

A FRACTAL TILE SET AND A METHOD FOR GENERATING THE TILE SET

FIELD OF THE INVENTION

The present invention relates to a fractal tile set and a method for generating the tile set.

BACKGROUND

In the field of geometric tiling, the basic arrangements of tiles were classified by the early civilizations. The Persians developed more complex systems in the Middle Ages. The field of tiling took a great leap in the 20th century. The field of tiling and patterns was analysed and codified by mathematicians in the 1950s to the 1970s. The field of tiling, long considered completed, was enlivened by the new discoveries of aperiodic tiling sets by Penrose (Gardner, M. *Penrose Tiles to Trapdoor Cyphers*, and the return of Dr Matrix (updated edition), WH Freeman, New York, 1989), Wang, Ammann and others, and the insights this gave into the fields of crystallography and quantum physics. Since the 1970s, there has been continued research into aperiodic tiling.

Uses for tiling prior to the 20th century were primarily in creating surfaces or modular elements in construction. The applied uses for tiling expanded in the late 20th century, including tiling of virtual surfaces, for instance "bitmap" background patterns for computer desktops, or tiling of surfaces within video games and virtual environments. Other uses have been in arrays of mirrors for telescopes.

Application of fractal geometry in tiling is relatively new. While some aspects of fractal geometry was explored by Peano in 1890 (Peano, G. (1890), "Sur une courbe, qui remplit toute une aire plane", *Mathematische Annalen* 36 (1): 157–160), Hilbert in 1891 (Hilbert, D. (1891), "Ueber die stetige Abbildung einer Line auf ein Flächenstück", *Mathematische Annalen* 38: 459–460) and Koch in 1904 (Sur une courbe continue sans tangente, obtenue par une construction géométrique élémentaire), it was defined as an area of

investigation by Benoit B. Mandelbrot in 1975 in "fractals: Form, Chance and Dimension, W.H.Freeman, San Francisco, 1977 and Martin Gardner, "Mathematical Games", Scientific American, Dec. 1976.

5 Applications of fractals have been implemented in Optics (US Patent 4,904,073), Acoustics (US Patent 6,772,859) and Antennas (US Patent 7,898,486), amongst others. In these cases, it is the multi-scalar quality of fractals and the way in which this multi-scalar quality affects the response to wavelengths of light, of sound, and radio waves which has the useful
10 application and novelty. None of these applications relates to tiling, or more specifically, fractal tiling or tile set i.e. a tiling set involving application of fractal geometry.

While there are some well known examples of fractal tiling such as the
15 Sierpinski Gasket, the methods for generating these create tiling sets that are not topological disks – i.e. they are not a continuous bounded area, but instead created arrangements that have "holes" or empty patches and/or "islands" or disconnected pieces. While of mathematical interest, these known fractal tiling sets are not useful for most instances of applied tiling
20 such as in the construction industry.

SUMMARY

25 In accordance with one aspect of the present invention, there is provided a method for generating a tile set, the method comprising the steps of: (a) determining a prototile for placing adjacent to one or more other prototiles with no gap and no overlap between them to form a composite tile; (b) arranging the prototiles to form the composite tile; (c) scaling the composite tile to a size matching area of the
30 determined prototile; (d) overlaying the scaled composite tile over the determined prototile for determining more than one composite tile boundary points, the composite tile boundary points including a composite tile starting point and a composite tile ending point, the composite tile starting point and the composite tile ending point being different points, each composite tile boundary point being a point
35 residing at a location on the perimeter of one of the prototiles arranged to form the scaled composite tile; (e) selecting prototile boundary points on each prototile, the prototile boundary points including a prototile starting point and a prototile ending

point, the prototile starting point and the prototile ending point being different points, each prototile boundary point being a point residing at a location on the perimeter of each prototile; (f) creating a first path linking the prototile starting point and the prototile ending point, the first path having a flow direction from the prototile starting point to the prototile ending point; (g) marking areas of each prototile separated by the first path with different markings; (h) arranging one or more of the marked prototile to form a marked composite tile having same shape, prototile arrangement and boundary points as the composite tile; (i) checking that arrangement criteria are met in each arrangement at step (h), the arrangement criteria comprising: the composite tile starting point of the marked composite tile being matched with the prototile starting point of one of the prototiles and the composite tile ending point of the scaled composite tile being matched with the prototile ending point of one of the prototiles; a second path being formed to run from the composite tile starting point of the marked composite tile to the composite tile ending point of the marked composite tile, the second path being formed by joining the first paths of the one or more marked prototile, and the flow directions of the first paths joined to form the second path are directing the second path to terminate at the composite tile ending point; areas of the marked composite tile separated by the second path being marked with same markings as the respective marked areas separated by the first path of the one or more marked prototile, each of the first paths forming the second path are not in contact with boundary points other than the prototile starting point and prototile ending point of the respective prototile; and areas with the same markings on the one or more marked prototile that are arranged to form the marked composite tile being arranged to contact one another; and (j) storing a marked composite tile fulfilling the arrangement criteria into a database as the generated tile set.

The intersections between the scaled composite tile and the determined prototile in step (d) may be selectable as composite tile boundary points.

The method may further comprise creating a reverse marked prototile by reversing the markings on the marked areas separated by the first path and reversing direction of the flow direction of the first path.

The method may further comprise (k) scaling a marked composite tile to match area of each prototile used for creating said marked composite tile; and (l) replacing each of the prototile in the marked composite tile of step (k) with a copy of the scaled composite tile of step (k), wherein the composite tile starting point and the composite

tile ending point of the scaled composite tile of step (k) are matched with the composite tile starting point and the composite tile ending point of each prototile respectively.

5 The method may further comprise checking whether the marked prototile has reverse marking symmetry; and if the marked prototile has reverse marking symmetry, obtaining a copy of the marked prototile for using as the reverse marked prototile.

10 The method may further comprise repeating step (e) to re-select new boundary points to resolve non-compliance of the arrangement criteria.

Step (e) may further comprise adding an additional prototile starting point and an additional prototile ending point in the prototile and step (f) may
15 further comprise creating an additional path in the prototile from the additional prototile starting point and additional prototile ending point.

Each side of each prototile in the generated tile set may be given a label to indicate which sides of each prototile are to be placed adjacent to each
20 other.

Sides of the prototile marked at step (g) with same markings may be provided with the same label.

25 Sides of the prototile marked at step (g) with same markings may be provided with a same design.

The method may comprise providing a design on each side of each prototile in the generated tile set, wherein the design intersects or is a continuation of
30 a design located on a side of another prototile in the generated tile set that is to be placed adjacent to the side of the prototile in the generated tile set.

A side of a prototile in the generated tile set may have a symmetrical edge and the side of the prototile may be made to match a corresponding
35 symmetrical edge of another side of another prototile in the generated tile set.

A side of a prototile in the generated tile set may have an asymmetrical edge and the side of the prototile may be made to match a corresponding asymmetrical edge of another side of another prototile in the generated tile set.

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The first path created at step (f) may link between 2 sides of the prototile.

The method may comprise providing different designs on a front surface and a back surface of each prototile in the generated tile set.

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In accordance with another aspect of the present invention, there is provided a fractal tile set comprising a predetermined prototile placed adjacent to one or more other prototiles with no gap and no overlap between them to form a composite tile, each prototile comprising a first path linking a prototile starting point and a prototile ending point, the first path having a flow direction from the prototile starting point to the prototile ending point, areas in each prototile separated by the first path being marked with different markings, the composite tile formed by the marked prototiles being a marked composite tile, the prototile starting point and a prototile ending point being selected from prototile boundary points on each prototile, the prototile starting point and the prototile ending point being different points, each prototile boundary point being a point residing at a location on the perimeter of each prototile; the composite tile having a composite tile starting point and a composite tile ending point being selected from more than one composite tile boundary points, the more than one composite tile boundary points being derived by scaling the composite tile to a size matching area of the predetermined prototile and overlaying the scaled composite tile over the predetermined prototile, the composite tile starting point and the composite tile ending point being different points, each composite tile boundary point being a point residing at a location on the perimeter of one of the prototiles arranged to form the scaled composite tile; wherein the composite tile starting point of the marked composite tile is matched with the prototile starting point of one of the prototiles and the composite tile ending point of the scaled composite tile is matched with the prototile ending point of one of the prototiles; a second path is formed to run from the composite tile starting point of the marked composite tile to the composite tile ending point of the marked composite tile, the second path is formed by joining the first paths of

the one or more marked prototile, and the flow directions of the first paths joined to form the second path are directing the second path to terminate at the composite tile ending point; areas of the marked composite tile separated by the second path are marked with same markings as the respective marked areas separated by the first path of the one or more marked prototile, each of the first paths forming the second path are not in contact with boundary points other than the prototile starting point and prototile ending point of the respective prototile; and areas with the same markings on the one or more marked prototile that are arranged to form the marked composite tile are arranged to contact one another.

Intersections between the scaled composite tile and the predetermined prototile may be selectable as composite tile boundary points.

The prototiles in the fractal tile set may comprise a reverse marked prototile created by reversing the markings on the marked areas separated by the first path and reversing direction of the flow direction of the first path.

The fractal tile may further comprise prototiles obtained by (k) scaling a marked composite tile to match area of each prototile used for creating said marked composite tile; and (l) replacing each of the prototile in the marked composite tile of step (k) with a copy of the scaled composite tile of step (k), wherein the composite tile starting point and the composite tile ending point of the scaled composite tile of step (k) are matched with the composite tile starting point and the composite tile ending point of each prototile respectively.

The fractal tile set may further comprise a marked prototile with reverse marking symmetry.

The fractal tile set may further comprise a marked prototile with an additional path in linking an additional prototile starting point and an additional prototile ending point.

Each side of each prototile in the fractal tile set may be given a label to indicate which sides of each prototile are to be placed adjacent to each other.

Sides of the prototile marked with same markings may be provided with the same label.

5 Sides of the prototile marked with same markings may be provided with a same design.

The fractal tile set may comprise a design on each side of each prototile in the fractal tile set, wherein the design intersects or is a continuation of a design located on a side of another prototile in the fractal tile set that is to be placed adjacent to the side of the prototile in the fractal tile set.

15 A side of a prototile in the fractal tile set may have a symmetrical edge and the side of the prototile may be made to match a corresponding symmetrical edge of another side of another prototile in the fractal tile set.

A side of a prototile in the fractal tile set may have an asymmetrical edge and the side of the prototile may be made to match a corresponding asymmetrical edge of another side of another prototile in the fractal tile set.

20 The first path may link between 2 sides of each prototile.

The fractal tile set may comprise different designs on a front surface and a back surface of each prototile of the fractal tile set.

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BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

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Figure 1 shows a flowchart for generating a set of marked tiles. It is noted that all references to Figure 1 refers to Figure 1A and 1B in combination.

Figure 2 shows a flowchart for generating a larger set of marked tiles.

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Figure 3 shows a flowchart for deriving edge matching rules that are used to design tiles of the larger set of marked tiles.

Figures 4, 24 and 44 each shows a tile.

Figures 5, 25 and 45 each shows a composite tile.

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Figures 6, 26 and 46 each shows a composite tile laid over a tile and size reduction of a tile.

Figures 7 and 27 each shows a composite tile laid over a tile with certain areas shaded.

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Figures 8, 28 and 47 each shows a composite tile laid over a tile with boundary points marked up.

Figures 9 and 29 each shows a marked tile.

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Figures 10 and 30 each shows a reverse version of the marked tile respectively.

Figures 11 and 32, each illustrates creation of composite tiles using marked tiles.

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Figure 12 illustrates unacceptable composite tiles.

Figures 13 and 33, each illustrates deflation of marked tiles.

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Figures 14, 34 and 51 each illustrates a subsequent step in deflation of the marked tiles.

Figures 15, 35 and 52 each illustrates a further step in deflation of the marked tiles.

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Figure 16, 36 and 53 each illustrates another step in deflation of the marked tiles.

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Figures 17, 37, 54, 64 and 68 each illustrates a marked up tiling set.

Figures 18, 38, 55 and 57 each illustrates association of tiles with edge matching conditions.

Figures 19, 39, 56 and 58 each illustrates association of tiles with edge matching conditions.

Figures 20, 40 each illustrates tile designing with edge matching conditions.

Figures 21, 41 each illustrates tile designing with edge matching conditions.

Figures 22, 42 each illustrates tile designing with edge matching conditions.

Figure 23, 43 and 60 each illustrates a patch of tiles with a particular tile design.

Figures 31, each shows an additional marked tile required to fulfil certain arrangement criteria.

Figures 48 and 49 each shows a plurality of marked tiles with different markings.

Figure 50 illustrates deflation of marked tiles, including a subsequent step of deflation.

Figure 59 illustrates tile designing with edge matching conditions.

