CPSC 426: Computer Animation
Practice Questions

April 14, 2014

Answer the questions in the spaces provided on the question sheets. If you run out of room for an answer, continue on the back of the page.

Name: Solutions

Student Number: ____________________

Question 1	/ 4
Question 2	/ 4
Question 3	/ 4
Question 4	/ 9
Question 5	/ 5
Question 6	/ 6
Question 7	/ 3
Question 8	/ 4
TOTAL	/ 39

There are 8 questions, for a total of 39 points.

1. (4 points) Equations of Motion

   Given the equations for linear momentum, $\overrightarrow{P} = m\overrightarrow{V}$, and angular momentum, $\overrightarrow{L} = I\overrightarrow{\omega}$, derive the Newton-Euler equations of motion and circle the unknowns that are solved for during forward dynamics simulation.

Newton equation:

$$\sum F = \frac{dP}{dt}$$

$$\sum F = \frac{d}{dt}(m\vec{V})$$

$$= \underbrace{\frac{dm}{dt}}_{0}\vec{V} + m\frac{d\vec{V}}{dt}$$

$$\sum F = m\dot{\vec{V}}$$ or, equivalently, $\sum F = m\vec{a}$

$\sum F = m\ddot{x}$

Euler equation

$$\sum \tau = \frac{dL}{dt}$$

$$\sum \tau = \frac{d}{dt}(I\vec{\omega})$$

$$= \frac{dI}{dt}\vec{\omega} + I\frac{d\omega}{dt}$$

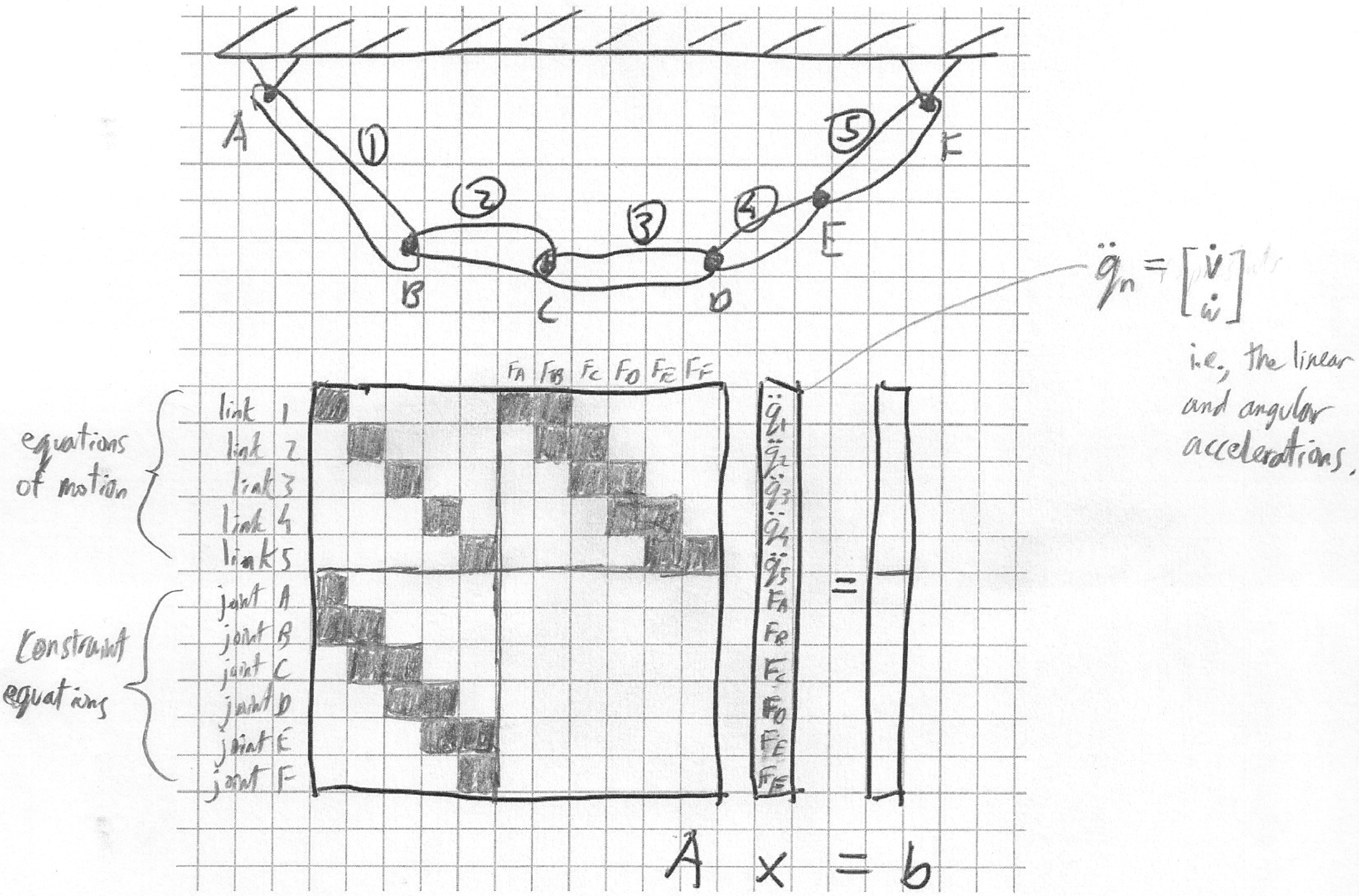
$$\sum \tau = \vec{\omega} \times I\vec{\omega} + I\dot{\vec{\omega}}$$

