COMP220: Graphics & Simulation

10: Simulation & Animation

Learning outcomes

By the end of this week, you should be able to:

- **Recall** the key concepts involved in solving mechanics problems
- **Write** programs which feature realistic physics simulations
- **Describe** how a rigged model is transformed to produce animation

Agenda

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- Lecture (async):
  - **Recap** the mathematical concepts of Newtonian physics.
  - **Explain** the role of rigging in 3D animation.
  - **Introduce** the scene graph and techniques for enhancing character animation.

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  - **Recap** the mathematical concepts of Newtonian physics.
  - **Explain** the role of rigging in 3D animation.
  - **Introduce** the scene graph and techniques for enhancing character animation.
- Workshop (sync):
  - **Include** the Bullet Physics library in the OpenGL application.
  - **Explore** physics and animation techniques in code.

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Newtonian Mechanics

Calculus: differentiation

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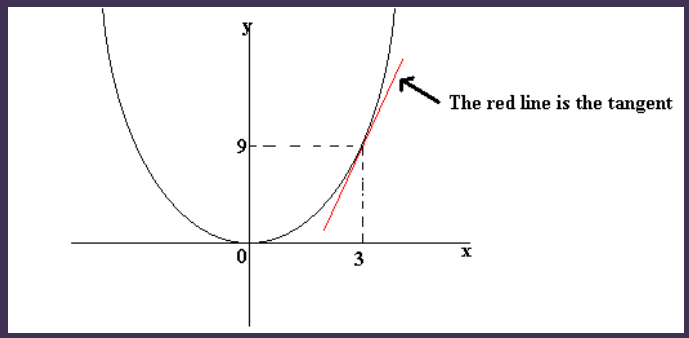

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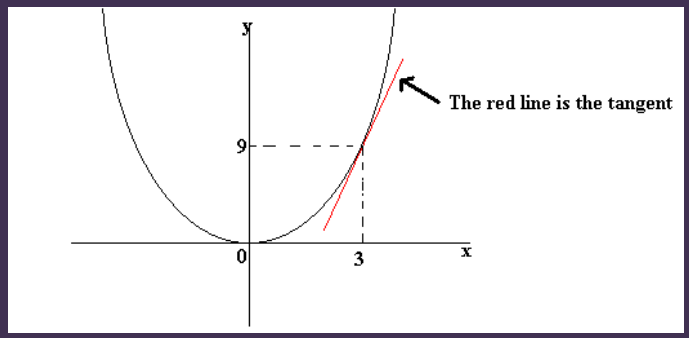

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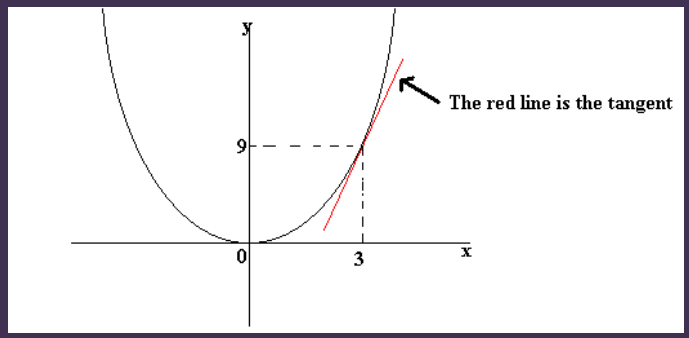

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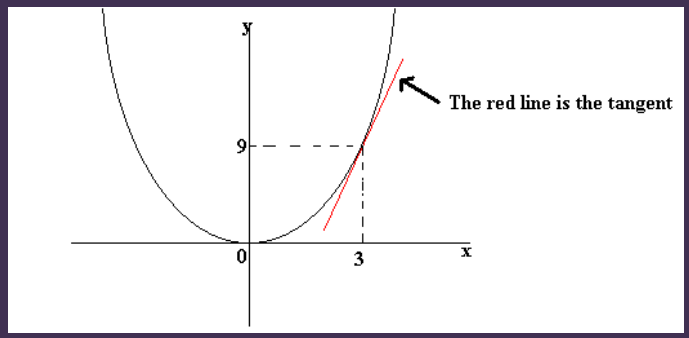

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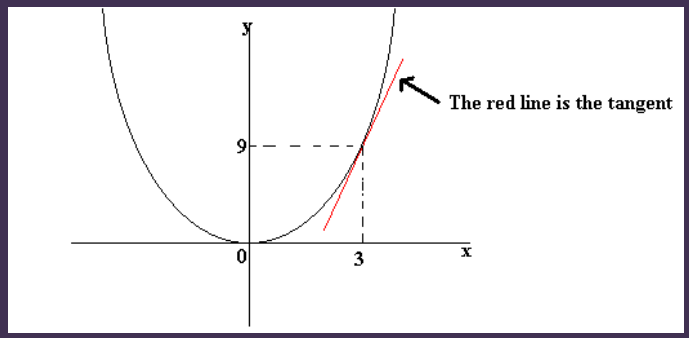

