AUTOMATIC MOTION CONTROL

- **in future animation systems based on synthetic actors, motion control will be performed automatically using artificial intelligence and robotics techniques**
    - **motion will be planned at a task level and computed using physical laws**
- **five steps to automatic motion control**
    - **positional constraints and inverse kinematics**
    - **motion control using dynamics**
    - **impact of the environment**
    - **task planning**
    - **behavioral animation**

Positional Constraints and Inverse Kinematics

- an inverse kinematics problem
  - What are the angle values for the shoulder, elbow and wrist if the hand needs to reach a certain position and orientation in space?
- in an animation system based on inverse kinematics
  - the animator specifies discrete positions and motions for end parts
  - the system computes joint angles and orientations for other parts of the body to produce the desired positions and motions
    - constraints can be imposed on various parts of the body
    - precedence is specified for constraints which cannot be satisfied simultaneously
    - typically, a human model is kinematically redundant, leading to infinitely many solutions
      - some solutions minimize variations in angles
      - collision avoidance reduces the number of solutions
  - complexity increases as the number of linkeages increases
  - no closed form solution in general

Motion Control Using Dynamics

- more complex, but more realistic than positional constraints and inverse kinematics

- motion of a synthetic actor is governed by forces and torques applied to limbs

- two problems

    - direct dynamics

        - finding the trajectories of some point as the end effector with regard to the forces and torques that cause the motion

    - inverse dynamics

        - determining the forces and torques required to produce a prescribed motion

- the time sequence of joint torques required to achieve the desired time sequence of positions, velocities and accelerations can be computed

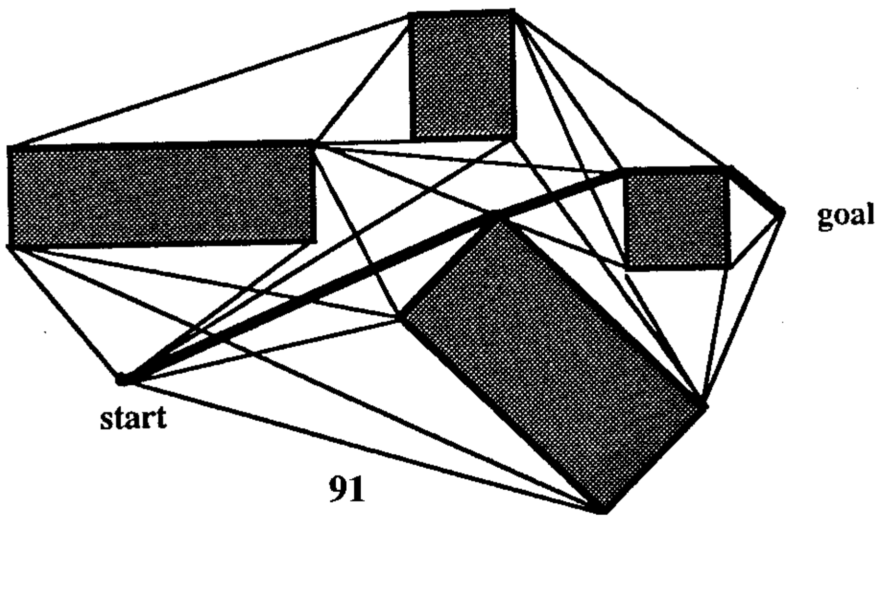
    - equations of motion for articulated bodies are derived using Lagrange's equation for motion for nonconservative systems

Motion Control Using Dynamics, cont.

- factors which motivate dynamics for motion control
  - dynamics free the animator from having to describe motion using the physical properties of solid objects
  - natural phenomena can be rendered more realistically
  - bodies can react automatically to external and internal constraints
    - fields
    - collisions
    - forces
    - torques
- factors which discourage dynamics for articulated bodies
  - animators do not think in terms of forces and torques
  - the solution of motion equations is computationally intense
  - even though dynamics-based motions are realistic, they are too regular

Adaptive Motion Control

- the actor has an impact on the environment and vice versa
  - precludes rotoscopy and key framing
- reduces the amount of information which the animator must enter
- requires trajectory planning and obstacle avoidance
- trajectory planning
  - studied extensively in artifical intelligence and robotics
  - animation also considers aesthetic criteria
- obstacle avoidance
  - avoidance of static objects (decor) or objects grasped by actors
  - avoidance of dynamic objects
  - visibility graphs show vertices which can "see" each other
    - a collision-free path is the shortest path from the start to the goal in the visibility graph
    - unfortunately, a moving object is represented as a point



- collisions
  - several methods exist for calculating forces between colliding rigid bodies
    - simultaneous collisions can be modeled as a slightly staggered series of single collisions
    - bodies in resting contact are prevented from interpenetrating by modeling their contacts as a series of frequently occurring collisions
- finite elements and local deformations
  - physical objects should react to forces such as gravity, pressure and contact
    - collisions between elastic objects are simulated by creating potential energy around each object (i.e. a repulsive collision force)
  - intrinsic properties can be exploited using the finite element method
    - (the decomposition approach) an object can be decomposed into several deformable subobjects which can interact with each other for modeling penetrating shocks between two or more deformable objects
    - (the composition approach) objects can be considered as independently evolving subobjects until a contact is detected for modeling contacts without penetration between two or more objects
      - a global object is composed after contact

Task Planning

- a major problem in robotics and artificial intelligence
- given a task description, the task must be decomposed into a sequence of elementary movements
- needed information
  - a description of the scene (topology, positions, and orientations of the objects)
  - rules (e.g. stand up before walking)
  - actor behavior (which modifies the ways of doing movements)
  - actor skills (a library of elementary movements)
- example: "answer the phone"
  - stand up
  - find a trajectory which avoids obstacles
  - walk along the trajectory
  - determine a trajectory for grasping the phone
  - grasp the phone
  - answer

Task Planning, cont.

- task specification
  - by example
  - by a sequence of model states
  - by a sequence of commands
    - most suitable and popular

Behavioral Animation

. behaviors of characters must be designed

. distributed behaviors model flocks, herds and schools

. a flock

  - an elaboration of a particle system

  - the result of interactions between individual birds

  - birds must stick together, but must also avoid collisions with other birds and with obstacles in the environment