ARTIFICIAL INTELLIGENCE SUMMIT

On All Fours

- Creating Realistic Quadruped Locomotion

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Background

- Project Fang
  - Virtual Pet

Background

- Project Fang
  - Virtual Pet
  - For Microsoft HoloLens
    - This talk is not HoloLens specific

Overview

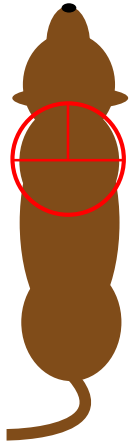
- Quadruped locomotion
  - Using mostly common techniques
  - Should fit well within the CPU budget of any application

Overview, cont'd

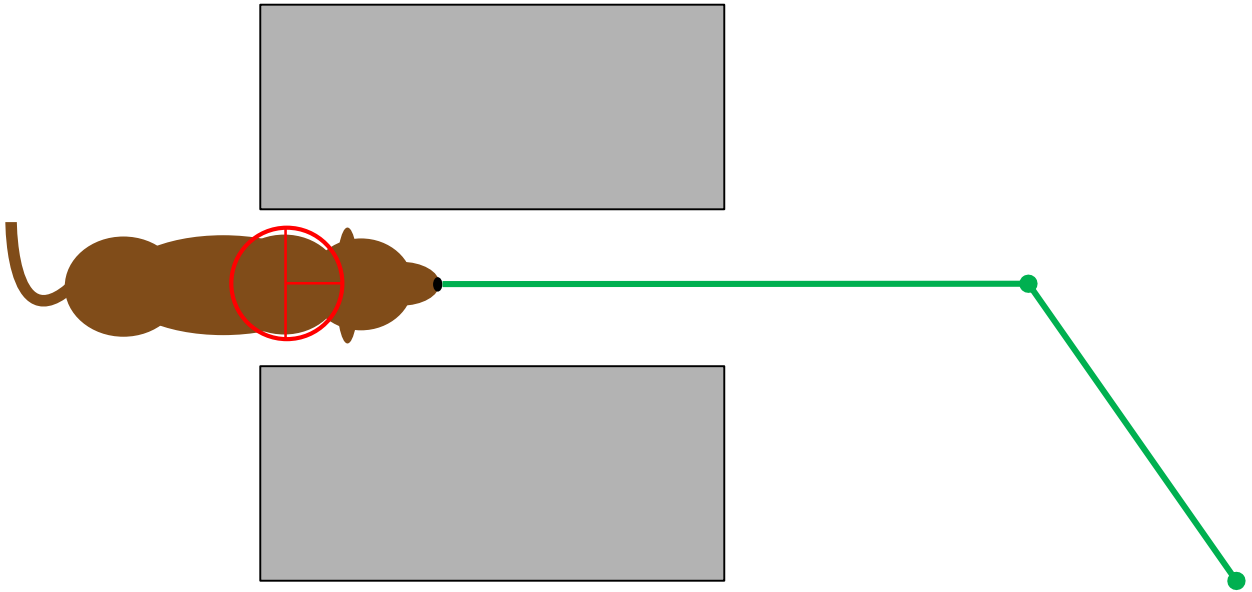
- The Algorithm
  - Generate a smooth, realistic path to follow
  - Use a mix of procedural and caned animations to create realistic looking motion
- Various tips and tricks

Pathfinding Size

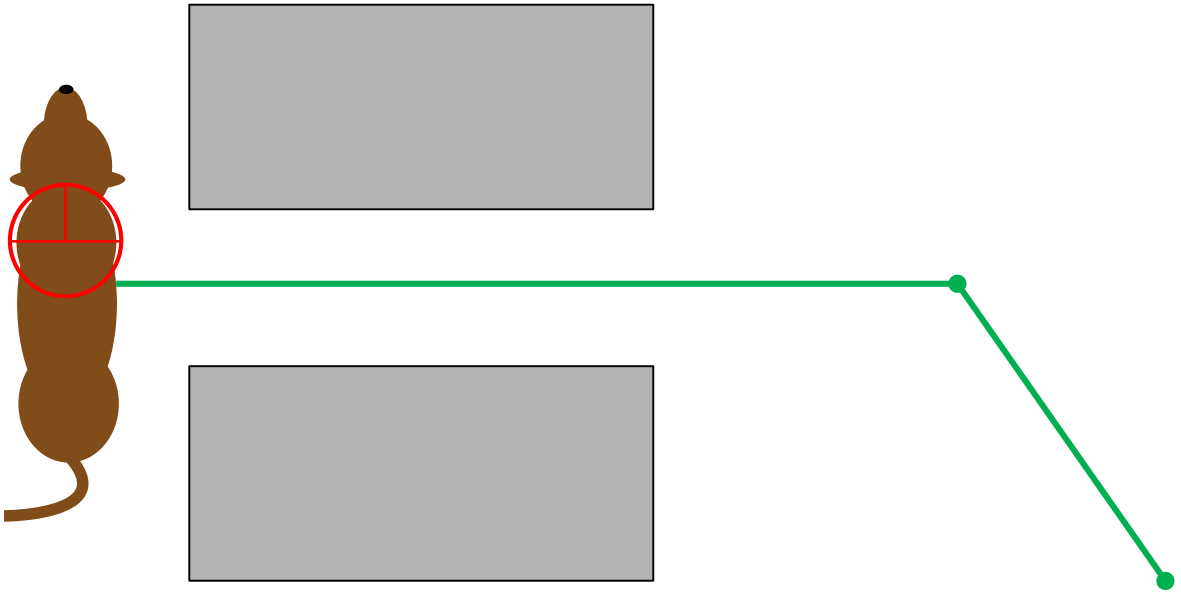
- Use a pathfinding radius equal to half the dog's shoulder width



Pathfinding Size, cont'd



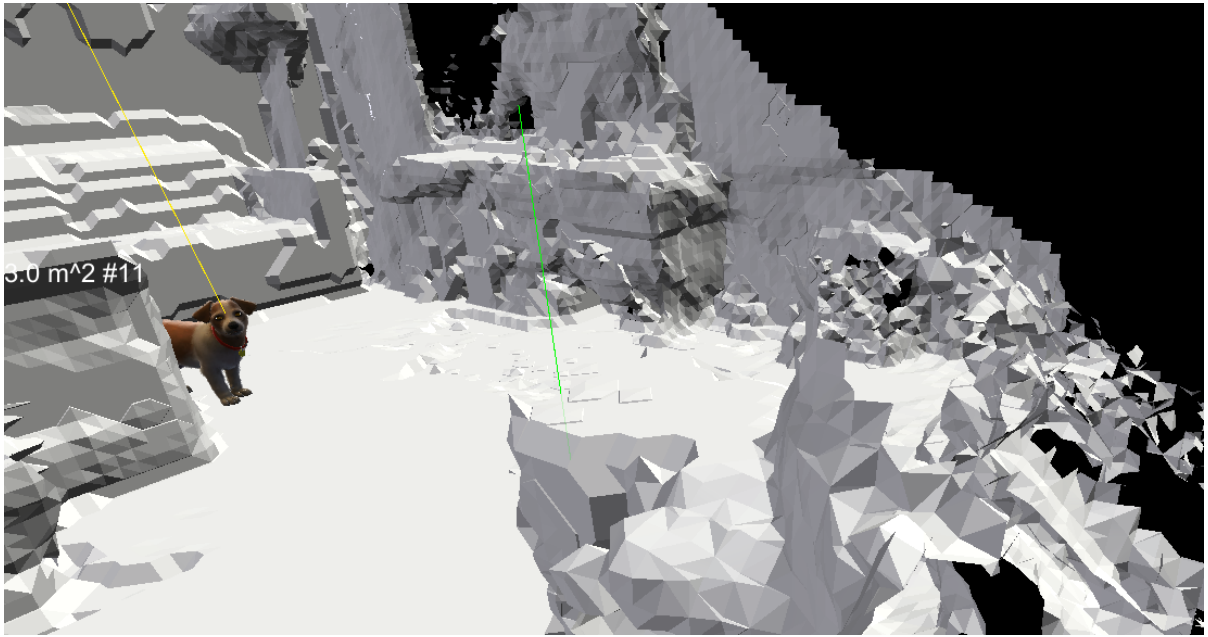
Pathfinding Size, cont'd



Turn limitations

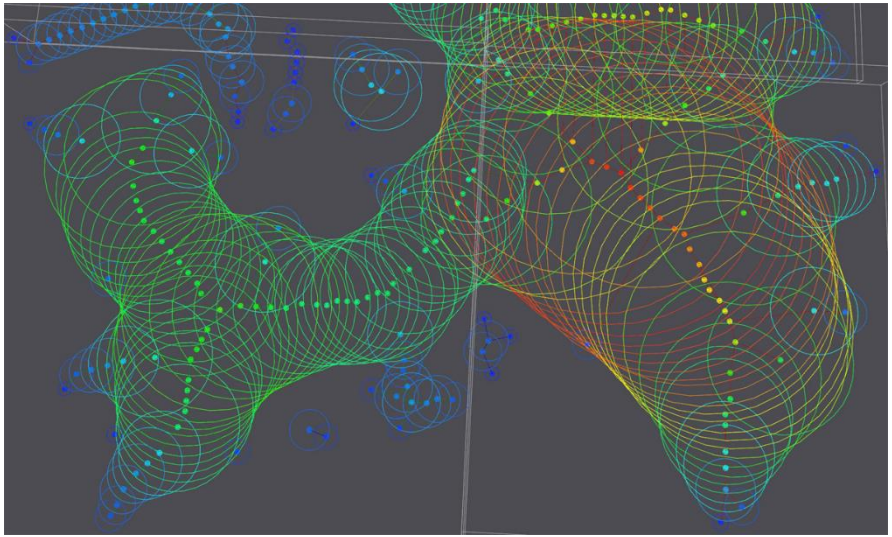
- No limitation on turning
  - Smoothing removes sharp corners
  - Dog can turn around any real world corner

