plotPDF : a PDF output module in FreeFEM

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Dec. 12, 2022

PlotPDF is a FreeFEM plug-in module (dynamic loading module) to write objects in PDF files. The latest version is distributed at `http://www-an.acs.i.kyoto-u.ac.jp/~fujiwara/ff`.

1 Getting started

```
mesh Th = square(10,10);
fespace Vh(Th,P1);
Vh u = ...;

load "plotPDF"     // without semi-colon

// only mesh
plotPDF( "filename", Th );

// real or complex-valued functions
plotPDF( "filename", Th, u );

// vector-valued functions
plotPDF( "filename", Th, [u,v] );
```

- The suffix ”.pdf” is automatically added to `filename`.
- If the built-in variable `verbosity` is greater than or equal to 90, then all options are listed in `stdout`.

2 Limitations

- Two dimensions, triangular meshes
- serial computation

3 Displaying PDF with multiple pages in LaTeX

LaTeX can include PDF files by `includegraphics`. If a PDF file has multiple pages, the desired page is specified by `page` option. The default is `page=1`, thus only the first page of the PDF file appears.

```
\includegraphics[width=\textwidth,page=2]{filename.pdf}
```

4 Options

4.1 Page control options

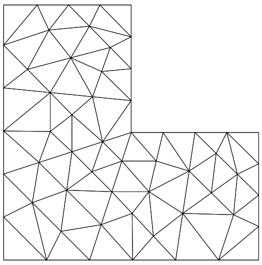
options	default	
`bool meshpage`	`true`	true if show mesh page
`bool index`	`false`	true if show mesh with index page
`bool belabel`	`false`	true if show boundary edge labels defined by ”`border ...  { label=...; }`” in .edp

`bool isoline`	`true`
	
	`false`
		(real-valued function)
		true if show contours of profile
		(vector-valued function)
		true if show contours of norm

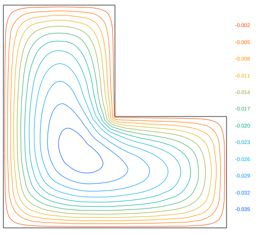
`bool fill`	`true`	true if show profile with fill-style For vector-valued, this option is ignored.

- In plotting a real-valued function, by default, the output PDF file consists of three pages (mesh, contour lines, and fill-style pages), if plotPDF is invoked with a mesh with a function. To remove the mesh page, specify the option `meshpage=false` (or `meshpage=0`).

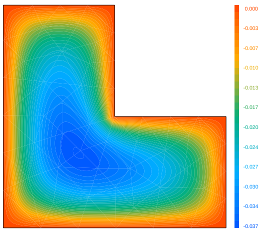
  One can also get mesh with indices by `index=true` (or `meshpage=1`), or boundary labels by `belabel=true` (or `belabel=1`).



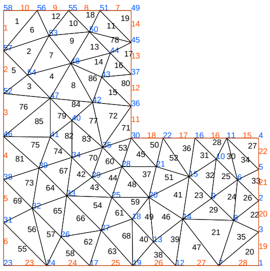
`meshpage=true`
(default)



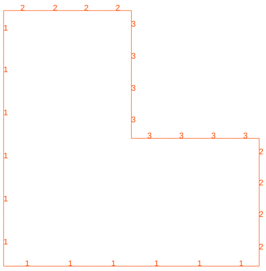
`isoline=true`
(default)



`fill=true`
(default)



`index=true`
(option)



`belabel=true`
(option)

4.2 Page format options

`int size`	`512`	figure pane sizes in pixel
`real ar`	*auto*	aspect ratio, x/y
`real[int] fmargin`	`[0,0,0,0]`	margin (left, bottom, right, and top)

