

CLAIMS

WHAT IS CLAIMED IS:

1. An animation method, comprising:
providing a display environment for presentation on a display device;
providing a body for display in the display environment; and
determining a motion path for a first portion of the body relative to a second portion of the body.
2. The method of claim 1, where determining a motion path further comprises:
displaying a curve in the display environment that defines the motion path in space over time.
3. The method of claim 1, further comprising:
providing a control in the display environment for manipulating the motion path; and
manipulating the motion path in response to a user interaction with the control.
4. The method of claim 1, where the display environment is a three-dimensional space.
5. The method of claim 1, where the display environment is a two-dimensional space.
6. The method of claim 1, where the body is from a group of bodies including articulated bodies, rigid bodies and bodies with one or more deformable surfaces.
7. The method of claim 1, further comprising:
receiving input from an input device manipulated by a user while viewing the body in the display environment.

8. The method of claim 2, where manipulating the motion path further comprises:
deforming one or more surfaces of the body.
9. The method of claim 2, where displaying a curve further comprises:
determining points along the motion path at discrete sample times; and
rendering the points to define the curve through space over time.
10. The method of claim 9, further comprising:
rendering the curve using a number of points based at least in part on the
speed of the body along the motion path.
11. The method of claim 9, further comprising:
automatically rendering the curve to pass through a reference point on the
body in response to user input.
12. The method of claim 9, further comprising:
dilating the curve about a point in space to improve visibility of the curve
in the display environment.
13. The method of claim 9, further comprising:
stretching the curve out in time to improve visibility of the curve in the
display environment.
14. The method of claim 9, further comprising:
rendering the line segments relative to a moving camera view.
15. The method of claim 1, further comprising:
displaying one or more portions of the curve in one or more colors to
improve visibility of the curve in the display environment.
16. The method of claim 1, further comprising:
displaying information along the motion path to indicate rate of
movement of the body over a section of the motion path.

17. The method of claim 1, further comprising:
displaying information along the motion path to indicate timing and one or more values associated with animation key frames.
18. The method of claim 3, further comprising:
rendering ghost geometry along a section of the motion path during interactive manipulation of the motion path.
19. The method of claim 1, further comprising:
animating the first portion of the body to follow the motion path.
20. The method of claim 19, further comprising:
providing ghost images of the first portion of the body along the motion path during animation.
21. The method of claim 19, further comprising:
providing cached data associated with frames of animation over time, where at least some of the cached data is used during animation.
22. The method of claim 1, further comprising:
defining the body by an expression graph with cycles.
23. The method of claim 22, further comprising:
providing one or more articulated variables for changing values within the expression graph.
24. An animation method, comprising:
providing a display environment for presentation on a display device;
providing a body for display in the display environment;
providing a first motion path for a first portion of the body relative to a second portion of the body;

providing a second motion path for the first portion of the body relative to a second portion of the body; and

providing a mechanism for animating the first portion of the body to follow either the first or second motion path.

25. The method of claim 24, further comprising:

associating the first motion path with a first layer; and
associating the second motion path with a second layer.

26. The method of claim 25, further comprising:

associating the first and second layers with a class from a group of layer classes including: kinematic, forward dynamic, multipoint dynamic, procedural, sampled and stochastic.

27. The method of claim 24, further comprising:

defining the first and second layers as a layer set.

28. The method of claim 24, further comprising:

performing one or more operations on the first and second layers in response to user input.

29. A method of creating expression graphs for an animation system, comprising:

providing a graphical user interface;
receiving a first node selection from a plurality of node types;
receiving a second node selection from the plurality of node types;
displaying graphical representations of the selected nodes in the graphical user interface; and
providing a connection mechanism for enabling a user to connect at least one output of the first node with at least one input of the second node to form a graphical structure that represents a unified generalized expression graph with cycles.

