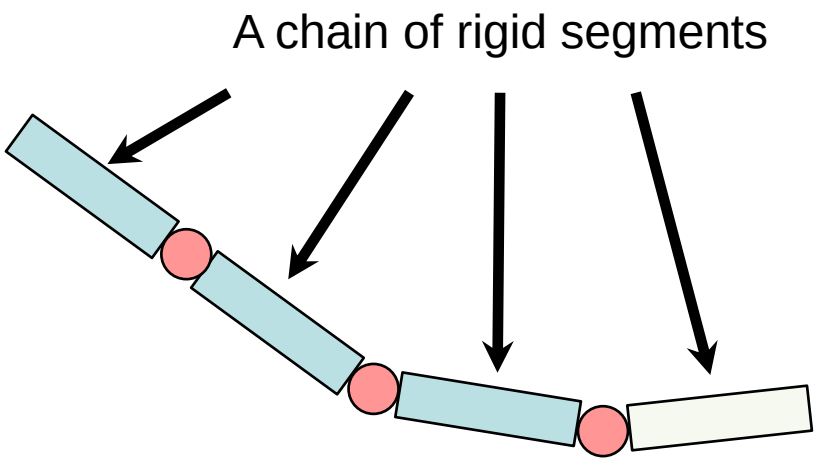
Inverse Kinematics

CS-116B: Computer Graphics Algorithms
Spring 2018

What is inverse kinematics?

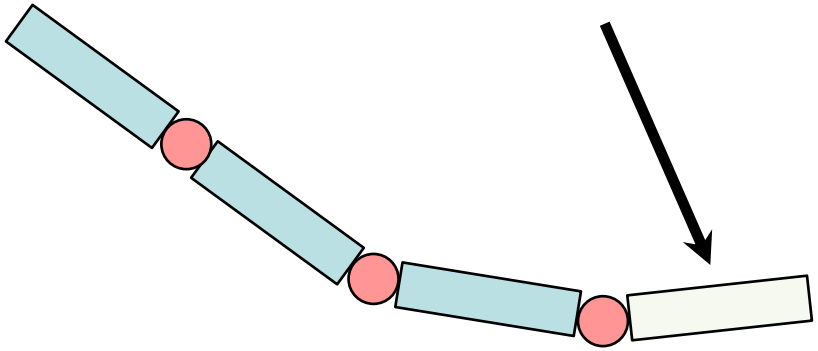
- Inverse kinematics (IK): the process of computing the positions of a series of connected segments based on the position of the end effector.

Anatomy of a chain



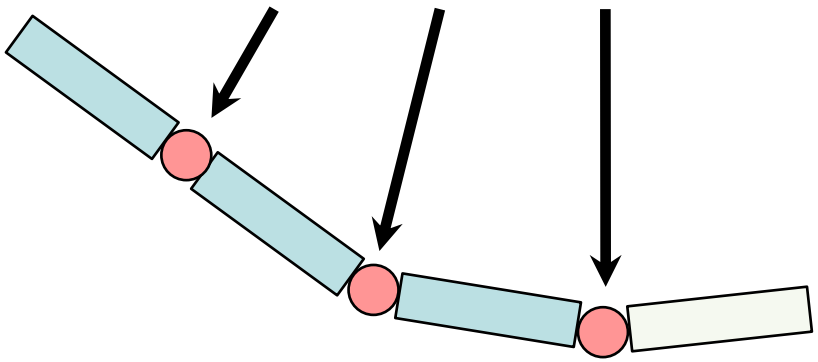
Anatomy of a chain

End effector: the last segment of the chain.



Anatomy of a chain

Joints: These enable the rigid segments to pivot.



