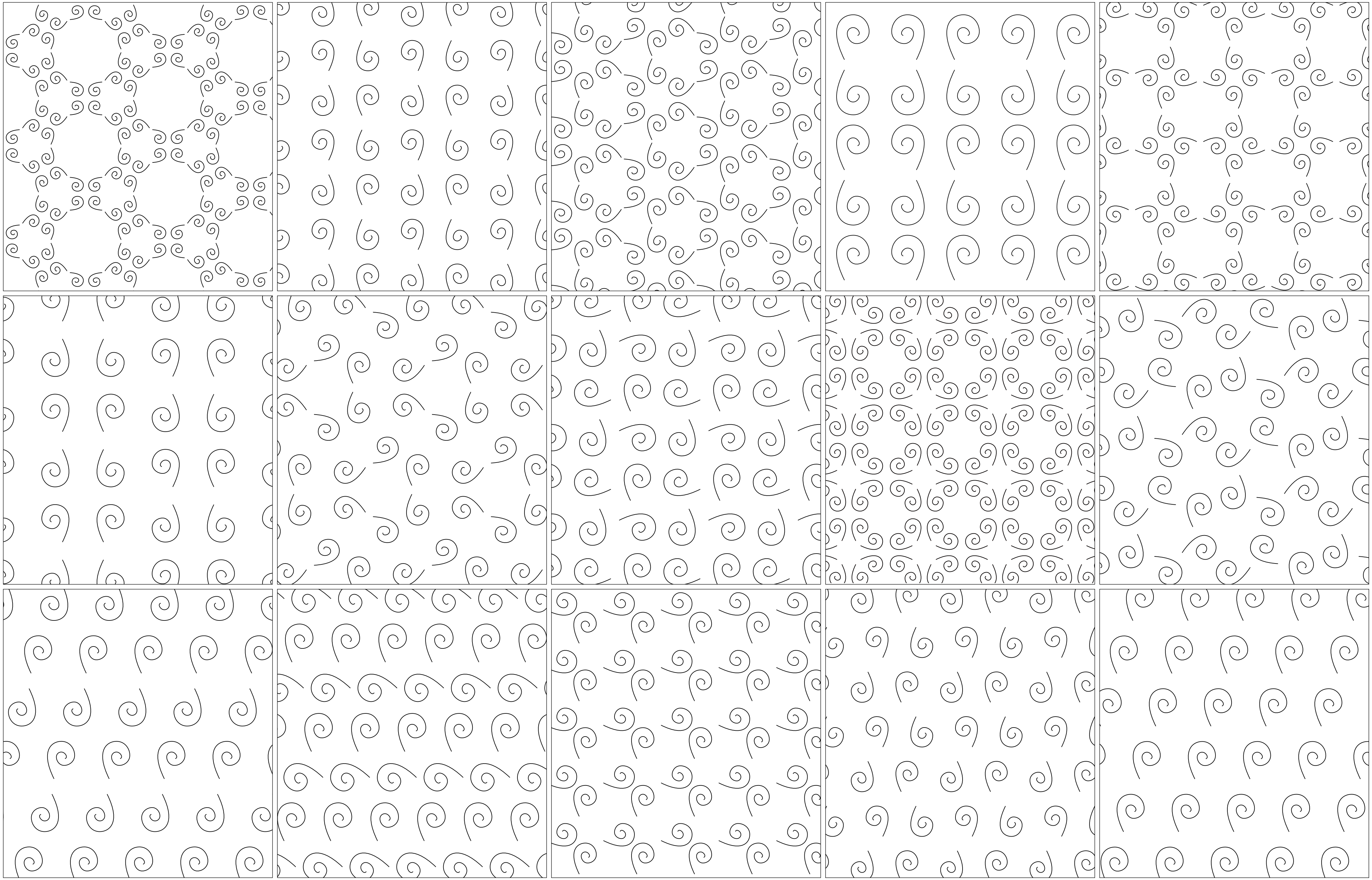

Orbi User Manual 0.5

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Digital Publication

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Cover Image:
Fifteen Wallpaper Groups

Contents

I. Introduction: Symmetry Groups in Grasshopper

*Orbi i*s a plug-in for Grasshopper that generates patterns parametrically with symmetry groups.

Orbi allows to select a symmetry group and define any geometry as the fundamental region of a pattern. The fundamental region is the smallest part that is repeated in a pattern.

In Orbi the shape of the fundamental region is displayed and used as drawing area for an input geometry. The fundamental region can be freely arranged and oriented in space. Once the fundamental region and the symmetry group are defined, the corresponding pattern is generated automatically.

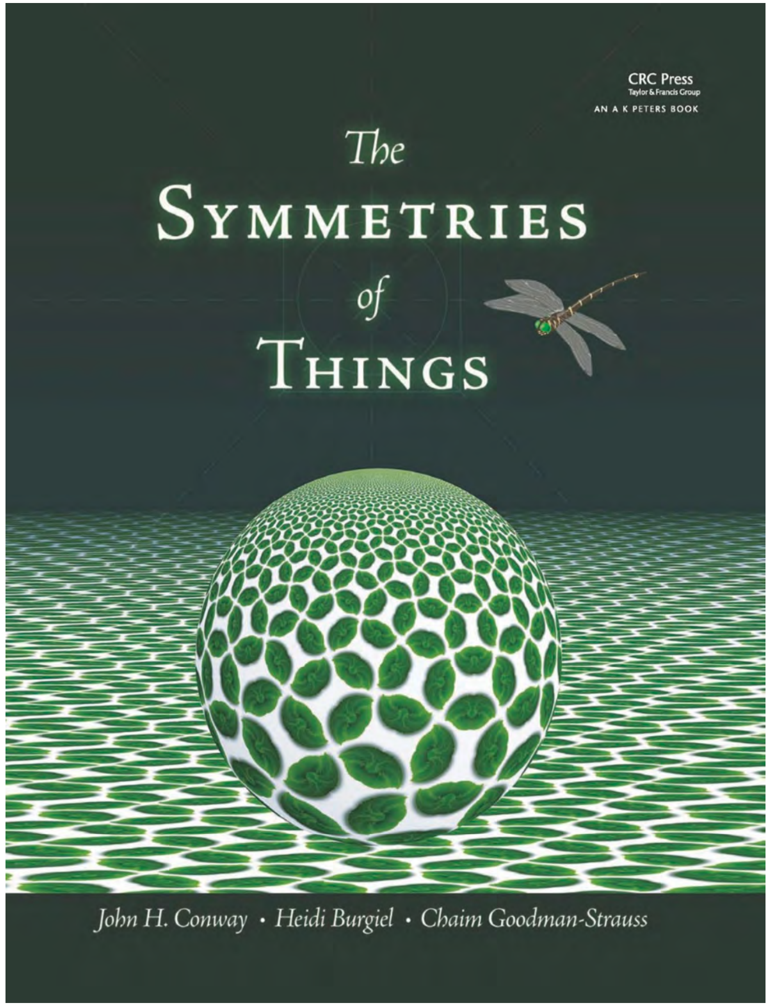
Orbi offers clusters for symmetries of all rosette groups, frieze groups, wallpaper groups and spherical groups. Each cluster has the name of the symmetry group in Orbifold notation.

