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# **FieldAnimation Documentation**

***Release 0.1.0***

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**Sep 14, 2018**



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## FOREWORD

FieldAnimation has been developed by two programmers working in the [Aerial Operations](#) group of the IRI Research Section at [OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale](#).

Python is their favourite programming language since 2006.

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## WHAT IS FIELDANIMATION?

It is a Python package to represent vector fields through particles that move along the flow lines of the field at a speed and color proportional to its modulus.

A background image can be shown to add information for the interpretation of the results.

An **example application** with interactive control of speed, color and number of animated particles is available in the examples direcorey.





## FIELDANIMATION IN A NUTSHELL

- create a `fieldanimation.FieldAnimation` instance
- call its `fieldanimation.FieldAnimation.draw` method in the main rendering loop



## **DEPENDENCIES**

It relies on [PyOpenGL](#) and [numpy](#). The rendering of the OpenGL image must be carried out by a library that handles windows, input and events like [GLFW](#) or [PyQt](#).



## 5.1 fieldanimation Package

**fieldanimation** classes:

**fieldanimation.FieldAnimation**

**fieldanimation.glInfo()**

Return OpenGL information dict WARNING: OpenGL context MUST be initialized !!!

**Parameters** **None** –

**Returns** OpenGL information dict

**fieldanimation.field2RGB(field)**

Return 2D field converted to uint8 RGB image (i.e. scaled in [0, 255])

**Parameters** **field** (`numpy.ndarray`) – (u, v) 2D vector field instance

**Returns**

( **rgb** (`numpy.ndarray`): uint8 RGB image, **uMin** (`float`): u min, **uMax** (`float`): u max, **vMin** (`float`): v min, **vMax** (`float`): v max, ) (tuple): Return value

**fieldanimation.modulus(field)**

Return normalized modulus of 2D field image

**Returns** normalized modulus of 2D field image (i.e. scaled in [0, 1.])

**class fieldanimation.FieldAnimation**(*width, height, field, computeSahder=False, image=None*)

Bases: `object`

Field Animation with OpenGL

1. **draw the modulus of the vector field or a user defined image** if requested;
2. **set a framebuffer texture (screen texture) as the main**

**rendering target:**

- (a) draw the background texture on the screen texture with a fixed opacity;
  - (b) decode the particles positions from the `currentTracersPosition` texture and draw them on the screen texture;
3. set the rendering target to the active window;

4. draw screen texture on the active window;
5. swap screen texture and background texture;
6. **calculate the new particles positions** (in the update shader) and encode them in the nextTracersPosition texture;
7. **swap nextTracersPosition texture and** currentTracersPosition texture;

**\_\_init\_\_** (*width, height, field, computeShader=False, image=None*)  
Animate 2D vector field

**Parameters**

- **width** (*int*) – width in pixels
- **height** (*int*) – height in pixels
- **field** (*np.ndarray*) – 2D vector field
- **= True selects the compute shader version** (*cs*) –
- **= Optional background image** (*image*) –

**setField** (*field*)

Set the 2D vector field. Must be called every time a new vector field is selected.

**Parameters** **field** (*np.ndarray*) – 2D vector field

**setRenderTarget** (*texture*)

Set texture as rendering target

**Parameters** (**class** (*texture*)) – *texture* instance): 2D vector field

**setSize** (*width, height*)

Set instance size. Must be called when the window is resized.

**Parameters**

- **width** (*int*) – window width in pixels
- **height** (*int*) – window height in pixels

**resetRenderTarget** ()

Bind first (default) framebuffer and reset the viewport.

**tracersCount**

Return tracers count

**Returns** number of tracers

**\_initTracers** ()

Initialize the tracers positions

**draw** ()

Render the OpenGL scene. This method is called automatically when the scene has to be rendered and is responsible for the animation.

**drawScreen** ()

Draw background texture and tracers on screen framebuffer texture

**drawModulus** (*opacity*)

Draw the modulus texture.

**Parameters** **opacity** (*float*) – opacity (alpha) of the texture: 0 -> transparent 1 -> opaque

**drawImage** ()

Draw an image texture in background.

**drawTexture** (*texture, opacity*)

Draw *texture* on the screen.

**Parameters**

- `(texture)` – class:Texture): texture instance
- **opacity** (*float*) – opacity (alpha) of the texture 0 → transparent 1 → opaque

**drawTracers ()**

Draw the tracers on the screen

**updateTracers ()**

Update tracers position using the fragment shader provided by the graphic card for computing.

**updateTracersCS ()**

Update tracers position using the compute shader provided by the graphic card for computing.

