Image Based Flow Visualization

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Based on
Image Based Flow Visualization
by J. van Wijk

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Proceedings of ACM SIGGRAPH 2002,
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Introduction

- Fluid flow is dominant in many fields, for instance climate prediction, industrial processes, thermodynamic flows etc. Animation is crucial for physical insight.
- Computations are usually done on large data-sets and high resolutions.
- The method proposed by the author produces efficient visualizations of *unsteady flows*.

Basic Idea

Basic idea for *Image Based Flow Visualization* (IBVF):

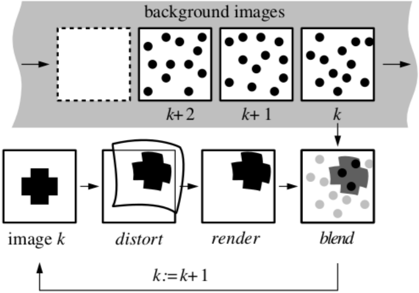

Figure 1: Pipeline image based flow visualization

Formal Setup

$\boldsymbol{v}(\boldsymbol{x}, t) \in S \subset \mathbb{R}^2$

Path lines $\boldsymbol{p}(t)$, following $d\boldsymbol{p}(t)/dt = \boldsymbol{v}(\boldsymbol{p}(t), t)$.

For a field (image) $F(\boldsymbol{x}, k)$ representing some property of the flow we have:

$$F(\boldsymbol{p}_{k+1}, k+1) = \begin{cases} F(\boldsymbol{p}_k, k) \text{ if } \boldsymbol{p}_k \in S \\ 0 \text{ otherwise} \end{cases}$$

Problem: this leads to an empty (black) space.

Formal Setup

Solution: blend with background.

$$F(\boldsymbol{p}_k, k) = (1-\alpha)F(\boldsymbol{p}_{k-1}, k-1) + \alpha G(\boldsymbol{p}_k, k)$$

where α is called the *blending mask*.

If we write out the recurrence:

$$F(\boldsymbol{p}_k, k) = \alpha \sum_{i=0}^{k-1} (1-\alpha)^i G(\boldsymbol{p}_{k-i}, k-i)$$

Background Image Generation

What type of background images should be used?

Completely random: variation too strong and no streaming.

Make G periodic:

$$G_{i,k} = w((k/M + \phi_i) \mod 1)$$

Phase Profiles

Different phase profiles lead to different textures:

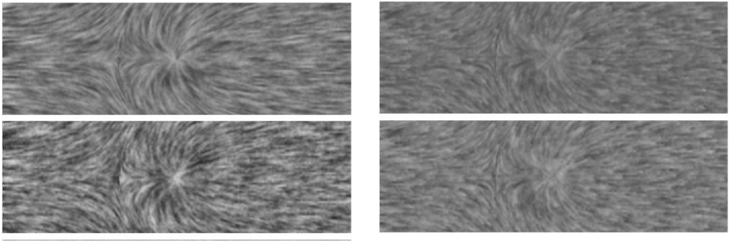

Figure: Results for different profiles: cosine (upper left), square (lower left), exponential decay (upper right), saw tooth (lower right).

Algorithm

- Calculate a distorted mesh R according to flow lines (in case of unsteady flow).
- Render R, texture mapped with the previous image.
- Overlay a random noise pattern in the rectangle and blend with a factor α, whereas the texture mapping of R is blended with a factor $1 - \alpha$.
- Draw injected dye (if present).
- Render combined image on screen, together with overlay.

Results

See demo:

- Meshes.
- Grid generation functions.
- Layouts (arrows, particles, topology, smeared, warped).
- Values for α.

Efficiency

High degree of efficiency because of:

- Highly optimized for use on graphics cards.
- Only 2 operations over the screen used per frame.
- Exploiting frame to frame coherence.
- Velocity field resolution is smaller than image resolution.

Developments

- IBFV model has been implemented in 3D.
- There are many methods using similar techniques like LEA, UFAC, UFLIC and many others.
  See website by Dr. Zhanping Liu.

A. Telaru, J. van Wijk *3D IBFV: Hardware-accelerated 3D Flow Visualization.*, 2003, Proceedings of the 14th IEEE Visualization Conference, 233-240

http://www.zhanpingliu.org/research/flowvis/auflic/comparison.html

The End

Questions?