A BOARD GAME FOR *KOLAM* DESIGNS

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A b s t r a c t

'Fibonacci *Kolams'* is a family of *Kolam* designs based on Fibonacci Recurrence. Every Fibonacci *Kolam* (FK) is an assembly of unit square 'tiles' on a grid of unit square 'cells'. It is found - based on a large number of FK's - that the tiles come in only 8 different shapes called A B C D E F G H; each shape can be rotated by 90º, 180º, 270º. This feature renders possible the design of a Board game for *kolams*. For assembling an FK on the board one needs a book of *kolams* (resource material), a board with a grid of unit squares and a 'tile bank' containing multiple copies of the 8 tiles. As a 'solitaire' game, a given *kolam* can be built on the board with tiles from the bank. The assembly can be adapted as a two-person game in which two players alternately place tiles according to certain rules. To make the game competitive, values are assigned to the tiles and the cells on the board. As an illustration, the building of a 5 x 6 *kolam* by two players is simulated with scores for each player to decide the winner. The rules of the game are fashioned on the lines of the popular word-building game 'Scrabble'. The essential features of the Board game are spelled out and a prototype has been produced with a 14 x 14 board and 300 tiles. The Board game can be adapted for play on a computer.

A BOARD GAME FOR *KOLAM* DESIGNS

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Art is the imposing of pattern on experience and our aesthetic enjoyment in recognition of the pattern ..... A.N. Whitehead.

Introduction.

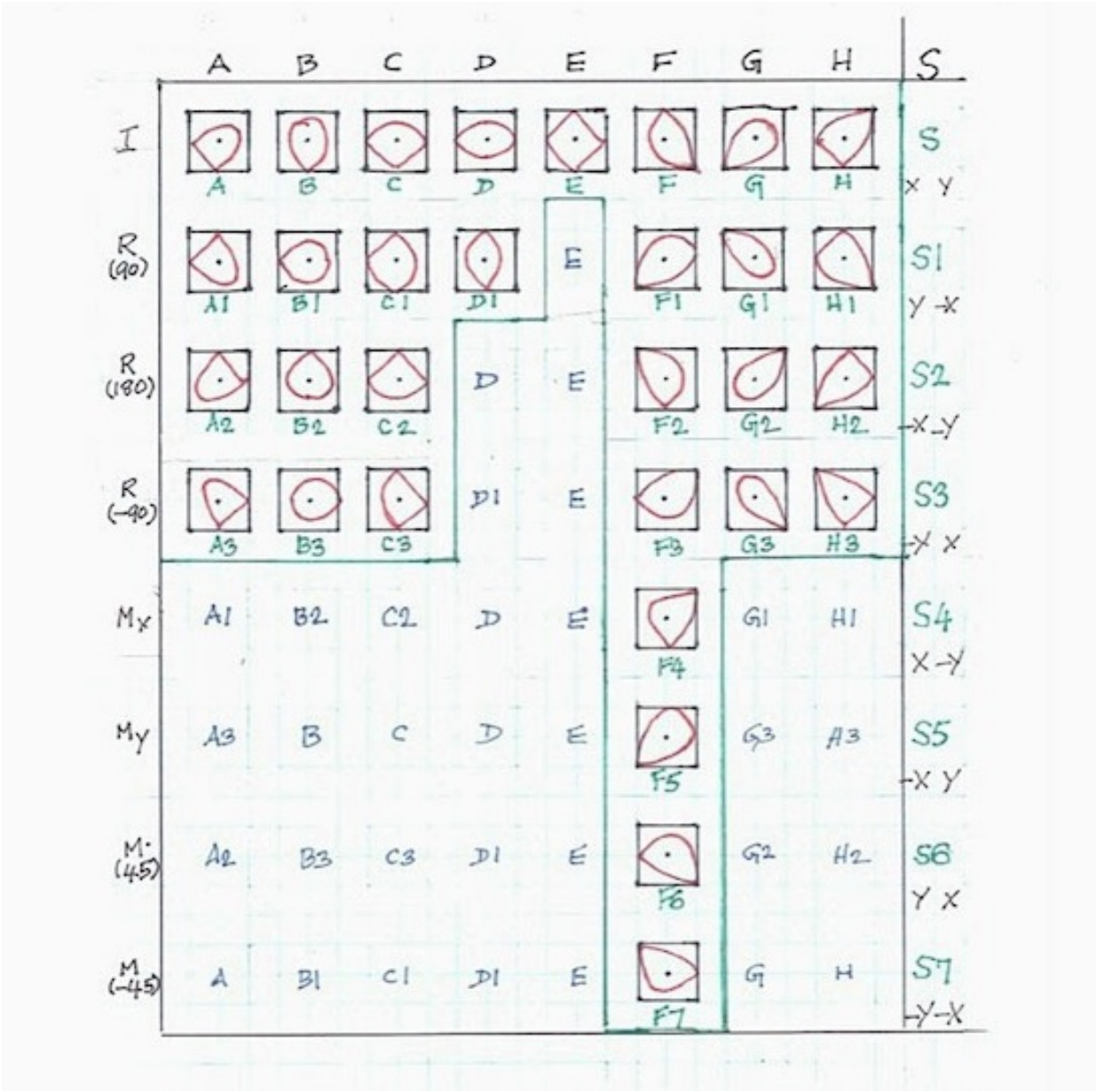
All Fibonacci *Kolams* have unit cells, each with one dot at the centre and a shape. There are 8 basic shapes A B C D E F G H which we call 'tiles' (Figure 1 top row). Each square tile can be rotated by 90^o, 180^o and 270^o or reflected about X-axis, Y-axis and two diagonals. Not all operations yield distinct shapes; there are only 31 distinct shapes or variants as shown in Figure 1. Some *kolam* designs are shown in Figure 2 along with their codes. For example in the 3 x 4 *kolam* the first tile in the top row is G3 (G rotated 270^o). The 8 basic shapes have been drawn using MS EXCEL. Each of the 31 variants is assigned a 'macro code' as indicated in Figure 3. For example the code for A is 'CA' or CTRL A. For A1 the code is 'CSA' or CTRL+SHIFT A. Any Fibonacci *Kolam* can be 'typed' using the macros. For details on Fibonacci *Kolams* see www.vindhiya.com/snaranan/fk/index.htm [1]

On a board with a grid consisting of square unit cells, a *kolam* can be assembled using the 8 basic tiles. The building of a *kolam* design on the board can be adapted as a competitive game played by two persons. By assigning values for the cells on the board and for the tiles, each player gets a score. On completion of the game, the one who has the larger score wins.