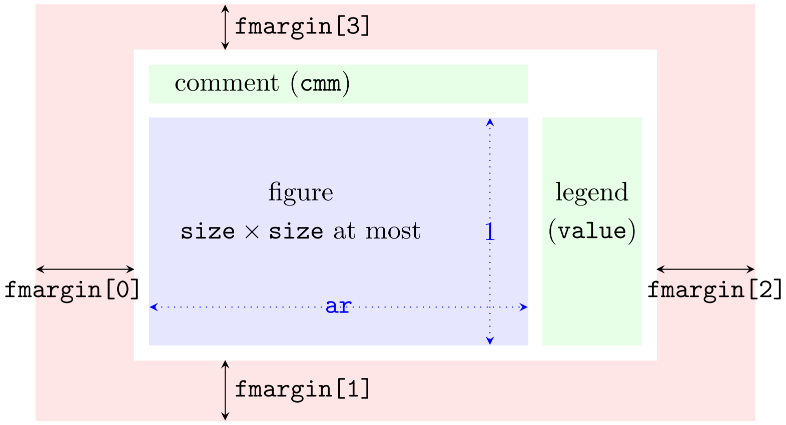
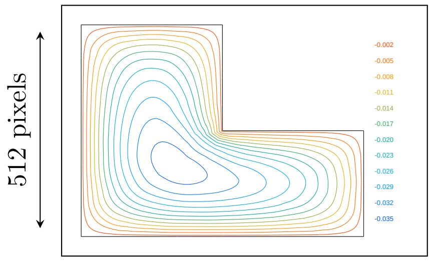
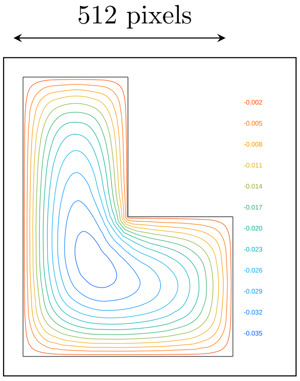


Figure 1: Page components. White paddings are 20 pixels width. The aspect ratio of the figure pane (blue area) is given by the option `ar`. It is scaled to fit to `size` × `size`. The comment is given by `cmm` (empty by default). The legend is hidden if `value=false` (`true` by default).

- The aspect ratio of the figure pane is determined so as to keep the original aspect of the domain by default.
- Note that `ar=4/3` is equivalent to `ar=1` due to truncation in the integer division.



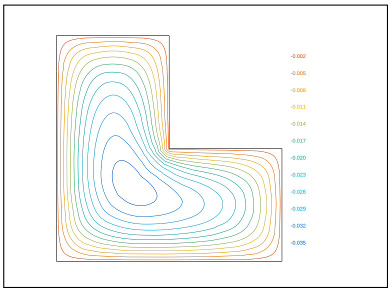
`ar=4.0/3.0`



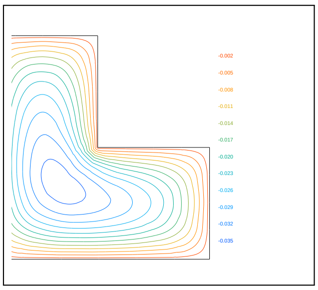
`ar=3.0/4.0`

- No options are available to change spaces between the figure pane and legend or comment.
- The option `fmargin` is effective with `fontscale` (> 1) or plotting vector-valued functions, since some objects might be shown outside of figure pane.

- Negative margines mean to hide figures.



`fmargin=[80,20,120,30]`

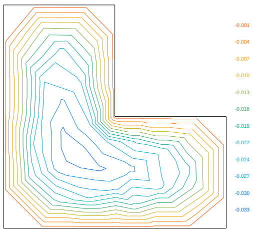


`fmargin=[-80,20,120,30]`

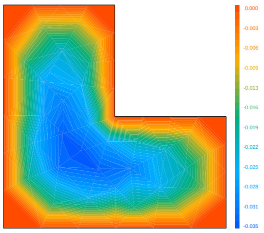
4.3 Common plot-style options

`string fetype`	`"P1"`	finite element type `P0`, `P1`, `P2`, `P1nc` are available.
`bool logscale`	`false`	true if plot functions in logarithmic scale
`real withmesh`	`0.0`	thickness of over-layed mesh, `0` : white (none), `1` : black
`string title`		title of the output PDF file default : ”FreeFEM plotPDF module” It is usually shown on application window.
`string cmm`	`""`	comment shown on the graph
`real fontscale`	`1.0`	ratio of font size for `index`, `belabel` and `cmm`
`bool value`	`true`	true if show legend in `isoline` and `fill`
`int prec`	`3`	number of digits in legend
`real lw`	`1.0`	line width of contours and arrows in vector-valued function
`bool gray`	`false`	true if monochrome (black white)
`bool bw`	`false`	equivalent to `gray`
`real[int,int] palette`	*auto*	color specifications for functions

