LCG_turtle

1.0

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Contents

Chapter 1

Python <A HREF="https://docs.python.org/3/library/turtle.html">Turtle Graphics - A set of simple python programs for practicing CG concepts.

The set is made up of 12 small programs in increasing order of difficulty.
The most challenging script aims at drawing some parametric curves, defined in `polar coordinates`, using the turtle intrinsic coordinate system.

Only the **forward, left** and **right** commands should be used (no setposition). This way, one may imagine controlling an airplane or a drone, as if a remote control were being used.

In 3D, this would resemble the ubiquitous **yaw, pitch** and **roll** rotation paradigm.

1.1 release.notes

These programs run either in python 2.7 or python 3.6

1. `README`
2. `refman.pdf`

To run any program:

- python prog_name.py or
- python3 prog_name.py

where the prog_name is the name of a file, with a python 2 or 3 source code, such as:

- python `turtle/polar.py`

Chapter 2

Namespace Index

2.1 Namespace List

Here is a list of all namespaces with brief descriptions:

Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 4

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4.1 File List

Here is a list of all files with brief descriptions:

Chapter 5

Namespace Documentation

5.1 flailDriver Namespace Reference

Classes

- class FlailDriver

Functions

- def title (s)
- def setup (width, height)
- def bgcolor (r, g, b)
- def window_width ()
- def window_height ()
- def setworldcoordinates (x0, y0, x1, y1)
- def speed (v)

5.1.1 Function Documentation

5.1.1.1 bgcolor()

```
def flailDriver.bgcolor (
              r,
              g,
              b )
```

Definition at line 7 of file flailDriver.py.

5.1.1.2 setup()

```
def flailDriver.setup (
              width,
              height )
```

Definition at line 4 of file flailDriver.py.

5.1.1.3 setworldcoordinates()

```
def flailDriver.setworldcoordinates (
              x0,
              y0,
              x1,
              y1 )
```

Definition at line 16 of file flailDriver.py.

5.1.1.4 speed()

```
def flailDriver.speed (
              v )
```

Definition at line 19 of file flailDriver.py.

5.1.1.5 title()

```
def flailDriver.title (
              s )
```

Definition at line 1 of file flailDriver.py.

5.1.1.6 window_height()

```
def flailDriver.window_height ( )
```

Definition at line 13 of file flailDriver.py.

5.1.1.7 window_width()

```
def flailDriver.window_width ( )
```

Definition at line 10 of file flailDriver.py.

5.2 polar Namespace Reference

Plot polar equations.

Functions

- def drawAxis (length, ticks=10)

  Draw and put labels onto an axis, which is aligned with the coordinate system.
- def axes (w, h)

  Plot a pair of perpendicular axes.
- def updateBBOX (BBOX, x, y)

  Update a curve bounding box, by adding a new point to it.
- def toInt (x)

  Convert a float number, representing a length, to an integer, with a fixed number of bits.
- def toFloat (b)

  Get the float representation of an integer number.
- def toBinary (num, count=0, sign="")

  Get the binary representation of a number, recursively.
- def toDenary (b)

  Converts a string representing a binary number to denary.
- def _toDenary (a)

  Return the decimal number represented by binary digits in a list.
- def _toDenaryRec (a)

  Return the decimal number represented by binary digits in a list.
- def toUBAM (x)

  Convert an angle to UBAM.
- def float2UBAM (num)

  Convert a float number to an Unsigned Binary Angle Measurement (UBAM).
- def float2BAM (_num)

  Convert a float number to a signed Binary Angle Measurement (BAM).
- def BAM2float (b)

  Convert BAM to float.
- def f0 (c, t, a=0, b=1/(2 ∗pi))

  Archimedean spiral.
- def f6 (a, t)

  Lemniscate of Bernoulli.
- def f12 (c, t, a=2, b=3)

  Limaçon of Pascal.
- def f14 (a, t)

Cochleoid.
- def f15 (a, t)

  Fermat's Spiral.
- def f19 (a, t, e=1, l=1)

  Parabola.
- def f20 (a, t)

  Hyperbola.
- def f21 (a, t)

  Ellipse.
- def f23 (a, t)

  Star.
- def f24 (a, t)

  Cannabis.
- def help (j=None)

  Print curve identifications.
- def move (x, y, mode=True)

  Move the turtle to a given point.
- def drawBox (b)

  Draw a box.
- def polarRose (func, turns, initialAng=0.0, title=None, nseg=None)

  Draw some polar equations.
- def main (argv=None)

  Main program.

Variables

- bool usingFlail = True

  Whether using the flail driver for writing a file, instead of turtle for drawing on screen.
- int WIDTH = 800

  Canvas width.
- int HEIGHT = 800

  Canvas height.
- int LW = 680

  World Coordinate width.
- int LH = 680

  World Coordinate height.
- veclen = lambda x,x1,y,y1: sqrt((x-x1)∗(x-x1) + (y-y1)∗(y-y1))

  Length of vector from point (x1,y1) to (x,y).
- dotprod = lambda x,x1,x0,y,y1,y0: ((x1-x0) ∗ (x-x1) + (y1-y0) ∗ (y-y1))

  Dot product of vectors from point (x0,y0) to (x1,y1) and from (x1,y1) to (x,y).
- crossprod = lambda x,x1,x0,y,y1,y0: (x1-x0)∗(y-y1) - (y1-y0)∗(x-x1)

  Cross product of vectors from point (x0,y0) to (x1,y1) and from (x1,y1) to (x,y).
- clamp = lambda a: min(max(-1,a),1)

  Clamp a value to range [-1,1].
- polar2Cartesian = lambda r,a: (r∗cos(a),r∗sin(a))

  Get cartesian coordinates from polar coordinates.

- cartesian2Polar = lambda x,y: (sqrt(x*x+y*y), atan2(-y,-x)+pi)

  Get the polar coordinates from cartesian coordinates.
- setColor = lambda v: joe.color("red" if v $<$ 0 else "blue")

  Set the color of the curve.
- int wrapPi = lambda x: x - 360 * ((x + 180) // 360)

  Wraps an angle to ± 180.
- bool __toDebug__ = False

  Toggle debugging mode.
- int NBITS = 8

  Number of bits after binary point.
- int BSCALE = 2**NBITS

  Scale for fixed point: 256 or 65536, for instance.
- float2Int = lambda f: int(f*BSCALE)

  Maps a float number to integer.
- int2Float = lambda b: ldexp(float(b),-NBITS)

  Maps an integer number to float.
- list bam_bit_table = [0.0055, 0.0109, 0.0219, 0.0439, 0.088, 0.1757, 0.3515, 0.703, 1.406, 2.8125, 5.625, 11.25, 22.5, 45.0, 90.0, 180.0]