The Board Game.

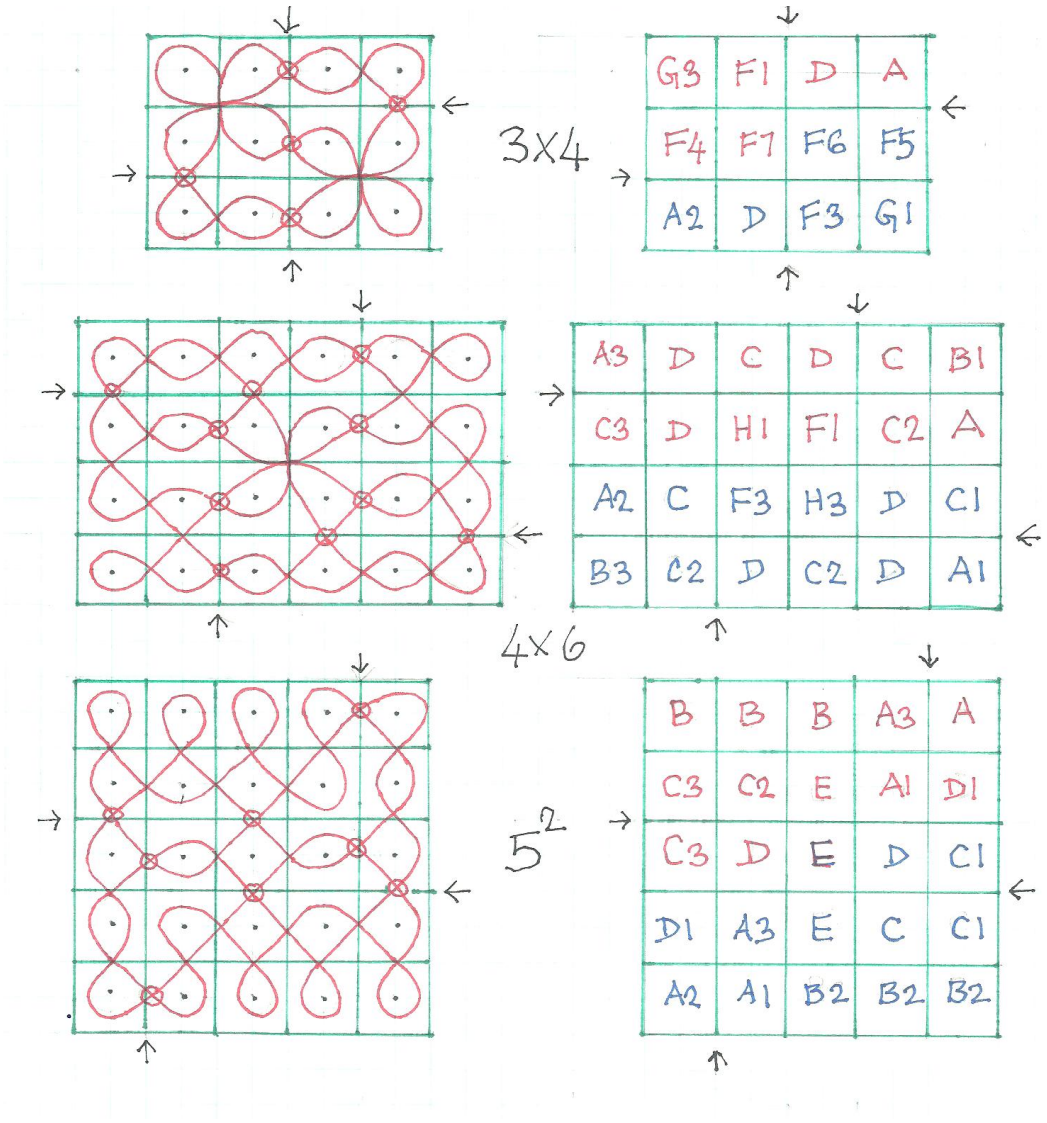
The three main ingredients are (1) a **book** of *kolam* designs, (2) a **collection** of multiple copies of tiles and (3) a **board** with a grid of unit cells. They are described below.