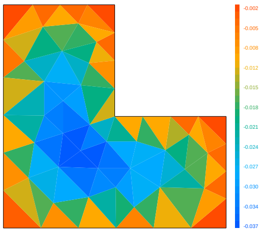
- If plotting with `fetype="P0"`, the option `isoline` is ignored.
- If the function is P_2, then plotting it with `fetype="P2"` is recommended. Otherwise, one gets a piecewise linear interpolated profile.



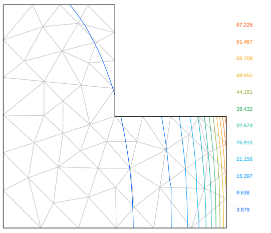
`isoline` with
`fetype="P1"` (default)



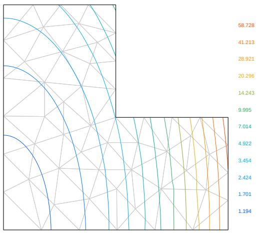
`fill` with
`fetype="P1"` (default)



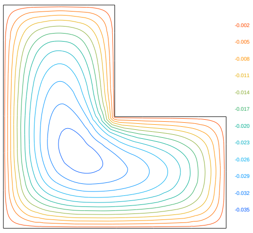
`fetype="P0"`



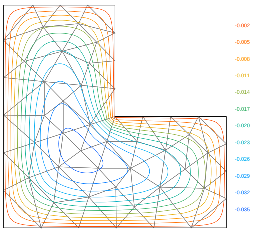
$\exp(4x^2+y^2)$ by default



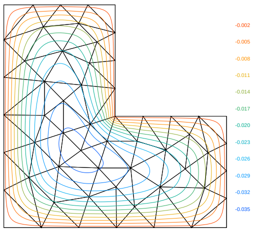
$\exp(4x^2+y^2)$ with `logscale=true`



default (`withmesh=0`)

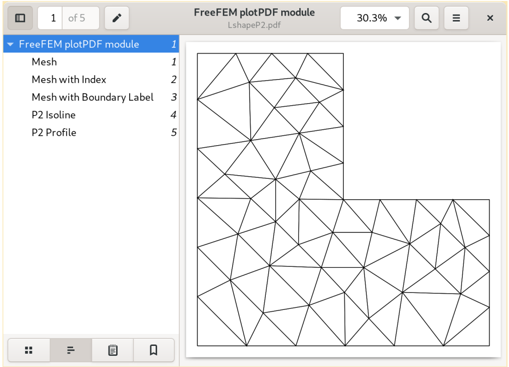


`withmesh=0.5`



`withmesh=1`

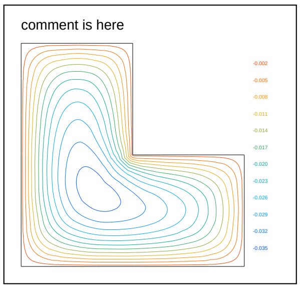
- In a PDF viewer, the option `title` is shown on the window title and bookmark. Each page has a pre-defined page title shown in bookmark.