The Pathfinding Data



The Pathfinding Data

- A simplified representation is created from the raw data
  - Nodes with positions and a radius
  - A minimal tree connecting the nodes



Path Generation

- Create rough path using A*
- Optimize path using string pulling

Better Path Generation

- Subdivide the path
- Smooth the path

Smoothing

- Uses a physics based model of connected springs
  - Torsion springs and linear springs
  - A technique used for creating racing lines

Smoothing Problems

- Springs worked great – most of the time
  - Occasionally produced paths with kinks and knots in them.
  - Required a very large number of iterations for extreme cases

Smoothing Solutions

- Think of smoothing as an optimization problem
  - There are many algorithms for solving optimization problems

Faster Smoothing

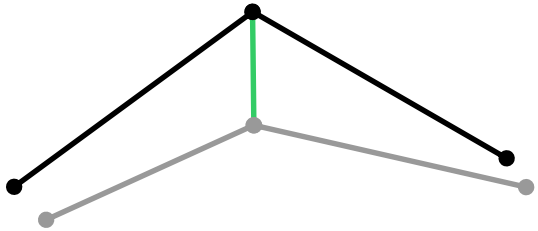
- Chambolle-Pock
  - First-order primal-dual algorithm
- An order of magnitude more effective
  - Two passes over the data per iteration
  - Works well with constraints

Chambolle-Pock

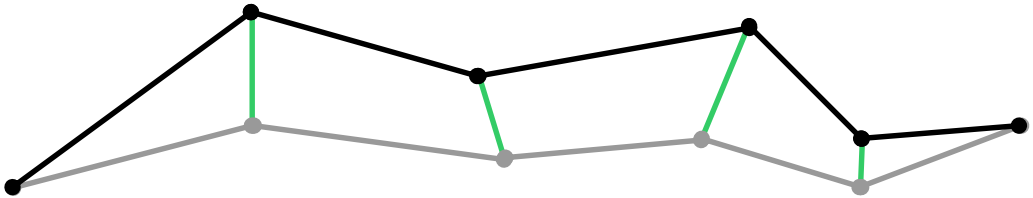
- Requires convex objective functions
  - New model for smoothing

Chambolle-Pock, Function 1

- Minimize the distance the point has moved from its original position
  - Ensure that the smooth path doesn't deviate too far from the optimal path

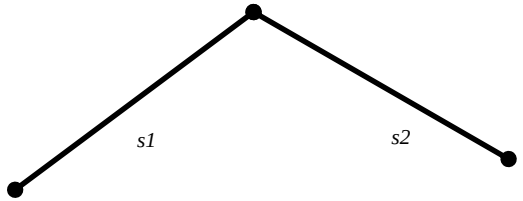


Chambolle-Pock, Function 1



Chambolle-Pock, Function 2

- Minimize the square of the height of this construct
  - Roughly equivalent to minimizing the angle



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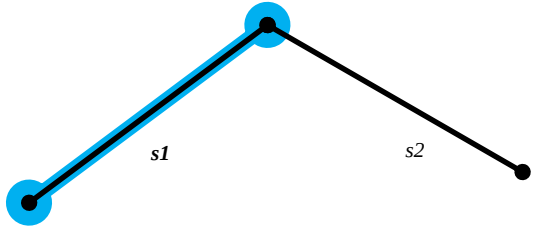

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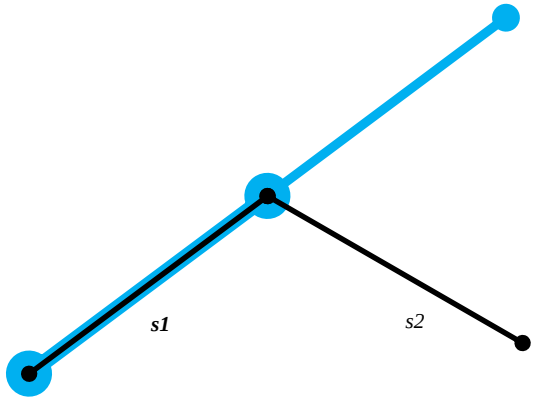

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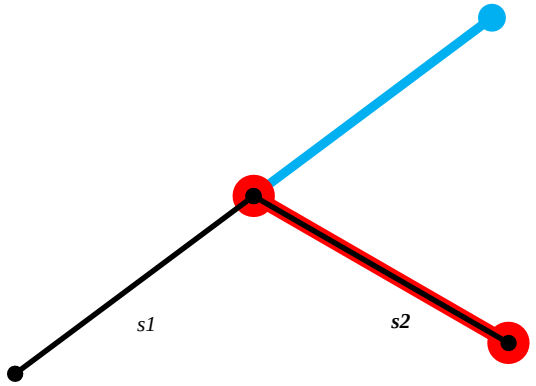

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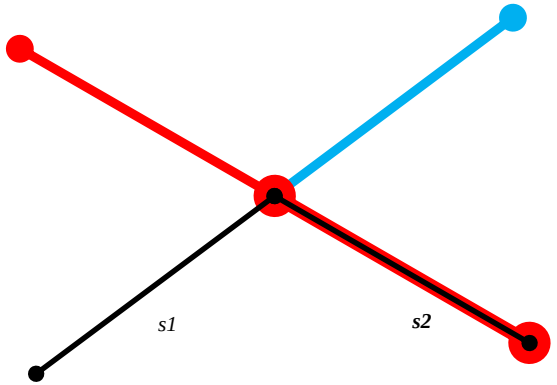

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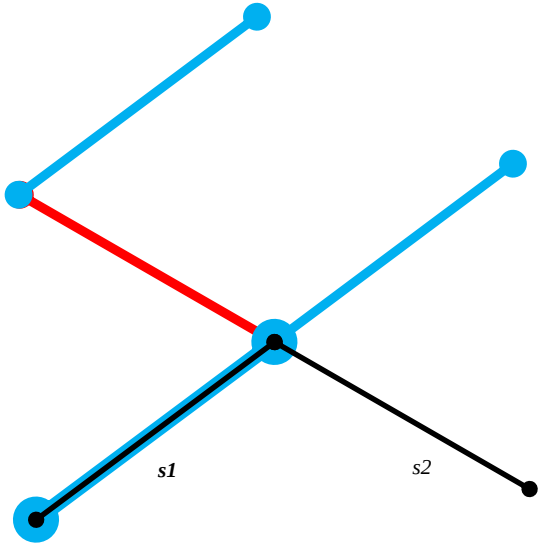

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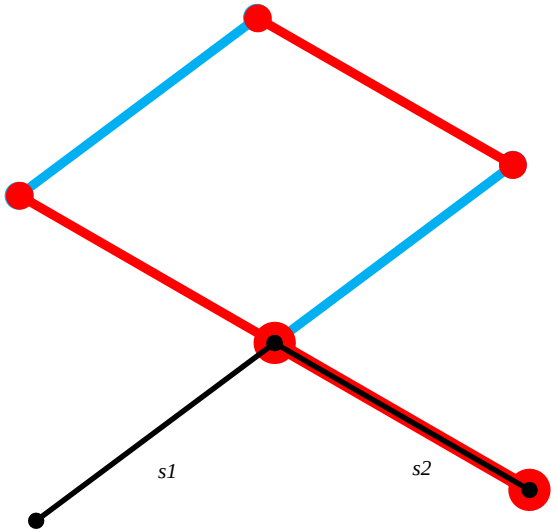

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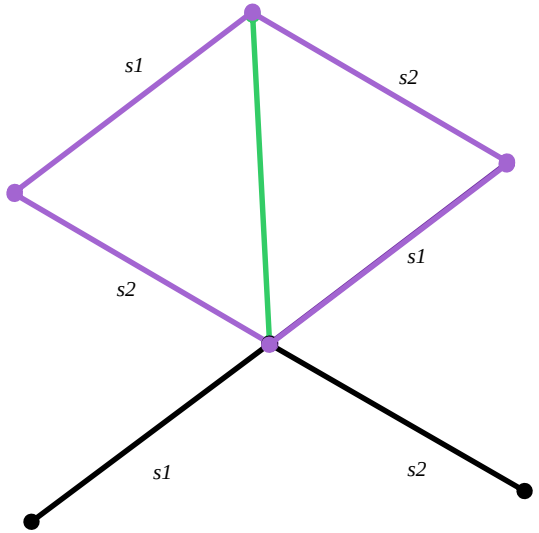

