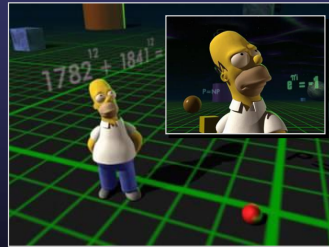


Applications of Computer Graphics in Cel Animation



Adam Finkelstein
Princeton University

3-D and 2-D animation



Homer 3-D



Homer 2-D

Advantages of 3-D

- Complex lighting and shading
- Reuse from scene to scene
- Automatic in-betweening
- Ease of camera motion
- Realism
- Texture mapping



Advantages of 2-D

- Easier for traditional animators
- Simple gestures convey emotion
- Art form refined for 80 years



Key idea

Use 3-D methods in 2-D animation!

- Expressiveness of 2-D
- Technical benefits of 3-D

Related work

Automating cel animation pipeline

[Fekete 95, Robertson 94,
Shantzis 94, Wallace 81]

Hybrid 2D/3D for cel animation

[Rademacher 99, Williams 91]

Two forms of art work



Overview

- Introduction
- Multiperspective panoramas
- Texture mapping
- Shadows

Multiperspective Panoramas for Cel Animation

Daniel Wood  University of Washington
Adam Finkelstein  Princeton University
John Hughes  Brown University
Craig Thayer  Disney Feature Animation
David Salesin 

[SIGGRAPH '98]

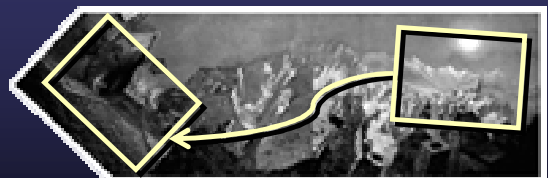


[*Pinocchio*, 1940]

Suggesting a moving camera

A *multiperspective panorama* incorporates many perspectives into a single locally coherent image.

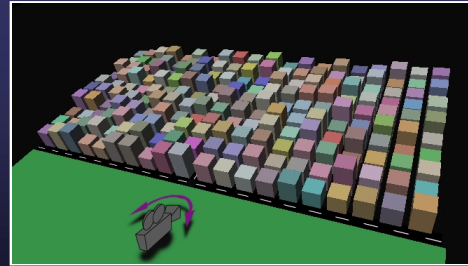
A *moving window* slides across the panorama, selecting frames for the animation.



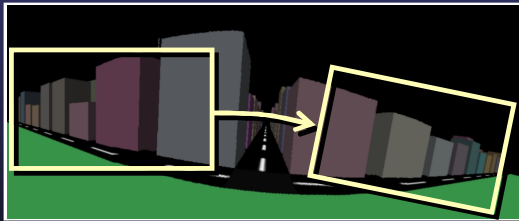
Objective

Given: 3D model and camera path

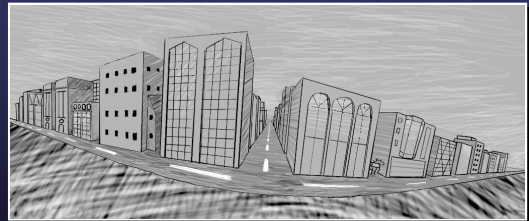
Create: Panorama and moving window
such that the 2D animation
resembles the 3D animation