Figure 1



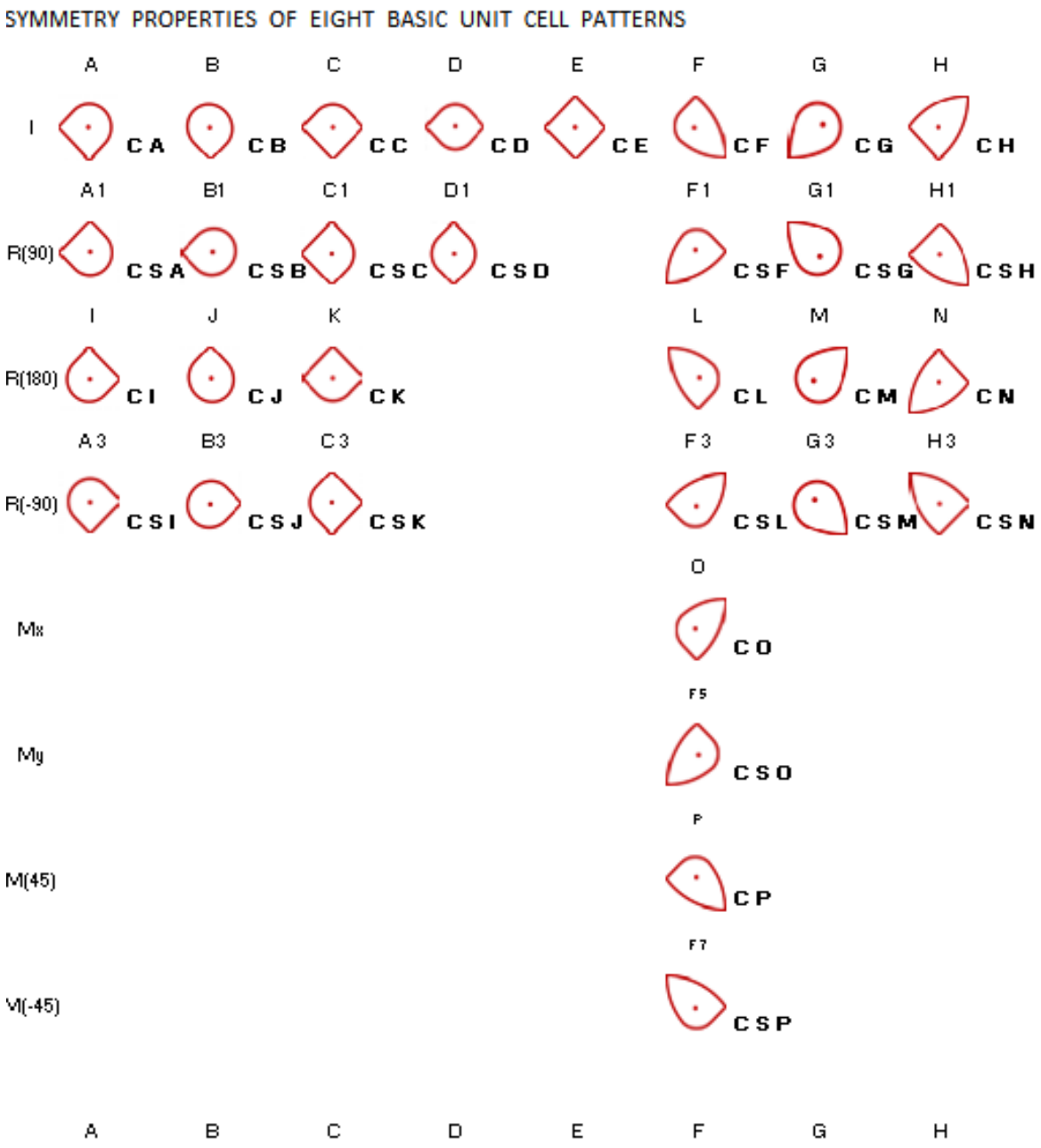
Eight Basic Tile Shapes and their Symmetry Properties

Figure 2



Some Kolams and their Codes

Figure-3



Variants (31) of tiles and their Macro-codes

The **book** consists of *kolam*s of varying sizes typed using the 31 macros: ranging from the small 2 x 3 rectangle to the large 14 x 14 square. The *kolam* shapes are squares, rectangles and other non-standard shapes. For each *kolam* the types of tiles used and their frequency of occurrence in the *kolam* are specified. This is necessary since not all tile types are used in a *kolam*. The two players jointly choose a *kolam* for assembling on the board taking turns.

The **collection of tiles**, the 'tile bank' contains multiple copies of the 8 basic tiles A to H. In placing a tile on the board, it can be rotated;. for example A1, A2, A3 are obtained by rotating A by 90^o, 180^o and 270^o. Similar operations apply for the other tile types too (Figure 1). It is found necessary and convenient to assign a separate tile for F4, which is the mirror reflection of F about the X-axis. Rotation of F4 by 90^o, 180^o and 270^o gives respectively F6, F5 and F7. A tenth type of tile is the BLANK; it can substitute for any of the other nine types but has no value. The tiles are assigned values as given below.

Tile:	A	B	C	D	E	F	G	H	F4	BLANK
Value:	2	2	1	1	3	3	4	4	4	0

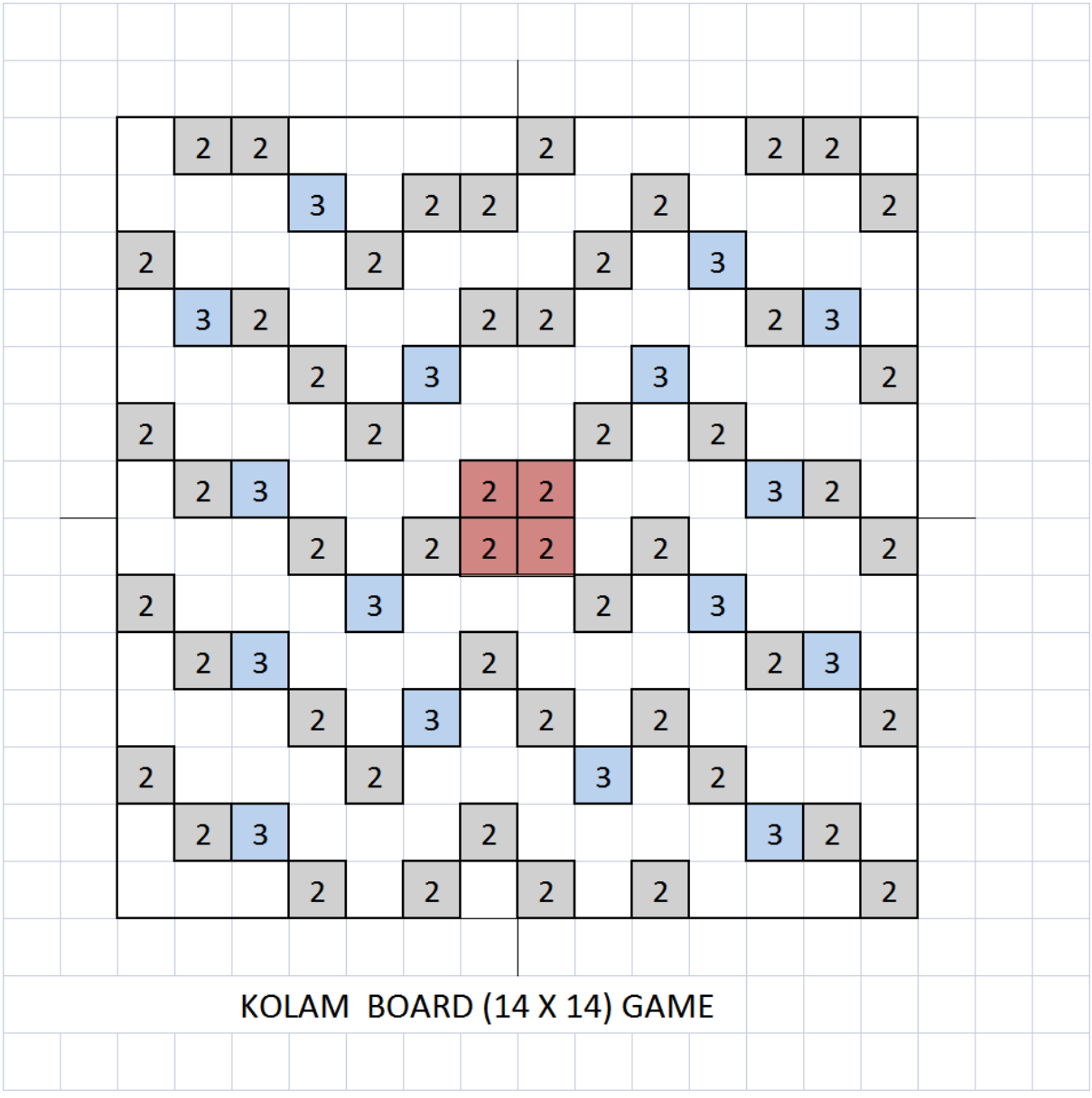
The number of copies of different tile types is as follows:

Tile:	A	B	C	D	E	F	G	H	F4	BLANK
# copies:	40	30	90	50	20	16	16	16	16	6

The total number of tiles is 300. These numbers are based on the frequencies of different tile types across a wide range of *kolam*s. Tiles occurring more frequently have lower values; for example C and D have value 1 whereas less frequent ones like G H F4 have value 4. The tiles are not labelled, but have their values inscribed in the top left corner (North-West). Only the shape and the dot at the centre are shown as in Figure 3. The reverse side of a tile is blank.

The **board** has a square grid of size 14 x 14 unit cells. Some cells have premium values 2 or 3 and they are distributed quasi-randomly across the board. There are 52 tiles (grey) with value 2 and 16 tiles (blue) with value 3; the rest (white) are single-valued (Figure 4). Four cells in the centre are shown in red to

Figure 4



indicate that the game starts with the first tile placed on one of them. But their value is 2 like the grey cells. The premium tiles (68) account for 35 % of the total (196). When a tile is placed on a cell, its value is multiplied by the value of the cell. For example if tile F is placed on a 3-value cell (blue) its value is increased from 3 to 9; tile A placed on a single-valued cell has the value 2.

The Play

All tiles are face-down. The first player is determined by tossing a coin. Each player draws 6 tiles from the bank and places them on his rack. The building of the *kolam* on the grid starts from one of the 4 central cells shown in red. In over-laying the *kolam* on the grid, the 4 central tiles of the *kolam* correspond to the 4 central red cells of the grid [2]. If the first player has a tile that matches any one of them, he places it on the cell choosing the right orientation. He can place more tiles contiguous to the first if he has the suitable tiles. He calculates and records his score taking into account the values of the tiles and the cells they occupy. Before the turn passes to the second player, he draws tiles from the bank equal to the number he has discarded to keep the number of tiles as 6. (Since not all types of tiles are used in a *kolam*, the player has to discard unusable tiles as they are drawn from the bank).

The second player places tiles from his rack so that they are contiguous to the tiles on the board. He records his score and picks up tiles from the bank to restore his number of tiles to 6 before the turn passes to the first player for the second round. In any turn if a player has no suitable tiles to play, he can 'pass' to the other player. He has also the option to discard one or more tiles face down and pick up an equal number from the bank. But he loses his turn to play. The play ends when the last tile is placed to complete the *kolam*. The last player gets bonus points equal to 15 % of the total score of both the players. In any round if a player plays all his 6 tiles, he gets bonus points equal to 15 % of the total score.

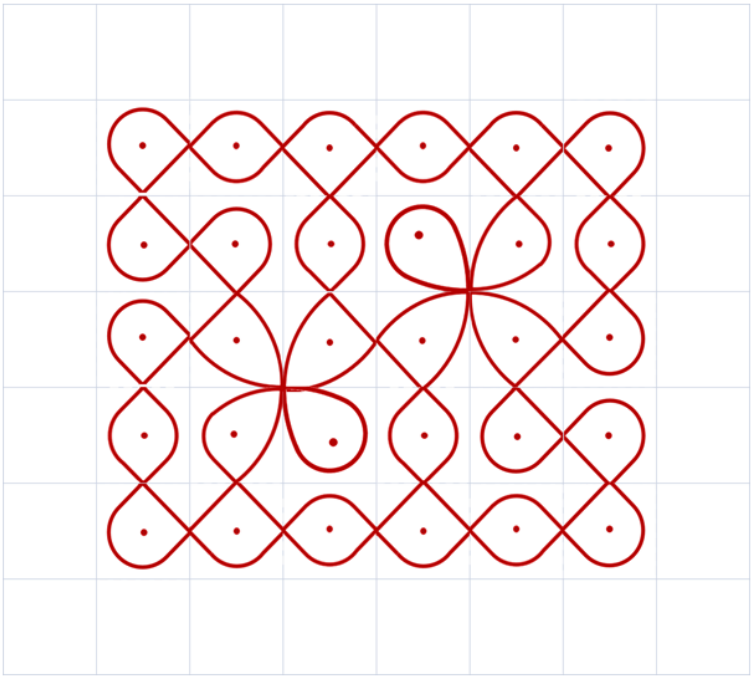
The final score of a player is reduced by the sum of the values of unplayed tiles. In addition, if the last player has used all his tiles, his score is increased by the sum of the values of the unplayed tiles of the other player. The winner is the one with the higher score.

A Simulation.

To illustrate the game, I have simulated the assembly of a 5 x 6 rectangular *kolam*. In Figure 5 at the top is the *kolam* and below on the left are the unit cells of the *kolam* labelled with the tile type [3]. It is over-laid by the grid of the board such that the 2 x 2 central red region overlaps the centre of the *kolam*. Notice the premium value cells in grey (value 2) and blue (value 3). The central red cells too have value 2. On the right side are shown the scores of the individual unit cells (product of tile value and cell value). The total score for the *kolam* is the sum of all the cell scores - in this case 98. Now to find the winner of the two players X and Y, I assign arbitrarily at random some cells (14) to X (red); the others (16) are assigned to Y (black). The scores are 40 for X and 58 for Y. Assuming that X played the last tile of the *kolam*, he gets a bonus of 15 % of the total score - in this case 15 - taking his score to 55. To account for the penalty of unplayed tiles, I assign (again arbitrarily) value 8 to both X and Y. Subtracting these scores, the final score is 47 for X and 50 for Y. So, Y is the winner.

