Computer-Generated Watercolor

simulation of a specific traditional medium

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Watercolor

- Unique medium
  - Contains the motion of water
  - Transparant and luminous quality
- Complex to simulate

Self portrait(1895), Paul Cézanne, Wikipedia

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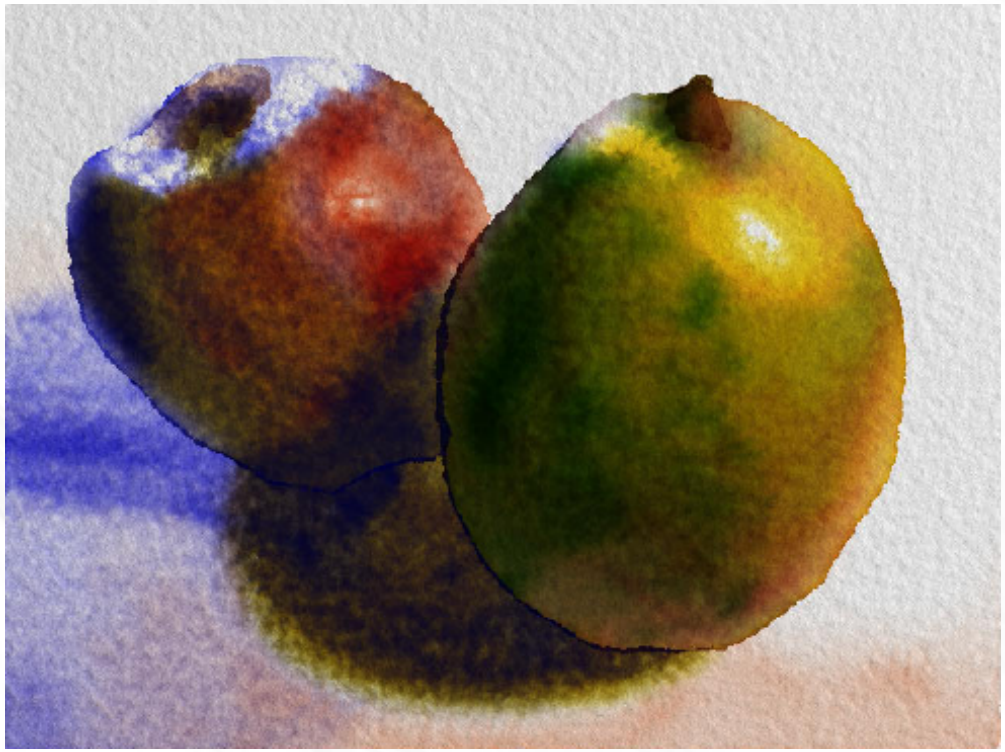
Source: http://zenkaku.huh.harvard.edu

Behavior of watercolor paint

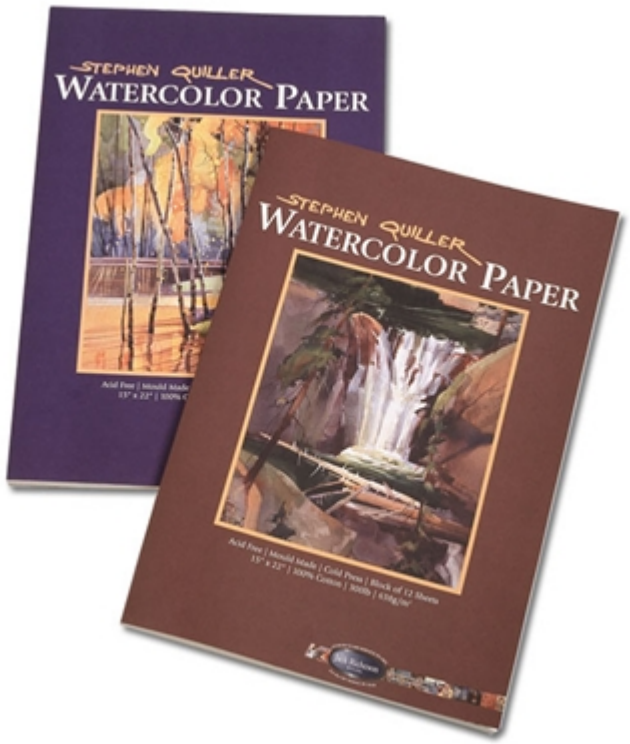
Why study the behavior of paint?



