Interactively Directing Virtual Crowds in a Virtual Environment

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Outline

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- **System Architecture:** three major software modules
- **Planning for Crowd Motions**
  - **Path planning for leaders**
  - **Emergent behavior for followers**
- **Implementation and Experiments**
- **Conclusions**

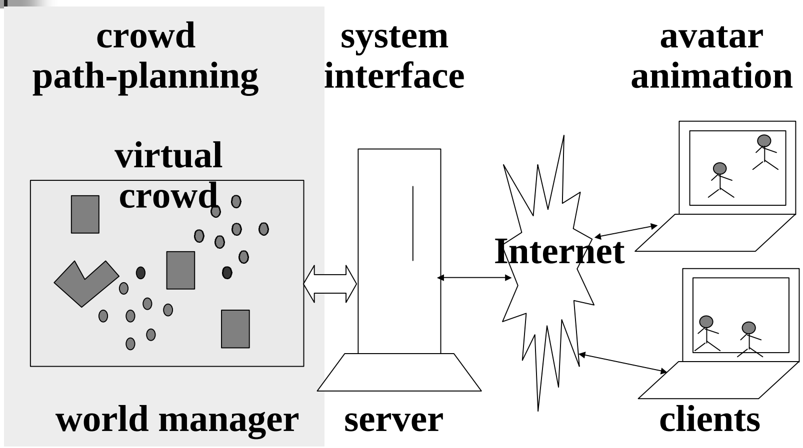
Introduction

- **Most current shared virtual environments (SVE):** only allow real-user login.
- **Desirable features:**
  - **A SVE system allows coexistence of virtual and real users**
  - **A world manager can interactively direct virtual crowds.**
  - **The system can generate collision-free paths for each avatars in a virtual crowd.**
- **Applications:** <u>3D virtual shopping mall</u>

Related Work

- Simulating **emergent behaviors** such as flocking [*Reynolds87*][*Tu94*]
- Incorporating practical **AI techniques** to create real-time animation [*Funge99*]
- Creating realistic **humanoid group motions** through various levels of controls [*Capin98*]
- Using **motion-planning** techniques to generate movie or customized guided tour [*Koga94*][*Li99*]
- Research in **shared virtual environments** [*VNet*], [*ActiveWorld*], [*Blaxxun*]

System Architecture



Three Major Software Modules

- **System interface module:**
  - An interface between VE server and world manager for controlling virtual crowds
- **Avatar animation module:**
  - Using a modified messaging protocol to send parameterized animations to the clients
- **Crowd path-planning module:**
  - Generating the motion of group leaders directed by a world manager

Problem Description

- **System Objectives :**
  - **An interactive interface for directing virtual avatars in a virtual environment**
  - **Generating realistic and safe motions for virtual avatars**
- **Problem :** the path planning problem has high computation complexity.
  - **Dimension of the composite C-space (*C*) for the whole virtual avatars is** 2*m*, **where** *m* **is the number of virtual avatars.**

Problem Simplifications

- **Using an enclosing circle to represent an avatar (reduce DOFs from (x, y,** *q* **) to (x, y))**
- **Ignoring real avatars' (unpredictable) motions at planning time**
- **Using a *leader-follower* model:** not every virtual avatar needs high-level planning

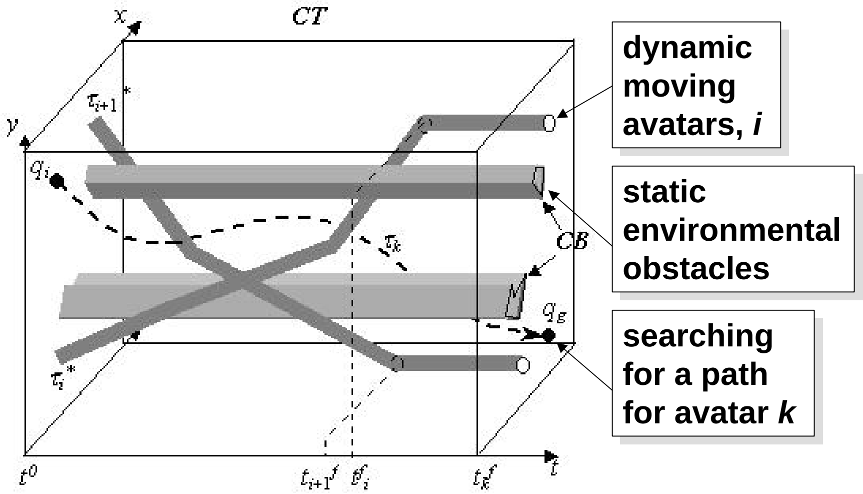
Centralized and Decoupled Planning for Group Leaders

- **Centralized :**
  - **considering composite C-space**
  - **impractical to search exhaustively**
- **Decoupled :**
  - **Velocity tuning:** Each robot is planned independently and then their motions are then coordinated by velocity tuning.
  - ⇨ **Sequential:** Each robot is planned under the constraint of the robots whose motions are generated earlier.

Our Approach to Planning Group Leaders' Motions

- **Decoupled planning approach:** to implement our crowd control system
- **2D potential field:** to account for static environmental obstacles
- **Best-First (BFP) algorithm:** to search for a collision-free path in CT-space
- **Additional constraint:** The goal configuration must be later than the latest finish time of all other virtual avatars.

