Time-Coherent Streamline Placement

Bachelor's Thesis

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Abstract

Vector field visualizations are used in many fields like aerospace engineering, fluid dynamics, or physics. A common graphical representation of such fields are instantaneous integral lines, called streamlines. The placement of such streamlines for a continuous and steady vector field is subject of contemporary research, with a multitude of algorithms that can generate such streamline placements in an optimal way w.r.t different criteria. This thesis's focus will be on the time-coherent placement of streamlines, i.e. minimizing streamline movement during changes of the underlying continuous, but unsteady vector field. We present an iterative procedure that starts by seeding streamlines with a greedy algorithm for a single timestep. The seeds are then optimized to make them time coherent for as many lines a possible. The performance and complexity using different streamline seeding and modification strategies are examined and compared. Finally some limitiations, possible imporovements, and ideas for future work will be listed.

Zusammenfassung

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Contents

1 Introduction

For steady fields, there are several papers showing different strategies to generate streamlines according to different criteria. Commonly preferred attributes are high streamline length, and uniform line density, which are often labelled as "coherence". Both of which greatly enhance the information uptake by preventing visual clutter; thereby allowing a focus on more important features and characteristics of the field at hand. As soon as a change in the field is introduced, however, these methods are no longer optimal when examined over the entire time span. Therefore, we will start by introducing a new criterion termed "temporal coherence" (opposed to the aforementioned spatial coherence). This essentially defines how lines move through time; low coherence means a lot of movement. For a more detailed explanation, see the next section. The procedure outlined by this paper has a simple modus operandi: We start by generating a spacially coherent streamline structure for every time step using a greedy algorithm. Then we start walking along the generated lines, trying to find those of high temporal cohrence, and keep them. The others we try to optimize by moving their seeds around, or, if no sensible movement is possible, simply delete them. In the final step, we fill the blank spaces left by the deletion according to the chosen seeding algorithm, and are finished.

1.1 Problem Statement

Creating animations containing streamlines is difficult because streamlines are not time-coherent when generated using conventional methods described in ...

1.2 Proposed Solution

By adding the time coherence constraint, animated streamline visualizations look much better and do not introduce aritfacts etc. etc.

2 Related Work

Most of the works published in the field of streamline placement present algorithms that can be divided into two categories:

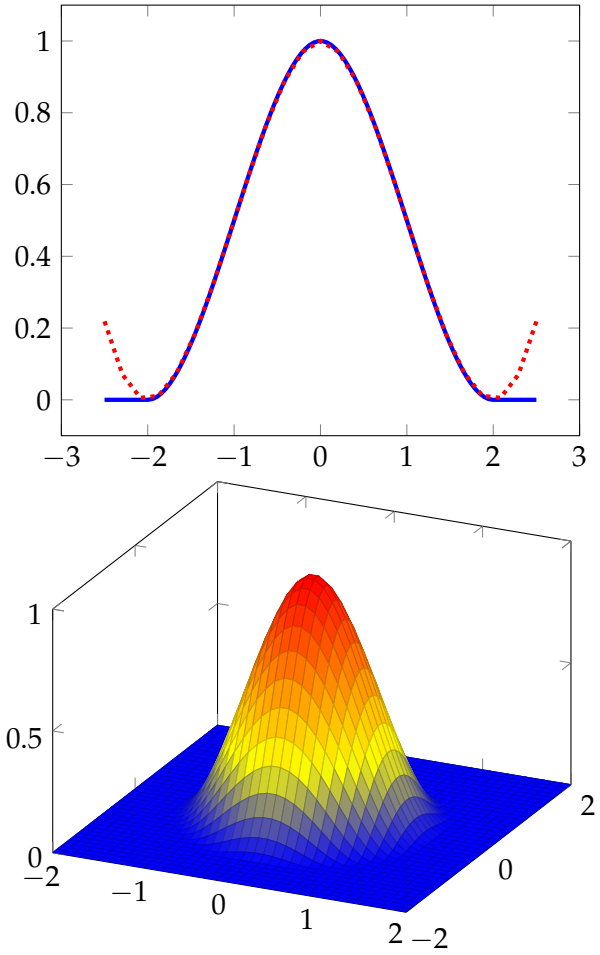
2.0.1 Image-Guided

The goal of this approach is to achieve a very uniform, almost "hand-drawn" appearance. Generated images will usually have high visual quality, at the risk of potenitally missing or misrepresenting important features.