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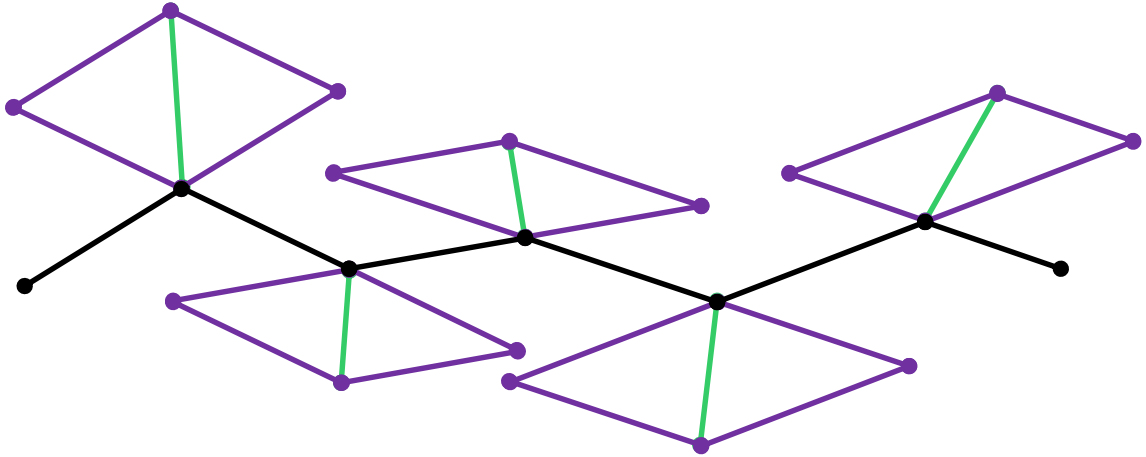
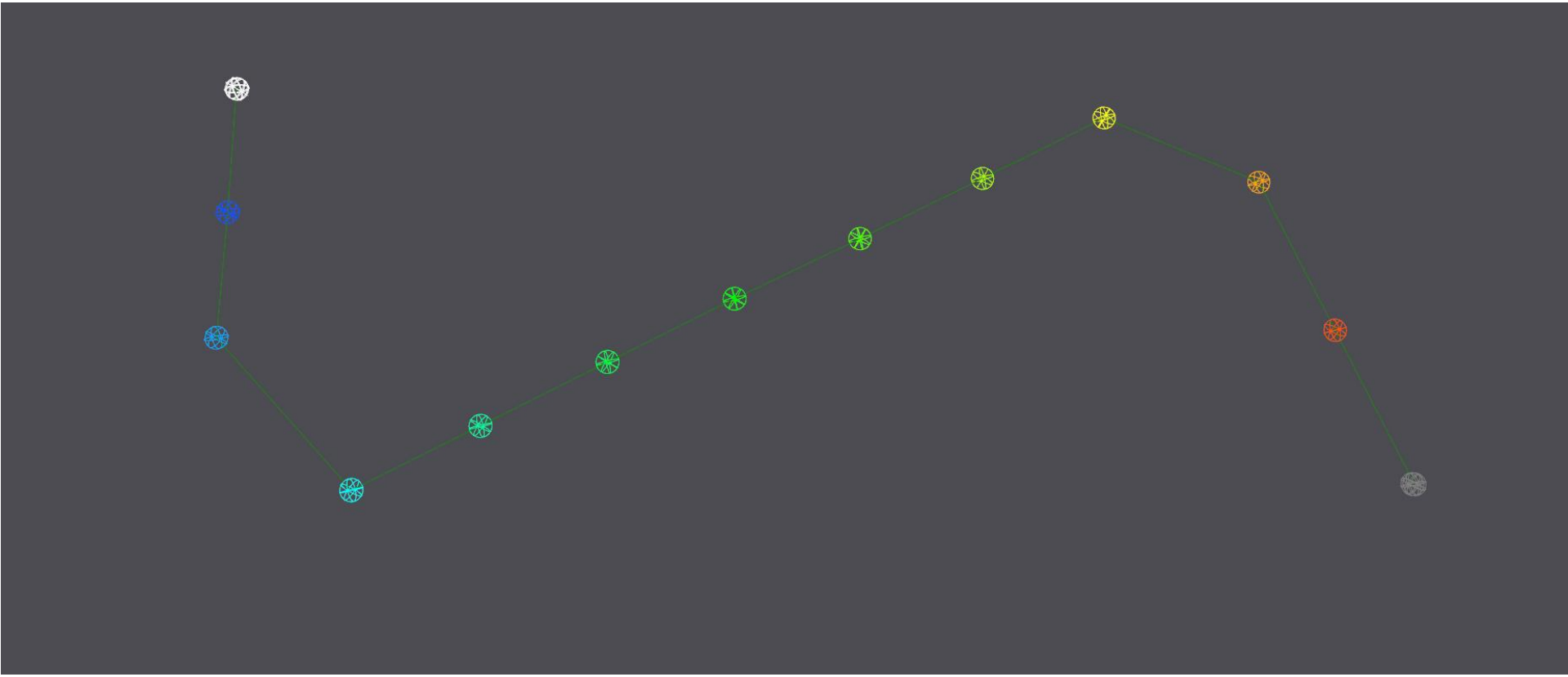