Here are a few caveats to the above illustration. There is some arbitrariness in the overlapping of the *kolam* and the grid. Here the four central cells (red) overlap on the tiles H2 H G1 D1 of the *kolam*. There is another way of making the overlap by shifting the grid up by one row, with the four central cells on the tiles D1 G3 H2 H [4]. Obviously the total score depends on the particular overlap chosen. All the cell assignments for the two imaginary players X and Y are arbitrary. Only the final assembled *kolam* is shown and one can imagine many evolutionary paths of the game towards its completion. For instance suppose X placed the first tile G1. Then the overlap of the entire

Figure 5



A3	D	C	D	C	A
A2	A	D1	G3	F5	D1
A3	H1	H2	H	H3	A1
D1	F4	G1	D1	A2	A
A2	C2	D	C2	D	A1

2	3	1	1	1	6
4	2	1	4	8	1
2	4	8	8	4	1
1	8	8	2	2	4
6	1	1	1	2	1

Value 3 Value 2

Value 1 Value 2

SCORE: X = 40 Y = 58 Total = 98

RED: PLAYER X BLACK: PLAYER Y

Codes and Scores for 5 x 6 Rectangular Kolam

kolam on the grid is decided. Next Y places tile D1 contiguous to G1. Note that the game evolves by placing of tiles contiguous to each other. It is presumed that the players are roughly equally matched and chance plays an important role in deciding the winner [5]. The reader may amuse himself by choosing alternative scenarios [6].

Discussion.

In this game the *kolam* is regarded as a jig-saw puzzle to be assembled on a board. The tiles are all squares unlike the twisted zigzag shapes of jig-saw puzzle. Each tile can be placed in one of four orientations which calls for some skill in pattern recognition. Players can quickly grasp the patterns because there are only 9 basic patterns. The trickiest tiles are F and F4 which have a subtle difference; they are mirror images along the X-axis. (For the other types of tiles mirror images are not distinct: for instance A4 the mirror image of A is the same as A1). On purpose the tiles are not labelled with the types, but the values in the NW corner can help infer some tile types. For example F and F4 have different values 3 and 4. Incidentally F4 can be obtained by flipping over F along the X-axis, but since only one side of a tile is to be used, different tiles are provided for F and F4.

Even if a player's tile matches a tile in the *kolam* on the board, he can place it only if it is contiguous to an already placed tile. The tile may be playable in subsequent rounds depending on the tiles placed by the other player. Depending on the skill level of the players, the players may opt to set a time limit for each turn. This will help in limiting the total time required to complete the game, which can be long especially for large *kolam*s. The game ends when the last *kolam* tile is placed.

The assignment of numerical values to tiles and cells and the rules of play are on lines similar to those in the popular word-building game SCRABBLE [7]. In SCRABBLE interlocking words are formed in 'cross-word fashion'.

There are 27 types of tiles (26 letters of the alphabet and one blank), each type with a value 1 to 10 (Q and Z have maximum value 10). Number of copies of a letter is 1 to 12 (maximum is 12 for letter E). The total number of tiles is 100. The board has a grid of 15 x 15 cells, some of which have premium values. The game is open-ended. It ends when all the 100 tiles are drawn from the bank [8].

Kolam board has 14 x 14 or 196 unit cells. The total number of tiles is 300 to accommodate the considerable variation in type usage in different *kolams*. With 20 mm tiles the largest *kolam* will be 28 cm square and the board size can be a moderate 30 cm square. Some *kolams*, small and big are given in the Appendix (Figs A1 to A8).

Acknowledgment. I thank T.V. Suresh for help in drawing the 8 basic *kolam* shapes and assigning macro codes in MS EXCEL. I thank my daughters Venil Sumantran and Gomathy Naranan for suggestions that have helped improve the presentation of this paper. Swarna Srinivasan has helped in adapting the game for the computer and also in producing the physical board and tiles for play. I am grateful to her.

Notes

[1] This website contains several articles related to *Kolams* based on Fibonacci Numbers. There are four papers, Parts I, II, III, IV (referred to as Papers I, II, III, IV in the sidebar). An 'Overview' Paper covers all the 4 papers. There are two sets of slides as PowerPoint files: *Kolam* Slides and Special *Kolams*.

[2] In certain *kolams* there is no unique set of 4 central squares. For an example see the 'simulation' of assembling a 5 x 6 *kolam* (Figure 5).

[3] All FK's are single-loop and have rotational symmetry: 4-fold in the case of squares and 2-fold for rectangles. Square *kolams* look the same viewed from N E S W directions and rectangles look the same from N and S or E and W. Square *kolams* can have the lower 2-fold symmetry, as the 5 x 5 in Figure A4.

[4] The overlapping of the *kolam* on the Board is unique only when both sides of the *kolam* are even numbers.

[5] Occasionally a player has a choice of two possible cells, both contiguous, to place a tile. He will choose the cell with a higher value. If both have the same value, the choice will depend on which option offers less advantage to the other player. This is an example of a choice not entirely determined by chance.

[6] For example in the simulated game, suppose X had, in one round, played all his 6 tiles. He gets a bonus of 15 % of the total score, 15 points. This added to his score of 47 becomes 62, exceeding Y's score of 50 reversing the outcome of the game.

[7] Manufactured by Selchow and Righter Co., New York, N.Y (1953) for The Production & Marketing Co.

[8] Like most games the Board game for *Kolams* too can be adapted for play on the computer. Simulation on a computer can help in tweaking the rules for optimum enjoyment of this competitive game. For example, the number of tiles drawn in each round can be 5 or 7 instead of 6. A *kolam* can also be assembled by a single player as a 'solitaire' game.

Figure Captions.

Figure 1. Eight Basic Tile Shapes and their Symmetry Properties.

Figure 2. Some Kolams and their Codes.

Figure 3. Variants (31) of the tiles and their Macro-codes.

Figure 4. *Kolam* Board (14 x 14) Game.