One of the first and most prominent examples in this category was written by Greg Turk and David Banks [96]. In their research paper, a function (called the "Energy Function") is defined such that it maps an input image containing the potential streamlines to a scalar. The scalar represents the quality of the image, roughly defined as the uniformity of the grey scales it contains. Adding/moving/removing/resizing streamlines is done randomly, at every step the energy function is used to determine whether the change gets accepted or discarded. The algorithm is finished when the energy function reaches a minimal threshold, or a maximum number of consecutive rejected steps is exceeded.

2.0.2 Feature-Guided

Feature-Guided algorithms examine the underlying field structure before placing seeds. They search for critical points or patterns in the field and then seed around them, capturing them in much higher detail. The resulting images inherently represent the critical points much better, at the cost of some visual appeal compared to the aforementioned group.



2.0.3 Other Relevant Works

- Time Coherence in 2D
- Approach I've used so far due to simplicity

Do not forget to use references [Han+19] like done here [HS19] to enable the bibliography [Jun+17; SJMS19; SRS18; ZRLS19].

3 Fundamentals

3.1 Vector Fields

A vector field represents how vectorized elements act over a spatial domain. Intuitively, this means that for every point in a domain we can obtain the force that acts at that point.

3.1.1 Definitions

More formally, a vector field can be defined as a map from a domain of points to a vector. We can write it as an n-m-valued function, mapping an n-dimensional input to an m-dimensional output. In this thesis, we will only care about cases of $n = m$ in two and three dimensions.

There are several ways such fields can be obtained, a simple algebraic definition could be e.g. $u(x, y) = (1, 0)$. This gives us a field that represents a force of magnitude one towards positive x and no influence on the y component.

If we want our force to not only depend on spacial input, but also on another scalar like a time component, we write this as $u(x, y, t)$.

Vector fields are called *steady* if they do not have a time component, otherwise they are referred to as *unsteady*. Another distinction is *continuity*, this is the same as the algebraic definition for other functions. The fields in this paper are all going to be continuous.

3.1.2 Critical Points

A vector field can have points with special characteristics, called critical points. In the 2D case, there are only four commonly used critical points:

- Source: Given a field such as $u(x, y) = (x, y)$, we can see that to every point applies a force away from the origin. If we think about this as the flow of a liquid, then this would mean that (in the case of noncompressible flow) liquid is *created* at the point $(0, 0)$. We therefore refer to such a point as a *source*.

- Sink: Similarly, $u(x, y) = (-x, -y)$ would give us a *sink* at $(0, 0)$, essentially destroying liquid.
- Saddle: A saddle is an area where liquid is compressed in one direction, and stretched in another, e.g. by $u(x, y) = (-x, y)$
- Periodic orbit: $u(x, y) = (-y, x)$ creates circular paths around the origin, where after travelling a distance of $2\pi r$ you will end up at the point you started with. These critical points are therefore called *periodic orbits*.

3.2 Streamlines

Given a vector field u and a point P, we can trace the movement of this point through u by integrating over the field. Intuitively, we just step through the field by choosing the next point $P_n = P_{n-1} + c * u(P_{n-1})$, with c being a step size scale. If we do this an infinte number of times with positive and negative values for c, we end up with a set of points S we have passed through, which defines the streamline. S has two notable properties:

- For every point P inside this set, the direction of its derivative is equal to $u(P)$. This means that the streamline is tangent to the vector field at every points.
- No matter which point inside S we use as P_0, we will always obtain the same set S as its streamline.

