A Vector Field Design Approach to Animated Transitions

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http://home.cse.ust.hk/~ywangct/proj/vf_animation.html
Background
Animated Transitions

• They are pervasive in data visualization
• They show the general switching between two visualization views
Animated Transition Tasks

• When using animated transitions, users often want to
  - Track the movement of *individual data points*
  - Track the movement and evolution of *point clusters*

*It is challenging due to the essential dynamic changes of data!*
Motivation – Psychology Studies

• Two key observations from psychology studies:
  
  - *Coordinated motion*
    
    o Points in the same group should move together with similar trajectories[1] (*the law of common fate*)
  
  - *Crowding avoidance*
    
    o Putting data points too close to each other can result in identity confusion[2]


Motivation – Related Work

• Two representative methods of animated transition

Motivation – Related Work

• Two representative methods of animated transition

<table>
<thead>
<tr>
<th></th>
<th>Linear Transition</th>
<th>Bundled Trajectory[^3]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coordinated Motion</strong></td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Crowding Avoidance</strong></td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

Can we enhance coordinated motion and avoid crowding simultaneously in animated transitions?
Our Approach

• Animated transition based on **vector field design**
  - *Input*: the start and end positions of clustered points
  - *Output*: transition trajectories of points
  - *Goal*: improve object tracking of animated transitions by enhancing coordinated motion within clusters and avoiding crowding
Our Approach

• Animated transition based on vector field design
  - General Idea:

1. **Desirable Initial Path**
2. **Vector Field**
3. **Object Trajectories**
4. **Initial Path Generation**
5. **Vector Field Computation**
6. **Point Advection**
Our Approach – Initial Path Generation

• Automated approach:
  - a force-directed model in 3D space
    o Repulsion
    o Attraction
    o Smoothening
Our Approach – Initial Path Generation

• Manual sketching:
  - Designers may like flexible design for animation in certain cases
  - A user interface is provided
Our Approach – Vector Field Computation

• How to construct a vector field based on an initial path?

- Core idea:
  o Overlay an $n \times n$ grid over the screen to define the vector field
  o Propose two types of constraints to restrict the vector field
  o Apply the above two steps to each cluster of points
Our Approach – Vector Field Computation

- Path constraint

\[ \lambda_u \vec{u} + \lambda_v \vec{v} + \lambda_w \vec{w} = \vec{b} \]
\[ \lambda_u + \lambda_v + \lambda_w = 1 \]
Our Approach – Vector Field Computation

• Smoothing constraint

\[ \tilde{z} - \frac{1}{4} \tilde{v}_1 - \frac{1}{4} \tilde{v}_2 - \frac{1}{4} \tilde{v}_3 - \frac{1}{4} \tilde{v}_4 = 0 \]
Our Approach – Vector Field Computation

• By now, we build an over-constrained linear system:

\[ Ax = b \]

Path constraint
(T * n^2 matrix)

Smooth constraint
(n^2 * n^2 matrix)

Grid corners defining VF
(n^2 * 2 matrix)

Conjugate gradient method is used to solve this linear system
Our Approach – Point Advection

• Given the vector field, we treat the points of each cluster as particles in a flow and advect them

The standard 4th-order Runge-Kutta method
Our Approach – Point Advection

• Given the vector field, we treat the points of the group as particles in a low and advect them.

It DOES NOT guarantee each point will definitely reach their end positions!
Our Approach – Point Advection

- **Interpolation** of forward and reverse advection
Trajectory Examples
Demo

Manual Transition Design
Evaluation
Evaluation – Qualitative User Interview

• Purpose: evaluate the usability of manual transition design

• Ask 4 participants to do manual sketching for animated transition design and collect their feedback

• Major feedback
  - Participants enjoy the flexibility of designing transitions by themselves
  - More point clusters bring more difficulty for manual sketching

Evaluation – Metric Evaluation

- **Metrics**
  - *Occlusion*
  - *Dispersion*
  - *Deformation*

- **Datasets**
  - 50 synthetic transitions
  - 20 real transitions

Illustration figure from Reference [3]

Evaluation – Metric Evaluation

• Results
  - Our approach strikes a good balance in reducing crowding and deformation in animated transitions
    o Compared with linear transition: lower outer occlusion
    o Compared with trajectory bundling: lower deformation
    o For more details, pls refer to our paper
Evaluation – Formal User Study

Tasks: ask 24 participants to track 2 or 3 targets in transitions of high outer occlusion
Evaluation – Formal User Study

• Tasks: ask 24 participants to track 2 or 3 targets in transitions of high outer occlusion

• Experiment setting:
  - 3 techniques (ours, linear transition, trajectory bundling.)
  - 2 target number (high: 3, low: 2)
  - 2 group size (10 pts/group, 5 groups; 5 pts/group, 10 groups)
Evaluation – Formal User Study

• Results - accuracy

- Our approach has better accuracy (or less error)
Summary and Discussion

• The proposed animated transition approach using vector field design:
  - Strike a good balance in lowering occlusion and deformation
  - Enhance coordinated motion and avoid crowding
  - Improve tracking accuracy in transitions of high occlusion

• Limitations
  - Scalability issues
  - Very curved trajectory may influence tracking accuracy
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