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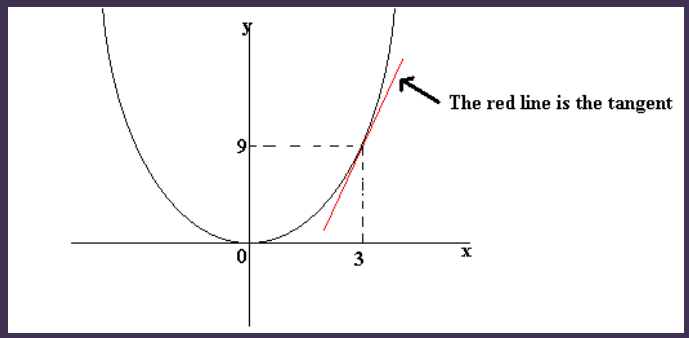

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  - NB **speed** is the **magnitude** of velocity

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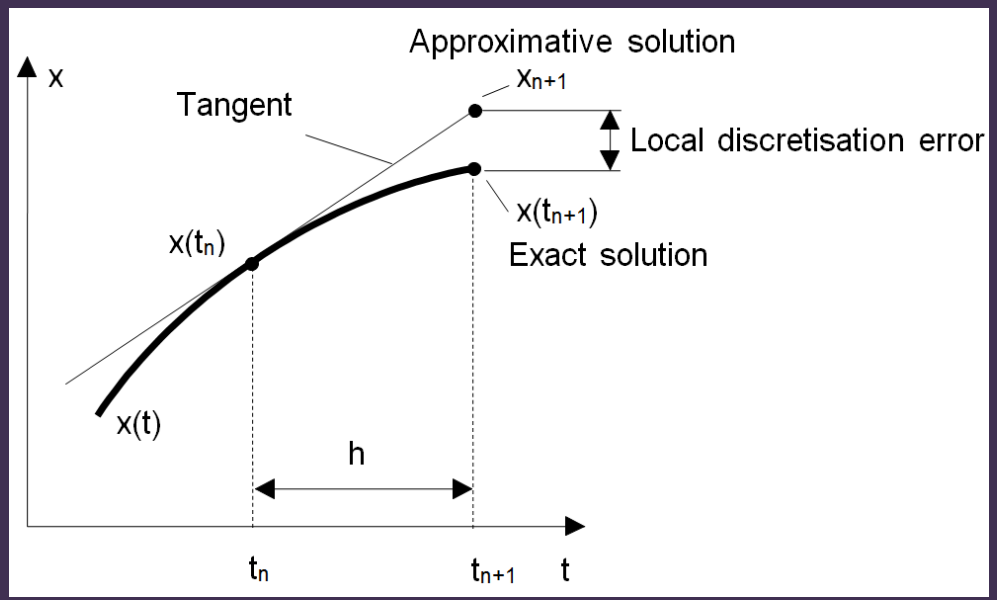

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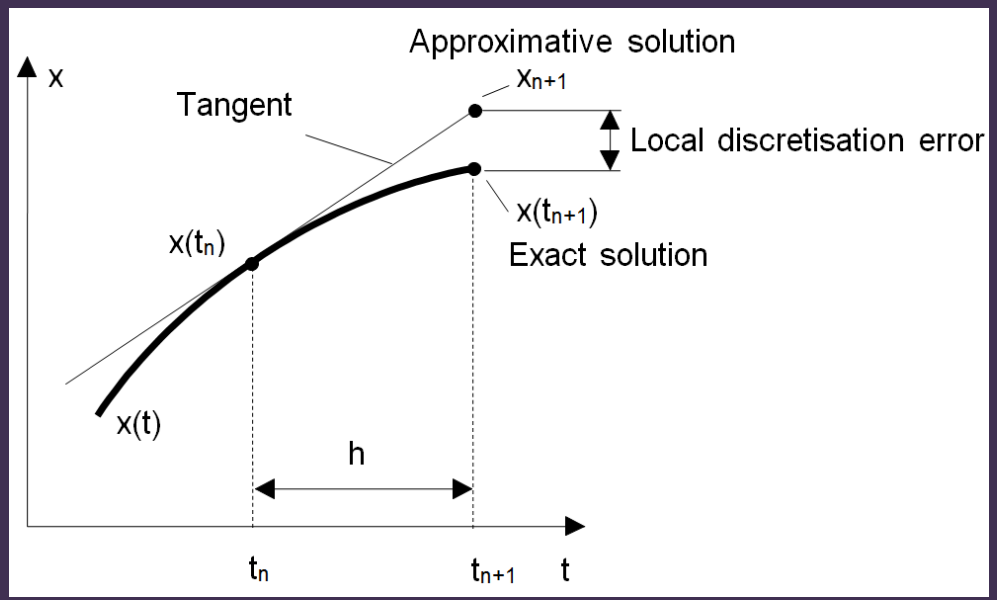