1. 3-D scene and camera path



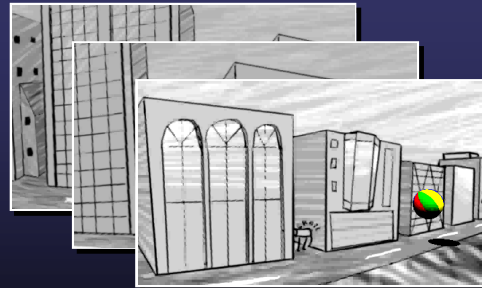
2. Panorama and moving window



3. Illustrated panorama



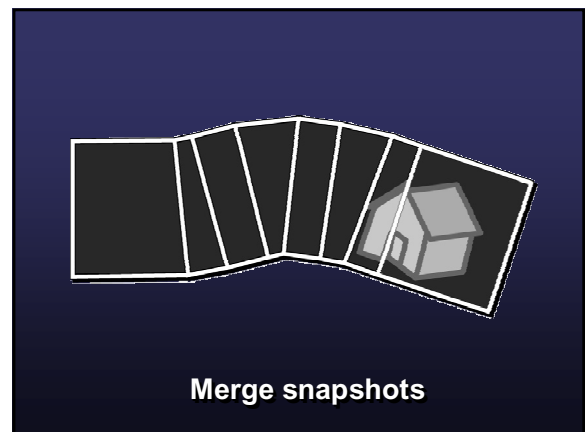
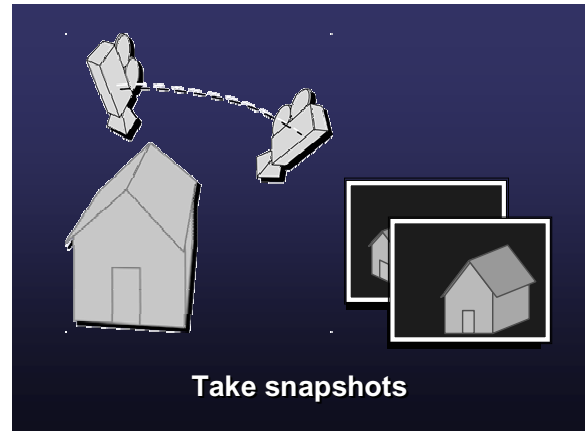
4. Extracted frames



5. CG Elements

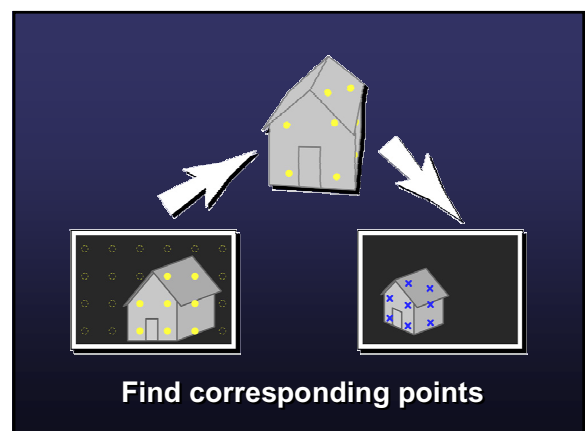
Creating a panorama

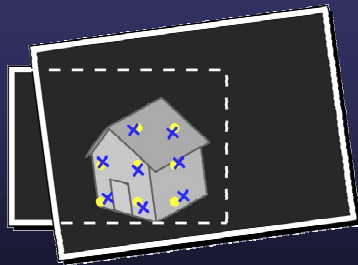
- Take snapshots of 3D scene
- Arrange snapshots in a plane
- Merge snapshots into single image



Arrange consecutive snapshots

1. Sample points from first snapshot
2. Find corresponding points on second snapshot
3. Align snapshots using a transform



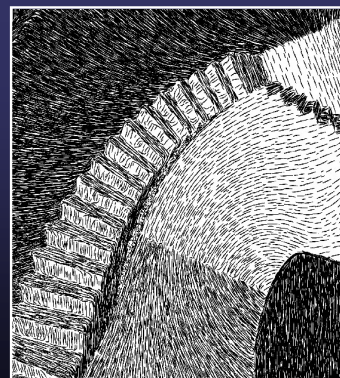
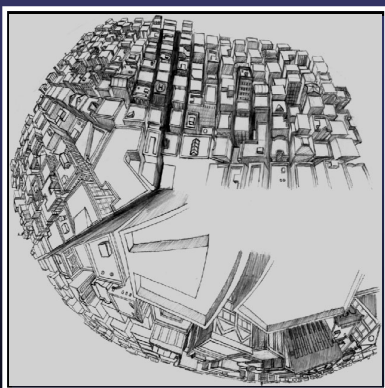
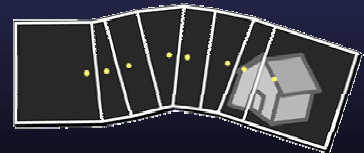


Align snapshots

Untrimmed



Trimmed



Limitations

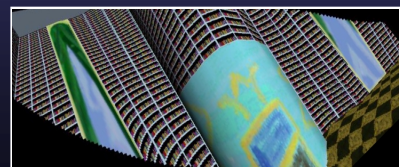
Panoramas cannot do it all
(e.g., circling centerpiece of table)

Our method does not do it all
(e.g., *Beauty and the Beast* library)