The Orbifold notation for symmetry groups goes back to William Thurston and John Conway and is probably the clearest and simplest taxonomy of symmetry groups. If you want to get a deeper insight into the Orbifold notation and symmetry groups, „*The Symmetries of Things*“ is a very clear and understandable introduction.

Symmetry groups are elementary forms of repetition. Unfortunately, however, they appear almost exclusively in the curriculum of mathematicians. Architects, designers and engineers are often not aware that there is more than point and mirror symmetry. They don´t know that there are different and very specific symmetries possible around a point, along a line or on a flat or spherically curved surface. And the astonishing fact that there are exactly 17 wallpapergroups, 14 spherical groups and 7 frieze groups is hardly known among many people professionally dealing with form. *Orbi* is supposed to change this and make symmetry groups accessible as a practical tool for designers using Rhino and Grasshopper.

Orbi was created out of enthusiasm in a small class on digital folding at the faculty of architecture of Nuremberg Tech during sprint term in 2020. Programming a symmetry group in order to generate a folding pattern was an introductory exercise of that class. It turned out that symmetry groups are really usefull and fun. So we formed the *Grasshopper Collective* at Nuremberg Tech as idealistic group of unexperienced programmers in order to build *Orbi*.

Flower of a passiflora with 3, 5 and 10-fold mirror symmetry around the center. In Orbi you could use the mirror-symmetric rosette group three times to create this pattern. Image by Matteo Tausch, 2020 CC-BY-NC-SA



Cover of *Conway, J.H., Burgiel, H., Goodman-Strauss, C., 2016. The Symmetries of Things. CRC Press.*

II. How Orbi works
Program Structure

In Orbi there is a cluster for each of the 40 symmetry groups which are sorted into four groups.

Rosette groups:	2
Wallpaper groups:	17
Spherical groups:	14
Frieze groups:	7

On the following pages you will find illustrative examples for each group that is represented by a cluster in *Orbi*.

Some of the clusters do not only comprise a single symmetry group but a whole family of symmetries of the same type but of variable degree.

An example is the rotationally symmetric rosette group, where the degree of division around the center is arbitrary and can be controlled by a parameter of the cluster.

Therefore, if you want to create a simple fivefold rotational symmetry around a point, you have to select not only the cluster for the symmetry group, but also the have to input the number five for the degree of symmetry.

To create a pattern with a certain symmetry group with *Orbi*, one selects the cluster of the symmetry group and feeds any geometry into the fundamental region of the group.

Typically the steps to generate a pattern are:

1. Select a symmetry group and place the cluster of the group in Grasshopper.
2. Input of a plane into the cluster for orientation and localization of the fundamental region.
3. Display and bake the fundamental region.
4. Draw or place any geometry in the fundamental region.
5. Feeding a geometry in the fundamental region into the cluster in Grasshopper.
6. Set further input parameters of the cluster in Grasshopper
7. Generate pattern and bake pattern geometry.

On the following pages the data structure and the functionality of the individual clusters are explained. Furthermore, we show an exemplary pattern for each cluster, which results from the input of a spiral into the fundamental region.

Data Structure

Symbol	*Data type*	*Explanation*	*Cluster*
A	Real number	Angle in degrees	Some spherical groups, wallpaper groups and frieze groups
D	Real number	Displacement in x-direction	Some spherical groups, wallpaper groups and frieze groups
Fx	Integer	Multiplication of the fundamental region in x-direction. Ornamental and frieze groups are infinite patterns, however, Orbi must contain a finite number of repetions of the fundamental region. High values can become computationally intensive.	Some wallpaper groups and frieze groups
Fy	Integer	Multiplication of the fundamental region in y-direction.	Some wallpaper groups and frieze groups
G	Geometry	Input geometry into the fundamental region. Geometry data can be of arbitrary type and structure. Trees of geometry are possible and should be preserved.	All groups

Data Structure

Shortcut	*Data type*	*Explanation*	*Cluster*
N	integer	Degree of symmetry around a point or axis and thus equivalent to the number of copies of the fundamental region in rosette groups.	Rossette groups and spherical groups
P	plane	Reference plane for the position and orientation of the fundamental region and reference plane of the output pattern. It is possible to input more than a single plane, however the resulting multiple patterns are quite quite hard to foresee. if their fundamental region has a different orientation.	All groups
R	real number	radius of the circle in rosette groups and of the sphere in spherical groups.	Rosette groups and spherical groups
S	real number	Uniform scale factor of the fundamental region.	Both rosette groups, some wallpaper groups and frieze groups
Sx	real number	Scale factor of the fundamental region in x-direction.	Some wallpaper groups and frieze groups
Sy	real number	Scale factor of the fundamental region in y-direction.	Some wallpaper groups and frieze groups

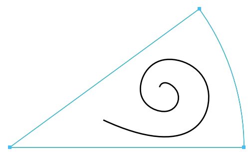
Rosette Groups

*N∘

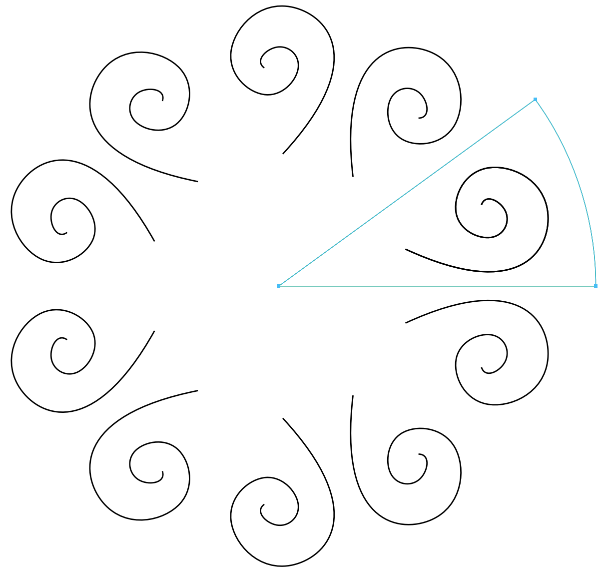
- point centric group
- mirror symmetry
- N variable degrees of symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius of the circle or arc (type: real number)
- N: Number of mirroring axes, i.e half the number of fundamental regions (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



