Chapter 7

Modelling and Animating Human Figures

Chapter 7

Introduction

Modeling and animating an articulated figure is one of the most formidable tasks that an animator can be faced with. It is especially challenging when the figure is meant to realistically represent a human. There are several major reasons for this. First, the human figure is a very familiar form. This familiarity makes each person a critical observer. When confronted with an animated figure, a person readily recognizes when its movement does not “feel” or “look” right. Second, the human form is very complex, with more than two hundred bones and six hundred muscles. When fully modeled with linked rigid segments, the human form is endowed with approximately two hundred DOF.

Chapter 7

Virtual Human Representation

Body geometry
- polygonal representations
- patch representations
- subdivision surfaces
- implicit surfaces

Chapter 7

Geometry

- Data acquisition
- Geometry deformation
- Surface Detail
- Layered approach

Image courtesy of Adaptive Perception

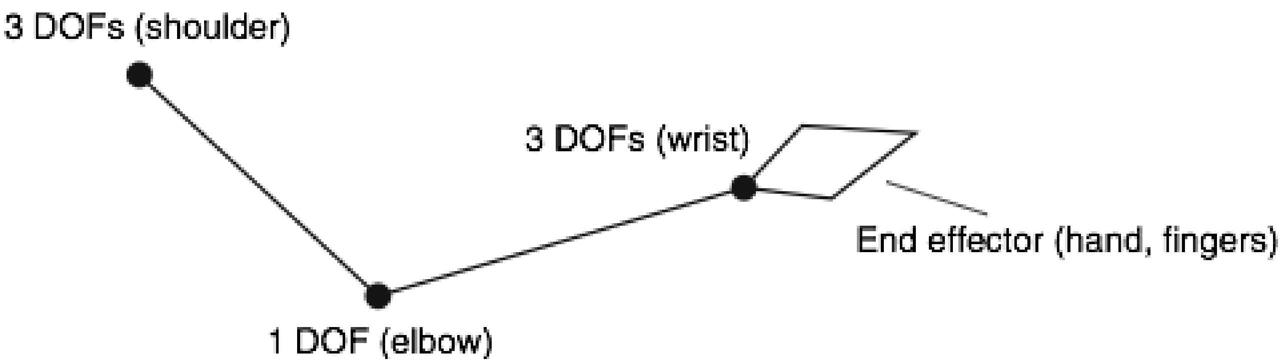
Chapter 7

Reaching

Modeling the arm
The shoulder joint
The hand
Coordinated movement
Obstacles
Strength

Chapter 7

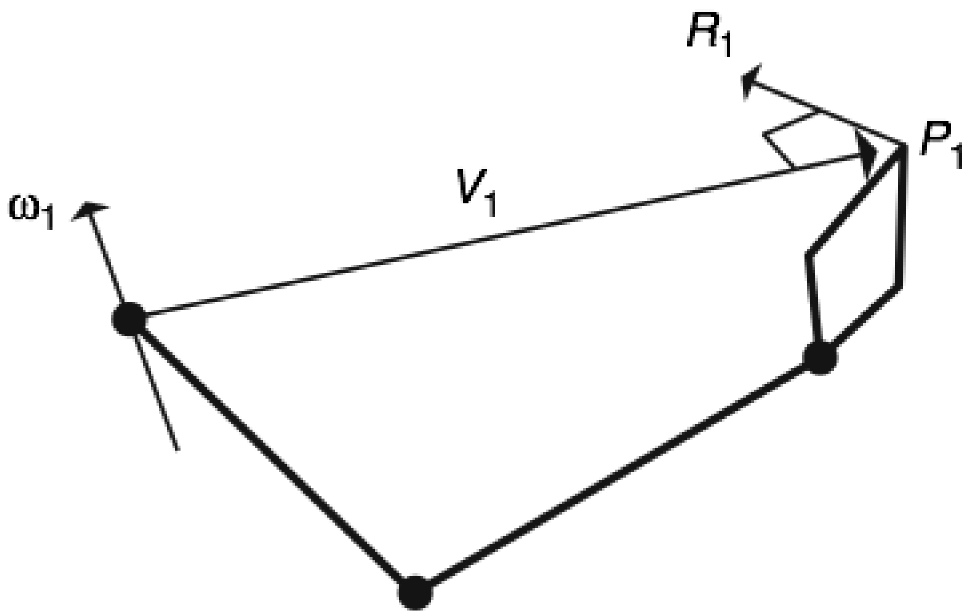
Modeling the Arm



Basic model of the human arm

Chapter 7

Modeling the Arm



Effect of the first DOF on the end effector: $R_1 = \omega_1 \times V_1$

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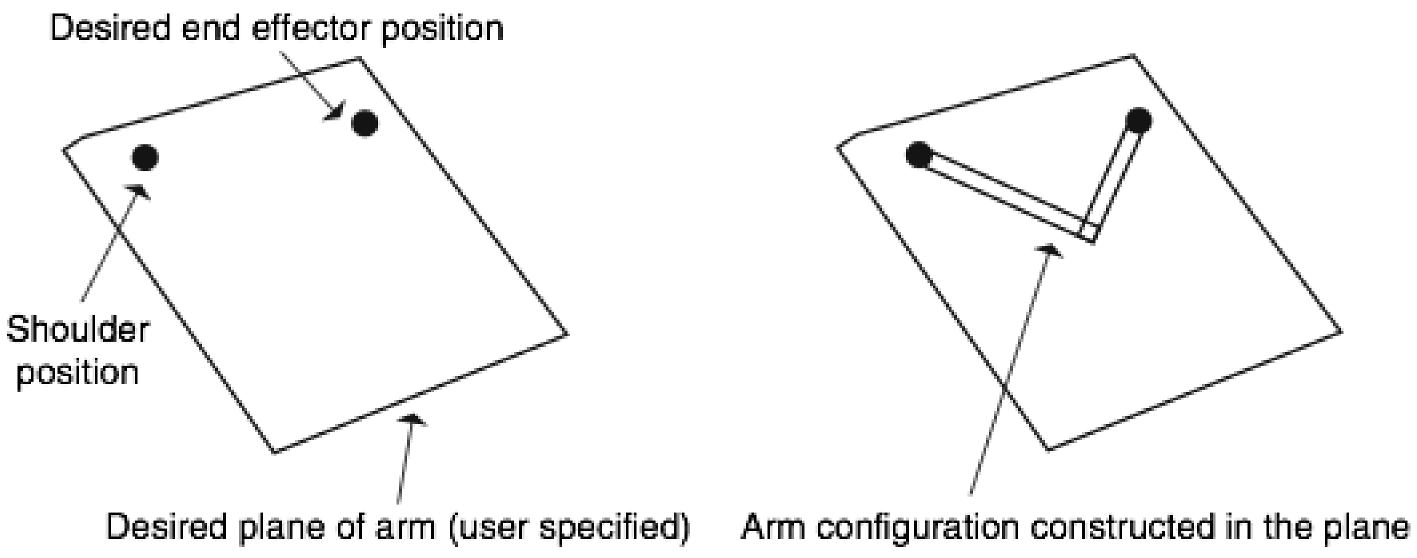
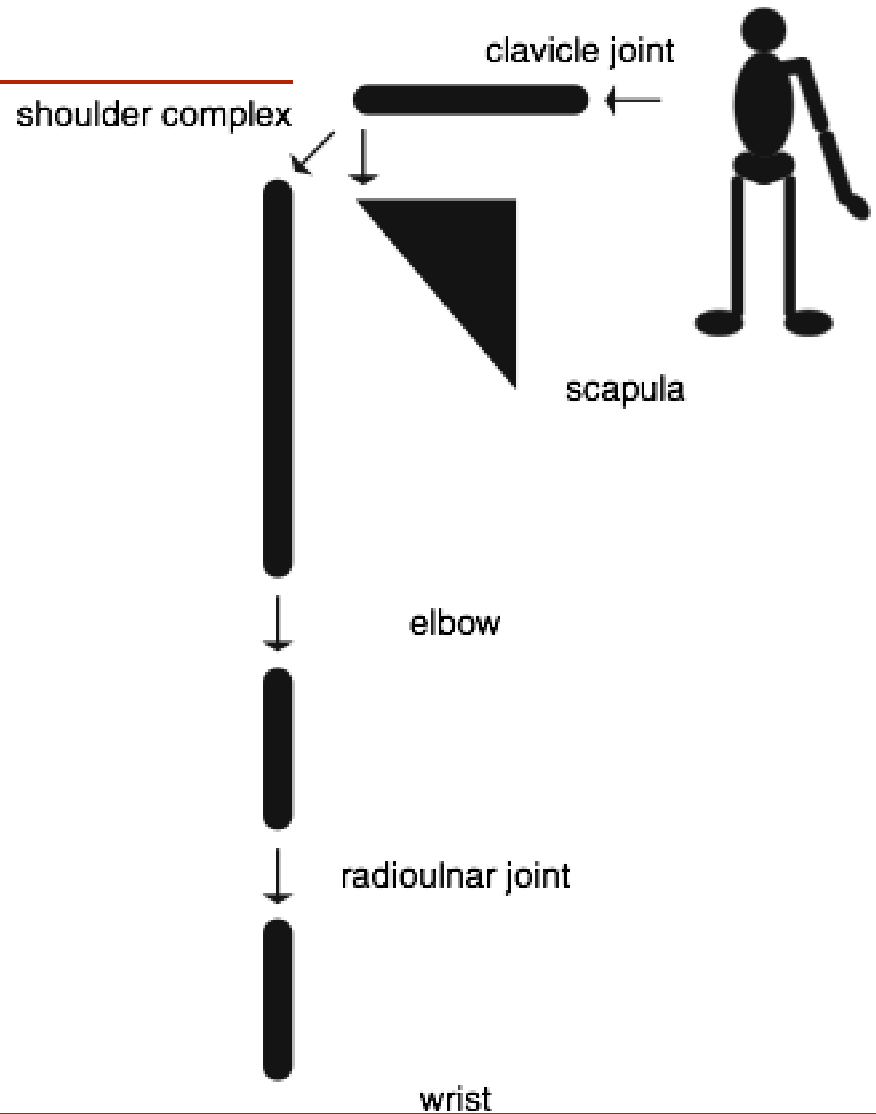
Modeling the Arm



Constructing the arm in a user-specified plane

Chapter 7

Modeling the Shoulder



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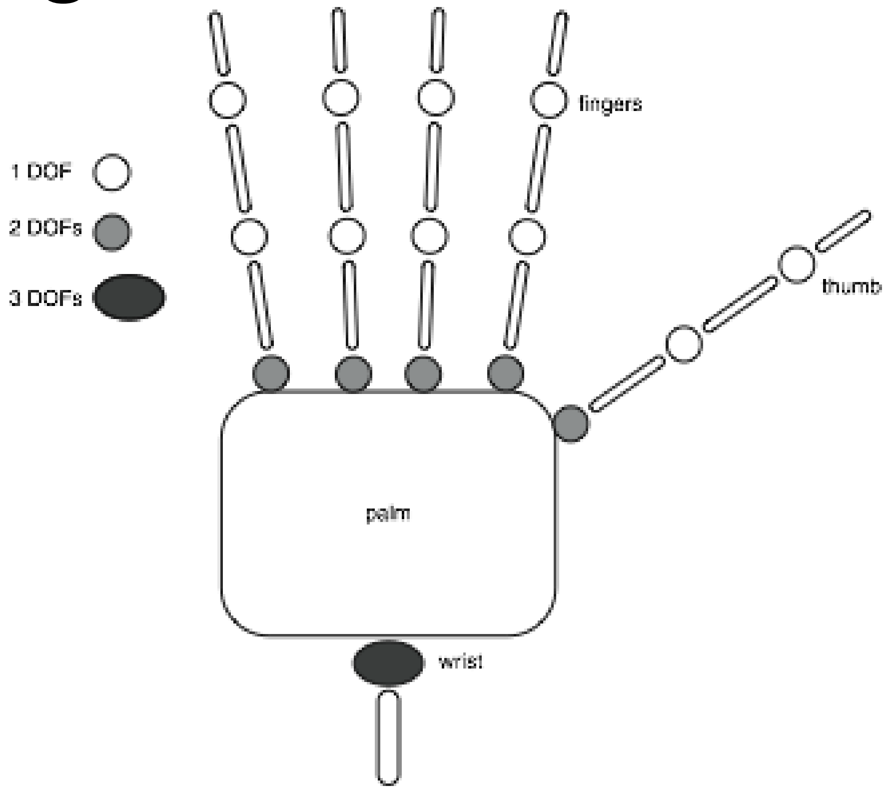
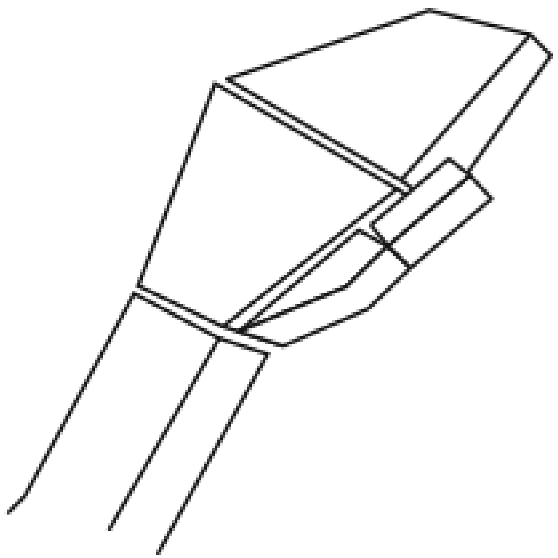
Modeling the Hand



