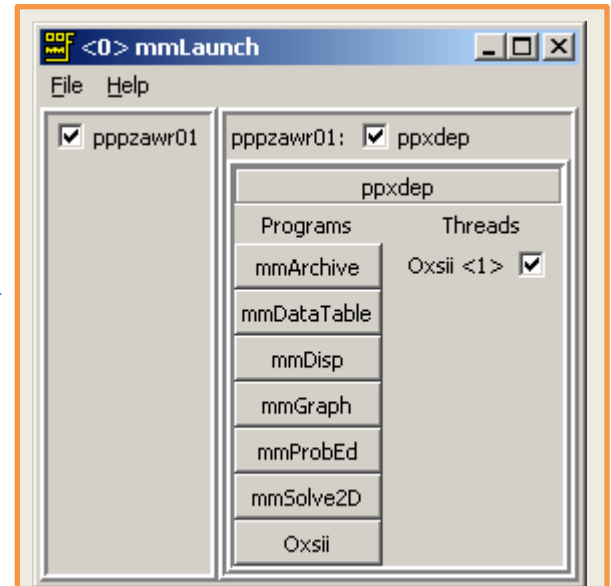
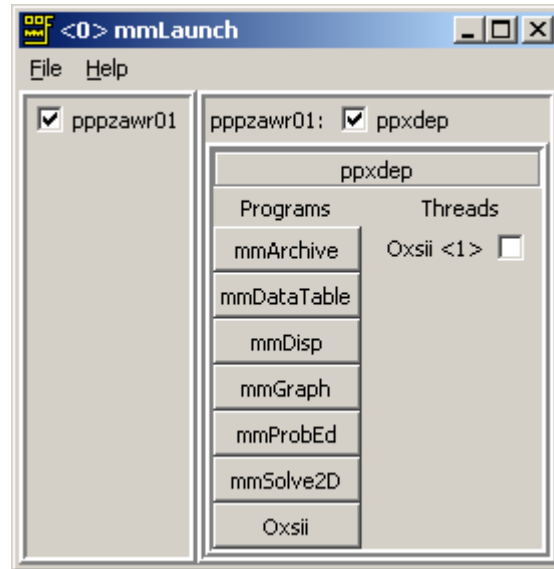
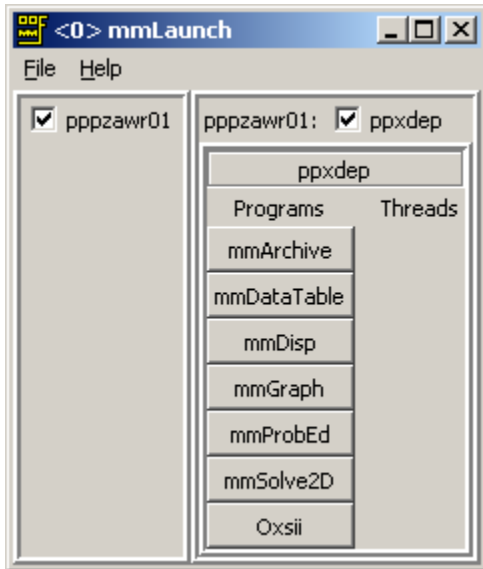
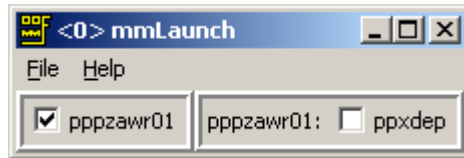
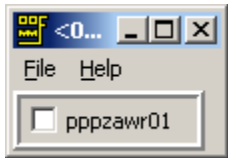


