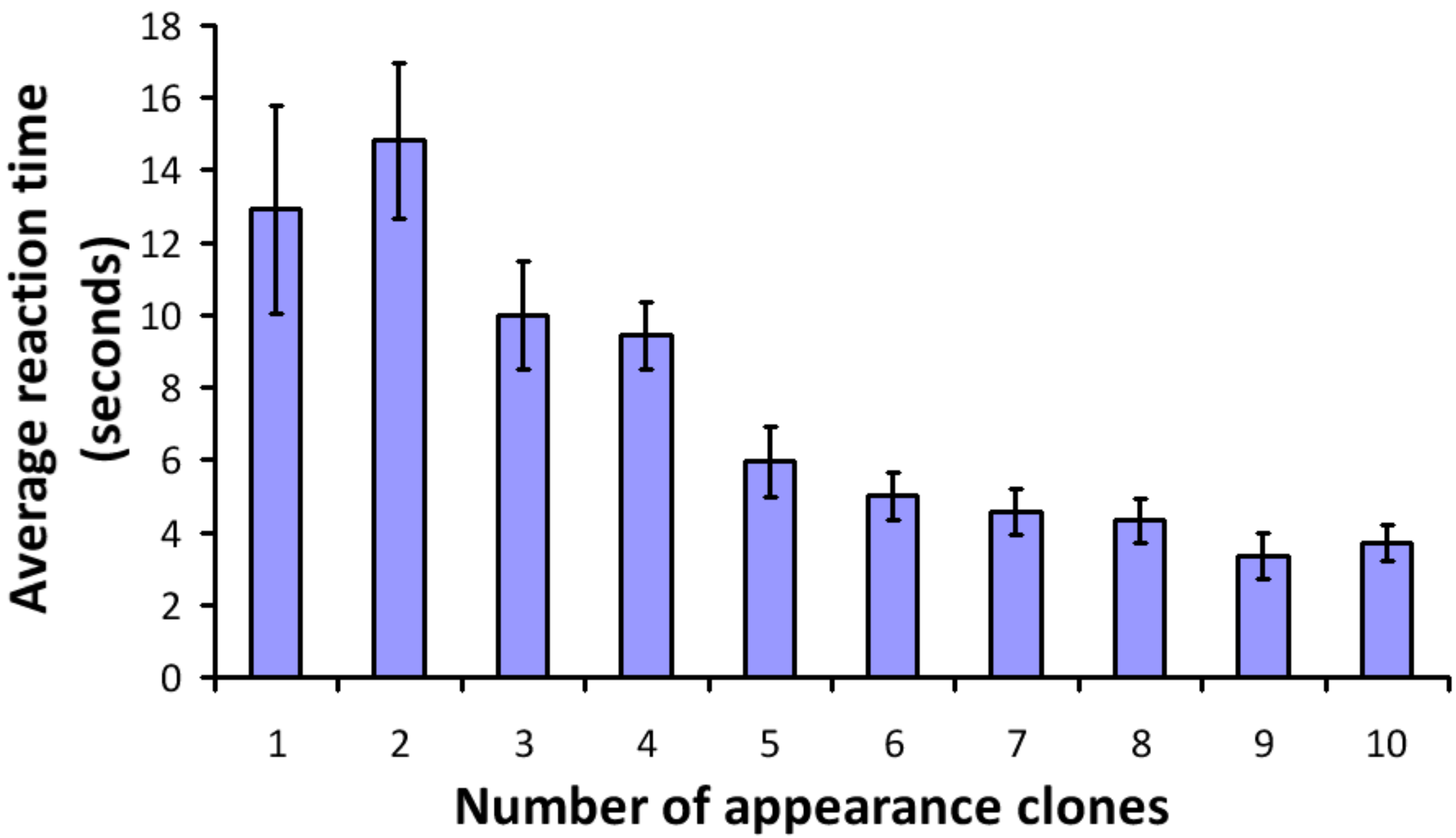
McDonnell, R., Larkin, M., Dobbyn, S., Collins, S.,O'Sullivan, C.

- Study **-** Perception of variety in crowd.
- Issue - when simulating large crowds, the models and motions of many virtual characters are often cloned. However, What is the proper degree of the duplication in terms of the perception of variety in crowds?