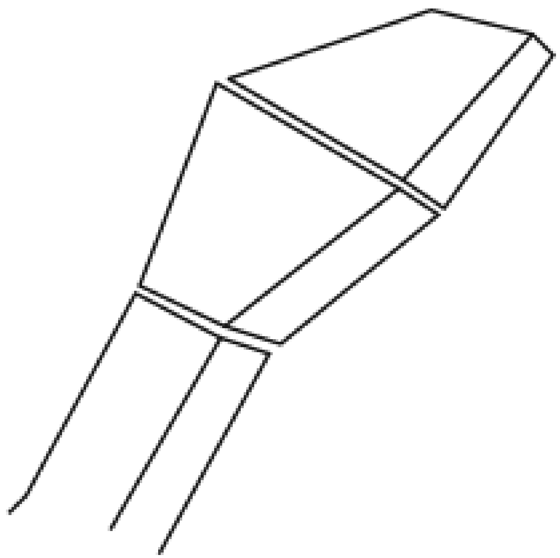
Simple model of hands and fingers

Chapter 7

Grasping



With opposable thumb

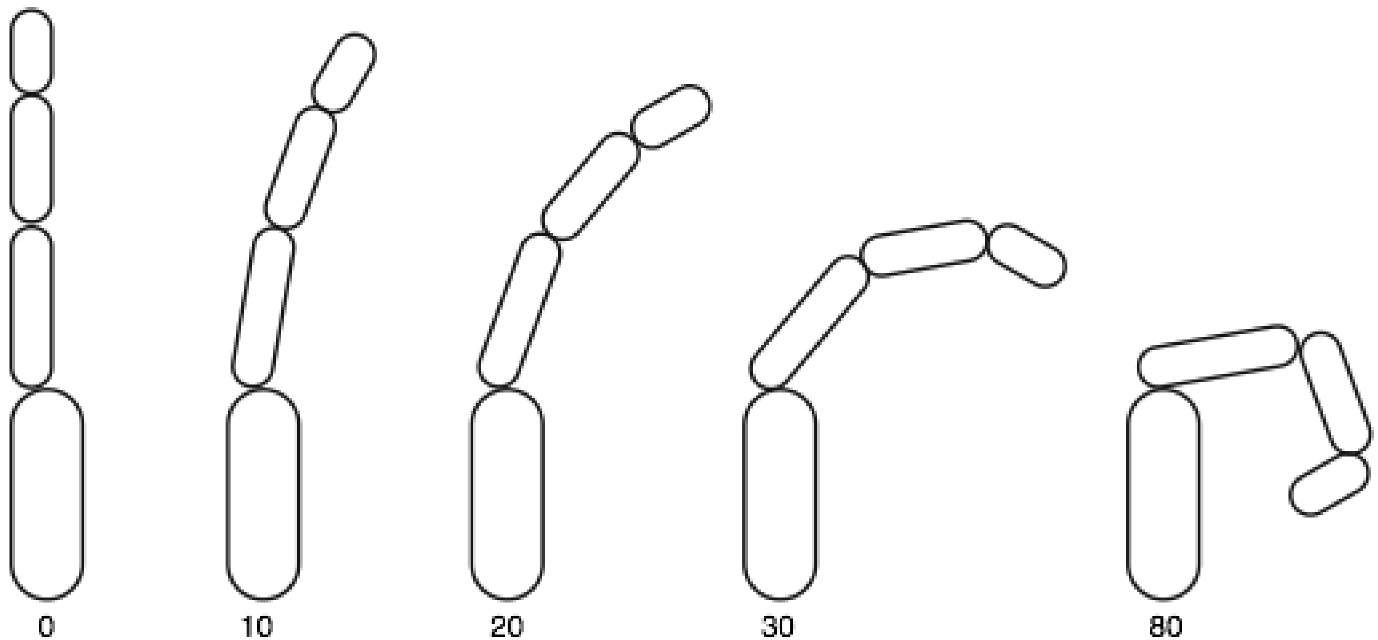


Without opposable thumb

Simplified hands

Chapter 7

Grasping



Finger flexion controlled by single parameter; the increase in joint angle (in degrees) per joint is shown

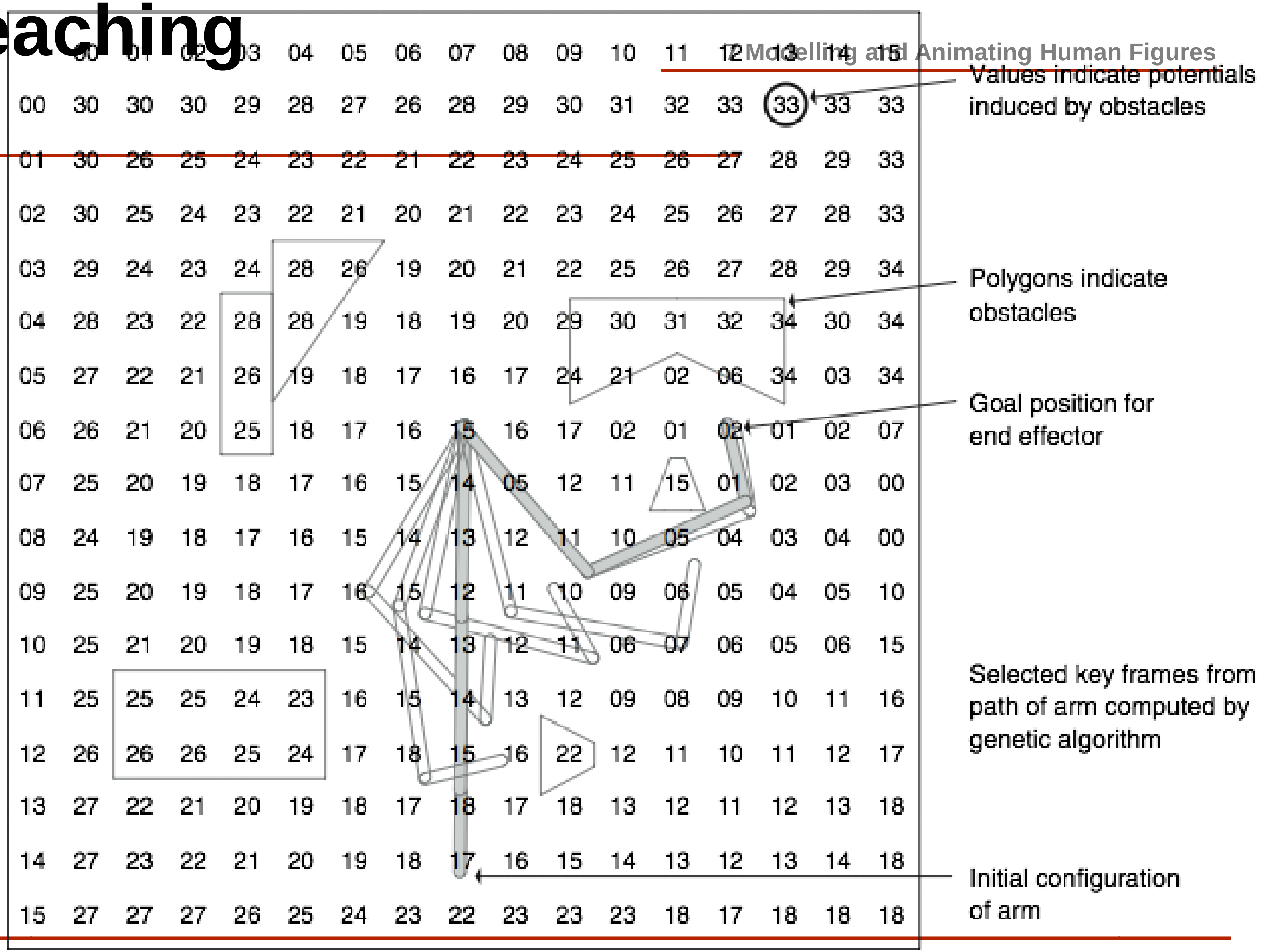
Chapter 7

Reaching

To further complicate the specification and control of reaching motion, there may be obstacles in the environment that must be avoided. Of course, it is not enough to merely plan a collision-free path for the end effector. The entire limb sweeps out a volume of space during reach that must be completely devoid of other objects to avoid collision.

Genetic algorithms, for example, have been used to search the space for an optimal path. The genetic fitness function can be tailored to find an optimal path in terms of one of several criteria such as shortest end effector distance traveled, minimum torque, and minimum angular acceleration.

Reaching


00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
00 30 30 30 29 28 27 26 28 29 30 31 32 33 33 33 33
01 30 26 25 24 23 22 21 22 23 24 25 26 27 28 29 33
02 30 25 24 23 22 21 20 21 22 23 24 25 26 27 28 33
03 29 24 23 24 28 26 19 20 21 22 25 26 27 28 29 34
04 28 23 22 28 28 19 18 19 20 29 30 31 32 34 30 34
05 27 22 21 26 19 18 17 16 17 24 21 02 06 34 03 34
06 26 21 20 25 18 17 16 15 16 17 02 01 02 01 02 07
07 25 20 19 18 17 16 15 14 05 12 11 15 01 02 03 00
08 24 19 18 17 16 15 14 13 12 11 10 05 04 03 04 00
09 25 20 19 18 17 16 15 12 11 10 09 06 05 04 05 10
10 25 21 20 19 18 15 14 13 12 11 06 07 06 05 06 15
11 25 25 25 24 23 16 15 14 13 12 09 08 09 10 11 16
12 26 26 26 25 24 17 18 15 16 22 12 11 10 11 12 17
13 27 22 21 20 19 18 17 18 17 18 13 12 11 12 13 18
14 27 23 22 21 20 19 18 17 16 15 14 13 12 13 14 18
15 27 27 27 26 25 24 23 22 23 23 23 18 17 18 18 18
Values indicate potentials induced by obstacles
Polygons indicate obstacles
Goal position for end effector
Selected key frames from path of arm computed by genetic algorithm
Initial configuration of arm

Chapter 7

Walking

Walking, along with reaching, is one of the most common activities in which the human form engages. An aspect that differentiates walking from typical reaching motions is that it is basically cyclic. While its cyclic nature provides some uniformity, acyclic components such as turning and tripping occur periodically. In addition, walking is responsible for transporting the figure from one place to another and is simultaneously responsible for maintaining balance. Thus, dynamics plays a much more integral role in the formation of the walking motion than it does in reaching.