Hand-
designed



Automatic



Strengths

- Wide variety of camera motion
- Easy experimentation
- Easy CG integration
- Illustrator creates detail
- Hand-drawn artistic style

Texture Mapping for Cel Animation

Wagner Corrêa 
Rob Jensen  Princeton University
Craig Thayer  Disney Feature Animation
Adam Finkelstein 

[SIGGRAPH '98]

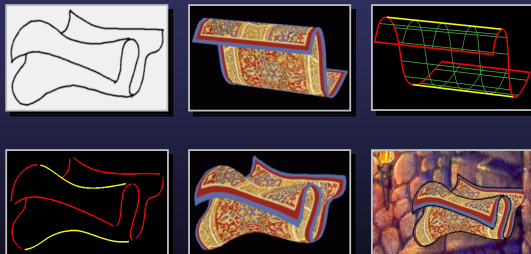
Traditional cel animation



Textured cel animation



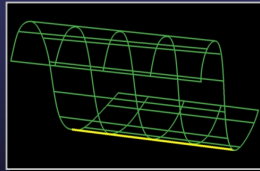
The process



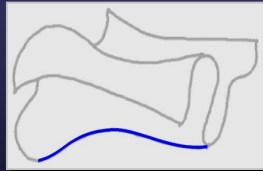
Input of the warp



Marker curves

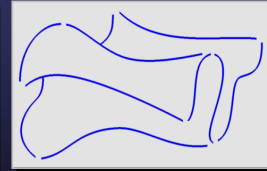
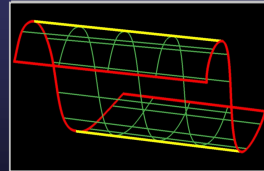


model marker

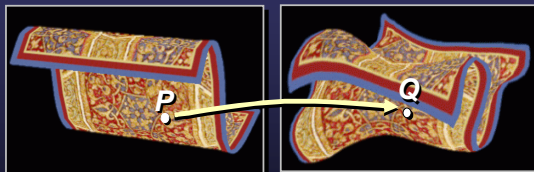


drawing marker

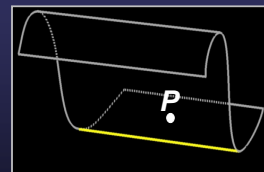
Input of the warp



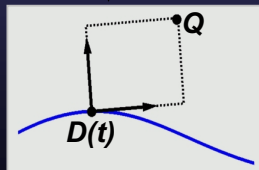
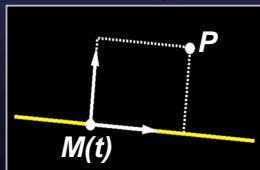
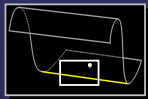
Output of the warp



