

Figured Magic Squares of Order 30 Using Bordered Magic Rectangles: A Systematic Procedure

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Abstract

*Recently, author constructed even order magic squares from orders 6 to 20 with different styles and models, for examples the order 20 is with 1616 magic squares, order 18 with 810 magic squares, etc. These can be seen at [31, 32, 33, 33, 34, 35, 36, 37]. The aim is to proceed for the further orders of magic squares. In this work there are few examples of magic squares given as figures of order 30. A systematic procedure to construct these magic squares is given. It is based on the magic squares of orders 4, 6, 8 etc. at corners and small blocks of **bordered magic rectangles** forming external borders. Then the internal borders are filled with previous known magic squares. The presentations is in figures instead of numbers. The readers can find replies in numbers from references given above. For the orders multiples of 4, we can always write magic squares with equal sums blocks of magic squares of order 4. This procedure is very helpful for the orders of type $2p$, where p is a prime number, for examples, 14, 22, 26, 34, 38, etc. For the orders like 18, 30, etc. we can make good external blocks with order 4, and for orders like 16, 20, 28, 32, etc. we can make good external borders of order 6, and so on.*

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Contents

1	Introduction	3
2	Magic Squares of Order 30	4
2.1	Block-Wise and Bordered Square of Order 30	4
2.2	Magic Squares of Order 30 With BMRs	12
2.3	Cornered Magic Squares of Order 4	17
2.4	Closed Border of Order 4	44
2.5	Cornered Magic Squares of Order 6	65
2.6	Closed Border of Order 6	84
2.7	Cornered Magic Squares of Order 8	96
2.8	Closed Border of Order 8	113
2.9	Equal Sums Blocks of Order 10	119
2.10	Closed Border of Order 10	130
2.11	Cornered Magic Squares of Order 12	133
2.12	Closed Border of Order 12	158
2.13	Magic Squares of Orders 14, 16 and BMRs of Order 14 × 16	162
2.14	Extra Examples	168
3	Appendix	173
4	Author’s Contribution to Magic Squares and Recreation Numbers	174

1 Introduction

The magic sums of order n of consecutive numbers from 1 to n^2 is given by

$$S_{n \times n} := \frac{n \times (1 + n^2)}{2}, n \geq 3. \quad (1)$$

Recently, the author [31, 32, 33, 34, 35, 36, 37] constructed magic squares of even orders from 8 to 20 using **bordered magic rectangles**. This construction is based on two aspects:

- (i) Using **magic rectangles** or **bordered magic rectangles**.
- (ii) Using algebraic formula like $(a + b)^2, a \neq b$.

For the above magic squares no construction procedure is explained. The aim is to proceed further orders of magic squares. In this work, a systematic procedure to construct these magic squares is given. It is based on the magic squares and bordered magic rectangles (BMR) of orders 4, 6, 8 etc forming external borders. Then the internal borders are filled with previous known magic squares. For the orders multiples of 4, we can always write magic squares with equal sums blocks of magic squares of order 4. This procedure is very helpful for the orders of type $2p$, where p is a prime number, for examples, 14, 22, 26, 34, 38, etc. For the orders like 18, 30, etc., we can make good external blocks with order 4, and for orders like 16, 20, 28, 32, etc. we can make good external borders of order 6, and so on. There is no explanations for the orders 6, 8, 10 and 12. The real construction starts from the order 14.

The whole the work is done manually, without use of any programming language, except for the constructions of small blocks of **bordered magic rectangles**. This construction is based on the software due to H. While. Later, these BRMs are readopted according to distribution of each magic square. The distribution of **magic squares** or **bordered magic rectangles** is based on **half-sequential** numbers. By **half-sequential** numbers we understand that the total numbers in each case are divided in two equal parts. The first part is one sequence and the second part is another sequence. Due to **half-sequential** numbers, it is not possible to construct all orders **bordered magic rectangles**. In Appendix 3, there are tables showing the existence of these **bordered magic rectangles** for **half-sequential**. For simplicity, we shall write **BMR** as **bordered magic rectangle**. This work is for order 30. The previous works can be seen at [38, 39, 40, 41, 42, ?].

