Fluid Computational Model for Mineral and Vegetal Pigments Diffusing in Chinese Color-ink Painting

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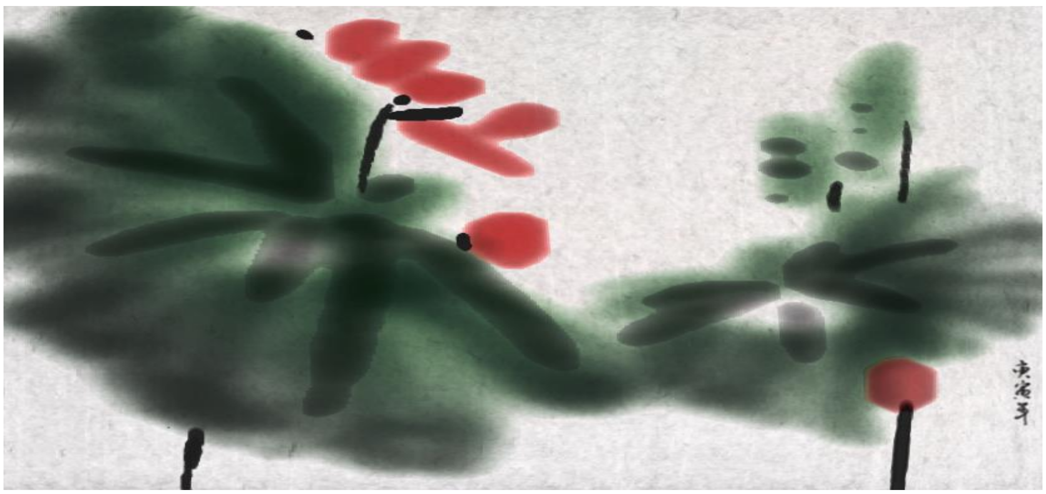

Figure 1: *A digital artwork created by using our system.*

ABSTRACT

In this paper, simulation of artistic vegetable and mineral pigments diffusing effects of Chinese color-ink painting is presented, using a novel physical model according to the Second Fick's diffusing law and Brownian motion theory. Due to the fact that generation of most art effects depends on complicated pigment-water motion simulation such as diffusing and pigment mixing on and under traditional fabric cotton paper (Xuan paper) surface, the proposed model is found effective for simulating the pigment-water motion in art creating process. Implemented on the GPU, the simulation operations in our system can be accomplished in a real-time manner. The effectiveness of the proposed techniques is validated in our developed Digital Painting System, where various art effects can be successfully re-produced including the Initial area-Darkened initial edge-Diffusion area-Lightened diffusion edge (IDDL) effect for vegetable pigments, the Initial area-Darkened initial edge-Diffusion area-Darkened diffusion edge (IDDD) effect for mineral pigments, and multi-stroke superimposing effects and achieves. In addition, quantitative evaluation is also introduced and shows superior performance of the proposed model in comparison with state-of-the-art techniques[1] .

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CCS CONCEPTS

• **Computing methodologies →Computer graphics →Animation** →Physical simulation

ADDITIONAL KEYWORDS AND PHRASES

Pigment Diffusion, Chinese Painting, Mineral Pigments, Vegetable Pigments

1 INTRODUCTION

Generating non-photorealistic in traditional art styles is a challenging topic in computer graphics[1] and digital media[2], where Chinese color-ink painting is one of these fantastic colorful art styles. Chinese color-ink painting takes water as a major medium, and paints with special ink and pigments. The artworks often exhibit beautiful textures and strokes that are created by interactive motion between water and pigment particles across fabric Xuan papers. However, most of the existing techniques failed to provide a simulating model applicable both for variant vegetable and mineral pigments diffusion and multi-stroke superposition, to this end, we aim to propose a novel physical model to simulate water-pigment diffusing effects and produce

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i3D 2018 Posters, May 15–18, 2018, Montreal, Canada
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various kinds of vegetable and mineral pigments diffusing and superimposing art effects which are unique to Chinese color-ink painting by only adjusting several parameters.

