EPToolbox package

Initialization

This package includes a smal suite of supporting functions for varied applications.

To get things going, load the package.

```
Needs["EPToolbox`"]
```

(Note that this is possible because the package has been installed, by adding the line $Path=Join[$Path,{“/home/episanty/Work/CQD/Project/Code/EPToolbox/EPToolbox”}] to the file /home/episanty/.*Mathematica/*Kernel/init.m.)

Testing

```
Quit
```

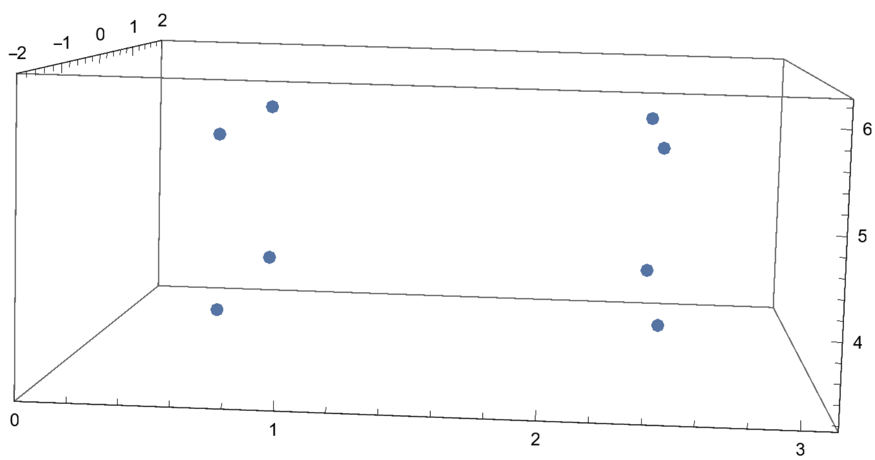
```
NSolve[{1 + (1 - Sin[t])^2 == 0.1 Sin[tt], 2 + (1 - Sin[tt])^2 == 0.01 Cos[t]}, {t, tt}]
```

NSolve::ifun : Inverse functions are being used by NSolve, so some solutions may not be found; use Reduce for complete solution information . ≫

```
{{t → 0.639625 - 1.00689 i, tt → 0.546377 + 1.27521 i},
  {t → 0.639625 + 1.00689 i, tt → 0.546377 - 1.27521 i},
  {t → 0.725756 - 1.06149 i, tt → 0.543716 - 1.2739 i},
  {t → 0.725756 + 1.06149 i, tt → 0.543716 + 1.2739 i},
  {t → 2.41547 - 1.06152 i, tt → 0.544452 + 1.27946 i},
  {t → 2.41547 + 1.06152 i, tt → 0.544452 - 1.27946 i},
  {t → 2.50234 - 1.00692 i, tt → 0.541816 - 1.27817 i},
  {t → 2.50234 + 1.00692 i, tt → 0.541816 + 1.27817 i}}
```

```
(results = FindComplexRoots [
            {1 + (1 - Sin[t])^2 == 0.001 Sin[tt], 1 + (1 + Sin[tt])^2 == 0.001 Cos[t]}
            , {t, -2 ⅈ, 2 π + 2 ⅈ}, {tt, 0, 2 π + 2 ⅈ}
            , SeedGenerator → RandomSobolComplexes
            , Seeds → 100
            , Tolerance → 0.01
          ]) // Sort // Length
ListPointPlot3D[
  Flatten[{ReIm [t], Re[tt]}] /. results
  , ImageSize → 450
  , PlotRange → {{0, π}, {-2, 2}, {π, 2 π}}
  , PlotStyle → PointSize[Large]
]
```

8




```
RandomSobolComplexes
```

```
Solve
```

Functions

FindComplexRoots

This is a function to solve numerically (mainly trascendental) equations on the complex plane. It is documented in depth in http://mathematica.stackexchange.com/a/57821.

Its main usage is as follows:

```
Quit
```

```
?FindComplexRoots
Options[FindComplexRoots]
?Seeds
?SeedGenerator
?Tolerance
```

FindComplexRoots[e1==e2, {z, zmin, zmax}] attempts to find complex
roots of the equation e1==e2 in the complex rectangle with corners zmin and zmax.