Any point inside S is referred to as a *seed*, yielding the streamline S.

3.2.1 Spatial Coherence

If we want to visualize a vector field, we want its features to be easily identifiable. At the same time, we do not want to introduce distractions or artifacts due to the visualization technique. Deciding factors of uniformity in streamline visualization are streamline length and density. Longer streamlines make for a smoother appearance, whereas many short lines tend to obfuscate and hinder recognition of important features like critical points.

3.2.2 Maybe Temporal Coherence?

4 Method

At first, a heuristic criterion for temporal coherence between stream lines is defined. Then ...

- old implementation
- issues, why sth else was used
- turk and banks
- why turk and banks? (spacial coherence?)
- time coherence definition

4.1 Temporal Coherence

Temporal Coherence refers to how a vector field behaves through different time steps. Intuitively, we consider areas within the field to be of high temporal coherence if the lines drawn on them are relatively stationary. Vice versa, we can say that an area of high fluctuation will be of low temporal coherence. A more formal definition employed in our algorithm is as follows: Given a field F and a starting point S_0 (called the "seed"), we can integrate over the field. This yields a set of points S^0 which define a streamline containing every reached point, written as $S^0 = \int(S_0, F)$. We can therefore assign a streamline to every point in our field (and vice versa). Given S_0 and an unsteady field $F(t)$, compute for each time step $t_1 ... t_n$ the streamline $S^{0,t_i} = \int(S_0, F(t_i))$. In order to convert these sets of lines to a scalar, we use the Hausdorff Distance $dist(S^i, S^j)$, giving us the greatest minimal distance between any pair of two sets. We can therefore create a map $coh(S_i, F(t)) : max(dist(\int(S_i, F(t_k)), \int(S_i, F(t_l))))$, sending each point in an unsteady vector field to a scalar, and thereby determining its temporal coherence.

4.2 Technical details

4.2.1 Energy Measure

The method used by Turk and Banks defines three important components to measure image quality as the sum of deviations of a low-pass image from a uniform greyscale target.

1. The first component is a collection of (straight) line segments from each line, each of which can be converted to a line formula of the form $p = start + (end - start) * c$. The formula is then evaluated to obtain points as pixels where the low-pass filter in the 2nd listing is applied. In their paper, they call the implicit image obtained from the line segments' footprint I.

$$I(x,y) = \begin{cases} 1, & \text{pixel lies on line} \\ 0, & \text{else} \end{cases}$$

2. The second component is the low-pass filter L. It uses a kernel to generate the filtered image of a line. Given a falloff distance R and $r = \sqrt{x^2 + y^2}/R$, the kernel is defined as:

$$K(x,y) = \begin{cases} 2r^3 - 3r^2 + 1, & r < 1 \\ 0, & r >= 1 \end{cases}$$

   For every pixel a line passes through, this kernel is applied additively, with its origin centered on the pixel containing the line. When applied consecutively along a line segment, the kernel will overlap and produce numbers from 1 to R for pixels close to the line.

3. In order to determine the energy of the image generated by the kernel application, the following expression is used:

$$E(I) = \int_x \int_y [(L * I)(x,y) - t]^2 \, dx \, dy$$

   With t referring to the *target brightness*, in their source code the number one is used.

Our implementation works similarly, except that instead of the cubic Hermite filter, we use a two-dimensional Gauss filter. We also use the distance R as the radius of

the filter, and calculate a small segment of a straight line in order to determine how the brightness of the filter should be scaled to reach $1.5t$, so that we do not have to deal with differences depending on integration step size. More precisely, given the radius R and filter diameter $D = 2R + 1$, we define a line footprint $A \in \mathbb{R}^{D \times D}$:

$$A_{x,y} = \begin{cases} 1, & x = R \\ 0, & \text{otherwise} \end{cases}$$

We then apply our filter with $\sigma = R/3$, and use $1.5t / A_{[R,R]}$ as our filter scale s, (in our case $t = 1$). Having obtained the filter scale, we can now compute the filtered image $L * I$ as $L * I = s \cdot Gauss(I, \sigma, R)$. The computation of $E(I)$ is otherwise identical.