unknowns : $\dot{\vec{V}}$: linear acceleration

$\dot{\omega}$: angular acceleration

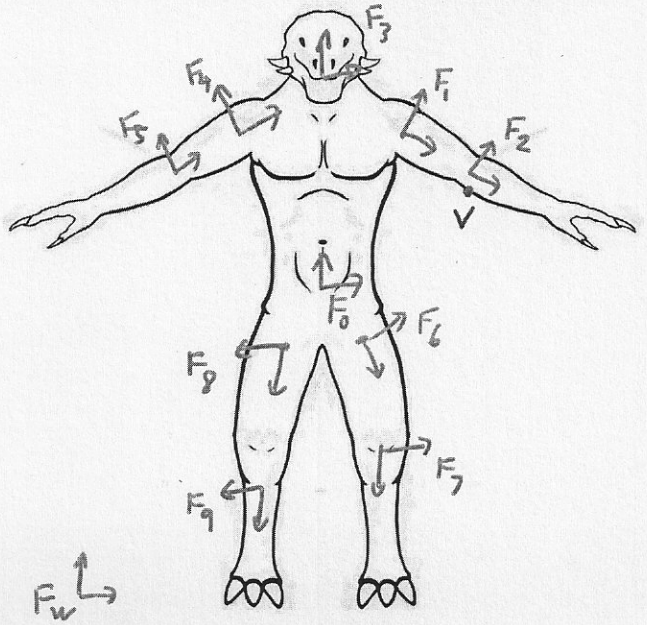
2. (4 points) Articulated Figure Dynamics

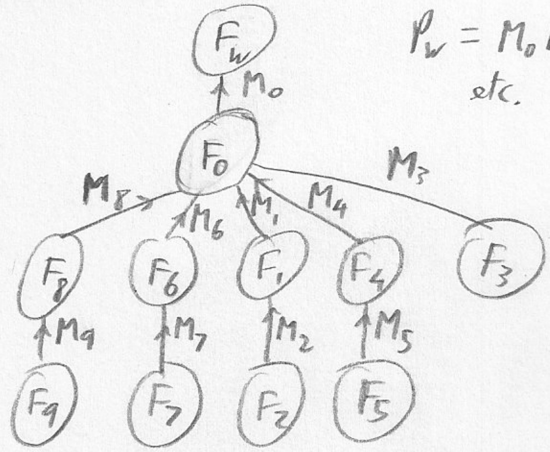
   Provide the block structure for the equations of motion, $Ax = b$, for the following articulated figure by: (a) providing a list of the unknowns in the x column, and (b) shading the blocks within the A matrix that would have non-zero entries.



3. Skinning

(a) (1 point) Sketch the scene hierarchy for the character shown below. On this diagram, also label the relative transformation matrices M_n, where, M_n takes a point from coordinate frame n to its parent's coordinate frame.





$P_w = M_0 P_0$

etc.

(b) (1 point) Give expressions for:

$M_{2\to W} =$ $M_0 M_1 M_2$ i.e., $P_w = \overbrace{M_0 M_1 M_2}^{M_{2\to w}} P_2$

$M_{3\to 2} =$ $M_2^{-1} M_1^{-1} M_3$ i.e., $P_2 = \underbrace{M_2^{-1} M_1^{-1} M_3}_{M_{3\to 2}} P_3$

(c) (1 point) A vertex V has the following skinning weights: $w_1 = 0.2, w_2 = 0.8$. Let $M_{1\to W}$ and $M_{2\to W}$ define the transformation matrices for the skeleton in the bind-pose, i.e, the above T-pose. Let $M'_{1\to W}$ and $M'_{2\to W}$ define the transformation matrices for a current desired pose. Give an expression for the new vertex coordinates, V'_W for a vertex that has coordinates given by V_W in the original bind pose.