FindComplexRoots[{e1==e2, e3==e4, …}, {z1, z1min, z1max}, {z2, z2min,
z2max}, …] attempts to find complex roots of the given system of equations in the
multidimensional complex rectangle with corners z1min, z1max, z2min, z2max, ….

```
{AccuracyGoal → Automatic, Compiled → Automatic, DampingFactor → 1,
 Evaluated → True, EvaluationMonitor → None, Jacobian → Automatic,
 MaxIterations → 100, Method → Automatic, PrecisionGoal → Automatic,
 StepMonitor → None, WorkingPrecision → MachinePrecision, Seeds → 50,
 SeedGenerator → RandomComplex, Tolerance → Automatic, Verbose → False}
```

Seeds is an option for FindComplexRoots which determines
how many initial seeds are used to attempt to find roots of the given equation.

SeedGenerator is an option for FindComplexRoots which determines the function used to generate the seeds
for the internal FindRoot call. Its value can be RandomComplex, RandomNiederreiterComplexes,
RandomSobolComplexes, DeterministicComplexGrid, or any function f such that f[{zmin,
zmax}, n] returns n complex numbers in the rectancle with corners zmin and zmax.

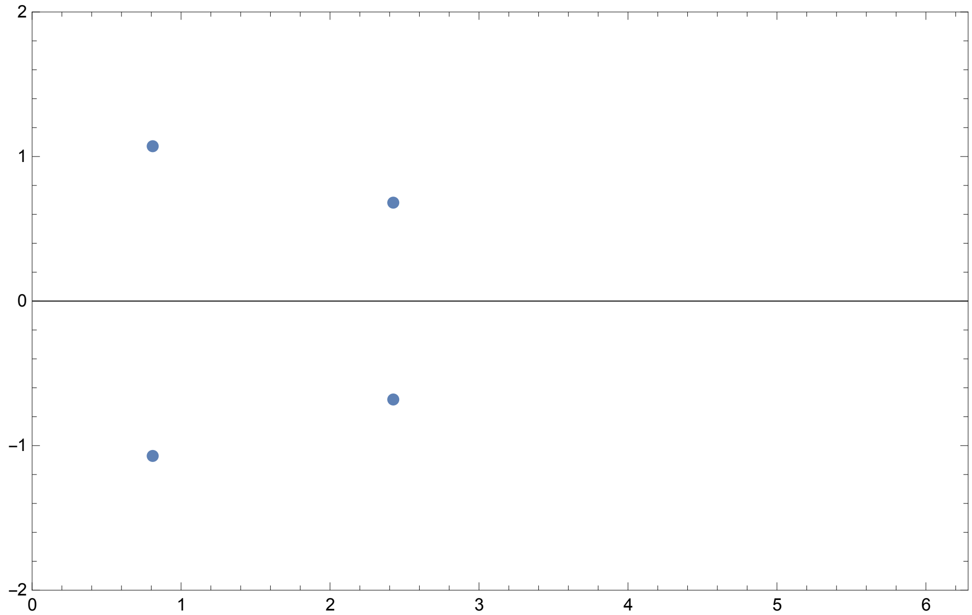
Tolerance is an option for various numerical options which
specifies the tolerance that should be allowed in computing results. >>

Some simple examples:

```
FindComplexRoots[1 + (1 - Sin[t])^2 == 0.1 t, {t, -2 ⅈ, 2 π + 2 ⅈ}]
```

```
{{t → 2.46095 + 0.963404 ⅈ}, {t → 0.709879 - 1.06182 ⅈ},
 {t → 2.46095 - 0.963404 ⅈ}, {t → 0.709879 + 1.06182 ⅈ}}
```

```
ListPlot[
  {Re[t], Im [t]} /. FindComplexRoots [1 + (1 - Sin[t])^2 == 0.3 t, {t, -2 ⅈ, 2 π + 2 ⅈ}]
  , Frame  → True
  , ImageSize  → 500
  , PlotRange → {{0, 2 π}, {-2, 2}}
]
```



Benchmarking suite for FindComplexRoots

FindComplexRoots works probabilistically, by randomly seeding points in the given rectangle and then using descent methods to find roots. This means that if not enough seeds are tried (i.e. the Seeds option is too low) then the function may behave erratically and return an incomplete (and varying) set of roots. To deal with this behaviour, the following is a benchmarking suite to help determine the seeding characteristics required by each equation for consistent behaviour.