  BAM bit table.
- int WSIZE = len(bam_bit_table)-1

  Word size for BAM.
- int LSB = 2**-WSIZE * 180

  Least Significant Bit.
- int f1 = 4: (a * 2*sin(n*t), t)

  A rose of n or 2n petals.
- int f2 = lambda a, t: f1(a,t,5)

  A rose of five petals.
- int f3 = lambda a, t: f1(a,t,3)

  A rose of three petals.
- int f4 = lambda a, t: f1(a,t,2)

  A rose of four petals.
- f5 = lambda a, t: (a * cos(t/2.0), t)

  Double Loop.
- f7 = lambda a, t: (a * 2 * sin(t), t)

  Circle.
- f8 = lambda a, t: (a * (2*sin(2*t)+1), t)

  Bowtie.
- f9 = lambda a, t: (a * (cos(5*t)**2 + sin(3*t) + 0.3), t)

  Oscar's butterfly.
- f10 = lambda a, t: (a * (sin(t) + sin(5*t/2)**3), t)

  Crassula Dubia.
- f11 = lambda a, t: (a/6 * (9 - 3*sin(t) + 2*sin(3*t) - 3*sin(7*t) + 5*cos(2*t)), t)

  Majestic butterfly.
- f13 = lambda a, t: ((100*a if t $<=$ 0.01 else a/t), t)

  Hyperbolic Spiral.
- f16 = lambda a, t: (a * (sin (2**t) - 1.7), t)

  A Face.

- f17 = lambda a, t: (a∗0.8 ∗ (2 - 2 ∗ sin(t) + sin(t) ∗ (sqrt(abs(cos(t)) / (sin(t) + 1.4)))), t)

  Heart.
- f18 = lambda a, t: (a ∗ (1 - cos(t) ∗ sin(3∗t)), t)

  Ameba.
- f22 = lambda a, t: (a ∗ (1 + 2 ∗ sin(t/2)), t)

  Freeth's Nephroid.
- list curveList

  List of tuples with: polar equation function, angle range, initial angle, title and number of segments.

5.2.1 Detailed Description

Plot polar equations.

Author

Paulo and Flavia Roma

Date

01/01/2019

See also

https://en.wikipedia.org/wiki/Polar_coordinate_system
http://jwilson.coe.uga.edu/emt668/emat6680.2003.fall/shiver/assignment11/polargraphs.htm
http://wwwp.fc.unesp.br/~mauri/Down/Polares.pdf
http://jwilson.coe.uga.edu/emat6680fa08/kimh/assignment11hjk/assignment11.html
https://elepa.files.wordpress.com/2013/11/fifty-famous-curves.pdf

5.2.2 Function Documentation

5.2.2.1 _toDenary()

```
def polar._toDenary (
              a )  [private]
```

Return the decimal number represented by binary digits in a list.

Non recursive version.

Definition at line 219 of file polar.py.

5.2.2.2 _toDenaryRec()

```
def polar._toDenaryRec (
              a )  [private]
```

Return the decimal number represented by binary digits in a list.

Recursive version.

Definition at line 228 of file polar.py.

Referenced by toDenary().

5.2.2.3 axes()

```
def polar.axes (
              w,
              h )
```

Plot a pair of perpendicular axes.

Definition at line 84 of file polar.py.

References drawAxis(), and move().

Referenced by polarRose().

5.2.2.4 BAM2float()

```
def polar.BAM2float (
              b )
```

Convert BAM to float.

Adding 180° to any angle is analogous to taking its two's complement.

Consider the LSB (least significant bit) of an *n-bit* word to be $2^{-(n-1)}$, with most significant bit $(MSB) = 180^{\circ}$.

- sum(v $*$ ((b>>i)&1) for i,v in enumerate(bam_bit_table)) =
- $(180\ b_{15} + 90\ b_{14} + 45\ b_{13} + 22.5\ b_{12} + ... +\ 0.0055\ b_0) =$
- $180\ (b_{15} + b_{14}\ 2^{-1} + b_{13}\ 2^{-2} + b_{12}\ 2^{-3} + ... +\ b_0\ 2^{-15}) =$
- $180 * 2^{-15} (b_{15}\ 2^{15} + b_{14}\ 2^{14} + b_{13}\ 2^{13} + b_{12}\ 2^{12} + ... +\ b_0) =$
- $180 * 2^{-15} * b$

The range of any angle θ represented this way is:

- $0^{\circ} \leq \theta \leq 360 - 180 \times 2^{-(n-1)^{\circ}}$.

Parameters

b	BAM angle.

Returns

a float pointing number: b ∗ LSB ∗ MSB.

See also

https://www.cs.cornell.edu/~tomf/notes/cps104/twoscomp.html
Software Engineering for Image Processing Systems, Page 154

Definition at line 352 of file polar.py.

Referenced by main(), toFloat(), and toUBAM().

5.2.2.5 drawAxis()

```
def polar.drawAxis (
              length,
              ticks = 10 )
```

Draw and put labels onto an axis, which is aligned with the coordinate system.

The origin is at the middle of the axis and there will be the same number of ticks on each side of the axis.

Parameters

length	axis length.
ticks	number of divisions.

Definition at line 71 of file polar.py.

Referenced by axes().

5.2.2.6 drawBox()

```
def polar.drawBox (
              b )
```

Draw a box.

Definition at line 710 of file polar.py.

References move().

Referenced by polarRose().

5.2.2.7 f0()

```
def polar.f0 (
              c,
              t,
              a = 0,
              b = 1/(2*pi) )
```

Archimedean spiral.

The spiral becomes tighter for smaller values of "b" and wider for larger values.

- $r(\theta) = a + b\theta$.

The Archimedean spiral has two arms, one for $\theta > 0$ and one for $\theta < 0$.

- The two arms are smoothly connected at the origin.

The negative arm is shown in red on the accompanying graph.

- Taking the mirror image of this arm across the y-axis will yield the other arm.

Parameters

c	scale factor to be applied.
t	parametric value.
a	origin of the spiral: (a,0).
b	controls the distance between successive turnings.

Returns

a tuple (r, θ) representing a point in polar coordinates.

See also

https://en.wikipedia.org/wiki/Archimedean_spiral

Definition at line 373 of file polar.py.

References setColor.

5.2.2.8 f12()

```
def polar.f12 (
              c,
              t,
              a = 2,
              b = 3 )
```

Limaçon of Pascal.

- $r(\theta) = a + b\, sin(\theta)$.
- When a $<$ b: limacon with and inner loop.
- When a $>$ b: dimpled limacon.
- When a $>$= 2b: convex limacon.
- When a = b: cardioid.

Changing from sine to cosine does not affect the shape of the graph, just its orientation.