Figures 61 and 65 each shows basic tiles required to create a composite tile.

Figures 62 and 66 each illustrates basic tiles with certain edge matching conditions.

Figures 63 and 67 each illustrates marked composite tiles.

Figures 69 and 70 illustrate creation of marked composite tiles.

Figure 71 illustrates deflation of marked composite tiles.

Figures 72, 74 and 78 illustrate creation of marked composite tiles.

Figures 73, 76, 77 and 80 each shows a tiling design.

5 Figures 75 and 79 illustrate creation of composite tiles with design.

Figure 81 illustrates a three dimensional implementation of a tile set.

Figure 82 illustrates a three dimensional tile set.

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Figure 83 shows a block diagram of a computer.

DETAILED DESCRIPTION

15 With reference to Figures 1 to 3, there is provided a method 100 for creating a fractal tiling set (or tile set). The tile set refers to a set of tiles, which incorporates a fractal path. It is noted again that all references to Figure 1 refers to Figure 1A and 1B in combination.

20 The method 100 generates a tile set which possess, amongst other things, 3 qualities, namely, the multi-scalar properties of fractal geometry (hereinafter "quality 1"), a fractal path structure that traverses every tile along a continuous path (hereinafter "quality 2") and visual complexity at system level with simplicity at component level (hereinafter "quality 3"). The utility of the
25 sets of tiles generated by the method lies in the exploitation of one or more of these qualities.

Broadly, the method 100 is provided for the generation of tile sets that are topological disks arranged on continuous fractal path geometry. Starting from
30 prototiles, composite tiles are formed and boundary points are determined and selected. In the mathematical theory of tessellations, a "prototile" is one of the shapes of a tile in a tessellation. For example, if a tiling is composed on just one shape and size of tile, it is said to have one prototile, and every instance of tile within the tiling will be congruent with the prototile. If a tiling
35 is composed of tiles of 3 different sizes and shapes, it is said to have 3 prototiles, and each instance of tile within the tiling will be congruent with one of the 3 prototiles.

Paths are marked to link the boundary points within the prototiles. The edges are coloured and directional arrows are added to the path.

- 5 For each marked prototile there are two versions, a basic tile and a reversed tile. The reversed tile has the same path as the basic tile but with the edge colours and the directional arrow reversed.

10 A path is then made with the prototiles within the composite tiles, taking into consideration edge colouring conditions and start and end points of the marked prototile.

An iterative process of deflation (a process also known as substitution tiling), substituting scaled versions of the composite tiles for the original marked
15 prototile creates a patch of tiles of any desired size which maintains the edge conditions and start and end points of the original marked prototile.

Edge matching rules (involving labeling of the prototiles) are derived from a colouring system which can then be used to generate decorative or functional
20 tiling sets, which have embedded fractal, multi-scalar, properties, as well as continuous path properties. These "edge condition" sets with edge-matching rules have utility as templates for a range of decorative and functional uses.

It is appreciated that while current fractal mathematics research has focused
25 on either a path, or a tile, it has not been focused on a combination of path and tile, which the method 100 illustrates. As such, advantageously, the fractal paths generated by the method 100 have the particular property that they traverse every tile within the topological disk within a continuously connected path. The path itself has the general fractal quality of being multi-
30 scalar. The tiles themselves can be simple, but the arrangement embeds a fractal complexity in the resultant tile set layout.

In the present description, attributing to quality 2 of the sets of tiles generated by the method 100, a tile set generated by the method would for
35 convenience be known herein as "flow tiles".

System theory shows that the value in a system is derived from its organisation and interfaces, and that the properties of a system are very different from the properties of its components. The flow tiles herein described are part of a system where the properties are embedded in the organisation and interfaces of the tiles, rather than in the tiles themselves.

It is appreciated that the multi-scalar properties i.e. quality 1 of the flow tiles have both visual and functional advantages.

For visual advantage, the multi-scalar properties allow new decorative designs for tile sets that are suitable for large spaces to be developed. Traditional tiles have one scale of pattern, where the pattern can be discerned from a certain distance, beyond which the pattern becomes visually repetitive and boring. Patterns which are arranged in a layout based on a fractal in the case of the flow tiles have patterns discernible at multiple scales. This would allow the design of carpet tiles, for instance, which have an attractive pattern at a close scale, but also look good when viewed in a very large space, for instance in an airport, or exhibition hall, or atrium.

For functional advantage, the fractal multi-scalar property allows tiles, which perform functions related to wavelengths of any kind of electro-magnetic waves, to avoid resonances, aberrations or harmonics. This could apply to tiles which scatter, reflect, filter or absorb light, heat, sound, radio waves and other spectrums.

The connected path property i.e. quality 2 of the flow tiles also has both visual and functional advantages.

The visual advantage of the path structure allows decorative designs for tiles which have complex connected patterns that avoid repetition and boredom.

The functional advantage of the path structure allows tiles which perform a function that relies on being connected, such as circuits or networks, where a regular grid may create problems with resonances, aberrations or harmonics.

The structure also allows for a fully tiled surface to be connected with a path that avoids a single-scaled arrangement.

Similarly, the “complex system from simple components” quality i.e. quality 3 of the flow tiles has both visual and functional advantages as well.

Having fewer and simpler components has great utility for manufacturing, storage, delivery and installation of any kind of tile of any scale or function. Be it complex visual patterns, or complex physical properties, if these arise out of simple tiles then value has been created.

In the 21st century, new uses for applied tiling are projected to be, among others, in the field of surfaces that harvest energy or perform environmental functions, such as photovoltaic cells, phase change materials, or catalytic converters of pollutants. Nanotechnology will expand the range of scales at which tiling of components needs to be done. It is appreciated that these are possible fields in which the method 100 described with reference to Figures 1 to 3 could be applied.

Three examples of tile sets created using the method 100 and which demonstrate at least one of quality 1, quality 2 and quality 3 are as follows.

A carpet formed by a tile set comprising 2 square tiles, which has a pattern that flows across the 2 square tiles according to certain edge matching rules. Advantageously, the carpet formed by arranging a plurality of the 2 square tiles together is comprised of only simple components i.e. 2 standard tiles, and the resultant pattern of the carpet is visually complex (quality 3). The pattern, due to the fractal curve structure, flows continuously across the tiles (quality 2). The pattern demonstrates interesting patterns up close and from a distance (quality 1).

A building integrated photovoltaic panel cladding system that is formed by a tile set comprising 3 hexagonal tiles. In this case, each panel is a tile. When installed, the 3 hexagonal tiles have a surface pattern that flows across the 3 square tiles according to certain edge matching rules. The resultant pattern of the photovoltaic panel cladding system is visually complex (quality 3). The panels are electrically connected along a conduit that follows the fractal design path, linking all the panels together into a single main conduit (quality 2) that follows the decorative pattern that appeals aesthetically both at the scale of the building inhabitants, and from that of the city skyline (quality 1).

A nano-material comprising 2 nano-tiles of a semiconductor manufactured, each nano-tile having a hole in a different location and of a different diameter when compared to each other (quality 3). In this manner, the properties of the variably spaced holes would cause a material covered with the tiles to emit light of a particular wavelength, in a similar fashion to the way bird's feathers can cause bright colours to be emitted. It is appreciated that certain brightly coloured birds have feathers embedded with a not so random arrangement of air pockets. With this not so random arrangement, wavelengths of light that are related to the distance between the air pockets get scattered and built up more than others, thus emitting the feathers' colours brightly. The complexity of the pattern generated by the method 100 that produces pockets of local order in an aperiodic scalar layout can be utilised to create the not so random arrangement of holes on the nano-material for producing the bright colour effects (quality 1).

In more detail, 3 examples of the method are illustrated using different geometries and highlighting particular aspects of the method. Specifically, 4 tile sets are illustrated.

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The steps of the method 100 are described with reference to Figures 1 to 3 as follows. It is noted that all references in the present description to Figure 1 refers to Figure 1A and 1B in combination. Figure 1 is a flowchart 101 illustrating creation of marked tiles, composite marked tiles and assembly of a composite tile. The composite tile would be elaborated later. Figure 2 is a flowchart 201 illustrating a method for iterative deflation to generate tile sets of a required size. Figure 3 is a flowchart 301 illustrating a method of deriving edge matching rules to create templates for tiling design. Figures 4 to 23 would be referred to in the description to illustrate concepts in the steps taken.

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The method 100 generates tile sets that are topological disks and are arranged on continuous fractal path geometry. The steps of the method 100 can be performed using computer software executed using a computer. In the illustration as follows, the method 100 is exemplified by way of execution of computer software.

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At step 102, a prototile is determined by selecting the prototile shape with a tiling geometry that suits a required purpose. The prototile shape selected should have a basic shape that is able to tile a plane with no gaps and no overlaps. The prototile shape should be suitable for placing adjacent to one or more other prototiles with no gap and no overlap between them to form a composite tile. For example, Figure 4 shows a predetermined square shaped prototile 400. It is appreciated that other basic shapes such as hexagon, triangles, diamond and lozenge (or in other words, a rhombus) shapes could also be used. In some cases, if a particular tiling design requires, two or more prototiles of different basic shapes could be selected at step 102.

Generally, the basic shape of a prototile is the simplest geometric representation of a tile capable of tiling the plane without gaps or overlaps with other prototiles. The prototile has edges that are straight lines meeting at vertices. Alternatively, the prototile will maintain the same vertices, but the single straight edges of the basic tile may be replaced with more complex curves that would still allow tiling of the plane with no gaps or overlaps when the prototiles are used. The composite tile may also have edges with even more complex form, as they are assembled multiple examples of the edges of the prototiles.

At step 104, a few of the prototiles of step 102 are arranged to form the composite tile. For example, Figure 5 shows a composite tile 500 made of five of the same square shaped prototile 400 in Figure 4. The five square shaped prototiles of the composite tile 500 in Figure 5 are arranged to form a cross resembling a '+' sign.

At step 106, conceptually, the composite tile is scaled to a size matching area of the determined prototile at step 102. More specifically, the composite tile is scaled to a size that can overlay and match the total area of the prototile (e.g. 400 in Figure 4) as closely as possible or exactly. For example, Figure 6 illustrates a tile 600 in the composite tile 500 of Figure 5 that is scaled. Figure 6 also illustrates the scaled composite tile 500 in Figure 6 being rotated anti-clockwise to overlay and match the area of the prototile 400 in Figure 4 as closely as the shapes could be matched. Step 106 ensures that the composite tile 500 can replace the prototile 400 at a later step, without any gaps between tiles or overlaps when the composite tile 500

is placed adjacent to another tile. There will be therefore a one to one correspondence, in location and orientation, between the prototile and the composite tile that replaces it.

- 5 At step 108, the ratio between the original size of the prototile at step 102 and the reduced tile size of a tile (e.g. 602 in Figure 6) in the scaled composite tile (e.g. 500 in Figure 5) is recorded as a scaling factor. Step 108 is responsible for determining the scaling factor, which is used in later steps. It is appreciated that the area of the scaled composite tile (e.g. 500 in Figure
10 5) is equal to the total area of the original size of the prototile.

For example, the original size of the prototile 400 is illustrated in Figure 4. The reduced tile size of a tile 602 in the scaled composite tile 500 in Figure 6 is illustrated in Figure 6. Figure 7 shows the scaled composite tile 500 in
15 Figure 6 laid over the prototile 400 in Figure 400. The scaled composite tile 500 in Figure 6 matches the area of the prototile 400 exactly, however, some areas 702 of the scaled composite tile 500 extend outside the area of the prototile 400. This extended area outside of the area of the prototile 400 is referred to as added area 702 and the area of the prototile 400 not
20 overlapping with the overlaid scaled composite tile 500 in Figure 6 is referred to as subtracted area 704. The added area and the subtracted area must be exactly equal.

At step 110, conceptually, the scaled composite tile (e.g. 500 in Figure 5) is
25 laid over the prototile (e.g. 400 in Figure 4) to determine composite tile boundary points (e.g. 800, 802 and 804 in Figure 8) which are suitable to be used for a path starting point (also known as composite tile starting point) and a path ending point (also known as composite tile ending point). The composite tile starting point and the composite tile ending point are different
30 points. Each composite tile boundary point is a point residing at a location on the perimeter of one of the prototiles (e.g. 400 in Figure 400) arranged to form the scaled composite tile (e.g. 500 in Figure 5).