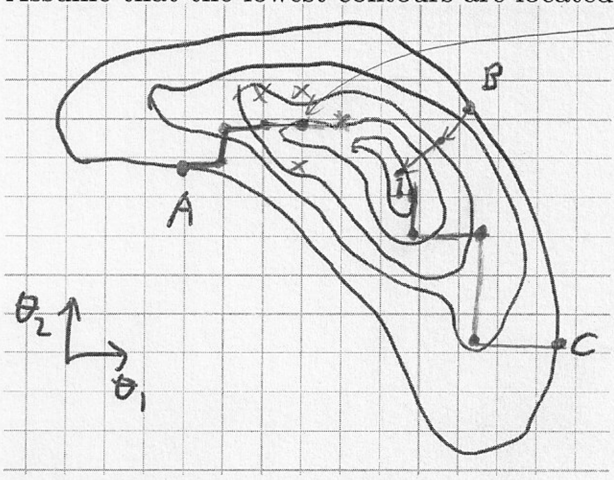
$$V_w' = w_1 M'_{1\to w} \underbrace{M_{1\to w}^{-1} V_w}_{= V_1 \text{ i.e, vertex } V \text{ in frame } F_1} + w_2 M'_{2\to w} \underbrace{M_{2\to w}^{-1} V_w}_{= V_2 \text{ i.e., vertex } V \text{ in frame } F_2}$$

(d) (1 point) Linear blend skinning will cause "pinching" artifacts at joints when they bend. How can this be fixed within a linear blend skinning framework?

Extra "virtual bones" can be added, which rotate at half the angle of the full joint angles. Mesh vertices can then be assigned blend weights such that these "virtual links" contribute to their deformation.

4. Inverse Kinematics

Consider the minimization problem depicted using the "contour map" shown below. Assume that the lowest contours are located in the middle.



search could terminate here, as all the fixed-step function values are equal or greater than the current value.

cyclic coordinate descent finds the minimum at each search step, using a simple analytic solution for the rotation that moves the end effector closest to the desired target.

(a) (1 point) Sketch the path that coordinate descent with a fixed step size would follow from point A, beginning with the θ_1 direction.

(b) (1 point) Sketch the path that gradient descent with a fixed step size would follow from point B.

(c) (1 point) Sketch the path that cyclic coordinate descent would follow from point C, beginning with the θ_1 direction.

(d) (1 point) Which of the above methods would make use of the Jacobian transpose?

The J^T method effectively implements gradient descent.

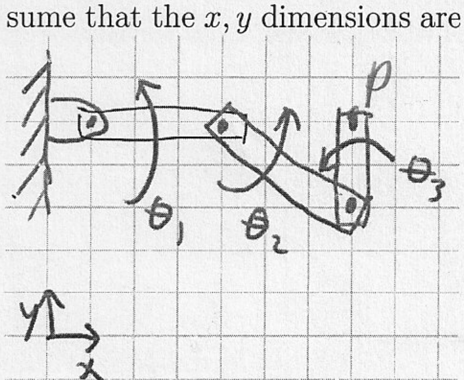
(e) (1 point) T or F: The pseudoinverse method takes steps that minimize the movement in joint space.

(f) (1 point) T or F: Inverse kinematics problems are generally overconstrained.

IK problems are usually underconstrained.

(g) (1 point) T or F: Iterative IK methods converge to the same solution regardless of the intial starting state. The solution depends on the starting state.

(h) (2 points) Give the Jacobian matrix for the arm configuration shown below. Assume that the x, y dimensions are measured in units where 1 grid cell equals 1 unit.



$$J = \frac{\partial P}{\partial \theta} = \begin{bmatrix} \frac{\partial x}{\partial \theta_1} & \frac{\partial x}{\partial \theta_2} & \frac{\partial x}{\partial \theta_3} \\ \frac{\partial y}{\partial \theta_1} & \frac{\partial y}{\partial \theta_2} & \frac{\partial y}{\partial \theta_3} \end{bmatrix}$$

$$J = \begin{bmatrix} 0 & 0 & -2 \\ 6 & 3 & 0 \end{bmatrix}$$

for θ_1:

$\Delta P = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \times \begin{bmatrix} 6 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 6 \\ 0 \end{bmatrix}$ or $x = 6\cos\theta_1$ $\frac{\partial x}{\partial \theta_1} = -6\sin\theta_1$

$y = 6\sin\theta_1$ $\frac{\partial y}{\partial \theta_1} = 6\cos\theta_1$

5. Particle systems

(a) (2 points) Give the basic pseudocode for a simple particle system simulation, where all particle move independently and experience a gravitational force as well as a drag force that is porportional to the current velocity. Assume that the particle positions and velocities have already been initialized.

for each particle i

$\vec{F}_i = m_i\vec{g} - k_d\vec{V}_i$ accumulate forces

$\vec{a}_i = \vec{F}_i / m_i$ Solve equations of motion

$\vec{X}_i = \vec{X}_i + \Delta t\, \vec{V}_i$

$\vec{V}_i = \vec{V}_i + \Delta t\, \vec{a}_i$

} Euler integration to update the state.