30. The method of claim 29, where at least some of the node types are templates.

31. The method of claim 29, where the expression includes one or more conditions.
32. The method of claim 29, further comprising:
 - providing an expression language for entering mathematical expressions into an input of one or more of the first and second nodes.
33. The method of claim 29, where at least one of the first and second nodes is associated with a cache structure for storing one or more values for various discrete sample times.
34. The method of claim 29, where at least one of the first and second nodes is configurable to broadcast a value on a named channel which can be received by one or more receiver nodes.
35. The method of claim 29, where at least one of the first and second nodes is configurable to solve kinematic problems.
36. The method of claim 29, where a user can specify either the first node or the second node as a root node.
37. The method of claim 29, where the graphical structure is a hierarchy which is configurable to allow data to flow bi-directionally through the hierarchy.
38. A method of creating an expression graph for an animation system, comprising:
 - providing a text-based programming language for specifying expression graphs for an animation system;
 - executing a program developed with the programming language to generate an expression graph; and
 - animating a body in a display environment using the expression graph.
39. An animation method, comprising:
 - providing a display environment for presentation on a display device;

providing a first body for display in the display environment;
providing a second body for display in the display environment; and
determining a motion path for a portion of the first body relative to the
second body.

40. An animation method, comprising:

providing a display environment for presentation on a display device;
providing a body for display in the display environment; and
determining a motion path for a portion of the body relative to a
coordinate system associated with the display environment.

41. An animation method, comprising:

providing a display environment for presentation on a display device;
providing a body for display in the display environment;
evaluating an expression graph associated with the body at a first rate;
processing body geometry at a second rate; and
rendering the body in the display environment at a third rate, where the
first and second rates are decoupled from the third rate.

42. A computer-readable medium having stored thereon instructions which, when

executed by a processor, causes the processor to perform the operations of:
providing a display environment for presentation on a display device;
providing a body for display in the display environment; and
determining a motion path for a first portion of the body relative to a
second portion of the body.

43. A computer-readable medium having stored thereon instructions which, when

executed by a processor, causes the processor to perform the operations of:
providing a display environment for presentation on a display device;
providing a body for display in the display environment;

providing a first motion path for a first portion of the body relative to a second portion of the body;

providing a second motion path for the first portion of the body relative to a second portion of the body; and

providing a mechanism for animating the first portion of the body to follow either the first or second motion path.

44. A computer-readable medium having stored thereon instructions which, when executed by a processor, causes the processor to perform the operations of:

providing a display environment for presentation on a display device;

providing a body for display in the display environment;

providing a first motion path for a first portion of the body relative to a second portion of the body;

providing a second motion path for the first portion of the body relative to a second portion of the body; and

providing a mechanism for animating the first portion of the body to follow either the first or second motion path.

45. A computer-readable medium having stored thereon instructions which, when executed by a processor, causes the processor to perform the operations of:

providing a display environment for presentation on a display device;

providing a first body for display in the display environment;

providing a second body for display in the display environment; and

determining a motion path for a portion of the first body relative to the second body.

46. A computer-readable medium having stored thereon instructions which, when executed by a processor, causes the processor to perform the operations of:

providing a display environment for presentation on a display device;

providing a body for display in the display environment; and

determining a motion path for a portion of the body relative to a coordinate system associated with the display environment.

47. A computer-readable medium having stored thereon instructions which, when executed by a processor, causes the processor to perform the operations of:
- providing a display environment for presentation on a display device;
 - providing a body for display in the display environment;
 - evaluating an expression graph associated with the body at a first rate;
 - processing body geometry at a second rate; and
 - rendering the body in the display environment at a third rate, where the first and second rates are decoupled from the third rate.

CLAIMS

WHAT IS CLAIMED IS:

1. An animation method, comprising:
 - providing a display environment for presentation on a display device;
 - providing a body for display in the display environment; and
 - determining a motion path for a first portion of the body relative to a second portion of the body, wherein determining the motion path comprises:
 - displaying a curve in the display environment that defines the motion path in space over time, wherein displaying the curve comprises:
 - determining points along the motion path at discrete sample times;
 - rendering the points to define the curve through space over time;
 - and
 - dilating the curve about a point in space to improve visibility of the curve in the display environment.
2. The method of claim 1, further comprising:
 - stretching the curve out in time to improve visibility of the curve in the display environment.
3. The method of claim 1, further comprising:
 - rendering the points relative to a moving camera view.
4. The method of claim 1, further comprising:
 - defining the body by an expression graph with cycles.
5. The method of claim 4, further comprising:

providing one or more articulated variables for changing values within the expression graph.