Step 110 is basically responsible for determining boundary points, which are
35 used in later steps. More specifically, the scaled composite tile (e.g. 500 in Figure 5) could be laid over the prototile (e.g. 400 in Figure 4) in a manner such that the vertices of the scaled composite tile (e.g. 500 in Figure 5)

coincide with the vertices of the prototile (e.g. 400 in Figure 4). Also, edges of the scaled composite tile (e.g. 500 in Figure 5) could be positioned to match the edges of the prototile (e.g. 400 in Figure 4) where possible. Suitable locations for the boundary points (e.g. 800, 802 and 804 in Figure 8) are located at the points where the edges and corners of the scaled composite tile (e.g. 500 in Figure 6) intersect with the edges and corners of the prototile (e.g. 400 in Figure 4). It is appreciated that such intersections between the scaled composite tile (e.g. 500 in Figure 5) and the prototile (e.g. 400 in Figure 4) are selectable as composite tile boundary points. The final decision to use any of these options for boundary points depends on whether the arrangement criteria or conditions described with reference to Figure 11 later are fulfilled.

For example, Figure 8 shows the scaled composite tile 500 in Figure 6 laid over the prototile 400 in Figure 4 with all the key boundary points marked out. The key boundary points include prototile boundary points 800, reduced prototile boundary points 802 and suitable boundary points 804. prototile boundary points 800 are points strategically marked out in the corners and sides of the prototile 400. These boundary points 800 are points where the scaled composite tile 500 intersects the perimeter of the prototile 400. Reduced prototile boundary points 802 are considered "reduced" because they are boundary points in the scaled composite tile 500, which contains prototiles that are reduced in size. In this case, 8 boundary points are used for the prototile 400. Four of which are each located at each of the four sharp corners of the square shaped prototile 400. Four of which are each located at a location midway of each of the four sides of the prototile 400.

With regard to the scaled composite tile 500 in Figure 6, the reduced boundary points 802 are marked out at the same locations on each of the five square tiles according to how the prototile boundary points 800 are marked out on the square shaped prototile 400. As the five square tiles are joined, any overlapping points at the same location are taken to be a single point. Thus, in all, there are 28 points marked out for the scaled composite tile 500 in Figure 6.

The suitable boundary points 804 are the points of intersection of the scaled composite tile 500 in Figure 6 with the prototile 400 when it is laid over the

prototile 400. All the intersected points coincide with all the prototile boundary points 800 of the prototile 400. The suitable boundary points 804 are considered "suitable" as they all have the potential to be selected as actual boundary points to be used in the present method 100.

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Furthermore, with information on the options for boundary points from step 110, prototile boundary points are also selected for each prototile (e.g. 400 in Figure 4) of the composite tile either by a computer or entered by a user in the case of an electronic implementation. The prototile boundary points include a prototile starting point and a prototile ending point. The prototile starting point and the prototile ending point are different points. Each prototile boundary point is a point residing at a location on the perimeter of each prototile.

15 In an electronic implementation, all the suitable boundary points for the composite tile (e.g. 500 in Figure 5) and the prototile (e.g. 400 in Figure 4) could be highlighted for user selection or automatically selected/suggested by a computer. At step 112, the prototile (e.g. 400 in Figure 4) is marked with a path and a directional arrow from one boundary point to another boundary point. More specifically, a first path is created to link the selected prototile starting point and the prototile ending point at step 110. The first path is given a flow direction from the prototile starting point to the prototile ending point. The flow direction is marked using a directional arrow indicating flow from the prototile starting point to the prototile ending point.

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Step 112 is responsible for determining the boundary points and directional path of each prototile (e.g. 400 in Figure 4). Depending on the boundary points actually selected for use, there may be a need to increase the number of marked prototiles making up the scaled composite tile (500 in Figure 5) or add more boundary points and paths so as to fulfil the arrangement criteria or conditions described later with reference to Figure 11.

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For example, with regard to Figure 9, in a marked prototile 900, a curved first directional path 902 with a directional arrow 912 is marked from one of the selected prototile boundary points 904 at a first corner of the prototile 400 to another selected prototile boundary point 906 at a second corner. prototile boundary points 904 and 906 are determined at step 110.

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At step 114, the marked prototile (e.g. 900 in Figure 9) in step 112 is recorded as "marked prototile N+1" where N is the previous number of marked prototiles. If there is no previous number, N is zero. For example, in
5 Figure 9, N is zero, thus the marked prototile 900 is named as marked prototile 1.

At step 116, areas of the marked prototile (e.g. 900 in Figure 9) separated by the path are marked or toned with different markings i.e. colours, drawings,
10 labels or shadings, for instance, in the case of two separated areas, gray on one side of the path, and white on the other. It is noted that another reason why the prototiles is named with the word "marked" at step 114 is that the areas of the prototile would be marked at the present step 116. It is appreciated that a marked prototile for the purposes of the present
15 description could indicate that the prototile has areas marked with different markings and/or indicate that boundary points and flow directions have been marked out. It is appreciated that step 116 is not limited to the type of markings discussed herein. The purpose of step 116 is to mark out different regions using different markings on the tiles to aid further processing. For
20 example, Figure 9 shows a first area 908 (shaded) and a second area 910 (non-shaded) of the marked prototile 900 residing on both sides of the path 902.

At step 118, it is checked whether the marked prototile (e.g. 900 in Figure 9)
25 has reverse marking symmetry with itself when the markings in the areas separated by the path (e.g. 902 in Figure 9) are reversed and the direction of the directional arrow is reversed. In other words, whether the marked prototile (e.g. 900 in Figure 9), when the markings or in this case tones are swapped and directional arrow direction reversed, would result in identical
30 markings. If the marked prototile (e.g. 900 in Figure 9) has reverse marking symmetry, step 132 as follows is omitted and the method proceeds with step 120 below. If the marked prototile (e.g. 900 in Figure 9) does not have reverse marking symmetry, the method proceeds with step 132. It is appreciated that checking of reverse marking symmetry at step 118 is
35 optional and if skipped, all marked prototiles can simply proceed to step 132. One benefit for having step 118 is to cut down on computing required to perform step 132. Step 120 requires lesser computing.

At step 132, a reverse marked prototile is created by reversing the markings on the marked areas separated by the first path and reversing direction of the flow direction of the first path. More specifically, a reverse marked version of the marked prototile (e.g. 900 in Figure 9) (also known as reverse marked prototile) is created by reversing the markings i.e. marked colours, drawings, labels or shadings in the areas separated by the path (e.g. 902 in Figure 9), reversing the positions of the starting and ending boundary points of step 112 and reversing the direction of the directional arrow determined in step 112. Figure 10 shows a reversed marked prototile 1000 of the marked prototile 400 in Figure 4. In the reversed marked prototile 1000, the colour of a third area 1004 corresponding to the first area 908 of the marked prototile 400 is the colour of the second area 910 of the marked prototile 400. The colour of a fourth area 1002 corresponding to the second area 910 is the colour of the first area 908 of the marked prototile 900 in Figure 9. The direction of a second directional path 1006 separating the third area 1004 and the fourth area 1002 is in a reverse direction from the direction of the path 902 in Figure 9. The reversed marked prototile 1000 is named as 'reverse marked prototile 1'.

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At step 134, the marked prototile (e.g. 900 in Figure 9) and the reverse marked prototile (e.g. 1000 in Figure 10) created at step 132 are deemed to be completed and data associated with them are stored. Each reverse marked prototile created for a marked prototile $N + 1$ of step 114 is given a name "reverse marked prototile $N + 1$ ".

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At step 120, the marked prototile created after going through step 116 is deemed to be completed and data associated with it is stored. No reversed marked prototile needs to be created at this step as it was determined that the marked prototile has 180 degrees rotational symmetry at step 118. It is appreciated that in the prototile described with reference to Figure 9 has no reverse Marking Symmetry. An example of a prototile with reverse Marking Symmetry would be marked prototile 2 3100 in Figure 31.

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At step 122, the marked prototile (e.g. 900 in Figure 9) and the corresponding reversed marked prototile (e.g. 1000 in Figure 10), or the obtained marked prototile (e.g. 900 in Figure 9) of step 120, recorded at step

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134 or 120 is or are scaled by the scaling factor recorded in step 108. Data of the scaled and marked prototile (e.g. 1100 in Figure 11) and the corresponding reversed scaled and marked prototile (e.g. 1102 in Figure 11), or the obtained marked prototile (e.g. 900 in Figure 9) of step 120, are stored
5 at step 122.

At step 124, one or more of the marked prototile (e.g. 900 in Figure 9) and one or more of the reverse marked prototile (e.g. 1000 in Figure 10) are arranged to form a marked composite tile having the same shape, prototile
10 arrangement and boundary points as the composite tile of step 104. More specifically, the scaled and marked prototile of step 122 and the corresponding reversed scaled and marked prototile of step 122, or the obtained marked prototile (e.g. 900 in Figure 9) of step 120, and previous marked prototiles, if any, referred to in step 114 are arranged to form a
15 marked composite prototile (e.g. 1102 and 1112 in Figure 11) (also known as marked composite tile), for example, one like the composite tile of step 110 (e.g. 500 in Figure 6). The marked composite tile (e.g. 1102 and 1112 in Figure 11) is then laid over a prototile (e.g. 400 in Figure 4) having the shape and size determined at step 102, for example, in the manner like the
20 composite tile 500 in Figure 6. The marked composite tile (e.g. 1102 and 1112 in Figure 11) is to be formed with the following arrangement criteria or conditions.

With reference to the two examples 1140 and 1150 in Figure 11 and Figure
25 9, the arrangement criteria or conditions as follows are checked to ensure that they are complied with.

1) The composite tile starting point of the marked composite tile (e.g. 1104 in Figure 11) should be matched with the prototile starting point of the prototile
30 (e.g. 904 in Figure 9) and the composite tile ending point of the scaled composite tile (e.g. 1106 in Figure 11) should be matched with the prototile ending point of the prototile (e.g. 906 in Figure 9).

2) A second path (e.g. 1160 in Figure 11) is formed to run from the composite
35 tile starting point of the marked composite tile (e.g. 1104 in Figure 11) to the composite tile ending point of the marked composite tile (e.g. 1106 in Figure

11). The second path (e.g. 1160 in Figure 11) is formed by joining the individual paths of the one or more marked prototile and the one or more reverse marked prototile, and the flow directions of the paths joined to form the second path (e.g. 1160 in Figure 11) are directing the second path (e.g. 1160 in Figure 11) to terminate at the composite tile ending point (e.g. 1106 in Figure 11).

3) The areas of the marked composite tile separated by the second path (e.g. 1160 in Figure 11) being marked with the same markings as the respective marked areas separated by the path of the one or more marked prototile or the one or more reverse marked prototile.

4) Each of the paths forming the second path (e.g. 1160 in Figure 11) are not in contact with boundary points other than the prototile starting point (e.g. 904 in Figure 9) and prototile ending point (e.g. 906 in Figure 9) of the respective prototile.

5) Areas with the same markings on the one or more marked prototile and the one or more reverse marked prototile that are arranged to form the marked composite tile (e.g. 1102 and 1112 in Figure 11) are arranged to contact one another.

The following illustrates the preceding 5 criteria. The marked composite tile 1102 is to be formed using three scaled and marked prototile 1100 and two corresponding reversed scaled and marked prototile 1110 in the case of example 1140. In the case of example 1150, the other marked composite tile 1112 is to be formed using two scaled and marked prototile 1100 and three corresponding reversed scaled and marked prototile 1110. It is appreciated that the marked composite tile 1112 is the corresponding reverse version of the marked composite tile 1102. As there are 3 prototiles and 3 corresponding reverse prototiles used here to form the marked composite tile 1102 and 1112, it is appreciated that steps 114 and the other steps subsequently leading up to step 124 (in this case, in respective order, steps 116, 118, 132, 134 and 122) would have been looped through 3 times to generate 3 prototiles named "marked prototile 1", "marked prototile 2", and "marked prototile 3" and their corresponding reverse prototiles, "reverse marked prototile 1", "reverse marked prototile 2", and "reverse marked

prototile 3". This also means that steps 124 and 126 would have carried out 3 times and step 136 would have gone through twice. The details of steps 126 and 136 would be described later. The shape and size of the marked composite tiles 1102 and 1112 is similar to the shape of the scaled composite tile (e.g. 500 in Figure 6) of step 110.

There is a condition for a first scaled and marked prototile 1124 (example 1140) or 1134 (example 1150) to have its directional path 1108 (example 1140) or 1118 (example 1150) respectively starting from a starting point 1104 (example 1140) or 1114 (example 1150) respectively located at the same position as the starting boundary point location (904 in Figure 9) of the marked prototile of step 112.

There is a further condition for a final scaled and marked prototile 1126 (example 1140) or 1136 (example 1150) to have its directional path 1120 (example 1140) or 1122 (example 1150) respectively ending at an ending point 1106 (example 1140) or 1116 (example 1150) respectively located at the same position as the ending boundary point location (906 in Figure 9) of the marked prototile of step 112.