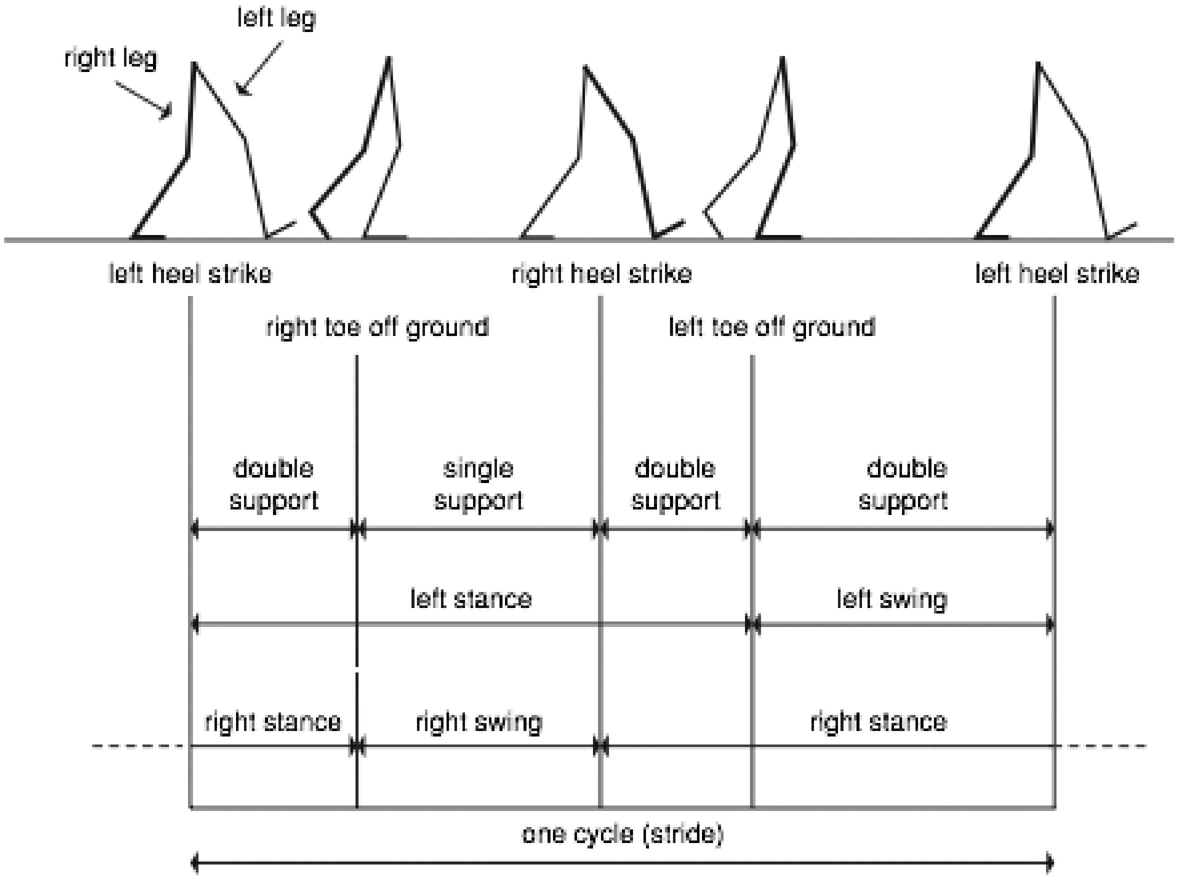
Chapter 7

Walking

The mechanics of locomotion
walk cycle
run cycle
Pelvic transport
Pelvic rotation
Pelvic list
Knee flexion
Ankle and toe joints

Chapter 7

Anatomy of the Walk (walk cycle)



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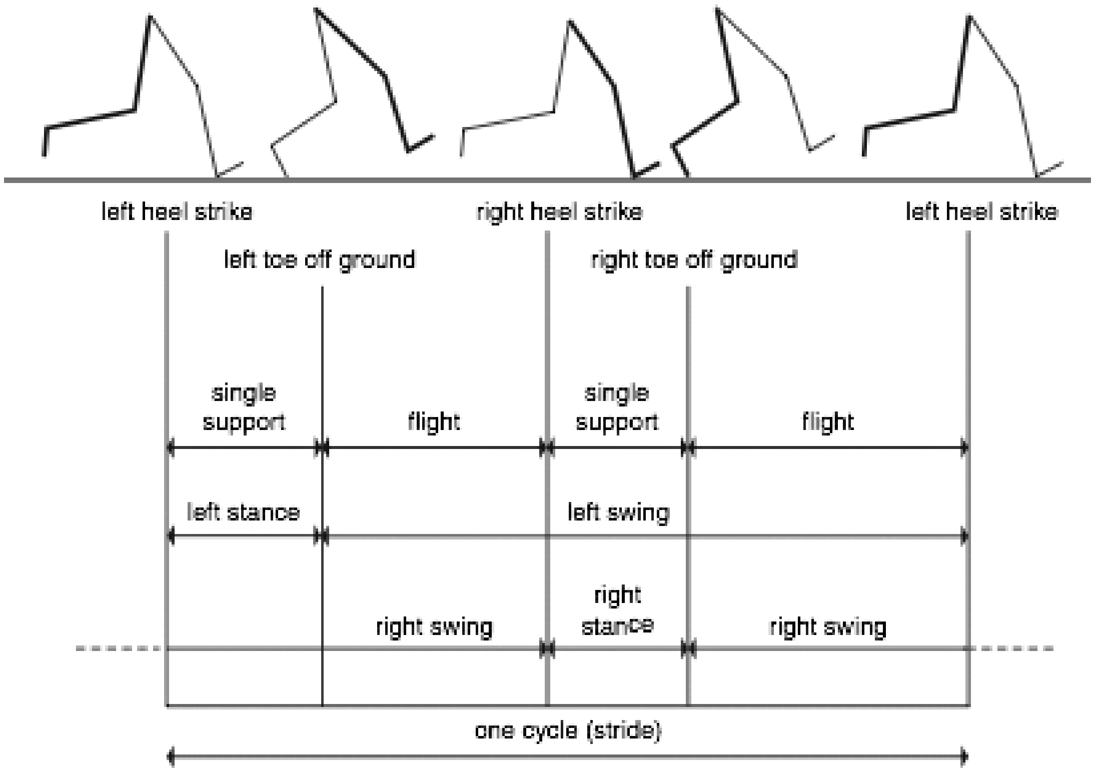
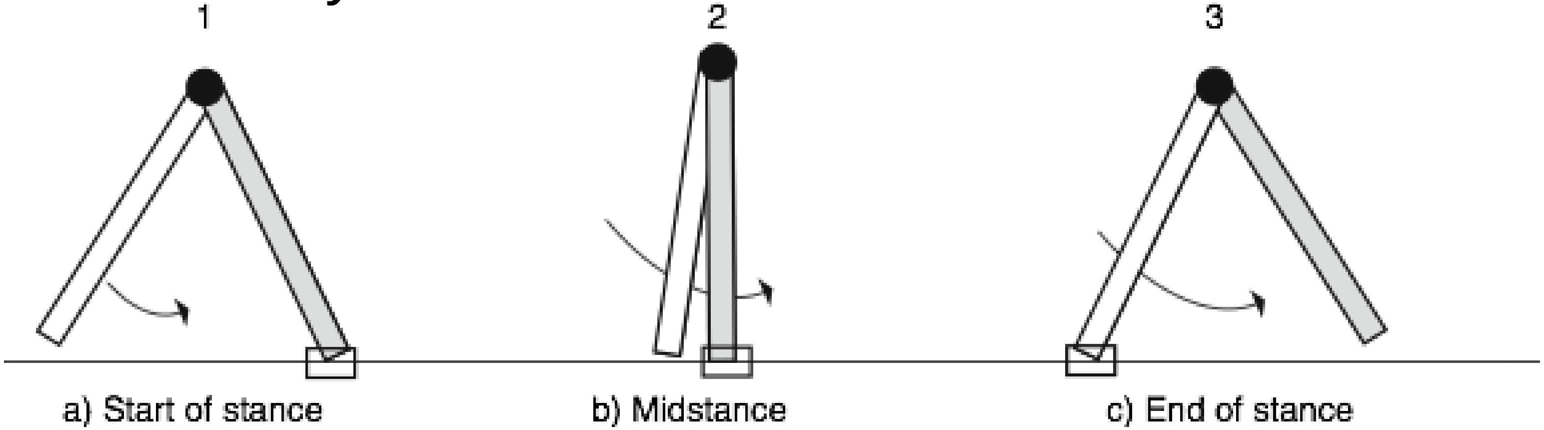
Anatomy of the Run (run cycle)



Chapter 7

Kinematics of the Walk

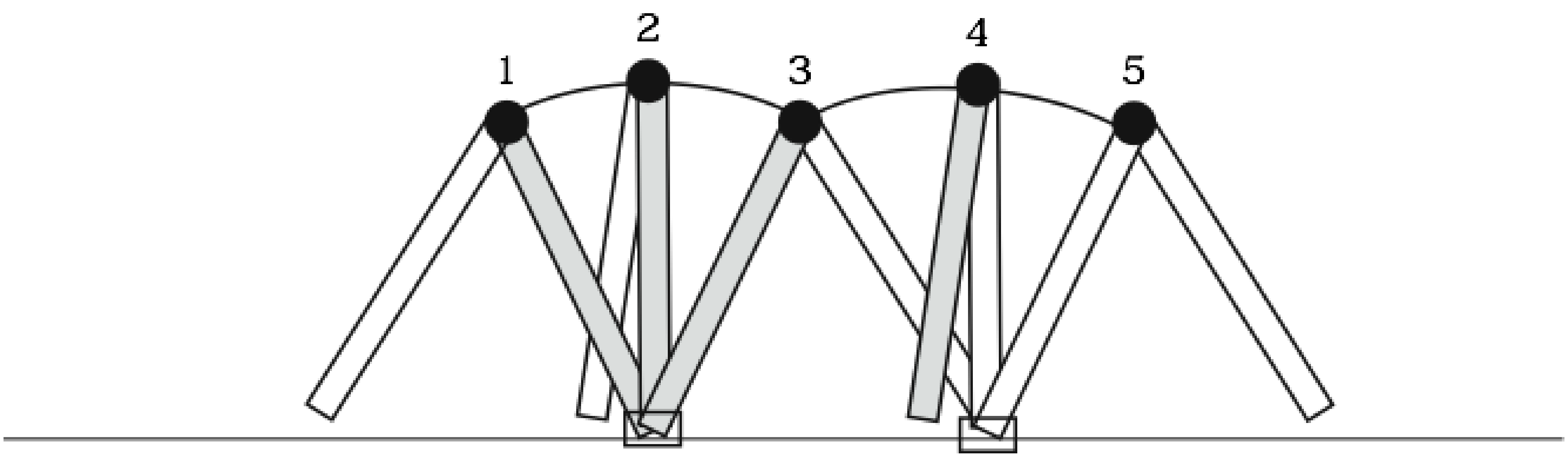
For present purposes, let the pelvis represent the mass of the upper body being transported by the legs. Using a simplified representation for the legs, the image below shows how the pelvis is supported by the stance leg at various points during the stance phase of the walk cycle.



Chapter 7

Kinematics of the Walk

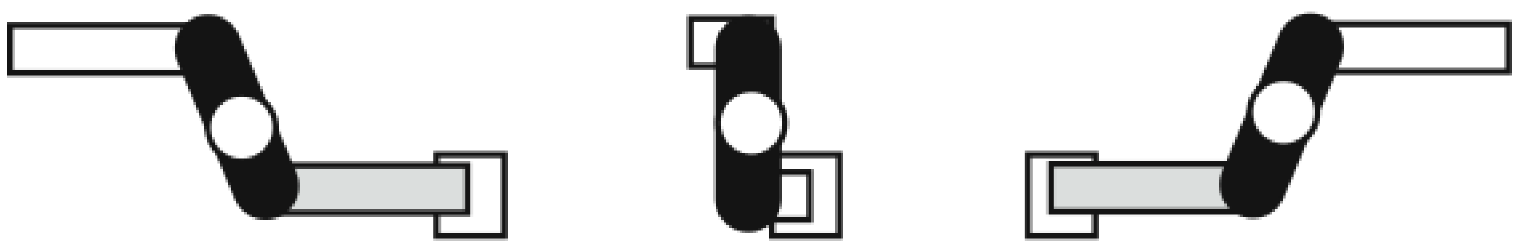
The image below shows these positions superposed during a full stride and illustrates the abutting of two-dimensional circular arcs describing the basic path of the pelvis as it is transported by the legs.



Chapter 7

Kinematics of the Walk

The pelvis represents the connection between the lefs and the structure that separates the legs in the third dimension. The pelvis rotates about a vertical axis centered at the stance leg, helping to lengthen the stride as the swing leg stretches out for its new foot placement.