4.2.2 Randomized Optimizations

Turk and Banks define six actions:

- **Insert, Delete:** Add or remove a line from the image.
- **Lengthen, Shorten:** In-/Decrease the length of a line on one or both ends.
- **Combine:** Join two lines head-to-tail.
- **Move:** Translate the seed of a line by a small distance.

These actions are selected randomly with random parameters, then applied to a random line. The algorithm terminates after an energy range was reached, or accepted changes become rare enough to not introduce changes anymore.

If the change was deemed beneficial according to a decrease in energy, it is accepted, otherwise the changes are reverted. This causes a "drift" of the lines toward a more uniform energy level. Naturally, this depends heavily on the choice of t. If t were to be chosen closer to 2, the image would become very crowded to reach the increased target gray level.

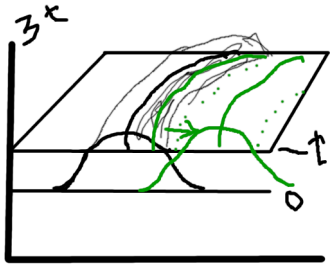


Figure 4.1: A line (green) being shifted away from an existing one (black)

We have chosen to keep most of these actions as-is, the only difference introduced

is a change to how the lengthening and shortening is done. Instead of the two binary choices of lengthen/shorten and front/back, which only add/subtract a tiny bit at a time, we decided to choose a segment count at random between -5 and 5 for each end. This allows faster growth/shrinking (and hence faster convergence) while still preventing overlaps.

4.2.3 Initial Seeding

We prepare the image for the optimization routine by adding many streamlets with seeds on a regular grid to the image. This can also be done randomly yielding similar image quality, however strided access is more efficient with little to no benefit for the latter.

4.2.4 Oracle

The oracle from Turk and Bank's algorithm is used to suggest shorten/lengthen and move operations. Our oracle focuses on shorten/lengthen suggestions only.

4.2.5 Adding time coherence

We added two important modifications to the aforementioned algorithm to make it partially time-coherent. The first modification affects how seeds are chosen in the beginning of an optimization pass; the second affects how the energy measure is computed and lines are guided toward their final positions.

Shattering

At the end of a time step's optimization phase, we break every streamline apart into smaller streamlets. This leaves each line with the appearance of simply being a dashed line, with each fragment having its own seed. The seeds obtained this way are then used as the initial seeding strategy for the subsequent frame; the regular grid is only used for the first frame. This way, we obtain many seeds that, if the field does not change too much, will quickly merge back into the line they came from. If the field *does* change, some segments will still reconnect and therefore keep their temporal coherence, whereas areas of strong fluctuation will connect to different seeds. This results in changes being limited to parts where change is necessary, and not affecting streamline trajectory too much on a global level.

Coaxing

Since the energy function is used to move the image toward a constant desired target brightness, we achieve a uniform spacing of lines. Unfortunately, this does not guarantee the lines be placed at similar positions as they were in the previous frame. In order to coax the algorithm into favoring previous line positions, we modify t to not be a constant anymore. Instead, given the previous frame's L (written L') we replace t with $T \in \mathbb{R}^{x \times y}$ defined as

$$T_{x,y} = t + \left(L'_{x,y} \Big|_0^{2t} - t \right) \cdot 0.4$$

The remaining operations stay the same, so our new energy expression becomes:

$$E(I,T) = \int_x \int_y [(L * I)(x,y) - T(x,y)]^2 \, dx \, dy$$

This gives us some more fine-grained control of where lines will end up. Due to the squishing of the typical $[0, \approx 2t]$ domain of the last filtered image to only $[-.4t, .4t]$, we soften the impact of the previous frame. Otherwise, adding a line at the exact same position would only yield the target brightness, causing a bunching of lines around these footprints.
How does choosing the Gauss filter impact the ditches left by time coherence in the field?