$$x(t+h) \approx x(t)+h\times\frac{dx}{dt}(t)$$

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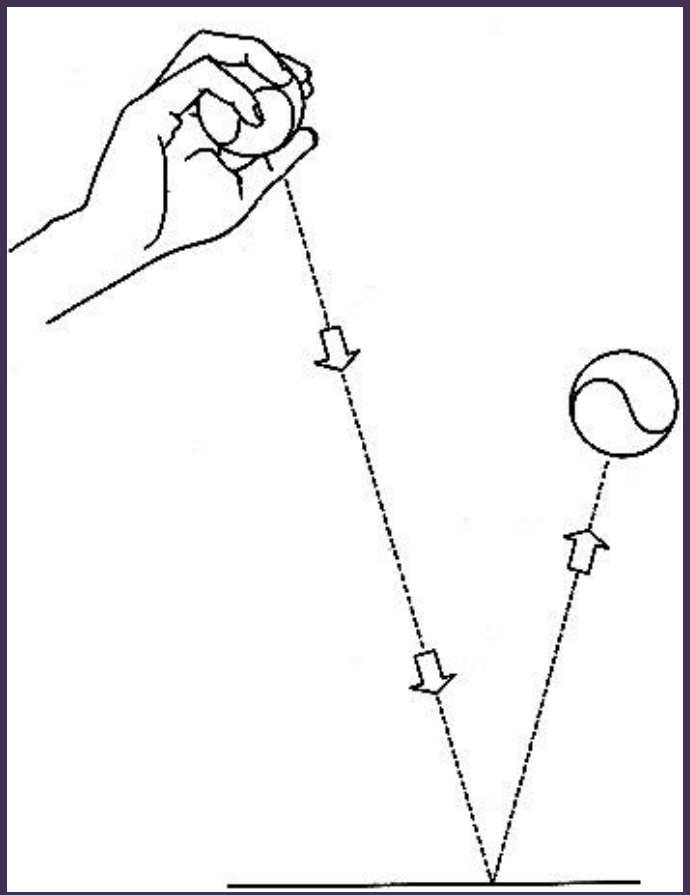
When one body exerts a force on another, the second body exerts an equal and opposite force on the first

Basic collision response



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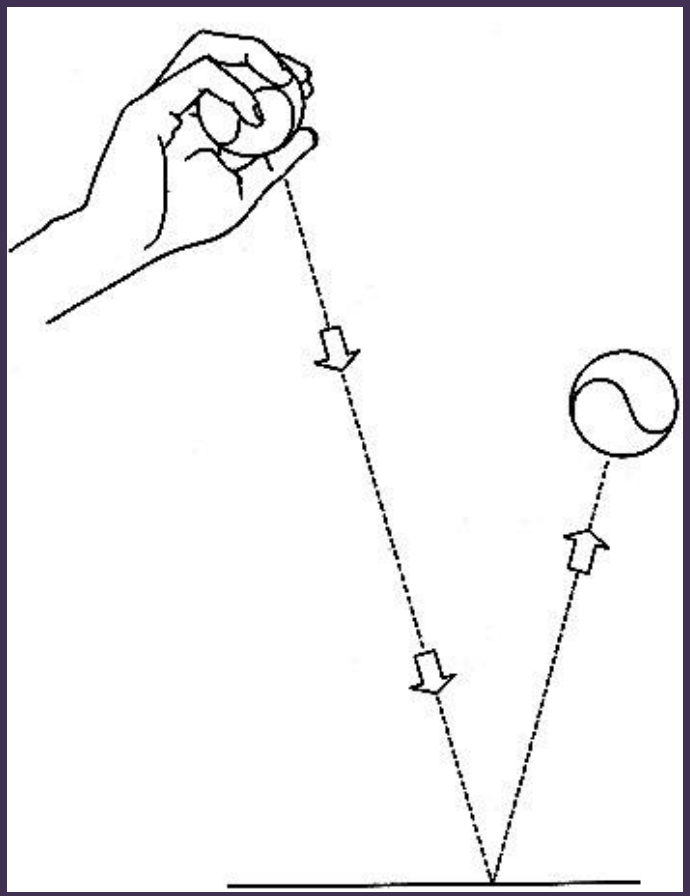