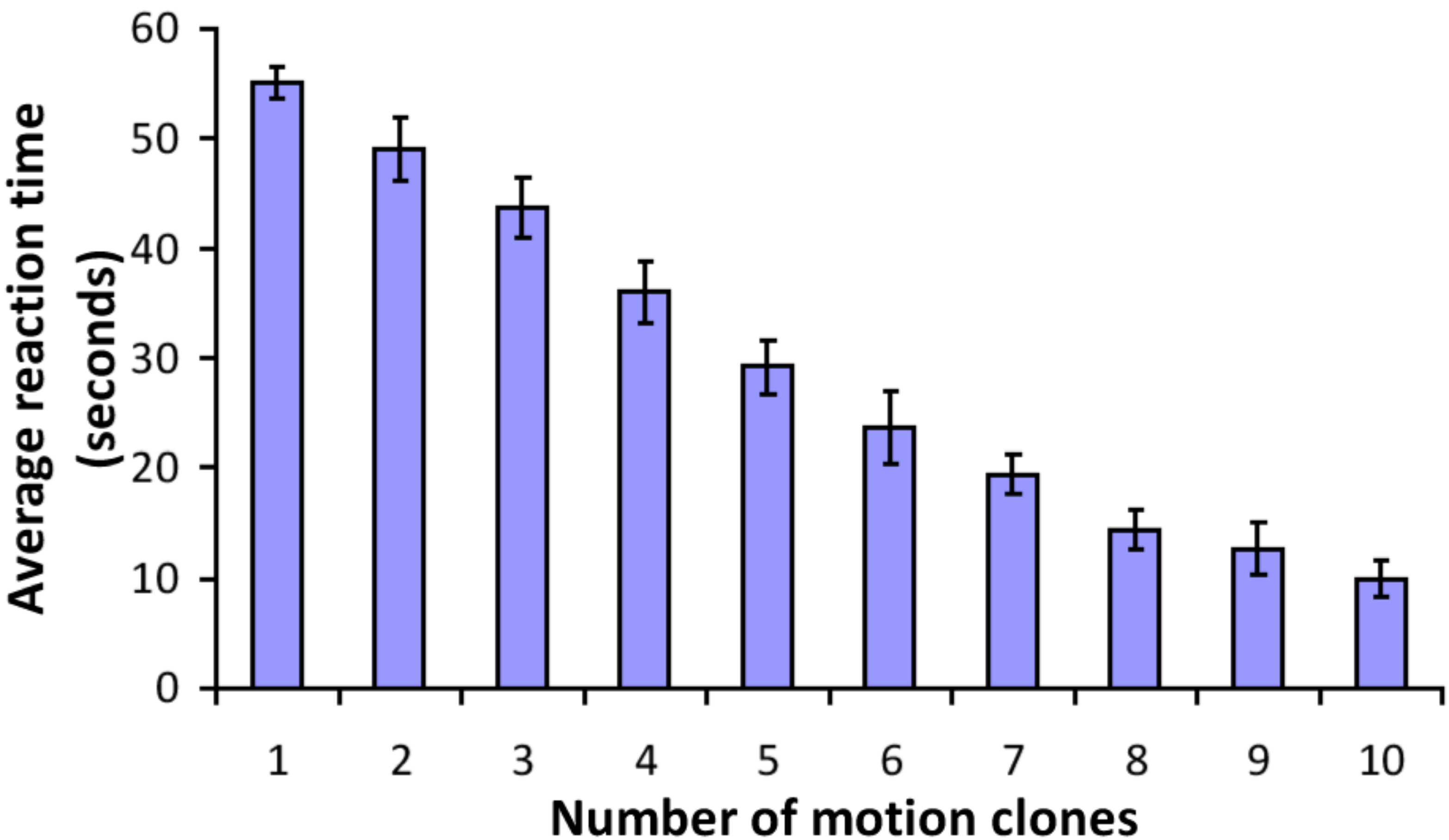
Clone Attack! (cont.)

- Baseline Experiments (single clone) –study the factors that affect the people's ability to identify a single pair of clones in crowd.
- Multiple Clone Experiments
  – Main hypothesis is that increasing the number of clones of a single model or motion will make clone pairs easier to find.

Clone Attack! (cont.)



Clone Attack! (cont.)



Clone Attack! (cont.)

Summary of effects:

- Appearance clones were easier to detect than motion clones
- Increasing clone multiplicity reduced variety significantly
- No appearance model was more easily detected than others
- Certain gaits were more distinctive than others
- Color modulation and spatial separation effectively masked appearance clones
- Combined appearance/motion clones were only harder to find than static appearance clones when their cloned motions were out-of-step
- Appearance clones were also harder to find when combined with random motions
- Motion clones were not affected at all by appearance, even with random appearances

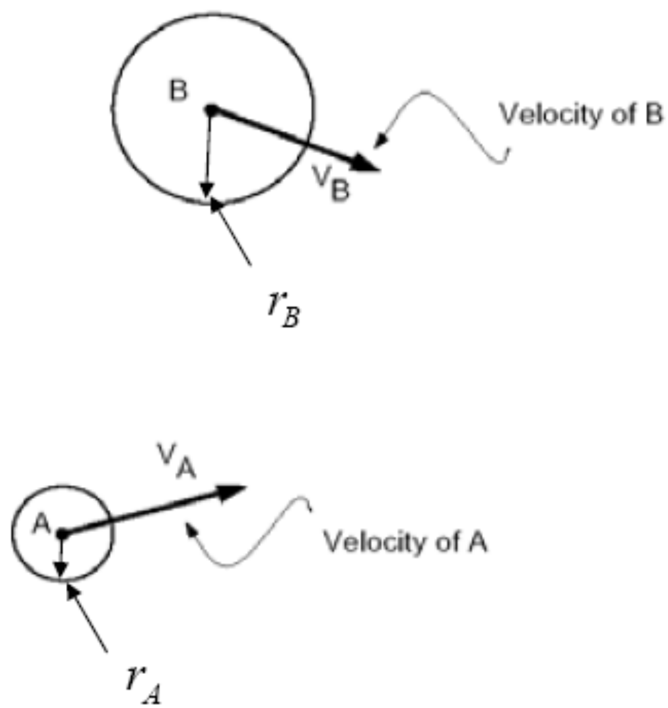
Motion Planning

- A hard problem in a dynamic environment
- Path planning - a kinematic problem involving the computation of a collision-free path from start to goal.
- Velocity planning - the consideration of robot dynamics and actuator constraints.

