Master of Science in Informatics at Grenoble
Master Informatique
Specialization Graphics, Vision, and Robotics

Sketch-Based Posing, Animation, and Interaction of Multiple Characters: Animating Dancing Couples

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Abstract

Your abstract goes here...

Résumé

Your abstract in French goes here...

Acknowledgement

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— 1 —
Introduction

1.1 Background

3D animation can be a painstakingly tedious activity. To create a desired animation, animators go through the long process of keyframing. Keyframes are set positions that define the start and end points of a movement, sequences of poses which are transformed in time. Typically, animators assign poses to certain frames over time, so that in-between motions can be generated by a computer. To get an accurate animation, artists usually must assign many keyframes, then spend time adjusting and editing them to be more precise. The fact that industry professionals take so much time and effort to do this shows that for an amateur or untrained artist, creating *good* 3D animation is close to impossible.

In Figure 1.1, the highlighted object – the ball flying through the window – has keyframes attached to it on the timeline, shown in the yellow box, which represent its various positions and rotations in time. Even in a simple bouncing ball animation like this one, relatively speaking, many keyframes are required: 20 keyframes for a simple object to move within seven seconds. I invite the reader to imagine the amount of keyframes an articulated character might require, considering each joint is its own object.

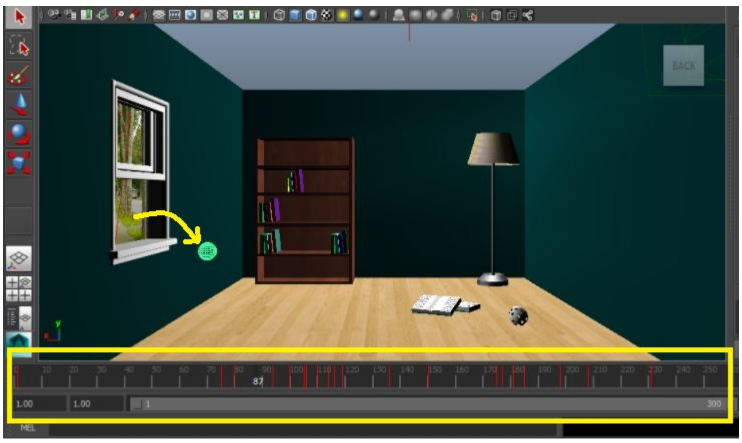
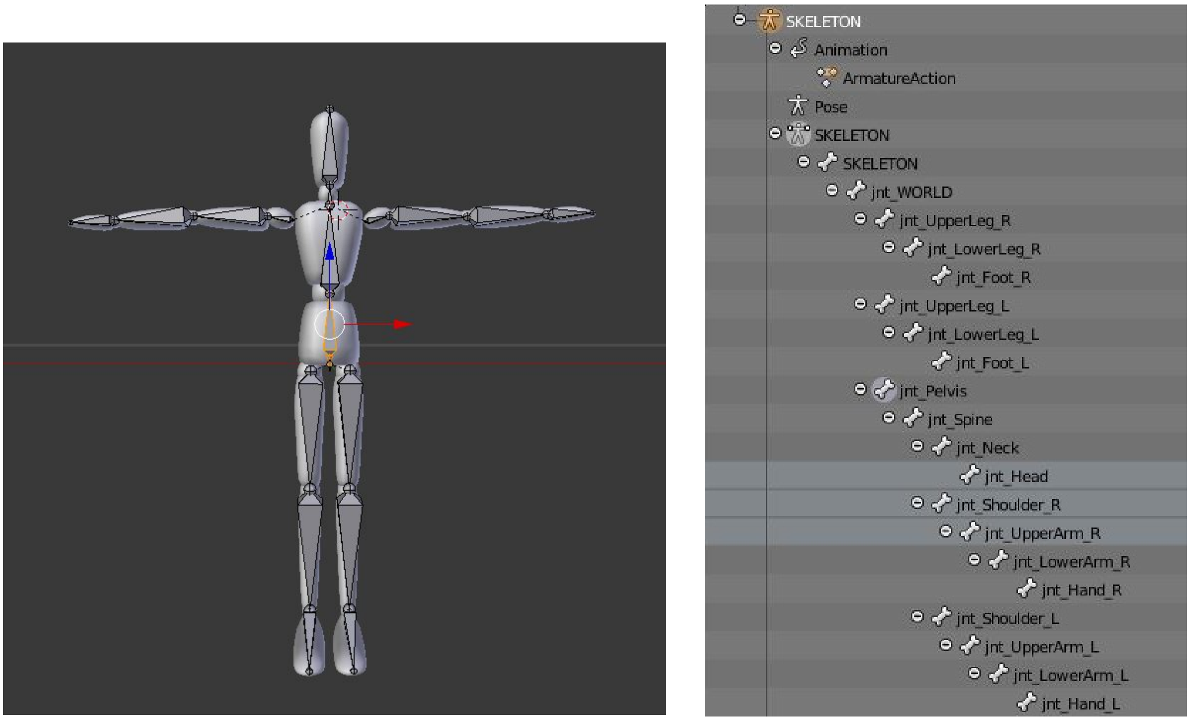


