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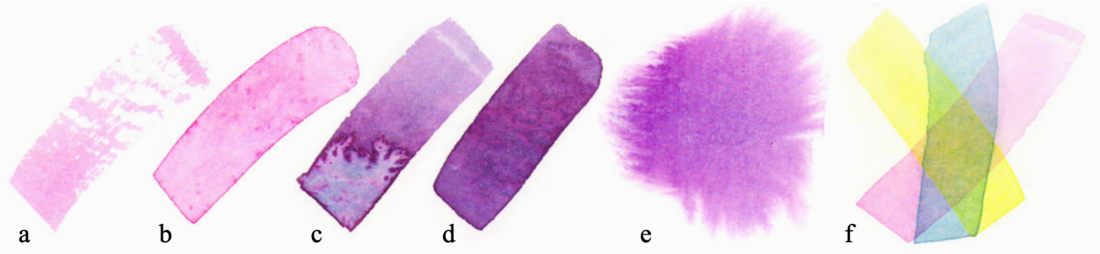
CPSC 679
Tuesday April 12

Simulating Physical Effects of Watercolor Painting

Final Project Proposal



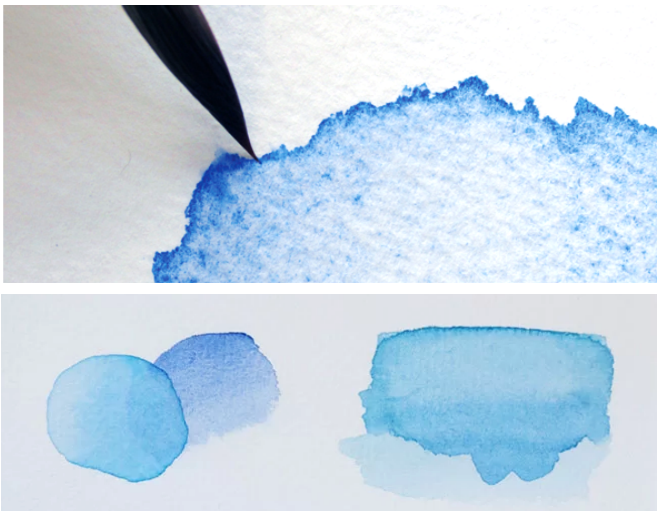
Real watercolor effects: drybrush (a), edge darkening (b), backruns (c), granulation (d), flow effects (e), and glazing (f). From Curtis et al. 1997.

Digital painting tools such as Adobe Photoshop, Procreate, and Corel Painter, to name a few, feature wide selections of brushes that emulate the look of countless drawing mediums (charcoal, ink, marker, pastels, etc.) on different surfaces. Among the drawing mediums, watercolor is unique because pigments are carried in water; water flows and moves, and the results depend on the amount of water and how it interacts/flows with the paper medium. Watercolor flows: capillary action diffuses water that is absorbed in paper. Unlike graphite, which for the most part is deposited onto paper and remains there statically (aside from smudging), watercolor changes and spreads over time, and its final image reveals its motion.

The main literature I will be implementing from is Curtis et al. 1997, *Computer-Generated Watercolor*. The paper implements all the watercolor effects (a-f) in the image above. They use the Kubelka-Munk (K-M) model to simulate the optical effect of multiple overlapping "glazes". For my final project, I would like to achieve a subset of these effects: edge darkening (b), backruns (c), granulation (d), flow effects (e), and basic glazing (f). Curtis et al. 1997 details the multiple parts of its simulation, from the main animation loop to all its sub-functions which facilitate each of the mentioned watercolor effects.

They present a three-layer model of simulating watercolors: 1) the *shallow-water layer*, where water flows above the surface of the paper, 2) the *pigment-deposition layer*, where pigment is absorbed by/desorbed from the paper, and 3) the *capillary layer*, where water is absorbed by capillary action. The paper utilizes a staggered grid and solves forward using Euler's Method. These layers are simulated sequentially each timestep. The methods of the main loop are, and in this order: *MoveWater*(), *MovePigment*(), *TransferPigment*(), and *SimulateCapillaryFlow*().

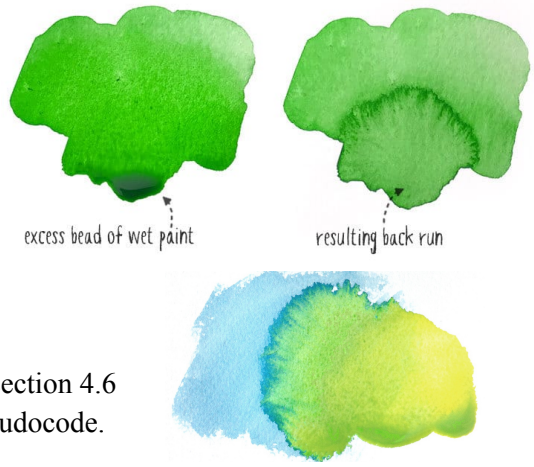
Edge darkening (aka hard edges)



When too much water is used, the surface tension of water does not allow the brushstroke to spread and be absorbed in the water. This causes the pigment to flow on the layer of unabsorbed water to the outer edges, creating a darker deposit at the edges of the stroke.

Edge darkening is described in section 4.3.3 of Curtis et al. 1997 in the *FlowOutward*() pseudocode. At every time step, an amount of water is removed according to the distance to the boundary of the wet-area.

