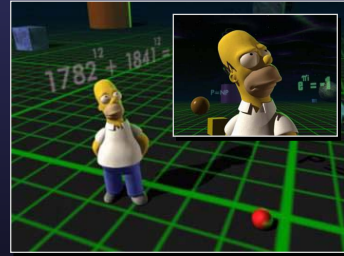


## Applications of Computer Graphics in Cel Animation



Adam Finkelstein  
Princeton University  
COS 426 Spring 2003

## 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.

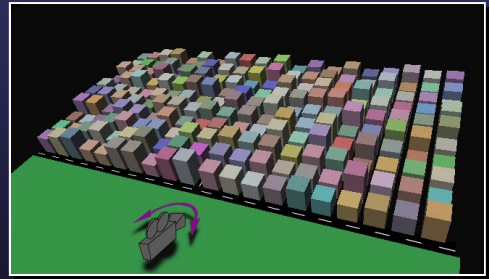
A *moving window* slides across the panorama, selecting frames for the animation.



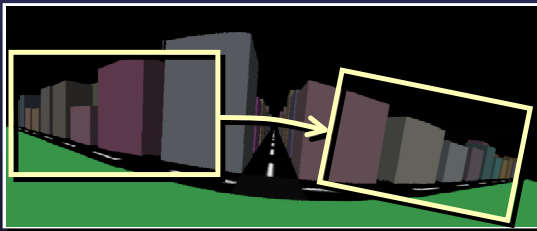
## Objective

Given: 3D model and camera path

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



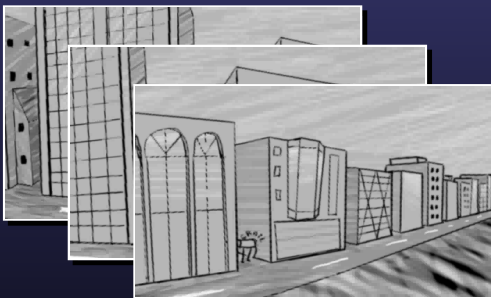
1. 3-D scene and camera path



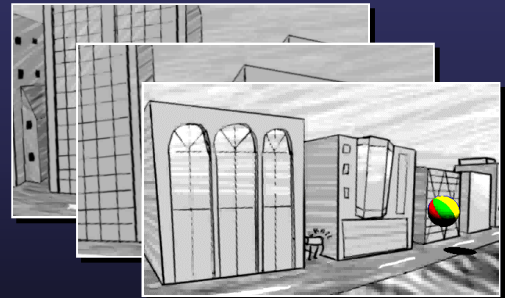
2. Panorama and moving window



3. Illustrated panorama



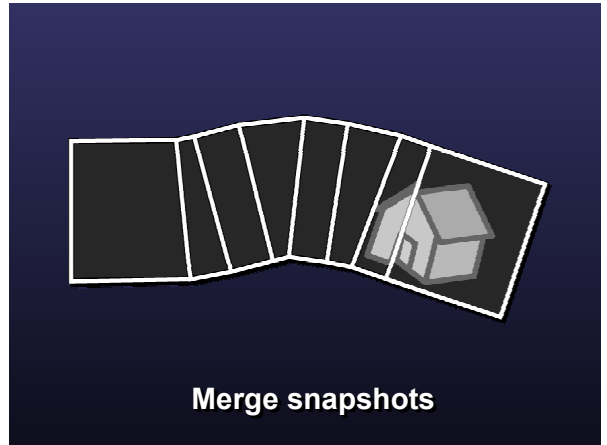
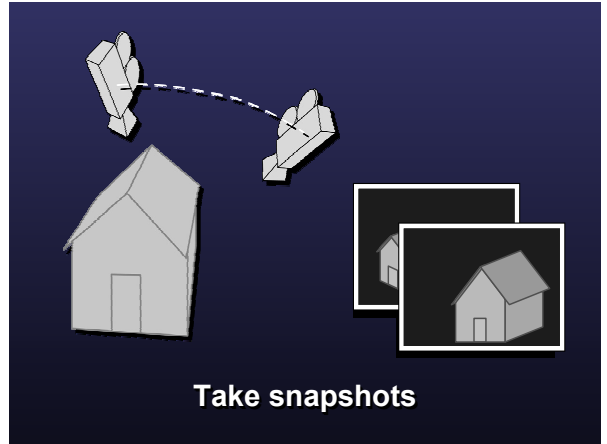
4. Extracted frames