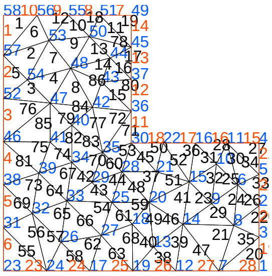
FreeFEM plotPDF module
LshapeP2.pdf

1 of 5 | 30.3%

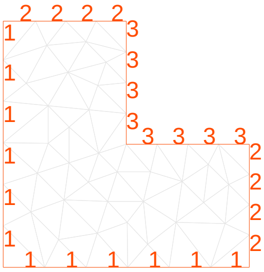
- FreeFEM plotPDF module 1
  - Mesh 1
  - Mesh with Index 2
  - Mesh with Boundary Label 3
  - P2 Isoline 4
  - P2 Profile 5



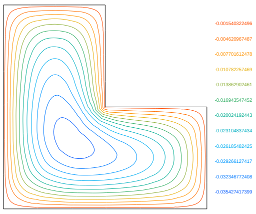
`cmm="comment is here"`



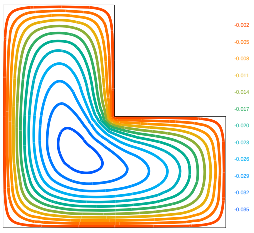
mesh page with `fontscale=2`



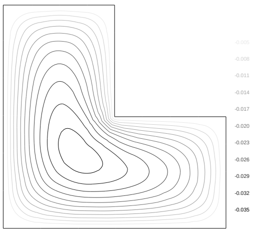
`belabel` with `fontscale=3`



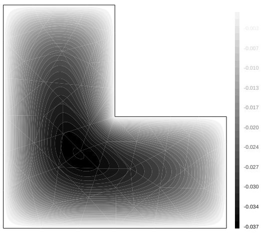
`prec=12`



`isoline` with `lw=6`



isoline with `bw=true`

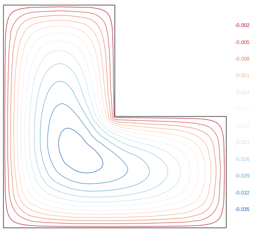


fill-stype with `bw=true`

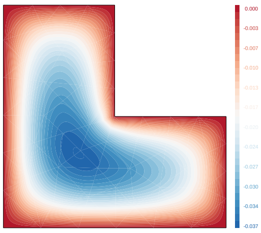
- The option `palette` consists of N (≥ 2) triplets. Each triplet is formed by three integers between 0 to 255 corresponding to red, blue, and green (RGB). The first and last triplets specify RGB used for minimum and maximum values, respectively. The interval between the minimum and maximum values are divided into $N-2$ disjoint subintervals, and RGB of the n-th border corresponds to the n-th triplet. In the subintervals, RGB is linearly interpolated.

- The next example gives *Paul Tol's BuRd*.

```
real[int,int] BuRd = [
  [ 33,102,172], // RGB for minimum value
  [ 67,147,195],
  [146,197,222],
  [209,229,240],
  [247,247,247],
  [253,219,199],
  [244,165,130],
  [214, 96, 77],
  [178, 24, 43] // RGB for maximum value
];
plotPDF( "file", Th, u, fetype="P2", palette=BuRd );
```



`isoline` with BuRd

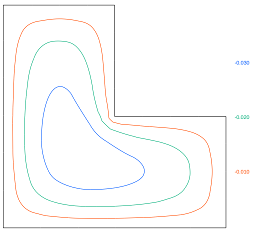


`fill` with BuRd

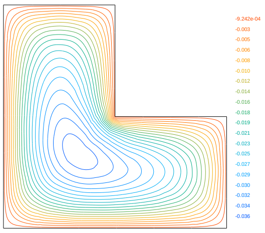
4.4 Contour : `isoline=true`

`real[int] viso`	*auto*	values to plot contours
`int nbiso`	`12`	number of contours

- If `fetype="P0"`, then `isoline` is ignored.
- If both `viso` and `nbiso` are specified, `viso` is prior to `nbiso`. (`nbiso` is ignored.)