Individual directional paths of the prototiles in the marked composite tiles 1102 and 1112 is required to be joined and continuously linked to form respective resultant adjoined paths 1160 and 1162, and each of the directional arrows (i.e. arrows like 912 in Figure 9) of the individual paths are to be pointing in a direction towards the starting point (i.e. a point like the starting boundary point 904 in Figure 9) of an adjacent prototile in the marked composite tiles 1102 and 1112. In this case, the respective adjoined paths 1160 and 1162 begins from the directional path 1108 of the first scaled and marked prototile 1124 (example 1140) or 1134 (example 1150) respectively, flows through the directional paths of the intermediate scaled and marked prototiles 1128, 1130 and 1132 (example 1140) or 1138, 1144 and 1142 (example 1150) respectively, and ends with the directional path 1120 of the final scaled and marked prototile 1126 (example 1140) or 1136 (example 1150) respectively.

Each of the respective adjoined paths 1160 and 1162 is to divide the marked composite tiles 1102 and 1112 such that all portions on one side of the

adjoined paths 1160 and 1162 respectively is marked i.e. coloured, labeled, drawn or shaded in one way and the other portions on the other side is to be marked in another way. Furthermore, the marking scheme of the marked composite tiles 1102 and 1112 should generally follow that of the marking
5 scheme of the respective marked prototile 1100 and 1110. That is, for instance, if an upper half of a marked prototile located on one side of its directional path is gray in colour and the lower half on the other side of the directional path is white in colour, the corresponding marked composite tile would also be gray in its upper half located on one side of its adjoined
10 directional path of the marked composite tile and white in its lower half on the other side of the adjoined directional path.

With reference to Figure 11, the marked composite tile 1102 has all disjoined portions 1156 on one side of the adjoined path 1160 uniformly shaded. The
15 orientation of the prototiles in the marked composite tiles 1102 and 1112 and the ratio of the scaled and marked prototile 1100 and the corresponding reversed scaled and marked prototile 1110 to use are in a manner ensuring that the adjoined paths 1160 and 1162 would divide the marked composite tiles 1102 and 1112 with a marking scheme for the respective portion(s) as
20 mentioned above.

The marked composite tiles 1102 and 1112 are to be arranged such that none of their directional paths intersect with one another. An intersection occurs when three or more directional paths branch from the same boundary
25 point. If this happens, the tile arrangement effect to be achieved would be lost.

After the marked composite tiles 1102 and 1112 are arranged and manipulated in the manner described, each of the marked composite tiles
30 1102 and 1112 are provided with a name called "composite tile".

Figure 12 illustrates what has not fulfilled the arrangement criteria or conditions described with reference to Figure 11.

35 There are two negative examples 1240 (non-compliant marked prototile 1 Step 1; "non-compliant" indicating non-compliance with the arrangement criteria or conditions described with reference to Figure 11) and 1250 (non-

compliant reverse marked prototile 1 Step 1; "non-compliant" indicating non-compliance with the arrangement criteria or conditions described with reference to Figure 11) in Figure 12, the marked composite tile 1202 is formed using two scaled and marked prototile 1200 and three corresponding reversed scaled and marked prototile 1210 in the case of example 1240 and the other marked composite tile 1212 is formed using one scaled and marked prototile 1200 and three corresponding reversed scaled and marked prototile 1210 in the case of example 1250. The shape and size of the marked composite tiles 1202 and 1212 is similar to the shape of the scaled composite tile (e.g. 500 in Figure 6) of step 110.

There is a first scaled and marked prototile 1224 (example 1240) or 1234 (example 1250) having its directional path 1208 (example 1240) or 1218 (example 1250) starting from a starting point 1204 (example 1240) or 1214 (example 1250) that is located at the same position as the starting boundary point location (904 in Figure 9) of the marked prototile of step 112. There is no violation to the position requirement of the starting point of the directional path 1208 (example 1240) or 1218 (example 1250).

There is a final scaled and marked prototile 1226 (example 1240) or 1236 (example 1250) having its directional path 1220 (example 1240) or 1222 (example 1250) ending at an ending point 1206 (example 1240) or 1216 (example 1250) that is located at the same position as the ending boundary point location (906 in Figure 9) of the marked prototile of step 112. There is no violation of the requirements for the final scaled and marked prototile 1226 (example 1240) or 1236 (example 1250). There is no violation to the position requirement of the ending point of the directional path 1220 (example 1240) or 1222 (example 1250).

Unlike the marked composite tiles 1102 and 1112 in Figure 11, the resultant path 1268 of the marked composite prototile 1202 formed by the directional paths of the first scaled and marked prototile 1224 (example 1240), the final scaled and marked prototile 1226 (example 1240) and the intermediate scaled and marked prototiles 1228, 1230 and 1232 (example 1240) of the marked composite tile 1202 are not continuously linked. A prototile 1230 in the marked composite tile 1202 located between a prototile 1224 in the marked composite tile 1202 and another prototile 1228 in the marked

composite tile 1202 is oriented such that its directional path 1258 breaks away from linking a directional path 1258 of the prototile 1224 to a directional path 1264 of the prototile 1228. Also, a directional path 1264 of the prototile 1228 is not linked at a boundary point 1260 to the directional path 1258 of the adjacent prototile 1230.

With reference to the resultant paths 1268 and 1270 of the marked composite tiles 1202 and 1112 respectively, each of them divides the respective marked composite tiles 1102 and 1112 into having more than one shading in the portions on one side of the resultant paths 1268 and 1270. This does not fulfil the requirement of all portions on one side of an adjoined path having a mark different from the marking of all portions on the other side of the adjoined path. Furthermore, in the marked composite tile 1202, the prototiles 1224, 1226, 1228 and 1232 are not oriented correctly to create an adjoined path dividing two sides with different marking. Moreover, for the marked composite tile 1212, the ratio of scaled and marked prototile 1200 and corresponding reversed scaled and marked prototile 1210 is not right for creating the required marking.

In addition, for the marked composite tile 1202, it is arranged such that three directional paths 1258, 1272 and 1220 branch from the same boundary point 1262. This does not fulfill the requirement for having less than three directional paths branching from the same boundary point.

Referring back to Figure 1, at step 126, it is checked whether the arrangement criteria or conditions set out in step 124 can be achieved. Carrying out through computer software executed using a computer, different combinations and permutations can be tested to verify whether the arrangement criteria or conditions can be achieved.

After running through the different combinations and permutations at step 126, if any of the arrangement criteria or conditions still cannot be fulfilled, a scaled and marked prototile (i.e. prototile 1100 in Figure 11) and/or the corresponding reversed scaled and marked prototile (i.e. prototile 1110 in Figure 11) is/are added to try and resolve the criteria non-compliance at step 136. Alternatively or by choice of a user, in addition to or in place of adding a scaled and marked prototile (i.e. prototile 1100 in Figure 11) and the

corresponding reversed scaled and marked prototile (i.e. prototile 1110 in Figure 11), new boundary points may be selected and additional directional paths may be added to resolve the criteria non-compliance. For instance, in some cases where the basic shape of the prototile used is a triangle, single directional paths may be exhausted when linking boundary points to one another under the arrangement criteria or conditions. In this case, an additional direction path may be marked out in one of the triangular prototiles.

After step 136 is performed, the prototile naming step at 114 and the subsequent steps leading up to step 126 would be performed. This basically checks whether adding one more scaled and marked prototile has helped to fulfil the arrangement criteria or conditions. In this case where step 136 is required, there would be at least one previous marked prototile when step 114 is executed after step 136, which is the one that failed the criteria test at step 126.

If it turns out that all arrangement criteria or conditions are fulfilled, at step 128, data of each scaled and marked prototile (i.e. prototile 1100 or 1110 in Figure 11) composing the marked composite tile (i.e. prototile 1102 or 1112 in Figure 11) is stored and a name "composite tile B (Step 1)" is given, where B is a reference number given to the corresponding scaled and marked prototile. "Step 1" refers to completion of one iteration of the steps carried out in Figures 1A and 1B to arrive at a marked composite tile. The purpose of step 128 is to rename each of the stored scaled and marked prototiles composing the marked composite tile that have fulfilled the arrangement criteria or conditions. For instance, if 5 scaled and marked prototiles (i.e. 1124, 1126, 1128, 1130 and 1132 of Figure 11) with names (named at steps 114 and 134) "marked prototile 1", "marked prototile 2", "marked prototile 3", "Reverse marked prototile 1" and "reverse marked prototile 2" are used to compose the marked composite tile (i.e. 1102 of Figure 11), the new names given at step 128 would be "composite tile 1 (Step 1)", "composite tile 2 (Step 1)", "composite tile 3 (Step 1)", "composite tile 4 (Step 1)" and "composite tile 5 (Step 1)" respectively. It is appreciated that other suitable names clearly indicating the step and tile number could also be provided.

At step 130, the marked composite tile of step 128 will be assigned with a name "marked composite tile Set (Step 1)" or any other name indicating that it is a set fulfilling the arrangement criteria or conditions. Other than the "marked composite tile set (Step 1)", what will also be an output of step 130 is a "marked prototile set" including all the marked prototiles used to compose the marked composite tile of step 128. A "marked prototile set" may include both marked and reversed marked tiles. For instance, the 5 scaled and marked prototiles (i.e. 1124, 1126, 1128, 1130 and 1132 of Figure 11) with names (named at steps 114 and 134) "marked prototile 1", "marked prototile 2", "marked prototile 3", "reverse marked prototile 1" and "reverse marked prototile 2" are part of the "marked prototile set" used to compose the marked composite tile (i.e. 1102 of Figure 11) of step 128.

With reference to Figure 2, there is provided a flowchart 200 illustrating an iterative process for deflation of the marked composite tile set (Step 1) as described with reference to Figure 1 to generate a larger tile set with a desired tile arrangement. Figures 13 to 17 illustrate the deflation process.

Following from step 130 of Figure 1, at step 202, data of the "marked prototile set" is acquired for processing.

At step 204, every scaled and marked prototile named as marked prototile $N + 1$ in step 128 of Figure 1 is replaced with a marked composite tile set (Step $N + 1$) from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1. Furthermore, if present, every scaled and marked reverse prototile named as reversed prototile $N + 1$ in step 128 is replaced with a corresponding reversed marked composite tile set (Step $N + 1$) that is reduced in scale by the scaling factor of step 108 in Figure 1. The reversed marked composite tile set (Step $N + 1$) is the corresponding reverse version of the marked composite tile set (Step $N + 1$) that is created after step 130.

When the replacement takes place, the marked composite tile set (Step $N + 1$) is oriented such that the location of the respective coloured, marked or shaded portions divided by the adjoined path (e.g. 1160 in Figure 11) of the marked composite tile set (Step $N + 1$) are best matched with the location of the same coloured marked or shaded portion in the marked prototile $N + 1$.

More specifically, the marked composite tile set (Step N + 1) or reverse marked composite tile set (Step N + 1) is oriented such that its starting and ending boundary points would be matched with the respective starting and ending boundary points of each respective marked prototile or reverse prototile to be replaced. The starting and ending boundary points of the marked composite tile set (Step N + 1) is defined as the boundary points where the adjoined path (e.g. 1160 in Figure 11) of the marked composite tile set (Step N + 1) begins (e.g. 1104 in Figure 11) and ends (e.g. 1106 in Figure 11) respectively.

Figure 13 illustrates the replacement process at step 204.

Figure 13 shows a composite marked prototile 1350 containing 5 prototiles 1300, 1334, 1336, 1338 and 1352 to be replaced. Three of the 5 prototiles 1300, 1334 and 1336 are marked prototiles and the other two 1338 and 1352 are reverse prototile versions of the three marked prototiles. Figure 13 also shows various marked composite tile sets (Step 1) 1340, 1342 and 1346, and reverse composite tile sets (Step 1) 1348 and 1344 for replacing each of the 5 prototiles 1300, 1334, 1336, 1338 and 1352 respectively. Each of the marked composite tile sets (Step 1) and the reverse marked composite tile sets (Step 1) are to be oriented such that their respective starting and ending boundary points would be matched with the respective starting and ending boundary points of each prototile or reverse prototile to be replaced. Specifically, starting and ending boundary points 1310 and 1312 (pertaining to 1340) would be matched to starting and ending boundary points 1330 and 1308 of prototile 1300. Starting and ending boundary points 1314 and 1316 (pertaining to 1342) would be matched to starting and ending boundary points 1302 and 1304 of prototile 1334. Starting and ending boundary points 1322 and 1324 (pertaining to 1346) would be matched to starting and ending boundary points 1330 and 1308 of prototile 1336. Starting and ending boundary points 1320 and 1318 (pertaining to 1344) would be matched to starting and ending boundary points 1330 and 1308 of prototile 1338. Starting and ending boundary points 1326 and 1328 (pertaining to 1348) would be matched to starting and ending boundary points 1330 and 1308 of prototile 1352.