5. CG Elements

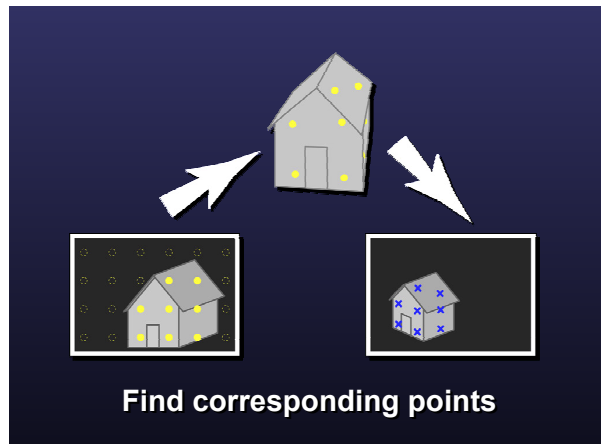
## Creating a panorama

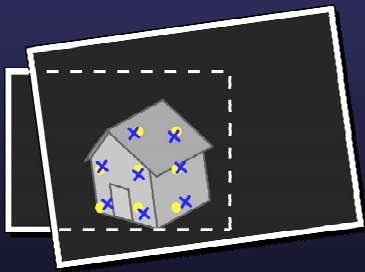
- Take snapshots of 3D scene
- Arrange snapshots in a plane
- Merge snapshots into single image



## Arrange consecutive snapshots

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



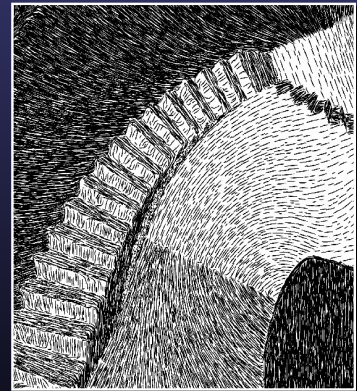
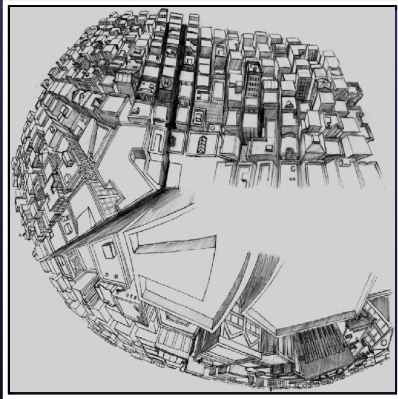


Align snapshots

Untrimmed



Trimmed



## Limitations

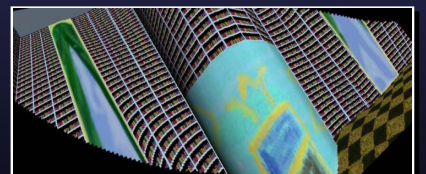
Panoramas cannot do it all  
(e.g., circling centerpiece of table)

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

Craig Thayer

Adam Finkelstein

Princeton University

Disney Feature Animation

[SIGGRAPH '98]

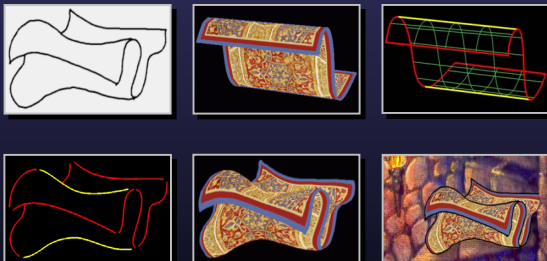
## Traditional cel animation



## Textured cel animation



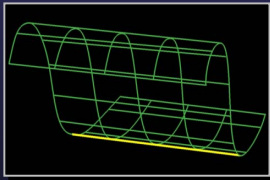
## The process



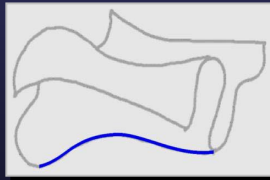
## Input of the warp



## Marker curves

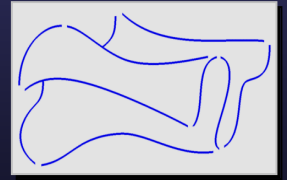
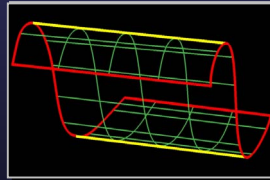


model marker

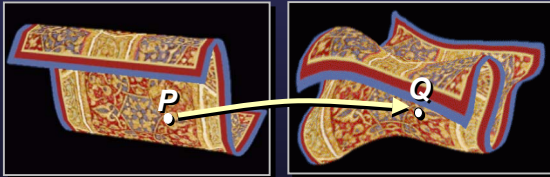


drawing marker

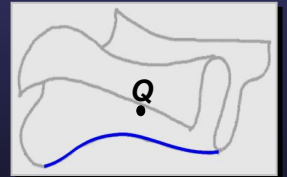
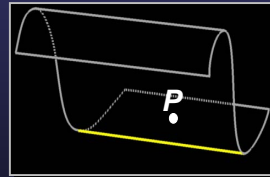
## Input of the warp