Source: Curtis et al.

Behavior of watercolor paint

- The paint
  - Pigment particles
  - Water
  - Binder
  - Surfactant
- The paper
  - Cotton (no wood)
  - Impregnated with sizing



Paint: pigment

- Penetrate the paper
- Varying density (small particles travel further)
- Staining power (how well does it adhere)
- Granulation / Flocculation (pigments clumping)

Source: utrechtart.com

Behavior of watercolor paint

- The effects
  - Dry Brush
  - Edge darkening
  - Backruns
  - Granulation
  - Flow patterns
  - Glazing

The Effects: Dry-brush

- Dry Brush
- Rough paper
- Depends on the height and angel of the brush

Source: Curtis et al.

The Effects: Edge darkening

- Wet-on-dry technique
- Pigment travels to edges
  - Paper sizing
  - Surface tension

Source: Curtis et al.

The Effects: Backruns

- Intentional effect
- Water to damp region
- Water pushes pigment

Source: Curtis et al.

The Effects: Granulation

- Grainy texture
- Texture of paper

Source: Curtis et al.

The Effects: Flow patterns

- Wet-on-wet technique
- Paint moves freely
- Soft shapes, that follow the water flow

Source: Curtis et al.

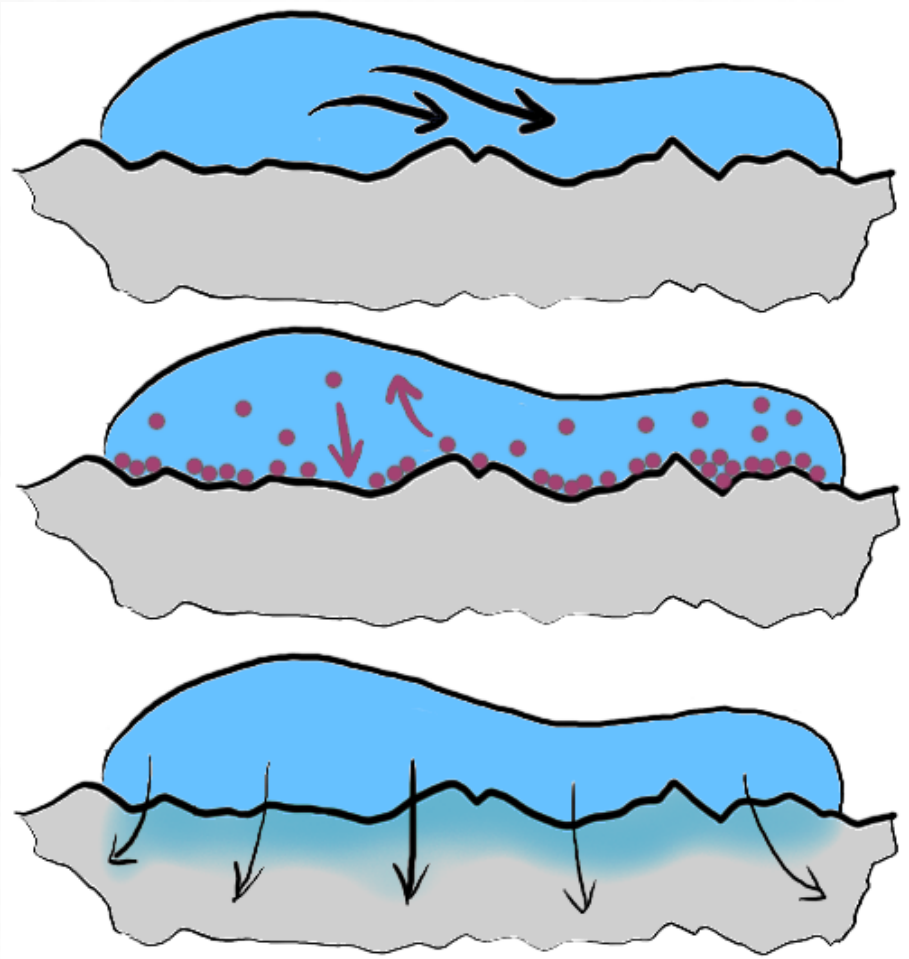
The Effects: Color Glazing

- Adding up layers of color
- Wet-on-dry
- Clear and even effect

Source: Curtis et al.