2 DIFFUSION MODEL

2.1 Theory Basis

As a good description of mass transfer phenomena, we choose Fick's [3] diffusion theory to simulate the water and pigment diffusing process. The diffusion coefficients are obtained by Brownian's motion theory [4]. we model the physical diffusing process in two stages. The main character of the first stage is pigment particles flow driven by water convection motion. In the second stage, the main character is Brownian motion of pigment particles in water environment.

2.2 Paper Model

In real color-ink drawing, the structure of paper affects water flow and ink diffusion greatly. For simplicity, we assume that flow layer of our paper model is consisted of individual fibers and their interweaving networks as introduced in [5]. By setting various values for the parameters the effect of different kinds of "Xuan" paper can be generated, according to which the simulation results are also different just like real painting.

2.3 Simulation Process

2.3.1 Simulation of Water Particles Diffusing. To simulate water behavior on the surface of flow layer, the diffusion process is assumed to be constrained by Fick's law. During the diffusion process, since the water concentration is variable, according to Fick's second law and the Taylor series expansion, we can achieve the Simulation of Water Particles Diffusing. In particular, variable permeability of paper is one key element in our model that works on the different diffusion patterns. We use blocking factor which is fractional value to represent the permeability of each site of paper, denoted as k. The higher the k is, the harder diffusion would be. We can set variable values and distribution of k to model paper's special attributes.

2.3.2 Simulation of Pigment Transportion. Pigment transport processes in the paper may be divided into two categories: advection and diffusion. Advection refers to transport with the mean water flow. In contrast, diffusion refers to the transport of compounds through the action of random Brownian motions. Like water diffusing simulation, we achieve the Pigment Transport Simulation according to Fick's Second Law.

2.3.3 Simulation of Water Evaporation. Water evaporation is mainly affected by three factors, the environmental temperature, the external area of the liquid exposed to the air, and the speed of air flow on liquid surface. Here we only consider the external area of the liquid exposed in the air, on the premise of taking the environmental temperature as a constant and ignoring the air flow on liquid surface. Since water particles distribute evenly in fibers of paper, the amount of water evaporation in a unit area within unit time is a constant. We do this by reducing the water concentration at a rate of ε_a, where $\varepsilon_a \in [0,0.003]$ is used in our simulation.

2.4 Pigment's Fixture on the Paper Fibers

During the process of pigment diffusion, pigments in the flow layer are gradually transferred to the fixture layer, because the particles' velocity is relatively low and be easy to be captured by paper fibers. Furthermore the transfer is a two-way process, because some real dried pigment particles can be washed away by water. To satisfy the realistic pigment conditions, we propose a simple pigment fixture algorithm. The data in the flow layer and fixture layer is updated by GPU.

3 COLOR RENDERING

The result of real-time color computing depends on the kinds of pigment particles and their respective concentration on the paper location, for which we have to solve two problems. The first is how to compute multiple pigments mixing. The second is how to compute color superimposing from multiple overlapping strokes. In order to solve these rendering problems for pigment mixing and multi-stroke superimposing, we incorporate the Kubelka-Munk (KM) model[6] to perform the optical compositing of various kinds of pigment.

4 EXPERIMENTAL RESULTS

Based on our water-pigment diffusing model, we have developed an interactive system that allows users to paint the color-ink painting in real-time with visual feedback. For the painting system, the virtual brush could be controlled dynamically, provided that the brush touches paper with sufficient strength, and the brush will deform dynamically and produce different color of the brush trail on paper simultaneously. Meantime, the diffusion starts as soon as the color is shown on the paper.

5 CONCLUSIONS AND FUTURE WORK

In this paper, we have introduced a novel water-pigment diffusing model based on Fick's diffusing law and Brownian's motion theory. Our model doesn't merely imitate the superficial effect, but also the process in real time, which makes the result more vivid and intuitive. Through adjustment of a series of parameters, various effects can be achieved via controlling relevant aspects of the diffusion process. This model has been successfully applied in a digital painting system and also Mobile phone platforms. Some digital artworks painted with our system are shown in Fig. 1. We hope the proposed model and techniques can be widely used and extended in the field of 3D water-ink simulation and other related areas in future work.

ACKNOWLEDGMENTS

We would like to thank the color-ink painting artist Yi Shang who created many artworks by our software system. This work was supported by the grant [61572351] [61772360] from the National Natural Science Foundation, China.

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