- Equations using sine will be symmetric to the vertical axis,
- while equations using cosine are symmetric to the horizontal axis.
- The sign of b will also affect their orientation.

See also

https://en.wikipedia.org/wiki/Limaçon

Definition at line 483 of file polar.py.

5.2.2.9 f14()

```
def polar.f14 (
              a,
              t )
```

Cochleoid.

- $r(\theta) = a\, \frac{sin(\theta)}{\theta}$.
- $r(0) = a$.

Negative angles in red.

Parameters

a	scale to be applied on the curve.
t	parametric value.

Returns

a tuple (r, θ) representing a point in polar coordinates.

See also

https://en.wikipedia.org/wiki/Cochleoid

Definition at line 515 of file polar.py.

References setColor.

5.2.2.10 f15()

```
def polar.f15 (
              a,
              t )
```

Fermat's Spiral.

- $r^2(\theta) = a^2\ \theta$.
- $r(\theta) = \pm a\sqrt{\theta}$.

Negative angles (red) return $r = -a\sqrt{\theta}$.

Parameters

a	scale to be applied on the curve.
t	parametric value.

Returns

a tuple (r, θ) representing a point in polar coordinates.

See also

https://en.wikipedia.org/wiki/Fermat%27s_spiral

Definition at line 530 of file polar.py.

References setColor.

5.2.2.11 f19()

```
def polar.f19 (
              a,
              t,
              e = 1,
              l = 1 )
```

Parabola.

- $r(\theta) = \frac{l}{1+ \ e \ cos(\theta)}$.

Parameters

a	scale factor to be applied.
t	parametric value.
e	is the eccentricity of the conic section,
l	is the length of the semi-latus rectum (the distance along the y-axis from the pole to the curve).

Using the equation above, the conic section will always have a focus at the pole.

The directrix will be the line $x = \frac{1}{e}$

- $r = \frac{1}{e} sec(\theta)$ in polar form.

Different values of *e* will give different kinds of conic sections:

- If e == 0, then the curve is a circle.
- If 0 $<$ e $<$ 1, then the curve is an ellipse.
- If e == 1, then the curve is a parabola.
- If e $>$ 1, then the curve is a hyperbola.

See also

https://brilliant.org/wiki/polar-curves/

Definition at line 577 of file polar.py.

References setColor.

Referenced by f20(), and f21().

5.2.2.12 f20()

```
def polar.f20 (
              a,
              t )
```

Hyperbola.

- $r(\theta) = \frac{1}{1+1.5\ cos(\theta)}$.
- If $cos(\theta) = -\frac{1}{1.5} \Rightarrow \theta = acos(-\frac{1}{1.5}) = \pm 2.30052$ rad $= \pm 131.81° \Rightarrow$
  - $lim_{\theta \to -2.3^-} r(\theta) = \infty$
  - $lim_{\theta \to -2.3^+} r(\theta) = -\infty$
  - $lim_{\theta \to 2.3^-} r(\theta) = \infty$
  - $lim_{\theta \to 2.3^+} r(\theta) = -\infty$
- Throw an exception (raise ValueError) when $(2.05 \leq \theta \leq 2.481)$ or $(-2.481 \leq \theta \leq -2.05)$.

See also

https://brilliant.org/wiki/polar-curves/

Definition at line 593 of file polar.py.

References f19().

5.2.2.13 f21()

```
def polar.f21 (
              a,
              t )
```

Ellipse.

- $r(\theta) = \frac{1}{1+0.5\ cos(\theta)}$.

See also

https://brilliant.org/wiki/polar-curves/

Definition at line 604 of file polar.py.

References f19().

5.2.2.14 f23()

```
def polar.f23 (
              a,
              t )
```

Star.

- $r(\theta) = sin^2(1.2\theta) + cos^3(6\theta)$

See also

https://www.originlab.com/index.aspx?go=products/origin/graphing

Definition at line 619 of file polar.py.

References setColor.

5.2.2.15 f24()

```
def polar.f24 (
              a,
              t )
```

Cannabis.

- $r(\theta) = (1 + 0.9\ cos(8\theta))\ (1 + 0.1\ cos(24\theta))\ (0.9 + 0.1\ cos(200\theta))\ (1 + sin(\theta))$

See also

https://www.wolframalpha.com/input/?i=(1%2B0.9+cos(8+θ))+(1%2B0.1+cos(24+θ))+(0.9%2↩
B0.1+cos(200+θ))+(1%2Bsin(θ))+polar+-pi+to+pi

Definition at line 628 of file polar.py.

References setColor.

5.2.2.16 f6()

```
def polar.f6 (
             a,
             t )
```

Lemniscate of Bernoulli.

- $r^2(\theta) = 2a^2\ cos\ (2\theta)$.
- $r(\theta) = \pm a\ \sqrt{2\ cos\ (2\theta)}$.

The length is 2a. Valid angle ranges into [], and invalid into ().

- [-pi/4 , pi/4] (pi/4 , 3pi/4) [3pi/4 , 5pi/4] (5pi/4 - 7pi/4)

Negative angles in red.

Parameters

a	scale to be applied on the curve.
t	parametric value.

Returns

0 for invalid angles or (r, θ) otherwise.

See also

https://en.wikipedia.org/wiki/Lemniscate_of_Bernoulli

Definition at line 421 of file polar.py.

References setColor.

5.2.2.17 float2BAM()

```
def polar.float2BAM (
              _num )
```

Convert a float number to a signed Binary Angle Measurement (BAM).

Parameters

_num	a float number.

Returns

a Short Integer [-32768 to 32767] corresponding to an angle [-180 to 180).

See also

https://github.com/borcun/bams/blob/master/bams.c
http://electronicstechnician.tpub.com/14091/css/Binary-Angular-Measurement-316.↩
htm

Definition at line 326 of file polar.py.

References float2UBAM().

Referenced by toInt().

5.2.2.18 float2UBAM()

```
def polar.float2UBAM (
              num )
```

Convert a float number to an Unsigned Binary Angle Measurement (UBAM).

BAM data words are specifically designed to represent up to $360°$ of angular displacements in binary form, often in steps, or increments of, as small as the LSB value ($0.0055°$ for a 16 bit word).

This 16-bit word '11001000 00000000' $(b_{15} * 2^{15} + ... + \ b_0 * 2^0)$ can represent a $281.25°$ angle:

- 281.25 = 180 + 90 + 11.25
- float2UBAM(281.25) = $(1 << 15) + (1 << 14) + (1 << 11) = 2^{15} + 2^{14} + 2^{11}$ = 51200

When set to one, the LSB (Least Significant Bit) is equal to $0.0055°$, while the MSB (Most Significant Bit) is equal to $180°$.