Timings and generation of the benchmarks

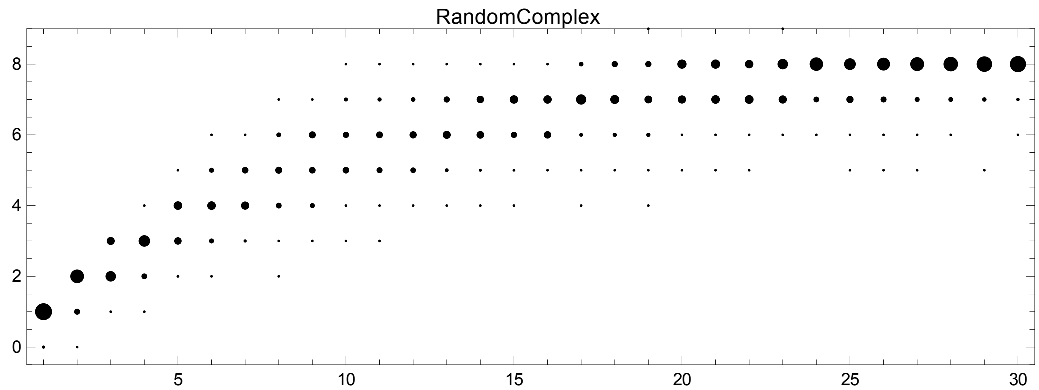
```
Monitor[
    Table[
      {seedGenerator, AbsoluteTiming [
            benchmark [seedGenerator] = Flatten[Table[
                    {seedNumber , Length[#[[2]]], #[[1]]} & [AbsoluteTiming [
                        FindComplexRoots [
                          (1 + (1 - Sin[t])^2) (1 + (1 + Sin[t])^2) == 0.01 t, {t, -2 ⅈ, 2 π + 2 ⅈ}
                          , Tolerance → Automatic ,
                          Seeds → seedNumber , SeedGenerator → seedGenerator
                        ]
                    ]]
                    , {seedNumber , 1, 30}, {repetition, 100}
                  ], 1];
          ][[1]]}
      , {seedGenerator, {RandomComplex , RandomSobolComplexes ,
          RandomNiederreiterComplexes , DeterministicComplexGrid }}]
    , {seedGenerator, seedNumber , repetition}] // TableForm
```

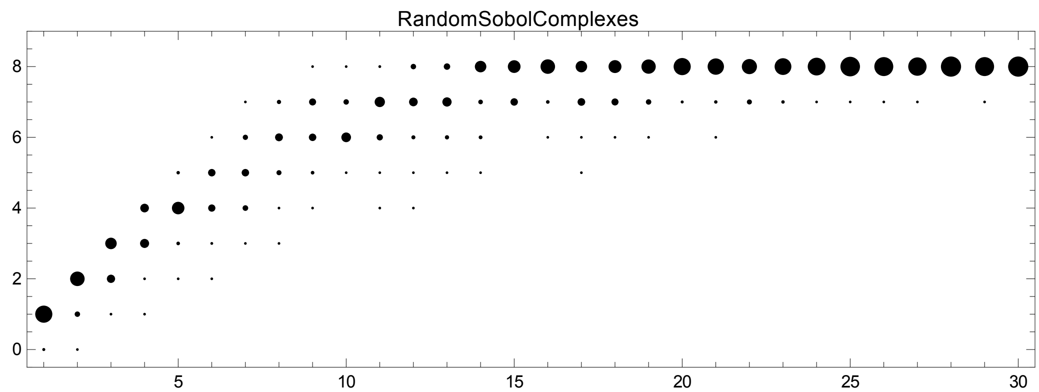
RandomComplex	35.126341
RandomSobolComplexes	35.993279
RandomNiederreiterComplexes	36.162666
DeterministicComplexGrid	64.186886