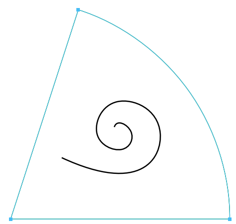
rosette group *5∘

N∘

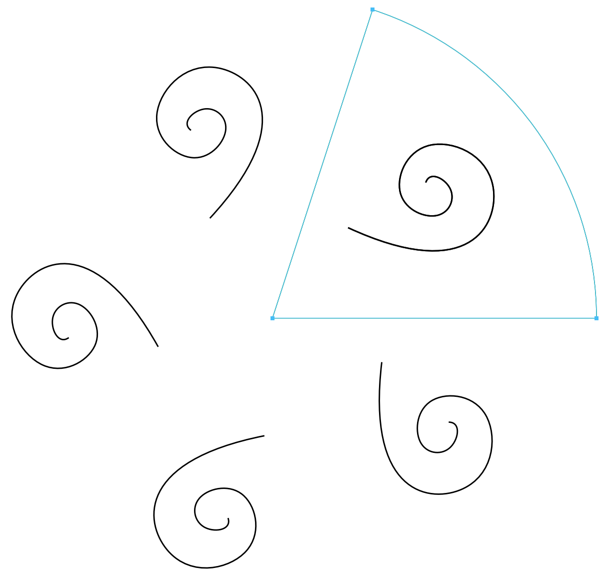
- point centric group
- rotational symmetry
- N variable degrees of symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius of the circle or arc (type: real number)
- N: Number of mirroring axes, i.e. number of fundamental regions around the circle (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



rosette group 5∘

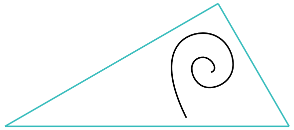
Wallpaper Groups

*632

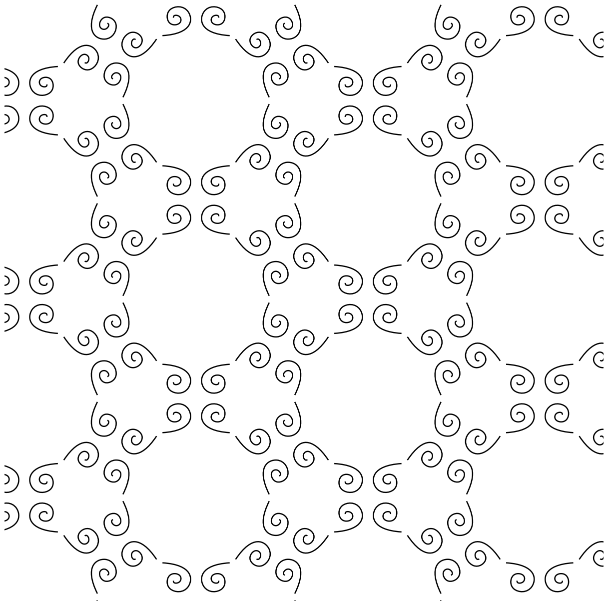
- planar wallpaper group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



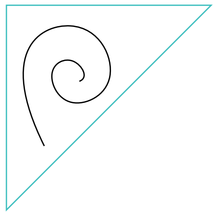
wallpaper group *632

*442

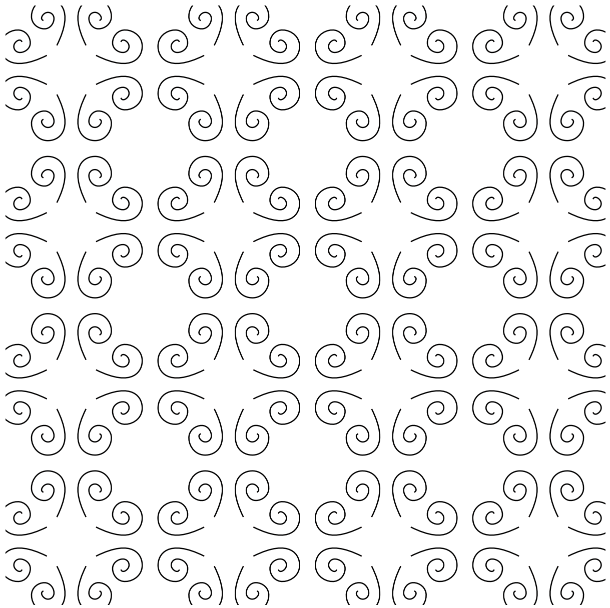
- planar wallpaper group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



wallpaper group *442

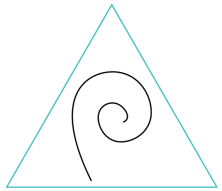
Wallpaper Groups

*333

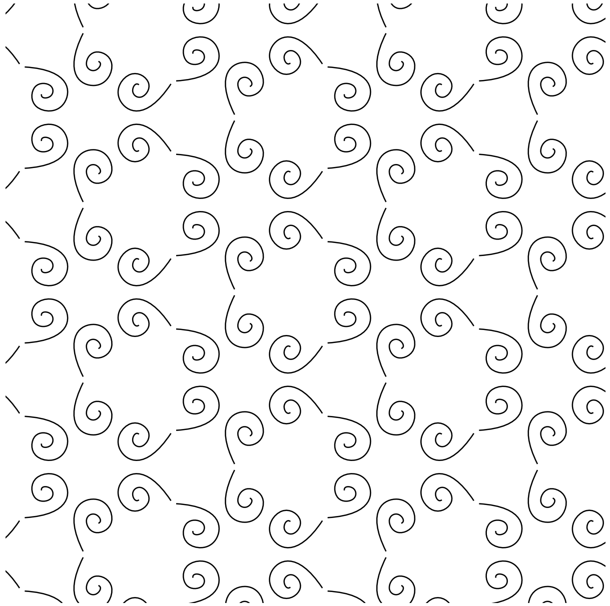
- planar wallpaper group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



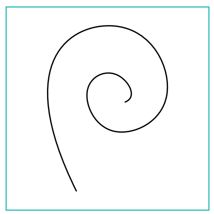
wallpaper group *333

*2222

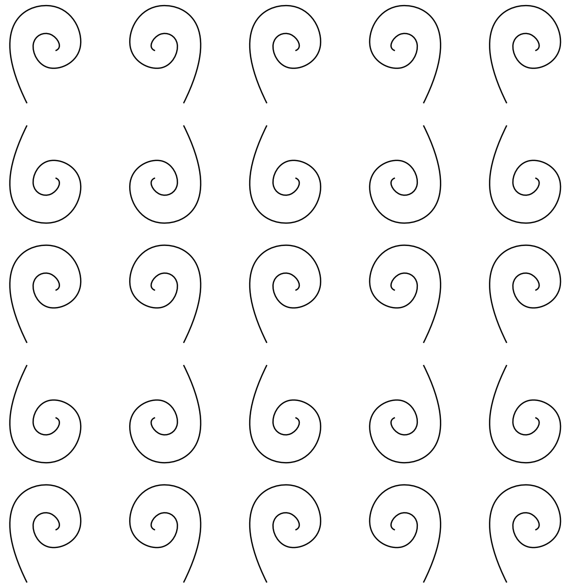
- planar wallpaper group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region