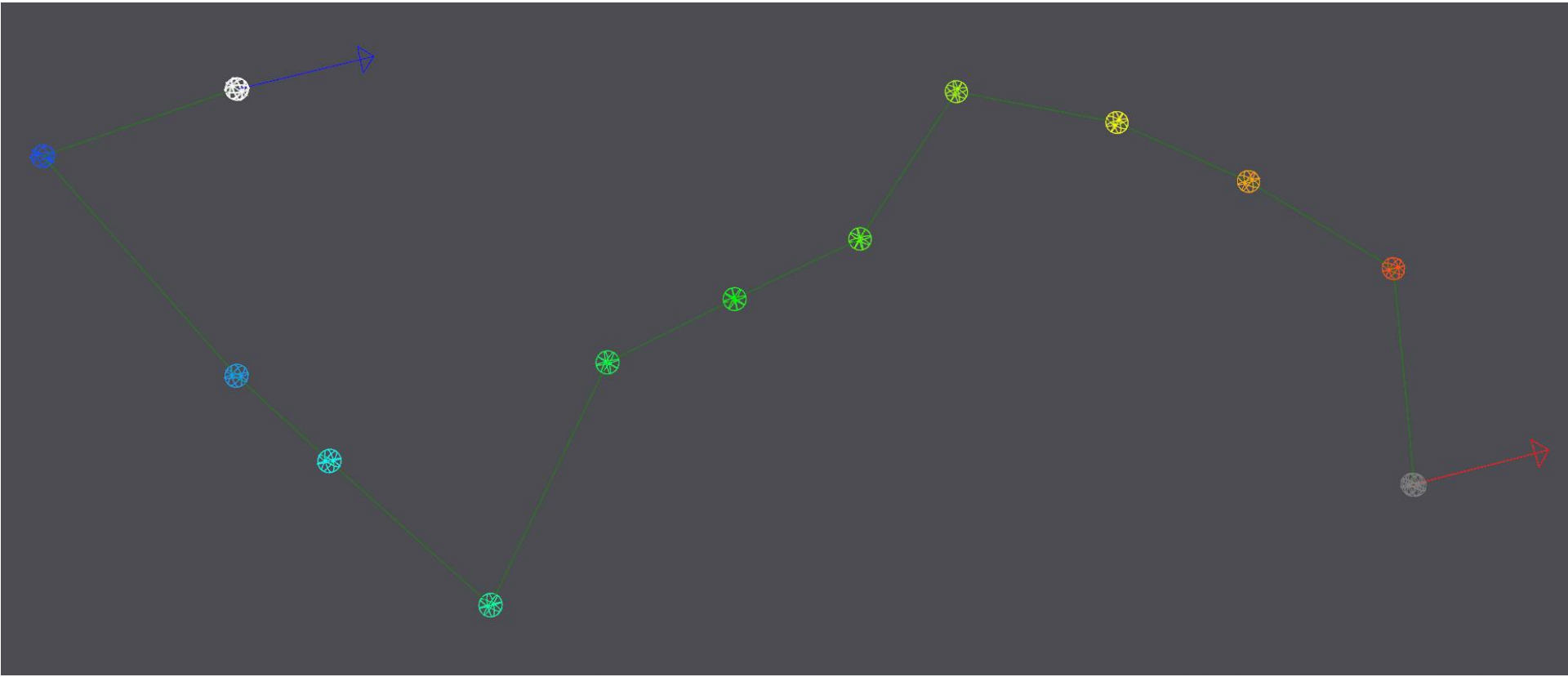
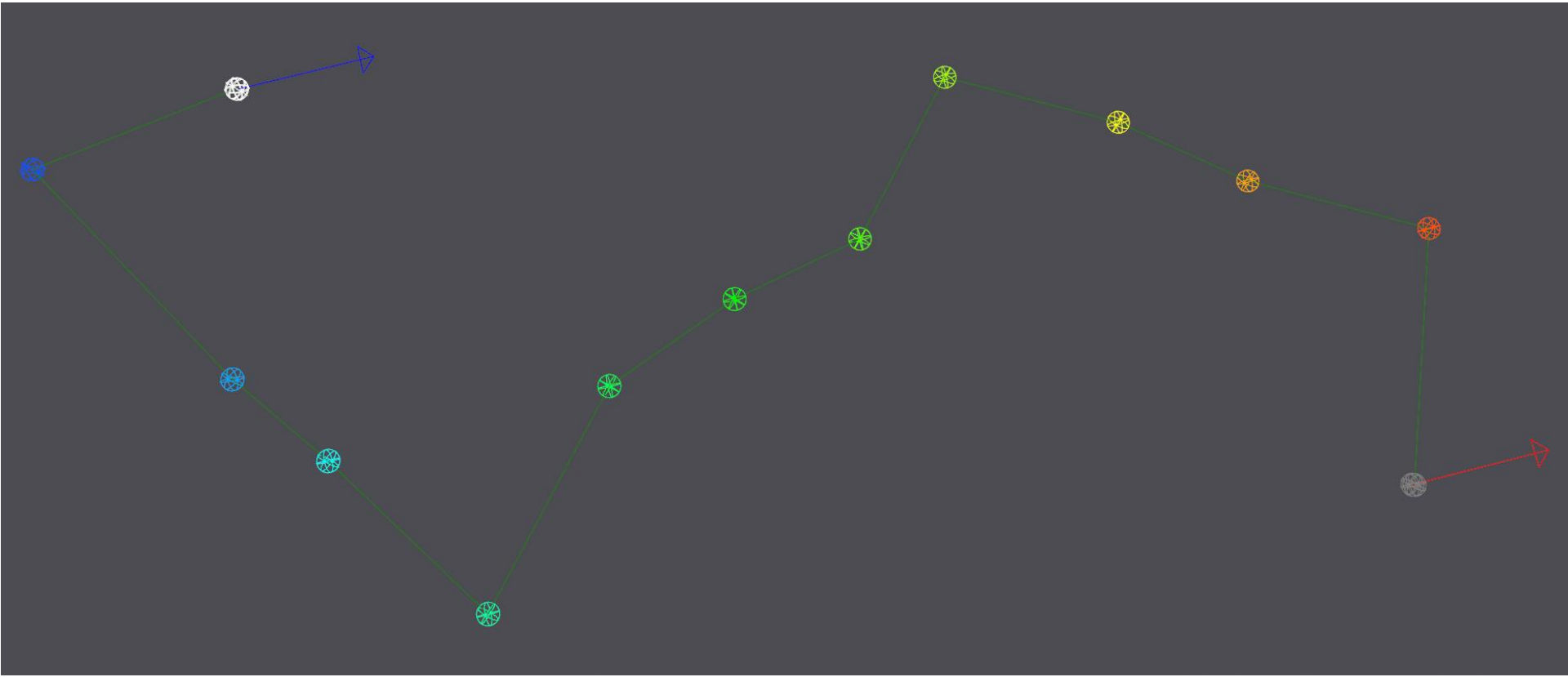
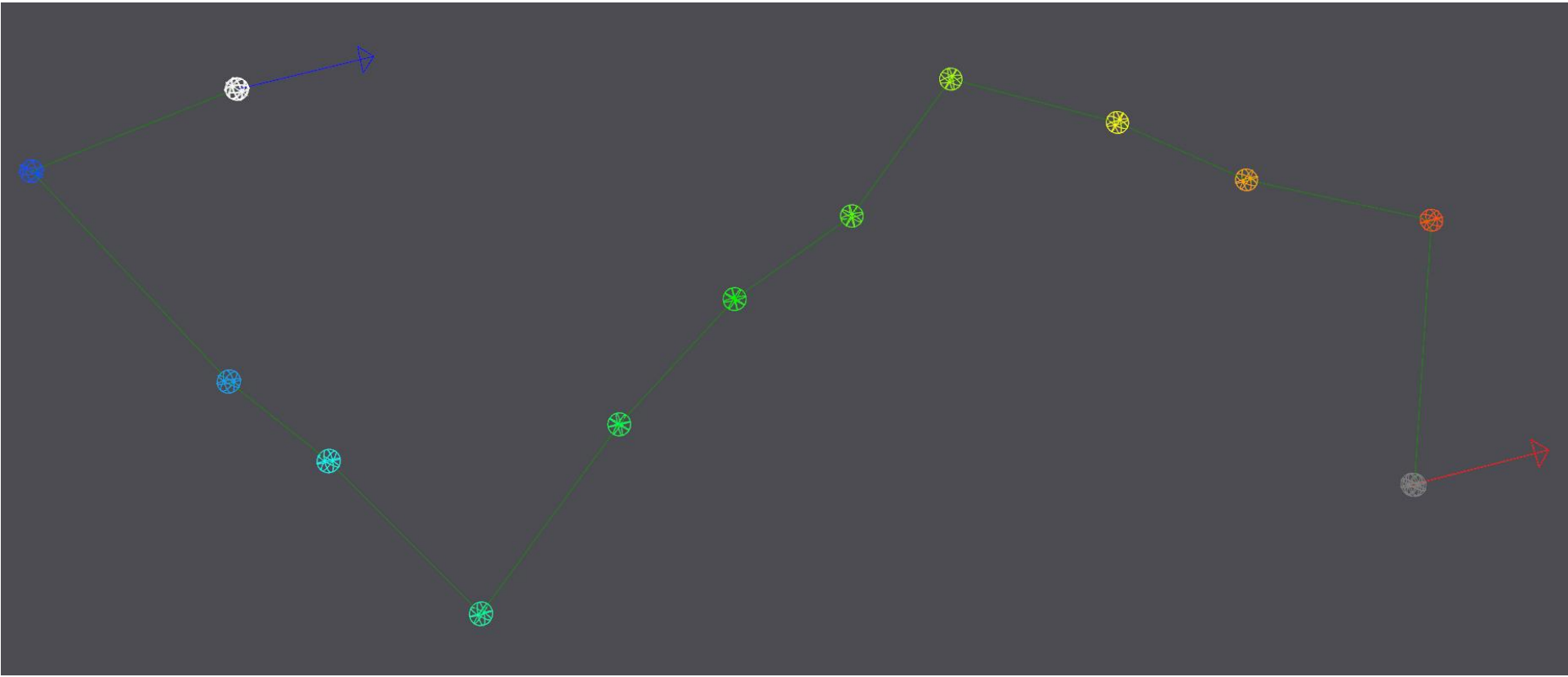
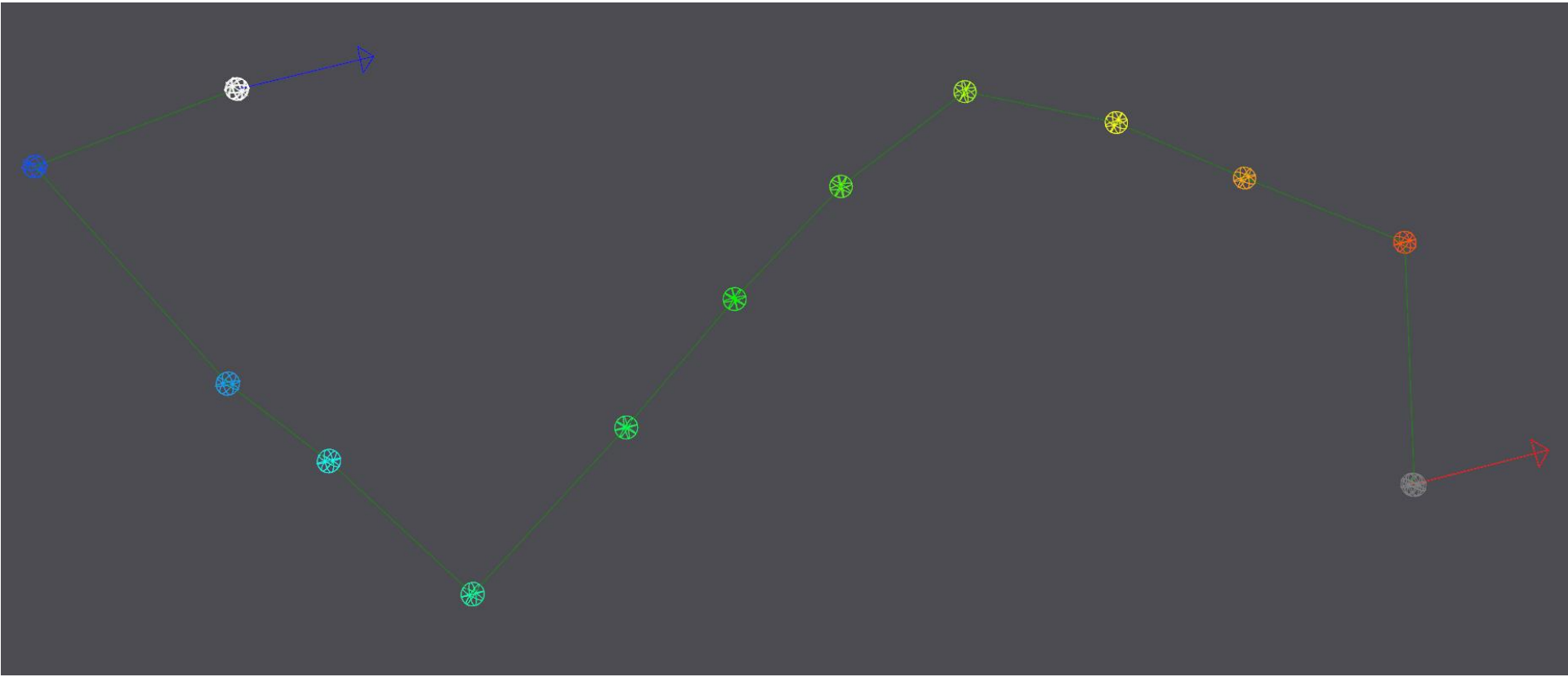


