Using Dynamics in Disney's Production Environment

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Introduction

"Most people think the word 'animation' means movement. But it doesn't. It comes from 'animus' which means 'life or to live.' Making it move is not animation, but just the mechanics of it."

- Frank Thomas and Ollie Johnston.

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Who Are We?

- Tool developers and technical directors
- Use 3rd party and in-house software.
- Mike Blum — Tools Lead, Core/3D Technology.
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- Umakanth Thumrugoti —Technical Director.
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Why Are We Here?

- Design solutions to merge 3D CGI with traditional artwork.
- Use physically based modeling in production environment.

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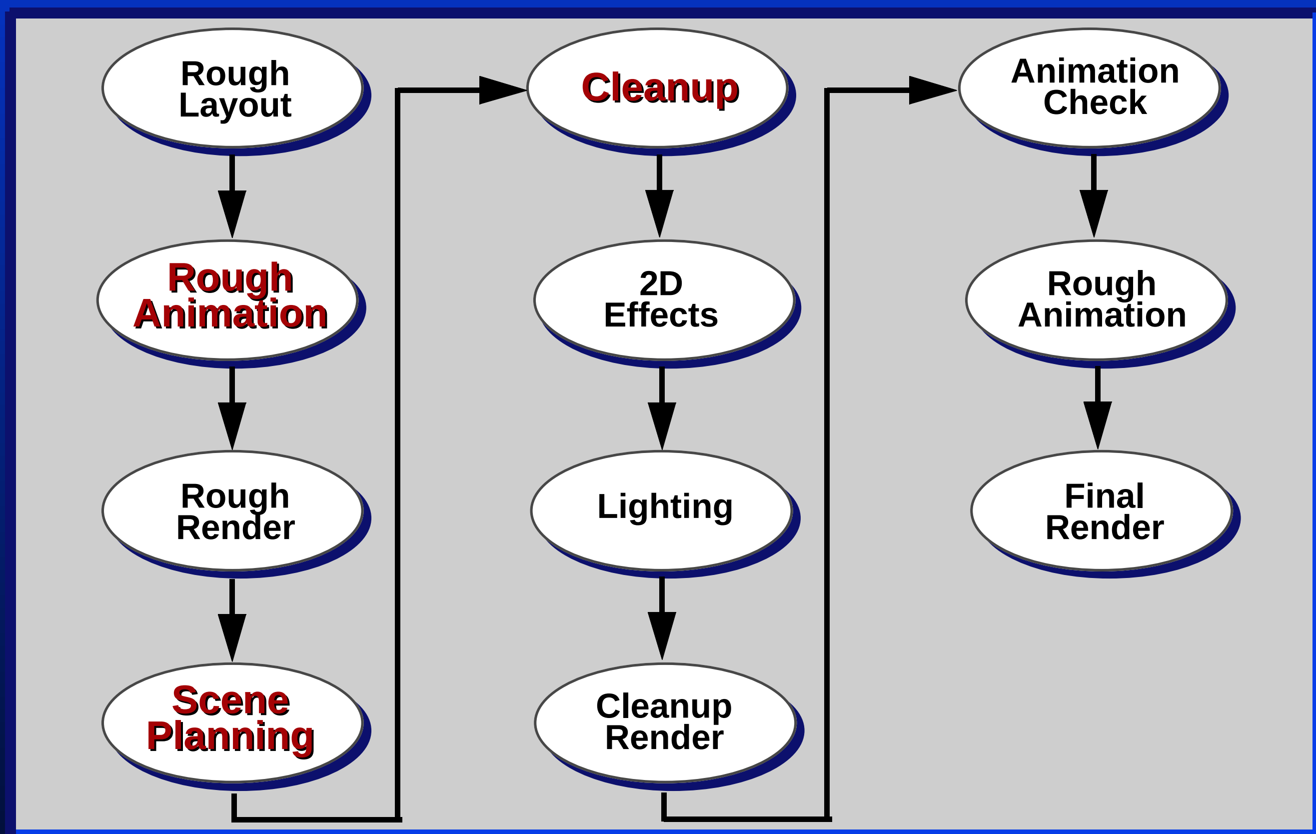
Simplified CGI Pipeline



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Why Use Dynamics?