Physical Simulation

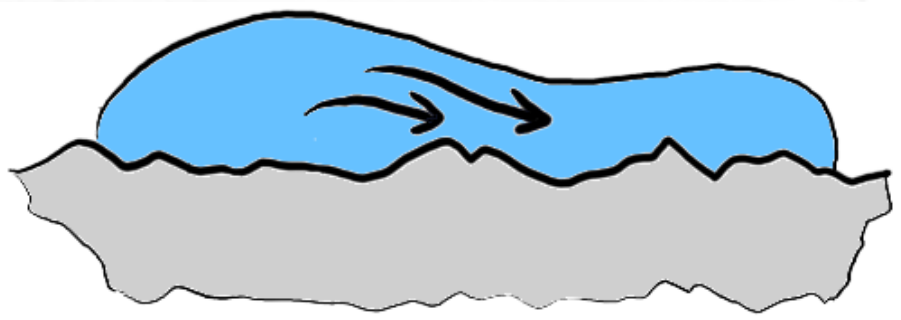
- Fluid simulation (Curtis et al.)
- Three-layer model
  - Shallow water
  - Pigment deposition
  - Capillary
- Discretized over 2D grid



Source: Curtis et al.

Shallow-water Layer

- Water flowing across the surface
- Bounded by a 'wet-area mask'
- Lifts/caries/deposits pigments

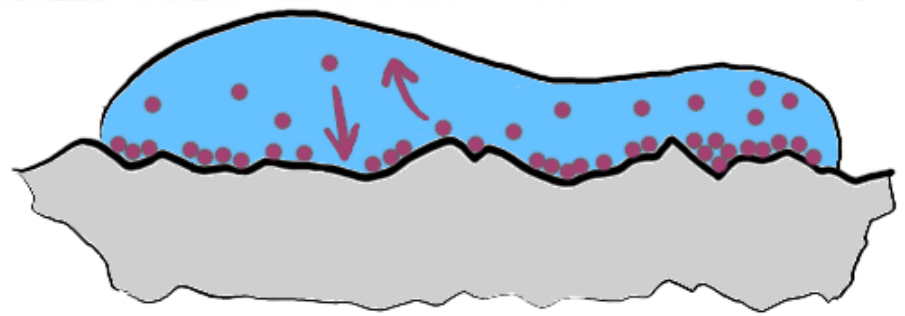


Source: Curtis et al.

- Parameters: wet-area mask, velocity of the water, pressure of the water, concentration of pigment, slope of paper

Pigment-deposition Layer

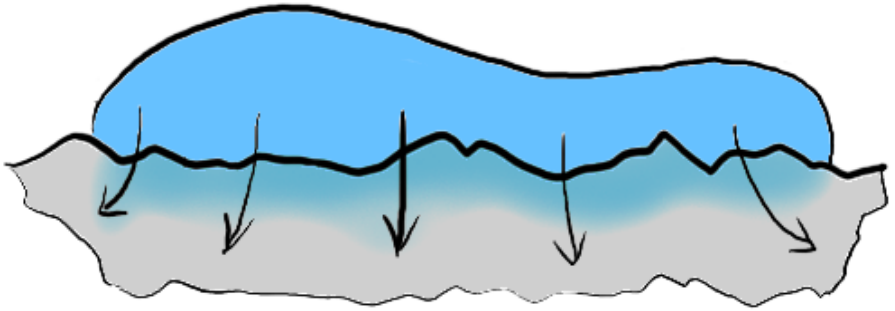
- Adsorption and desorption of pigment
- Physical properties of pigments
  - Density
  - Staining power
  - Granularity



Source: Curtis et al.