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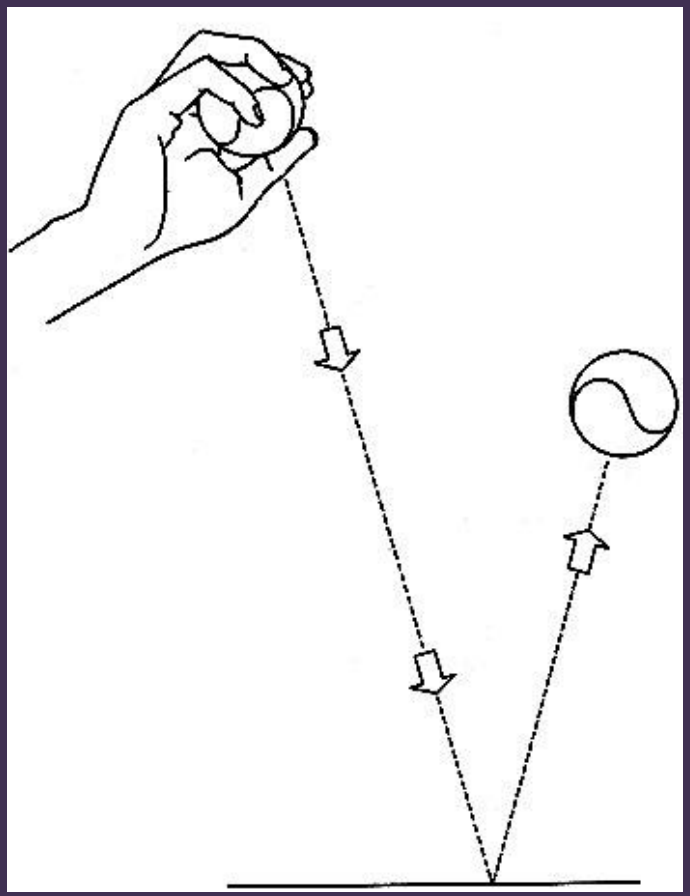

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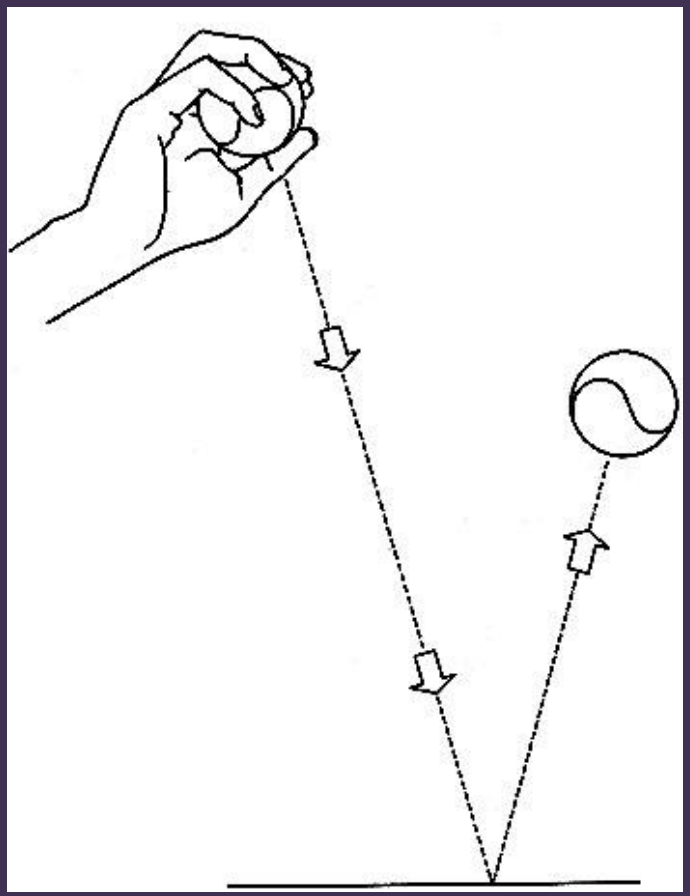