6. A method of creating expression graphs for an animation system, comprising:
 - providing a graphical user interface;
 - receiving a first node selection from a plurality of node types;
 - receiving a second node selection from the plurality of node types;
 - displaying graphical representations of the selected nodes in the graphical user interface; and
 - providing a connection mechanism for enabling a user to connect at least one output of the first node with at least one input of the second node to form a graphical structure that represents a unified generalized expression graph with cycles.
7. The method of claim 6, where at least some of the node types are templates.
8. The method of claim 6, where the expression includes one or more conditions.
9. The method of claim 6, further comprising:
 - providing an expression language for entering mathematical expressions into an input of one or more of the first and second nodes.
10. The method of claim 6, where at least one of the first and second nodes is associated with a cache structure for storing one or more values for various discrete sample times.
11. The method of claim 6, where at least one of the first and second nodes is configurable to broadcast a value on a named channel which can be received by one or more receiver nodes.
12. The method of claim 6, where at least one of the first and second nodes is configurable to solve kinematic problems.

13. The method of claim 6, where a user can specify either the first node or the second node as a root node.
14. The method of claim 6, where the graphical structure is a hierarchy which is configurable to allow data to flow bi-directionally through the hierarchy.
15. An animation method, comprising:
 - providing a display environment for presentation on a display device;
 - providing a camera view of a body in the display environment, the body including at least one point;
 - providing, in the camera view of the body, a motion path of the point;
 - associating one or more control mechanisms with the motion path, the control mechanisms being configured to control a movement of at least a portion of the body in space and a rate of the movement in time; and
 - in response to an input received through the one or more control mechanisms, animating the body based on the motion path.
16. The method of claim 15, where animating the body comprises:
 - determining a shape of the motion path based on the movement of the portion of the body in space; and
 - determining the rate of the movement in time independently of the shape of the motion path, including interpolating along at least a segment of the motion path based on the input, where manipulating the shape of the motion path is decoupled from manipulating the rate of the movement in time.
17. The method of claim 15, where animating the body comprises:
 - controlling the motion path relative to a user specified reference that is at least one of a world space, another portion of the body, a moving camera, or a node in a scene; and

providing for display the motion path relative to the reference.

18. The method of claim 15, where the point is at least one of:

a user selectable point on or relative to a surface of the body; or

a user selectable point on or relative to a skeleton to which the surface of the body is bound.

19. The method of claim 15, where at least one of the portion of the body or the point is determined automatically in response to a user interaction with the body.

20. The method of claim 15, where the body includes at least one of a forward kinematic hierarchy, an inverse kinematic hierarchy, a rigid body, a deformable body, or a solution to an arbitrary expression.

21. The method of claim 15, where associating the one or more control mechanisms with the motion path comprises:

providing one or more visual markings along at least a segment of the motion path, the visual markings configured to control at least one of a rate of interpolation, a motion tangent, or a rate of twist.

22. The method of claim 21, where:

providing the one or more visual markings includes providing a spacing between two visual markings, the spacing indicating the rate of interpolation, where at least one of the visual markings is configured to receive a slide input to adjust the spacing and control the rate of interpolation.

23. The method of claim 15, where providing for display the motion path comprises:

determining points along the motion path at discrete sample times; and

interpolating the points to define a curve through space over time.

24. The method of claim 23, where determining the points along the motion path includes evaluating a movement of the portion of the body through space over time.
25. The method of claim 15, where associating the one or more control mechanisms with the motion path comprises:
- providing one or more visual indications along the motion path, each visual indication indicating a position of the point corresponding to an animation time, where an adjustment of the one or more visual indications changes the corresponding animation times.
26. The method of claim 15, further comprising:
- stretching the motion path in time to improve visibility of the motion path, the stretching including:
 - mapping the time to three dimensional vectors in a three dimensional space, each three dimensional vector having a direction and a magnitude, wherein:
 - the direction of the three dimensional vector controls the direction in which the motion path is stretched; and
 - the magnitude of the three dimensional vector controls an amount in which the motion path is stretched.
27. The method of claim 15, wherein animating the body comprises:
- receiving an input manipulating the motion path;
 - determining a degree of freedom in which the portion of the body is to move in response to the input; and
 - determining an amount of change in the degree of freedom.
28. The method of claim 15, where animating the body comprises:

maintaining a manipulation mode, each manipulation mode corresponding to one or more modalities of manipulation, the modalities of manipulations including at least one of a translation, a rotation, a scale, a bend, a squash, a stretch, a mesh deformation, or a global deformation, where the manipulation mode is associated with a control mechanism; and

providing the manipulation mode to a user when the control mechanism is active.