Figure 5. Codes and Scores for 5 x 6 Rectangular *Kolam.*

Figures A1 – A8. Appendix

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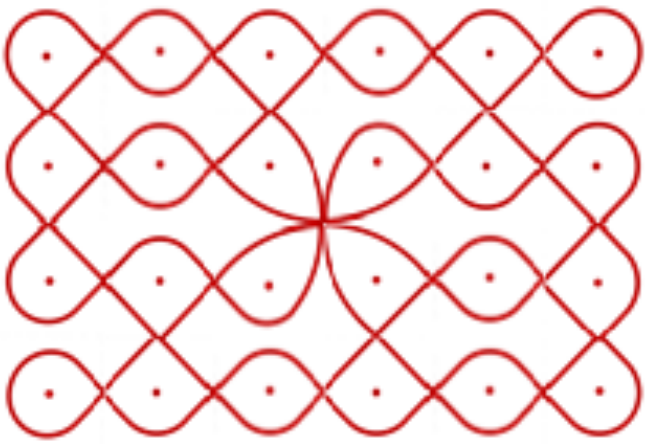
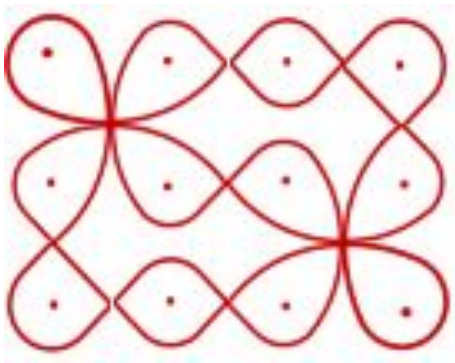
A P P E N D I X