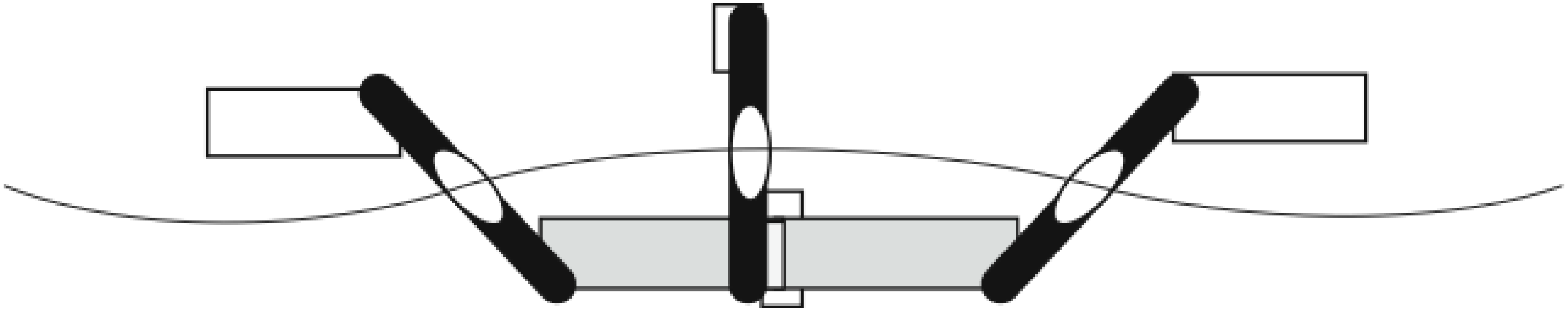


Start of stance Midstance End of stance

Chapter 7

Kinematics of the Walk

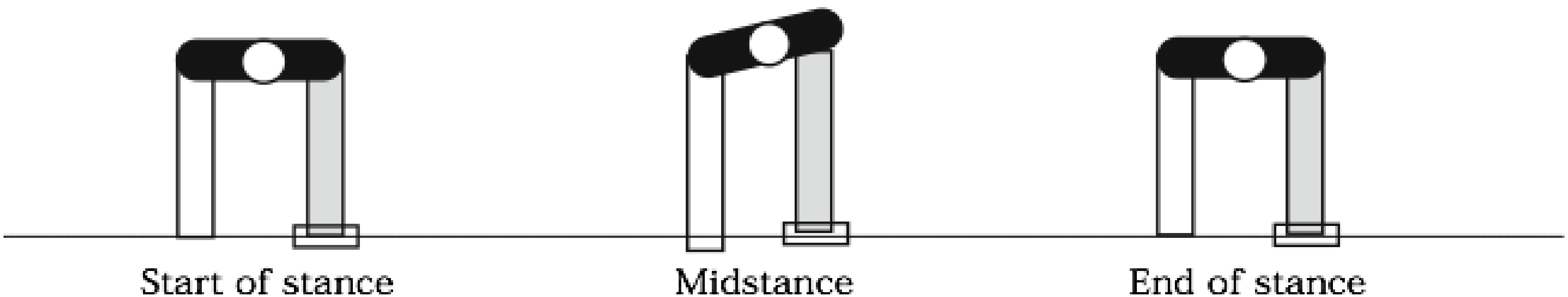
The path of the center of the pelvis resembles a sinusoidal curve:



Chapter 7

Kinematics of the Walk

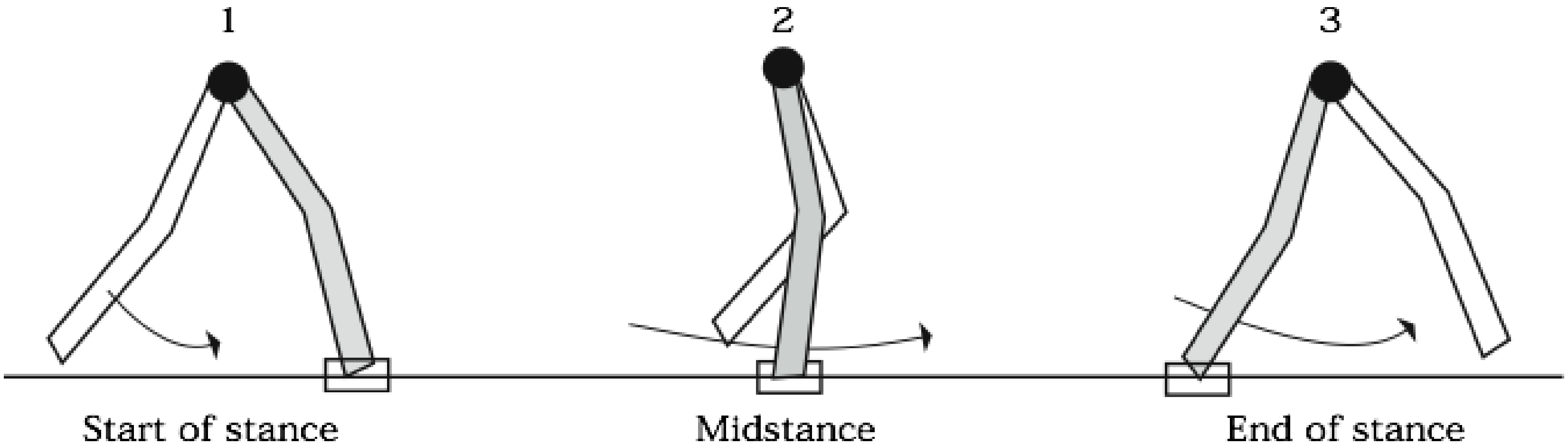
The transport of the pelvis requires the legs to lift the weight of the body as the pelvis rotates above the point of contact with the floor. To reduce the amount of lift, the pelvis lists by rotating in the coronal plane, i.e. the plane perpendicular to the ground that divides the body into front and back halves.



Chapter 7

Kinematics of the Walk

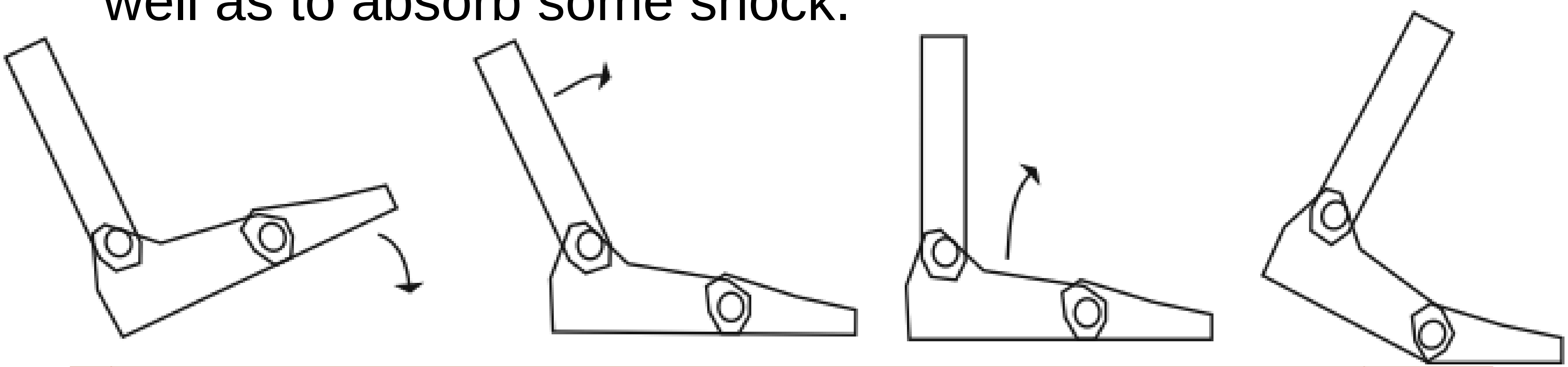
In a pelvic list with one-piece legs, the swing leg would penetrate the floor. Bending the knee joint allows the swing leg to safely pass over the floor and avoid contact. Flexion at the knee of the stance leg also produces some leveling out of the pelvis arcs produced by the rotation of the pelvis over the point of contact with the floor.



Chapter 7

Kinematics of the Walk

The final part of the puzzle to the walking motion is the foot complex, consisting of the ankle, the toes, and the foot itself. This complex comprises several bones and many DOF and can be simply modeled as two hinge joints per foot. The ankle and toe joints serve to further flatten out the rotation of the pelvis above the foot as well as to absorb some shock.



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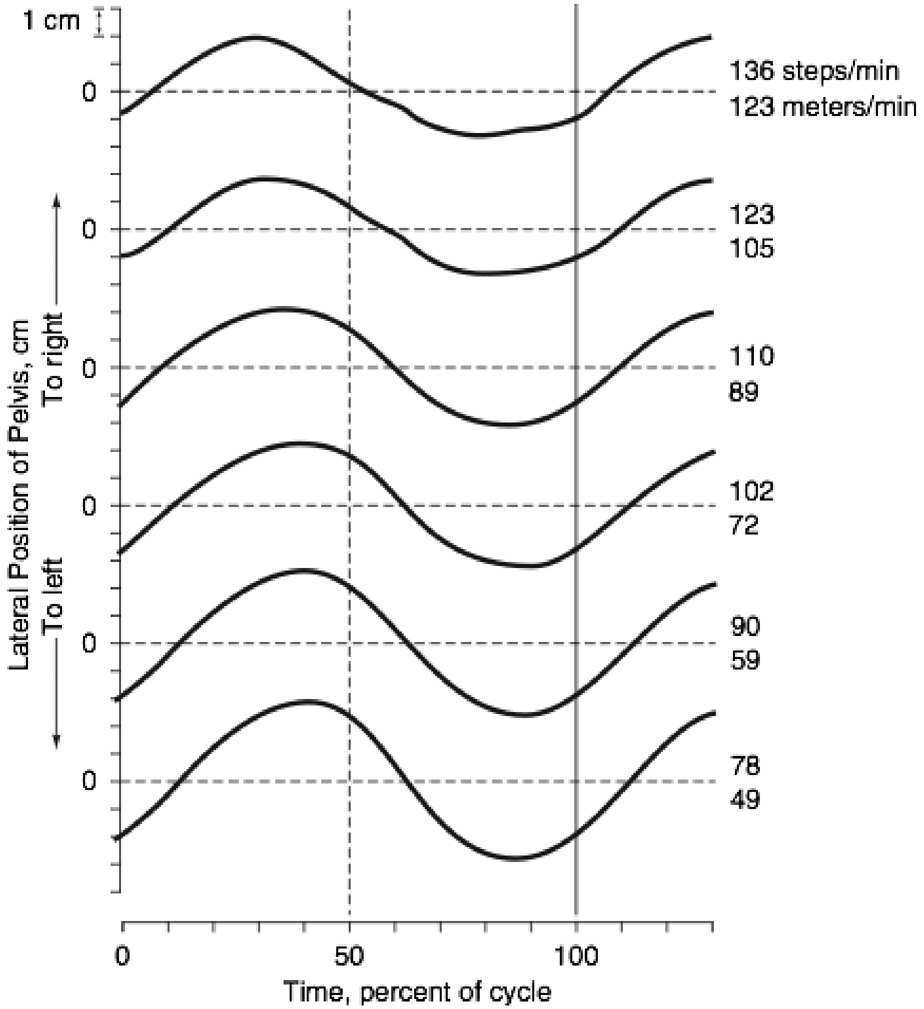
Walk Data