Capillary Layer

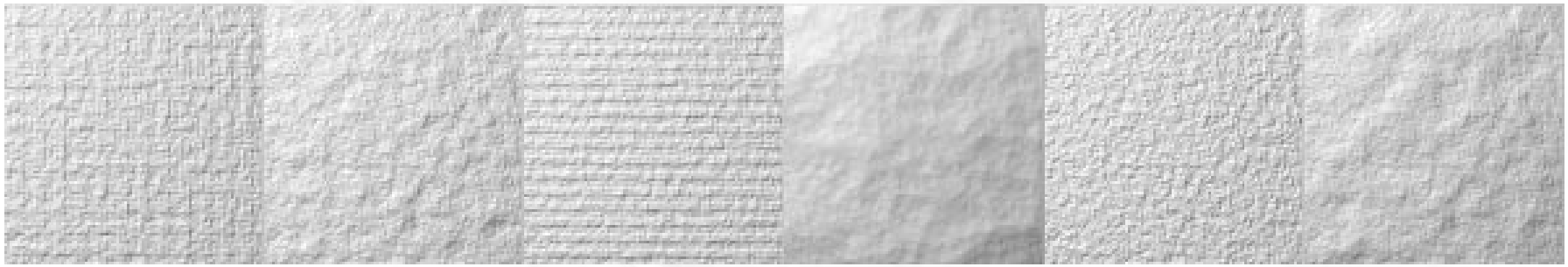
- Capillary flow of water through pores of paper
- Determines the wet-area mask
- Properties of the paper
  - Water saturation
  - Fluid holding capacity



Source: Curtis et al.

The Paper

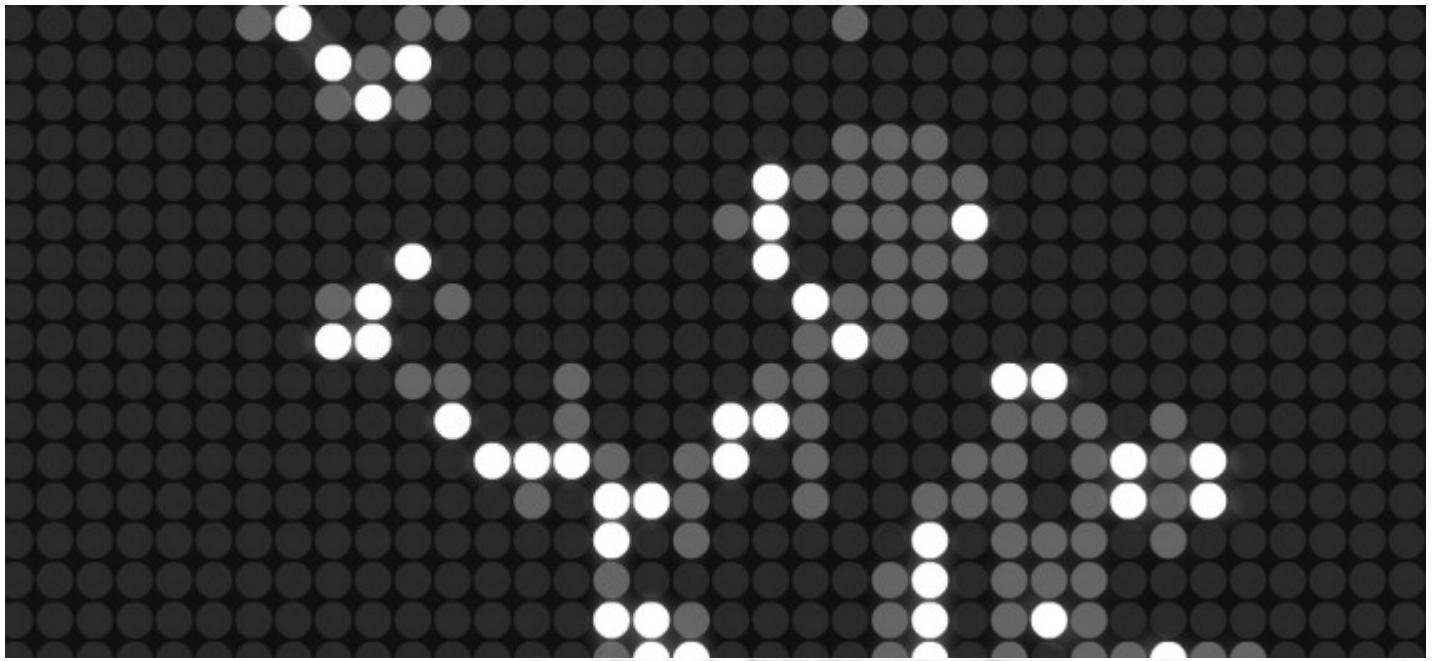
- Height field (*h*)
  - Pseudo-randomly generated
- Fluid capacity field (*c*)
  - $c = h * (c_{max} - c_{min}) + c_{min}$



