Combining Multiple Flow Fields for Editing Existing Fluid Animations

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Abstract

In this paper, we develop a method for synthesizing desired flow fields by combining existing multiple flow fields. Our system allows the user to specify arbitrary regions of the precomputed flow fields and combine them to synthesize a new flow field. In order to maintain plausible physical behavior, we ensure the incompressibility for the combined flow field. To address this, we use stream functions for representing the flow fields. However, there exist discontinuities at the boundaries between the combined flow fields, resulting in unnatural animation of fluids. In order to remove the discontinuities, we apply Poisson image editing to the stream functions.

Keywords: fluid, combining multiple flow fields, incompressible

Concepts: •**Computing methodologies** → **Animation;** *Physical simulation;*

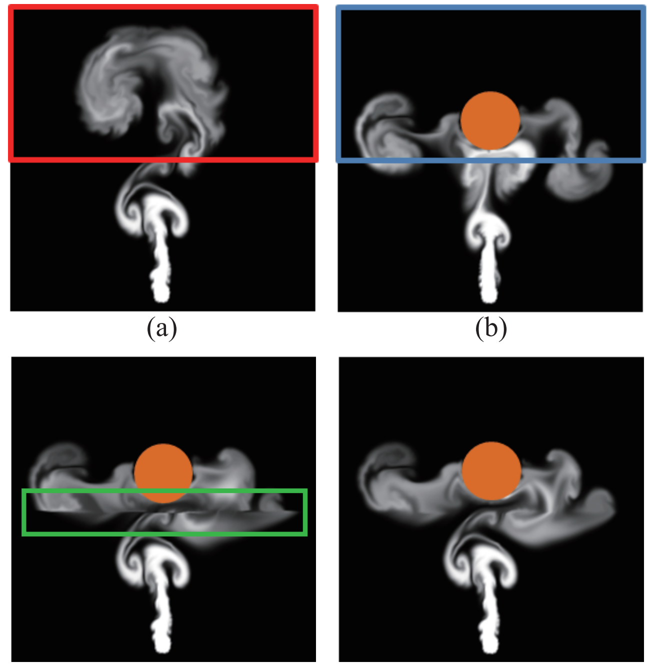
1 Introduction

The physically-based simulation of fluids has become an important element in many applications, such as movies and computer games. However, computational costs are very expensive for executing the physically-based simulation. Therefore, animators might reuse existing fluid animations to different scenes. In this case, editing of the existing flows, such as adding obstacles, might be required. However the fluid simulation must be executed for adding the obstacles in the existing flows.

In this paper, we develop a method for reusing existing flow fields at different scenes by combining multiple flow fields. Note that incompressibility is not satisfied, if flow fields are simply combined. To address this problem, we could preserve incompressibility by using vector potentials [Bhatia et al. 2013]. In this paper, we focus on 2D flow fields for experiments, so the vector potentials are scalar functions called stream functions. However, large velocities are caused by discontinuities of the stream functions at boundaries of synthesis regions, if the stream functions are simply combined. Therefore, our method applies a Poisson Image Editing [Perez et al. 2003] to the stream functions, to reduce the discontinuities. Our method can create desired flow fields by combining multiple existing flow fields.

2 Our Method

First, our method precomputes stream functions Ψ from input velocity fields $\mathbf{u}$ calculated by using a fluid simulation (Please refer to [Bhatia et al. 2013] for details). Next, in runtime process, we combine multiple velocity fields. For the sake of clarity of explanation, we treat a case using two dataset, Ψ_a and Ψ_b. The user specifies a region Ω_b used for a synthesis in Ψ_b, and also set a region Ω_a where synthesize Ψ_b in Ψ_a. Then, we replace Ψ_a to Ψ_b in the specified region, and obtain a replaced stream function Ψ^*. Next, we apply Poisson Image Editing [Perez et al. 2003] to Ψ^*. In detail, our method calculates Poisson equation $\Delta\tilde{\Psi} = \Delta\Psi^*$ with a boundary condition $\tilde{\Psi} = \Psi_a$, where $\tilde{\Psi}$ is a resultant stream function and Δ is Laplace operator. Finally, a resultant velocity field is obtained by applying curl operator to $\tilde{\Psi}$.



(a) (b) (c) (d)

Figure 1: *Comparison of our method and a simple synthesis. (a) and (b) show two input animations. (c) shows the results generated by simply replacing the stream functions. (d) is synthesized by using our method.*

3 Result and Future Work

Fig. 1 shows a result created using our method and an example created by simply replacing input stream functions. The number of grid points for each velocity fields is 256×256. The flow fields are visualized by advecting the smoke density and orange circles indicate obstacles. The red and blue lines on (a) and (b) are user specified regions used for synthesis. (c) is generated by simply replacing the stream functions from (a) to (b). (d) is synthesized by using our method. As shown in (c), discontinuity can be found in the green rectangle. In contrast, our method can combine multiple flow fields with less discontinuities. The videos corresponding to these examples and other results, comparisons with other methods

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can be found in the supplementary material.

One of the limitations of our method is the fact that the flow fields generated by our method might have discontinuities at the boundary of synthesis regions, if both flows are largely different. To address this problem, we detect regions that has smaller error between flow fields used for the synthesis than user specified regions. In addition, we will develop a method for realizing faster synthesis.

References

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