lateral displacement of pelvis



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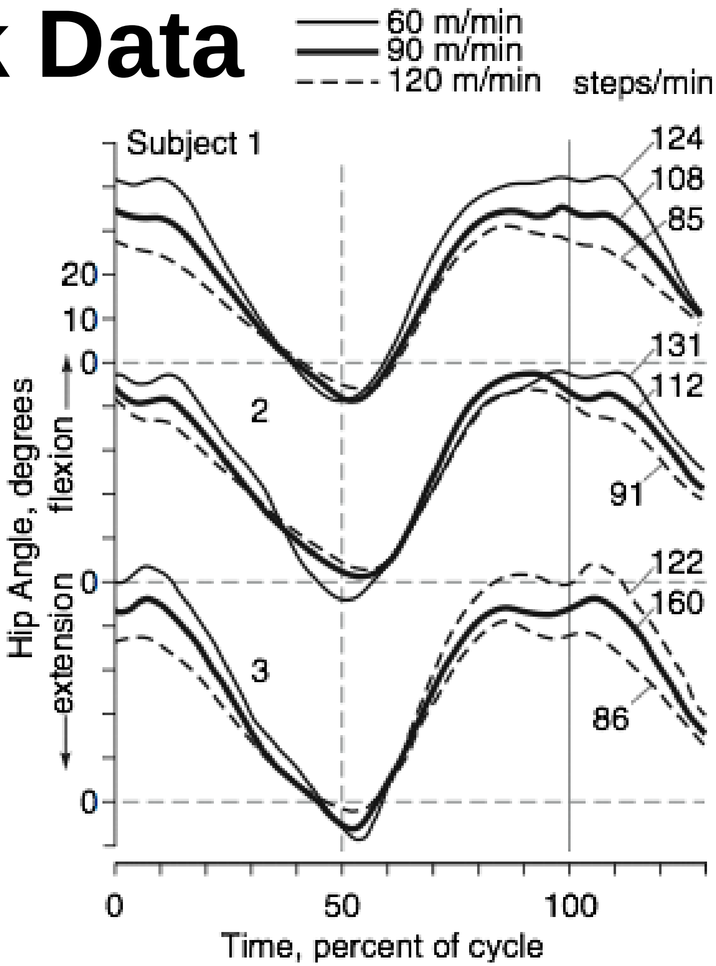
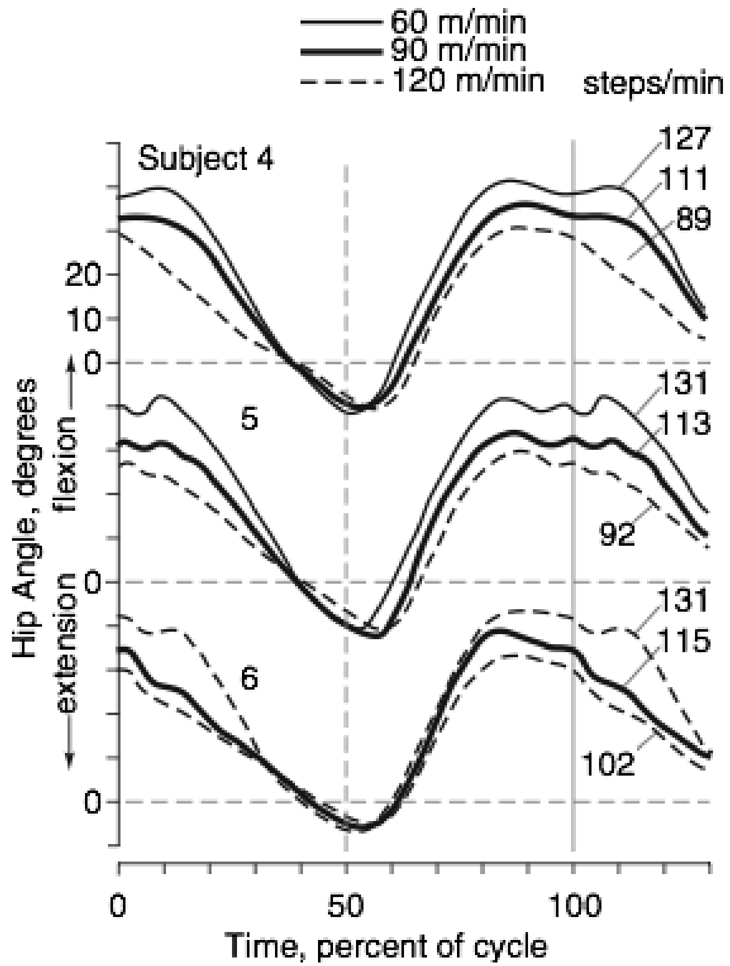
Walk Data

hip angles





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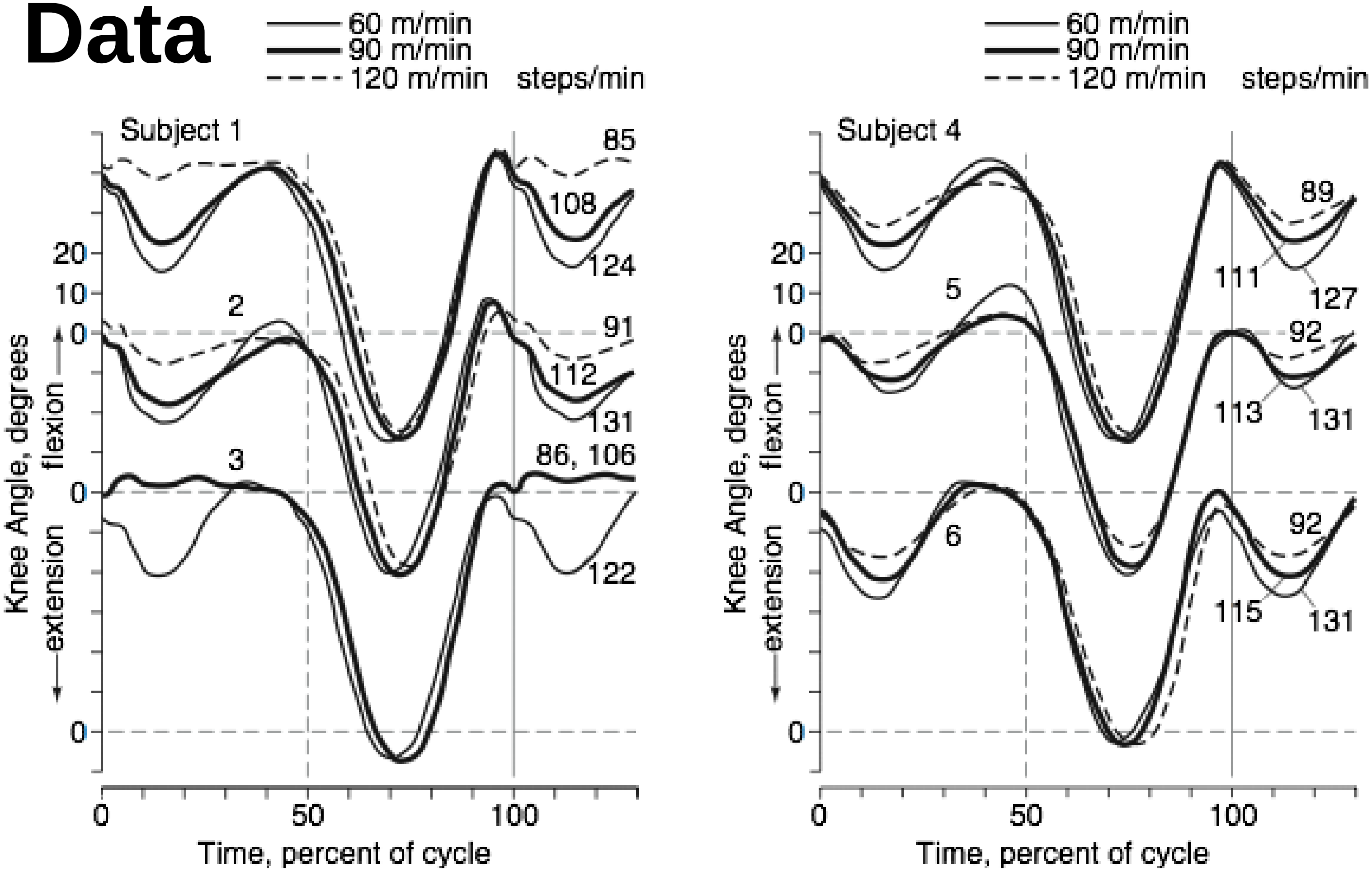
Walk Data

knee angles



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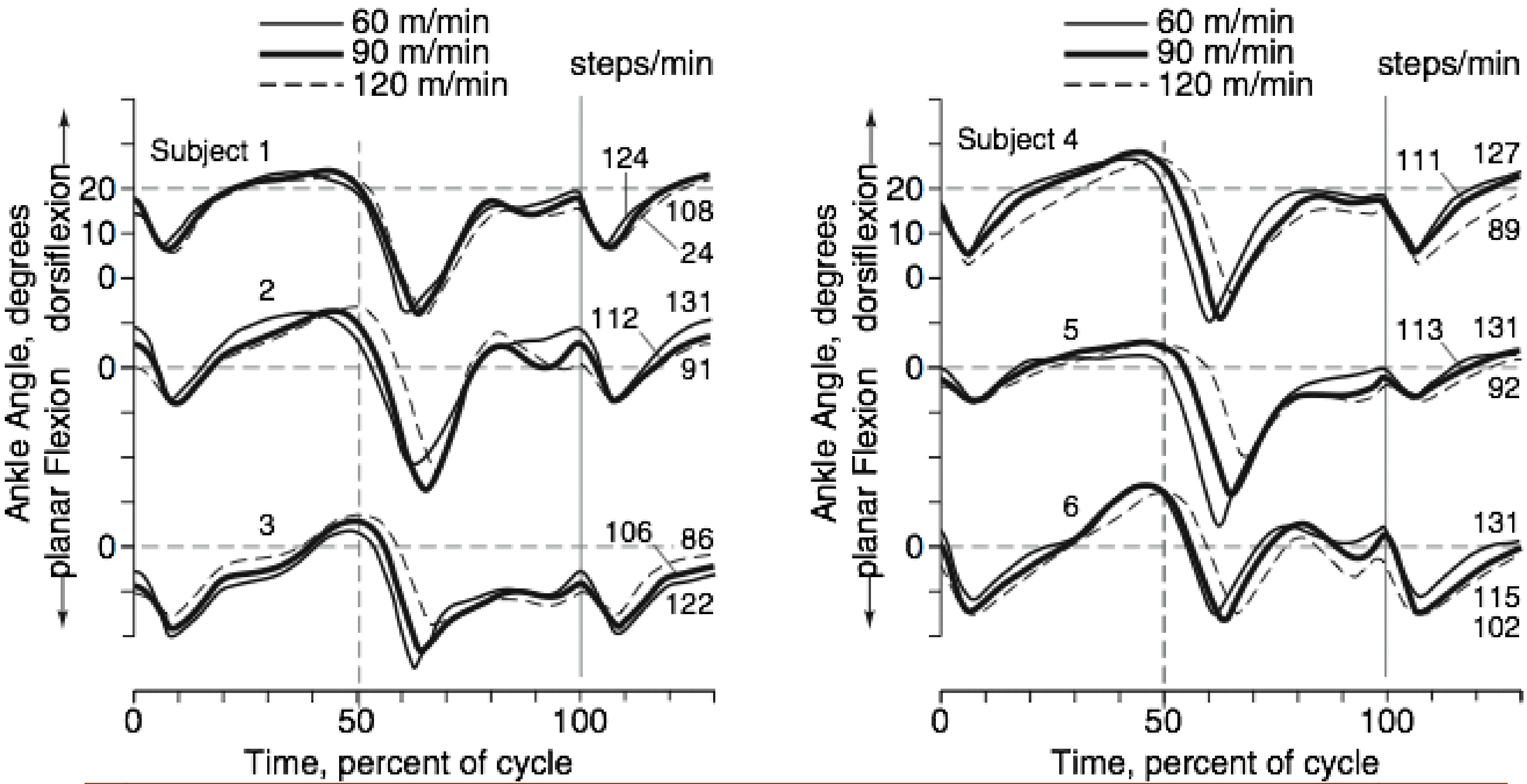
Walk Data ankle angles