**5.1.1 shader Module**

shader classes:

fieldanimation.shader.Shader

**class** fieldanimation.shader.Shader (*path=None, \*\*kargs*)

Bases: object

Base shader class

**\_\_init\_\_** (*path=None, \*\*kargs*)

**addUniform** (*uniform, utype=None*)

Add a uniform variable to the shader. If utype is not none it defines the setter function. Valid utypes are i, b, f, 2f, 4fv

**addUniforms** (*uniformlist*)

**\_build\_shader** (*sourceCode, shader\_type*)

Actual building of the shader

**delete** ()

**\_link** ()

Link the program

**bind** ()

Bind the program, i.e. use it

**unbind** ()

Unbind whatever program is currently bound - not necessarily this program, so this should probably be a class method instead.

**setUniform** (*name, value*)

**setUniforms** (*nameandvalue*)

**code** (*shader='v', lineno=False*)

Return shader code.

**Keyword Arguments**

- **shader** (*string*) – v for vertex, f for fragment, g for geometry
- **lineno** (*boolean*) – add line numbers to code

**Returns** shader source code

**vertex\_code** (*lineno=False*)

Return vertex shader code with optional line numbers

**fragment\_code** (*lineno=False*)

Return fragment shader code with optional line numbers

**geometry\_code** (*lineno=False*)

Return geometry shader code with optional line numbers

## 5.1.2 texture Module

**texture** classes:

fieldanimation.texture.Texture

```
class fieldanimation.texture.Texture (data=None,                                width=None,
                                     height=None,                             filt=GL_NEAREST,
                                     dtype=GL_UNSIGNED_BYTE)
```

Bases: object

```
__init__ (data=None,                width=None,                height=None,                filt=GL_NEAREST,
          dtype=GL_UNSIGNED_BYTE)
```

Texture object. If data is None an empty texture will be created

```
bind (texUnit=0)
```

```
handle ()
```

```
unbind ()
```

## 5.2 Example application

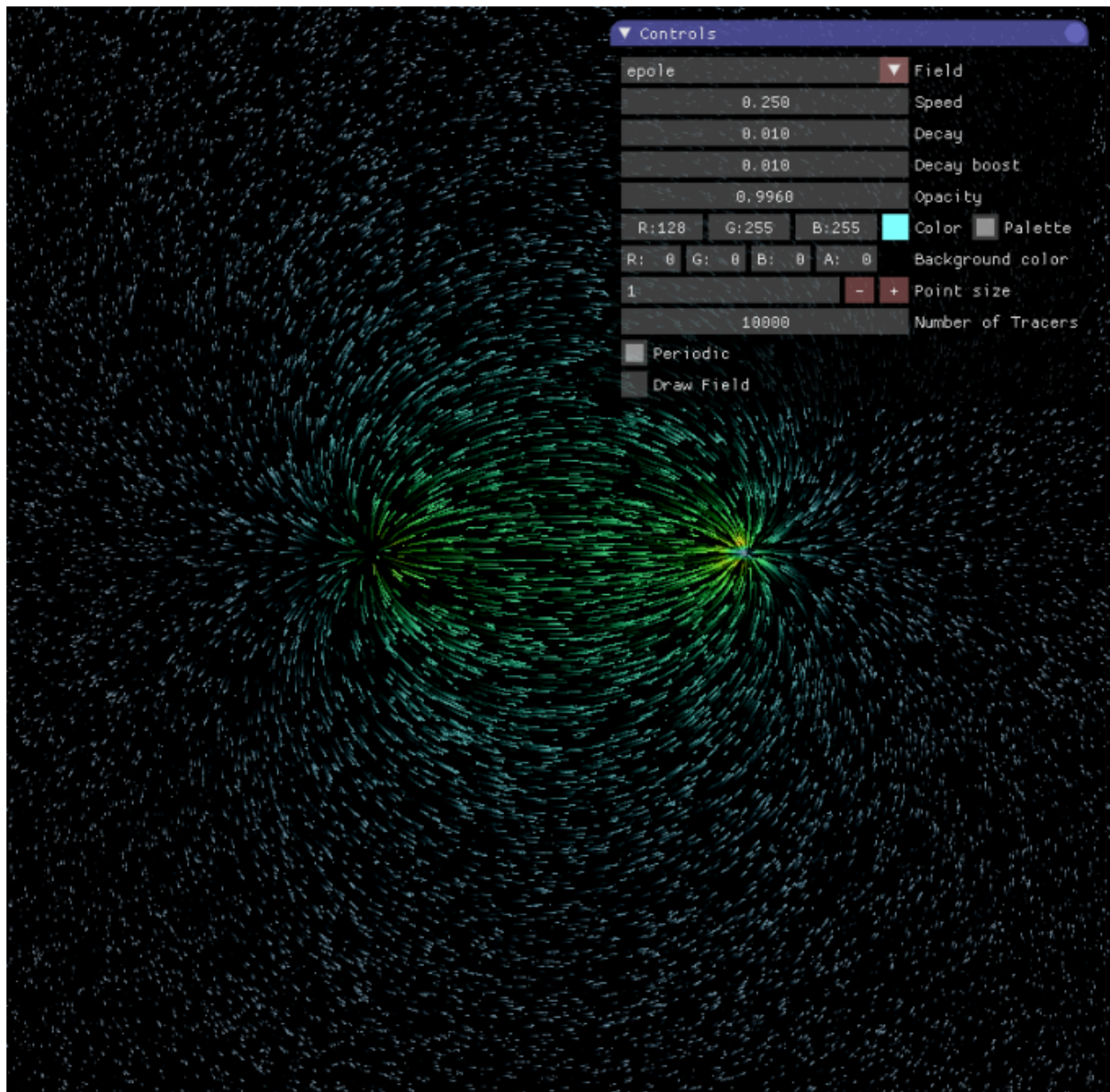
An example application appcode can be found in the [examples](#) directory.