Referring back to Figure 2, after completion of step 204, a new composite marked prototile (e.g. 1400 in Figure 14) would be created. The new composite marked prototile (e.g. 1400 in Figure 14) contains all the marked composite tile sets (Step $N + 1$) and the reverse marked composite tile sets (Step $N + 1$) that are used to replace the scaled and marked prototile named as marked prototile $N + 1$ of step 128 in Figure 1 and the scaled and marked reverse prototile named as reversed prototile $N + 1$ of step 128 respectively.

With the new composite marked prototile (e.g. 1400 in Figure 14) created after step 204, a check is performed at step 208 on the new composite marked prototile (e.g. 1400 in Figure 14) to see if the tile patch i.e. the number of prototiles in the new composite marked prototile (e.g. 1400 in Figure 14) is sufficient for providing a required patch of tiles for a predetermined area.

If the number of tiles in the tile patch generated exceeds the extent of the required patch of tiles, step 210 would be carried out. Otherwise, step 206 would be carried out. Step 206 would be looped if the tile patch does not exceed the required number of tiles. As each loop involves an exponential increase in the number of tiles in the tile patch created, a large numbers of tiles can be generated after a few loops.

As an example, given a square shaped room area of 9 square metres, a tile patch consisting of 100 tiles having 0.09 square metres is required to tile the room area. Hence, in this case, step 208 would check that there are at least 100 tiles formed in the shape of a square in the created tile patch before proceeding to step 210.

At step 206, every instance of the scaled and marked prototile i.e. the marked prototile $N + 1$ composing the new composite marked prototile created at step 204 or, if present, a previous new composite marked prototile created at step 206, is replaced with a marked composite tile set (Step $N + 1$) from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1. Furthermore, if present, every scaled and marked reverse prototile i.e. the reversed prototile $N + 1$ in step 128 is replaced with a corresponding reversed marked composite tile set (Step $N + 1$) that is reduced in scale by the scaling factor of step 108 in Figure 1. If step 206 is executed for the first

time, the new composite marked prototile created at step 204 would be subjected to replacement. Otherwise, the new composite marked prototile created in the previous instance at step 206 would be subjected to replacement instead.

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Figure 14 illustrates the completed replacement process carried out at step 206. More specifically, Figure 14 shows a new composite marked prototile 1400 created after the tile replacement has taken place in the example of Figure 13.

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In Figure 14, every instance of the scaled and marked prototile i.e. the marked prototile 1 (Step 1) in step 128 composing the new composite marked prototile 1300 created by step 204 is replaced with a marked composite tile set (Step 1) from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1. Furthermore, if present, every scaled and marked reverse prototile i.e. the reversed prototile 1 (Step 1) in step 128 is replaced with a corresponding reversed marked composite tile set (Step 1) from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1.

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20 It is observed that the adjoined path 1402 of marked composite tile set 1342 (Step 1) is joined with the adjoined path 1410 of marked composite tile set 1344 (Step 1) at points 1302 and 1304. The adjoined path 1404 of marked composite tile set 1346 (Step 1) is joined with the adjoined path 1410 of marked composite tile set 1344 (Step 1) at points 1304 and 1306. The
25 adjoined path 1406 of marked composite tile set 1348 (Step 1) is joined with the adjoined path 1410 of marked composite tile set 1344 (Step 1) at points 1306 and 1308. The adjoined path 1408 of marked composite tile set 1340 (Step 1) is joined with the adjoined path 1410 of marked composite tile set (Step 1) 1344 at points 1308 and 1302. The starting and ending boundary
30 points of the new composite marked prototile 1400 are at points 1330 and 1332 respectively, which are the starting and ending boundary points of the previous composite marked prototile 1350 in Figure 13 respectively. The new composite marked prototile 1400 is named as "marked prototile 1 (Step 2)". Figure 14 also shows a prototile 1420 named as "reverse marked prototile 1
35 (Step 2)", which is the reverse version of the "marked prototile 1 (Step 2)".

At step 210, the tile patch generated that would exceed the extent of the required patch of tiles is outputted and extracted. The tile patch can be scaled up or down to any required scale for the desired application by the process of geometric enlargement or reduction. For example, scaling up to
5 have a better visual view of the tiling set on a computer display for extracting the required tiling set for the predetermined area.

Figure 15 illustrates a new marked composite tile 1501, which has been named as "marked prototile 1 (Step 3)", and its reverse version 1502, which
10 has been named as "reverse marked prototile 1 (Step 3)". The new marked composite tile 1501 is created by step 206 as follows.

Every instance of the scaled and marked prototile i.e. the marked prototile 1 (Step 1) in step 128 composing the new composite marked prototile 1400 i.e.
15 marked prototile 1 (Step 2) created by step 206 is replaced with a marked composite tile set (Step 1) from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1. Furthermore, if present, every scaled and marked reverse prototile i.e. the reversed prototile 1 (Step 1) in step 128 is replaced with a corresponding reversed marked composite tile set (Step 1)
20 from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1.

Figure 16 illustrates new marked composite tile 1601, which has been named as "marked prototile 1 (Step 4)", and its reverse version 1602, which has
25 been named as "reverse marked prototile 1 (Step 4)". The new marked composite tile 1601 is created by step 206 as follows.

Every instance of the scaled and marked prototile i.e. the marked prototile 1 (Step 1) in step 128 composing the new composite marked prototile 1501 i.e.
30 marked prototile 1 (Step 3) created by step 206 is replaced with a marked Composite Tile Set (Step 1) from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1. Furthermore, if present, every scaled and marked reverse prototile i.e. the reversed prototile 1 (Step 1) in step 128 is replaced with a corresponding reversed marked composite tile set (Step 1)
35 from step 130 that is reduced in scale by the scaling factor of step 108 in Figure 1.

Figure 17 illustrates an example of a tile patch 1700 extracted at step 210.

It is appreciated that no matter how large the number of tiles is present in the tile patch outputted at step 210, the arrangement criteria or conditions of step 124 in Figure 1 would be fulfilled.

After completion of the steps in the flowchart 200 and the further step of extracting the desired tiling area, the extracted tile patch (e.g. 1700 in figure 17) would contain the required number of tiles and scale and would be arranged to form a continuous fractal geometry path, as defined by the arrangement criteria or conditions of step 124 in Figure 1. Thereafter, each tile in the tile patch (e.g. 1700 in figure 17) is to be filled with an appropriate decorative or functional design (e.g. a design for an integrated photovoltaic panel cladding system, where each tile could be a solar panel) that can showcase the desired "multi-scalar" or "non-repetitive but yet with certain order" tiling effects of the tiling arrangement.

With reference to Figure 3, there is provided a flowchart 300 illustrating derivation of edge (or side) matching rules and conditions formulated to create tiling templates with the desired tiling design for the aforementioned resultant extracted tile patch (e.g. 1700 in figure 17). The output from the flowchart 300 would be an edge conditioned composite tile set containing the desired tiling design. It is appreciated that edge condition refers to how sides or edges of the tiles are shaped.

At step 302, a marked prototile set (e.g. 1140 or 1150 in Figure 11) is acquired for processing. The marked prototile set would be provided with a design that would be replicated throughout the resultant extracted tile patch (e.g. 1700 in figure 17). It is noted that the resultant extracted tile patch (e.g. 1700 in figure 17) is made up of a plurality of the marked prototile set.

At step 304, one or more different edge conditions for marking or shaping the area located along the sides of each tile in a marked prototile set (e.g. 1140 or 1150 in Figure 11) is created.

For instance, if one side of a marked tile is coloured grey for the entire length, this is one condition. If one side of a marked tile is coloured white for

the entire length, this is another condition. If one side of a marked tile is half grey, and half white, this is another condition. The number of conditions will depend on the number and location of boundary points used as starting points and ending points for the directional path in each tile. It is appreciated
5 that there could be more than one starting and ending points.

Each tile in the marked prototile set (e.g. 1140 or 1150 in Figure 11) may have different motifs or designs but they should satisfy the following edge conditions.

10 Sides of the tile having the same marking in the edge conditioned composite tile set should be provided with the same edge condition design (design meaning marking or shape created by replacing the edge with a more complex curve). The sides of adjacent tiles having a different marking in the
15 edge conditioned composite tile set should be provided with a different edge condition design. It is appreciated that the edge condition design may be customised to suit any design aesthetic or motif, the requirement is only that each similar edge condition has the same edge condition applied to it.

20 The motif or design within each tile can have complete freedom of design within the area of the tile except at the sides of the tile where the motif should incorporate the edge condition design.

The motif or design located at one side of a tile in an edge conditioned
25 composite tile set to be created should intersect or be a continuation of the motif or design located on the side of another tile that is adjacently placed.

For all tile sets with a symmetrical edge design, that is a design that is symmetric around the midpoint of the edge of the tile, the design will match
30 with the motif or design located on a corresponding side of another adjacently placed tile in any instance.

If it is desired to have an asymmetric pattern or motif on the tile, with an asymmetric edge design, then the original selection of the prototile is critical.
35 Choosing a prototile with an asymmetric curve or side as its edge will limit the way it is orientated as it tiles the plane, and limit the way it can be assembled into a composite tile patch. Building in asymmetry into the

prototile geometry will allow asymmetry in the design of the tile motif or pattern. It is appreciated that the prototile asymmetric edges must be placed in such a way that a curve that adds to the area of the basic shape on one edge, must be balanced by a corresponding opposite curve that subtracts from the area of the basic shape on another edge, such that the area of the prototile equals the area of the basic shape.

At step 306, different edge conditions in the marked prototile Set (e.g. 1140 or 1150 in Figure 11) are identified and similar edge conditions would be appended with a same reference indicator, for instance, edge condition A, edge condition B, and so on. The reference indicator is a useful guide for one performing actual tiling of the resultant extracted composite tile set in the physical environment. A different tile number is given for each tile having different directional path direction and marking. The number of different tile number given in this manner would determine the number of base tiles required for creating the desired tiling design in the desired tile arrangement.

At step 308, for every tile i.e. marked prototile 1 to "N" in the marked prototile set (e.g. 1140 or 1150 in Figure 11), remove the directional path previously included at step 112 in Figure 1, and marking previously added at step 116 in Figure 1 to produce respective edge conditioned prototiles 1 to "N". For any reverse version of the tiles in the resultant extracted composite tile set, the directional path, and marking are removed as well. Thereafter, imprint a design fulfilling the aforementioned edge conditions on each tile.

At step 310, an edge conditioned marked prototile set with the desired tiling design is outputted. The same design can be replicated in all the marked prototile sets present in a resultant extracted tile patch (e.g. 1700 in figure 17)

An example to illustrate the steps in Figure 3 is described as follows with reference to Figures 18 to 23. With reference to Figure 18, there are two tiles, a tile 1800 that is the same as the marked prototile 900 in Figure 9 and its corresponding reverse marked prototile 1802 that is the same as the marked prototile 1000 in Figure 10. When running the tile 1800 through step 306, it is identified that there are three sides 1804, 1806 and 1808 having the same shading (gray). Hence, each of these sides 1804, 1806 and 1808 would

be associated with an edge condition (i.e. a label) called "edge condition A" 1810. The remaining side 1814 having another shading (white) is then associated with an edge condition (i.e. a label) called "edge condition B" 1812. Furthermore, in this case, there are only two tiles with different directional path directions and marking. Hence, different tile number is given to the two tiles 1800 and 1802, more specifically, tile 1 for tile 1800 and tile 2 for 1802.

With regard to the reverse marked prototile 1802, when running it through step 306, it is identified that there are three sides 1816, 1818 and 1820 having the same shading (white). Hence, each of these sides 1816, 1818 and 1820 would be associated with the "edge condition B" 1812. The remaining side 1822 having the other shading (gray) is then associated with the "edge condition A" 1810.

After the edge conditions are associated, one could be guided by them to perform tiling in the physical environment. In the case of Figure 18, only tile sides with edge condition A can be placed adjacent with other tiles sides with edge condition A. The same goes for tile sides with edge condition B.

Figure 19 illustrates the association of a tiling set 1900 with the "edge condition A" 1810 in Figure 18 and the "edge condition B" 1812 in Figure 18. The tiling set 1900 is actually extracted from the composite tile set shown in Figure 17. In Figure 19, the directional path and marking are deliberately removed and the edge condition association and the tile numbering are deliberately included for illustration.

Figure 20 shows two tiles 2002 and 2004. The tiles 2002 and 2004 have the same edge condition association and tile numbering as the two tiles 1800 and 1802 in Figure 18 respectively. In this case, edge condition A is provided an edge design that appears as an elongate trapezium 2006 with two strips 2010 and 2012 evenly spaced away from centre 2018 of the trapezium 2006 and from the sharp end portions 2014 and 2016 respectively of the trapezium 2006. Edge condition B is provided an edge design that appears as an elongate trapezium 2008 with three strips 2020, 2022 and 2024. Strip 2022 is located at the centre 2026 of the trapezium 2006, and strips 2020 and 2024

are located at the respective sharp end portions 2028 and 2030 of the trapezium 2008.