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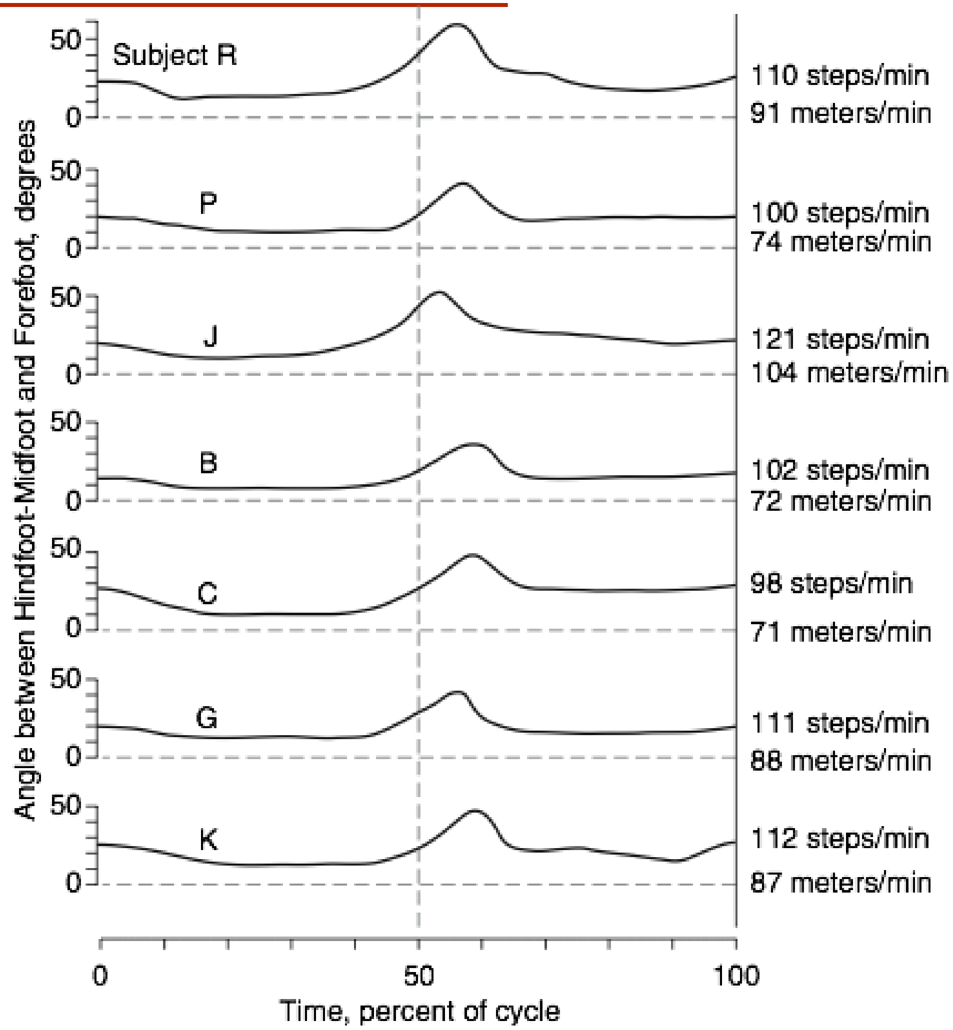
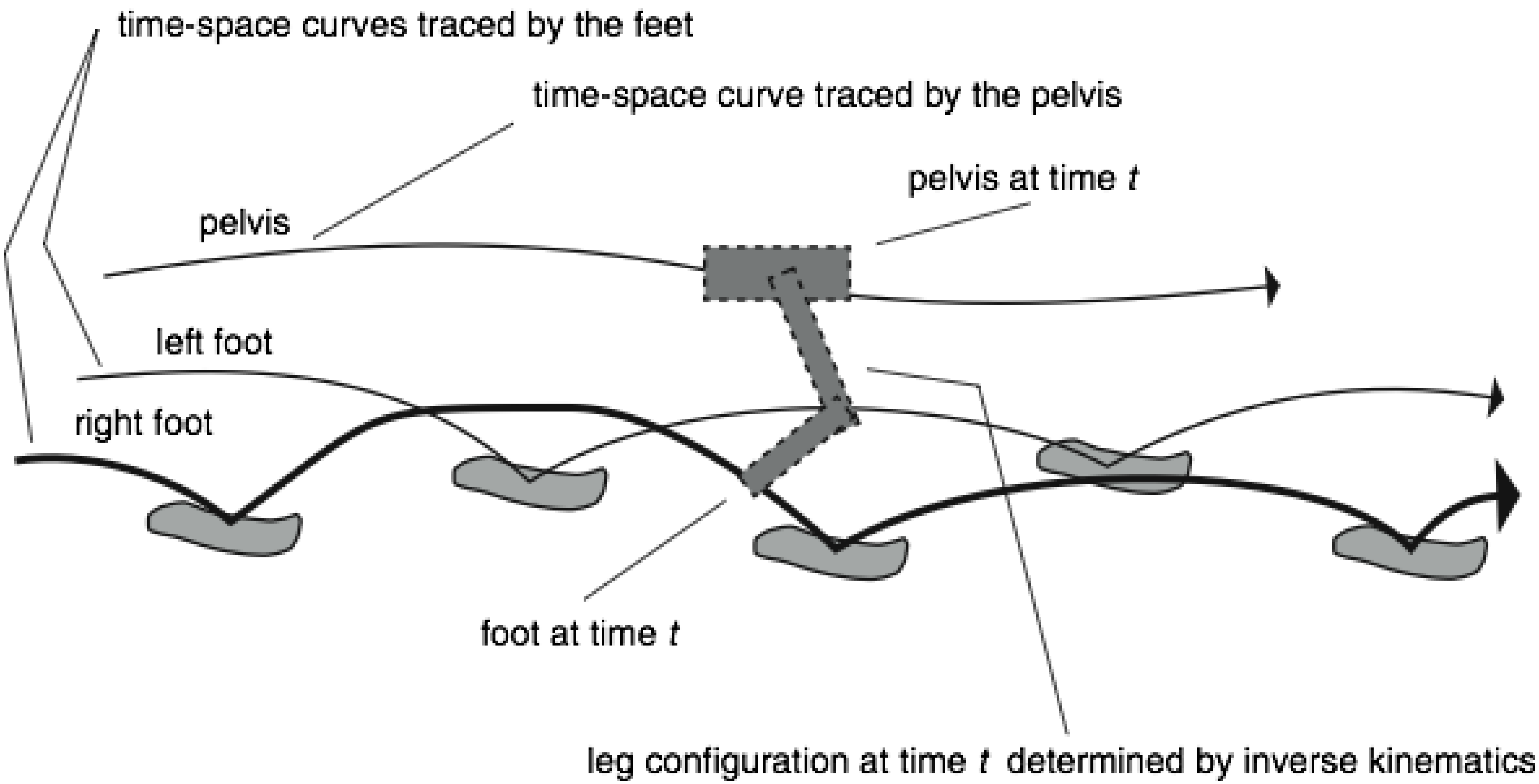
Walk Data

toe angles



Chapter 7

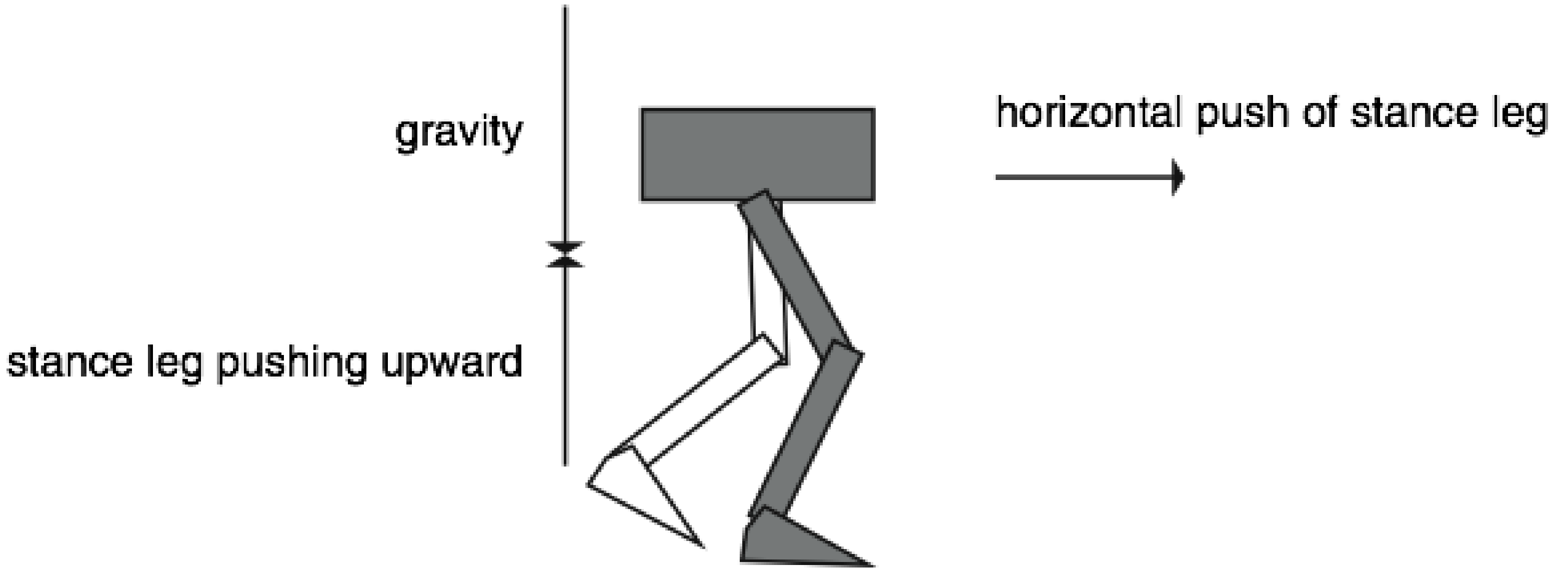
Using Dynamics in the Walk



Chapter 7

Using Dynamics in the Walk

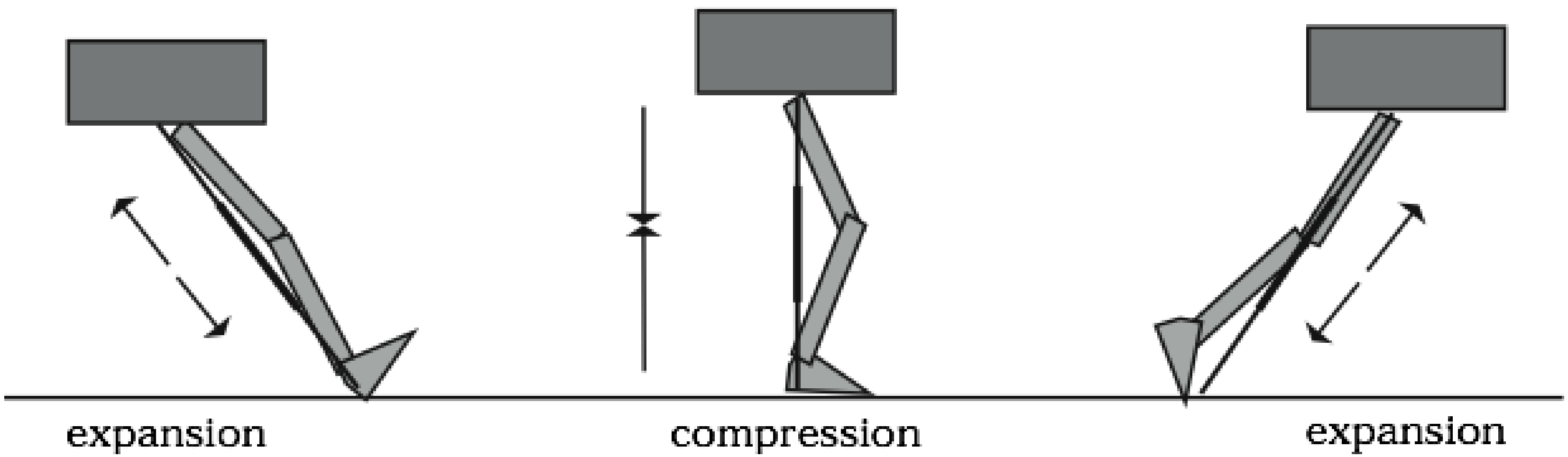
In achieving the proper motion of the upper body, the legs are used to impart forces to the mass of the upper body as carried by the pelvis.



Chapter 7

Using Dynamics in the Walk

More physics can be introduced into the lower body by modeling the leg dynamics with a telescoping joint (implemented as a parallel spring-damper system):



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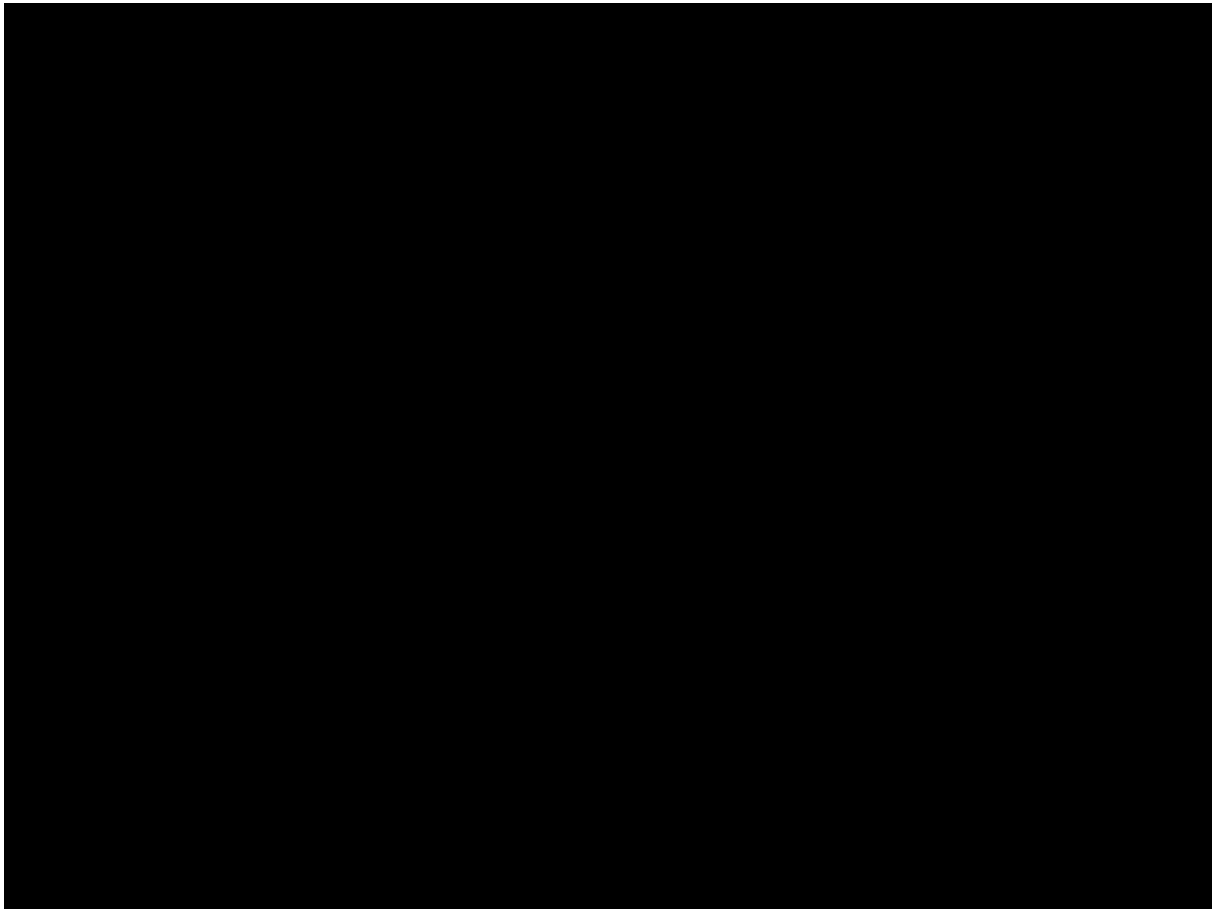
Human Walk Cycle (link)