- Can create richer, more complex animation.
- Cost too great using traditional methods.
- Get closer to director's vision through simulation refinement.

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Production Problems with Dynamics

- Don't want "real" physics but "animation" physics.
  - Difference in approach to traditional physical simulations.
- Difficult to provide adequate animator controls.

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Production Examples

Particle Systems

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Particle Systems

- Prince and the Pauper (1990)
- The Nightmare Before Christmas (1993)
- The Lion King
  - Used live action footage in the past.
  - Particle rain:
    - Match "look" of live action footage.
    - Perspective rain.

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Particle Systems

- Hunchback of Notre Dame:
  - Particle confetti:
    - Matching to 2D hand drawn characters.
    - Cheat: pull frames to change timing.
    - Hand drawn confetti.
    - Non-physically based tumbling.
    - Re-use stock simulations.

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Particle Systems

- Pocahontas:
  - Cycled textures for consistent film style.
  - Re-use stock footage.

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Production Examples

Dynamics on Curves

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Grass Tests

References

- Lion King
  - Simple wave movement.
- Bambi
  - Delicate, watery effect.
- Rescuers Down Under
  - How not to do it.

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Grass Tests

- Ground contours and colors represented by painted background.
- Grass blades modeled to fit style of film.
- Patches modeled in Alias to follow ground contours.

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Grass Tests

- Mapfile assigns patches to each type of grass blade.
- Single blade animated for each type of movement.
- Grass blades duplicated, animation applied.

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Grass Tests

- Grass color defined by painted background.
- Color at bottom of blade mapped from painting.
- Color ramped up the blade.

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Grass Tests

- Rough animation tests performed on sparsely populated patches.
- Grass population increased once animating properly.
- No collision detection.
- 3D grass will match the background painting exactly.

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Hair Introduction

- Uses Alias Power Animator® Plug-in architecture.
- Clusters:
  - Set of CVs assembled into a geometry node that has its own positioning node and pivot point.
- Skeleton:
  - Link/joint structure used to define character motion.

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Hair Model

- Hair geometry grouped into clusters.
- A skeleton passes through each strand of hair.
- A simple spring/mass chain approximates a skeleton.

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Hair Model

- Dynamic simulation animates the spring/ mass chain.
- Particles systems dynamics

  $v' = f/m$

  $x' = v$
- Spring-mass-damper system

  $mx'' + dx' + kx = f(t)$

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Hair Collisions

- Uses a repelling field. Points on the surface of the collision object checked against points on the strand.
- k-d tree used to search for points within the field.

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Miscellaneous Hair Info

- Positional information of masses converted into rotational information with respect to the top most joint.
- Hair geometry is deformed through cluster deformation.

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Hair Conclusion

- Simulation yielded —70% of final motion.
- Cleanup yielded —30% of final motion.
- "Real" physics don't always "look good."
  - Post simulation processes.

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Production Examples

Dynamics on Surfaces

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Skirt Goals

- Dynamically animate skirt behavior based on ballerina's animation.
- Ability to refine the skirt motion after dynamically animated.

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Technical Background

- Particles systems dynamics

  $v' = f/m$

  $x' = v$

- Spring-mass-damper system

  $mx'' + dx' + kx = f(t)$

- Hinge element

  $T = K\,\Delta\Theta$

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Skirt Model

- Plugin to Alias.
- Clusters.
- Skirt geometry is modeled in Alias:
  - 9 horizontal curves
  - 90 vertical curves
- 18 skeletons with 9 joints approximate the skirt.