(b) (1 point) Assume that the state of a dynamical system is given by a vector $X(t)$ and that $dX/dt = f(t, X(t))$. Write an expression for an explicit integration update of the state $X(t)$ after a time step of Δt.

$$X(t+\Delta t) = X(t) + \Delta t\, f(t, X(t))$$

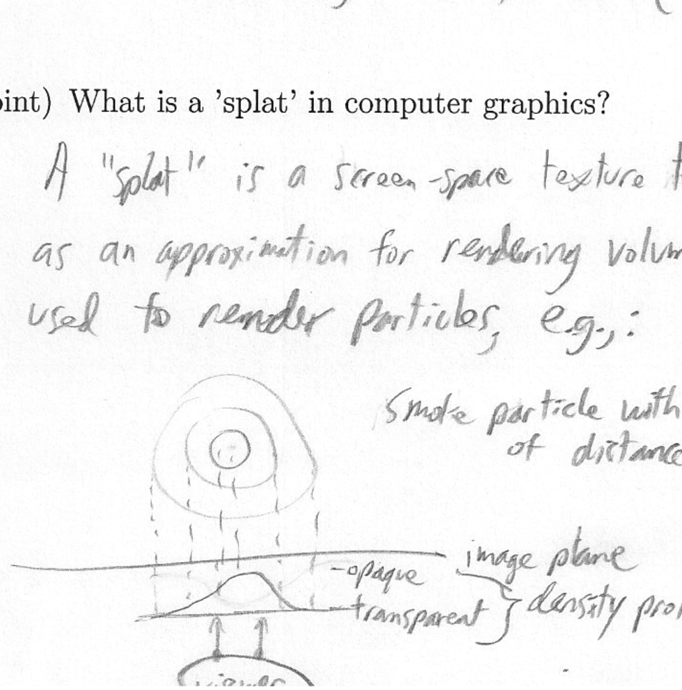
(c) (1 point) Using the same assumptions as above, write an expression or equation to be solved for an implicit integration update of the state $X(t)$ after a time step of Δt.

$$X(t+\Delta t) = X(t) + \Delta t\, f(t+\Delta t, X(t+\Delta t))$$

(d) (1 point) What is a 'splat' in computer graphics?

A "splat" is a screen-space texture that is often used as an approximation for rendering volumes, and is often used to render particles, e.g.,:

Smoke particle with decreasing density as a function of distance from the particle



6. Motion Capture

(a) (3 points) Define the following:

Motion retargeting:

Adapting motion capture data to a character having different dimensions or a new environment.

Footskate:

Adapting the motion of the feet so that they don't exhibit sliding artifacts when in contact with the ground.

Dynamic time warping, as applied to motion capture data:

Finding correspondences over time between two motions, so that they can be meaningfully interpolated or blended.

(b) (3 points) List the primary advantages and disadvantages of:

Passive optical motion capture:

+: - large capture volume
- highly accurate
- only requires lightweight markers

−: - expensive
- requires line-of-sight, i.e., bad for constrained environments
- requires visible markers.

Motion capture using intertial measurement units, i.e., accelerometers + solid-state gyros:

+: - no line-of-sight required
- cheap
- infinite capture volume

−: - not accurate because of drift due to integration errors
- scalability: capturing n people requires n times more IMUs

Mechanical motion capture, i.e., using potentiometers

+: - cheap
- no line-of-sight required
- infinite capture volume

−: - hardware can impair movements
- cannot be applied to facial motions, etc.

7. The Principles of Animation

   (a) (1 point) What is meant by "secondary action"?

   An action that is the resulting response to another (primary) action. e.g., the movement of long hair in response to the motion of the head.

   (b) (1 point) What is meant by "staging"?

   Leading the viewers eye to where the action will occur.

   (c) (1 point) Aside from the above, list four other principles of animation.

   - Squash and stretch
   - anticipation
   - follow through
   - arcs
   - timing and motion
   - overlapping action
   - exaggeration
   - ...

8. Guest lectures

   (a) (1 point) What is "curl noise"?

   This is a stochastic divergence-free vector field, as explained in Robert's guest lecture.

   (b) (1 point) Explain the difference between an animation studio and a visual effects studio.

   An animation studio produces fully digital films, e.g. Pixar, whereas VFX studios typically add digital elements to live action.

   (c) (1 point) What are the key steps in preparing a VFX shot?

   - collect the live action shot
   - track the camera
   - remove wires, etc. - "prepare the plate"
   - animate the CG
   - render
   - composite with original film
   - deliver to client (iteratively)

   (d) (1 point) What is an "animatic"?

   A rough first approximation of an animation - typically a series of still images that are representative of the shots, together with narration.