- The MSB value represents half the maximum value that may be transmitted.

When all 16 bits are set:

- an angle greater than $359.9939°$ is indicated,
- their sum is 359.9939, and corresponds to the maximum quantity that can be transmitted.

When all bits in the BAM data word are clear (with ZEROS), a $0°$ angle is represented.

BAM words are also used to transmit non-angular values, such as range, length or height.

- When non-angular values are being used, the LSB value contains the smallest step, or increment of the quantity being transmitted.

In C language, integers overflow behavior is different regarding the integer signedness.

Two situations arise: (Basics of Integer Overflow)

- signed integer overflow : undefined behavior
- unsigned integer overflow : safely wraps around (UINT_MAX + 1 gives 0)

One way, of mimicking this behaviour in Python, is using uint16 from numpy.

Parameters

num	a float number.

Returns

an Unsigned short integer [0 to 65535] corresponding to an angle [0 to 360).

See also

https://github.com/borcun/bams/blob/master/bams.c
http://electronicstechnician.tpub.com/14091/css/Binary-Angular-Measurement-316.↩
htm
https://loicpefferkorn.net/2013/09/python-force-c-integer-overflow-behavior/
https://docs.scipy.org/doc/numpy-1.13.0/user/basics.types.html

Definition at line 309 of file polar.py.

Referenced by float2BAM(), main(), polarRose(), and toUBAM().

5.2.2.19 help()

```
def polar.help (
        j = None )
```

Print curve identifications.

Definition at line 633 of file polar.py.

Referenced by main().

5.2.2.20 main()

```
def polar.main (
        argv = None )
```

Main program.

Parameters

argv	list of arguments. • argv[1] number of segments to draw a curve. • argv[2] scale factor to be applied on all curves.

Definition at line 878 of file polar.py.

References BAM2float(), float2UBAM(), help(), and polarRose().

5.2.2.21 move()

```
def polar.move (
              x,
              y,
              mode = True )
```

Move the turtle to a given point.

- $>$ direction of movement
-] turtle head.

Parameters

x	coordinate.
y	coordinate.
mode	whether to use setposition, or use only forward, left and right.

Definition at line 681 of file polar.py.

Referenced by axes(), drawBox(), and polarRose().

5.2.2.22 polarRose()

```
def polar.polarRose (
              func,
              turns,
              initialAng = 0.0,
              title = None,
              nseg = None )
```

Draw some polar equations.

We should keep three points: (x0,y0), (x1,y1), (x2,y2).

- $(x0, y0) \rightarrow (x1, y1)$ is the previous segment.
- $(x1, y1) \rightarrow (x2, y2)$ is the current segment.

First, we calculate the angle γ between these two segments, by using the dot product:

- $c = cos(\gamma) = \frac{(x_1-x_0,y_1-y_0)}{\sqrt{(x_1-x_0)^2+(y_1-y_0)^2}} \cdot \frac{(x_2-x_1,y_2-y_1)}{\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}} = \frac{(x1-x0)*(x2-x1)+(y1-y0)*(y2-y1)}{\sqrt{((x_1-x_0)^2+(y_1-y_0)^2)\ ((x_2-x_1)^2+(y_2-y_1)^2)}}$
- $\gamma = acos(min(max(c,-1),1)),$

so the turtle makes a left or right turn, based on the sign of the cross product of the two segments:

$$Or_2(P_0,P_1,P_2) = \text{sign} \begin{vmatrix} 1 & 1 & 1 \\ x_0 & x_1 & x_2 \\ y_0 & y_1 & y_2 \end{vmatrix} = x_1y_2 + x_2y_0 + x_0y_1 - x_1y_0 - x_2y_1 - x_0y_2 =$$

- $x_1(y_2 - y_0 - y_1 + y_1) - x_2(y_1 - y_0) - x_0(y_2 - y_1) =$
- $x_1(y_2 - y_1) + x_1(y_1 - y_0) - x_2(y_1 - y_0) - x_0(y_2 - y_1) =$
- $(x_1 - x_0)(y_2 - y_1) - (y_1 - y_0)(x_2 - x_1) \Rightarrow$
  - $(x_1 - x_0, y_1 - y_0) \times (x_2 - x_1, y_2 - y_1) = (x1 - x0) * (y2 - y1) - (y1 - y0) * (x2 - x1)$
    * $< 0 \rightarrow$ right turn
    * $> 0 \rightarrow$ left turn

Then, the turtle moves forward by a distance equal to the length of the current segment: $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

For the first point, we need the angle $\alpha \in [0, 2\pi]$ between the *x-axis* and the vector $(x_1 - x_0, y_1 - y_0)$:

- $\alpha = atan2(y0 - y1, x0 - x1) + \pi$
  - $atan2(y, x) \rightarrow \alpha \in [-\pi, \pi]$
  - $atan2(-y, -x) + \pi \rightarrow \alpha \in [0, 2\pi]$

Parameters

func	equation.
turns	polar angle range (extension).
initialAng	initial polar angle.
title	curve name.
nseg	number of segments.

See also

https://en.wikipedia.org/wiki/Inverse_trigonometric_functions
https://docs.python.org/3/library/math.html
https://www.mathsisfun.com/algebra/vectors-dot-product.html

Definition at line 765 of file polar.py.

References axes(), cartesian2Polar, clamp, crossprod, drawBox(), float2UBAM(), move(), polar2Cartesian, toInt(), toUBAM(), updateBBOX(), and veclen.

Referenced by main().

5.2.2.23 toBinary()

```
def polar.toBinary (
              num,
              count = 0,
              sign = "" )
```

Get the binary representation of a number, recursively.

Parameters

num	number to be parsed.
count	number of bits generated so far.
sign	string holding the sign of the number.

Returns

string representing the number, with the [amount] and its set of bits:

- e.g. toBinary(15) –> '[4] 1 1 1 1'
- e.g. toBinary(-215) –> '[8] -1 1 0 1 0 1 1 1 '

Definition at line 195 of file polar.py.

Referenced by toInt(), and toUBAM().

5.2.2.24 toDenary()

```
def polar.toDenary (
              b )
```

Converts a string representing a binary number to denary.

Definition at line 207 of file polar.py.

References _toDenaryRec().

Referenced by toInt(), and toUBAM().

5.2.2.25 toFloat()

```
def polar.toFloat (
              b )
```

Get the float representation of an integer number.

Definition at line 180 of file polar.py.

References BAM2float(), and int2Float.

Referenced by toInt().

5.2.2.26 toInt()

```
def polar.toInt (
              x )
```

Convert a float number, representing a length, to an integer, with a fixed number of bits.

Since we use polar coordinates, angles should be thought of as going from 0 to 360. Using two decimal places, this means going from 0 to 36000.