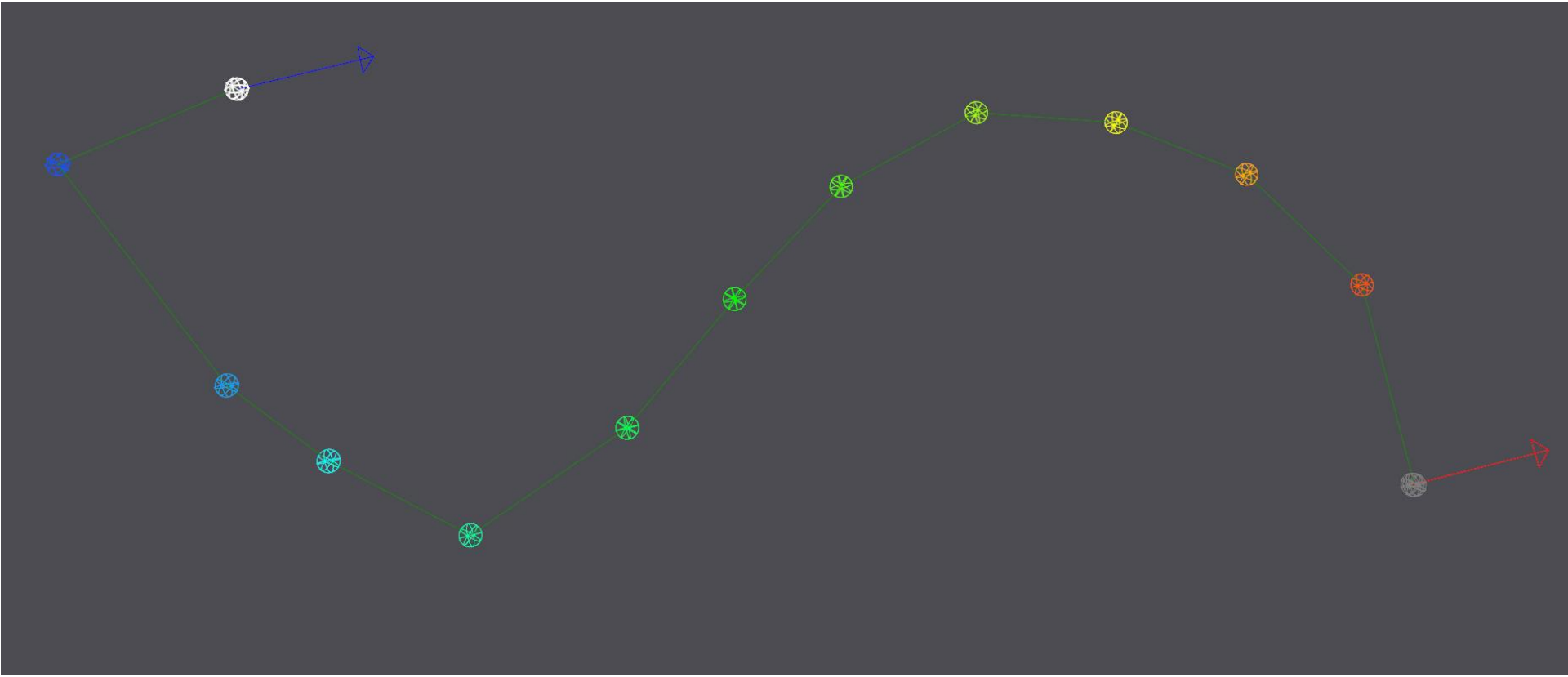


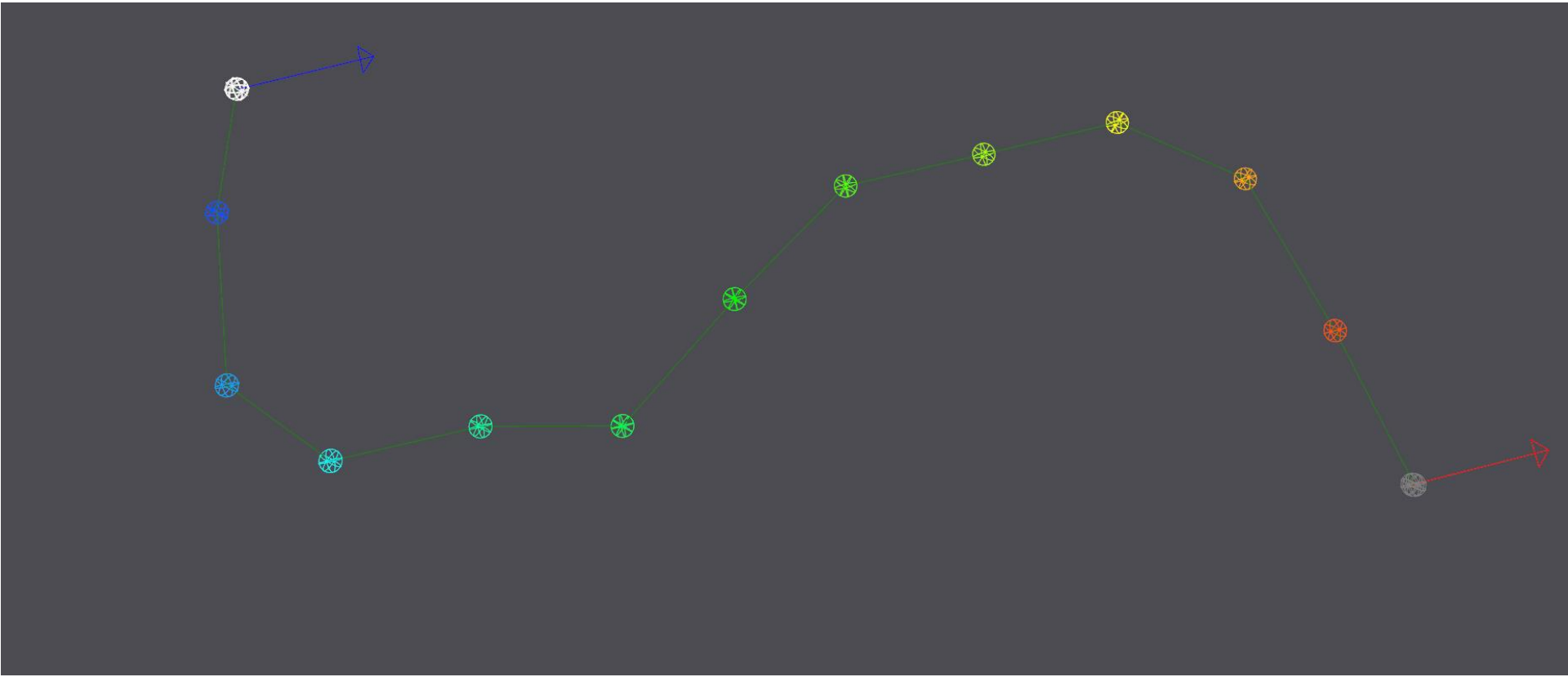


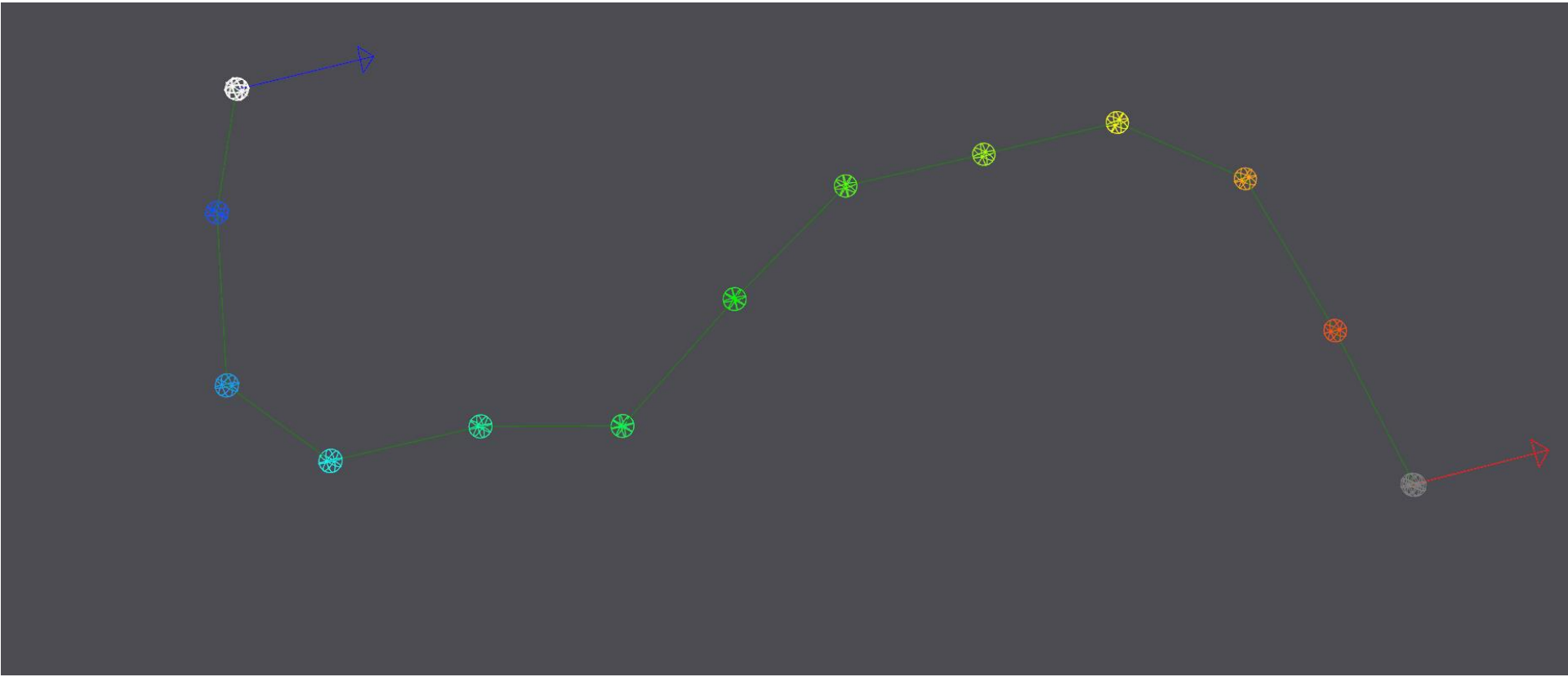


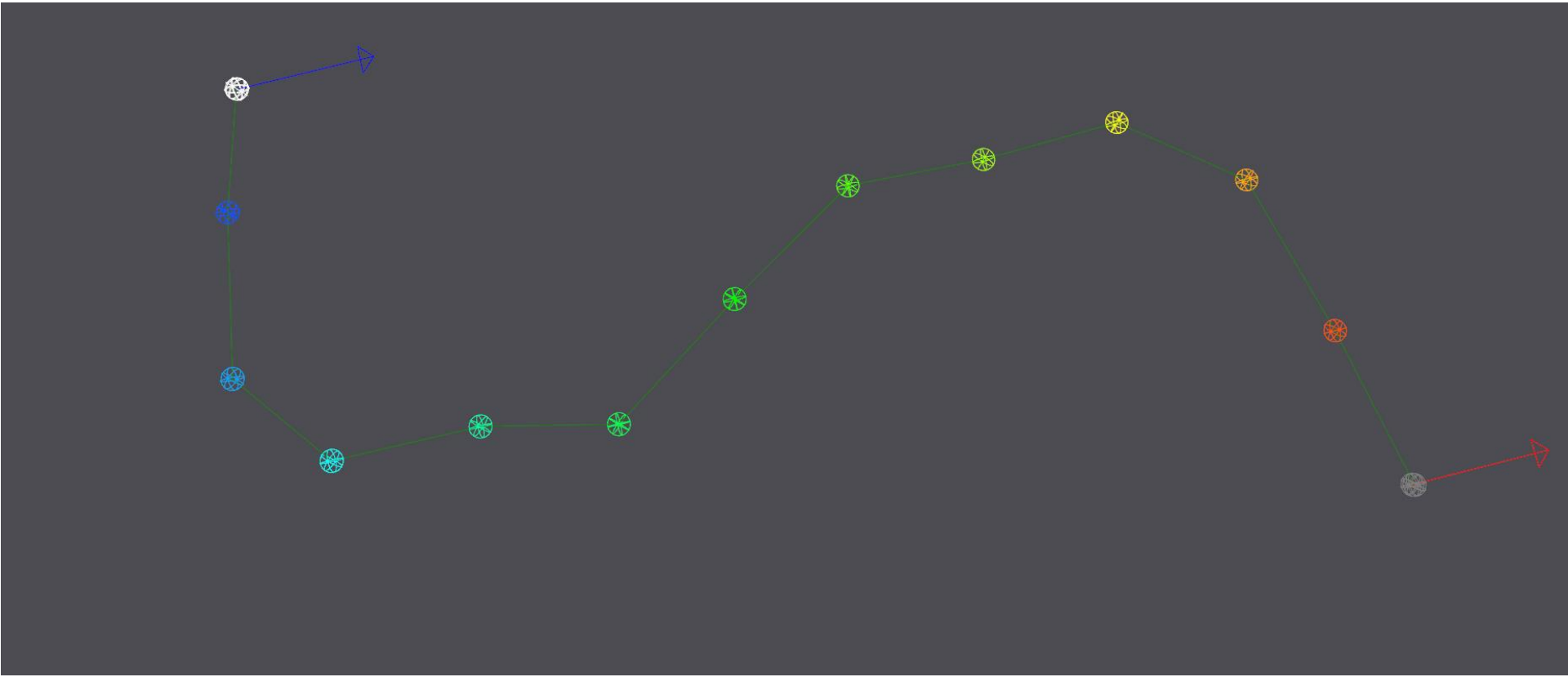


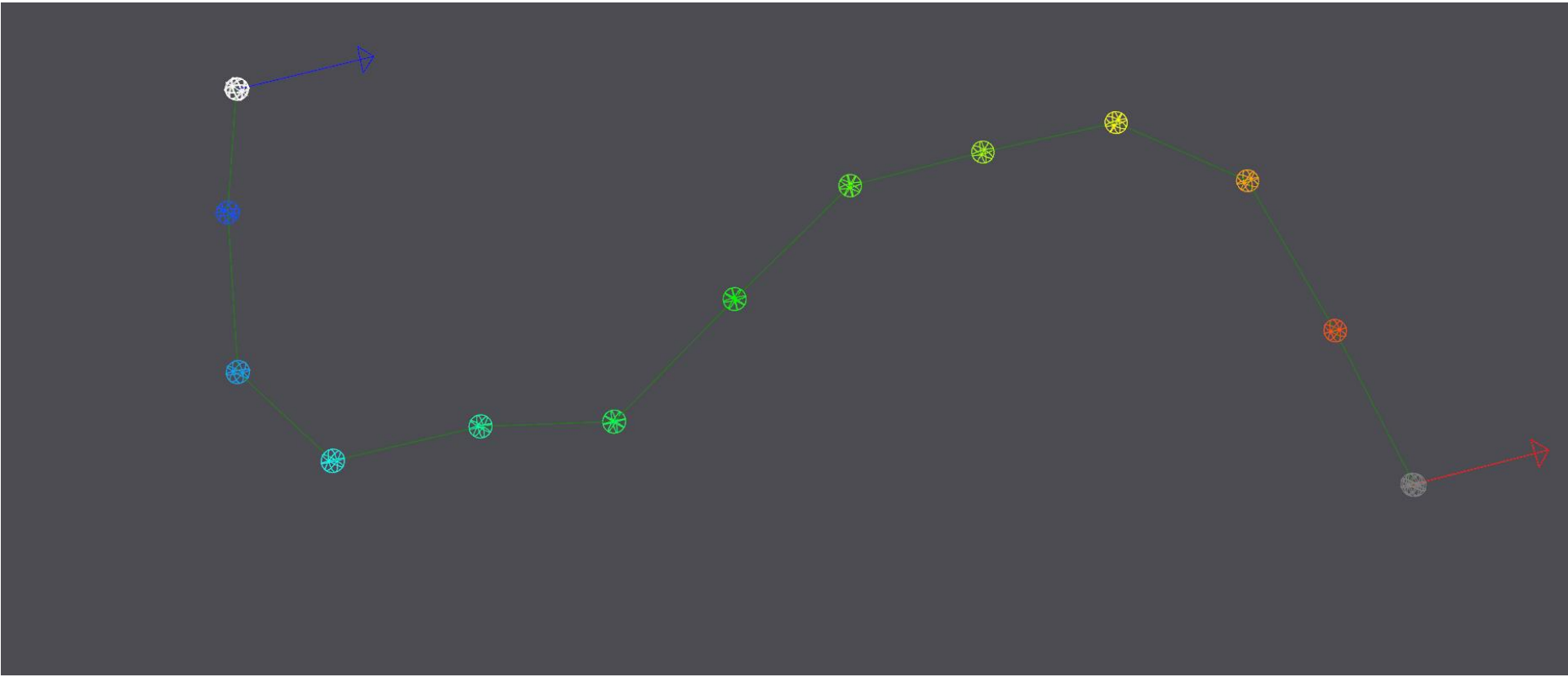


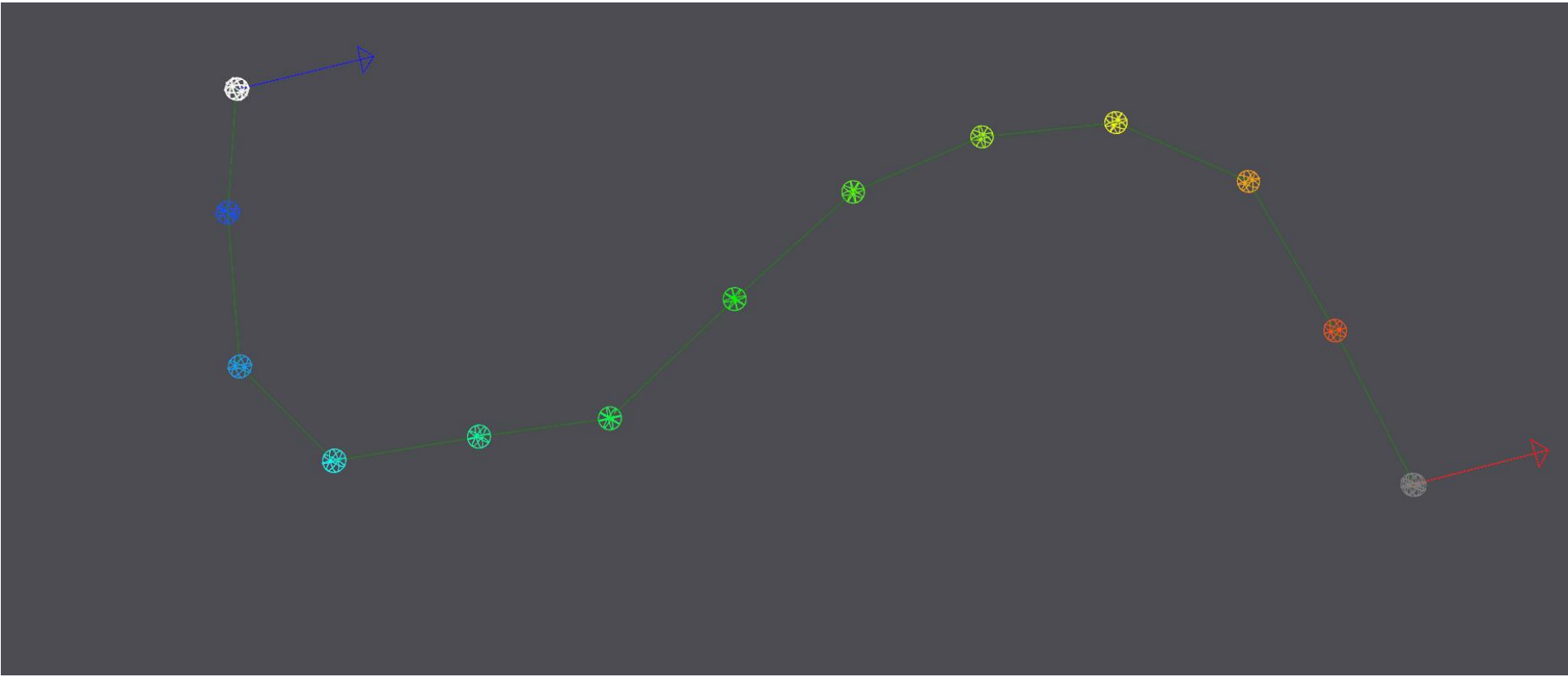


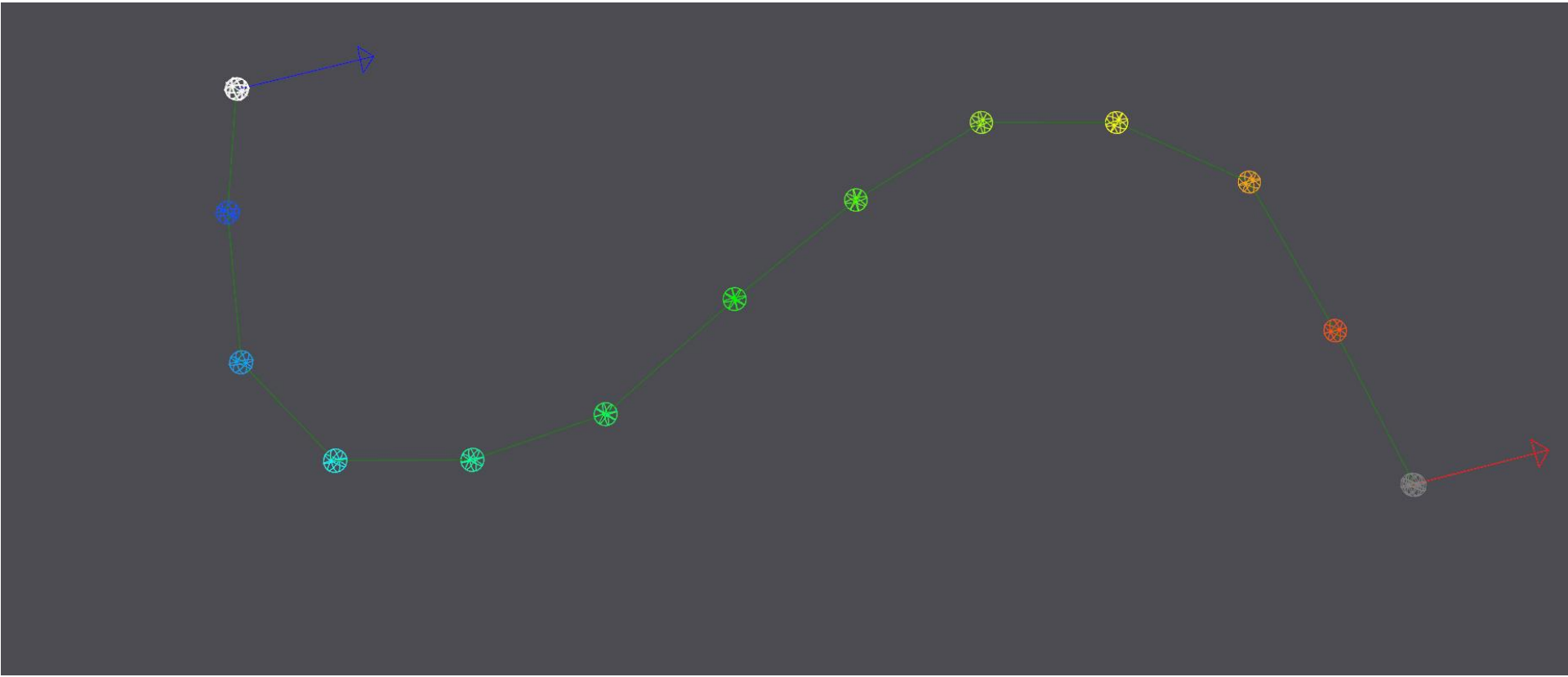