Figure 1.1 – Example of keyframing in Autodesk Maya. Red lines on the timeline indicate keyframes for the highlighted object, pointed to by the yellow arrow.

1.2 Problem Statement

Among the most complicated characters to animate in 3D animation are humanoid characters. To ease this task, animators create a skeleton for their character called a **rig**, that consists of joints connected by rigid links (bones) to give a structure to the character. Humanoid rigs can range in complexity from somewhat simple to extremely complicated depending on the amount of detail desired by the user. The structure is a hierarchy of joints that can also be seen as a tree with a root, which in the humanoid case, is usually the pelvis. The leaf nodes of this tree, which are loacted at the maximal parts of the body, are called **end effectors**. Leaf nodes come at the end of a **kinematic chain**, which can be followed back up to the root.



(a) Example of a humanoid skeleton.

(b) The hierarchy of joints corresponding to the skeleton.

Figure 1.2 – Humanoid skeleton shown in Blender.

1.2.1 Kinematics

Forward and inverse kinematics are two general animation methods used mainly in situations in which articulated characters need to move according to some contraints. In order to animate this structure successfully, controls are added that allow for forward and inverse kinematics. These controls help the animator move the character into poses that will then act as keyframes.

Forward kinematics (FK) is a method of calculating the position and orientation of the end effector (i.e. a hand or foot) given the positions and angles of the joints higher up in the chain all the way to the root.

Inverse kinematics (IK) is the method opposite of forward kinematics. That is, the goal is to calculate the angles and positions of joints in the chain, given the angle and position of the end effector. This goal is much harder to reach, seeing that more information needs to be calculated than is given. This problem is underconstrained. There can be more than one correct configuration that satisfies the constraints or there can even be no viable configurations. Many IK algorithms exist to calculate joint angles and positions, which will be explained further in chapter 3.

Inverse kinematics are clearly more desirable for an animator since it is easier and faster to pose a character and have the joint angles automatically computed than it is to manipulate the character's joints directly.

1.2.2 Multiple Characters

Although animation using kinematic controls is the standard, sketch-based interfaces have started to become a plausible option for both animators and those with less experience. Even manipulating controls can be time-consuming. Many papers have been authored dealing with the sketch-based posing of a single humanoid character, discussed later in chapter 2. However, the animation of multiple characters comes with its own unique set of challenges as well. The problem is discovered when humanoid characters interact, namely when they are in close proximity to each other or when they touch each other.

Collisions and contact are both already issues with one character, made worse when more than one character is involved. Self collisions are when a part of the character's body collides with another part of its own body. Contacts for one character are constraints between the character's body parts and itself or other objects in the scene, like the floor, for instance. Now when other characters are introduced to the scene, there are even more options for potential collisions and contacts between body parts of one character and body parts of another. In our case, we only have two characters, but this research could be further generalized to a larger number of characters.

1.2.3 Posing

The line of action is the concept of imagining a line that extends through the character's main action. It is commonly used by cartoonists in gesture drawings and the early stages of storyboarding to accentuate the motion and shape of the character. These lines are often dramatic in shape but smooth and simple in quality, usually containing only one or two extrema. The line of action goes through the majority of a character's body or through a part of the body and has a clear direction. See Figure 1.3.