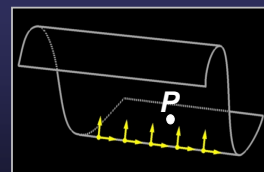
A pair of marker curves



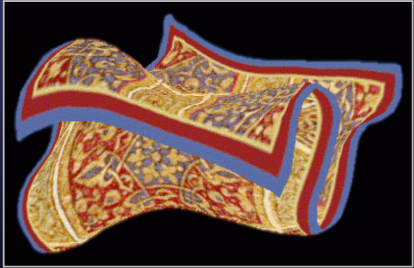
At parameter t



Many parameter values



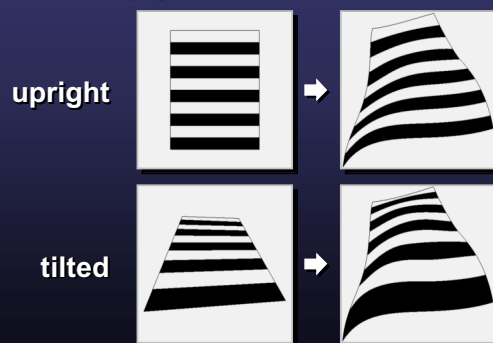
Output of the warp



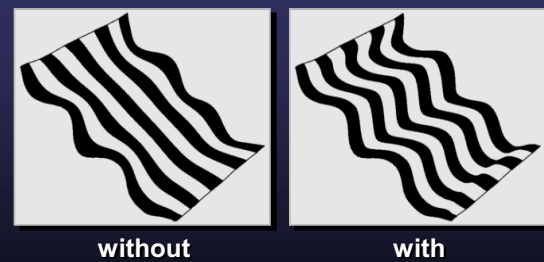
Controlling the warp

- Weights
- Viewing parameters
- Extra markers

Viewing parameters



Extra markers



Video



Limitations



Strengths

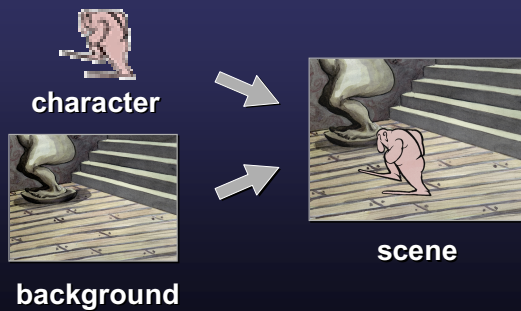
- Fits into current production pipeline
- Little effort per frame
- Avoids temporal artifacts
- Combines strengths of:
 - 2-D: gestures, timing, anticipation
 - 3-D: texture, occlusion, foreshortening

Shadows for Cel Animation

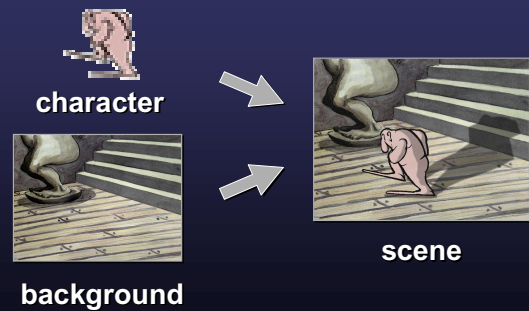
Lena Petrović 
 Brian Fujito  Princeton University
 Lance Williams  Disney Feature Animation
 Adam Finkelstein 

[SIGGRAPH '00]

Motivation



Motivation



Motivation

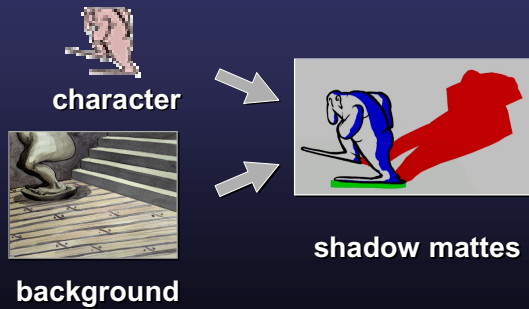


Shadow Mattes

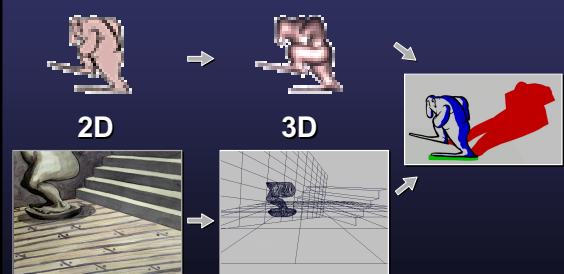
cast shadows (red) - shadows on background
tone mattes (blue) - character shading
contact shadows (green) - darkness underfoot



Project Goal

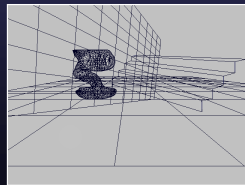


Approach: 3D Models



Process: Overview

- Background Construction
- Character Inflation
- Depth Specification
- Specifying Lights
- Rendering
- Compositing



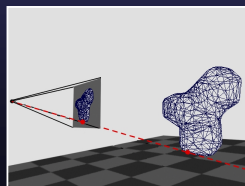
Process: Overview

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Process: Overview

- Background Construction
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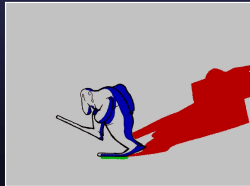
Process: Overview

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Process: Overview

- Background Construction
- Character Inflation
- Depth Specification
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Process: Overview

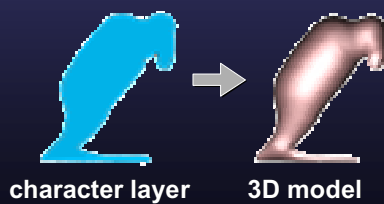
- Background Construction
- Character Inflation
- Depth Specification
- Specifying Lights
- Rendering
- Compositing



Character Inflation

Inflate 3-D shapes using Teddy [Igarashi 99]