Figure 21 shows two tiles 2102 and 2104 corresponding to tiles 2002 and 2004 in Figure 20 respectively. In the edge locations of the tiles 2102 and 2104 associated with edge conditions A and B, the trapezium 2006 in Figure 20 of edge condition A and the trapezium 2008 of edge condition B have been placed in the tiles 2102 and 2104 accordingly.

Figure 22 shows two tiles 2202 and 2204 corresponding to tiles 2102 and 2104 in Figure 21 respectively. In this case, for tile 2202, a design with parts in continuity with the two strips 2010 and 2012 of each edge condition A and parts in continuity with the three strips 2020, 2022 and 2024 in Figure 20 is created to fill in the centre portion 2206 not covered by the respective trapeziums 2006 and 2008. For tile 2204, another design with parts in continuity with the two strips 2010 and 2012 of each edge condition A and parts in continuity with the three strips 2020, 2022 and 2024 in Figure 20 is also created to fill in the centre portion 2208 not covered by the respective trapeziums 2006 and 2008.

Figure 23 illustrates a patch of tiles set 2300 containing the desired tiling arrangement derived after going through the steps in Figure 1 and 2, and the desired tiling design derived according to Figures 20, 21 and 22.

With reference to Figures 24 to 42, the same methods 100 in Figure 1, 200 in Figure 2 and 300 in Figure 3 are applied to the case where the "basic shape" determined is a hexagon. The steps are applied in the same manner as the example illustrated by Figures 4 to 23.

Steps 24 to 32 illustrate use of the method 100 for creation of marked tiles and composite marked tiles. The composite tile is made up of 7 hexagonal tiles. The marked composite tile has 3 different marked prototiles.

Figure 24 shows a hexagonal shaped prototile 2400, it is similar to prototile 400 in Figure 4 in concept.

Figure 25 shows a composite tile 2500, it is similar to prototile 500 in Figure 5 in concept. However, it is a composite tile 2500 that is made up of 7 hexagonal tiles.

5 Figure 26 is similar to Figure 6 in concept. The reduced scaled prototile 2602 corresponds to 602 in Figure 6.

Figure 27 is similar to Figure 7 in concept just that the reduced scaled prototile are hexagonal and the number of tiles in the composite tile is different. The added area and subtracted area in Figure 27 have the same definition as that in Figure 7.

Figure 28 is similar to Figure 8 in concept. The definitions of the similarly labeled boundary points are the same as those in Figure 8.

15 Figure 29 is similar to Figure 9 in concept. A prototile 2900 of the 3 different marked prototiles is shown.

Figure 30 is similar to Figure 10 in concept. A prototile 3000 of the 3 different marked prototiles is shown.

Figure 31 does not correspond with any figure in the previous example as it is an additional marked prototile 3100 required for fulfilling the 5 arrangement criteria. It is noted that marked prototile 3100 has the property of reverse marking symmetry, so there is no reverse marked prototile 2 required to complete the marked prototile Set.

Figure 32 is similar to Figure 11 in concept. Created marked composite tiles 3202, 3204 and 3206 are shown in Figure 32.

30 Figures 33 to 36 illustrate an iterative process to deflate the marked composite tiles 3202, 3204 and 3206 in Figure 32. The method 200 in Figure 2 is applied. It is appreciated that only one of the marked composite tiles 3202, 3204 and 3206 in Figure 32 is required to be selected for deflation and to be used as a template for tile designing.

Figure 33 is similar to Figure 13 in concept just that the reduced scaled prototile are hexagonal and the number of tiles in the composite tile is different.

5 Figure 34 is similar to Figure 14 in concept. More specifically, the prototile labeled "marked prototile 1 Step 2" 3401 in Figure 34 is similar to the new composite marked prototile 1400 in Figure 14. The prototile labeled "reverse marked prototile 1 Step 2" 3402 in Figure 34 is similar to the prototile labeled "reverse marked prototile 1 (Step 2)" i.e. 1420 in Figure 14. The prototile
10 labeled "marked prototile 2 Step 2" 3403 in Figure 34 is another possible composite marked prototile that could be formed in the present example.

Figure 35 is similar to Figure 15 in concept. Further deflation is conducted over the marked prototiles 3401, 3402 and 3403 illustrated in Figure 34.

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Figure 36 is similar to Figure 16 in concept. Figure 36 shows 3 deflated composite marked tiles 3602, 3604 and 3606 after 4 rounds of deflation.

Figure 37 is similar to Figure 17 in concept. Figure 37 shows a composite tile
20 set 3700 extracted from one of the deflated composite marked tiles after a few rounds of deflation.

Figures 39 to 43 illustrate derivation of edge matching rules for each tile in the extracted composite tile sets and adding design to each of the 3
25 prototiles 2900, 3000 and 3100 to create a completed tiling design. The method 300 is applied.

Figure 38 is similar to Figure 18 in concept. Figure 38 illustrates a "marked prototile Set" including the 3 basic marked prototiles 3801 used to compose
30 the marked composite tiles 3202, 3204 and 3206 in Figure 32. The 3 basic marked prototiles 3801 are appended with edge conditions A and B respectively and shown as appended prototiles 3802 in Figure 38. The appended prototiles 3802 have their directional paths and marking deliberately removed. Edge conditions and tile numbers have been
35 deliberately included in the appended prototiles 3802 for illustration.

Figure 39 is similar to Figure 19 in concept. The appended prototiles 3802 have replaced the basic marked prototiles 3801 in a composite tile set created by methods 100 in Figure 1 and 200 in Figure 2. Figure 39 is a useful tile arrangement plan for a tile layer to know how individual hexagonal tiles could be placed to achieve the desired effect after tile design has been provided on the tile surfaces.

Figure 40 is similar to Figure 20 in concept. Figure 40 is essentially showing the appended tiles 3802 in Figure 38. Different edge designs are provided for Edge conditions A and B respectively.

Figure 41 is similar to Figure 21 in concept. Figure 41 shows the appended tiles 3802 in Figure 38 provided with edge designs for edge conditions A and B respectively.

Figure 42 is similar to Figure 22 in concept. Figure 42 shows tiles in Figure 41 with completed tile designs. The designs correspond with the edge conditions A and B respectively.

Figure 43 corresponds to Figure 23. Figure 43 shows a completed tiling design 4300.

With reference to Figures 44 to 64, the same methods 100 in Figure 1, 200 in Figure 2 and 300 in Figure 3 are applied to the case where the "basic shape" determined is a triangle. The steps are applied in the same manner as the example illustrated by Figures 4 to 23.

Steps 44 to 49 illustrate use of the method 100 for creation of marked tiles and composite marked tiles. The composite tile is made up of 4 triangular tiles. The marked composite tile has 12 different marked prototiles.

Figure 44 shows a triangular shaped prototile 4400, it is similar to prototile 400 in Figure 4.

Figure 45 shows a composite tile 4500, it is similar to prototile 500 in Figure 5.

Figure 46 is similar to Figure 6 in concept. The reduced scaled prototile 4602 corresponds to 2602 in Figure 6.

5 Figure 47 is similar to Figure 8 in concept. The definitions of the similarly labeled boundary points are the same as those in Figure 8.

Figure 48 is similar to Figure 8 in concept. In this case, there are 12 different marked prototiles required to fulfil the 5 arrangement criteria. It is noted that marked prototile 4 and reverse marked prototile 4 in this set have two paths
10 in order to meet the composite tile arrangement criteria.

Figure 49 is similar to Figure 11 in concept. 12 marked composite tiles with different combinations are created in Figure 49.

15 Figures 50 to 54 illustrate an iterative process to deflate the 12 marked composite tiles in Figure 49. The method 200 in Figure 2 is applied. It is appreciated that only one of the marked composite tiles in Figure 49 is required to be selected for deflation and to be used as a template for tile designing.

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Figure 50 is similar to Figure 13 in concept just that the reduced scaled prototile are triangular and the number of tiles in the composite tile is different.

25 Figure 51 is similar to Figure 14 in concept. Numerous variations of marked prototiles can be achieved with the 12 different marked prototiles in Figure 48.

Figure 52 is similar to Figure 15 in concept. Further deflation has been
30 performed over the marked prototiles in Figure 51.

Figure 53 is similar to Figure 16 in concept. Figure 53 shows 12 deflated composite marked tiles after 4 rounds of deflation.

35 Figure 54 is similar to Figure 17 in concept. Figure 54 shows a composite tile set extracted from one of the 12 deflated composite marked tiles after a few rounds of deflation.

Figures 55 to 64 illustrate derivation of edge matching rules for each tile in the extracted composite tile sets and adding design to each of the 12 prototiles in Figure 48 to create a completed tiling design. The method 300 is applied. It is noted that by choosing broader edge matching rules more or fewer templates can be created as desired. Out of the 12 marked prototiles in Figure 48, the edge matching rules in Figure 55 would generate 10 different templates, while the edge matching rules in Figure 57 would generate 4 different templates. In the two sets of edge matching rules defined by Figure 55 and Figure 57 respectively, Quality 1 and quality 3 of the 3 qualities mentioned previously are maintained. This is advantageous as fewer components (e.g. 4 marked template tiles in Figure 57) have greater utility. There is greater utility in lesser number of marked template tiles because lesser marked template tiles is required to be manufactured to achieve the desirable pseudorandom effect in tiling as described herein.

Figures 55 and 57 are similar to Figure 18 in concept. Figures 55 and 57 represent different sets of edge matching rules.

In Figure 55, the edge matching rules are such that all sides assigned as 'A' is only associated with gray shading. In Figure 57, all sides assigned as 'A' is associated with gray or white shading.

Figures 56 and 58 are similar to Figure 19 in concept. Figure 56 illustrates edge conditions defined in Figure 55 and Figure 58 illustrates edge conditions defined in Figure 57.

Figure 59 is similar to Figures 20, 21 and 22 in concept.

Figure 60 corresponds to Figure 23. Figure 60 shows a completed tiling design.

In the same manner as the 3 examples provided above, a marked composite tile made up of 5 square tiles and 3 different marked prototiles can be created as illustrated in Figures 61 to 64. Figure 61 shows the 3 different marked prototiles, Figure 62 shows the edge conditions, Figure 63 shows the marked composite tile made up of 5 square tiles and Figure 64 shows a

template extracted from the result of one of the composite marked tiles created for this example after a few rounds of deflation.

5 In the same manner as the 4 examples provided above, a marked composite tile made up of 7 hexagonal tiles and 2 different marked prototiles can be created as illustrated in Figures 65 to 68. Figure 65 shows the 3 different marked prototiles, Figure 66 shows the edge conditions, Figure 67 shows the marked composite tile made up of 5 square tiles and Figure 68 shows a template extracted from the result of one of the composite marked tiles
10 created for this example after a few rounds of deflation.

Figure 69 shows a "diamond flowtile" example which is a tile set having two different "basic shapes" as starting point unlike the previous examples illustrated in Figures 4 to 68, which have just one prototile of a particular
15 basic shape. In the case of Figure 69, a square shaped prototile 6901 and a diamond shaped prototile 6902 are determined at step 102 in Figure 1. The two basic shapes are dimensioned such that each side of the diamond shaped prototile 6902 can match each side of the square shaped prototile 6901 when placed adjacent to one another.

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Figure 69 further illustrates how the two basic shapes 6901 and 6902 could be scaled down and arranged to fit into the shape of each of the two respective basic shapes of a square shaped prototile 6915 and a diamond shaped prototile 6916 i.e. steps 104 and 106 in Figure 1. To arrive at a
25 square shaped composite tile 6921 based on the square shaped prototile 6915, it would take 3 scaled down squares 6901 and 4 scaled down diamonds 6902 to provide the best fit. Two triangular voids 6911 and 6912 would be present in the space of the square shaped prototile 6915 and two triangular sections 6917 and 6918 of two respective scaled down squares
30 6901 would be jutting outside the space of the square shaped prototile 6915. To arrive at a diamond shaped composite tile 6922 based on the diamond shaped prototile 6916, it would take 2 scaled down squares 6901 and 3 scaled down diamonds 6902 to provide the best fit. Two triangular voids 6913 and 6914 would be present in the space of the diamond shaped prototile
35 6916 and two triangular sections 6919 and 6920 of two respective scaled down squares 6901 would be jutting outside the space of the diamond shaped prototile 6916.

Figure 69 also shows that the boundary points selected for the square and diamond composite tiles 6921 and 6922 in this case are not at the half way mark of each side of the square shaped prototile 6915 or the diamond shaped prototile 6916. The reason is that both the square and diamond composite tiles 6921 and 6922 have intersections with the best fit of the scaled down squares 6901 and scaled down diamonds 6902 at locations on each side of the square shaped prototile 6915 or the diamond shaped prototile 6916 that are, for instance, splitting each of those sides by the ratio 1:(1+square root of 2), which is an irrational number.