1.3 Scientific Approach to Posing and Animating Multiple Characters

The use case for this research in multi-character animation is a dancing couple. There are many combinations of poses a human can be in, let alone two humans *and* the two humans interacting. Specifically, a clip from the film "The Band Wagon" ([19]) was used to observe the common motions and poses in a dancing couple.

Almost inverting the problem at hand, we start from a pose to find the appropriate lines of action by tracing over the shapes of the dancers' bodies using the Grease Pencil Tool in

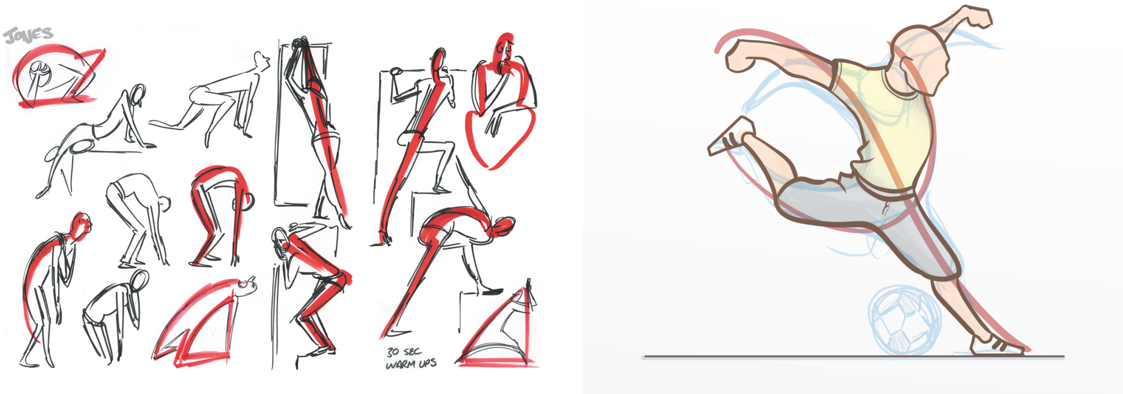
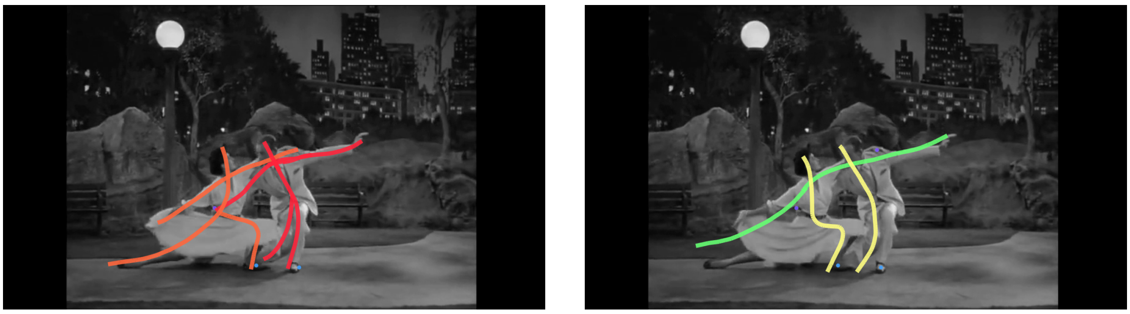


Figure 1.3 – Line of action examples.

Blender. It was carried out with the purpose of clarifying the properties and limitations of the typical line of action. After seeing at which point the actions started to repeat, a shorter sub-clip was chosen. Annotation was performed in five different ways:

1. tracking and marking each characters' contact with the ground
2. tracking and marking each characters' contact with each other
3. tracing lines of action for each character separately every few frames, using the previous line of action notation – the baseline method.
4. tracing lines of action for the characters and treating them as one using as few strokes as possible every few frames.
5. once the main common combinations were established from the above two methods, tracing lines of action only for the selected extreme combination poses.



(a) The typical lines of action trace out the whole skeleton, and in the worst case is 3 lines per character.

(b) Treating the characters as one bigger character allows the user to draw fewer lines to indicate the same pose.

Figure 1.4 – Comparing the old line of action and the new.