Example paper textures, Source: Curtis et al.

The simulation

- Cellular automaton
  - Discretized 2D grid
  - Next state of cell depends state of neighbours



Source: http://blog.soulwire.co.uk/laboratory/flash/2d-cellular-automata

The simulation

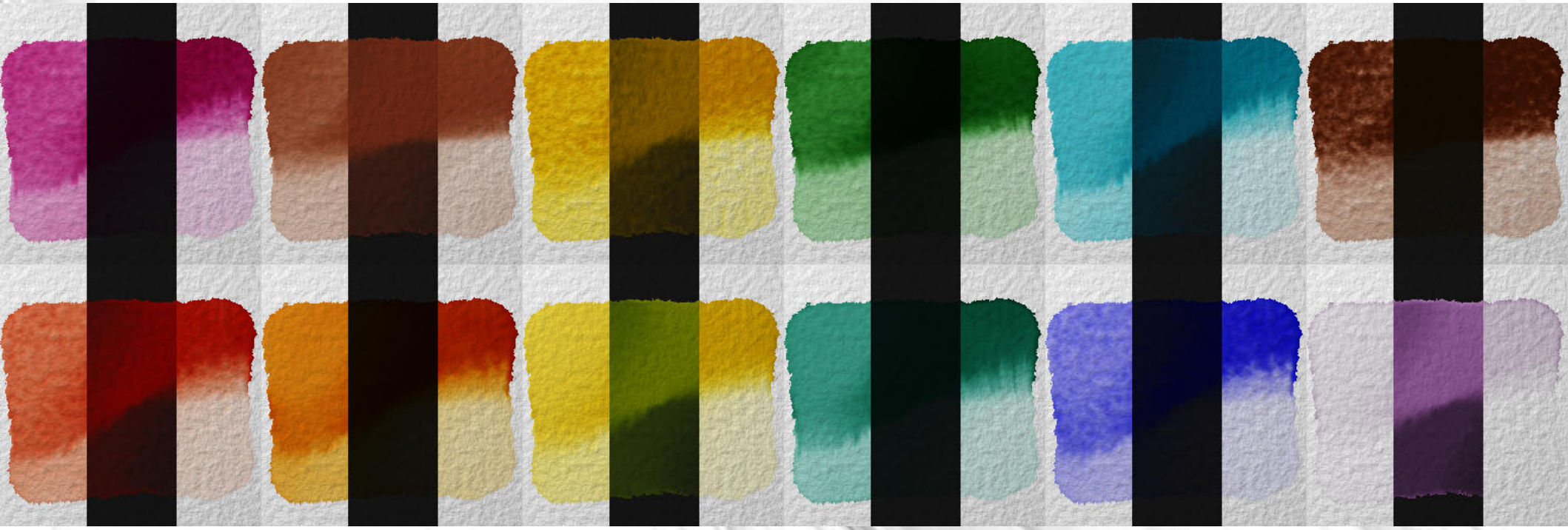
- Each time step, do the following
  - Move the water
  - Move the pigments
  - Transfer pigments (between layers)
  - Simulate the capillary flow