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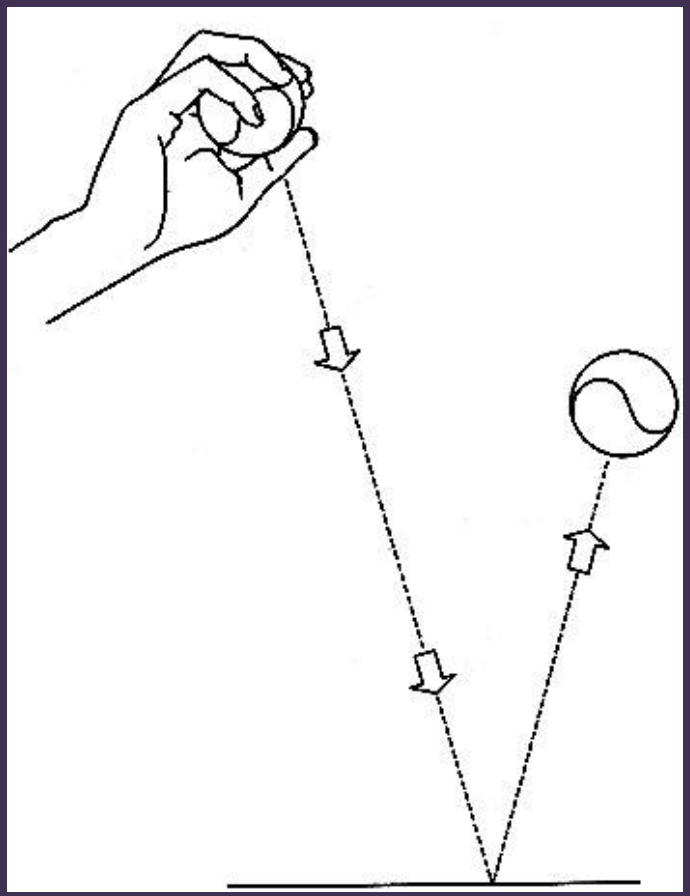

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- Flip the *y* component and multiply it by something between 0 and 1

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Skeletal Animation

Coordinate spaces

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Model space

Coordinate spaces

Model space

↓ Model matrix

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Model space

↓

World space

Model matrix

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↓ Model matrix

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- When performing calculations, **do not mix** vectors from **different coordinate spaces**
- E.g. when performing lighting calculations, ensure your fragment position, normal, light direction, eye direction are all in the **same** space

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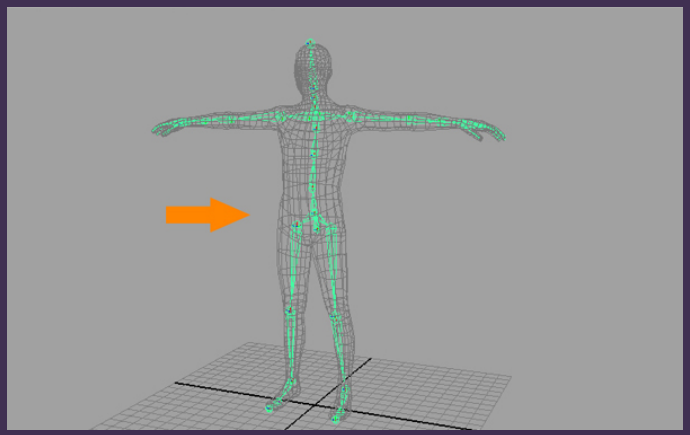
- The model matrix is the **product** of model matrices for the node and its ancestors

Rigging



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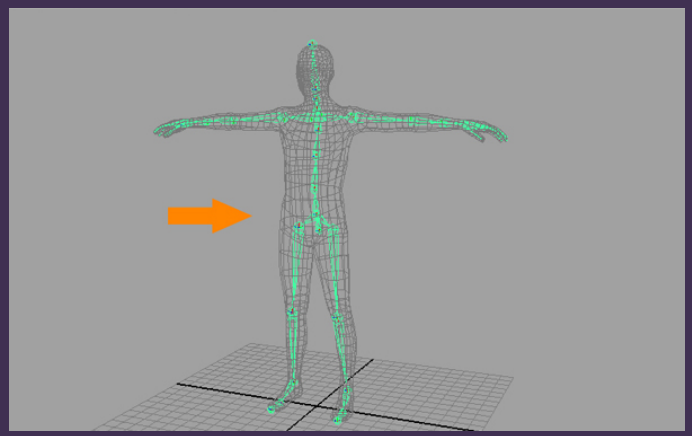

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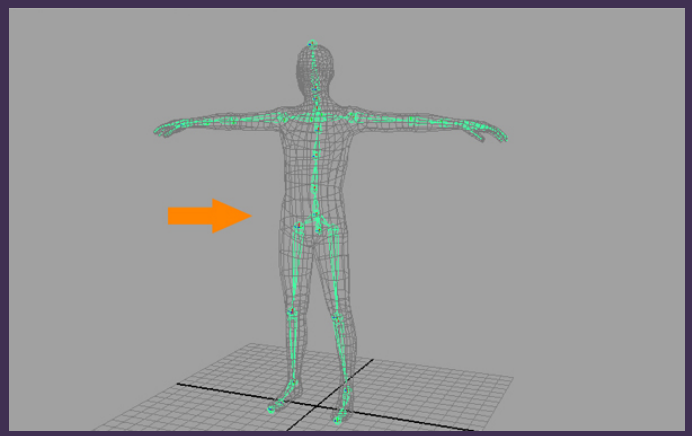