Path Following

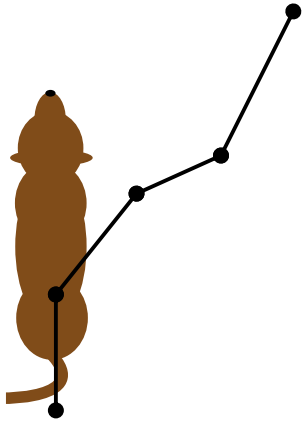
- Cannot just rotate the character like a biped

Animating the Spine

- Cannot use canned animations
  - Do not look good in transitions
- Procedurally animate the spine

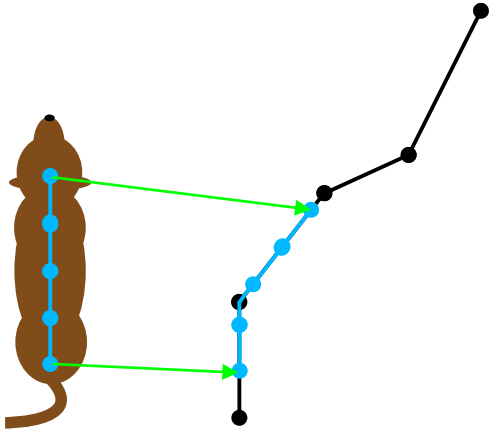
Spineflex

- Bend spine so that both pairs of feet straddle the path
  - While still maintaining the root position's direction



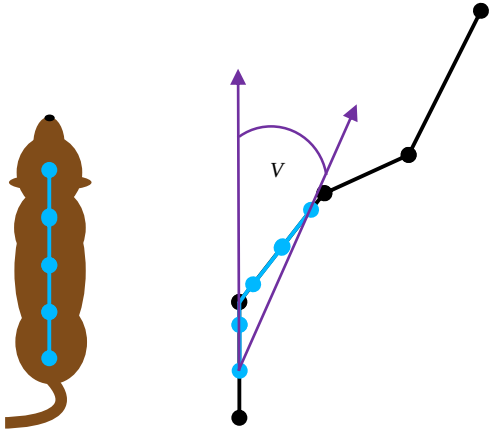
Spineflex: Step 1

- Find the position on the path that is the character's spine's length from its current position