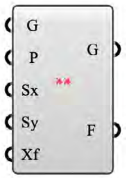


wallpaper group *2222

Wallpaper Groups

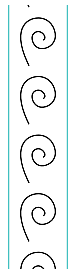
**

- planar wallpaper group similar to NN
- mirror symmetry
- the pattern is basically a frieze of infinite height which covers the plane. In *Orbi* the infinite height is finite and controlled by factor Sy.

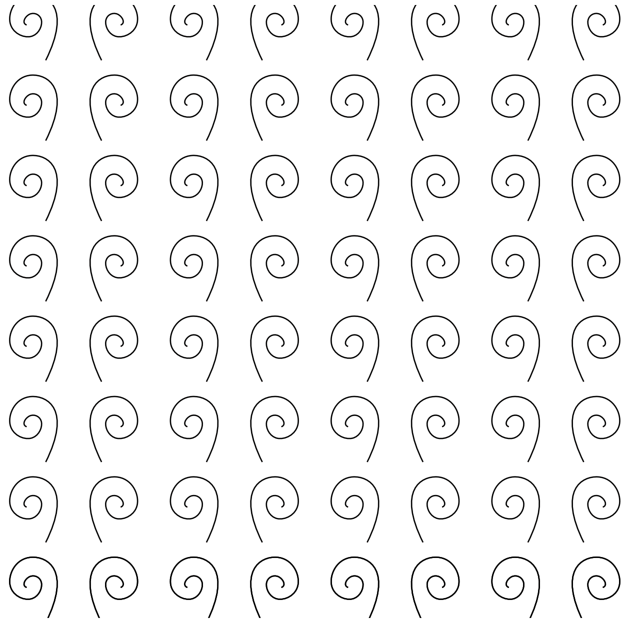


Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



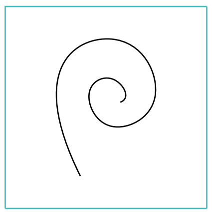
wallpaper group **

2*22

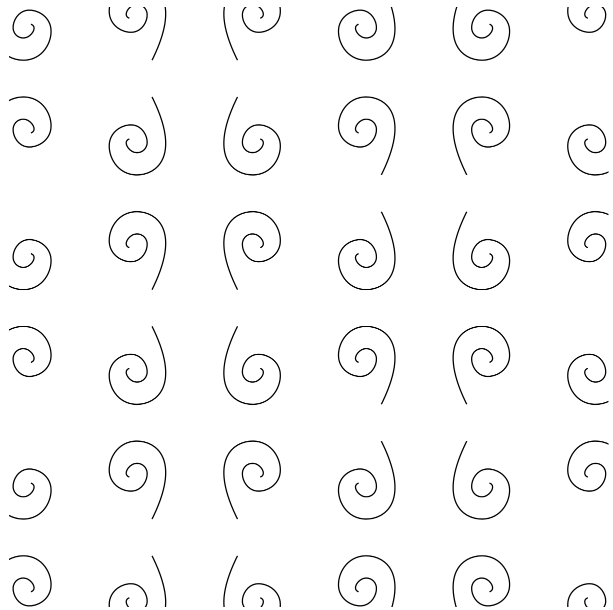
- planar wallpaper group
- mirror and rotational symmetry
- angles of 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



wallpaper group 2*22

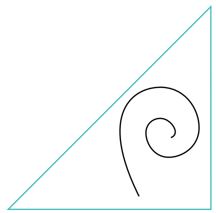
Wallpaper Groups

*x

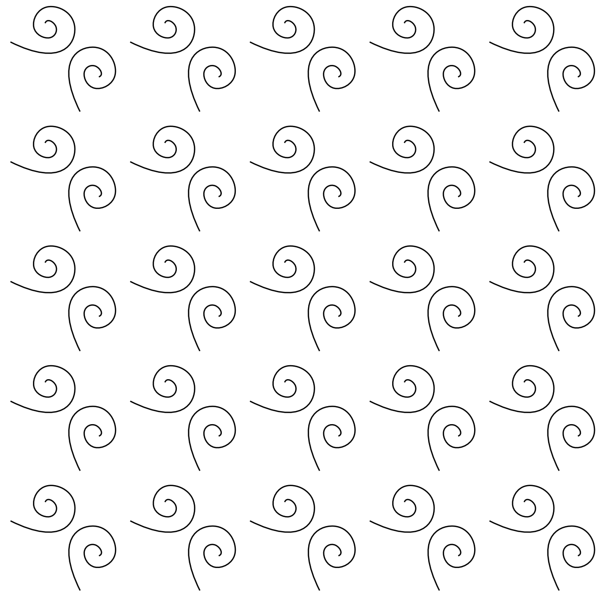
- planar wallpaper group
- mirror symmetry and glide reflection
- variable A controls the angle of the fundamental region and orients the vector of the glide reflection

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- A: Angle of the fundamental region in degrees (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

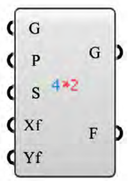


fundamental region



wallpaper group *x

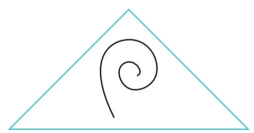
4*2



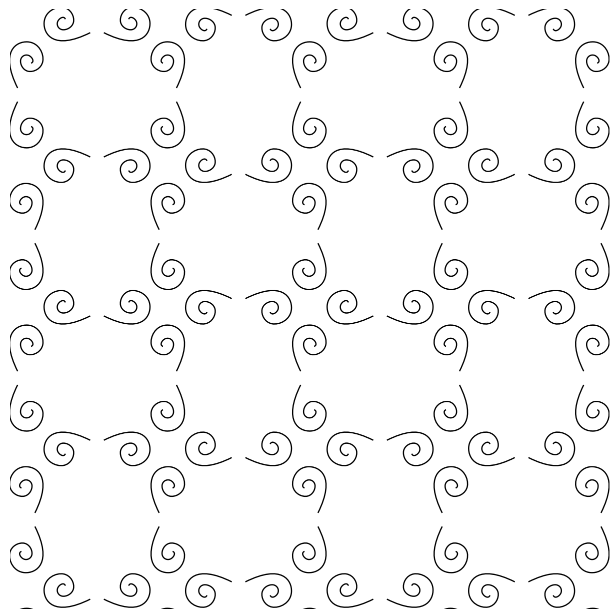
- planar wallpaper group
- rotational and mirror symmetry
- angles of 90°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