Through this process, certain patterns and common poses stood out, enabling the development of an improved notation for illustrating the poses of characters during their interactions with each other. Patterns included symmetry, parallelism, and repetition. Of course, using these patterns and assumptions to our advantage is what drove the development of a solution. It seemed that during many instances in the clip, it would be more efficient to draw lines over the two dancers as if they were one character. This morphed "combined" character should be easier to pose and animate.

(a) Parallelism. (b) Symmetry.

Figure 1.5 – Patterns in the poses.

Figure 1.6 – A selection of tracings over the dance clip from "The Band Wagon."

Using the previous work ([10], [11], and [12]), already in the process of being developed by the IMAGINE team, I extend the functionality of the line of action to be applied to multiple characters. Their software acted as the baseline with which to compare the new features. Baseline poses and animations were made by taking important keyframes from the film clip to recreate in their software. The amount of time spent running the program, the number of clicks, and number of lines drawn were recorded.

Since characters' skeletons are essentially trees, a novel approach to solving this problem was combining these kinematic trees into one in a new data structure with special attributes for posing and animating. An interesting way to evaluate this notion of animating a combined character was to, again, reproduce the same poses and animations as in the baseline, but this time using the new structure instead.

Results to come I hope

1.4 Contents of this report

In the following chapter (chapter 2), I cover the state-of-the-art for this particular problem. I discuss a brief history of dance notation – how choreographers and dancers use sketching on paper to brainstorm and communicate their ideas of motion, formation, and pose of dance. Then I will talk about the existing sketch-based systems used for posing articulated characters, covering the benefits and limitations of each. A sizeable portion of my work has had to do with kinematic trees and graph data structures, so I will go into a few important graph theory algorithms. Generating animation from existing data is also a widely relevant topic to my work. So, I also describe previous research regarding that.

In chapter 3, the fundamentals of character animation are more closely examined. (more to come when I actually write it...)

chapter 4 covers exactly how a solution was reached and what it entails. (more to come when I actually write it...)

chapter 5 is where I go over the methods of validating our solution. (more to come when I actually write it...)

Discussion of the lessons learned during this project and the concluding thoughts on the process are explored in chapter 6 and chapter 7, respectively. (more to come when I actually write it...)

— 2 —
State-of-the-Art

2.1 Dance

Valerie Sutton is a choreographer responsible for inventing Sutton Dance Writing, introduced in [25].

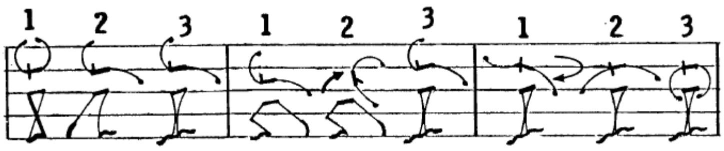


Figure 2.1 – An example of Valerie Sutton's Dancewriting.

Labanotation
Benesh Movement Notation

2.2 Sketch-Based Systems

The IMAGINE group at Inria has made it their mission to tackle this problem. They have made significant progress on a project where they aim to offer more intuitive tools to author 3D digital content. The IMAGINE team has invented (1) a type of notation made especially for posing and animating 3D characters (2) a technique for posing called the line of action, in which a user can draw a line in the shape they want a kinematic chain to take and (3) a technique for animation called space-time sketching, in which a user can draw a line in the path they want a model to take and it will be animated accordingly. As the character follows the path, its model bends and changes shape in a physically realistic way. Their system currently supports creating different movements with the path such as bouncing, rolling, and twisting.

The line of action technique works extremely well for a single humanoid character, and even multiple humanoid characters separate from each other.

The Line of Action: an Intuitive Interface for Expressive Character Posing – 2013
Adding dynamics to sketch-based character animations – 2015
Space-time sketching of character animation – 2015