- Therefore, 16 bits (2 bytes) are enough. For distances, this is also satisfactory, for radii (scales) not too small.
- To keep the integers small, we use BAM whenever possible, so only 2 bytes are enough.
- For radius $<$ 4, BAM does not provide the appropriate precision for distances, and the curve may not even close.

See also

https://ipfs.io/ipfs/QmXoypizjW3WknFiJnKLwHCnL72vedxjQkDDP1mXWo6uco/wiki/Binary_scaling.html
https://en.wikipedia.org/wiki/Binary_scaling
https://www.allaboutcircuits.com/technical-articles/fixed-point-representation-the-q-fc
https://www.eecs.umich.edu/courses/eecs373/readings/floating-point-to-fixed.pdf

Definition at line 157 of file polar.py.

References float2BAM(), float2Int, toBinary(), toDenary(), and toFloat().

Referenced by polarRose().

5.2.2.27 toUBAM()

```
def polar.toUBAM (
              x )
```

Convert an angle to UBAM.

The main advantage is using only two bytes, instead of the eight bytes of a float.

If the goal is to send angles through the net or write them on a file, we save 75% of space this way.

Parameters

x	an angle as a float.

Returns

another float angle, after coding x using two bytes.

See also

https://blogs.msdn.microsoft.com/shawnhar/2010/01/04/angles-integers-and-modulo-arithme

Definition at line 244 of file polar.py.

References BAM2float(), float2UBAM(), toBinary(), and toDenary().

Referenced by polarRose().

5.2.2.28 updateBBOX()

```
def polar.updateBBOX (
              BBOX,
              x,
              y )
```

Update a curve bounding box, by adding a new point to it.

Definition at line 110 of file polar.py.

Referenced by polarRose().

5.2.3 Variable Documentation

5.2.3.1 __toDebug__

```
bool polar.__toDebug__ = False  [private]
```

Toggle debugging mode.

Definition at line 125 of file polar.py.

5.2.3.2 bam_bit_table

```
list polar.bam_bit_table = [ 0.0055, 0.0109, 0.0219, 0.0439, 0.088, 0.1757, 0.3515, 0.703, 1.406,
2.8125, 5.625, 11.25, 22.5, 45.0, 90.0, 180.0 ]
```

BAM bit table.

sum(bam_bit_table) = 359.9939

Definition at line 257 of file polar.py.

5.2.3.3 BSCALE

```
int polar.BSCALE = 2**NBITS
```

Scale for fixed point: 256 or 65536, for instance.

Definition at line 131 of file polar.py.

5.2.3.4 cartesian2Polar

```
polar.cartesian2Polar = lambda x,y:  (sqrt(x*x+y*y), atan2(-y,-x)+pi)
```

Get the polar coordinates from cartesian coordinates.

Definition at line 107 of file polar.py.

Referenced by polarRose().

5.2.3.5 clamp

```
polar.clamp = lambda a:  min(max(-1,a),1)
```

Clamp a value to range [-1,1].

Definition at line 101 of file polar.py.

Referenced by polarRose().

5.2.3.6 crossprod

```
polar.crossprod = lambda x,x1,x0,y,y1,y0:  (x1-x0)*(y-y1) - (y1-y0)*(x-x1)
```

Cross product of vectors from point (x0,y0) to (x1,y1) and from (x1,y1) to (x,y).

Definition at line 98 of file polar.py.

Referenced by polarRose().

5.2.3.7 curveList

```
list polar.curveList
```

Initial value:

```
=  [(f0,12*pi,-6*pi,"Archimedean spiral"),
             (f1,2*pi,0,"A rose of eight petals"),
             (f2,pi,0,"A rose of four petals"),
             (f3,pi,0,"A rose of three petals"),
             (f4,2*pi,0,"A rose of five petals"),
             (f5,4*pi,0,"Double Loop"),
             (f6,6*pi/4,-pi/4,"Lemniscate of Bernoulli"),
             (f7,pi,0,"Circle"),
             (f8,2*pi,0,"Bowtie"),
             (f9,2*pi,0,"Oscar's butterfly"),
             (f10,4*pi,0,"Crassula Dubia"),
             (f11,2*pi,0,"Majestic butterfly"),
             (f12,2*pi,0,"Limaçon"),
             (f13,8*pi,0.25,"Hyperbolic Spiral",120),
             (f14,12*pi,-6*pi,"Cochleoid"),
             (f15,12*pi,-6*pi,"Fermat's Spiral"),
             (f16,2*pi,0,"A Face"),
             (f17,2*pi,0,"A Heart"),
             (f18,2*pi,0,"Ameba"),
             (f19,8*pi/5,-4*pi/5,"Parabola"),
             (f20,2*pi,-pi,"Hyperbola"),
             (f21,2*pi,-pi,"Ellipse"),
             (f22,4*pi,0,"Freeth's Nephroid"),
             (f23,10*pi,-5*pi,"Star"),
             (f24,2*pi,-pi,"Cannabis",600)]
```

List of tuples with: polar equation function, angle range, initial angle, title and number of segments.

Definition at line 646 of file polar.py.

5.2.3.8 dotprod

```
polar.dotprod = lambda x,x1,x0,y,y1,y0:  ((x1-x0) * (x-x1) + (y1-y0) * (y-y1))
```

Dot product of vectors from point (x0,y0) to (x1,y1) and from (x1,y1) to (x,y).

Definition at line 95 of file polar.py.

5.2.3.9 f1

```
int polar.f1 = 4:  (a * 2*sin(n*t), t)
```

A rose of *n* or *2n* petals.

- $r(\theta) = a\, 2\, sin(n\theta)$.

If *n* is an integer, the curve will be rose-shaped with

- *2n* petals if *n* is even, and
- *n* petals if *n* is odd.

Parameters

a	scale to be applied on the curve.
t	parametric value θ.

Returns

a tuple (r, θ) representing a point in polar coordinates.

See also

https://en.wikipedia.org/wiki/Rose_(mathematics)

Definition at line 389 of file polar.py.

5.2.3.10 f10

```
polar.f10 = lambda a, t:  (a * (sin(t) + sin(5*t/2)**3), t)
```

Crassula Dubia.

- $r(\theta) = sin(\theta) + sin^3(5\frac{\theta}{2})$.

See also

http://jwilson.coe.uga.edu/emt668/emat6680.2003.fall/shiver/assignment11/polargraphs.↩
htm

Definition at line 459 of file polar.py.

5.2.3.11 f11

```
polar.f11 = lambda a, t:  (a/6 * (9 - 3*sin(t) + 2*sin(3*t) - 3*sin(7*t) + 5*cos(2*t)), t)
```

Majestic butterfly.