# OOMMF Examples

Duncan Parkes

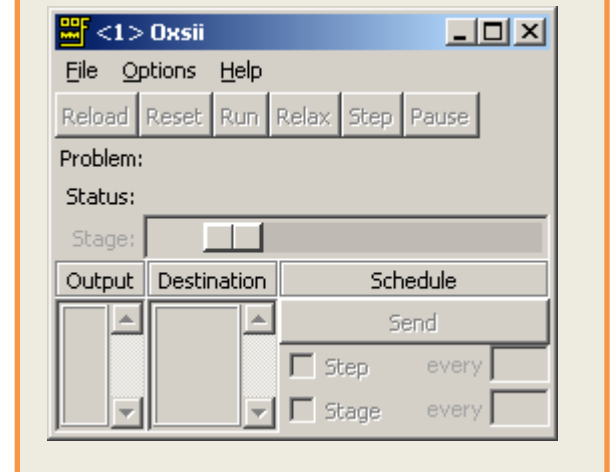
# Installing OOMMF and tcl/tk

- Get oommf:
- <http://math.nist.gov/oommf/> (Get the most recent version – even if it an alpha version)
- Install tcl/tk:
- **Windows:**
- <http://www.activestate.com/activetcl/downloads> (Make sure you get the right version for the version of OOMMF you downloaded).
- Install tcl/tk
- Unzip and run OOMMF
- **Linux:**
- <http://deparkes.wordpress.com/2012/06/02/installing-oommf-on-ubuntu-11-04/>



File -> load:

C:\loommf-1.2a5\app\oxs\examples



# C:\oommf-1.2a5\app\oxs\examples exchspring.mif

```
exchspring.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?

1 # MIF 2.1
2 # MIF Example File: exchspring.mif
3 # Description: Exchange spring example
4 set pi [expr 4*atan(1.0)]
5 set mu0 [expr 4*$pi*1e-7]
6
7 Specify Oxs_MultiAtlas:atlas {
8   atlas { Oxs_BoxAtlas {
9     xrange {0 300e-9}
10    yrange {0 300e-9}
11    zrange {49e-9 98e-9}
12    name top
13   } }
14   atlas { Oxs_BoxAtlas {
15     xrange {0 300e-9}
16     yrange {0 300e-9}
17     zrange {0 49e-9}
18     name bottom
19   } }
20 }
```

Multiple layers

```
exchspring.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?

22 Specify Oxs_RectangularMesh:mesh {
23   cellsize {10e-9 10e-9 7e-9}
24   atlas :atlas
25 }
26
27 Specify Oxs_Exchange6Nlgr:NiFe {
28   atlas :atlas
29   A {
30     top 20e-12
31     bottom 30e-12
32   }
33 }
34
35 Specify Oxs_UniaxialAnisotropy {
36   K1 { Oxs_AtlasScalarField {
37     atlas :atlas
38     values {
39       top 0
40       bottom 520e3
41     }
42   } }
43 }
44 axis { Oxs_UniformVectorField {
45   norm 1
46   vector {1 0 0}
47 } }
48 }
49
50 Specify Oxs_UZeeman [subst {
51   multiplier [expr 0.001/$mu0]
52   Hrange {
53     { 0 0 0 500 50 0 10 }
54     { 500 50 0 -500 -50 0 20 }
55     { -500 -50 0 500 50 0 20 }
56   }
57 } }
58
59 Specify Oxs_Demag {}
60
61 Specify Oxs_RungeKuttaEvolve:evolver {
62   alpha 0.5
63 }
64
65 Specify Oxs_TimeDriver {
66   basename exchspring
67   evolver :evolver
68   comment {1 deg/ns = 17453293 rad/sec; If Ms=8.6e5, and lambda is small,
69     then mxh=1e-6 translates into dm/dt = 2e5 rad/sec = 0.01 deg/ns}
70   stopping_dm_dt 1
71   mesh :mesh
72   Ms { Oxs_AtlasScalarField {
73     atlas :atlas
74     values {
75       top 860e3
76       bottom 1400e3
77     }
78   } }
79   m0 { Oxs_AtlasVectorField {
80     atlas :atlas
81     norm 1
82     values {
83       top { -1 10 0 }
84       bottom { 10 1 0 }
85     }
86   } }
87 }
88
```