Figures A1, A2

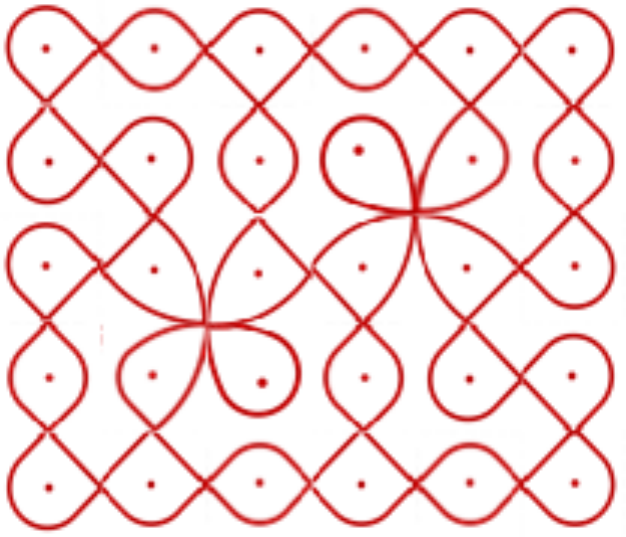


4 x 6

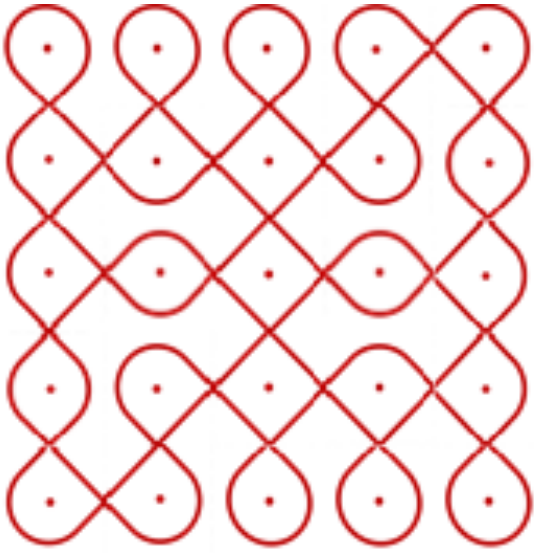


3 x 4

Figures A3, A4

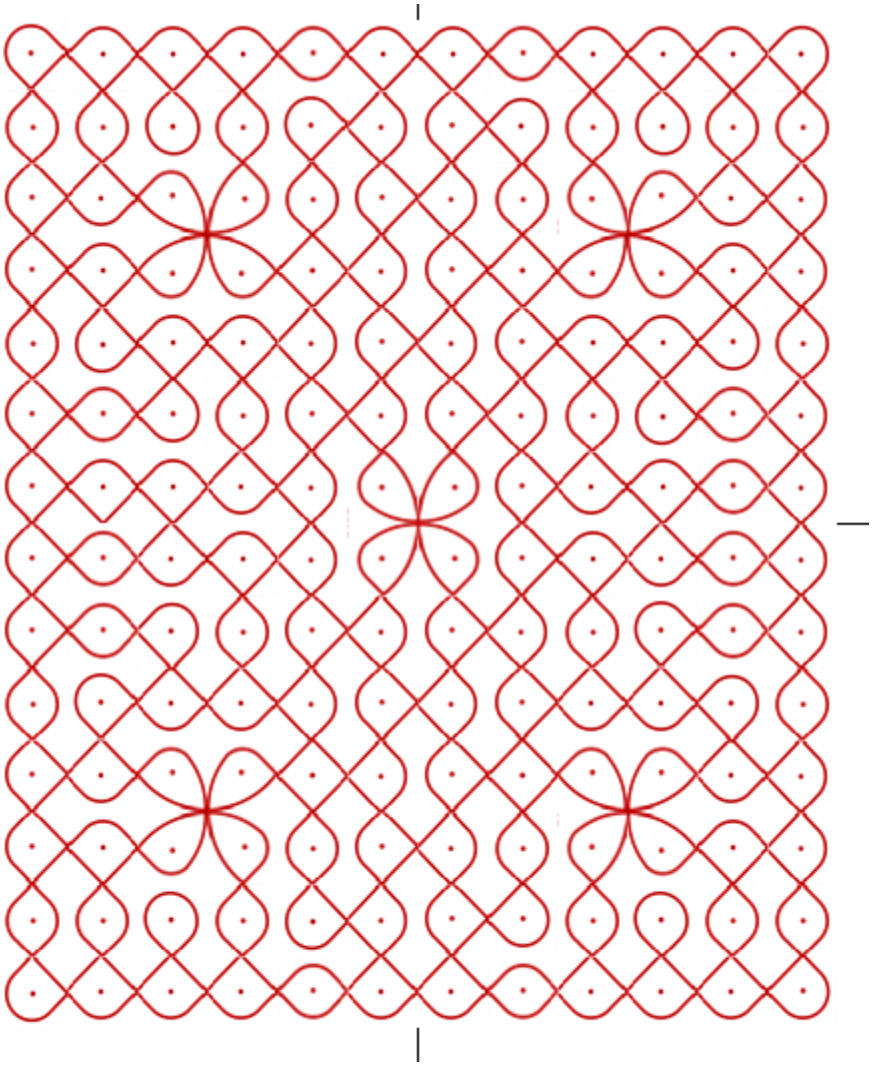


5 x 6



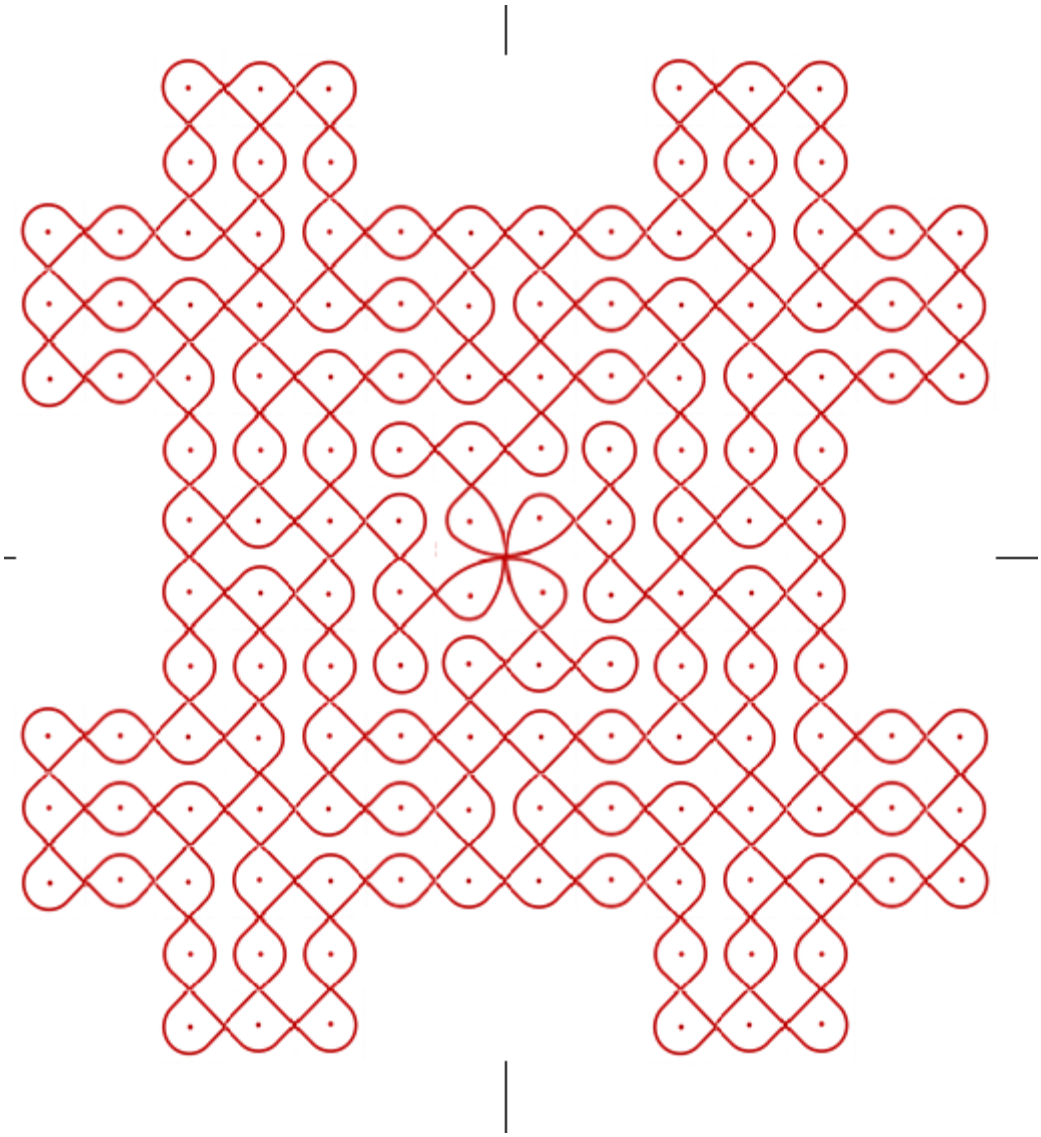
5 x 5

Figure A5