- $r(\theta) = 9 - 3\, sin(\theta) + 2\sin{(3\theta)} - 3\sin(7\theta) + 5\, cos(2\theta)$.

See also

https://www.desmos.com/calculator/pgyxrshobg

Definition at line 466 of file polar.py.

5.2.3.12 f13

```
polar.f13 = lambda a, t:  ((100*a if t <= 0.01 else a/t), t)
```

Hyperbolic Spiral.

- $r(\theta) = \frac{a}{\theta}$.

It begins at an infinite distance from the pole in the center (for θ starting from zero, $r = a/\theta$ starts from infinity),

- and it winds faster and faster around as it approaches the pole;
- the distance from any point to the pole, following the curve, is infinite.

The spiral has an asymptote at y = a:

- for t approaching zero the ordinate approaches a, while the abscissa grows to infinity.

Parameters

a	scale to be applied on the curve.
t	parametric value.

Returns

a tuple (r, θ) representing a point in polar coordinates.

See also

https://en.wikipedia.org/wiki/Hyperbolic_spiral

Definition at line 502 of file polar.py.

5.2.3.13 f16

```
polar.f16 = lambda a, t:  (a * (sin (2**t) - 1.7), t)
```

A Face.

- $r(\theta) = sin(2^{\theta}) - 1.7$.

See also

https://www.intmath.com/plane-analytic-geometry/8-curves-polar-coordinates.↩
php

Definition at line 540 of file polar.py.

5.2.3.14 f17

```
polar.f17 = lambda a, t:  (a*0.8 * (2 - 2 * sin(t) + sin(t) * (sqrt(abs(cos(t)) / (sin(t) + 1.↩
4)))), t)
```

Heart.

- $r(\theta) = 2 - 2\ sin(\theta) + sin(\theta) \frac{\sqrt{|cos(\theta)|}}{sin(\theta)+1.4}$.

See also

http://mathworld.wolfram.com/HeartCurve.html

Definition at line 547 of file polar.py.

5.2.3.15 f18

```
polar.f18 = lambda a, t:  (a * (1 - cos(t) * sin(3*t)), t)
```

Ameba.

- $r(\theta) = 1 - cos(\theta)\, sin(3\theta)$.

See also

https://brilliant.org/wiki/polar-curves/

Definition at line 554 of file polar.py.

5.2.3.16 f2

```
int polar.f2 = lambda a, t:  f1(a,t,5)
```

A rose of five petals.

Definition at line 392 of file polar.py.

5.2.3.17 f22

```
polar.f22 = lambda a, t:  (a * (1 + 2 * sin(t/2)), t)
```

Freeth's Nephroid.

- $r(\theta) = a(1 + 2\, sin(\theta/2))$

See also

https://elepa.files.wordpress.com/2013/11/fifty-famous-curves.pdf

Definition at line 612 of file polar.py.

5.2.3.18 f3

```
int polar.f3 = lambda a, t:  f1(a,t,3)
```

A rose of three petals.

Definition at line 395 of file polar.py.

5.2.3.19 f4

```
int polar.f4 = lambda a, t:  f1(a,t,2)
```

A rose of four petals.

Definition at line 398 of file polar.py.

5.2.3.20 f5

```
polar.f5 = lambda a, t:  (a * cos(t/2.0), t)
```

Double Loop.

- $r(\theta) = a\ cos(\frac{\theta}{2})$.

See also

http://jwilson.coe.uga.edu/emt668/emat6680.2003.fall/shiver/assignment11/polargraphs.↩
htm

Definition at line 405 of file polar.py.

5.2.3.21 f7

```
polar.f7 = lambda a, t:  (a * 2 * sin(t), t)
```

Circle.

Centered at (0,a) and diameter 2a.

- $r(\theta) = 2a\ sin(\theta)$.

Parameters

a	radius.
t	parametric value.

Returns

a tuple (r, θ) representing a point in polar coordinates.

Definition at line 438 of file polar.py.

5.2.3.22 f8

```
polar.f8 = lambda a, t:  (a * (2*sin(2*t)+1), t)
```

Bowtie.

- $r(\theta) = 2\ sin(2\theta) + 1.$

See also

http://jwilson.coe.uga.edu/emat6680fa08/kimh/assignment11hjk/assignment11.↩
html

Definition at line 445 of file polar.py.

5.2.3.23 f9

```
polar.f9 = lambda a, t:  (a * (cos(5*t)**2 + sin(3*t) + 0.3), t)
```

Oscar's butterfly.

- $r(\theta) = cos^2(5\theta) + sin(3\theta) + 0.3.$

See also

http://jwilson.coe.uga.edu/emt668/emat6680.2003.fall/shiver/assignment11/polargraphs.↩
htm

Definition at line 452 of file polar.py.

5.2.3.24 float2Int

```
polar.float2Int = lambda f:  int(f*BSCALE)
```

Maps a float number to integer.

See also

https://www.youtube.com/watch?v=wbxSTxhTmrs&fbclid=IwAR2f04_45mIFGtIczS↩
OzbB8nxfqb6SX0pkVlxySfnnBf4n6e8KdKRHXkY2I
https://www.cl.cam.ac.uk/teaching/1011/FPComp/fpcomp10slides.pdf?fbclid=↩
IwAR3G7UxIIrOGxOUJq7IMp8rzZMlBUex-9ZRyCyu_842LxPDTWaWyb4Xvyjc

Definition at line 137 of file polar.py.

Referenced by toInt().

5.2.3.25 HEIGHT

```
int polar.HEIGHT = 800
```

Canvas height.

Definition at line 58 of file polar.py.

5.2.3.26 int2Float

```
polar.int2Float = lambda b:  ldexp(float(b),-NBITS)
```

Maps an integer number to float.

Reconstruct the number with NBITS bits after the binary point.

Definition at line 141 of file polar.py.

Referenced by toFloat().

5.2.3.27 LH

```
int polar.LH = 680
```

World Coordinate height.

Definition at line 63 of file polar.py.

5.2.3.28 LSB

```
int polar.LSB = 2**-WSIZE * 180
```

Least Significant Bit.

LSB = bam_bit_table[0] = 2**-15 * 180 = 0.0054931640625

Definition at line 267 of file polar.py.

5.2.3.29 LW

```
int polar.LW = 680
```

World Coordinate width.

Definition at line 61 of file polar.py.

5.2.3.30 NBITS

```
int polar.NBITS = 8
```

Number of bits after binary point.

Definition at line 128 of file polar.py.

5.2.3.31 polar2Cartesian

```
polar.polar2Cartesian = lambda r,a:  (r*cos(a),r*sin(a))
```

Get cartesian coordinates from polar coordinates.

Definition at line 104 of file polar.py.