Figure 70 shows 8 rows of tiles. The first two rows 7001 illustrate 14 differently marked square prototiles and the third and fourth rows 7002 illustrate 12 differently marked diamond prototiles. All of the tiles in the first four rows 7001 and 7002 can be marked and arranged (i.e. add markings and directional paths in steps 112 and 116 to 130 in Figure 1) to form 14 different square composite tiles as shown in rows 7003 (e.g. 6921 in Figure 69 is one of them) and 12 different diamond composite tiles as shown in rows 7004 (e.g. 6922 in Figure 69 is one of them). Each of the composite tiles fulfils the 5 arrangement criteria described with reference to Figure 1. It is appreciated that all of the composite tile variants can be generated with the help of a computer.

It is noted that each of two of the 12 differently marked diamond prototiles 7005 and 7006 in the third and fourth rows 7002 has two directional paths.

Figure 71 also shows 8 rows of tiles and illustrates two stages of deflation of the 14 different square composite tiles as shown in rows 7003 of Figure 70 and 12 different diamond composite tiles as shown in rows 7004 of Figure 70. The method 200 in Figure 2 is applied. After sufficient rounds of deflation as required to fulfil a design need (e.g. to fill a room with tiles of certain dimension), it is appreciated that only one of the marked composite tiles in Figure 71 or in further deflation steps is required to be used as a template for tile designing employing the steps in Figure 3.

Figure 72 shows three square marked prototiles 7201, 7202 and 7203. Figure 72 also shows three composite tile sets 7204, 7205 and 7206 that could be

generated based on the three marked prototiles 7201, 7202 and 7203 using the method 100 in Figure 1. Figure 72 further shows three composite tile sets 7207, 7208 and 7209 derived after deflating the three respective composite tile sets 7204, 7205 and 7206 using the method 200 in Figure 2 (more specifically step 204).

Figure 73 shows three square prototiles 7301, 7302 and 7303 with "mid side" designs. The three prototiles 7301, 7302 and 7303 are derived by applying method 300 in Figure 3 based on the three basic marked prototiles 7201, 7202 and 7203 in Figure 72. After numerous rounds of deflation and providing the "mid side path" design, a tiling design 7304 with a "connecting path" pattern is formed. Characteristics of the "mid side path" design, in common with all tiles derived from this fractal method are that the connecting path in the design i.e. as shown in composite tiles 7204 to 7209 in Figure 72 visits each individual square prototile, never crosses or intersects any other path, and has a non-scalar path pattern. In addition, "the mid-side path" by avoiding path connections at the corners, allows for applications where a pattern, circuit or other connection can be neatly placed at a point between 2 sides, rather than at the corners, where the connection once it has an appreciable width, would by necessity overlap with all the tiles in the corner. The "mid-side-path" also creates the condition of asymmetric design at the sides intersected by the path. It is appreciated that such a design could be useful in the connection of certain electronic circuitries.

Figure 74 shows four hexagonal marked prototiles 7401, 7402, 7403 and 7404. Figure 74 also shows four composite tile sets 7404, 7405, 7406 and 7407 that could be generated based on the four marked prototiles 7401, 7402, 7403 and 7404 using the method 100 in Figure 1. Figure 74 further shows four composite tile sets 7409, 7410, 7411 and 7412 derived after deflating the four respective composite tile sets 7404, 7405, 7406 and 7407 using the method 200 in Figure 2 (more specifically step 204). Figure 74 also shows four composite tile sets 7413, 7414, 7415 and 7416 derived after deflating the four composite tile sets 7409, 7410, 7411 and 7412 using the method 200 in Figure 2 (more specifically step 206).

Figure 75 shows four hexagonal prototiles 7501, 7502, 7503 and 7504 with floral patterns and "mid side path" designs. The prototiles 7501, 7502, 7503 and 7504 are derived by applying method 300 in Figure 3 based on the four basic marked prototiles 7401, 7402, 7403 and 7404 in Figure 74. Figure 75
5 further shows four composite tiles 7505, 7506, 7507 and 7508 that are formed based on the four respective hexagonal prototiles 7501, 7502, 7503 and 7504. Figure 75 shows four more composite tiles 7509, 7510, 7511 and 7512 derived by deflating the four respective composite tiles 7505, 7506, 7507 and 7508. Figure 75 also shows four composite tiles 7513, 7514, 7515
10 and 7516 derived by deflating the four respective composite tiles 7509, 7510, 7511 and 7512.

Figure 76 shows an enlarged view 7601 of composite tile 7509 in Figure 75 without the outlines of the individual hexagonal tiles making up the composite
15 tile 7509 being drawn. The hexagonal "mid side path" design of the composite tiles 7405 to 7416 in Figure 74 has a quality of clean intersection of paths in a design. Points to note in the hexagonal "mid side path" design are that the directional paths of the four basic marked prototiles in 7401, 7402, 7403 and 7404 are not intersecting the corners of each hexagon tile.
20 Also, the connecting path in all of the composite tiles from 7405 to 7413 has a direction which can be expressed in the design provided for the tiles. The expression of the direction is represented by the secondary branches of the floral patterns, which can be seen in the enlarged view 7601 of composite tile 7509. All the secondary branches branch off in a consistent direction away
25 from a main branch 7602 as it moves from the start point at 7604 to the end point at 7603.

Another example of a square "mid side path" design is shown in Figure 77 that is based on the three marked prototiles 7201, 7202, and 7203 in Figure
30 72. Figure 77 shows three square prototiles 7701, 7702 and 7703 derived after applying method 300 in Figure 3 on the three marked prototiles 7201, 7202, and 7203 in Figure 72. Each of the three square prototiles 7701, 7702 and 7703 contains a hole as design. Notably, the sides of each of the three square prototiles 7701, 7702 and 7703 intersecting with the directional paths
35 in the three marked prototiles 7201, 7202, and 7203 in Figure 72 can be made to have asymmetric edge designs. An example of an asymmetric edge design is that the sides intersecting with the directional paths is formed with

a head (corresponding with the "arrow" (relates to the directional path arrow) head in the directional path) that always joins an "arrow" (relates to the directional path arrow) tail on the side of another tile. It could be that there is a "head" shape, which plugs into the "tail" shape. The other sides without intersection with the directional path can remain symmetric i.e. without the head or the tail.

Figure 77 also shows a tiling design 7706 created based on the three square prototiles 7701, 7702 and 7703. The sides of each of the square prototiles 7701, 7702 and 7703 corresponding with the arrow head as described earlier is provided with a tab 7704 (only one is marked out in Figure 77). The sides of each of the square prototiles 7701, 7702 and 7703 corresponding with the arrow tail as described earlier is provided with a socket 7705 (only one is marked out in Figure 77). The tab 7704 is made to fit into the socket 7705. It is appreciated that, in addition to, and independent from, the tab connections, the tiling design 7706 in Figure 77 could be a nano arrangement of pieces (i.e. individual square tiles) with holes placed off-centre, so as to create an arrangement of holes that have pockets of order at the local scale, while appearing random at the global scale.

Figure 78 shows four basic marked prototiles 7801, 7802, 7803, and 7804. Each of them has a four sided shape with curved edges, hence all 4 sides are asymmetrical. Four composite tiles 7805, 7806, 7807 and 7808 in Figure 78 are derived by applying method 100 in Figure 1 on the four basic marked prototiles 7801, 7802, 7803 and 7804. Figure 78 further shows four composite tiles 7809, 7810, 7811 and 7812 that are derived by deflating the four respective prototiles 7805, 7806, 7807 and 7808. Figure 78 shows four more composite tiles 7813, 7814, 7815 and 7816 derived by deflating the four respective composite tiles 7809, 7810, 7811 and 7812. Figure 78 also shows four composite tiles 7817, 7818, 7819 and 7820 derived by deflating the four respective composite tiles 7813, 7814, 7815 and 7816.

Asymmetrical qualities in designs can be achieved in several ways. Firstly by using symmetrical (e.g. straight as opposed to curved) edges where the arrow (relates to arrow of a directional path of a marked prototile) does not meet at a corner. Secondly, it could be achieved by choosing a prototile that

has asymmetric curves like in Figure 78. Thirdly, one can choose a tile that is with boundary points that are asymmetrically located along the sides, and "forces" the basic marked prototiles to join in a way that supports asymmetrical designs.

5

Figure 79 shows an example of a square "mid side" design, based on the square tile set shown in Figure 72. Sides where the marked prototiles in Figure 72 have a path intersecting them can be replaced with an asymmetric curve. Sides where there is no path can be replaced with a symmetric curve.

10 The sides of the square tiles in the design are provided with different asymmetrical edges 7901 and 7903, while the sides without path intersections are replaced with different symmetric curves 7902 and 7904. Four different edge markings 7905, 7906, 7907 and 7908 derived for the respective marked prototiles (shown in Figure 72) of the present example are
15 assigned with the respective different asymmetrical edges 7901, 7902, 7903 and 7904. Three prototiles 7909, 7910 and 7911 are derived using method 300 in Figure 3 from the respective marked prototiles (Not shown). Three composite tiles 7912, 7913 and 7914 are derived by applying method 100 in Figure 1 on the three basic prototiles 7909, 7910 and 7911. Figure 79 further
20 shows three composite tiles 7915, 7916 and 7917 that are derived by deflating the four respective prototiles 7912, 7913 and 7914. Each tile is designed to look like a lizard. The present lizard tessellation shows how the "mid side" design can have sides of individual tiles replaced with curves, asymmetrical design and symmetrical design depending on tile edge
25 marking.

Figure 80 shows a tiling design based on the prototiles in Figure 79.

Figure 81 shows how the tiles can be applied to a 3-dimensional surface
30 such as an architectural screen, breeze block wall, sunshade, room divider or the like. In this case, rather than the marked prototile 8101 and the reversed marked prototile 8102 being 2 separate and distinct tiles as they are in Figures 4-17, they can be combined into a single 3-dimensional tile, with the marked prototile as shown on the front surface of the tile 8103, and the
35 reversed marked prototile 8104 as shown on the back surface of the same tile. Following the same method 300 as described with reference to Figure 3,

this three dimensional tile can be assigned edge conditions on the front surface 8105 and back surface 8106. It will be appreciated that each surface of the tile could have different edge conditions on the front surface and the back surface, in the case illustrated, on one side of the tile, B on the back surface 8108 and A on the front surface 8107. This is further shown in Figure 82, where a screen design is shown, based on the prototiles shown in Figure 81. Here the A sides is a smooth edge, with holes in the corners, while the B side has two raised profiles. It can be seen in the three dimensional views of the front surface 8201 and the back surface of the same tile 8202 that each edge of the tile has both a smooth A edge and a profiled B edge. The actual orientation of the tile in use depends on the edge conditions assigned. 8203 shows the tile arranged to create a screen, illustrating how the tiles can be arranged by turning the tile over to use both the front and back surfaces of the tiles, in a similar arrangement to the set produced in Figures 4-17. In this case, the three desirable qualities possessed by the tile sets can be produced by a single component.

It will be appreciated that any set produced by this method, can be converted into a three dimensional tiling in this way. The number of tiles could be reduced by half, as the reversed marked prototiles will be paired with the marked prototiles.

Generally, the following may apply to embodiments of the method and tile set described herein.

25

Some information regarding composite tile arrangement is as follows.

- 1) The composite tile should be geometrically the same basic shape as the prototile.
- 2) The composite tile is able to tile the plane in the same way that the prototile can, although the composite tile may force a particular tile orientation due to the edge profile created by the composite arrangement.
- 3) The composite tile, when scaled to have the same area as the prototile, will have vertices coinciding (intersecting and coinciding are used exchangeably) with the prototile vertices.

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Some information regarding boundary point selection is as follows

- 1) The boundary points are used as starting points and ending points of the paths described herein which will, through the deflation process, cause the fractal arrangement of the tiles.
5
- 2) As such, they may be located at coinciding (intersecting and coinciding are used exchangeably) geometric points of the composite tile and the prototile when the composite tile is laid over the prototile.
10
- 3) The vertices of the prototile are useable as boundary points.
- 4) The points where the edges of the composite tile cross the edges of the prototile are useable as boundary points.
15
- 5) Points where the vertices of the composite tile are located on the edge of the prototile are useable as boundary points.
- 6) Edge midpoints may also be used as boundary points where the midpoint of a tile within the composite tile coincides (intersects and coincides are used exchangeably here) with the midpoint of the prototile.
20

Some simplified notes regarding arrangement criteria for the marked composite tile are as follows.