Moving the Water

- Differential equation, using forward Euler
- Boundary conditions enforce wet-area mask
- Remove water near edges of wet-area mask (edge darkening)

Rendering

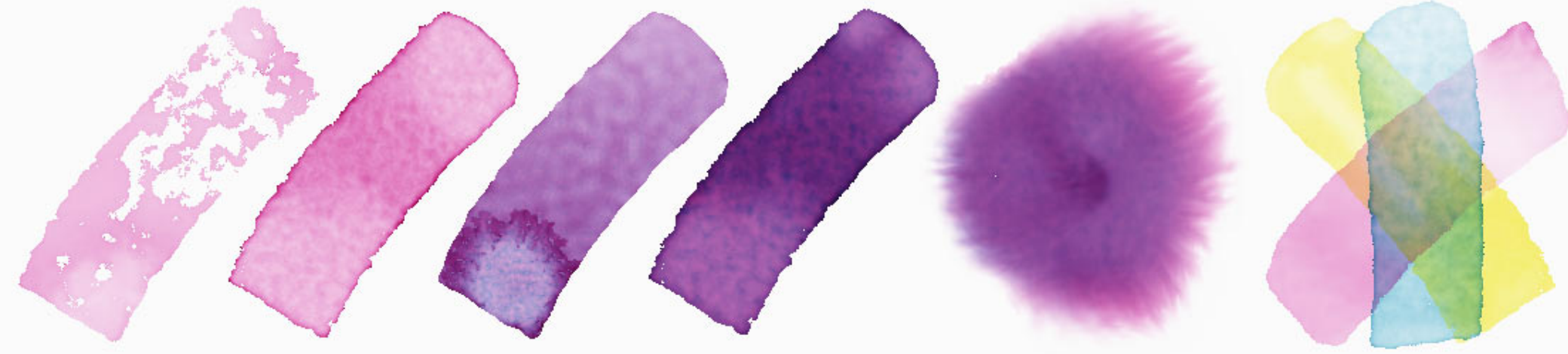
- Kubelka-Munk for optical composition of glazes



Optical composition of layers, Source: Curtis et al.

