Modeling Ranges of Limb Motion for Real-time Inverse Kinematics

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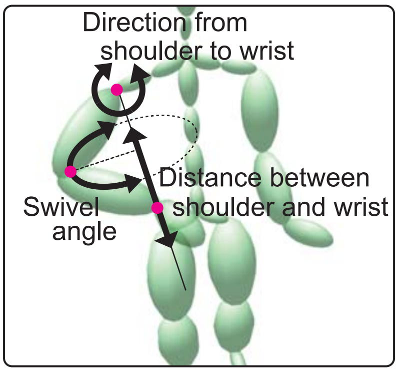
Introduction

Accurate modeling of ranges of joint motion (joint ROM) is a fundamental problem of articulated figure animation. The joint ROM should be carefully designed to avoid an impossible pose, requiring tedious work because of the complexity and extensiveness of human joints, especially shoulders and hips.We propose a model to represent *ranges of limb motion (limb ROM)*. The key idea of limb ROM is to define a space of possible pose of a limb, instead of defining ROM of each joint.

Range of limb motion (limb ROM)

A limb ROM model represents a valid range of directions from shoulder to wrist, and range of swivel angle and distance from shoulder to wrist along a direction; “swivel angle” [1] denotes a rotation angle of the elbow around an axis with which shoulder and wrist are connected.



Contributions

1. Our method successfully simulates a dependency between ROM of a joint and rotation of its neighbor.
2. Our limb ROM model is well suited to a real-time IK technique. Prior to executing the IK solver, an invalid limb pose is efficiently avoided by relocating the wrist position into the valid workspace and adjusting swivel angle while fixing the wrist position.
3. A compact limb ROM model is automatically estimated from a sparse collection of example poses.

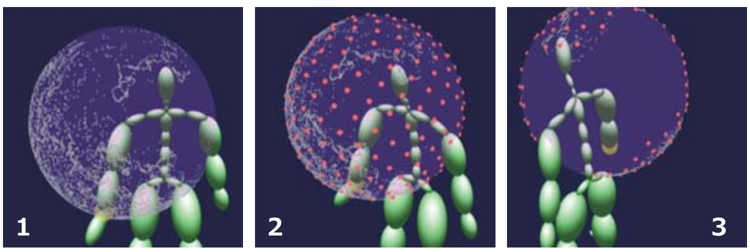
Example-based modeling

Example data

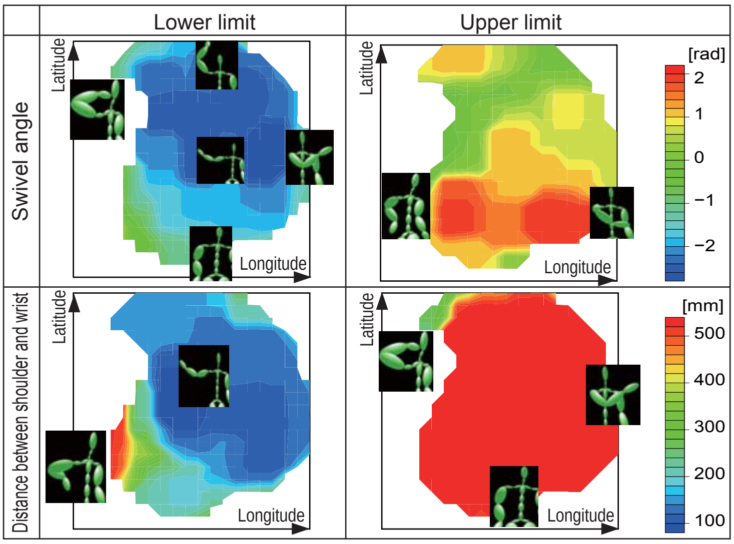
swivel angle and wrist position in a shoulder's local coordinate

An empirical assumption --- for reducing data dimensionality

a range of swivel angle changes depending on only direction from shoulder to wrist without being constrained by a distance to wrist



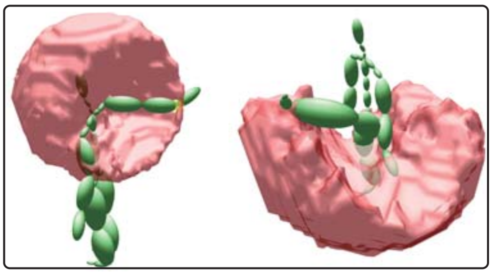
1. Pjojecting examples onto a surface of unit sphere on which a direction from shoulder to wrist is represented by a point.
2. Uniform sampling on the spherical surface: searching min & max values of swivel angle and those of distance to wrist within a certain radius around each sampling point.
3. Removing sampling points having no value, and detects closed outer hull which includes all available points.



2D Visualization of ROM of right arm using Lambert Azimuthal equal-area projection. White area represents where the wrist cannot reach.

Example data
- One actress
- Gymnastic motion
- 30000 poses

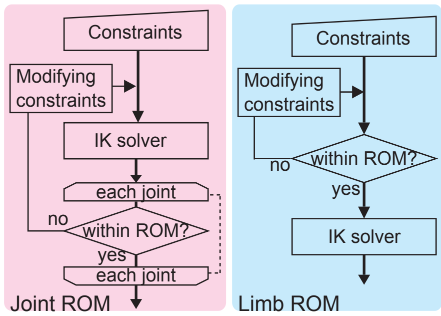
Data size
- 400 sampling points
- 3.1 kB

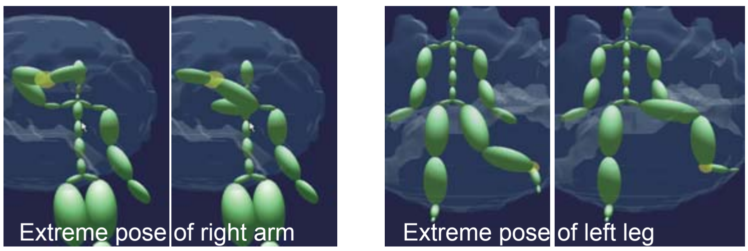


Estimated workspace of right wrist and left ankle

IK with limb ROM

Limb ROM detects invalid constraint in constant time prior to executing the IK solver[1] whereas existing joint ROM models require iteration process to fix invalid joint angle.





Conculusion

The experimental results demonstrate reasonable accuracy of our model. One major limitation is that our model still requires a large amount of memory which increases according to the number of sampling points. Our future work includes an investigation of a more compact, parametric limb ROM model.

References

[1] Tolani, D.,Goswami, A., and Badler, N. I. 2000. Real-time inverse kinematics techniques for anthropomorphic limbs. Graphical Models 62, 5, 353–388.