Path Searching in CT-Space (Configuration-Time Space)



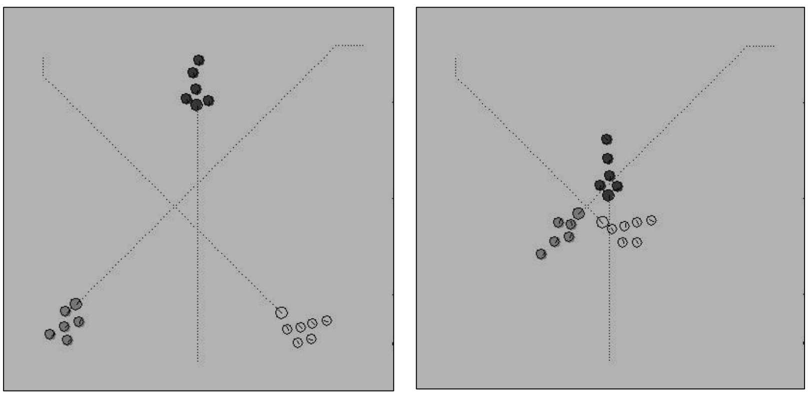
Followers' Emergent Behavior: Using Steering Forces

- **Separation (repulsive forces) :** by nearby avatars within the view cone
- **Cohesion (attractive force) :** the average position of its neighbor avatars
- **Alignment :**averaging together the velocity of the nearby avatars of the same group
- **Others :**
  - **Collision avoidance (repulsive forces):** from environmental obstacles
  - **Leader following (attractive force)**

Emergent Behavior for Followers

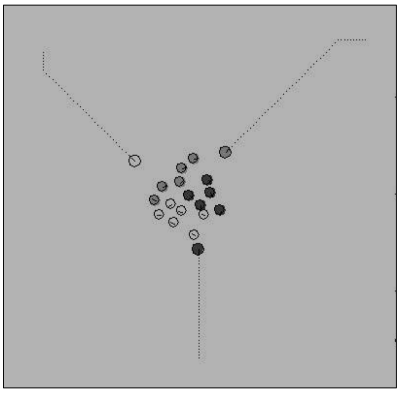
- **Force composition:** the weight of each force is dynamically adjustable by the current environmental status and the history.
- **Example:** Cohesion and alignment forces are ignored when colliding with environmental obstacles
- **Problem :** Followers may fall into local minimum of the composite force field.

Example of Grouping Motions for Three Crossing Crowds (I)



(1) (2)

Example of Grouping Motions for Three Crossing Crowds (II)



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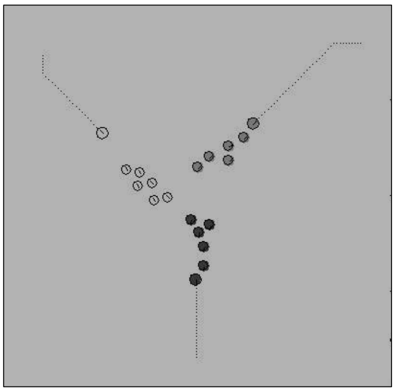

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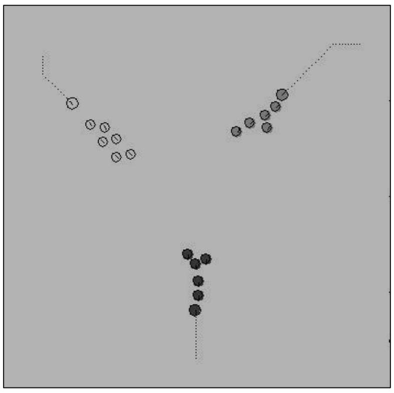
Example of Grouping Motions for Three Crossing Crowds (III)



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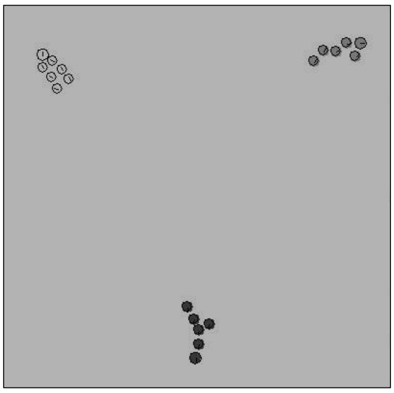

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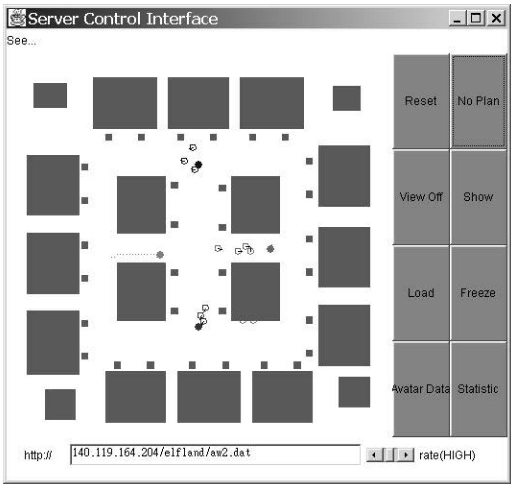
Implementation and Experiments

- **Experimental platform :**
  - **The VNet shared VE system**
- **Server-side 2D Control Interface:**
  - **A 2D user interface in Java to interactively direct virtual crowds.**
- **Client-side 3D Display Interface:**
  - **VRML browser + Java applet + EAI.**

Server-Side Control Interface



Client-Side 3D Display Interface with VRML (I)

Client-Side 3D Display Interface with VRML (II)

Client-Side 3D Display Interface with ActiveWorld

Conclusions

- **Virtual crowds can be controlled with high-level inputs via a GUI, and the system can generate collision-free motions with flocking behaviors for a group of avatars.**
- **The planning capability and efficiency have been successfully demonstrated in a public-domain shared virtual environment system.**