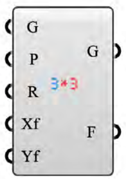
fundamental region



wallpaper group 4*2

Wallpaper Groups

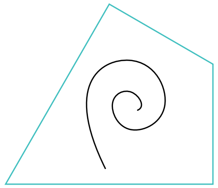
3*3



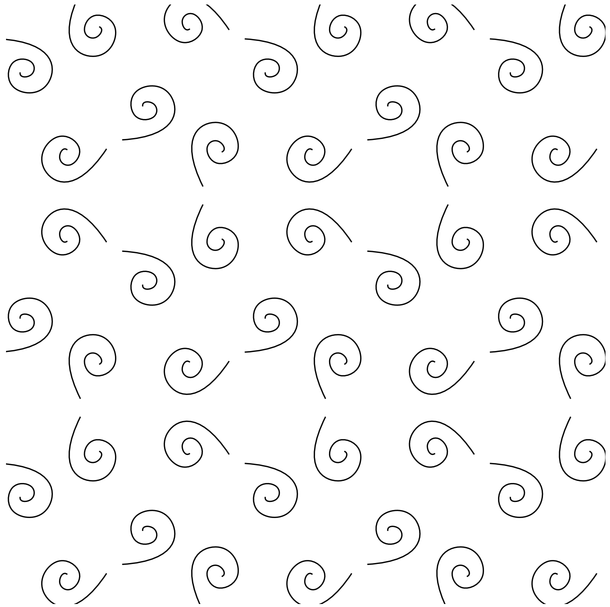
- planar wallpaper group
- mirror and rotational symmetry
- angles of 120°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



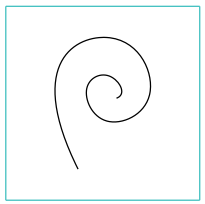
wallpaper group 3*3

22*

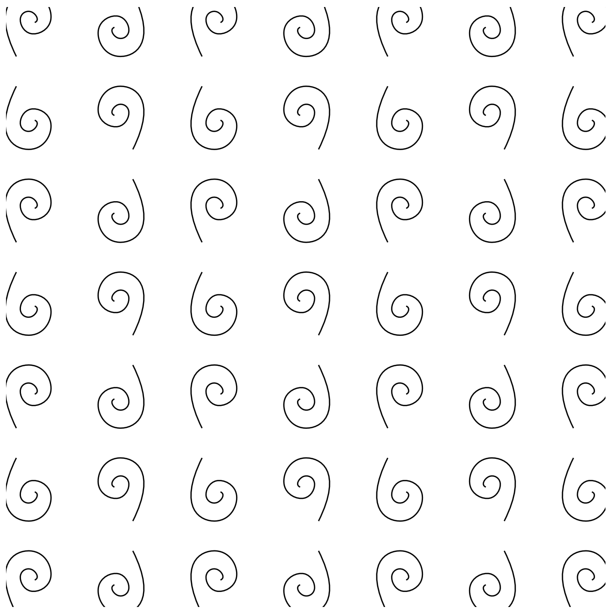
- planar wallpaper group
- rotational and mirror symmetry
- angles of 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



wallpaper group 22*

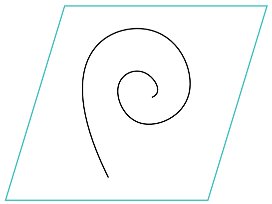
Wallpaper Groups

xx

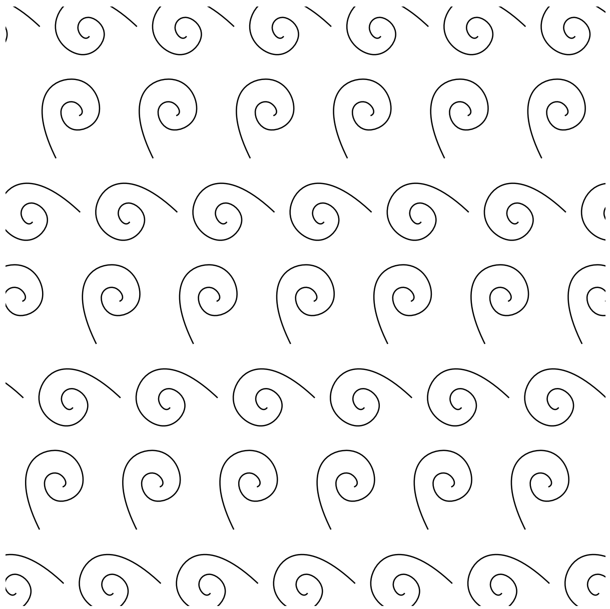
- planar wallpaper group
- glide reflection
- variable A controls the angle of the fundamental region and orients the vector of the glide reflection

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- A: Angle of the fundamental region in degrees (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



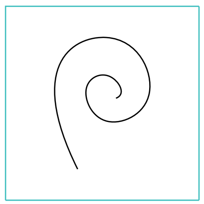
wallpaper group xx

22x

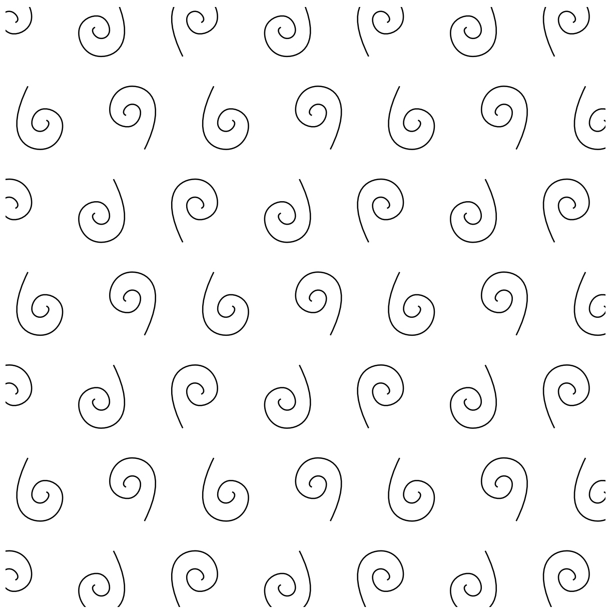
- planar wallpaper group
- rotational symmetry and glide reflection
- angles of 180