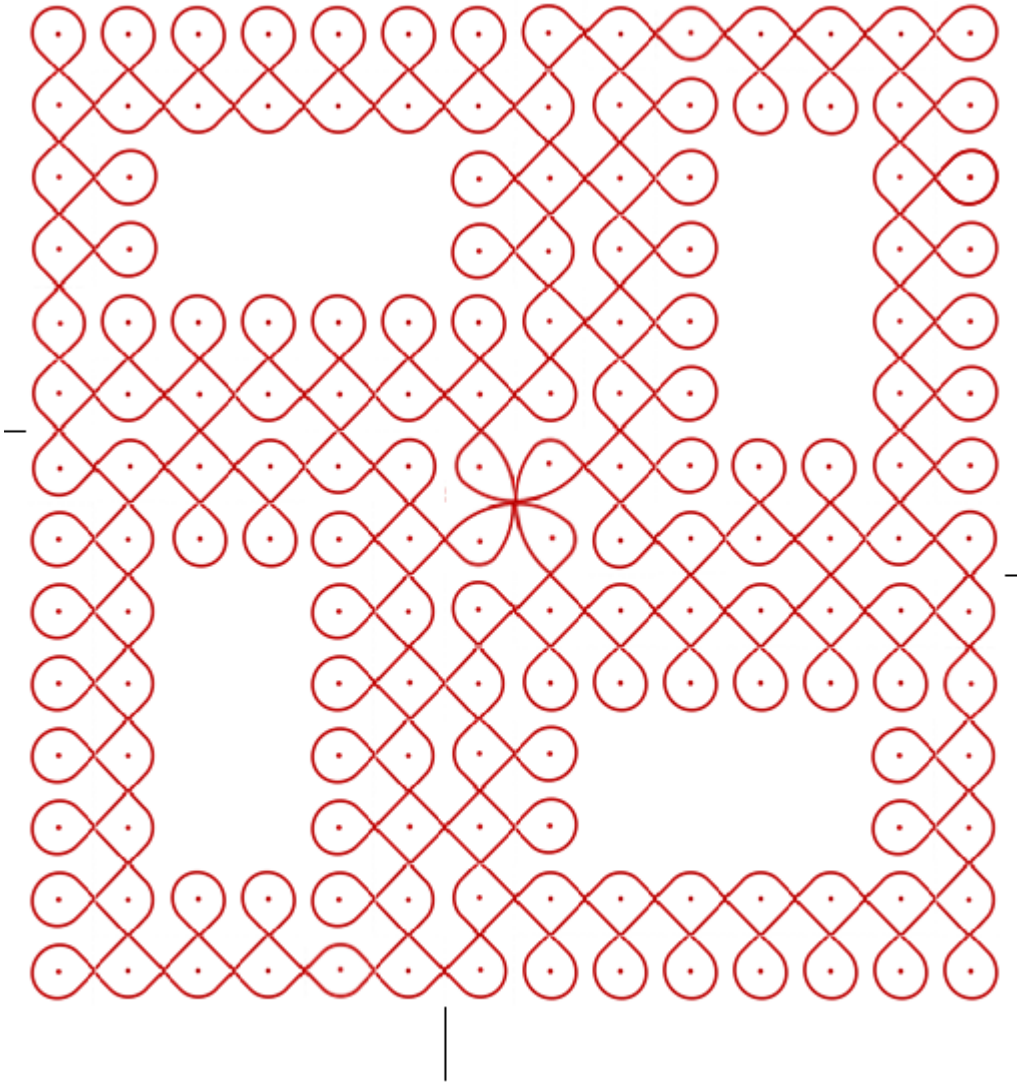
Symmetric Rectangular Kolam (Non-standard) 14 x 12

Figure A6



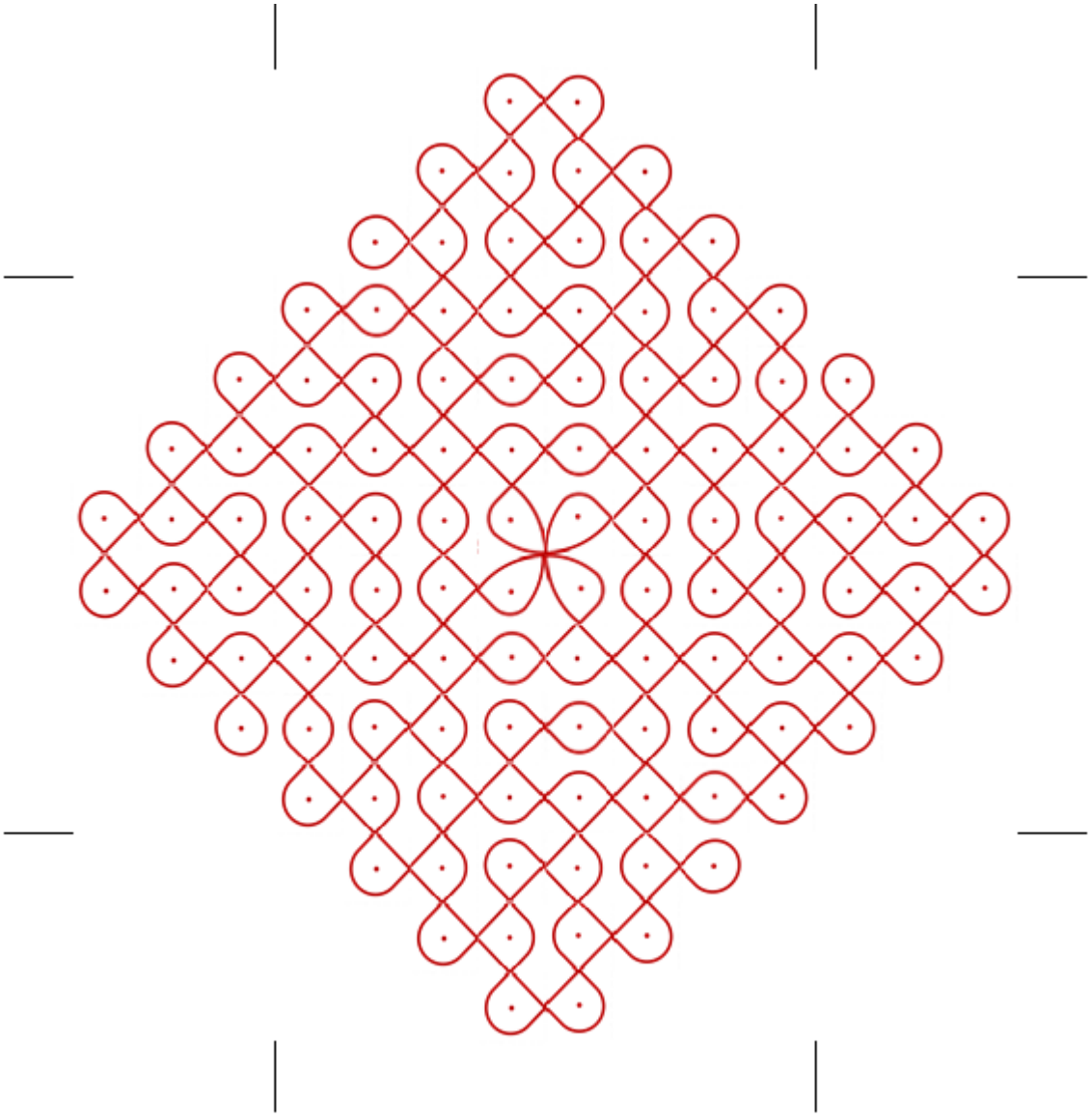
Square Kolam (Non-standard) 14 x 14

Figure A7



Square Kolam 14 x 14 (Non-standard)

Figure A8



Diamond Kolam (2 14 2)