Backruns (aka blooms, splotchiness)



Sometimes accidental and sometimes intentional, back runs are a wet-on-wet effect when water is spread back into a damp region of paint (a scenario would be trying to layer watercolors before the previous layer has not fully dried yet). When this happens, the wash dries unevenly and creates splotchy, darkened, or branching structures.

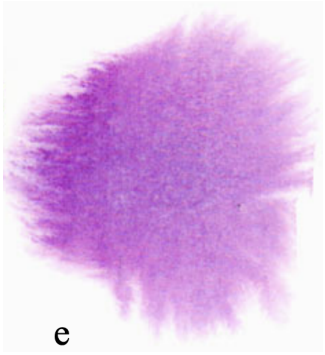
Backruns and simulating capillary flow is described in section 4.6 of Curits et al. 1997 in the *SimulateCapillaryFlow*() pseudocode.

Granulation

Granulation occurs when pigment particles clump together rather than settling evenly. Different pigment materials (artificial vs. natural earth pigments) have different particle sizes and thus granulate differently. Granulation yields a grainy texture, and accentuates the texture of the paper itself.

Granulation and general pigment adsorption and desorption effects are described in section 4.5 of Curtis et al. 1997 in the *TransferPigment*() pseudocode.

Flow effects (flow patterns)



Flow effects describe the general phenomena of wet-on-wet painting. They allow watercolor brushstrokes to spread freely and flow/spread on the paper. This results in soft, feathery edges that flow in the direction of the water flow.

Curtis et al. 1997 describes the behavior of water in the shallow-water layer and describes boundary conditions. It is described in section 4.3 and in the *UpdateVelocities*() routine.

Coloring and glazing

Initially, I will develop my simulation to only have one pigment color, and so darkness would simply be a function of the amount of pigment deposited at a location.

A stretch goal will be to use the Kubelka-Munk (K-M) model to optically composite glazed layers of watercolor. In the K-M model, rendering depends on each pigments' absorption and scattering coefficients, which are functions of wavelength. This method is described in section 5 of Curtis et al. 1997, which details formulas used to composite layers. It is also described in Sochorová and Jamriška 2021; their paper improves the unrealistic color blending found in current digital painting software.

Stretch goals

Stretch goals include implementing drybrush effects (a) and physically-accurate glazing. For improved glazing, I will also consult Sochorová and Jamriška 2021, *Practical Pigment Mixing for Digital Painting*, which describes a method using a latent color space (beyond three-channel RGB) to better simulate mixtures of pigments. I may also implement effect (a), drybrush, or a Backwards Euler method so that the flow animation does not depend on timestep.

All Together Now

Overall, I hope to simulate these flow effects of watercolor painting on paper. I will work to integrate this into our existing data structures (FIELD_2D, for example). I will consider this project successful if I can pre-deposit watercolor as squares on the canvas, and have it over-time spread and simulate the above-described effects of watercolor. I hope to get to rendering accurate colors and pigment mixing.

The next page describes a project timeline.

Timeline

All dates represent weeks of. For example, 4/11 means what I want accomplished by the end of the week, so by 4/17.

April 11

> ~~Complete project proposal due April 12.~~
> Read the paper again and again and again. Print it, annotate it, understand it.
> Implement basic 2D canvas, adapted from homework code or from 478.
> Plan program layout: create main loop, layout function declarations, plan source and header files, make sure everything makes and links.
> Develop data structures for a staggered grid and understand the methods in Curtis et al. 1997.

April 18

> Implement the shallow water layer: *MoveWater*, *UpdateVelocities*, *FlowOutward*.
> Implement the pigment deposition layer: *MovePigment*, *TransferPigment*.
> At this stage, only implement B&W (only one color pigment). Only when all three layers have been implemented and work on a single color should we move on to interaction between multiple pigments.
> By the end of the week, we should see water flow and pigment deposition. Edge darkening and granulation should work at this point. There is no capillary flow yet; pigments will not move after being deposited.

April 25

> Complete progress report due April 26.
> Implement the capillary layer: *SimulateCapillaryFlow*.
> If time permits and the program runs in real-time, implement a basic way for a user to interface with the canvas.
> If time permits, implement colored pigment rendering using the K-M model.
> If time permits, implement the dry brush effect.

May 2

> Prepare final animation demos to best present each intended watercolor effect.
> If time permits, implement backwards euler computation.
> Prepare for the final presentation on May 6.

May 9

> Final touches.
> Write final project write-up due May 12.

Sources Cited

Cassidy J. Curtis, Sean E. Anderson, Joshua E. Seims, Kurt W. Fleischer, and David H. Salesin. 1997. Computer-Generated Watercolor. In Proceedings of SIGGRAPH '97. 421–430.
https://maverick.inria.fr/Members/Cyril.Soler/DEA/NonPhotoRealisticRendering/Papers/p421-curtis.pdf

Practical Pigment Mixing for Digital Painting,
ŠÁRKA SOCHOROVÁ and ONDŘEJ JAMRIŠKA
https://dl.acm.org/doi/pdf/10.1145/3478513.3480549

Miscellaneous References

https://watercolour-workshop.com/preventing-hard-edges-in-watercolour/
https://www.erikalancaster.com/art-blog/exploring-watercolor-wet-on-wet-effects
https://www.watercoloraffair.com/all-you-ever-wanted-to-know-about-watercolor-granulation/
https://danielsmith.com/tutorials/jane-blundell-granulating-watercolors-what-why/