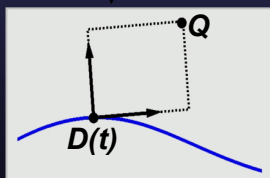
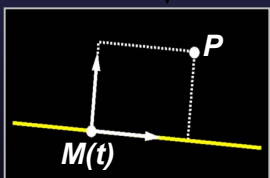
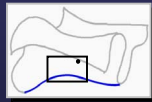
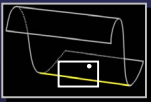
## Output of the warp



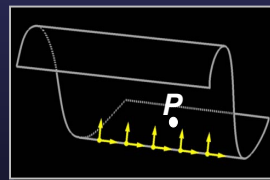
## A pair of marker curves



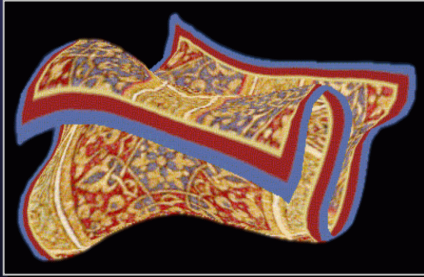
## At parameter $t$



## Many parameter values



## Output of the warp



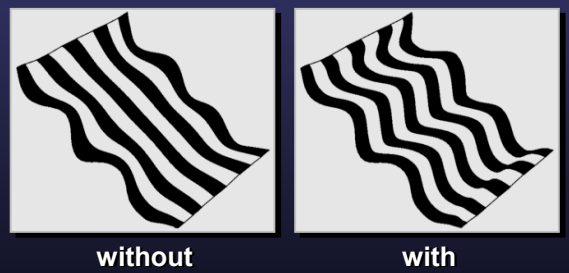
## Controlling the warp

- Weights
- Viewing parameters
- Extra markers

## Viewing parameters



## Extra markers



## Video



## Limitations





## Strengths

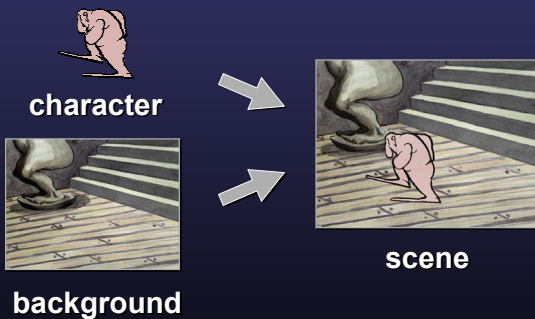
- Fits into current production pipeline
- Little effort per frame
- Avoids temporal artifacts
- Combines strengths of:
  - 2-D: gestures, timing, anticipation
  - 3-D: texture, occlusion, foreshortening

## Shadows for Cel Animation

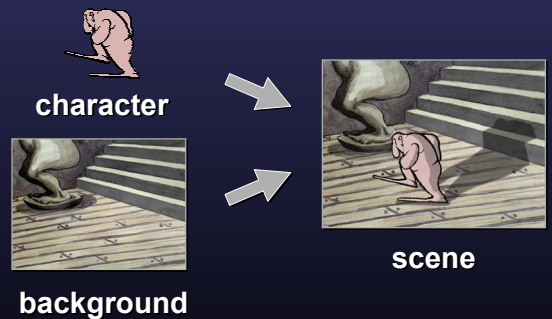
Lena Petrović   
Brian Fujito  Princeton University  
Lance Williams  Disney Feature Animation  
Adam Finkelstein 

[SIGGRAPH '00]