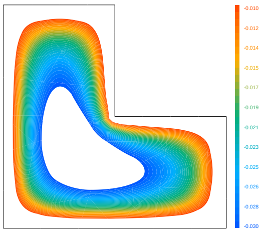
`viso=[-0.01,-0.02,-0.03]`



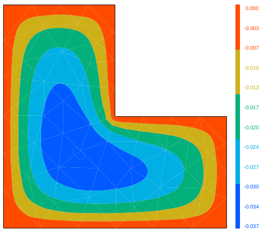
`nbiso=20`

4.5 Fill-style : `fill=true`

`real[int] frange`	*auto*	value range in fill-style
`int nbfill`	`32`	number of colors (levels) in fill-style



`frange=[-0.03,-0.01]`

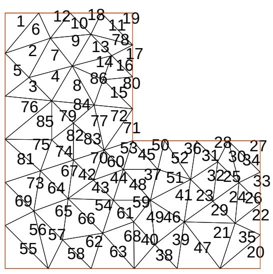


`nbfill=5`

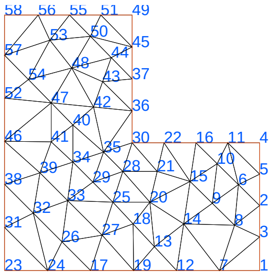
4.6 Index page : `index=true`

`bool idcell`	`true`	true if show cell (triangle) ID
`bool idvert`	`true`	true if show vertex ID
`bool idedge`	`false`	true if show edge ID

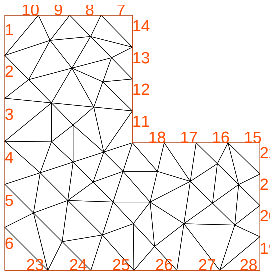
- In the index page, triangle IDs, vertex IDs, edge IDs are respectively shown in black, blue, and red (Edge IDs are hidden by default.) One can choose IDs to display by options `idcell`, `idvert`, and `idedge` with `index=true`.



Triangle ID
`idcell=true,`
`idvert=false,`
`idedge=false`



Vertex ID
`idcell=false,`
`idvert=true,`
`idedge=false`

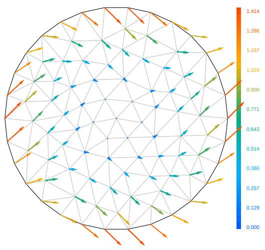


Edge ID
`idcell=false,`
`idvert=false,`
`idedge=true`

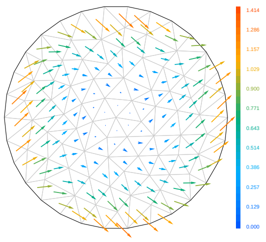
4.7 Vector-valued function

`real arrowsize`	`1.0`	scale for arrow head size
`real coef`	`1.0`	scale for arrow length
`bool unitarrow`	`false`	true if draw all arrows with same length

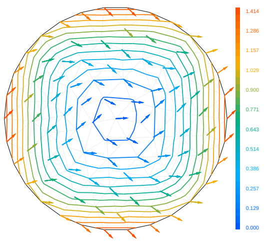
- The option `fill` is ignored.
- For each triangle, the vectors starting from the vertices (resp. the center) are drawn in `fetype="P1"` or `"P2"` (default) (resp. `fetype="P0"` or `"P1nc"`).
- Note that in plotting vector-valued functions, `isoline=false` by default.



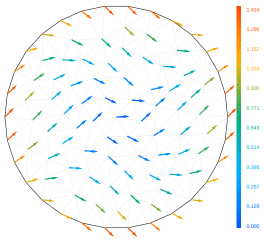
default



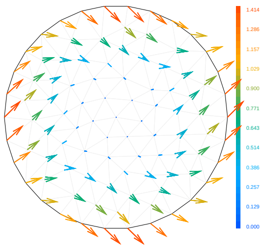
`fetype="P0"`



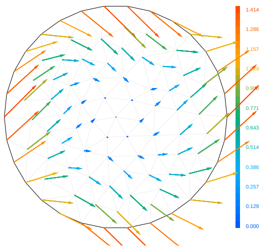
`isoline=true`



`unitarrow=true`



`arrowsize=3`

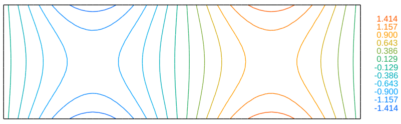


`coef=2`

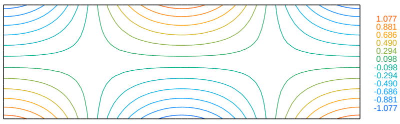
4.8 Complex-valued function

`bool zreal`	`true`	true if show real part
`bool zimag`	`true`	true if show imaginary part
`bool zabs`	`false`	true if show modulus (absolute value)
`bool zarg`	`false`	true if show argument