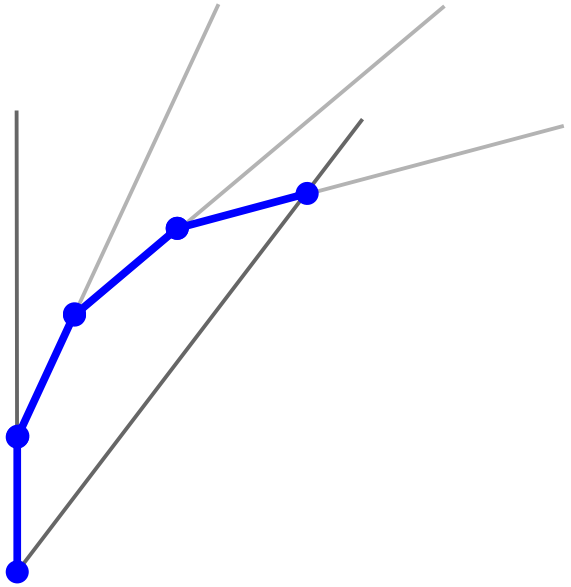
Spineflex: Step 2

- Find angle between projected position and path direction at hip position



Spineflex: Step 3

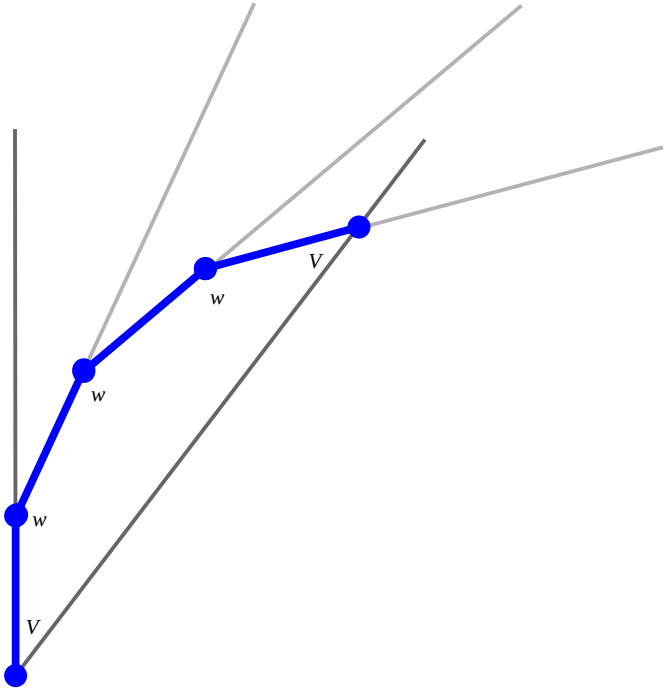
- Assume spine bones are of uniform length and rotate a uniform angle
  - Spine forms a polygon together with the line from spine start to spine end



Spineflex: Step 3

The equation for how much to rotate each bone in the spine:

$$w = \frac{(540 - 2v)}{3}$$



Flexing the Head

- Lead with the head
  - Crucial for natural looking movement
  - Look ahead is speed dependent

Spineflex and Character Type

- The amount of spineflex that looks good is dependent on the kind of character
  - Easy to make the dog move like a cat

Easing In & Out of Spineflex

- Need to transition in and out of spineflex
  - To ease in
    - Turn dog's front
    - Or ease in spineflex over the start walking animation
  - To ease out
    - Turn dog's rear

Tips & Tricks

- Overview
  - Local motion
  - Animation footprints
  - Breadcrumbs and backtracking

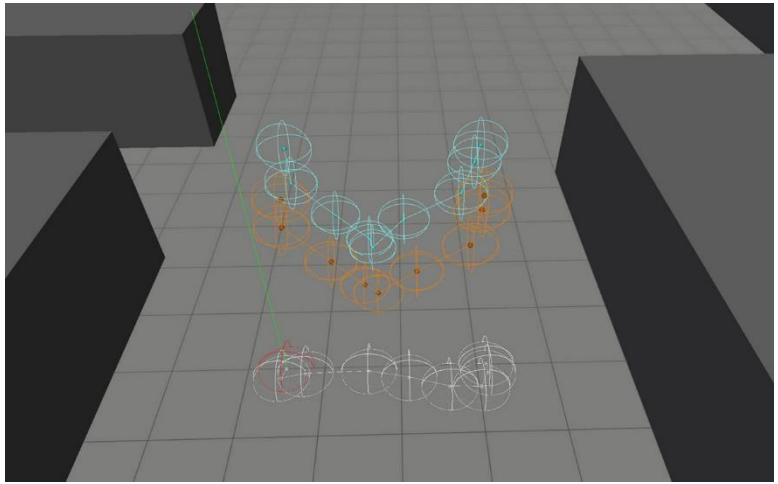
Local Motion

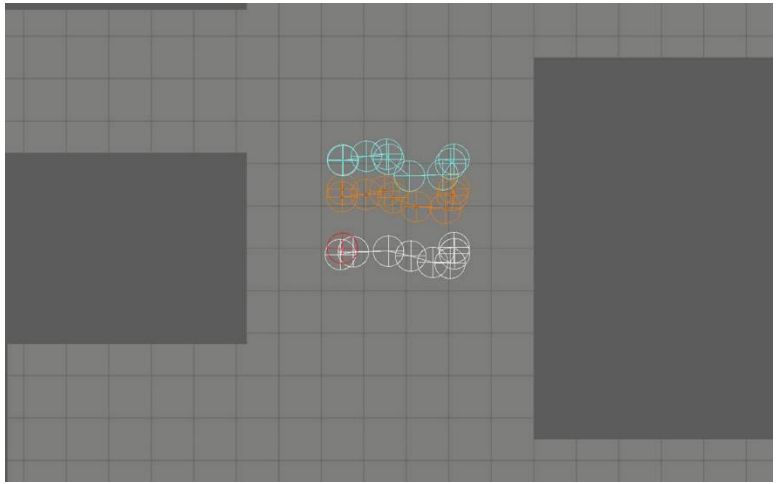
- Used for very short range motion and position adjustments
  - Achieved by a blending animations of multiple movements
  - Uses a pre-computed lookup table for blend parameters

Animation Footprint Checking

- Important to know if an animation can be played
  - Test head, shoulders, and root
  - Cannot ask the animation engine
  - Has multiple uses.

Animation Footprint Checking

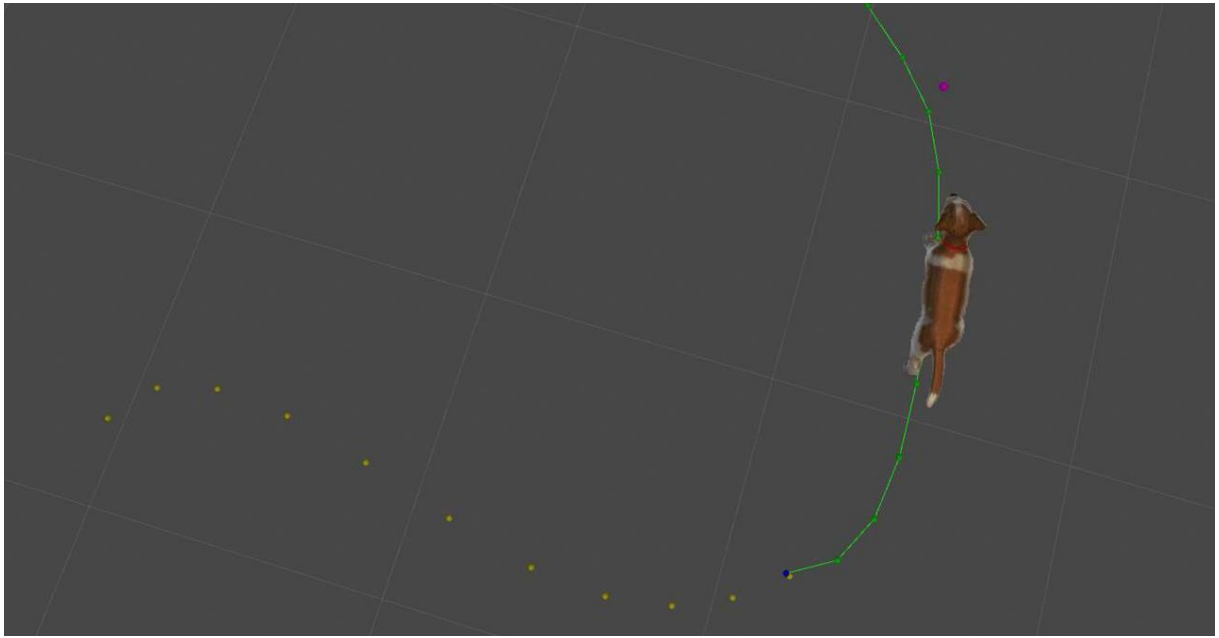




Breadcrumbs & Backtracking

- Need a way to get out of dead ends
  - Keep track of where the dog came from
  - Reverse along the breadcrumb path until there is enough room

Breadcrumbs & Backtracking



More Information

- The source code will be available online
  - On GitHub

More Information

- General questions:
  - Tobias Karlsson: tokarlss@Microsoft.com
- Chambolle-Pock:
  - Mark Langerak: helanger@Microsoft.com
- Local Motion:
  - Todd Heckel: theckel@Microsoft.com

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