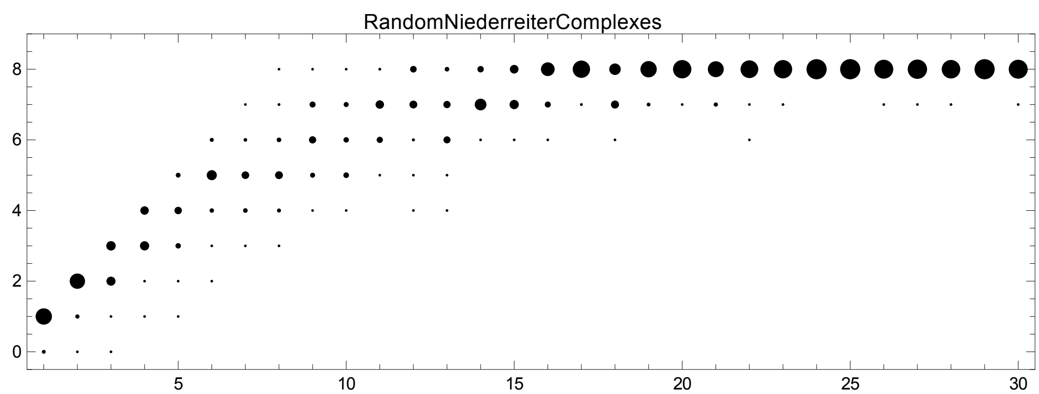
Number of roots found vs number of seeds

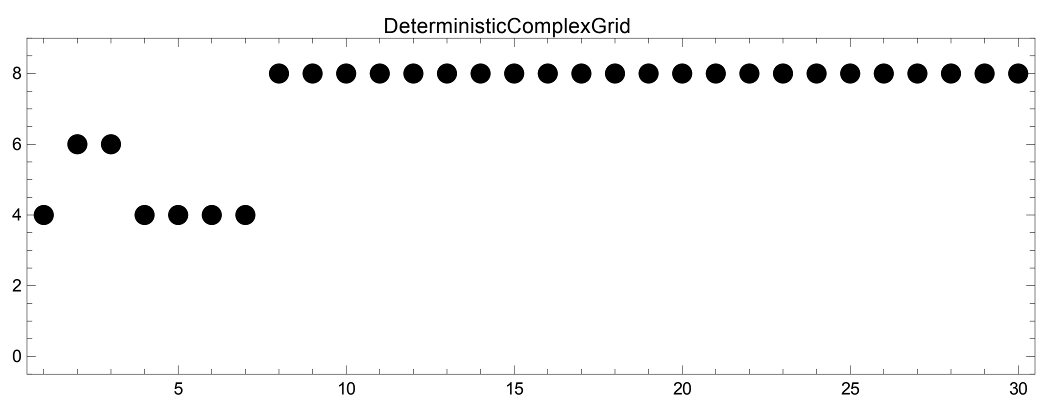
Dot diameter proportional to the number of repetitions that gave that number of roots.

```
GraphicsColumn [
  Table[
    Show[
      Graphics[
            {PointSize[0.0002 #2], Point[#1]}] &@@@Tally[
          benchmark [seedGenerator] [[All, {1, 2}]]
        ]
      , Frame → True
      , ImageSize → 600
      , AspectRatio→ 1 / 3
      , PlotRange→ {{.5, 30.5}, {-0.5, 9}}
      , PlotLabel → ToString[seedGenerator]
    ]
    , {seedGenerator, {RandomComplex , RandomSobolComplexes ,
        RandomNiederreiterComplexes , DeterministicComplexGrid }}]
]
```