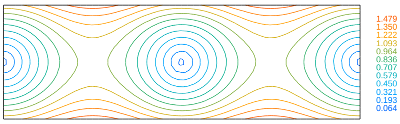
- By default, the file consists of 5 pages; `meshpage`, `isoline` of the real and imaginary parts, and `fill` for real and imaginary parts.
- Each page has title as "Real Part", "Imaginary Part", "Modulus", and "Argument" respectively. You can see them in a bookmark in a PDF viewer.



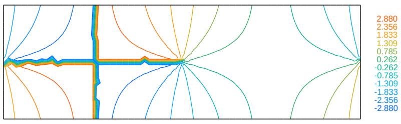
real part : `zreal=true` (default)



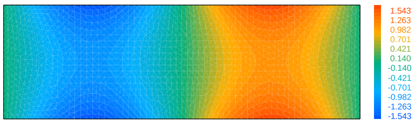
imaginary part : `zimag=true` (default)



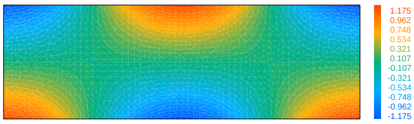
modulus : `zabs=true` (option)



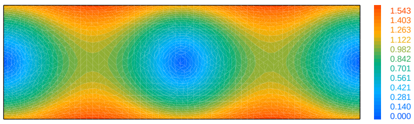
argument : `zarg=true` (option)



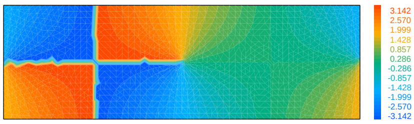
real part : `zreal=true` (default)



imaginary part : `zimag=true` (default)



modulus : `zabs=true` (option)



argument : `zarg=true` (option)

The argument of complex numbers is a multi-valued function, and the module adopts its principle value in the interval $(-\pi, \pi]$. The color wheel palette would be better to express this in some occasions. Furthermore, `P1`, `P1nc`, and `P2` elements produce peculiar output on triangles where arguments of the target function's value are close to $\pm\pi$ (the branch cut in `arg()` function in C++). Since $\pi + \epsilon$ and $-\pi - \epsilon$ are treated as $-\pi + \epsilon$ and $\pi - \epsilon$ respectively, small change near $\arg(f) \approx \pi$ or $-\pi$ appear as drastic color change.

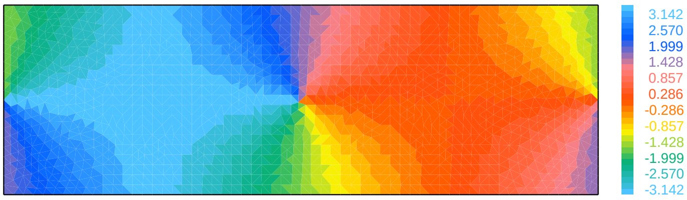
Using `P0` element can be block out it.

```
fespace Vh0(Th,P0);
Vh0<complex> f0 = sin( x + y*1i );

real[int] range = [-pi,pi];

real[int,int] cwheel= [
  [ 77, 196, 255], // RGB at arg=-pi (water blue)
  [  3, 175, 122], // RGB at arg=-pi/3 (green)
  [255, 241,   0], // RGB at arg=-2pi/3 (yellow)
  [255,  75,   0], // RGB at arg=0 (red)
  [255, 128, 130], // RGB at arg=pi/3 (pink)
  [  0,  90, 255], // RGB at arg=2pi/3 (blue)
  [ 77, 196, 255]  // RGB at arg=pi (water blue)
];

plotPDF( "zarg", Th, f0, fetype="P0", zarg=true,
         frange=range, palette=cwheel );
```



Produced by P0 FE with color wheel palette.