The creation of a FieldAnimation image is straightforward: just instantiate the `fieldanimation.FieldAnimation` class passing the vector field array and call its draw method within the main rendering loop. The visualization application shown above depends on two OpenGL packages:

- [pyimgui](#) for setting interactively the visualization parameters and [GLFW](#)

for rendering the OpenGL image created by FieldAnimation in a windowing system.



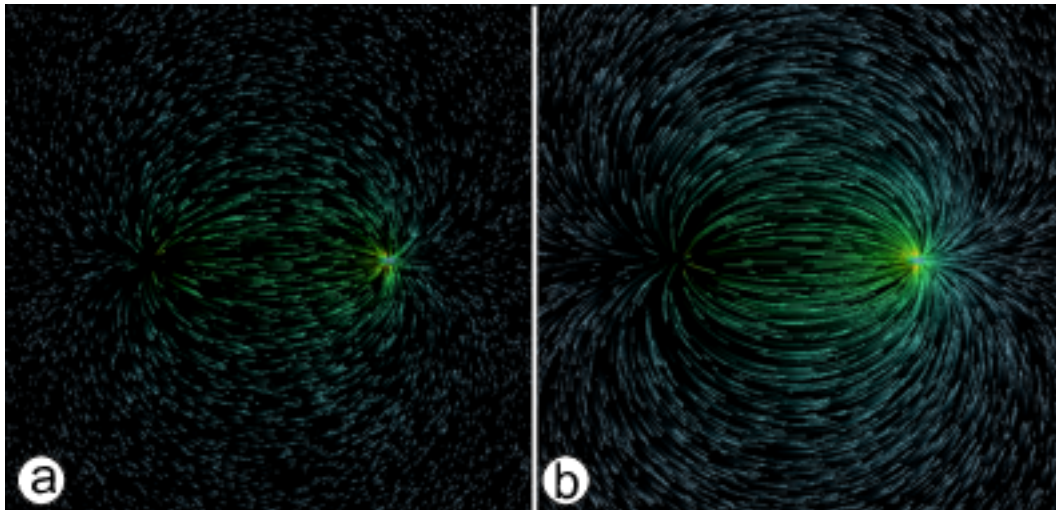


The interactive GUI in this figure allows to modify the visualization parameters that FieldAnimation embeds as instance attributes:

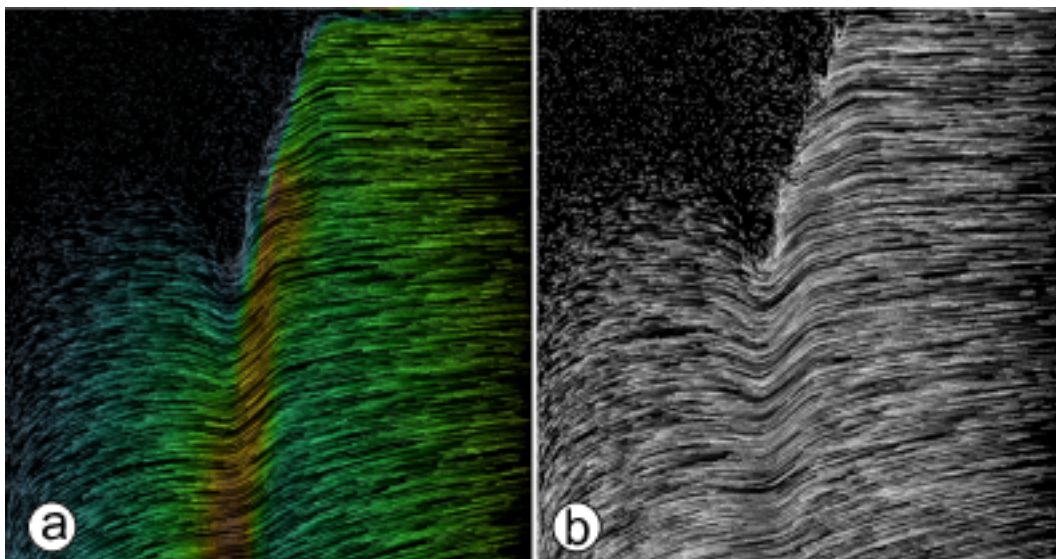
```
# Default values of the class attributes
FieldAnimation.speedFactor = 0.25
FieldAnimation.decay = 0.003
FieldAnimation.decayBoost = 0.01
FieldAnimation.fadeOpacity = 0.996
FieldAnimation.color = (0.5 , 1.0 , 1.0)
FieldAnimation.palette = True
FieldAnimation.pointSize = 1.0
FieldAnimation.tracersCount = 10000
FieldAnimation.periodic = True
FieldAnimation.drawField = False
```

Here is a detailed description of the controls that appear in the GUI:

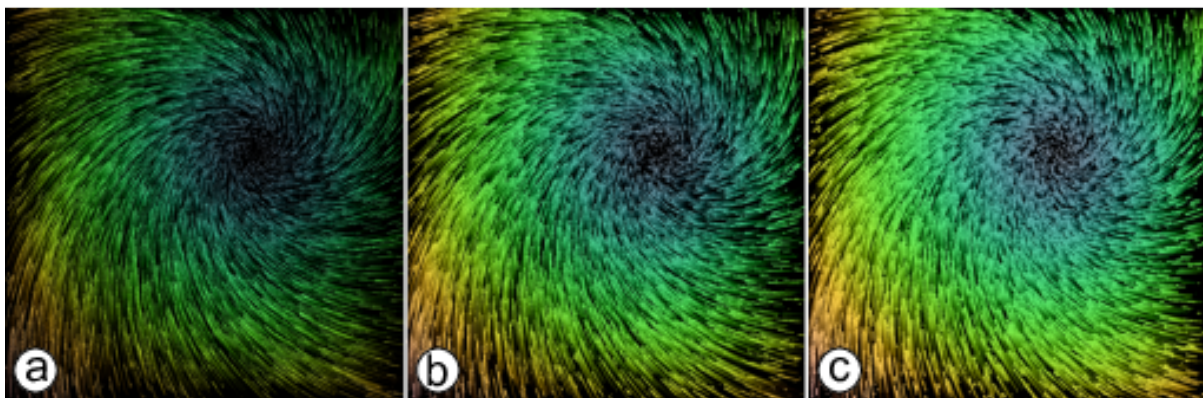
- **Field:** select one of the available vector fields implemented.
- **Speed:** set the length of the field pathlines i.e. the speed of the particles: the higher the value the longer the particle trace length.



- **Decay**: set the life span of a particle.
- **Decay boost**: increase points density in low intensity field areas.
- **Opacity**: set opacity of the particles over the background image.
- **Color**: set color of the particles according to the the field strength trough a cubehelix based color map.
- **Palette**: set color of the particles to a constant value.



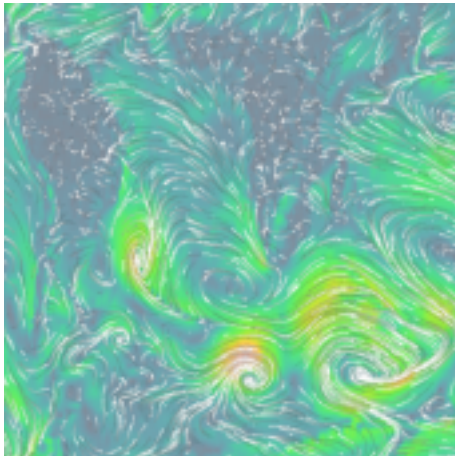
- **Point size**: set the size of the animated particles (in pixels).



- **Number of Tracers**: set the number of the moving particles.



- **Periodic:** if checked points that move outside the border of the rendering window will enter from the opposite one.
- **Draw Field:** Draw the field modulus as a background image. In this example application the field modulus is rendered through a cubehelix color map.