Combined

Combining shattering and coaxing, we obtain a somewhat reliable way of generating streamlines according to the footprint left behind by the last frame. The seeds created during the shatter process all lie inside the "valley" left behind by the previous streamline path. Due to the coaxing function of the modified energy measure, it is unlikely that they will leave this valley without a change in the field forcing them to.

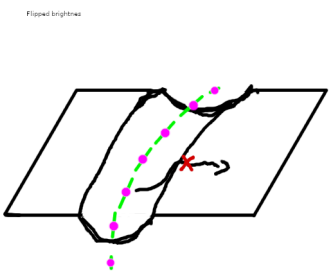


Figure 4.2: The Fragments' seeds (magenta) "trapped" inside the footprint of previous line

Due to the seeds being held in place in this way, it is very likely for them to rejoin to form the same lane they originated from. If the field changes drastically

in this region, the seeds can not fully connect to each other anymore, and will instead gravitate to a different footprint, forming long patches of coherent lines with interconnections between different paths.

5 Implementation

This chapter briefly mentions the used libraries, and focuses on the initial implementation of - and iterative additions to - the proposed algorithm.

5.1 Libraries

The algorithm is implemented in python3.10, and heavily relies on three libraries which are not part of the python3.10 standard library:

- Paraview v.5.12.0: A Scientific visualization software, combining data science and interactive visualization while providing custom algorithm support via the VtkPythonAlgorithm base class.
- VTK v.9.3.20231030 : The library used to manage anything related with the data to be visualized in Paraview.
- Numpy v.1.23.4: Widespread data manipulation/scientific computing library, which is used to edit the data encapsulated by VTK's objects.

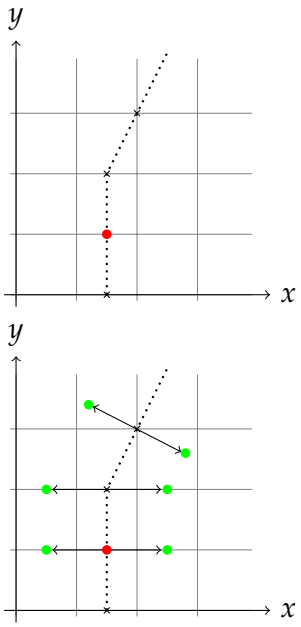
5.2 Steady Field Streamline Placement in 2D

We start with a simple algorithm to generate streamlines in a 2D slice of a vector field. The local z-component of the Cartesian grid is simply set to zero for the relevant sections of the algorithm. The algorithm uses two operations: Streamline Traversal and Seed Filtering, which are executed round-robin.

5.2.1 Streamline Tarversal

The Streamline Traversal process works as follows:

- **Step 1:** Choose a seed point from a list of candidates (initially an arbitrary point from the dataset) and remove it from the list. Then integrate forward and backward to obtain the other points on the streamline, until a number of steps is reached, we cross the bounding box, or we get too close to another streamline.
- **Step 2:** Compute the normals, add and subtract them to the succeeding point. The first point (according to step count in backward iteration) will not have a preceding normal, and is not used in this step. These points are new seed candidates for further streamline placement.



5.2.2 Seed Filtering

Since after the 1st iteration, roughly half of the points added by step 2 will be very close to the preceding iteration's points, we store the parent's points and remove any new points from the current step if they are too close to the parent's points. Furthermore, a grid is used to track the global state of the field w.r.t to lines existing in individual segments. This is used to determine whether a line is getting too close to another or if it has room to expand. Streamlines are removed if their length is shorter than 10 iteration steps.