RandomComplex
0
2
4
6
8
5
10
15
20
25
30

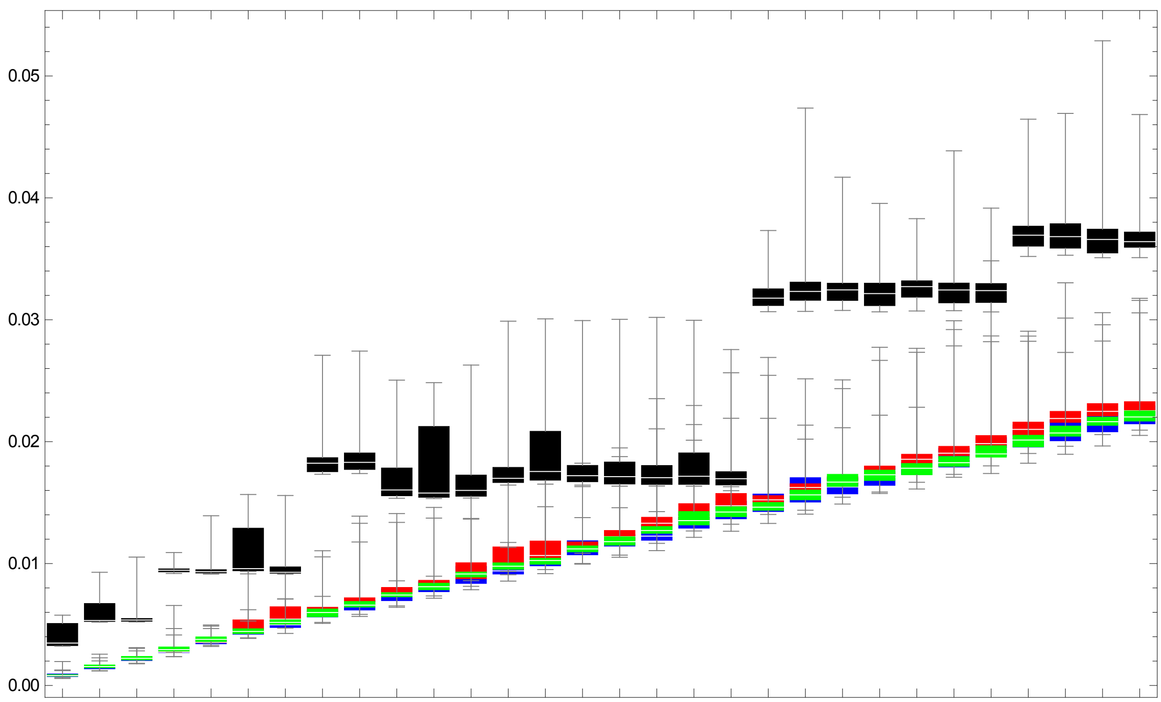

RandomSobolComplexes
0
2
4
6
8
5
10
15
20
25
30


RandomNiederreiterComplexes
0
2
4
6
8
5
10
15
20
25
30


DeterministicComplexGrid
0
2
4
6
8
5
10
15
20
25
30

More detailed statistics on the distribution of roots found

```
Show[
  Table[
    BoxWhiskerChart[
      SplitBy[
          benchmark [seedGenerator][[All, {1, 3}]]
          , First][[All, All, 2]]
      , ImageSize → 600
      , PlotRangePadding→ None
      , ChartStyle→ seedGenerator /. {
          RandomComplex   → Blue, RandomSobolComplexes   → Red,
          RandomNiederreiterComplexes  → Green, DeterministicComplexGrid → Black
        }
    ]
    , {seedGenerator, {RandomComplex  , RandomSobolComplexes  ,
        RandomNiederreiterComplexes  , DeterministicComplexGrid }}]
]
```



Quasirandom complex number generators.

The performance of FindComplexRoots can be increased, as shown above, by using quasirandom numbers instead of pure random selections. (Pseudo)random numbers tend to bunch up, in the plane, which increases the chances of roots being missed or repeated. To remedy this, it is often beneficial to use low-discrepancy quasirandom number generators, which are more evenly distributed on the complex plane.

```
?RandomComplex
?RandomSobolComplexes
?RandomNiederreiterComplexes
?DeterministicComplexGrid
```

RandomComplex[] gives a pseudorandom complex number with real and imaginary parts in the range 0 to 1.
RandomComplex[{z_{min}, z_{max}}] gives a pseudorandom complex number in the rectangle with corners given by the complex numbers z_{min} and z_{max}.
RandomComplex[z_{max}] gives a pseudorandom complex number in the rectangle whose corners are the origin and z_{max}.
RandomComplex[*range*, n] gives a list of n pseudorandom complex numbers.
RandomComplex[*range*, {n_1, n_2, …}] gives an $n_1 \times n_2 \times \ldots$ array of pseudorandom complex numbers. ≫