## 5.3 Code design

Nowadays the visualization of large numerical models is tricky due to the high demand of graphical resources needed. Furthermore scientist cannot take care of the efficiency of both the numerical model and the visualization system. Commercial applications or free ones, like [Visit](#) or [Paraview](#), are often used to visualize data and understand their meaning. Unfortunately these applications provide only standard visualizations tools, like quivers or streamplots, and are slow or need datasets converted to specific formats.

Field Animation was written during the development of the simulation package [PyGmod](#) for fast visualization of a geodynamic deformation field. It implements a particles tracing visualization algorithm where particles move according to the field streamlines giving an instantaneous picture of its pattern and line flow. FieldAnimation has been designed to process bidimensional arrays and uses both [PyOpenGL](#) and [numpy](#) to take the most of the available hardware .

The adoption of the OpenGL programming pipeline allows the usage of a large number of particles (millions) and hence more detailed models. Most of the computation is done by the GPU and it is instrumented by shaders written in GLSL. The CPU merely takes care of the initialization of some data structures and arrays. The programmer must only focus on the dataset and forget about the interfaces. The fieldanimation package consist of three modules: *fieldanimation*, *fieldanimation.texture* and *fieldanimation.shader*. The last two are just support modules that handle openGL textures and shader code loading, compiling and linking. *fieldanimation* is the core module in charge of arranging all the data, set the right parameters to the OpenGL context for rendering the scene and defines the drawing workflow. The animated image instance creation is straightforward:

```
animated_image = FieldAnimation(width, height, field)
```

- **width** and **height** are the vertical and horizontal pixels dimensions of the window
- **field** is an NxMx2 [numpy](#) array with the field components

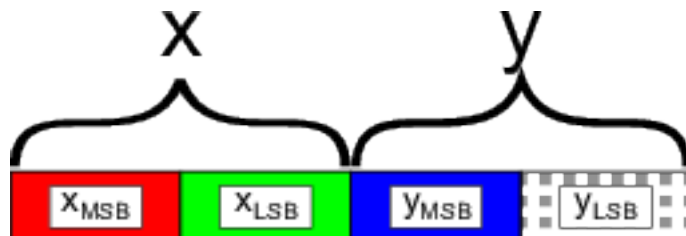
All modules are kept as simple as possible to reduce dependencies but new functionalities can be easily added subclassing *fieldanimation.FieldAnimation*. The package can be integrated in any windowing system.

### 5.3.1 Particle tracing algorithm

FieldAnimation implements a simple OpenGL sequence of stages to draw on the screen: a vertex shader, a compute shader and a fragment shader. OpenGL connects these shader programs with fixed functions glue. In the

drawing process the GPU executes the shaders piping their input and output along the pipeline until pixel will come out at the end. The vertex shader stage handles vertex processing such as space transformation, lighting and arranges work for next rendering stages. The fragment shader manages the stage after the rasterization of geometric primitive and defines the color of the pixel on the screen.

Particle tracing starts with the generation of an array of random particle positions on the screen. This array is stored in an OpenGL Texture object encoding them as colors (RGBA values). A 100 pixels x 100 pixels texture for example can store in this way 10.000 points positions. Particle coordinates are encoded into two bytes, RG for x and BA for y



Each texture pixel can therefore store 65536 distinct values for each coordinate. The texture is passed to the GPU in a vertex shader and the original particles positions are retrieved from the RGBA texture using the “texture fetched method” in the vertex shader:

```
#version 430
layout (location = 0) in float index;

uniform sampler2D tracers;
uniform float tracersRes;

// Model-View-Projection matrix
uniform mat4 MVP;
uniform float pointSize;

out vec2 tracerPos;

void main() {
    // Extracts RGBA value
    vec4 color = texture(tracers, vec2(
        fract(index / tracersRes),
        floor(index / tracersRes)
        / tracersRes));

    // Decodes current tracer position from the
    // pixel's RGBA value (range from 0 to 1.0)
    tracerPos = vec2(
        color.r / 255.0 + color.b,
        color.g / 255.0 + color.a);

    gl_PointSize = pointSize;
    gl_Position = MVP * vec4(
        tracerPos.x, tracerPos.y, 0, 1);
}
```

Decoding of particles position from texture is implemented through an array with absolute indexes of the particles, passed to the shaders.

**Warning:** This code has been tested *only* on Linux (Ubuntu 18.04.1 LTS and Ubuntu 17.10) but should work also on Mac and Windows.

**Warning:** This is work in progress!



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