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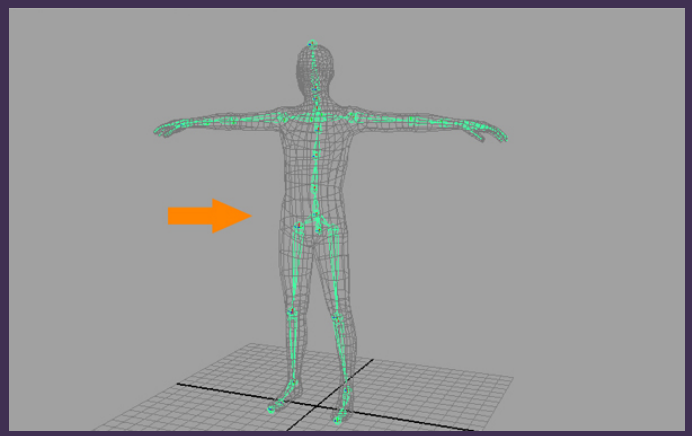

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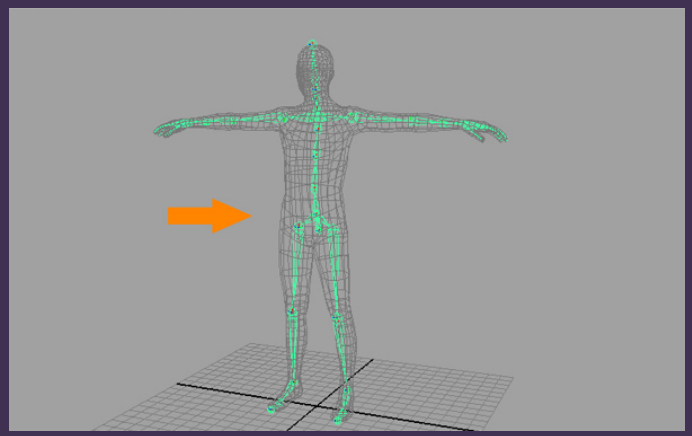

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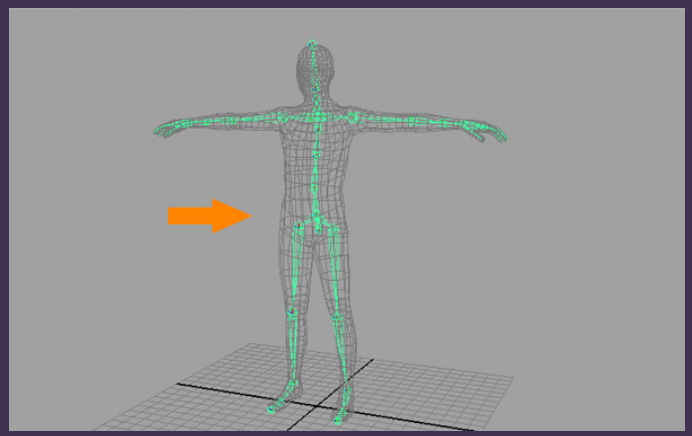

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  - 3D modelling software often represents bones as lines from parent bone to child bone

Keyframe animation

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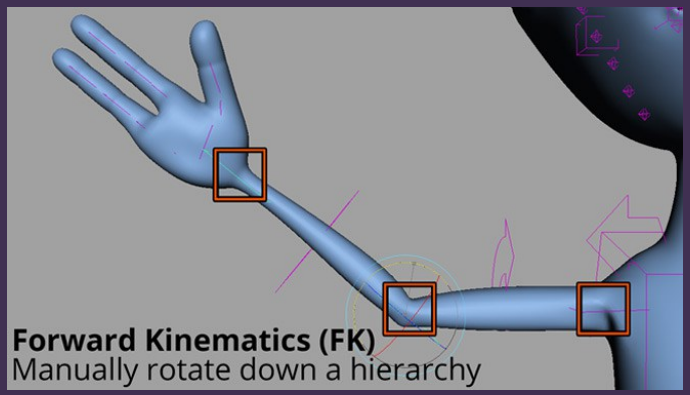
  - E.g. bottom half plays "walk" animation, top half plays "fire weapon" animation

Forward kinematics (FK)



