Data-Driven
Group and Crowd Behavior

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What determines how people move?

**Physics**
Mass, inertia, force

**Physiology**
Muscle, skeleton, tendon

**Culture and Psychology**
Style, mood
Group behavior is a complex system

Complex interaction of Individual behavior

Subtle changes of individual behavior may result in completely different group behavior

Principles and Observation

Do we need principles that determine group/crowd behavior?
  Rule-based agent model
  social force model
  potential fields

Do we simply imitate what we have seen before?
  Data-driven crowd simulation
Capturing Crowd Data
Record videos from a bird’s-eye view

Setup

Recorded video

Tracking pedestrians in video
Making Use of Observed Data

Record-and-playback is not enough
Create something new from canned data
Toolbox for animators/programmers
  edit, manipulate, segment, splice, blend, texture, adapt

Visual Characteristics of Crowds

Each crowd exhibit particular “style”

Spatial Formation
  Density, Regularity, Persistency

Characteristics of Individuals
  Distribution of velocities
  Style of locomotion
  Reaction to potential collision
Density

Regularity, Randomness, Clustering

Regular, Geometric  Random, Stochastic  Clustered
Temporal Persistency

Persistent

Transient

Texturing

Group Behavior from Video: A Data-Driven Approach to Crowd Simulation,
Kang Hoon Lee, Myung Geol Choi, Qyoun Hong, Jehee Lee, SCA 2007
Lining Up

Cluttered Formation
Group Behavior of Ants

Rule-Based Agent Model

Each agent perceives its state and decides the next action based on a set of rules.

State
Perceived state \( \in \mathbb{R}^N \)

Rule 1
Rule 2
Rule 3

Action
Two-dimensional movement \( \in \mathbb{R}^2 \)
Data-Driven Agent Model

Each agent perceives its state and decides the next action based on a set of examples.

State-action pairs collected from training data:

State: \( s_1, a_1 \) \( s_2, a_2 \) \( s_3, a_3 \) \( s_4, a_4 \) \( s_5, a_5 \) ... Action: Two-dimensional movement \( \in R^2 \)

State-Action Trajectories

Action: Two-dimensional vector

State: N-dimensional vector from a set of features
State-Action Trajectories

**Action**
Two-dimensional vector

**State**
N-dimensional vector from a set of features

- Speed
- Neighbor

State-Action Trajectories

**Action**
Two-dimensional vector

**State**
N-dimensional vector from a set of features

- Speed
- Neighbor
State-Action Trajectories

**Action**
Two-dimensional vector

**State**
N-dimensional vector from a set of features

- Speed
- Neighbor
- Pivot

Intended direction

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State-Action Trajectories

**Action**
Two-dimensional vector

**State**
21-dimensional vector from 4 features

- Speed
- Neighbor
- Pivot
- Intended direction
Collecting State-Action Pairs

Given the state of each agent, search similar states from data

Data-Driven Simulation

Given the state of each agent, search similar states from data
Data-Driven Simulation

Locally weighted linear regression

Motion Synthesis

Full-body motion from 2D trajectory using motion graph

Walk at variable speeds and angles

Stop at low speed

Standing gestures
Group Motion Editing

Direct manipulation of motion clips
Warp, Splice, Adapt, Copy-and-Paste, Group/Ungroup

Preserve the original quality as much as possible
Individual trajectories
Formation

Modeling group motion clips as 3D meshes

Group Motion Editing, Taesoo Kwon, Kang Hoon Lee, Jehee Lee, Shigeo Takahashi, Siggraph 2008

Direct Manipulation

Obstacle Avoidance
forcing a group through a narrow opening
Splice

Inhomogeneous Groups
Scissoring

Battlefield

Copy and Paste
Why is it Challenging?

**Unstructured formation**
Random, regular, clustered
Persistent vs time-varying

**Crowds are time-series data**
Eg) Aggressive pedestrians try to pass each other

**Arbitrary number of agents**
No one-to-one correspondence

Morphable Crowds

**Interpolate models instead of data**

**Models should have blendable features**

**Sampling-based modeling of**
high-dimensional neighborhood formation
individual trajectory

Morphable Crowds, Eunjung Ju, Myung Geol Choi, Minji Park, Jehee Lee, Kang Hoon Lee and Shigeo Takahashi, Siggraph Asia 2010
Transitoning

Aggressive

Stroll

Horizontonal

Vertical

Army

March to Chat to March

x3
Three-way Interpolation
Wrap Up

Data-Driven Crowd/Group Behavior
  Immediacy of control
  Direct manipulation over fine details

Group motion as a primary entity
  Texturing, style transfer, scissor/stitch
  Interactive editing, copy-paste, group/ungroup
  Blend, interpolate

Combine Principle and Observation

Learning principle from observation
  Capture symmetry, regularity, and patterns in data

Observation drives principles
  Data-driven physics simulation

Principle guides data manipulation
  Motion editing using physical properties
Principles
Algorithms
Methodologies

Observation
Data
Examples

Complexity
Size

Simplicity
Small

Modulation of data
Tailoring principles

Interface
The papers and videos are available at SNU Movement Research Lab

http://mrl.snu.ac.kr

Collaborators
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