29. The method of claim 15, where animating the body comprises inverting or pseudo inverting at least a portion of an expression graph.

30. The method of claim 15, where animating the body comprises performing constrained optimization on the motion of the body.

31. A system, comprising:
one or more processors configured to perform operations comprising:
providing a display environment for presentation on a display device;
providing a camera view of a body in the display environment, the body including at least one point;
providing, in the camera view of the body, a motion path of the point;
associating one or more control mechanisms with the motion path, the control mechanisms being configured to control a movement of at least a portion of the body in space and a rate of the movement in time; and
in response to an input received through the one or more control mechanisms, animating the body based on the motion path.

32. The system of claim 31, where providing for display the motion path comprises:
bleeding the motion path through an obscuring object.

33. The system of claim 31, where providing for display the motion path comprises:
providing for display the motion path using one or more color modes that include at least one of:

a colorstriping mode, where the motion path is to be displayed in multiple alternating colors, where the multiple alternating colors change based on a time interval, at each of the controls, or at user specified markers;

a color shift mode, where a portion of the motion path preceding a specified time is to be displayed in a first color, and a portion of the motion path following the specified time is to be displayed in a second color that is different from the first color; and

a fade out mode, where the motion path fades out at points progressively farther in time from the specified time.

34. A computer program product, stored on a non-transitory storage device, operable to cause one or more processors coupled to the storage device to perform operations comprising:

providing a display environment for presentation on a display device;

providing a camera view of a body for display in the display environment, the body including at least one first point;

providing, in the camera view, a first motion path of the first point;

associating one or more control mechanisms with the first motion path, the control mechanisms being configured to control a movement of at least a portion of the body in space and a rate of the movement in time; and

in response to an input received through the one or more control mechanisms, animating the body based on the first motion path.

35. The product of claim 34, the operations further comprising providing for display a second motion path, where the second motion path is at least one of:

a motion path of a second point of the body;

a motion path of another body; or
a motion path based on which the body is animated differently from
animation based on the first motion path.

36. The method of claim 15, where providing for display the motion path comprises:
receiving a specification of a time range, the specification including at least
one of:

a beginning time and an ending time;
a time interval relative to a specified time; or
a count of control points relative to a specified time; and

providing for display a portion of the motion path according to the
specification of the time range.

37. The method of claim 15, where providing for display the motion path comprises
dilating the motion path around a specified reference point, where:
dilating the motion path includes scaling points on the motion path around
the specified reference point by a scaling factor.

38. The method of claim 15, where the display environment is one of a two
dimensional virtual environment or a three dimensional virtual environment.

39. The method of claim 27, where determining the degree of freedom includes
receiving a specified degree of freedom.

40. The method of claim 27, where determining the amount of change includes
mapping changes from input manipulating the motion path to an amount of
change in the degree of freedom.

41. The method of claim 15, where associating the one or more control mechanisms with the motion path comprises:

providing for display one or more knots along at least a section of the motion path, each of the knots configured to control a position of the portion of the body in space; and

providing for display one or more tangent handles, each tangent handle being associated with one of the one or more knots and being configured to control a tangency of the motion path.

42. The method of claim 41, where providing for display the one or more knots and the one or more tangent handles comprises:

detecting a user interaction with the display environment; and

providing for display at least one of the one or more knots or the one or more tangent handles in response to the detected user interaction.

43. The method of claim 41, where at least one of the knots or at least one of the tangent handles is displayed in differentiated fashion to indicate that a tangent handle is broken.

44. The method of claim 21, where the one or more visual markings are configured to receive a selection input operable to select animation shot times upon which a subsequent program command involving time will operate, the animation shot times corresponding to the one or more visual markings.

45. The method of claim 21, further comprising: providing for display in association with the one or more visual markings at least one of:

a time of an animation key; or

a value of the animation key.

46. The method of claim 21, further comprising: hiding from display a visual marking that corresponds to a locked degree of freedom.

47. The method of claim 15, where associating the one or more control mechanisms with the motion path comprises:

providing one or more visual markings along at least a segment of the motion path, the visual markings configured to control at least one of a rate of interpolation, a motion tangent, or a rate of twist;

receiving a slide input on a first visual marking of the one of more visual markings, the slide input operable to cause the first visual marking to slide along the motion path; and

upon receiving the slide input, adjusting a spacing between at least two second visual markings of the one of more visual markings, each of the at least two second visual markings being different from the first visual marking.