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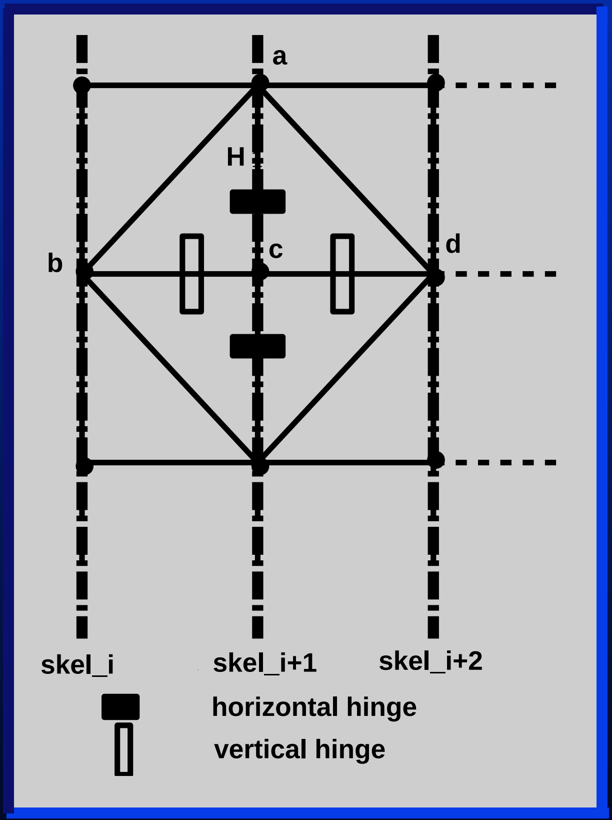
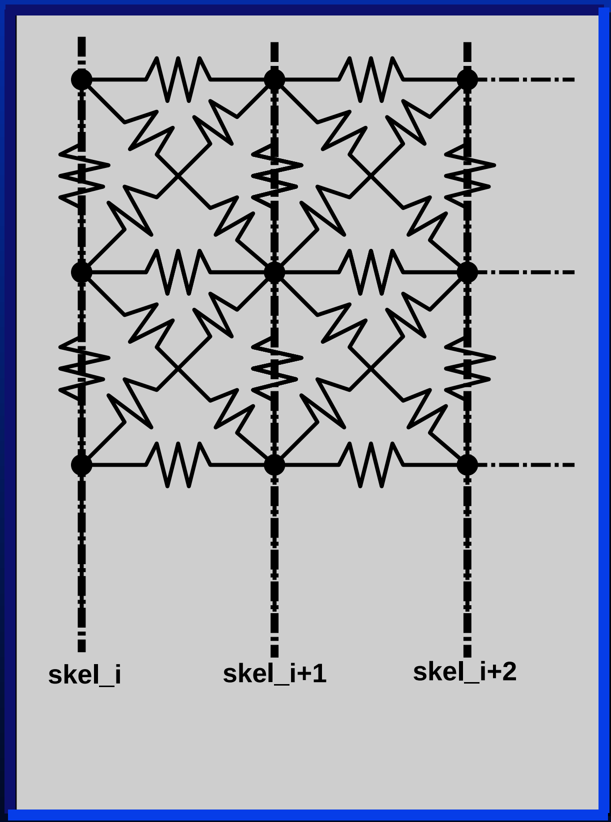
Skirt Model

- Grid Representation





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Skirt Model

- Constrained dynamics.
- Behavior based methods.

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Skirt Collisions

- Simple model is used for collision avoidance.
- Skirt-body collision avoidance.
  - Body parts approximated as tapered, capped cylinders.
  - Skeleton mesh is super-sampled.
  - The super-sampled particles are interpolated linearly.
- Self collision avoidance.
  - Adapative repulsion.