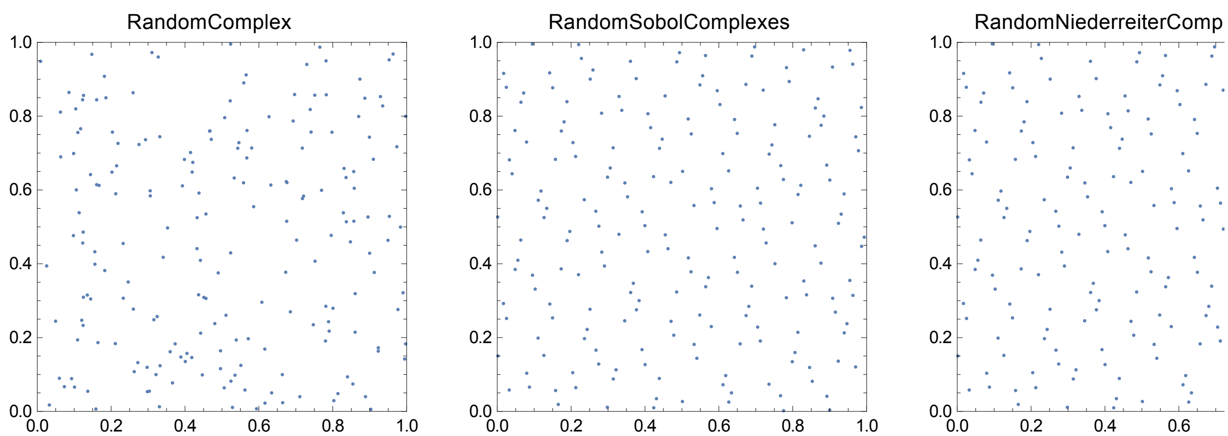
RandomSobolComplexes[{zmin, zmax}, n] generates a low–discrepancy Sobol sequence of n quasirandom complex numbers in the rectangle with corners zmin and zmax.

RandomNiederreiterComplexes[{zmin, zmax}, n] generates a low–discrepancy Niederreiter sequence of n quasirandom complex numbers in the rectangle with corners zmin and zmax.

DeterministicComplexGrid[{zmin, zmax}, n] generates a grid of about n equally spaced complex numbers in the rectangle with corners zmin and zmax.

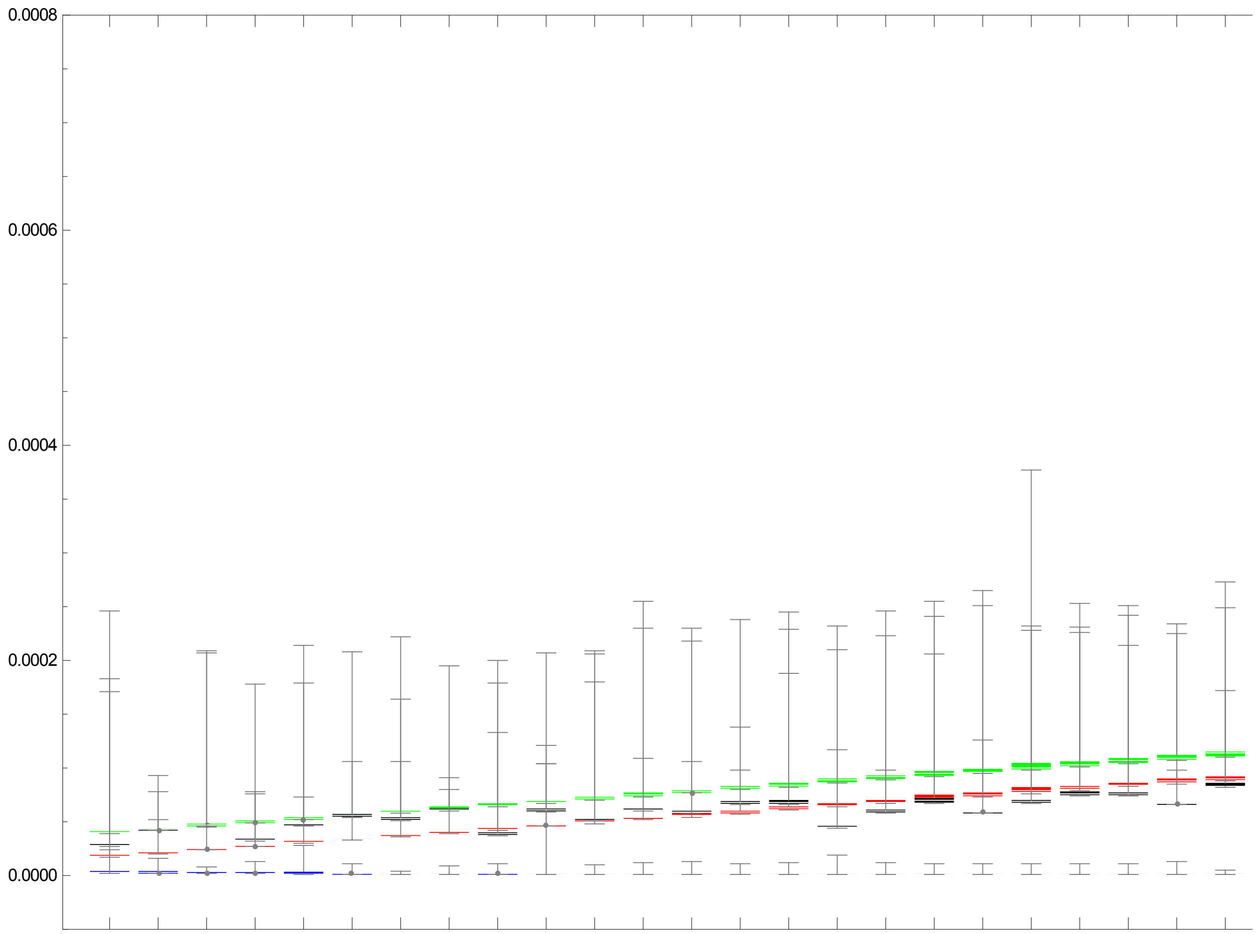
Distribution of the different (pseudo/quasi)random number generators on the complex plane

```
GraphicsRow[
  Table[
    ListPlot[
      {Re[#], Im [#]} & /@seedGenerator[{0, 1 + ⅈ}, 200]
      , Frame → True
      , PlotRange → {{0, 1}, {0, 1}}
      , AspectRatio→ 1
      , PlotLabel → ToString[seedGenerator]
      , ImageSize → 220
    ]
    , {seedGenerator, {RandomComplex , RandomSobolComplexes ,
        RandomNiederreiterComplexes , DeterministicComplexGrid }}]
]
```