Remark 1. *The **bordered magic squares** and **bordered magic rectangles** are with the property that if we remove external borders in each case, still we are left with **bordered magic squares** and **bordered magic rectangles** respectively with sequential number entries. The whole work is in figures instead of numbers. In the same magic square the **small equal figures** represents equal sums **magic squares** and/or equal sums **bordered magic rectangles**. The whole work is done manually*

2 Magic Squares of Order 30

This section brings in figures (without numbers) magic squares of order 30. In some cases, the idea of constructions are explained. It is based on **cornered magic squares**.

2.1 Block-Wise and Bordered Square of Order 30

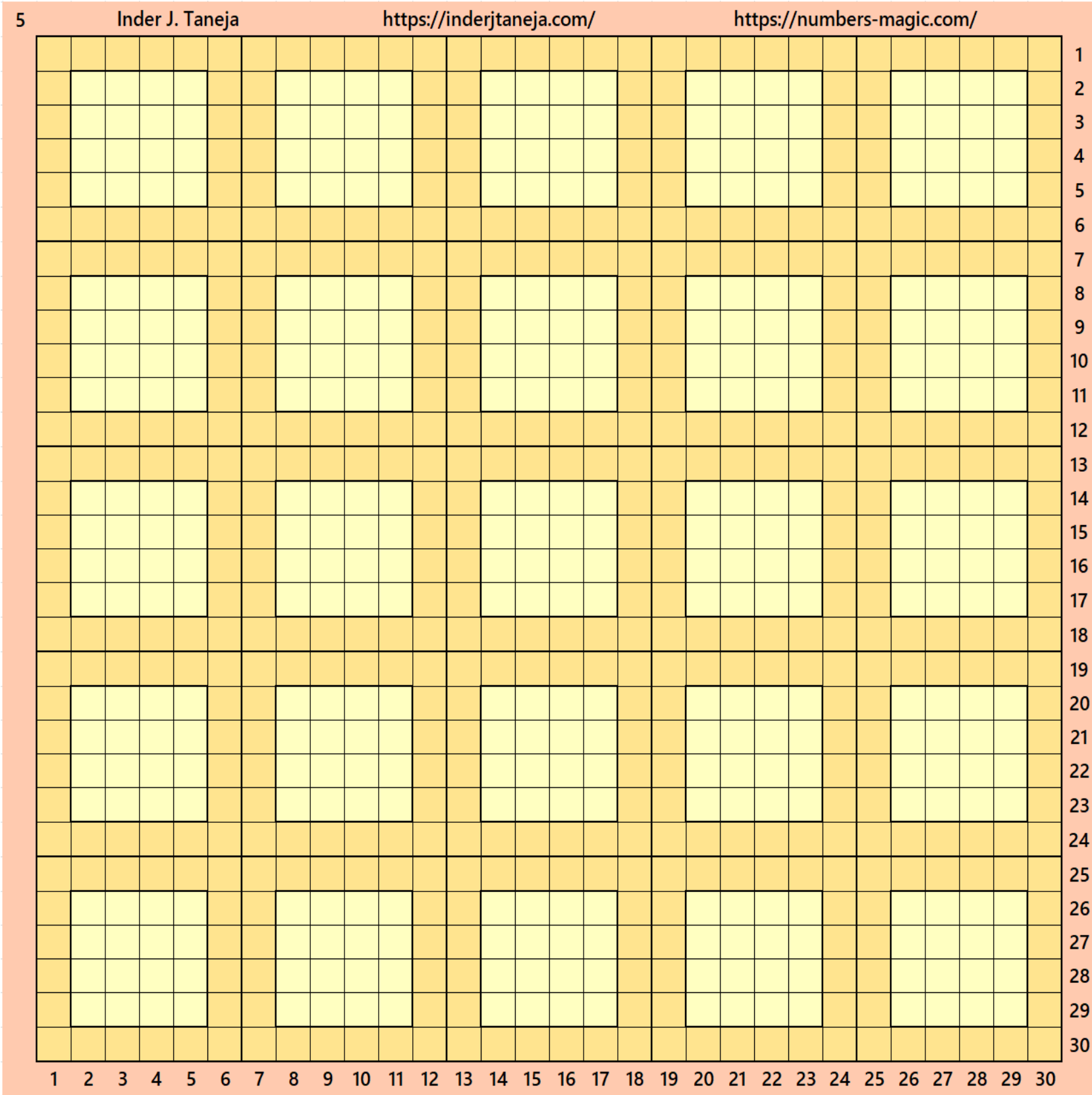
Below are magic squares of order 30 already known in the literature. For more details refer author's work [22, 24].