Set initial magnetisation

```
exchspring.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?

31 top bottom 20e-12
32 bottom bottom 30e-12
33 }
34 }
35
36 Specify Oxs_UniaxialAnisotropy {
37   K1 { Oxs_AtlasScalarField {
38     atlas :atlas
39     values {
40       top 0
41       bottom 520e3
42     }
43   } }
44   axis { Oxs_UniformVectorField {
45     norm 1
46     vector {1 0 0}
47   } }
48 }
49
50 Specify Oxs_UZeeman [subst {
51   multiplier [expr 0.001/$mu0]
52   Hrange {
53     { 0 0 0 500 50 0 10 }
54     { 500 50 0 -500 -50 0 20 }
55     { -500 -50 0 500 50 0 20 }
56   }
57 } }
58
59 Specify Oxs_Demag {}
60
61 Specify Oxs_RungeKuttaEvolve:evolver {
62   alpha 0.5
63 }
64
65 Specify Oxs_TimeDriver {
66   basename exchspring
67   evolver :evolver
68   comment {1 deg/ns = 17453293 rad/sec; If Ms=8.6e5, and lambda is small,
69     then mxh=1e-6 translates into dm/dt = 2e5 rad/sec = 0.01 deg/ns}
70   stopping_dm_dt 1
71   mesh :mesh
72   Ms { Oxs_AtlasScalarField {
73     atlas :atlas
74     values {
75       top 860e3
76       bottom 1400e3
77     }
78   } }
79   m0 { Oxs_AtlasVectorField {
80     atlas :atlas
81     norm 1
82     values {
83       top { -1 10 0 }
84       bottom { 10 1 0 }
85     }
86   } }
87 }
88
```

Uniaxial anisotropy

Applied field

# Squarecubic.mif

```
squarecubic.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
16 atlas :atlas
17 }
18
19 Specify Oxs_UniformExchange:NiFe {
20   A 13e-12
21 }
22
23 Specify Oxs_CubicAnisotropy {
24   K1 { Oxs_UniformScalarField { value 530e3 } }
25   axis1 { Oxs_UniformVectorField {
26     norm 1
27     vector {1 1 0}
28   } }
29   axis2 { Oxs_UniformVectorField {
30     norm 1
31     vector {1 -1 0}
32   } }
33 }
34
35 Specify Oxs_UZeeman [subst {
36   multiplier [expr 0.001/$mu0]
37   Hrange {
38     { 0 0 0 50 0 0 2 }
39   }
40 ]}]
41
42 Specify Oxs_SimpleDemag {}
43
44 Specify Oxs_EulerEvolve {
45   alpha 0.5
46 }
```

Cubic anisotropy

# Imageatlas.mif



```
imageatlas.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
1 # MIF 2.1
2 # MIF Example File: imageatlas.mif
3 # Description: Example use of the Oxs_ImageAtlas class.
4 #
5 set pi [expr 4*atan(1.0)]
6 set mu0 [expr 4*$pi*1e-7]
7
8 RandomSeed 1
9
10 Specify Oxs_ImageAtlas:atlas {
11   xrange {0 320e-9}
12   yrange {0 320e-9}
13   zrange {0 20e-9}
14   viewplane xy
15   image vortex.bmp
16   colormap {
17     magenta region_1
18     cyan region_2
19     yellow region_3
20     red region_4
21     blue region_5
22     green region_6
23     white vacuum
24   }
25 }
```

Image sets regions

```
imageatlas.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
Ln 11 / 99
34 }
35
36 Specify Oxs_UniaxialAnisotropy {
37   K1 { Oxs_AtlasScalarField {
38     atlas :atlas
39     default_value 50e3
40     values {
41       region_2 {-10e3
42       region_4 {-10e3
43       region_6 {-10e3
44       vacuum 0
45     }
46   }}
47   axis { Oxs_AtlasVectorField {
48     atlas :atlas
49     values {
50       region_1 {-1.0 0.7 0}
51       region_2 {-1.0 -0.2 0}
52       region_3 {-0.7 -1.0 0}
53       region_4 { 1.0 -0.5 0}
54       region_5 { 1.0 0.2 0}
55       region_6 { 0.6 1.0 0}
56       vacuum { 0 0 1}
57     }
58     norm 1.0
59   }}
60 }
61
62 Specify Oxs_UZeeman [subst {
63   multi-tiler favm 0.001/cm0
```