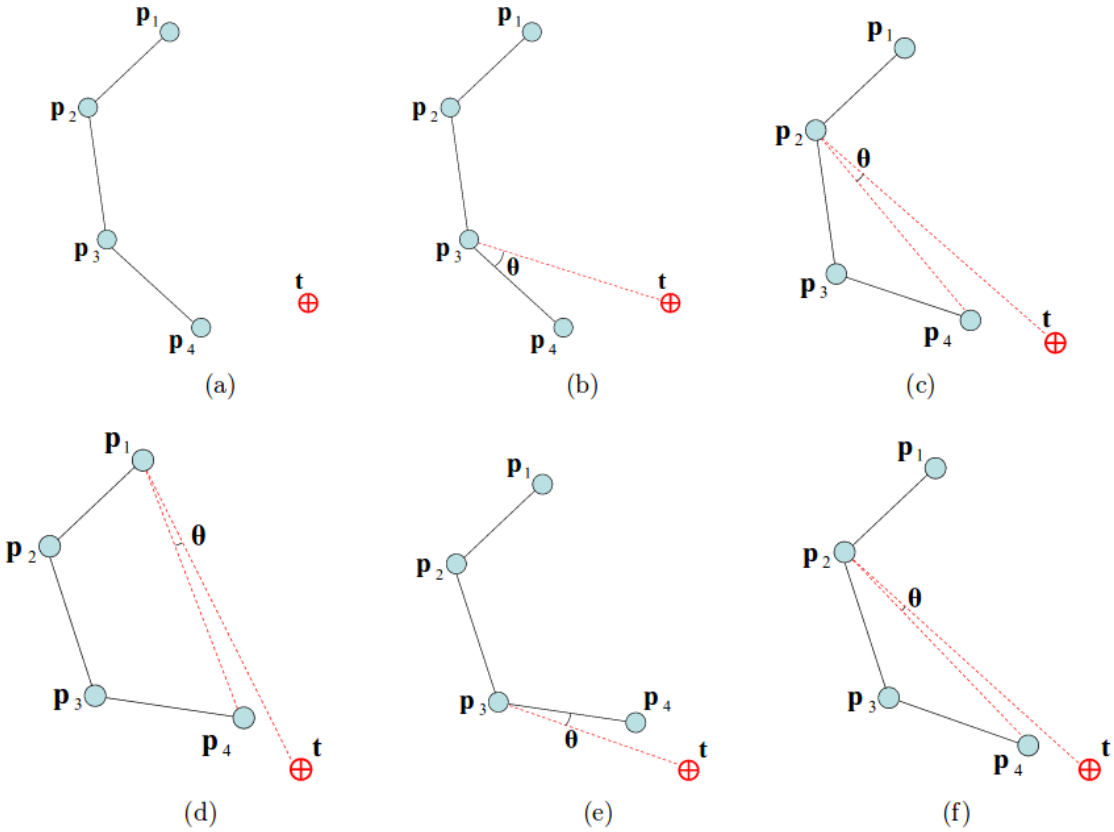
Why use inverse kinematics?

- In computer graphics, inverse kinematics is used for any sort of animation such as:
  - Biped (two-foot) creatures such as a human or kangaroo.
  - Quadruped (four-foot) creatures such as a cat, dog, or horse.
  - The geometry of a robotic arm!
- Inverse kinematics enables the animator to move only the end-effector of a chain.
  - The other segments of the chain are then calculated algorithmically based on the end-effector's position.
  - This saves an animator time from having to accurately move the segments individually to create animation.

Inverse Kinematics: Algorithms

- Jacobian inverse technique
- Damped Least Squares method
- Pseudo-inverse Damped Least Squares
- Selectively Damped Least Square
- Feedback Inverse Kinematic
- Broyden’s method
- Powell’s method
- Broyden, Fletcher, Goldfarb and Shann method
- Sequential Monte Carlo method
- Cyclic Coordinate Descent

Inverse Kinematics: Cyclic Coordinate Descent algorithm



“An example of visual solution of the IK problem using the CCD algorithm. (a) The initial position of the manipulator and the target, (b) find the angle θ between the end effector, joint p3 and the target and rotate the joint p4 by this angle, (c) find the angle θ between the end effector, joint p2 and the target and rotate joints p4 and p3 by this angle, (d), (e) and (f) repeat the whole process for as many iterations as needed. Stop when the end effector reaches the target or gets sufficiently close.” (p. 20).

Source: *Inverse Kinematics: a review of existing techniques and introduction of a new fast iterative solver*.

For Further Reading

- *Inverse Kinematics: a review of existing techniques and introduction of a new fast iterative solver* by Andreas Aristidou and Joan Lasenby. Available from: http://www.andreasaristidou.com/publications/CUEDF-INFENG,%20TR-632.pdf

- *Real-Time Inverse Kinematics Techniques for Anthropomorphic Limbs* by Deepak Tolani, Ambarish Goswami, and Norman I. Badler. Available from: https://www.cis.upenn.edu/~badler/gmod/0528a.pdf