Timings statistics

```
Show[
  Monitor[Table[
      BoxWhiskerChart[
        SplitBy[
            Table[
              {n, First[AbsoluteTiming [seedGenerator[{0, 1+ⅈ}, n]]]}
              , {n, 1, 30}, {repetitions, 500}]
            , First] [[All, All, All, 2]]
        , ImageSize → 800
        , PlotRange→{0, 0.004}
        , PlotRangePadding→None
        , ChartStyle→ (seedGenerator /. {
                RandomComplex → Blue, RandomSobolComplexes → Red,
                RandomNiederreiterComplexes → Green,
                DeterministicComplexGrid → Black
              })
        , ChartLegends→{RandomComplex , RandomSobolComplexes ,
            RandomNiederreiterComplexes , DeterministicComplexGrid }
      ]
      , {seedGenerator, {RandomComplex , RandomSobolComplexes ,
          RandomNiederreiterComplexes , DeterministicComplexGrid }}]
    , {seedGenerator, n, repetitions}]
  , PlotRange→{-0.00005, 0.0008}
]
```

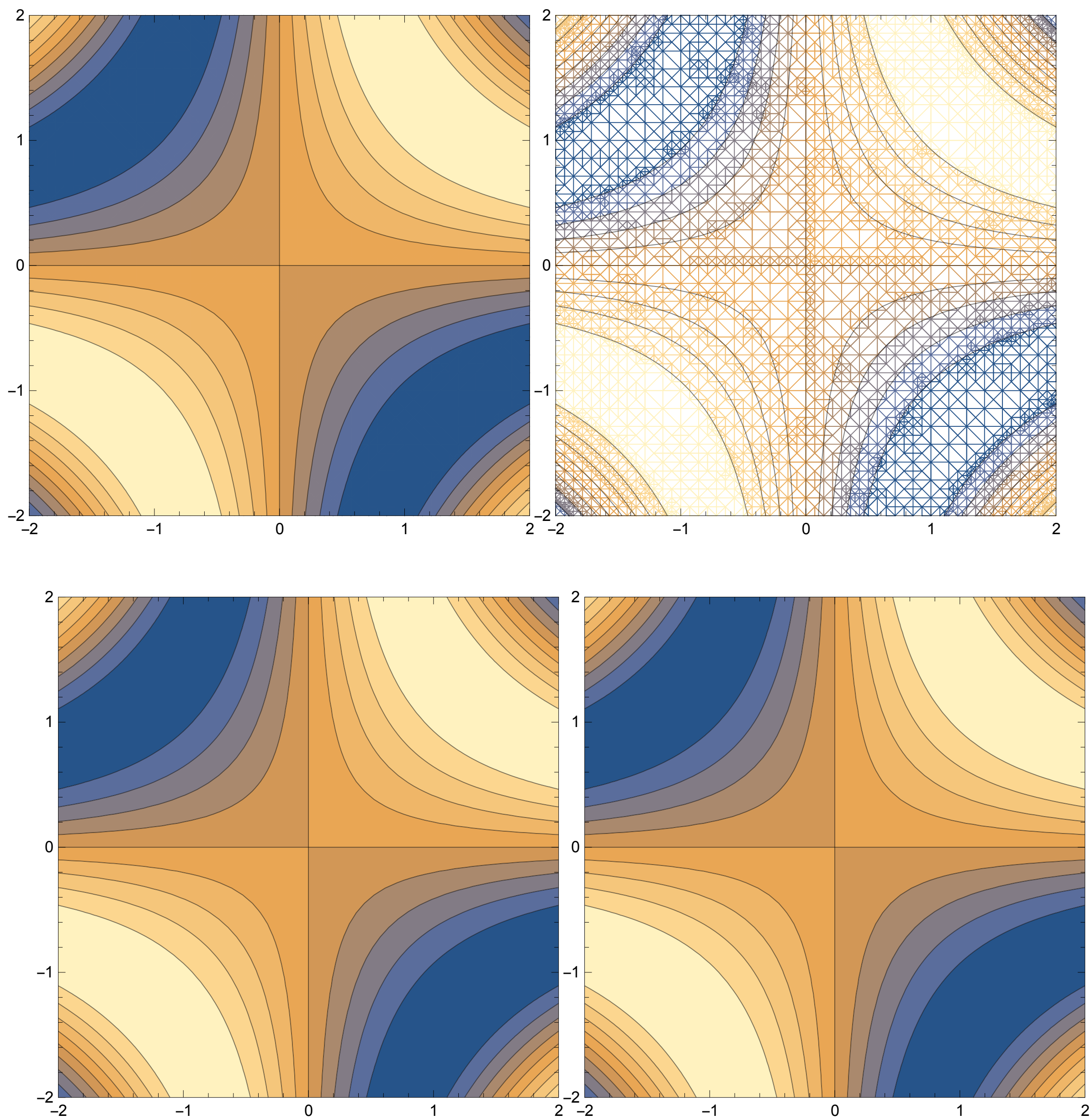


cleanContourPlot

This function cleans up automatically generated contour plots. Generically, a contour plot is made of a Polygon with a vast number of vertices in its interior, which are not necessary and only slow the plot down - including a large use of CPU when the mouse hovers above it, which is definitely unwanted. (In addition, these polygons can give rise to white edges inside each contour when printed to pdf, which is also undesirable.) This function changes such Polygons to FilledCurve constructs which no longer contain the unwanted mid-contour points.