Artist-oriented 3D character posing from 2D strokes – 2016

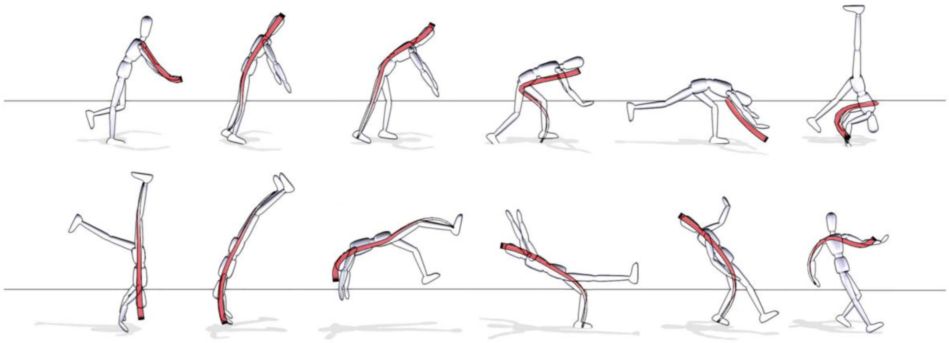


Figure 2.2 – One character's keyframes using the line of action technique from [10].

people in Switzerland also did the posing
Sketch to pose in Pixar's presto animation system – 2015

2.3 Graph Theory

Finding All the Elementary Cycles in a Directed Graph
A New Search Algorithm for Finding the Simple Cycles of a Finite Directed Graph
An Algorithm for Combining Graphs Based on Shared Knowledge

2.4 Generating Animation

FootSee: an Interactive Animation System
Footskate Cleanup for Motion Capture Editing
SketchiMo: Sketch-based Motion Editing for Articulated Characters – 2016
sketching for editing trajectories and poses

Retargetting Motion to New Characters

Using an Intermediate Skeleton and Inverse Kinematics for Motion Retargeting

Motion Graphs

Style-Based Inverse Kinematics – 2004
generative models for motion capture sequences used to build animations

Displacement constraints for interactive modeling and animation of articulated structures – 1994
fitting geometric constraints using physics

A constrained inverse kinematics technique for real-time motion capture animation – 1999
Dancing-to-Music Character Animation

Synthesizing Dance Performance Using Musical and Motion Features – 2006

between music and an animation generated from a motion graph built from motion capture

— 3 —
Theoretical Foundations of Animation

3.1 Skeletons, Rigs, and Controllers: Kinematics

3.2 In-betweening

3.3 The Line of Action

3.3.1 Notation

Taking inspiration from Sutton Notation, we propose a new notation for representing the poses of two characters both together and separately.

3.3.1.1 Common Multi-character Poses

Figure 3.1 – Dancing in the Dark.

There is a dance scene in the film "The Band Wagon," where Cyd Charisse and Fred Astaire start out by walking together side by side, exchanging twirls until it morphs completely into a swing style dance. This scene is our use case for inventing a notation which extends seamlessly to more than one character.

To determine which poses for these dancers were common, I annotated the video with what I thought good keyframes would be if the two characters were treated as one.

There are 6 poses combinations for the characters separately. The asymmetrical poses for the odd number of LOAs can be mirrored (for 3 and 5 LOAs); therefore there are actually 8 poses for two characters separately. There are 10 combinations for the characters together, treated as one character. There are 2 poses which can be mirrored, so there are actually 12 poses together. Overall, 20 poses exist for 2 articulated humanoid characters.

