# Pixar's semi-sharp creases

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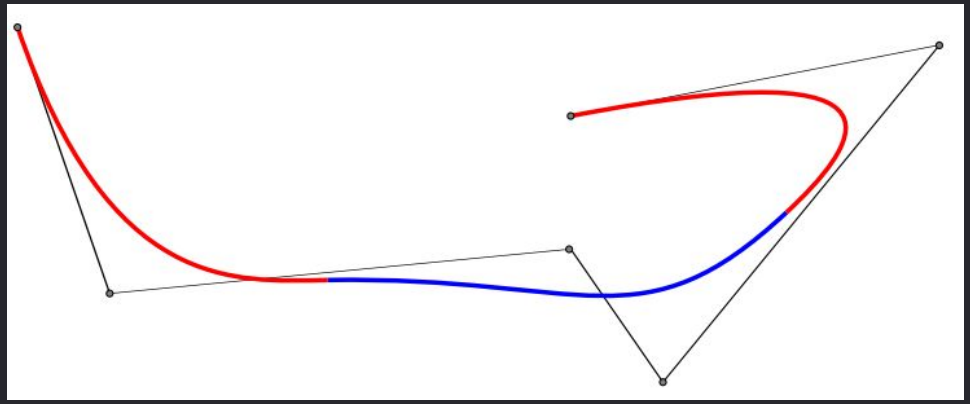
# Introduction

- Paper written by Pixar employees
- Around 1998, 3 years after Toy Story (and 1 before the sequel)
- Subdivision still early stage, not often used

# Splines recap

- A ‘composite’ join of multiple degree *d* polynomial curves
- Smoothness built into basis functions: B-splines
- The parameter values where pieces meet are called knots



# Restrictions of B-splines

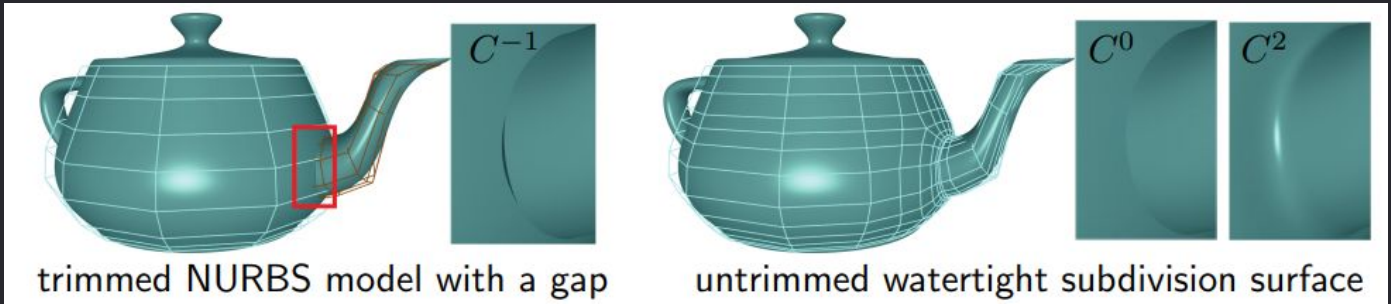
- Trimming is expensive and prone to numerical error
- It is difficult to maintain smoothness, or even approximate smoothness, at the seams of the patchwork as the model is animated

# B-Splines

- Many tools were available for B-Splines, but not for alternatives

# Subdivision surfaces

- Do not require trimming, so no gaps
- Smoothness is guaranteed, even while animating