## Motivation



## Motivation



## Motivation

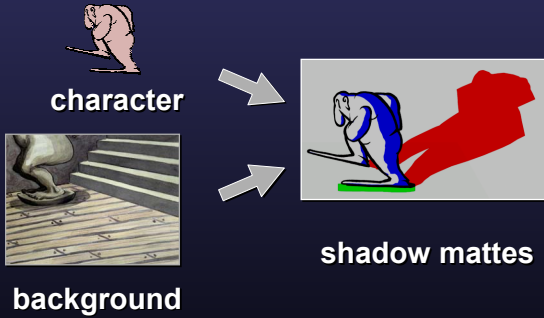


## Shadow Mattes

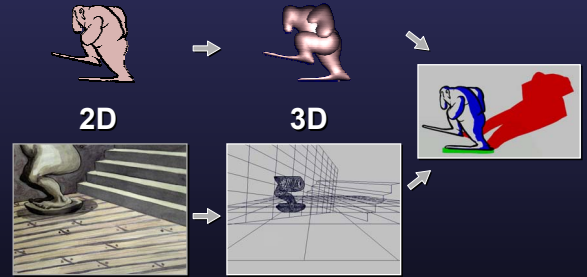
*cast shadows (red)* - shadows on background  
*tone mattes (blue)* - character shading  
*contact shadows (green)* - darkness underfoot



## Project Goal

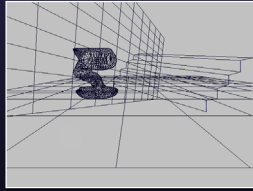


## Approach: 3D Models



## Process: Overview

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



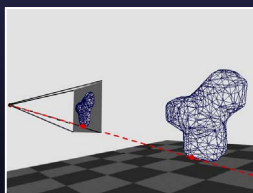
## Process: Overview

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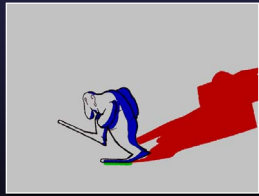
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- Background Construction
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## Process: Overview

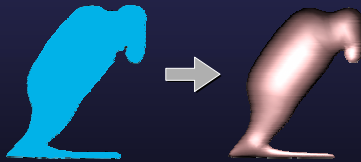
- Background Construction
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## Character Inflation

Inflate 3-D shapes using Teddy [Igarashi 99]

- Two caveats: perspective & layers



character layer

3D model

## Character Inflation

First layer

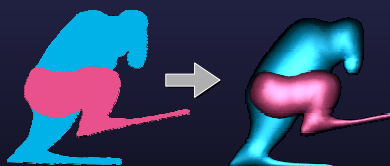


character layer

3D model

## Character Inflation

Adding a second layer

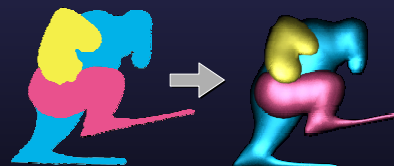


character layers

3D model

## Character Inflation

Adding a third layer

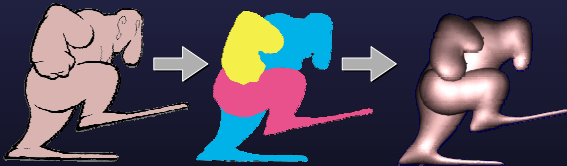


character layers

3D model

## Character Inflation

Obtaining layers

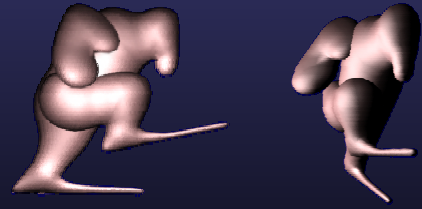


line art

layers

3D model

## Character Inflation

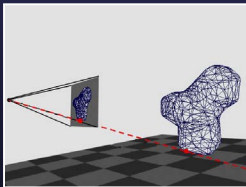


camera view

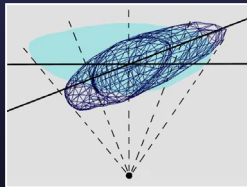
off-angle view

## Depth Specification

Adjust depth while preserving silhouette

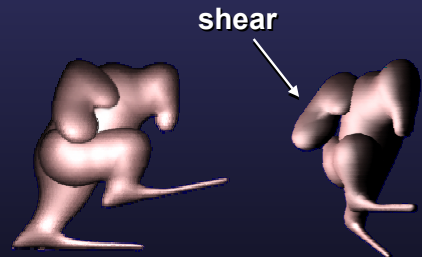


translation



shear

## Depth Specification



camera view

off-angle view

## Compositing

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



## Video



33 frames



16-frame  
cycle



16-frame  
cycle

## 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