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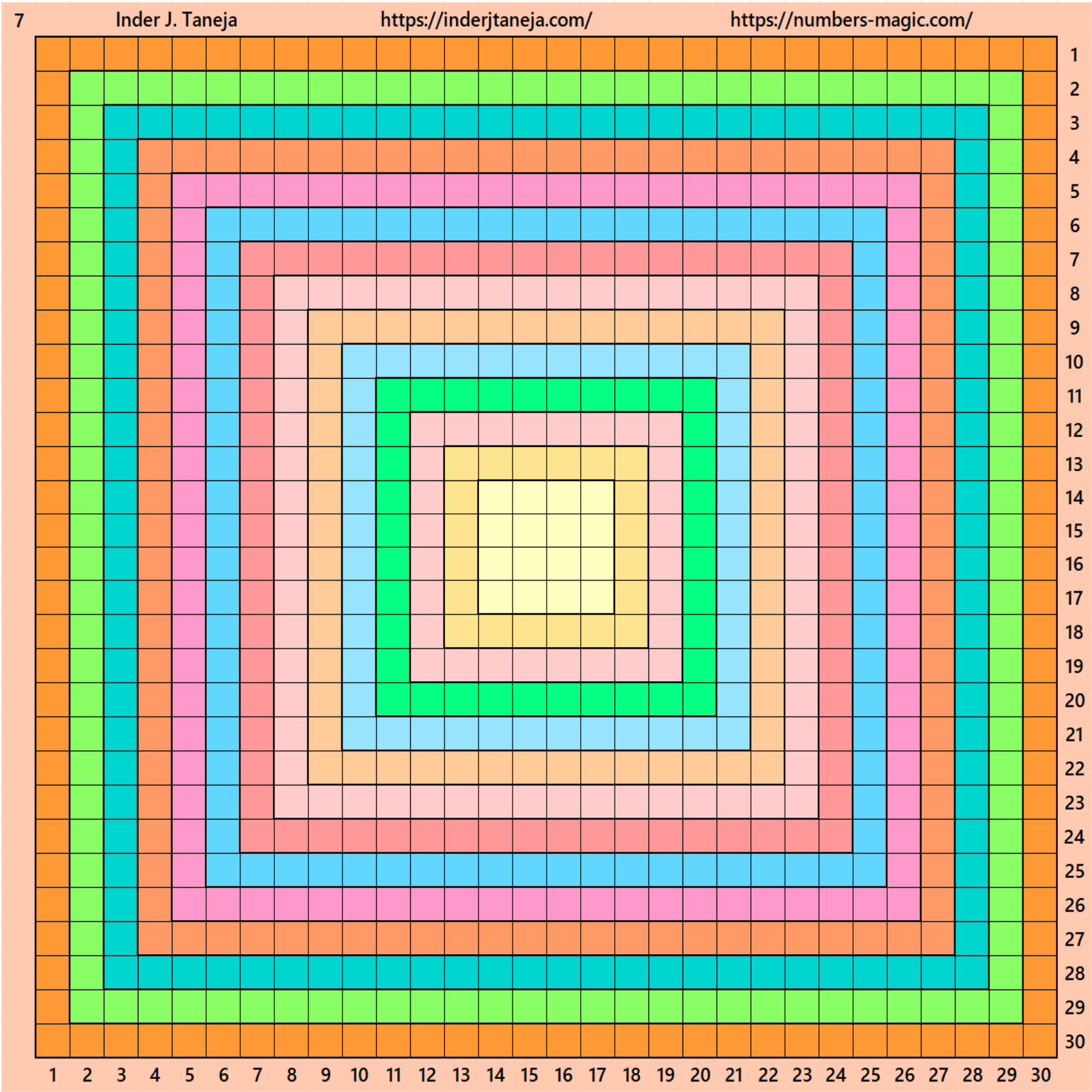