Different anisotropy depending region

```
imageatlas.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
71 Specify Oxs_CGEvolve {}
72
73 Specify Oxs_MinDriver {
74   basename imageatlas
75   evolver Oxs_CGEvolve
76   stopping_mXHxm 0.1
77   mesh :mesh
78   Ms { Oxs_AtlasScalarField {
79     atlas :atlas
80     default_value 8e5
81     values {
82       vacuum 0
83     }
84   }}
85   m0 { Oxs_AtlasVectorField {
86     atlas :atlas
87     values {
88       region_1 {-1.0 0.7 0}
89       region_2 {-1.0 -0.2 0}
90       region_3 {-0.7 -1.0 0}
91       region_4 { 1.0 -0.5 0}
92       region_5 { 1.0 0.2 0}
93       region_6 { 0.6 1.0 0}
94       vacuum { 0 0 1}
95     }
96     norm 1.0
97   }}
98 }
99
```

Different M0 depending on region

# Varalpha.mif

```
varalpha.mif [C:\oosmf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
37 }
38
39 Specify Oxs_UniformExchange {
40   A 13e-12
41 }
42
43 # For simplicity, no demag
44 Ignore Specify Oxs_Demag {}
45
46 # Time varying applied field
47 set Hw [expr {2*pi*$H_freq*1e9}] ;# Convert freq from GHz to radians/sec
48 proc Happ { t } {
49   # Import time is in seconds.
50   # Return value is field in mT.
51   global H_amp Hw
52   set Hy [expr {$H_amp*sin($Hw*$t)}]
53   set dHy_dt [expr {$Hw*$H_amp*cos($Hw*$t)}]
54   return [list 0. $Hy 0. 0. $dHy_dt 0.]
55 }
56 Specify Oxs_ScriptUZeeman [subst {
57   script_args total_time
58   script Happ
59   multiplier [expr {1.0/(1000.*$mu0)}]
60 }]
61
62
63 # Spatially varying damping parameter alpha
64 proc alphascript { x y z } {
65   global alphamin alphamax
66   return [expr {alphamin + (alphamax-alphamin)*$z}]
67 }
```

Time varying field

# Pulse.mif

```
pulse.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
Ln 46 | Col 1 | 80 | Sel 0 | Sel Ln 0 | 2.40 KB | ANSI | LF | INS | Shell Script

46
47 Specify Oxs_ScriptUZeeman {
48     script_args total_time
49     script GaussianPulse
50 }
51
52 proc GaussianPulse { total_time } {
53     global pamp pfac pwait
54     set t [expr {$total_time-$pwait}]
55     set Hy [expr {$pamp*exp($pfac*$t*$t)}]
56     set dHy [expr {2*$pfac*$t*$Hy}]
57     return [list 0 $Hy 0 0 $dHy 0]
58 }
59
60
61 # Add biasing field, 100 mT
62 Specify Oxs_FixedZeeman [subst {
63     field { 100 0 0 }
64     multiplier [expr {0.001/$mu0}]
65 }]
66
67
68 Specify Oxs_Demag {}
69
70 Specify Oxs_RungeKuttaEvolve:evolve {
71     alpha 0.02
72 }
73
74 proc CornerChunk { vx vy vz x y z } {
75     # Return projection for corner of block nearest origin:

```

Gaussian pulse

Note damping parameter

```
pulse.mif [C:\oommf-1.2a5\app\oxs\examples] - Notepad2-mod
File Edit View Settings ?
Ln 76 | Col 1 | 80 | Sel 0 | Sel Ln 0 | 2.40 KB | ANSI | LF | INS | Shell Script

76 # corner dimensions are 20 nm on each edge.
77 if {$x<20e-9 && $y<20e-9 && $z<20e-9} {
78     return [list $vx $vy $vz]
79 }
80 return [list 0. 0. 0.]
81 }
82
83 Specify Oxs_TimeDriver [subst {
84     basename pulse
85     evolver :evolve
86     comment {run for 5 ns total, with a stage event triggered every 0.2 ns
87         inside the first ns, and then every 0.05 ns for the next 4 ns.}
88     stopping_time {{0.2e-9 5} {0.05e-9 80}} :expand:
89     mesh :mesh
90     Ms 800e3
91     m0 { 1 0.02 0.01 }
92     projection_outputs {
93         mx_corner {Oxs_ScriptVectorField {
94             atlas :atlas
95             script {CornerChunk 1 0 0}
96             script_args rawpt
97         }}
98         my_corner {Oxs_ScriptVectorField {
99             atlas :atlas
100             script {CornerChunk 0 1 0}
101             script_args rawpt
102         }}
103         mz_corner {Oxs_ScriptVectorField {
104             atlas :atlas
105             script {CornerChunk 0 0 1}

```

Time resolution



# One of my own:

```
DepinningFieldsDynamic_v2.mif [C:\hpc\ppxdep\experiments\oommf\depinning_fields\problems] - Notepad...
File Edit View Settings ?
187 #Specify that the script should determine the demagnetising term.
188 Specify Oxs_Demag {}
189
190 Specify Oxs_RungeKuttaEvolve {
191   alpha {Oxs_AtlasScalarField {
192     atlas :atlas
193     values {
194       L2R 0.02
195       R2L 0.02
196       L2R_taper 0.5
197       R2L_taper 0.5
198       universe 0
199       notch 0
200     }
201   }}
202   do_precess 1
203   start_dm 0.01
204   min_timestep 1e-15
205   max_timestep 1e-15
206 }
207
208 # ---- Set us up the time driver ----
209 # Should be of the form:
210 #Specify Oxs TimeDriver:name {
211 #evolver evolver spec
212 #mesh mesh spec
213 #Ms scalar field spec
214 #m0 vector field spec
215 #stopping dm dt torque criteria
216 #stopping time time criteria
Ln 1 / 280 Col 1 / 80 Sel 0 Sel Ln 0 6.37 KB ANSI LF INS Shell Script
```

Set time evolution

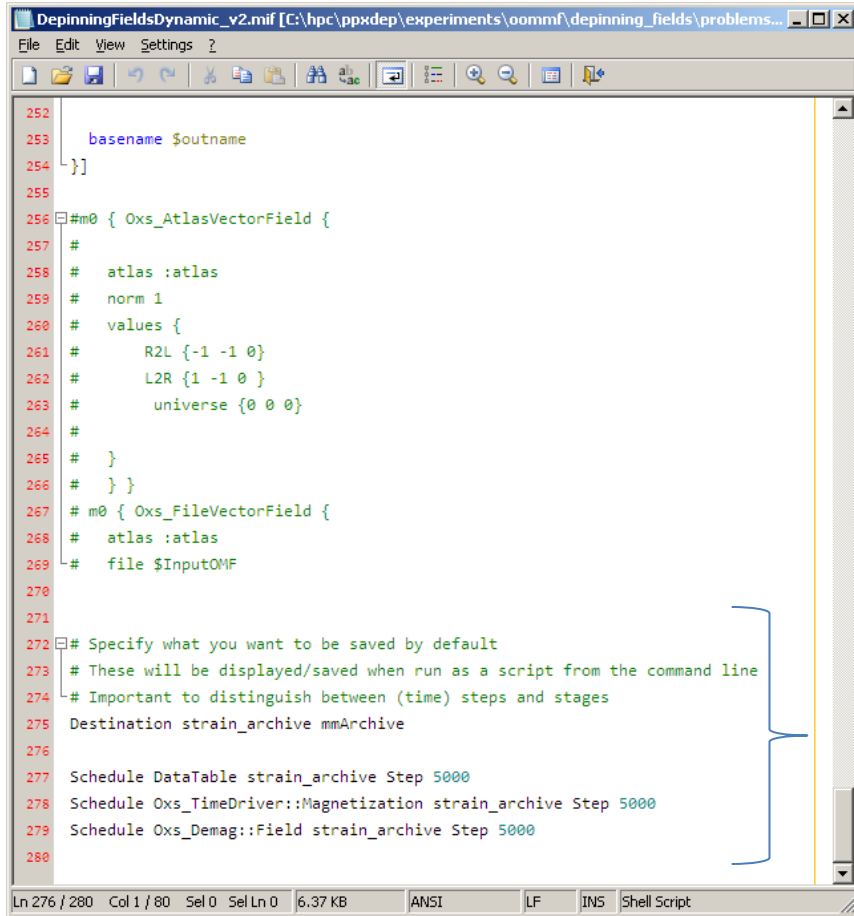
```
DepinningFieldsDynamic_v2.mif [C:\hpc\ppxdep\experiments\oommf\depinning_fields\problems] - Notepad...
File Edit View Settings ?
220 #stage count check test
221 #basename base file name
222 #scalar output format format
223 #vector field output format { style precision }
224 #}
225 # Can replace Ms scalar field with a random field one. See doc for details.
226 # If you just want the simulation to run until ~static use stopping_dm_dt.
227 # According to the help a value of 0.1 - 1.0 is reasonable.
228 Specify Oxs_TimeDriver [ subst {
229   evolver Oxs_RungeKuttaEvolve
230   stopping_dm_dt 1.0
231   mesh :mesh
232   checkpoint_file $checkpoint
233   checkpoint_cleanup done_only
234   Ms {Oxs_AtlasScalarField {
235     atlas :atlas
236     values {
237       universe 0
238       L2R $Ms
239       R2L $Ms
240       L2R_taper $Ms
241       R2L_taper $Ms
242       notch 0
243     }
244   }}
245 } } }
246
247 m0 { Oxs_FileVectorField {
248   atlas :atlas
249   file $OutputDir
Ln 219 / 280 Col 30 / 80 Sel 0 Sel Ln 0 6.37 KB ANSI LF INS Shell Script
```