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



wallpaper group 22x

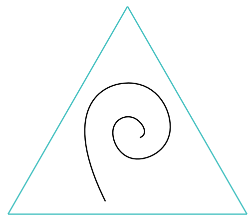
Wallpaper Groups

632

- planar wallpaper group
- rotational symmetry
- angles of 60°, 120°, 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region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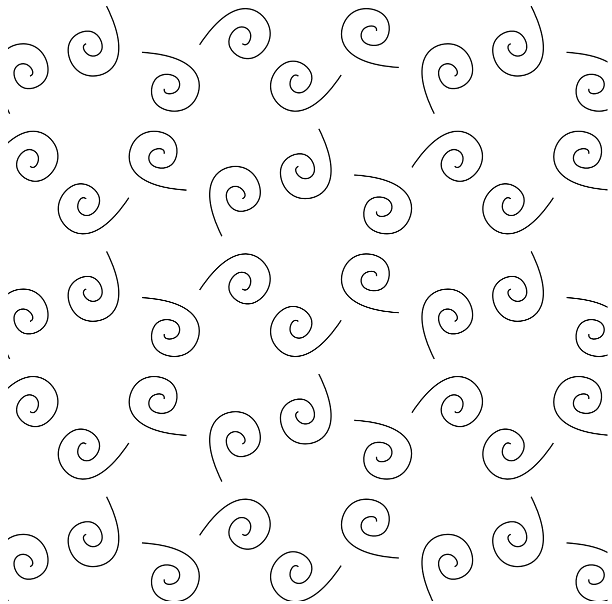
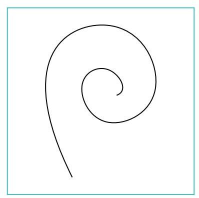

wallpaper group 632

442

- planar wallpaper group
- mirror symmetry
- angles of 90°, 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region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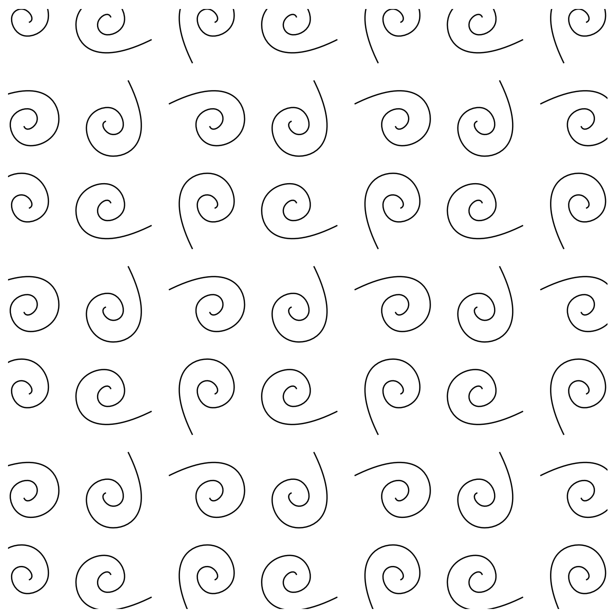

wallpaper group 442

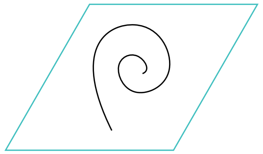
Wallpaper Groups

333

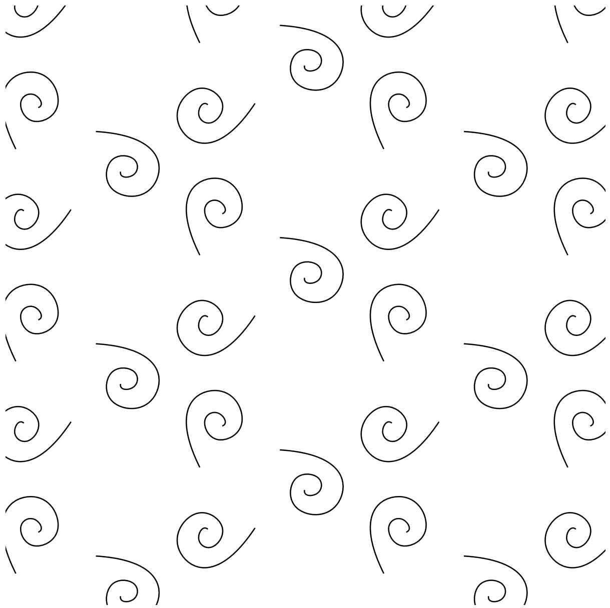
- planar wallpaper group
- mirror symmetry
- angles of 120°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- S: Scale of the fundamental region (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



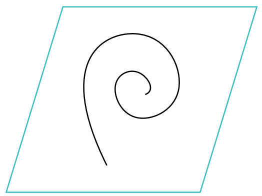
wallpaper group 333

2222

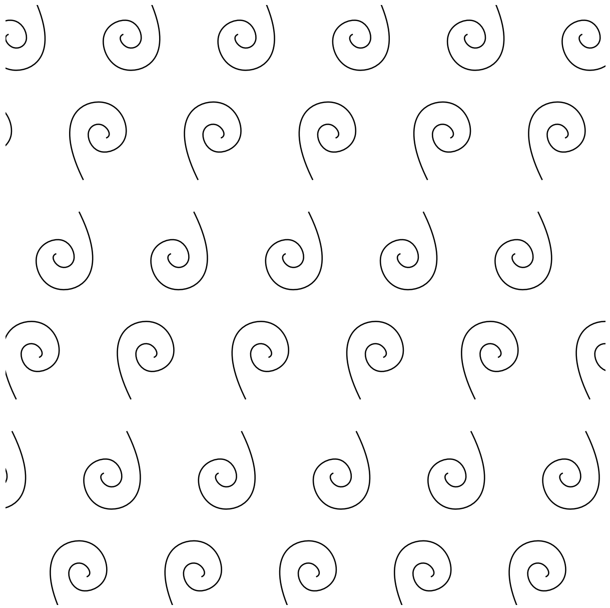
- planar wallpaper group
- rotational symmetry
- angles of 180° and variable angle of parallelogram

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)
- A: Angle of the fundamental region in degrees (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region