- 1) Start boundary point and end boundary point are the same as for the marked composite tile as for the corresponding marked prototile when overlaid.
25
- 2) There is a single connected curve between the start boundary point and end boundary point.
30
- 3) The directional arrows are all flowing in the same direction, from the start boundary point to the end boundary point.
- 4) The tones of the composite tile to the left and right of the path match the tones of the marked prototile.
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5) The path (which may be curve shaped) does not touch any of the other boundary points other than the start and end point.

6) A grey edge (one kind of marking) always touches a grey edge, and a white edge (another kind of marking) always touches a white edge on adjoining tiles.

The methods 100 in Figure 1, 200 in Figure 2 and 300 in Figure 3 may be accomplished with the aid of a computer. The computer 8300 can be schematically shown in Figure 83. There may be provided computer software, such as one or more computer programs being executed within the computer 8300, and instructing the computer 8300 to carry out the steps of the methods 100 in Figure 1, 200 in Figure 2 and 300 in Figure 3.

The computer 8300 comprises a processing unit 8302 for processing the one or more computer programs, and includes input modules such as a computer mouse 8336, keyboard/keypad 8304, and/or a plurality of output devices such as a display 8308.

The processing unit 8302 may be connected to a computer network 8312 via a suitable transceiver device 8314 (i.e. a network interface), to enable access to e.g. the Internet or other network systems such as a wired Local Area Network (LAN) or Wide Area Network (WAN). The processing unit 8302 may also be connected to one or more external wireless communication enabled devices 8334 via a suitable wireless transceiver device 8332 e.g. a WiFi transceiver, Bluetooth module, Mobile telecommunication transceiver suitable for Global System for Mobile Communication (GSM), 3G, 3.5G, 4G telecommunication systems, or the like.

The processing unit 8302 in the example includes a processor 8318, a Random Access Memory (RAM) 8320 and a Read Only Memory (ROM) 8322. The processing unit 8302 also includes a number of Input/Output (I/O) interfaces, for example I/O interface 8338 to the computer mouse 8336, I/O interface 8324 to the display 8308, and I/O interface 8326 to the keyboard 8304.

The components of the processing unit 8302 typically communicate via an interconnected bus 8328 and in a manner known to the person skilled in the relevant art.

- 5 The computer programs may further include one or more software applications for e.g. instant messaging platform, audio/video playback, internet accessibility, operating the computer 8300 (i.e. operating system), network security, file accessibility, database management, which are applications typically equipped on a desktop or portable computer.
- 10 The computer programs may be supplied to the user of the computer system 8300 encoded on a data storage medium such as a CD-ROM, on a flash memory carrier or a Hard Disk Drive, and are to be read using a corresponding data storage medium drive of a data storage device 8330. Such application programs may also be downloaded from the computer
- 15 network 8312. The application programs are read and controlled in its execution by the processor 8318. Intermediate storage of program data may be accomplished using RAM 8320.

- Furthermore, one or more of the steps of the computer programs may be
- 20 performed in parallel rather than sequentially. One or more of the computer programs may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a general purpose computer. The computer readable medium may also include
- 25 a hard-wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in the Wireless LAN (WLAN) system. The computer program when loaded and executed on such a general-purpose computer effectively results in an apparatus that implements the steps of the computing methods in examples herein described.

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- Many modifications and other examples can be made to a fractal tile set and a method for generating a tile set by those skilled in the art having the understanding of the above described disclosure together with the drawings. Therefore, it is to be understood that a fractal tile set and a method for
- 35 generating a tile set is not to be limited to the above description contained herein only, and that possible modifications are to be included in the claims of the disclosure.

CLAIMS

1. A method for generating a tile set, the method comprising the steps of:
 - (a) determining a prototile for placing adjacent to one or more other prototiles
5 with no gap and no overlap between them to form a composite tile;
 - (b) arranging the prototiles to form the composite tile;
 - (c) scaling the composite tile to a size matching area of the determined prototile;
 - (d) overlaying the scaled composite tile over the determined prototile for
10 determining more than one composite tile boundary points,
the composite tile boundary points including a composite tile starting point and a composite tile ending point,
the composite tile starting point and the composite tile ending point being different points,
15 each composite tile boundary point being a point residing at a location on the perimeter of one of the prototiles arranged to form the scaled composite tile;
 - (e) selecting prototile boundary points on each prototile,
the prototile boundary points including a prototile starting point and
20 a prototile ending point,
the prototile starting point and the prototile ending point being different points,
each prototile boundary point being a point residing at a location on the perimeter of each prototile;
 - 25 (f) creating a first path linking the prototile starting point and the prototile ending point, the first path having a flow direction from the prototile starting point to the prototile ending point;
 - (g) marking areas of each prototile separated by the first path with different markings;
 - 30 (h) arranging one or more of the marked prototile to form a marked composite tile having same shape, prototile arrangement and boundary points as the composite tile;
 - (i) checking that arrangement criteria are met in each arrangement at step (h), the arrangement criteria comprising:
35 the composite tile starting point of the marked composite tile being matched with the prototile starting point of one of the prototiles and the

composite tile ending point of the scaled composite tile being matched with the prototile ending point of one of the prototiles;

a second path being formed to run from the composite tile starting point of the marked composite tile to the composite tile ending point of the marked composite tile, the second path being formed by joining the first paths of the one or more marked prototile, and the flow directions of the first paths joined to form the second path are directing the second path to terminate at the composite tile ending point;

areas of the marked composite tile separated by the second path being marked with same markings as the respective marked areas separated by the first path of the one or more marked prototile,

each of the first paths forming the second path are not in contact with boundary points other than the prototile starting point and prototile ending point of the respective prototile; and

areas with the same markings on the one or more marked prototile that are arranged to form the marked composite tile being arranged to contact one another; and

(j) storing a marked composite tile fulfilling the arrangement criteria into a database as the generated tile set.

2. The method as claimed in claim 1, wherein intersections between the scaled composite tile and the determined prototile in step (d) are selectable as composite tile boundary points.

3. The method as claimed in claims 1 or 2, wherein the method further comprising creating a reverse marked prototile by reversing the markings on the marked areas separated by the first path and reversing direction of the flow direction of the first path.

4. The method as claimed in claims 1, 2 or 3, the method further comprising:

(k) scaling a marked composite tile to match area of each prototile used for creating said marked composite tile; and

(l) replacing each of the prototile in the marked composite tile of step (k) with a copy of the scaled composite tile of step (k),

wherein the composite tile starting point and the composite tile ending point of the scaled composite tile of step (k) are matched with the composite

tile starting point and the composite tile ending point of each prototile respectively.

5 5. The method as claimed in claim 3, the method further comprising:

checking whether the marked prototile has reverse marking symmetry;
and
if the marked prototile has reverse marking symmetry, obtaining a copy of the marked prototile for using as the reverse marked prototile.

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6. The method as claimed in any one of the preceding claims, the method further comprising:

repeating step (e) to re-select new boundary points to resolve non-compliance of the arrangement criteria.

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7. The method as claimed in any one of the preceding claims, wherein step (e) further comprising adding an additional prototile starting point and an additional prototile ending point in the prototile and step (f) further comprising creating an additional path in the prototile from the additional prototile starting point and additional prototile ending point.

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8. The method as claimed in any one of the preceding claims, wherein each side of each prototile in the generated tile set is given a label to indicate which sides of each prototile are to be placed adjacent to each other.

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9. The method as claimed in claim 8, wherein sides of the prototile marked at step (g) with same markings are provided with the same label.

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10. The method as claimed in any one of the preceding claims, wherein sides of the prototile marked at step (g) with same markings are provided with a same design.

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11. The method as claimed in any one of the preceding claims, wherein the method comprising:

providing a design on each side of each prototile in the generated tile set,

wherein the design intersects or is a continuation of a design located on a side of another prototile in the generated tile set that is to be placed adjacent to the side of the prototile in the generated tile set.

5 12. The method as claimed in any one of the preceding claims, wherein a side of a prototile in the generated tile set has a symmetrical edge and the side of the prototile is made to match a corresponding symmetrical edge of another side of another prototile in the generated tile set.

10 13. The method as claimed in any one of the preceding claims, wherein a side of a prototile in the generated tile set has an asymmetrical edge and the side of the prototile is made to match a corresponding asymmetrical edge of another side of another prototile in the generated tile set.

15 14. The method as claimed in any one of the preceding claims, wherein that the first path created at step (f) links between 2 sides of the prototile.

20 15. The method as claimed in any one of the preceding claims, wherein the method comprising providing different designs on a front surface and a back surface of each prototile in the generated tile set.

 16. A fractal tile set comprising:
25 a predetermined prototile placed adjacent to one or more other prototiles with no gap and no overlap between them to form a composite tile,
 each prototile comprising a first path linking a prototile starting point and a prototile ending point, the first path having a flow direction from the prototile starting point to the prototile ending point,
30 areas in each prototile separated by the first path being marked with different markings, the composite tile formed by the marked prototiles being a marked composite tile,
 the prototile starting point and a prototile ending point being selected from prototile boundary points on each prototile, the prototile starting point and the
35 prototile ending point being different points, each prototile boundary point being a point residing at a location on the perimeter of each prototile;

the composite tile having a composite tile starting point and a composite tile ending point being selected from more than one composite tile boundary points,
the more than one composite tile boundary points being derived by
scaling the composite tile to a size matching area of the
predetermined prototile and
overlying the scaled composite tile over the predetermined prototile,
the composite tile starting point and the composite tile ending point being different points, each composite tile boundary point being a point residing at a location on the perimeter of one of the prototiles arranged to form the scaled composite tile;
wherein the composite tile starting point of the marked composite tile is matched with the prototile starting point of one of the prototiles and the composite tile ending point of the scaled composite tile is matched with the prototile ending point of one of the prototiles;
a second path is formed to run from the composite tile starting point of the marked composite tile to the composite tile ending point of the marked composite tile, the second path is formed by joining the first paths of the one or more marked prototile, and the flow directions of the first paths joined to form the second path are directing the second path to terminate at the composite tile ending point;
areas of the marked composite tile separated by the second path are marked with same markings as the respective marked areas separated by the first path of the one or more marked prototile,
each of the first paths forming the second path are not in contact with boundary points other than the prototile starting point and prototile ending point of the respective prototile; and
areas with the same markings on the one or more marked prototile that are arranged to form the marked composite tile are arranged to contact one another.

17. The fractal tile set as claimed in claim 16, wherein intersections between the scaled composite tile and the predetermined prototile are selectable as composite tile boundary points.

18. The fractal tile set as claimed in claims 16 or 17, wherein the prototiles in the fractal tile set comprise a reverse marked prototile created by reversing the markings on the marked areas separated by the first path and reversing direction of the flow direction of the first path.

19. The fractal tile set as claimed in claims 16, 17 or 18, the fractal tile further comprising:

prototiles obtained by

(k) scaling a marked composite tile to match area of each prototile
5 used for creating said marked composite tile; and

(l) replacing each of the prototile in the marked composite tile of step (k) with a copy of the scaled composite tile of step (k),

wherein the composite tile starting point and the composite tile ending point of the scaled composite tile of step (k) are matched with the composite
10 tile starting point and the composite tile ending point of each prototile respectively.

20. The fractal tile set as claimed in claim 19, the fractal tile set further comprising a marked prototile with reverse marking symmetry.

21. The fractal tile set as claimed in any one of claims 16 to 20, the fractal tile set further comprising a marked prototile with an additional path in linking an additional prototile starting point and an additional prototile ending point.

22. The fractal tile set as claimed in any one of claims 16 to 21, wherein each side of each prototile in the fractal tile set is given a label to indicate which sides of each prototile are to be placed adjacent to each other.

23. The fractal tile set as claimed in claim 22, wherein sides of the prototile marked with same markings are provided with the same label.

24. The fractal tile set as claimed in any one of claims 16 to 23, wherein sides of the prototile marked with same markings are provided with a same design.

25. The fractal tile set as claimed in any one of claims 16 to 24, wherein the fractal tile set comprising:

a design on each side of each prototile in the fractal tile set,

wherein the design intersects or is a continuation of a design located on a side of another prototile in the fractal tile set that is to be placed adjacent to the side of the prototile in the fractal tile set.

5 26. The fractal tile set as claimed in any one of claims 16 to 25, wherein a side of a prototile in the fractal tile set has a symmetrical edge and the side of the prototile is made to match a corresponding symmetrical edge of another side of another prototile in the fractal tile set.

10 27. The fractal tile set as claimed in any one of claims 16 to 26, wherein a side of a prototile in the fractal tile set has an asymmetrical edge and the side of the prototile is made to match a corresponding asymmetrical edge of another side of another prototile in the fractal tile set.

15 28. The fractal tile set as claimed in any one of claims 16 to 27, wherein the first path links between 2 sides of each prototile.

 29. The fractal tile set as claimed in any one of claims 16 to 28, wherein the fractal tile set comprising different designs on a front surface and
20 a back surface of each prototile of the fractal tile set.