## Catmull-Clark

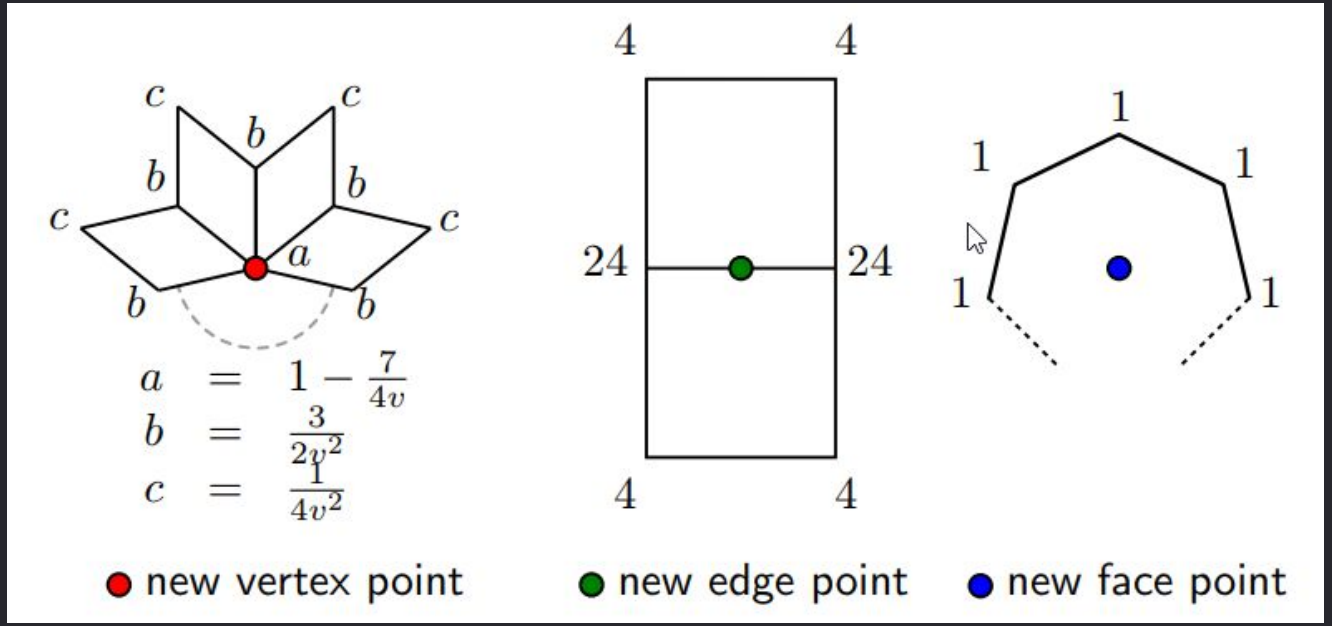
- Easier to use with existing in-house software
- Quads are better at capturing symmetries found in the world

- No mention that Catmull was Pixar's president…

## Difficulties to overcome in Catmull-Clark

- Difficult to model sharp edges
- Collision detection
- Texture mapping

# Catmull-Clark subdivision recap



# Modelling sharp edges

- Make creases by giving edges a “sharpness” value
  - Different rules for vertices with edges with sharpness > 0
  - These rules produce splines that only depend on vertices along the crease

## Hybrid Subdivision

- Use sharp rules a finite amount of times
- Afterwards, use smooth rules to the limit
- Two cases: sharpness is constant integer or constant decimal (non-constant is out of scope)

## Integer case

Edge has sharpness s:

- Subdivide using sharp rules s times
- Subdivide using smooth rules to the limit

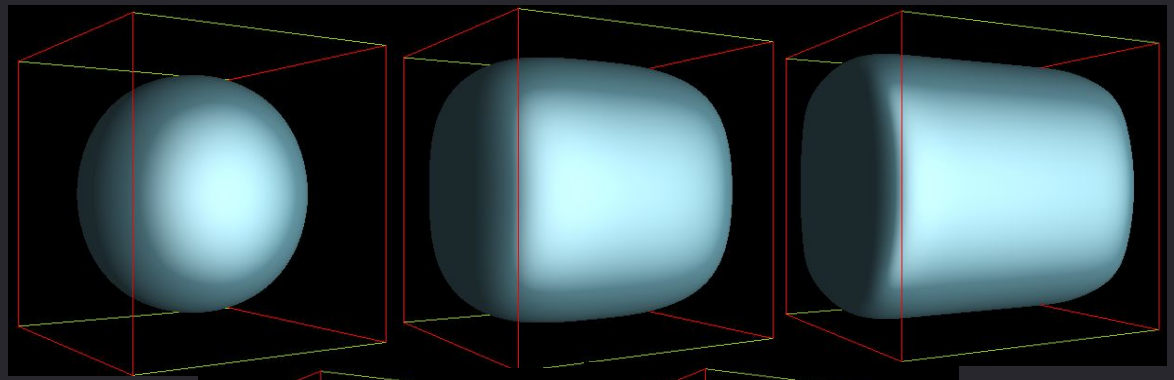
## Decimal case

Edge has sharpness s:

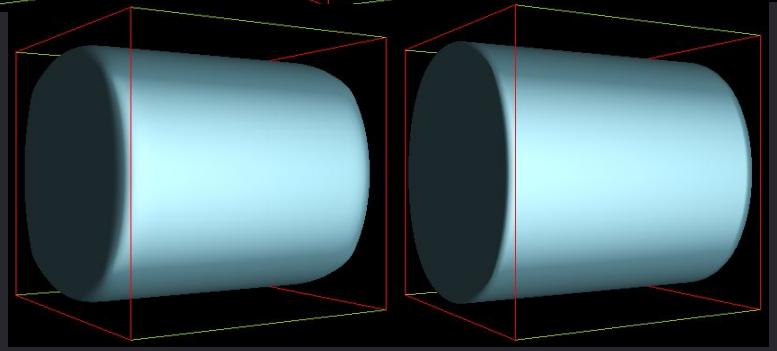
- Subdivide using sharp rules $s\downarrow$ times
- Subdivide once more ($s\uparrow$)
- Interpolate: vertex $v = (1 - \boldsymbol{\sigma})v_{s\downarrow} + \boldsymbol{\sigma}v_{s\uparrow}$
  where $\boldsymbol{\sigma} = (s - s\downarrow) / (s\uparrow - s)$
- Subdivide using smooth rules to the limit

# Examples of semi-sharp creases

0, 1, 2



3, 10



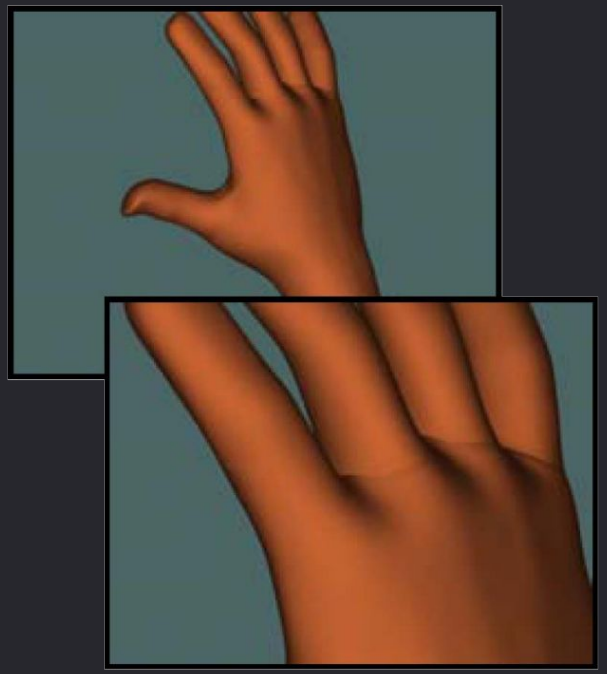
## Geri’s Game

- Pay attention to the fingernails and the pieces on the board, as well as the creases (wrinkles) on the face.

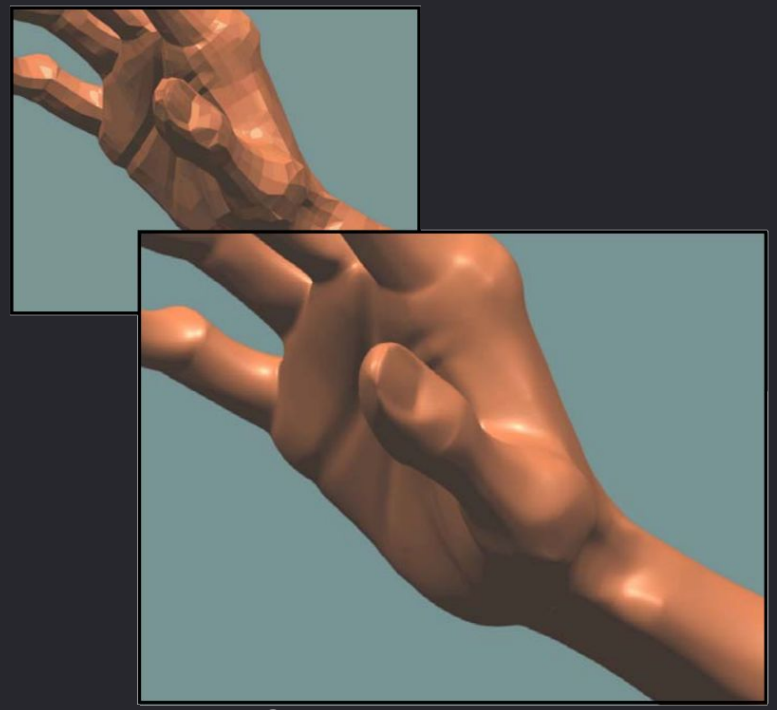
Geri’s game

# Geri’s Game

# Comparison



Woody’s hand (NURBS)



Geri’s hand (subdivision)

# Demo