Set stopping condition

# Analysis

- Making sure we get the right outputs
- Built-in OOMMF tools
- OOMMFTools

# Setting automatic output:

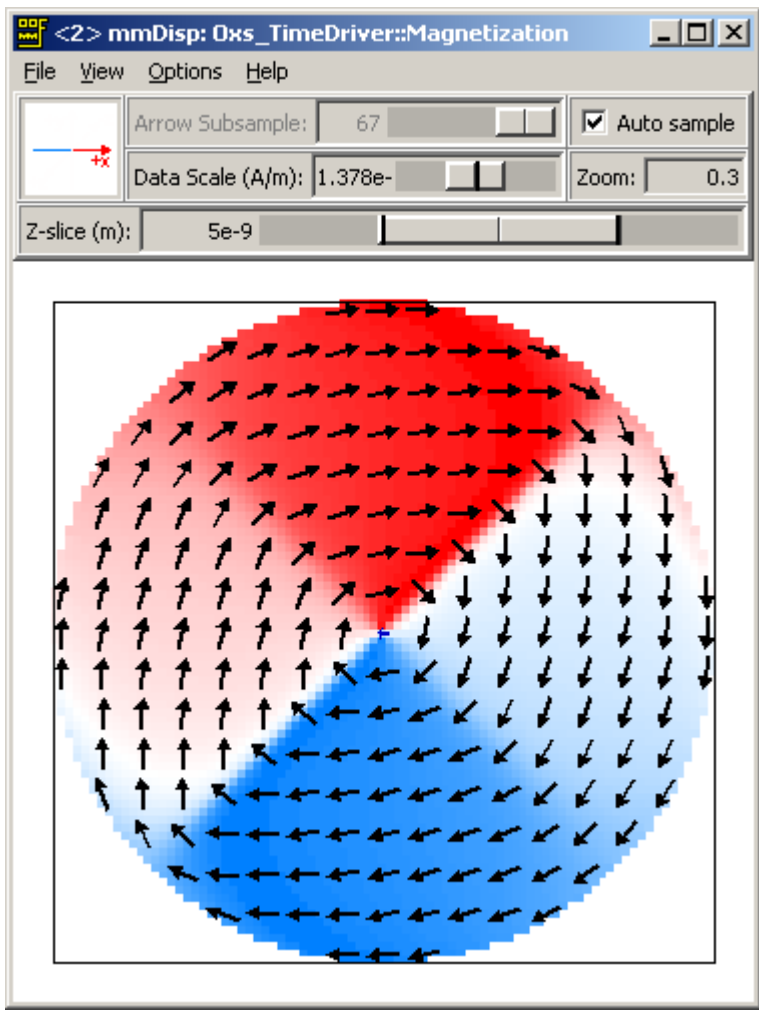


```
252
253   basename $outname
254 }]}
255
256 #m0 { Oxs_AtlasVectorField {
257 #
258 # atlas :atlas
259 # norm 1
260 # values {
261 #   R2L {-1 -1 0}
262 #   L2R {1 -1 0}
263 #   universe {0 0 0}
264 #
265 # }
266 # } }
267 # m0 { Oxs_FileVectorField {
268 # atlas :atlas
269 # file $InputOMF
270
271
272 # Specify what you want to be saved by default
273 # These will be displayed/saved when run as a script from the command line
274 # Important to distinguish between (time) steps and stages
275 Destination strain_archive mmArchive
276
277 Schedule DataTable strain_archive Step 5000
278 Schedule Oxs_TimeDriver::Magnetization strain_archive Step 5000
279 Schedule Oxs_Demag::Field strain_archive Step 5000
280
```