Referenced by polarRose().

5.2.3.32 setColor

```
polar.setColor = lambda v:  joe.color("red" if v < 0 else "blue")
```

Set the color of the curve.

Definition at line 117 of file polar.py.

Referenced by f0(), f14(), f15(), f19(), f23(), f24(), and f6().

5.2.3.33 usingFlail

```
bool polar.usingFlail = True
```

Whether using the flail driver for writing a file, instead of turtle for drawing on screen.

Definition at line 49 of file polar.py.

5.2.3.34 veclen

```
polar.veclen = lambda x,x1,y,y1:  sqrt((x-x1)*(x-x1) + (y-y1)*(y-y1))
```

Length of vector from point (x1,y1) to (x,y).

Definition at line 92 of file polar.py.

Referenced by polarRose().

5.2.3.35 WIDTH

```
int polar.WIDTH = 800
```

Canvas width.

Definition at line 56 of file polar.py.

5.2.3.36 wrapPi

```
int polar.wrapPi = lambda x:  x - 360 * ((x + 180) // 360)
```

Wraps an angle to ± 180.

See also

`3D Math Primer for Graphics and Game Development, page 241`.

Definition at line 122 of file polar.py.

5.2.3.37 WSIZE

```
int polar.WSIZE = len(bam_bit_table)-1
```

Word size for BAM.

Definition at line 261 of file polar.py.

Chapter 6

Class Documentation

6.1 flailDriver.FlailDriver Class Reference

Public Member Functions

- def __init__ (self, shape, visible)
- def setposition (self, x, y)
- def goto (self, x, y)
- def write (self, t)
- def dot (self)
- def penup (self)
- def home (self)
- def pendown (self)
- def reset (self)
- def pensize (self, val)
- def color (self, c)
- def setheading (self, h)
- def forward (self, dist)
- def backward (self, dist)
- def left (self, ang)
- def right (self, ang)

Public Attributes

- f

Static Public Attributes

- string formati = "(%d);\n"
- string formatu = "(%u);\n"

Private Member Functions

- def __del_ (self)

6.1.1 Detailed Description

Definition at line 22 of file flailDriver.py.

6.1.2 Constructor & Destructor Documentation

6.1.2.1 __init__()

```
def flailDriver.FlailDriver.__init__ (
              self,
              shape,
              visible )
```

Definition at line 27 of file flailDriver.py.

6.1.3 Member Function Documentation

6.1.3.1 __del_()

```
def flailDriver.FlailDriver.__del_ (
              self )  [private]
```

Definition at line 82 of file flailDriver.py.

References flailDriver.FlailDriver.f.

6.1.3.2 backward()

```
def flailDriver.FlailDriver.backward (
              self,
              dist )
```

Definition at line 70 of file flailDriver.py.

References flailDriver.FlailDriver.f, and flailDriver.FlailDriver.write().

6.1.3.3 color()

```
def flailDriver.FlailDriver.color (
              self,
              c )
```

Definition at line 58 of file flailDriver.py.

6.1.3.4 dot()

```
def flailDriver.FlailDriver.dot (
              self )
```

Definition at line 40 of file flailDriver.py.

6.1.3.5 forward()

```
def flailDriver.FlailDriver.forward (
              self,
              dist )
```

Definition at line 64 of file flailDriver.py.

6.1.3.6 goto()

```
def flailDriver.FlailDriver.goto (
              self,
              x,
              y )
```

Definition at line 34 of file flailDriver.py.

6.1.3.7 home()

```
def flailDriver.FlailDriver.home (
              self )
```

Definition at line 46 of file flailDriver.py.

6.1.3.8 left()

```
def flailDriver.FlailDriver.left (
              self,
              ang )
```

Definition at line 74 of file flailDriver.py.

References flailDriver.FlailDriver.f, and flailDriver.FlailDriver.write().

6.1.3.9 pendown()

```
def flailDriver.FlailDriver.pendown (
              self )
```

Definition at line 49 of file flailDriver.py.

6.1.3.10 pensize()

```
def flailDriver.FlailDriver.pensize (
              self,
              val )
```

Definition at line 55 of file flailDriver.py.

6.1.3.11 penup()

```
def flailDriver.FlailDriver.penup (
              self )
```

Definition at line 43 of file flailDriver.py.

6.1.3.12 reset()

```
def flailDriver.FlailDriver.reset (
              self )
```

Definition at line 52 of file flailDriver.py.

6.1.3.13 right()

```
def flailDriver.FlailDriver.right (
              self,
              ang )
```

Definition at line 78 of file flailDriver.py.

References flailDriver.FlailDriver.f, and flailDriver.FlailDriver.write().

6.1.3.14 setheading()

```
def flailDriver.FlailDriver.setheading (
              self,
              h )
```

Definition at line 61 of file flailDriver.py.

6.1.3.15 setposition()

```
def flailDriver.FlailDriver.setposition (
              self,
              x,
              y )
```

Definition at line 31 of file flailDriver.py.

6.1.3.16 write()

```
def flailDriver.FlailDriver.write (
              self,
              t )
```

Definition at line 37 of file flailDriver.py.

Referenced by flailDriver.FlailDriver.backward(), flailDriver.FlailDriver.left(), and flailDriver.FlailDriver.right().

6.1.4 Member Data Documentation

6.1.4.1 f

```
flailDriver.FlailDriver.f
```

Definition at line 28 of file flailDriver.py.

Referenced by flailDriver.FlailDriver.__del_(), flailDriver.FlailDriver.backward(), flailDriver.FlailDriver.left(), and flailDriver.FlailDriver.right().

6.1.4.2 formati

```
string flailDriver.FlailDriver.formati = "(%d);\n" [static]
```

Definition at line 24 of file flailDriver.py.

6.1.4.3 formatu

```
string flailDriver.FlailDriver.formatu = "(%u);\n" [static]
```

Definition at line 25 of file flailDriver.py.

The documentation for this class was generated from the following file:

- flailDriver.py

Chapter 7

File Documentation

7.1 flailDriver.py File Reference

Classes

- class flailDriver.FlailDriver

Namespaces

- flailDriver

Functions

- def flailDriver.title (s)
- def flailDriver.setup (width, height)
- def flailDriver.bgcolor (r, g, b)
- def flailDriver.window_width ()
- def flailDriver.window_height ()
- def flailDriver.setworldcoordinates (x0, y0, x1, y1)
- def flailDriver.speed (v)

7.2 polar.py File Reference

Namespaces

- polar

  Plot polar equations.