Approaches (planning)

- Velocity obstacle - P. Fiorini and Z. Shiller, "Motion planning in dynamic environments using velocity obstacles," Int. Journal of Robotics Research, vol. 17, no. 7, pp. 760–772, 1998.
- Reciprocal velocity obstacle - Van Den Berg J., Lin M., Manocha, D., "Reciprocal velocity obstacles for realtime multi-agent navigation. *Proc. of IEEE Conference on Robotics and Automation (2008).*

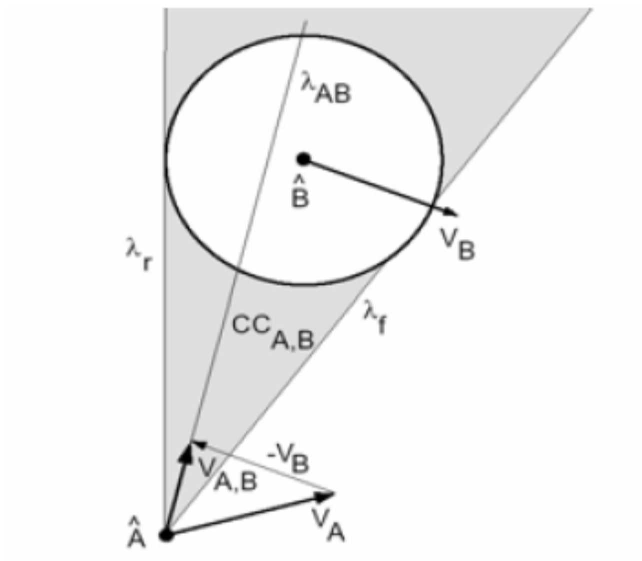
Motion planning in dynamic environments using velocity obstacles



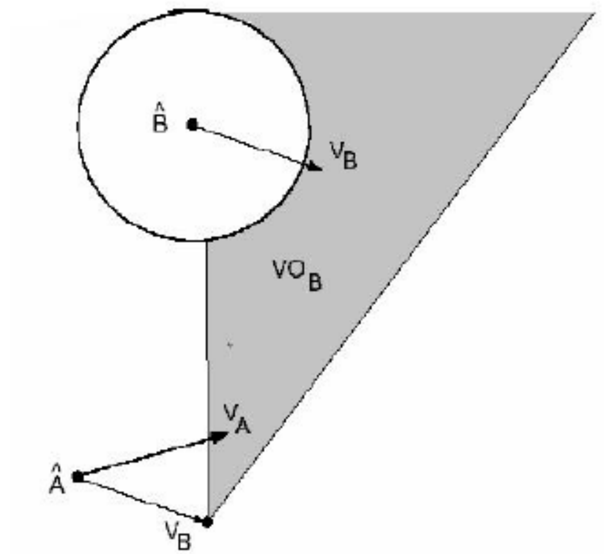
- A is the robot and B is obstacle.
- Each have a respective velocity, VA and VB.
- Assumption: Instantaneous state (position and velocity) is either known or measurable.
- Assumption: An obstacles maintains a constant velocity at least for a given time.

Motion planning in dynamic environments using velocity obstacles

Collision Cones (CC) and Velocity Obstacles (VO)



$$CC_{A,B} = \{\mathbf{v}_{A,B} \mid \lambda_{A,B} \cap \hat{B} \neq \emptyset\}$$



$$VO = CC_{A,B} \oplus \mathbf{v}_B$$

Motion planning in dynamic environments using velocity obstacles

- Collision Cone: set of colliding relative velocities between A' and B'.
- V(A,B) is the relative velocity of A' with respect to B', and λ(A,B) is the line of V(A,B)
- The velocities that lie between λr and λf will cause a collision between A' and B'.
- <u>Intuition behind velocity obstacles</u>: The cone represents those set of velocities that will cause the robot to collide with the obstacle.

Reciprocal velocity obstacles for realtime multi-agent navigation

- Reciprocal Velocity Obstacle - implicitly assumes that the other agents make a similar collision-avoidance reasoning.
- Under this assumption, the proposed framework is guaranteed to generate safe and oscillation-free motions.

Reciprocal velocity obstacles for realtime multi-agent navigation

- Reciprocal Velocity Obstacle - instead of choosing a new velocity for each agent that is outside the other agent's velocity obstacle, we choose a new velocity that is the average of its current velocity and a velocity that lies outside the other agent's velocity obstacle.

Future works

- Real-time crowd simulation and planning
- More dynamic control
- More variety of behaviors
- Trade-off between autonomy and the animator controls