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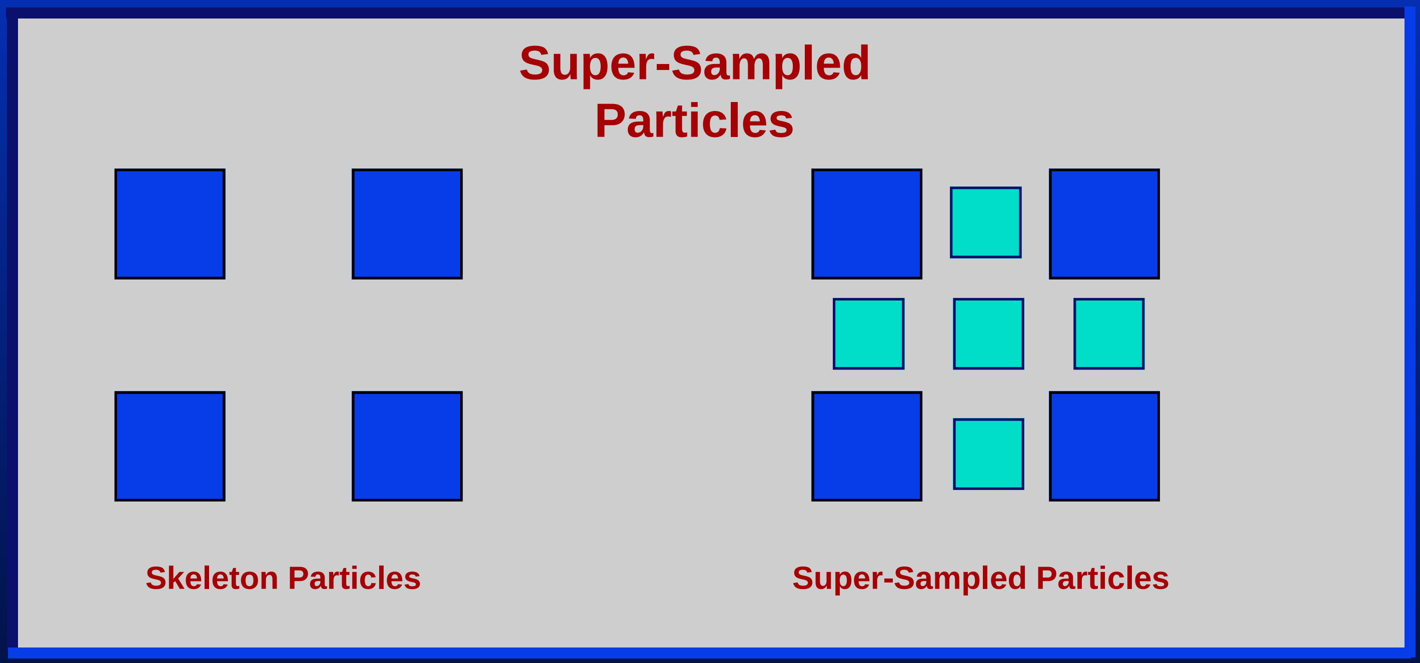
Skirt Collisions



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Skirt Collisions

- Positional information of masses converted into rotational information with respect to the top most joint.
- Skirt deformations using cluster animation.
- Rotations on skeleton joints are applied to the clusters.
- A weighted transformation enables the skirt folds to relax.

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Skirt Post-Processing

- Simulations did not always yield the desired results.
- Controls to key-framed motion on top of the dynamics results.
  - lift, twist, scale and rotate, etc.

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Skirt Conclusion

- Dynamics gave 75-85 % of the final motion on average.
- Produced over 140 feet of skirt animation.
- 35.69 secs per frame on 250 MHz High Impact running unoptimized code.
- Technique successfully captured desired "look and feel".

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Flags

- Dynamics did not match style of movie.
- Dynamics motion was too realistic.

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Production Examples

Novel Uses

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Torches

- Rejected torch effect approaches: Particle torch.
- Spring mass torch:
  - 3 concentric spring-mass meshes.
  - Simple forces and constraints: turbulence, gravity, etc.
  - Cycled texture maps applied to deformed meshes.

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Water

- Spring/mass mesh for low frequency oscillations.
- Evaluate whale/water intersection using a Renderman shader.
- Evaluate direction of wave propogation.
- Generate particles along direction of wave propogation.
- Particles used to generate displacement maps.

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Conclusion

- Animation exaggerates motion, action, and reaction.
- Do not want "real" physics, but animation "physics".
- Each film has different visual style and style of movement.
- Trade off accuracy for control: need more control.
- Keyframing physics would be excellent.

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