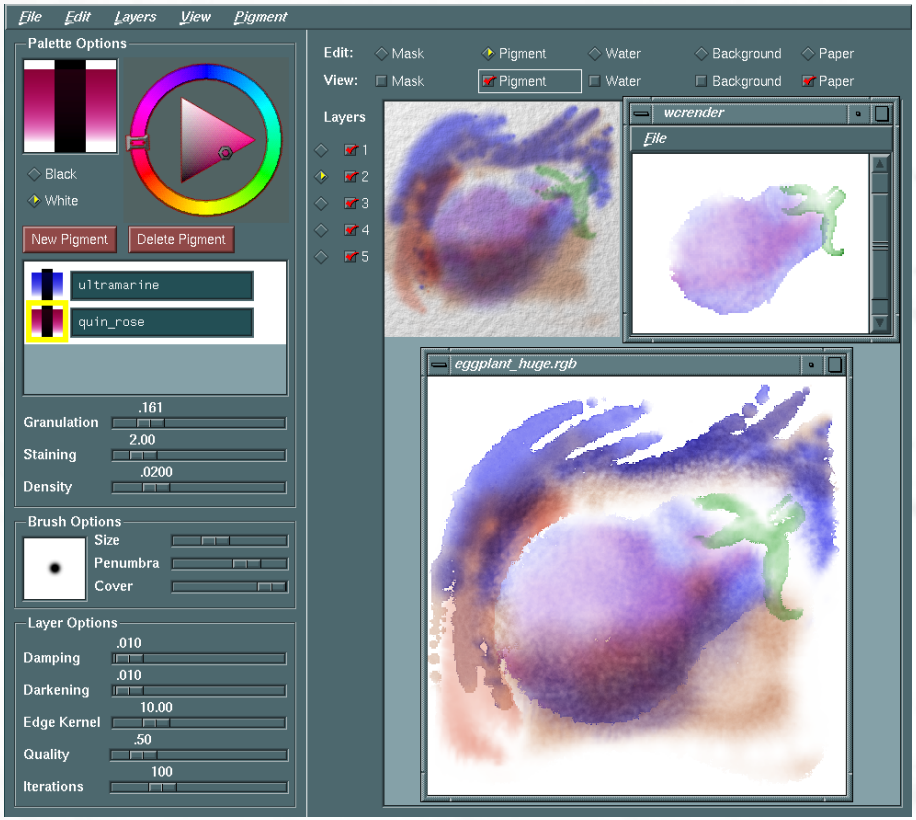
Real

Simulated



Applications

- Interactive painting
- Automatic image “watercolorization”
  - Brushstroke planning
- NPR rendering of 3D scenes



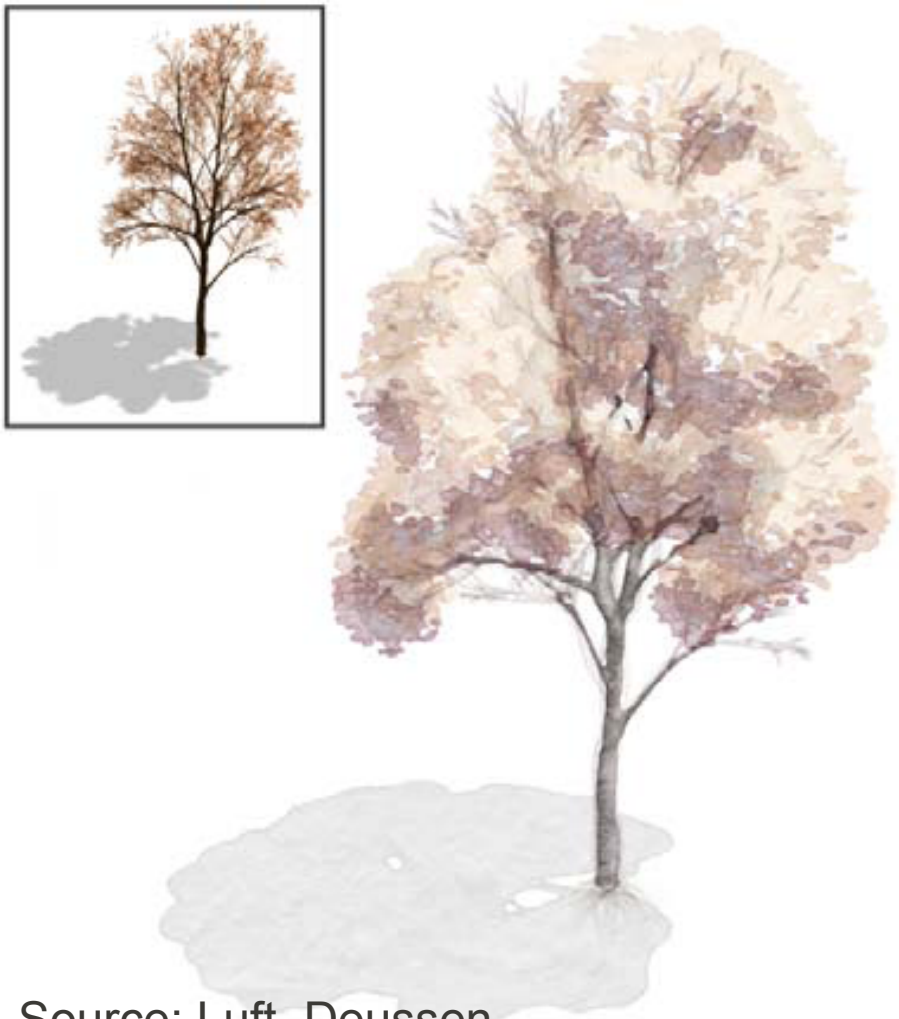
Interactive painting, Source: Curtis et al.

Limitations

- Speed (not real-time)
- Temporal coherence (“shower door” effect)
- Input parameters

Other approaches

- Blurred depth test
  - Frame-to-frame coherence
  - Real-time (shaders)
  - 3D models as input
  - Assumptions about the models (plants)



Source: Luft, Deussen.

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Questions?