Ln 276 / 280 Col 1 / 80 Sel 0 Sel Ln 0 6.37 KB ANSI LF INS Shell Script

Saves output every 5000 steps (in this case 1 step = 1ps)

# Built-in analysis



The screenshot shows the "Configure -- <2> mmDisp" dialog box. It is divided into several sections for configuring the plot's appearance and data handling.

Plot Type	Colormap	# of Colors	Color Quantity	Subsample	Size
<input checked="" type="checkbox"/> Arrow	Red-Black-Blue Blue-White-Red Green-White-Orange Teal-White-Red	256 <input type="checkbox"/> Reverse	z slice mag xy-angle	67 <input checked="" type="checkbox"/> Auto	1
<input checked="" type="checkbox"/> Pixel	Blue-White-Red Green-White-Orange Teal-White-Red Black-Gray-White	256 <input type="checkbox"/> Reverse <input checked="" type="checkbox"/> Opaque	x y z slice	13 <input checked="" type="checkbox"/> Auto	1

Additional settings at the bottom of the dialog:

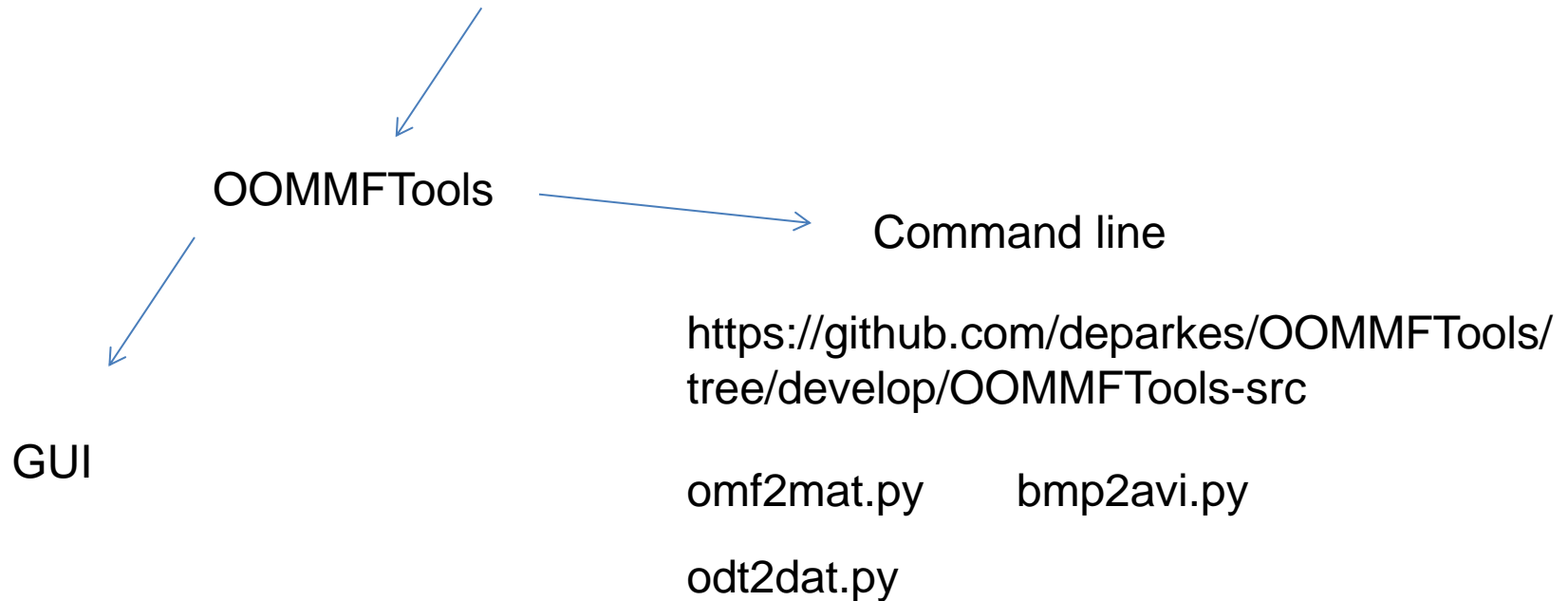
- Data Scale (A/m): 1.378e+01
- Zoom: 0.3
- Margin: 10
- Z-slice center (m): 5e-9
- Arrow span (m): 10.00e-9
- Pixel span (m): 10.00e-9
- Boundary width: 1
- Boundary color: black
- Background color: white

Buttons: Close, Apply, OK

Can save as bitmap  
Also command line tools, but...

## Other analysis

Contributed software: <http://math.nist.gov/oommf/contrib/>



Also <https://github.com/deparkes/scripts/>

mat2velocity.m

mat2strayfield.m

avf2bmp.py

} First attempts at processing in matlab

Convert oommf vector output to