- Two caveats: perspective & layers

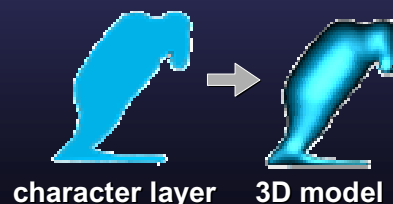


character layer

3D model

Character Inflation

First layer

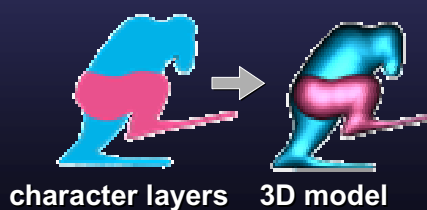


character layer

3D model

Character Inflation

Adding a second layer

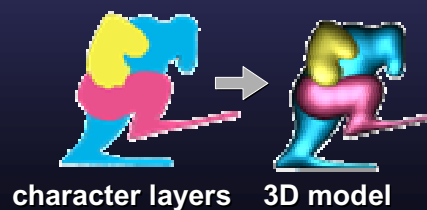


character layers

3D model

Character Inflation

Adding a third layer

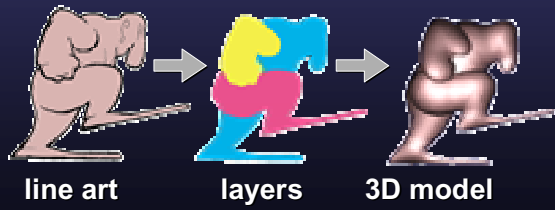


character layers

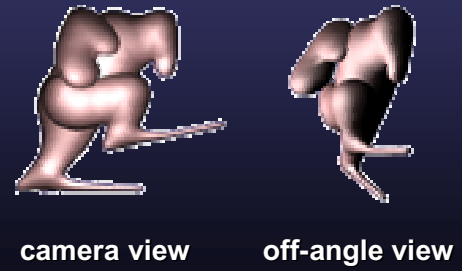
3D model

Character Inflation

Obtaining layers

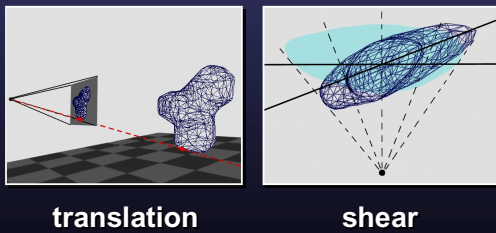


Character Inflation

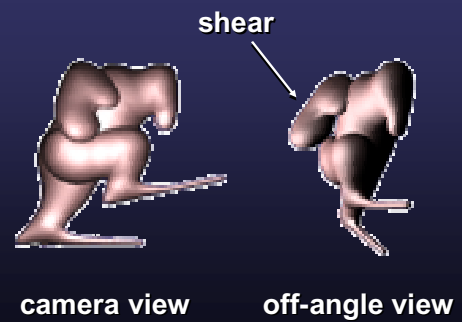


Depth Specification

Adjust depth while preserving silhouette

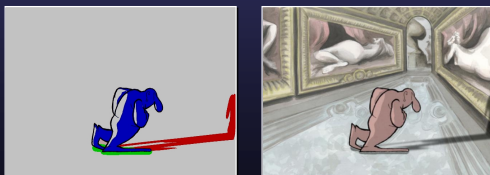


Depth Specification

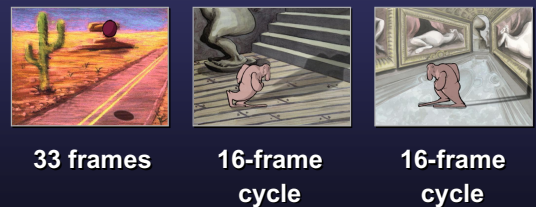


Compositing

Tone matte (blue) modifies character color.
Other mattes (red & green) darken background.



Video



Limitations

Manual creation of character layers

No aesthetic controls for:

- shadow simplification
- shadow stylization

Strengths

- Less human effort than hand-drawn
- Plausible shadows
 - even in complex scenes
- Lighting effects:
 - animated lights, gobos
- Freedom to experiment with lights

Conclusions

3D methods may be used in 2D for:

- reducing human effort
- achieving new effects

Lines between 3D and 2D are blurring

Conclusions



Lines between 3D and 2D are blurring