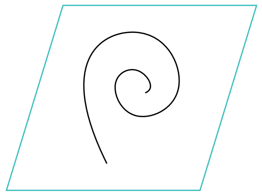
wallpaper group 2222

Wallpaper Groups

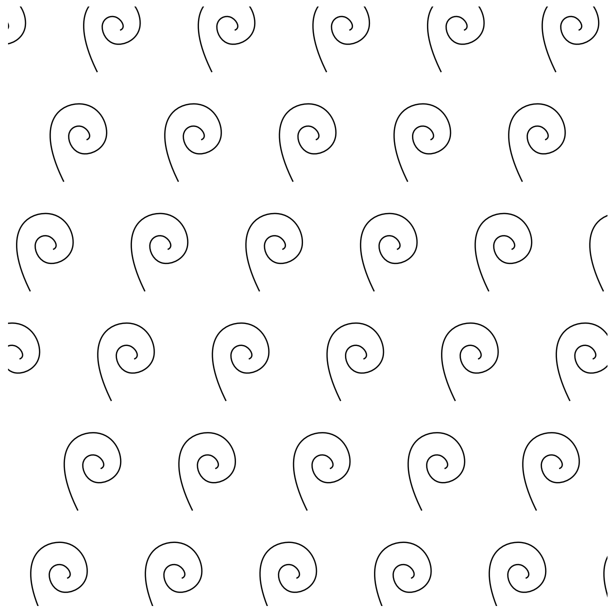
- planar wallpaper group
- translation in x- and y- direction

Input:

- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- A: Angle of the fundamental region in degrees (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Yf: Number of copies in y-direction (type: integer)



fundamental region



wallpaper group o

Spherical Groups

*532

- spherical group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region

spherical group *532

*432

- spherical group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region

spherical group *432

Spherical Groups

*332

- spherical group
- mirror symmetry

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region

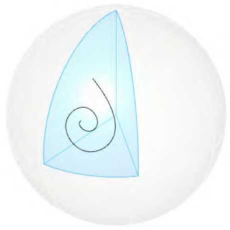
spherical group *332

*22N

- spherical group
- mirror symmetry
- n-fold symmetry around axis of opposite poles

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)
- N: Degree of symmetry or number of copies (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region

spherical group *22N

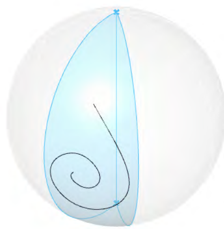
Spherical Groups

*NN

- spherical group
- mirror symmetry
- n-fold symmetry around axis of opposite poles

Input:
- G:	Geometry or tree of geometry (type: geometry)
- P:	Plane (type: plane)
- R:	Radius (type: real number)
- N:	Degree of symmetry or number of copies (type: integer)

Output:
- G:	Geometry or tree of the pattern
- F:	Fundamental region



fundamental region

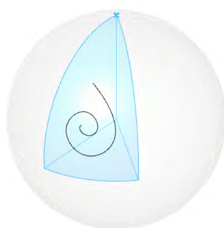
spherical group *NN

N*

- spherical group
- mirror symmetry at the equator
- n-fold symmetry around axis of opposite poles

Input:
- G:	Geometry or tree of geometry (type: geometry)
- P:	Plane (type: plane)
- R:	Radius (type: real number)
- N:	Degree of symmetry or number of copies (type: integer)

Output:
- G:	Geometry or tree of the pattern
- F:	Fundamental region

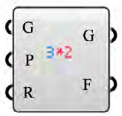


fundamental region

spherical group N*

Spherical Groups

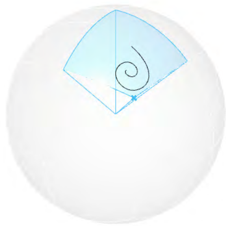
3*2



- spherical group
- rotational and mirror symmetry
- angles of 120°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region


fundamental region

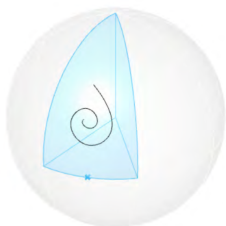

spherical group 3*2

2*N

- spherical group
- rotational and mirror symmetry
- angles of 180°
- n-fold symmetry around axis of opposite poles

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- N: Degree of symmetry or number of copies (type: integer)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

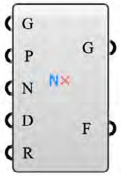

fundamental region


spherical group 2*N

Spherical Groups

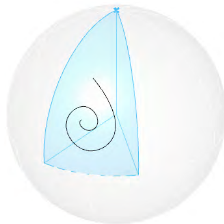
Nx

- spherical group
- n-fold symmetry around axis of opposite poles
- glide reflection



Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)
- N: Degree of symmetry or number of copies (type: integer)
- D: Distance of the glide reflection (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region

spherical group Nx

532

- spherical group
- rotational symmetry
- angles of 72°, 120°, 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region

spherical group 532

Spherical Groups

432

- spherical group
- rotational symmetry
- angles of 90°, 120°, 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region

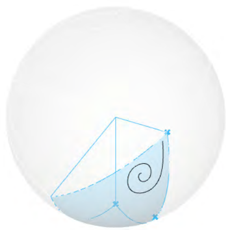
spherical group 432

332

- spherical group
- rotational symmetry
- angles of 120°, 180°

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region

spherical group 332

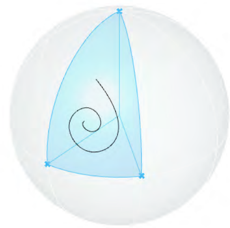
Spherical Groups

22N

- spherical group
- rotational symmetry
- angles of 180°
- n-fold symmetry around axis between poles

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- N: Degree of symmetry or number of copies (type: integer)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

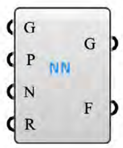


fundamental region

spherical group 22N

NN

- spherical group
- n-fold rotational symmetry around axis between poles



Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- N: Degree of symmetry or number of copies (type: integer)
- R: Radius (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region

spherical group NN

Frieze Groups

∞∞ (NN)

- linear frieze group
- rotation around two perpendicular points of infinite distance
- basically a translation
- infinite strip in x-direction but in *Orbi* x-fold finite

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

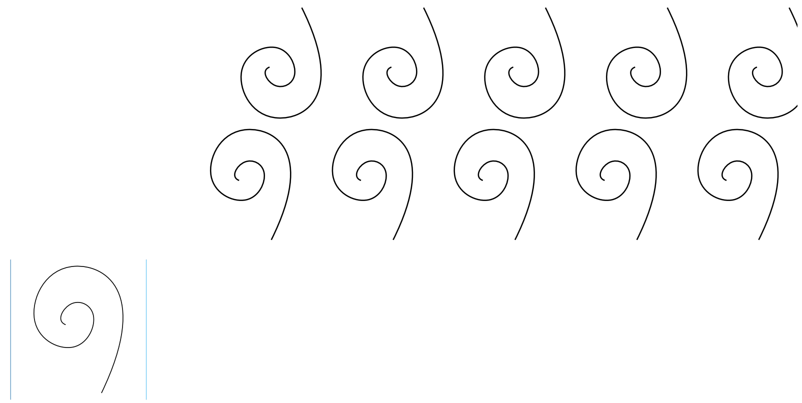
fundamental region   frieze group NN

∞x (Nx)