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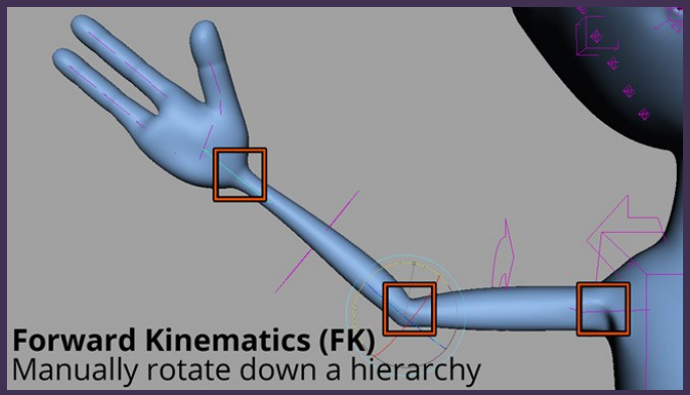

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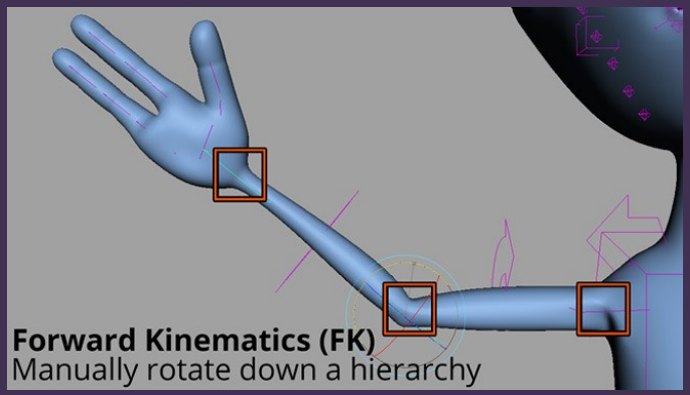

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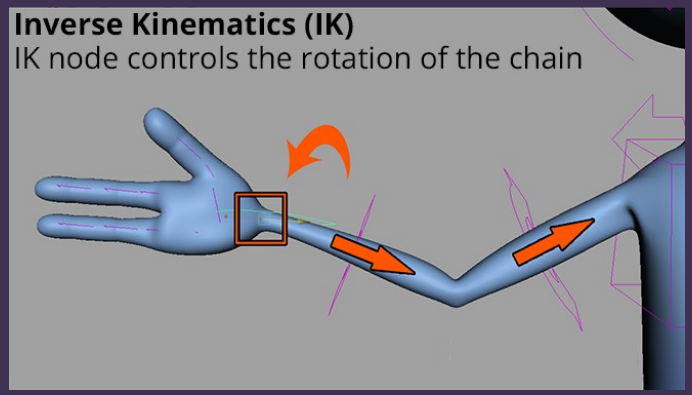
- Children are affected by parent transformations, e.g. if upper arm rotates, lower arm rotates with it

Inverse kinematics (IK)



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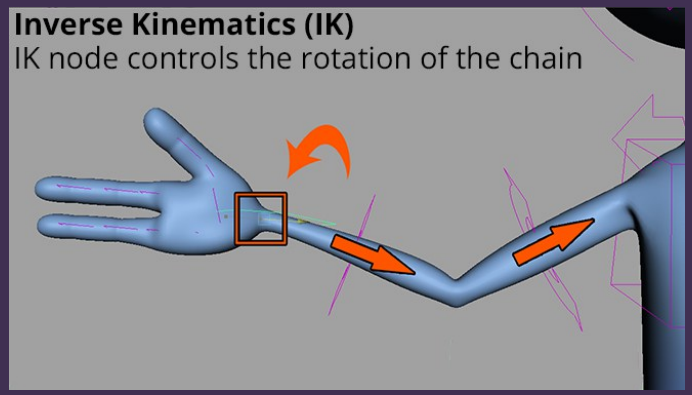

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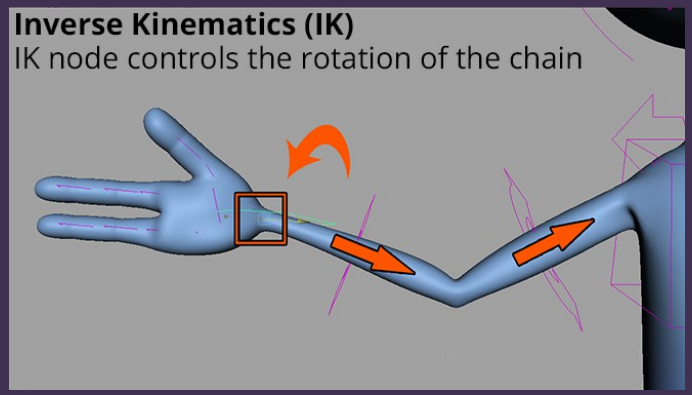