Chapter 7

Dressing the Figure

Cloth and clothing
Simple draping
Clothes
Modeling dynamics
Collision detection and response

Chapter 7

Dressing the figure – Simple Draping

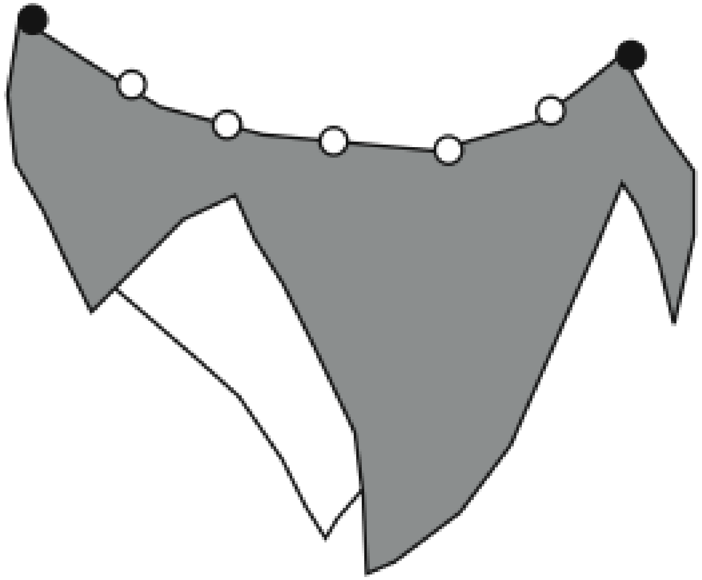
In the special case of a cloth supported at a fixed number of constrained points, the cloth will drape along well-defined lines. The cloth is represented as a two-dimensional grid of points located in three-space with certain of the grid points constrained to a fixed position.

The procedure takes place in two stages. In the first stage, an approximation is made to the draped surface within the convex hull of the constrained points. The second stage is a relaxation process that continues until the maximum displacement during a given pass falls below a user-defined tolerance

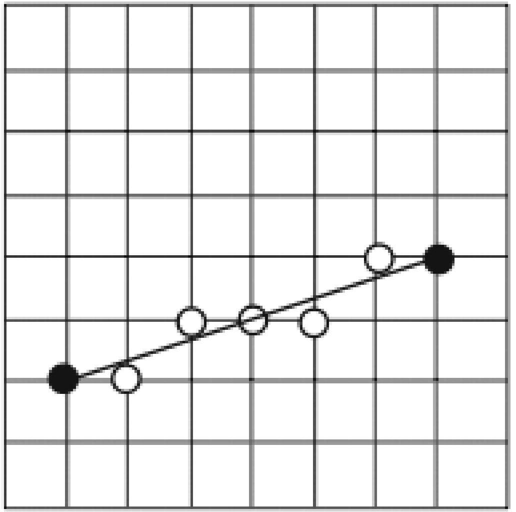
Chapter 7

Dressing the Figure

Catenary curves traced between paired constrained points are generated using vertices of the cloth that lie along the line between constrained vertices.



Cloth supported at two constrained points



Constrained points in grid space

Chapter 7

Dressing the Figure

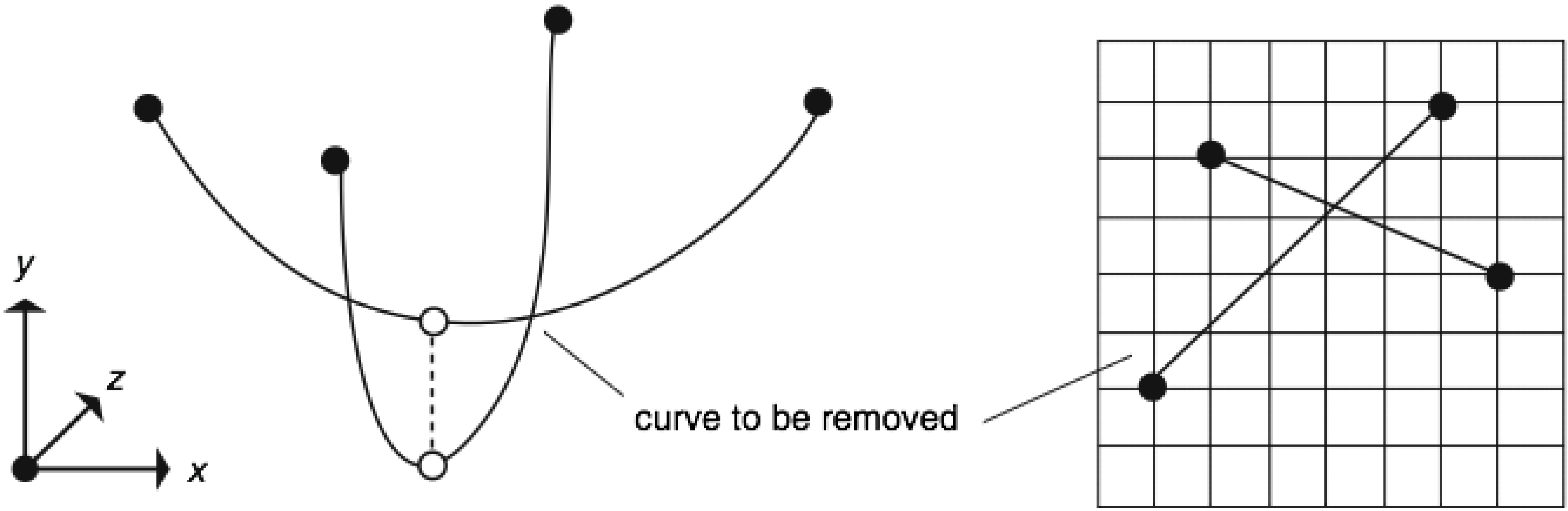
Catenary curves:

The curve theoretically assumed by a perfectly flexible and inextensible cord of uniform density and cross section hanging freely from two fixed points.

Chapter 7

Dressing the Figure

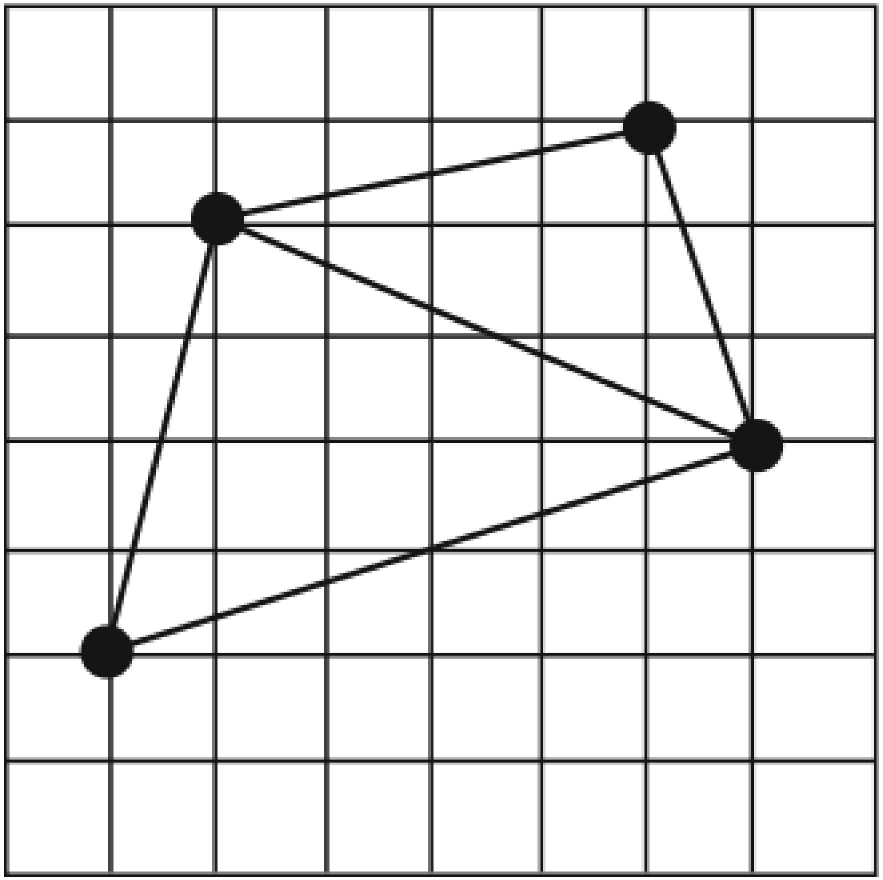
If two catenary curves cross each other in grid space, then the lower of the two curves is simply removed. The reason for this is that the catenary curves essentially support the vertices along the curve.



Chapter 7

Dressing the Figure

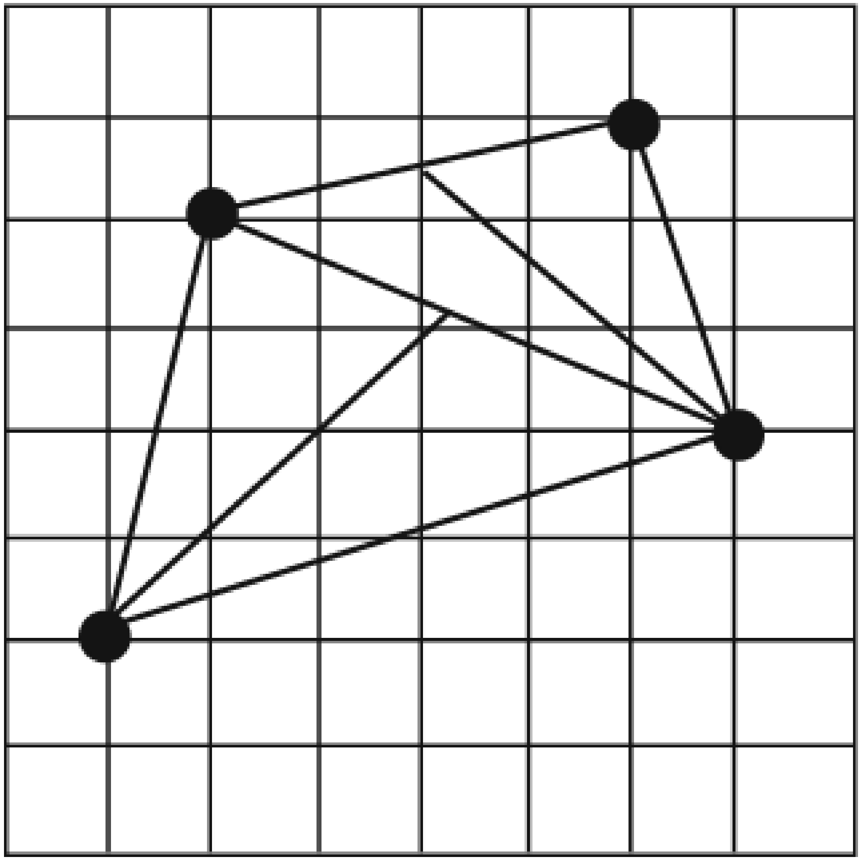
A catenary curve is traced between each pair of constrained vertices, After the lower of two crossing catenary curves is removed, a triangulation is produced.