- linear frieze group
- glide reflection of variable distance

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: integer)
- Dx: Displacement of second row in x-direction (type: real number)

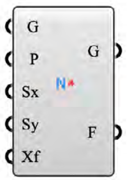
Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region   frieze group Nx

Frieze Groups

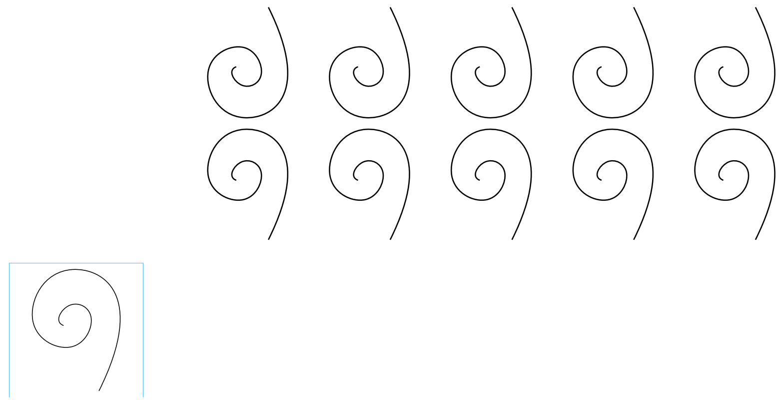
∞* (N*)



- linear frieze group
- mirror symmetry around horizontal axis
- infinite strip in x-direction but in *Orbi* x-fold finite

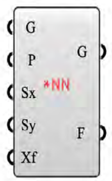
Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region frieze group N*

*∞∞ (*NN)



- linear frieze group
- vertical axis of mirror symmetry
- infinite strip in x-direction but in *Orbi* x-fold finite

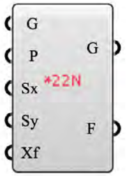
Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region

fundamental region frieze group *NN

Frieze Groups

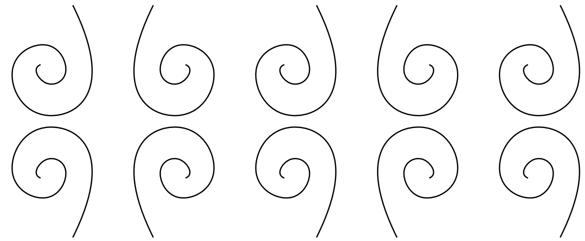
*22∞ (*22N)

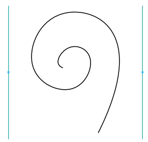


- linear frieze group
- mirror symmetry around horizontal and vertical axis
- infinite strip in x-direction but in *Orbi* x-fold finite

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: real number)

Output:
- G: Geometry or tree of the pattern
- F: Fundamental region





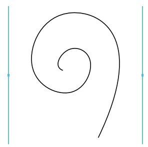
fundamental region   frieze group *22N

22∞ (22N)

- linear frieze group
- double rotational symmetry
- infinite strip in x-direction but in *Orbi* x-fold finite

Input:
- G: Geometry or tree of geometry (type: geometry)
- P: Plane (type: plane)
- Sx: Scale of the fundamental region in x-direction (type: real number)
- Sy: Scale of the fundamental region in y-direction (type: real number)
- Xf: Number of copies in x-direction (type: real number)

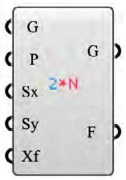
Output:
- G: Geometry or tree of the pattern
- F: Fundamental region



fundamental region   frieze group 22N

Frieze Groups

2*∞ (2*N)



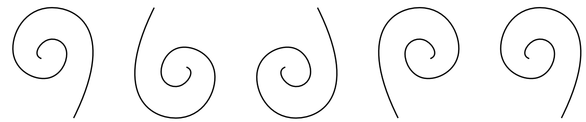
- linear frieze group
- rotational and vertical mirror symmetry
- infinite strip in x-direction but in *Orbi* x-fold finite

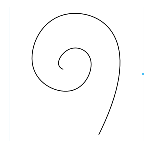
Input:

- G:	Geometry or tree of geometry (type: geometry)
- P:	Plane (type: plane)
- Sx:	Scale of the fundamental region in x-direction (type: real number)
- Sy:	Scale of the fundamental region in y-direction (type: real number)
- Xf:	Number of copies in x-direction (type: real number)

Output:

- G:	Geometry or tree of the pattern
- F:	Fundamental region





fundamental region   frieze group 2*N

Further Work

Orbi has been programmed by architects. This is why the software implementation is rather hacky and unprofessional from a programmers point of view. *Orbi* is not as fast as it could be and does not meet the usual requirements of good style in programming. You need to be patient with us: *Orbi* has been put togehter by idealistic students in architecture who wanted to have a useful symmetry tool to draw with.

We hope that *Orbi* is still useful for others. The interface is adapted to our own needs as designers. We like to throw any kind of geometry into a fundamental region and need to orient our patterns in space to integrate them into larger design projects. Currently all cluster operations are based on basic commands of Grasshopper. *Orbi* should be able to run both the Windows and Mac-versions of Rhino 6 and we have tried to avoid dependency on further plug-ins of Grasshopper.

In the future we might define all transformations of *Orbi* in matrix form in a programming language such as Python or C++ instead of running the operations on top of the Grasshopper interface. Moving a level down in programming languages would probably result in a considerable speed up and be a good basis for porting *Orbi* to other software environments. Since we would like *Orbi* to be freely available for non-commercial purposes and sympathize with the FOSS movement, we are also interested in a solid Python or C++ base in order to offer a plugin for Blender or FreeCad, making symmetry groups even more accessible. Any help with this would be very welcome.

We could have started with Phyton right away, but as architects it was more obvious for us to start with Grasshopper‘s intuitive programming environment, which enabled us to develop *Orbi* without any in-depth programming knowledge and focuss on geometry. The 40 clusters that have now been put together cover a good part of symmetry groups in 2D. But there can bee done more:

- Hyperbolic symmetry groups
- Quotient groups for colorations and subgroups
- Crystallographic groups in 3D

We welcome anybody who would like to join us in making Orbi better, porting it to other environments or expanding its functionality. Reports about bugs and errors, function requests and suggestions for improvement can be sent to:

ar-grasshopper-collective [at] th-nuremberg.de

References

Conway, J.H., Burgiel, H., Goodman-Strauss, C., 2016. *The Symmetries of Things*. CRC Press.

Grünbaum, B., Shephard, G.C., 2013. *Tilings and Patterns*. Dover Publications.

Jones, O., Bedford, F., Waring, J.B., 1856. *The grammar of ornament*. London: Day and Son.

Plate IX, Egyptian 06 in Owen Jones: *The Grammar of Ornament*