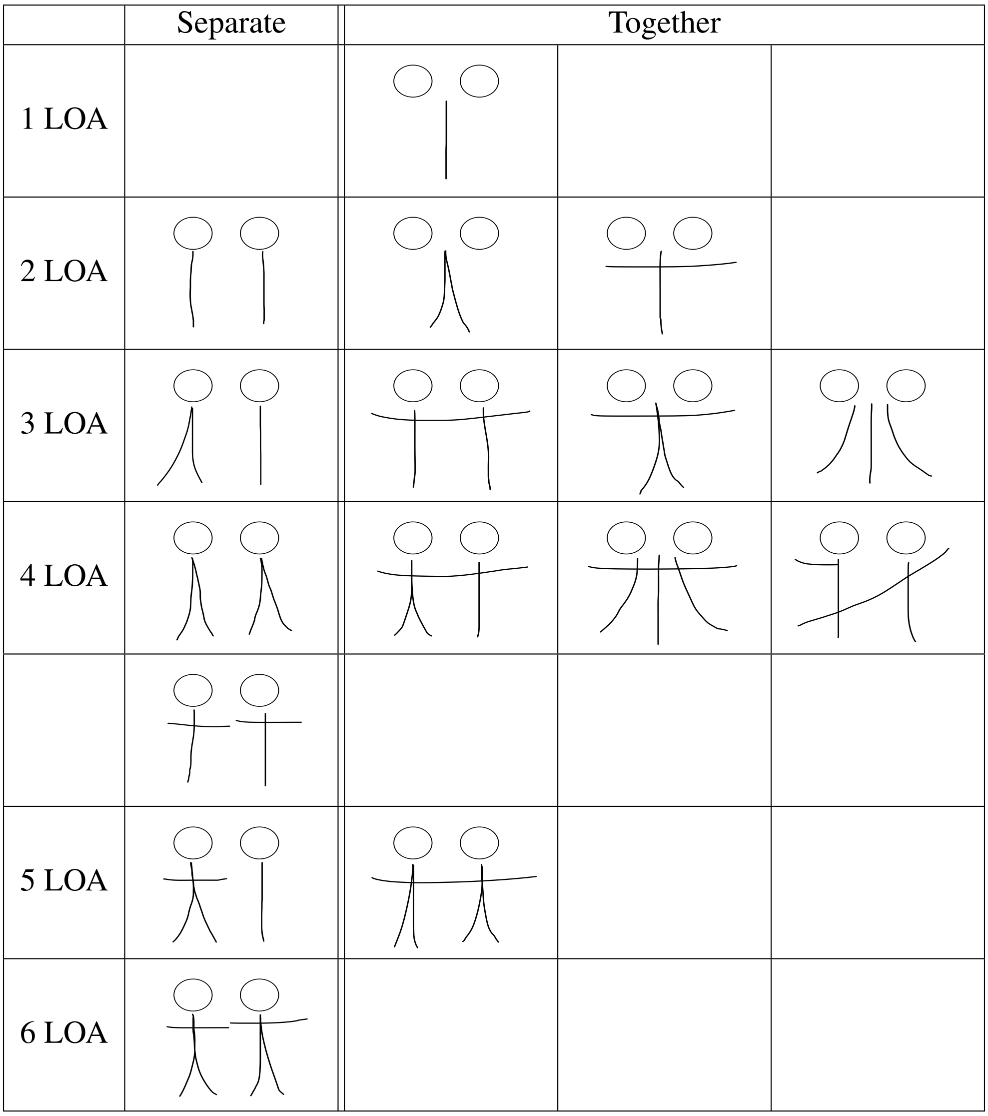


Table 3.1 – Types of Keyframes for Two Dancing Characters

3.4 Space-time Sketching

3.5 Optimization Problems

The Conjugate Residual Method for Constrained Minimization Problems – 2015
Constrained Closed Loop Inverse Kinematics – 2010

3.6 Rig Combinations as Trees

— 4 —

Implementing a Character Connection Algorithm

4.1 Interface

4.2 Intelligently Connecting Rigs

Rather than changing the whole LOA concept and optimization algorithm, we reduce the more complex problem of using LOAs on multiple characters to the original LOA problem and utilize (nearly) the exact same minimization.

4.3 Challenges

4.4 User Constraints

Only allowed to connect and disconnect skeletons at keyframes.

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Experimental Validation of Solution

5.1 Carefully Selecting Sample Keyframes

5.2 Establishing a Baseline for Comparison

5.3 Our Solution

5.3.1 Experiment

Describe the performance metrics, experimental hypotheses, experimental conditions, test data, and expected results. Provide the test data. Interpret the results of the experiments. Pay special attention to cases where the experiments give no information or did not come out as expected. Draw lessons and conclusions from the experiments. Explain how additional experiments could validate or confirm results.

5.3.2 Results

5.3.3 Conclusions and Future Experiments

— 6 —
Discussion

Discussion lessons learned from the experiments, and new problems that are raised.

— 7 —
Conclusion

Give a summary of the problem, approach, implementation and evaluation. Discuss the principal results in abstract terms. Discuss expected impact and further research directions. Explain how the project satisfies the evaluation criteria for a Masters Research project.

— A —
Appendix

A.1 Glossary

CCD
cyclic coordinate descent

articulated character
definition

controller
definition

end effector
definition

forward kinematics
definition

inverse kinematics
definition

keyframe
definition

kinematic chain
definition

rig
definition

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