Chapter 7

Dressing the Figure

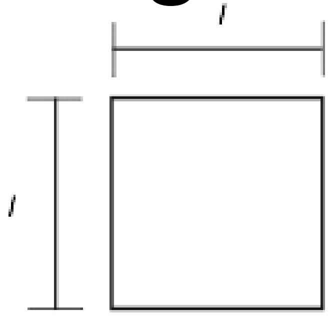
Each of these triangles is repeatedly subdivided by constructing a catenary from one of the vertices to the midpoint of the opposite edge on the triangles. This is done for all three vertices of the triangle. The highest of the three catenaries so formed is kept and the others are discarded. This continues until all interior vertices have been positioned.



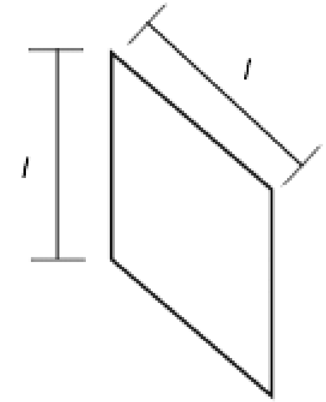
Chapter 7

Dressing the Figure

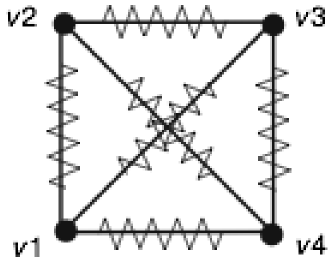
The dynamics of the cloth can then be modeled using a spring-damper system. Diagonal springs can be used to control distortions.



(a) Original quadrilateral of mesh



(b) Skew of original quadrilateral without changing the length of edges

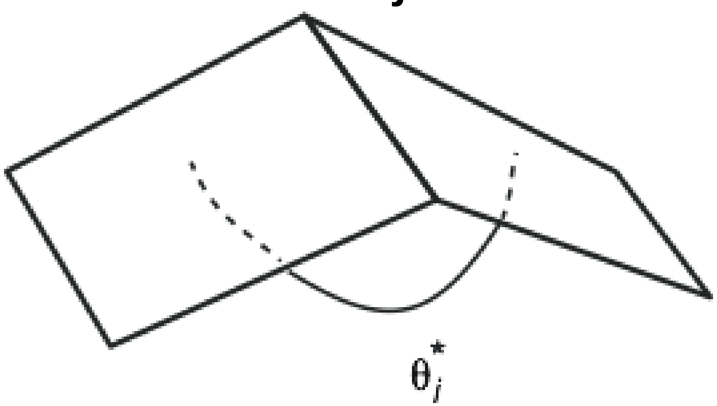


(c) Diagonal springs to control skew

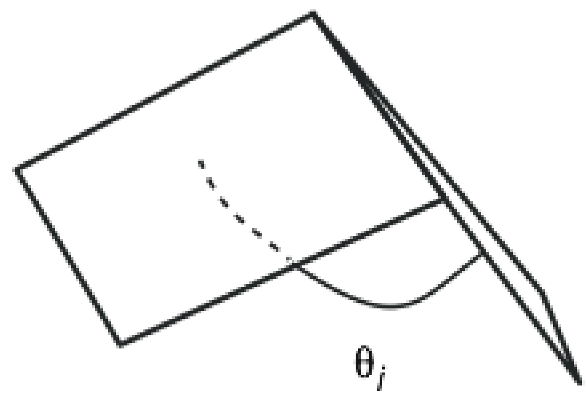
Chapter 7

Dressing the Figure

Bending can be controlled by either restricting the dihedral angles (the angle between adjacent quadrilaterals) or controlling the separation among a number of adjacent vertices:



Original dihedral angle

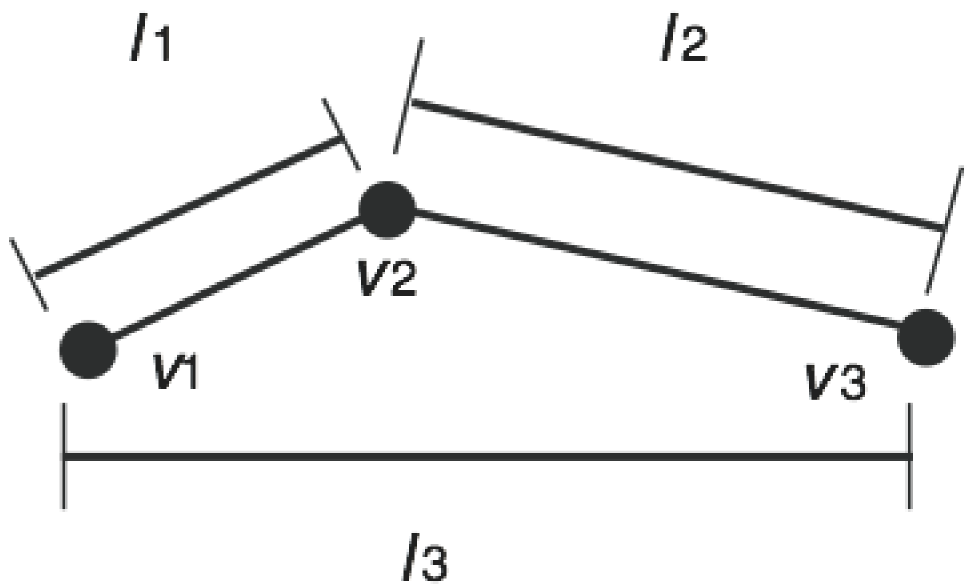


Bending along the edge that changes dihedral angle

Chapter 7

Dressing the Figure

Bending can also be controlled by considering the separation of adjacent vertices in the direction of the warp and weft of the material:



$$l_1 = |v_2 - v_2|$$

$$l_2 = |v_3 - v_2|$$

$$l_3 = |v_3 - v_1|$$

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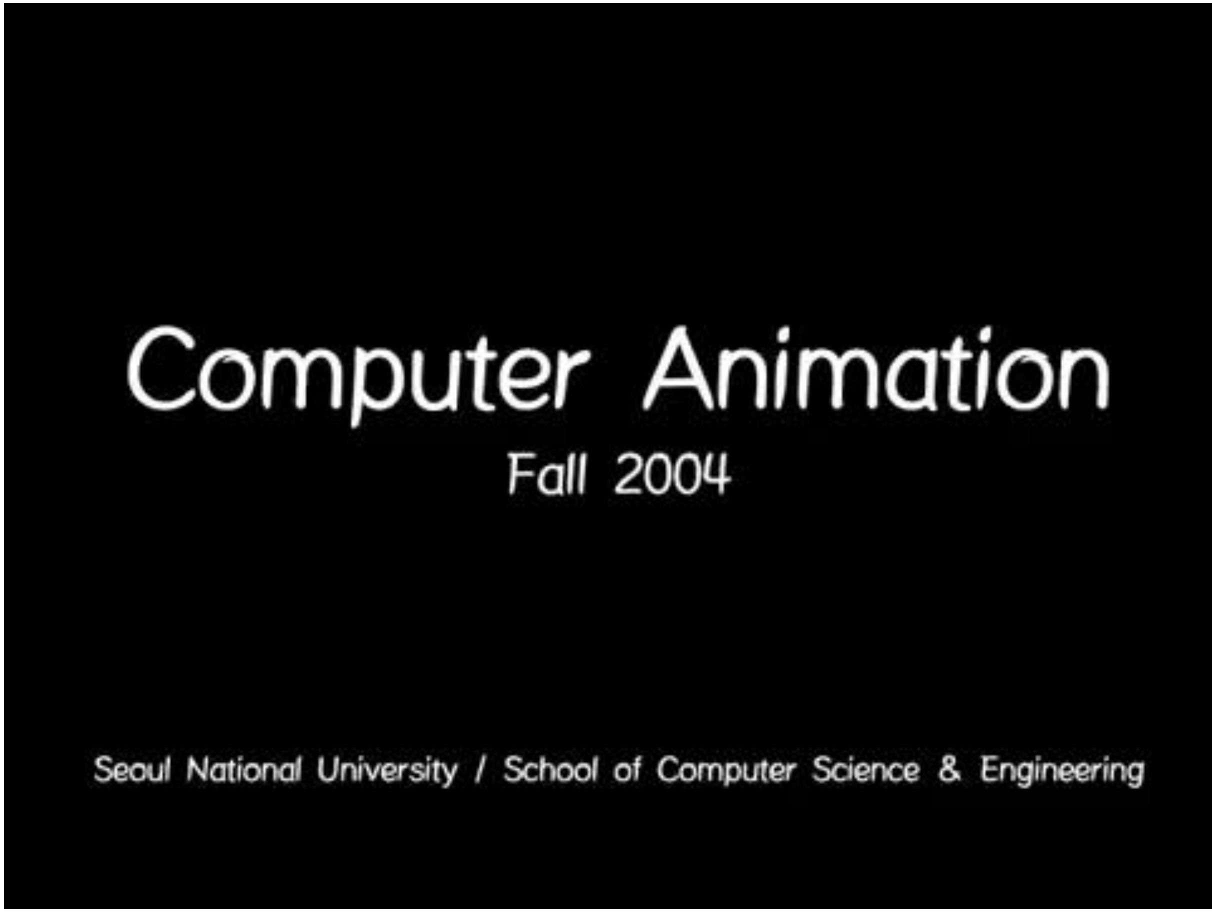
Dressing the Figure - Sample



Chapter 7

Hair

Complexity
rigid
springs
articulated linkages

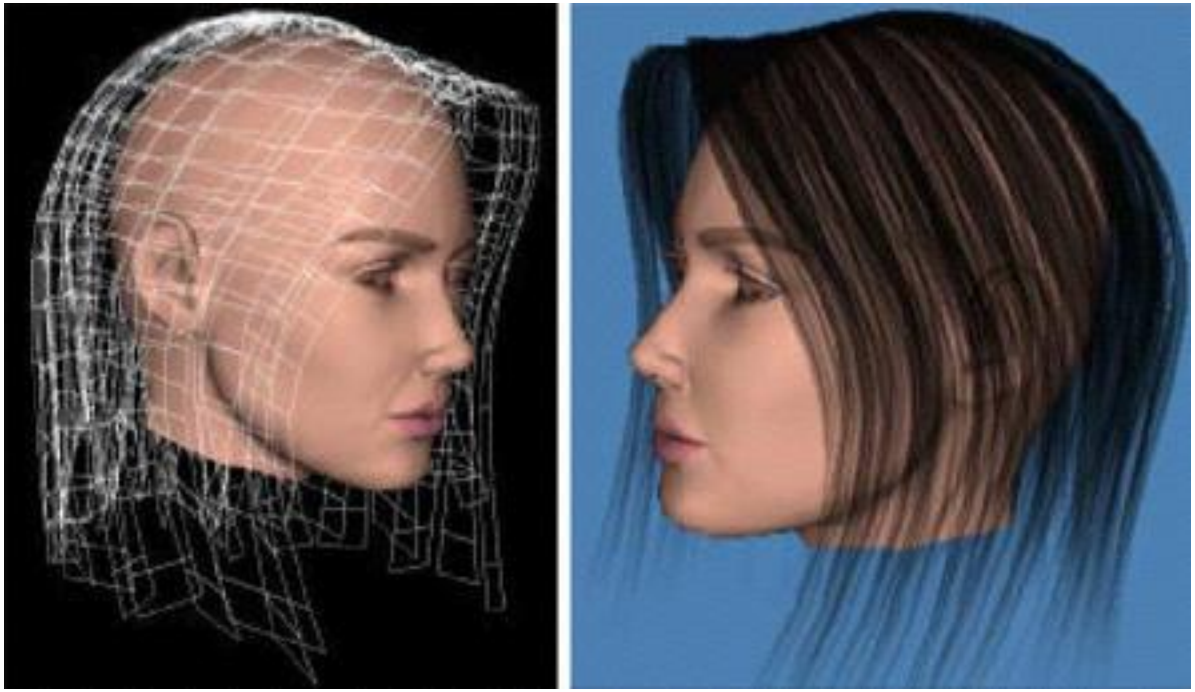
Chapter 7

Hair

Hair modeled as rigid geometry

Chapter 7

Hair



Hair modeled as strips of strands

Chapter 7

Hair

Hair modeled using multiple levels of detail

Chapter 7

Hair

Example: the movie *monsters*