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- E.g. we want character's hand to touch an object; IK calculates rotations of upper and lower arm to achieve this subject to constraints

The most common use for IK

Ragdolls

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- Many games mix and blend some or all of keyframe animation, IK, and physics simulation

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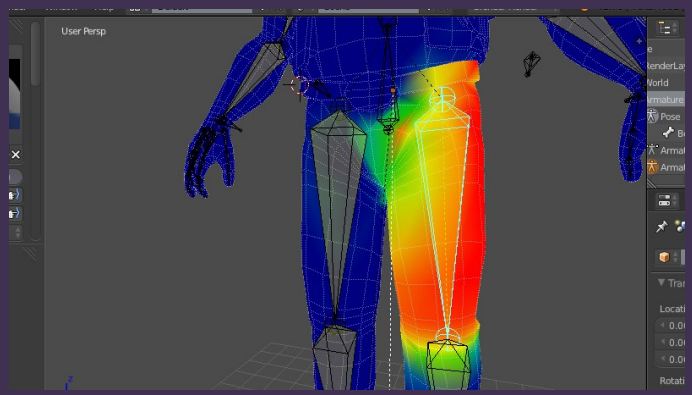
- Generally handled by a **vertex shader**
- Uses **bone weights** to specify how much each vertex is affected by each bone's transformation

Bone weights



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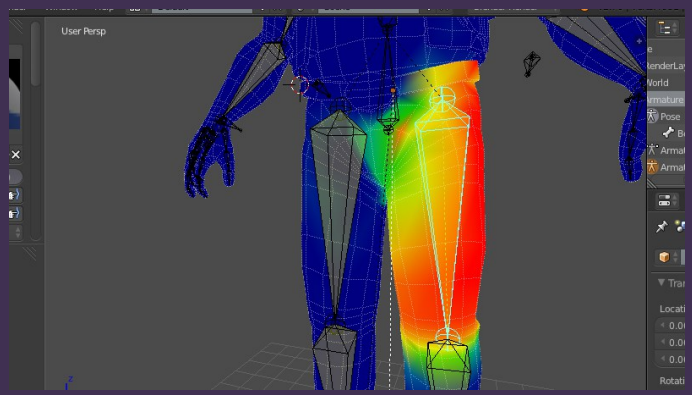

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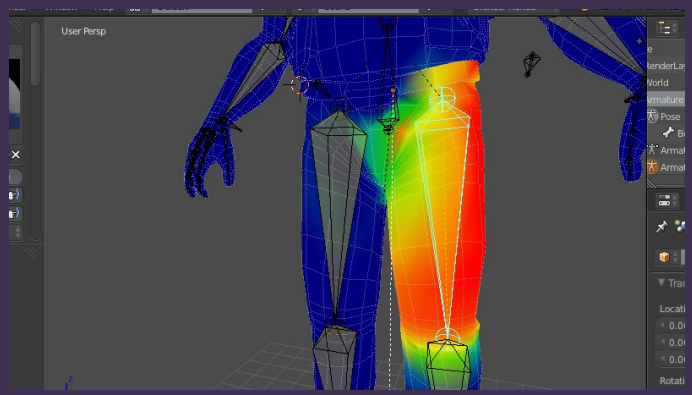

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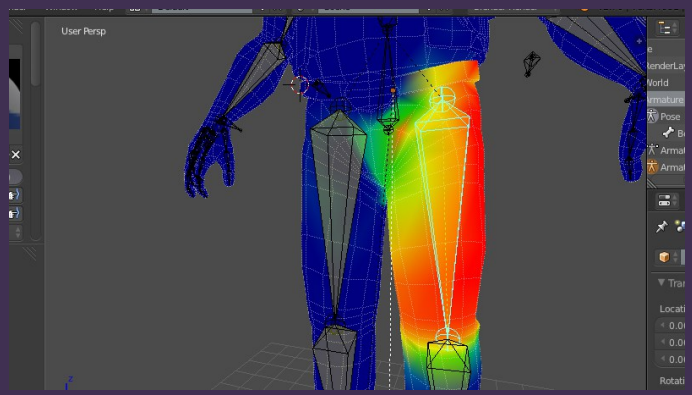

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- Vertex position is calculated as a weighted average of joint transforms

Secondary effects

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- A popular approach is to use **morph targets** (aka **blend shapes**)

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Image source: `https://antongerdelan.net/opengl/blend_shapes.html`

Next steps

- **Review** the additional asynchronous material for more background on physics and animation techniques.
- **Attend** the workshop to learn how to use the Bullet Physics library in your own applications.