master\_depinning.py

Master script for several processing scripts

Things to watch out for:

- Staircase discretisation: non-90-degree angles will have steps in them
- Cell size: generally needs to be below exchange length for accurate calculation

$$l_1 = \sqrt{\frac{2A}{\mu_0 M_s^2}} \quad l_2 = \sqrt{\frac{A}{K_1}}$$

# Sources of help

- OOMMF manual (comes with oommf download)
- muMag mailing list  
<http://www.ctcms.nist.gov/~rdm/mumag.org.html>
- [deparkes.wordpress.com](http://deparkes.wordpress.com)
- OOMMF example files

# References

## **Parallelizing a Micromagnetic Program for Use on Multiprocessor Shared Memory Computers**

ieee trans magn 45 10 2009

J. Fidler, R. W. Chantrell, T. Schrefl, M. Wongsam, and J. Fidler,  
“Micromagnetics I: Basic principles,” Encyclopedia of Materials: Science and  
Technology, K. H. J. Buschow, R. W. Cahn, M. C. Flemings, B. Ilschner, E. J.  
Kramer, S. Mahajan (eds.), Elsevier, 2001, pp. 5642-5651.

<http://magnet.atp.tuwien.ac.at/ts/papers/ema108015.pdf>

## **Numerical Micromagnetics: Finite Difference Methods**

Micromagnetism

Fundamentals of Micromagnetism and Discrete Computational Models

Jacques E. Miltat<sup>1</sup>,

Michael J. Donahue<sup>2</sup>



# Resources

- <http://magnetism.eu/esm/2009/abs/chubykalo-abs2.pdf>
- Analytical micromagnetics:  
<http://magnetism.eu/esm/2009/slides/fruchart-tutorial.pdf>
- <http://nmag.soton.ac.uk/nmag/0.2/manual/html/tutorial/doc.html>