This function was written by Szabolcs Horvát (http://mathematica.stackexchange.com/users/12/szabolcs) and was originally posted at http://mathematica.stackexchange.com/a/3279 under a CC-BY-SA license.

```
Row[{#, # /. Polygon → Line, cleanContourPlot[#],
      cleanContourPlot[#] /. Polygon → Line}] &@ContourPlot[
   Sin[x y]
   , {x, -2, 2}, {y, -2, 2}
   , ImageSize → 300, PlotRangePadding → None
  ]
```



profileDynamics

This function produces a profiling suite for any dynamics constructs, which can be used to see which parts of a Dynamic application take up the most processing time and calls.

This function was written by Rui Rojo (http://mathematica.stackexchange.com/users/109/rojo)and was originally posted at http://mathematica.stackexchange.com/a/8047 under a CC-BY-SA license.

```
profileDynamics [
  DynamicModule [
    {a = 0.1, point= {1, 1}},
    Column [{
        Slider[Dynamic [a]],
        LocatorPane[
          Dynamic [point],
          Dynamic [
            Show[
              ContourPlot[
                Sin[a x y], {x, -5, 5}, {y, -5, 5}
                , ImageSize → 300, PlotRangePadding→ None
              ],
              Graphics[Line[{{0, 0}, Dynamic [point]}]]
            ]
          ]
        ],
        Dynamic [point]
      }]
  ]
]
```