Functions

- def polar.drawAxis (length, ticks=10)

  Draw and put labels onto an axis, which is aligned with the coordinate system.
- def polar.axes (w, h)

  Plot a pair of perpendicular axes.
- def polar.updateBBOX (BBOX, x, y)

  Update a curve bounding box, by adding a new point to it.
- def polar.toInt (x)

  Convert a float number, representing a length, to an integer, with a fixed number of bits.
- def polar.toFloat (b)

  Get the float representation of an integer number.
- def polar.toBinary (num, count=0, sign="")

  Get the binary representation of a number, recursively.
- def polar.toDenary (b)

  Converts a string representing a binary number to denary.
- def polar._toDenary (a)

  Return the decimal number represented by binary digits in a list.
- def polar._toDenaryRec (a)

  Return the decimal number represented by binary digits in a list.
- def polar.toUBAM (x)

  Convert an angle to UBAM.
- def polar.float2UBAM (num)

  Convert a float number to an Unsigned Binary Angle Measurement (UBAM).
- def polar.float2BAM (_num)

  Convert a float number to a signed Binary Angle Measurement (BAM).
- def polar.BAM2float (b)

  Convert BAM to float.
- def polar.f0 (c, t, a=0, b=1/(2 ∗pi))

  Archimedean spiral.
- def polar.f6 (a, t)

  Lemniscate of Bernoulli.
- def polar.f12 (c, t, a=2, b=3)

  Limaçon of Pascal.
- def polar.f14 (a, t)

  Cochleoid.
- def polar.f15 (a, t)

  Fermat's Spiral.
- def polar.f19 (a, t, e=1, l=1)

  Parabola.
- def polar.f20 (a, t)

  Hyperbola.
- def polar.f21 (a, t)

  Ellipse.
- def polar.f23 (a, t)

  Star.
- def polar.f24 (a, t)

Cannabis.

- def polar.help (j=None)

  Print curve identifications.

- def polar.move (x, y, mode=True)

  Move the turtle to a given point.

- def polar.drawBox (b)

  Draw a box.

- def polar.polarRose (func, turns, initialAng=0.0, title=None, nseg=None)

  Draw some polar equations.

- def polar.main (argv=None)

  Main program.

Variables

- bool polar.usingFlail = True

  Whether using the flail driver for writing a file, instead of turtle for drawing on screen.

- int polar.WIDTH = 800

  Canvas width.

- int polar.HEIGHT = 800

  Canvas height.

- int polar.LW = 680

  World Coordinate width.

- int polar.LH = 680

  World Coordinate height.

- polar.veclen = lambda x,x1,y,y1: sqrt((x-x1)∗(x-x1) + (y-y1)∗(y-y1))

  Length of vector from point (x1,y1) to (x,y).

- polar.dotprod = lambda x,x1,x0,y,y1,y0: ((x1-x0) ∗ (x-x1) + (y1-y0) ∗ (y-y1))

  Dot product of vectors from point (x0,y0) to (x1,y1) and from (x1,y1) to (x,y).

- polar.crossprod = lambda x,x1,x0,y,y1,y0: (x1-x0)∗(y-y1) - (y1-y0)∗(x-x1)

  Cross product of vectors from point (x0,y0) to (x1,y1) and from (x1,y1) to (x,y).

- polar.clamp = lambda a: min(max(-1,a),1)

  Clamp a value to range [-1,1].

- polar.polar2Cartesian = lambda r,a: (r∗cos(a),r∗sin(a))

  Get cartesian coordinates from polar coordinates.

- polar.cartesian2Polar = lambda x,y: (sqrt(x∗x+y∗y), atan2(-y,-x)+pi)

  Get the polar coordinates from cartesian coordinates.

- polar.setColor = lambda v: joe.color("red" if v $<$ 0 else "blue")

  Set the color of the curve.

- int polar.wrapPi = lambda x: x - 360 ∗ ((x + 180) // 360)

  Wraps an angle to ± 180.

- bool polar.__toDebug__ = False

  Toggle debugging mode.

- int polar.NBITS = 8

  Number of bits after binary point.

- int polar.BSCALE = 2∗∗NBITS

  Scale for fixed point: 256 or 65536, for instance.

- polar.float2Int = lambda f: int(f∗BSCALE)

  Maps a float number to integer.
- polar.int2Float = lambda b: ldexp(float(b),-NBITS)

  Maps an integer number to float.
- list polar.bam_bit_table = [0.0055, 0.0109, 0.0219, 0.0439, 0.088, 0.1757, 0.3515, 0.703, 1.406, 2.8125, 5.625, 11.25, 22.5, 45.0, 90.0, 180.0]

  BAM bit table.
- int polar.WSIZE = len(bam_bit_table)-1

  Word size for BAM.
- int polar.LSB = 2∗∗-WSIZE ∗ 180

  Least Significant Bit.
- int polar.f1 = 4: (a ∗ 2∗sin(n∗t), t)

  A rose of n or 2n petals.
- int polar.f2 = lambda a, t: f1(a,t,5)

  A rose of five petals.
- int polar.f3 = lambda a, t: f1(a,t,3)

  A rose of three petals.
- int polar.f4 = lambda a, t: f1(a,t,2)

  A rose of four petals.
- polar.f5 = lambda a, t: (a ∗ cos(t/2.0), t)

  Double Loop.
- polar.f7 = lambda a, t: (a ∗ 2 ∗ sin(t), t)

  Circle.
- polar.f8 = lambda a, t: (a ∗ (2∗sin(2∗t)+1), t)

  Bowtie.
- polar.f9 = lambda a, t: (a ∗ (cos(5∗t)∗∗2 + sin(3∗t) + 0.3), t)

  Oscar's butterfly.
- polar.f10 = lambda a, t: (a ∗ (sin(t) + sin(5∗t/2)∗∗3), t)

  Crassula Dubia.
- polar.f11 = lambda a, t: (a/6 ∗ (9 - 3∗sin(t) + 2∗sin(3∗t) - 3∗sin(7∗t) + 5∗cos(2∗t)), t)

  Majestic butterfly.
- polar.f13 = lambda a, t: ((100∗a if t <= 0.01 else a/t), t)

  Hyperbolic Spiral.
- polar.f16 = lambda a, t: (a ∗ (sin (2∗∗t) - 1.7), t)

  A Face.
- polar.f17 = lambda a, t: (a∗0.8 ∗ (2 - 2 ∗ sin(t) + sin(t) ∗ (sqrt(abs(cos(t)) / (sin(t) + 1.4)))), t)

  Heart.
- polar.f18 = lambda a, t: (a ∗ (1 - cos(t) ∗ sin(3∗t)), t)

  Ameba.
- polar.f22 = lambda a, t: (a ∗ (1 + 2 ∗ sin(t/2)), t)

  Freeth's Nephroid.
- list polar.curveList

  List of tuples with: polar equation function, angle range, initial angle, title and number of segments.

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