5.3 Steady Field Streamline Placement in 3D

Instead of the trivial normal(s), we now use a normal plane around the streamline trajectory, created via numpy's QR-decomposition. The algorithm returns orthonormalized vectors, the first column vector's direction being equal to the first provided input vector. We can therefore feed it the streamline trajectory and two basis vectors, and receive 2 orthonormal basis vectors b_0, b_1.
With i being the complex number, we obtain k roots of unity via

$$n_j = e^{ji2\pi/k}, j = 0, 1, ..., k-1$$

We then transform them into our 3D frame of reference using

$$v_i = re(n_i) * b_0 + im(n_i) * b_1$$

This gives us k uniformly placed vectors in the normal plane around the current streamline segment. The rest of the algorithm stays largely the same, the grid is simply extended into the 3rd dimension.

5.4 Unsteady Field Streamline Placement in 3D

5.5 Complexity Analysis

6 Results

In Chapter 6, Section 6.1, we will see bla, specifically in Section 6.1.1 this will be emphasized. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

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6.1 Section

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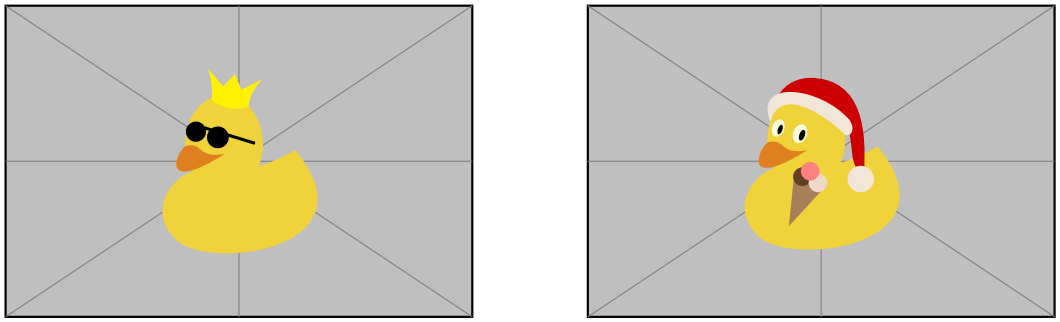

(a) (b)

Figure 6.1: Example for two (a) sub-figures (b).

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6.1.1 Subsection

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7 Conclusion

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Bibliography

[96] "Image-Guided Streamline Placement". In: 1996 (cit. on p. 3).

[Han+19] K. Hanser, S. Meggendorfer, P. Hügel, F. Fallenbüchel, H. M. Fahad, and F. Sadlo. "Energy-Based Visualization of 2D Flow Fields". In: *Proceedings of International Conference on Information Visualization Theory and Applications (IVAPP)*. 2019, pp. 250–258 (cit. on p. 4).

[HS19] L. Hofmann and F. Sadlo. "The Dependent Vectors Operator". *Computer Graphics Forum* 38:3, 2019, pp. 261–272 (cit. on p. 4).

[Jun+17] P. Jung, P. Hausner, L. Pilz, J. Stern, C. Euler, M. Riemer, and F. Sadlo. "Tumble-Vortex Core Line Extraction". In: *Proceedings of SIBGRAPI WVIS*. 2017 (cit. on p. 4).

[SJMS19] A. Sagristà, S. Jordan, T. Müller, and F. Sadlo. "Gaia Sky: Navigating the Gaia Catalog". *IEEE Transactions on Visualization and Computer Graphics* 25:1, 2019, pp. 1070–1079 (cit. on p. 4).

[SRS18] K. Sdeo, B. Rieck, and F. Sadlo. "Visualization of Fullerene Fragmentation". In: *Short Paper Proceedings of IEEE Pacific Visualization Symposium (PacificVIS)*. 2018, pp. 111–115 (cit. on p. 4).

[ZRLS19] B. Zheng, B. Rieck, H. Leitte, and F. Sadlo. "Visualization of Equivalence in 2D Bivariate Fields". *Computer Graphics Forum* 38:3, 2019, pp. 311–323 (cit. on p. 4).