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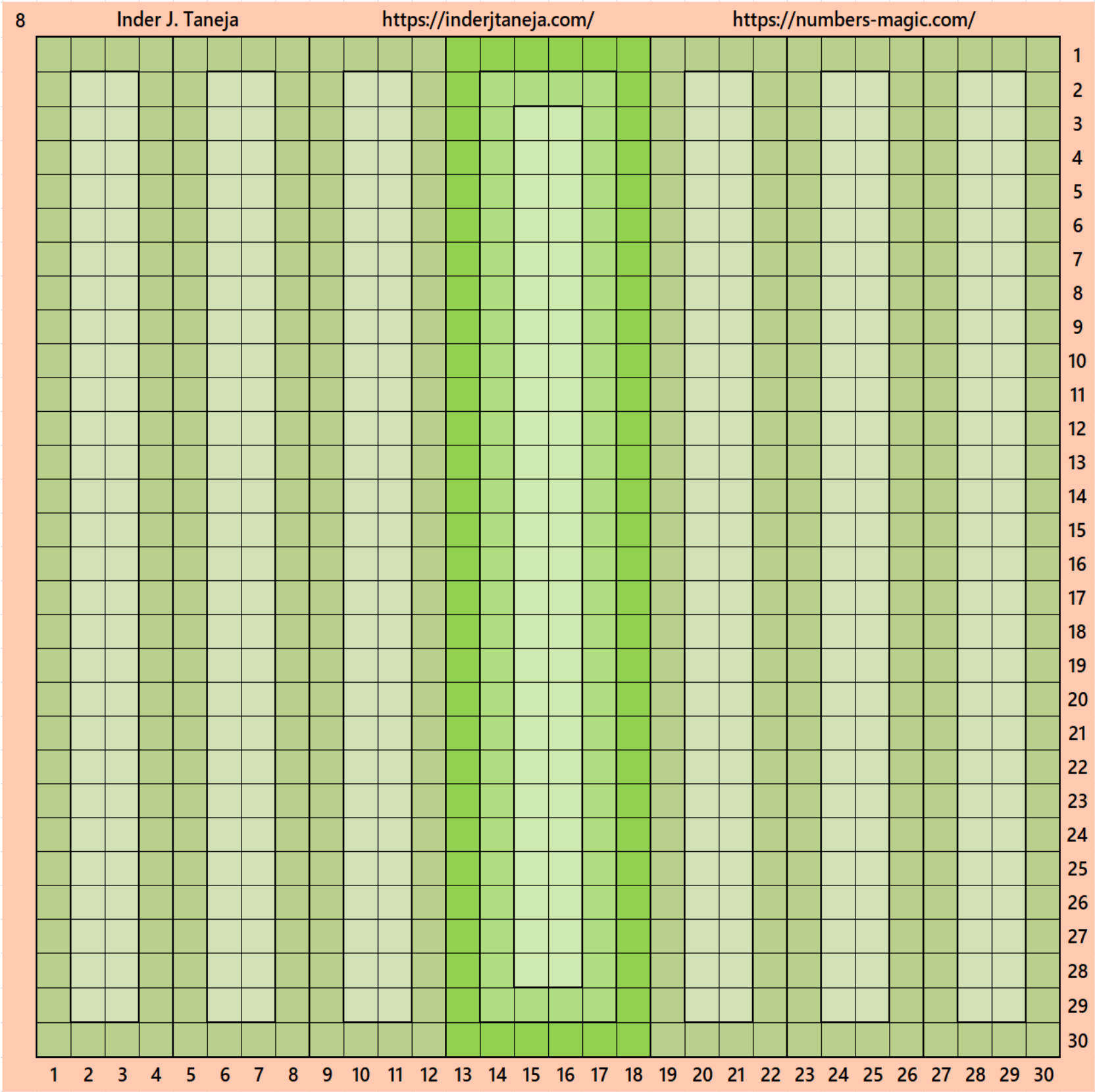


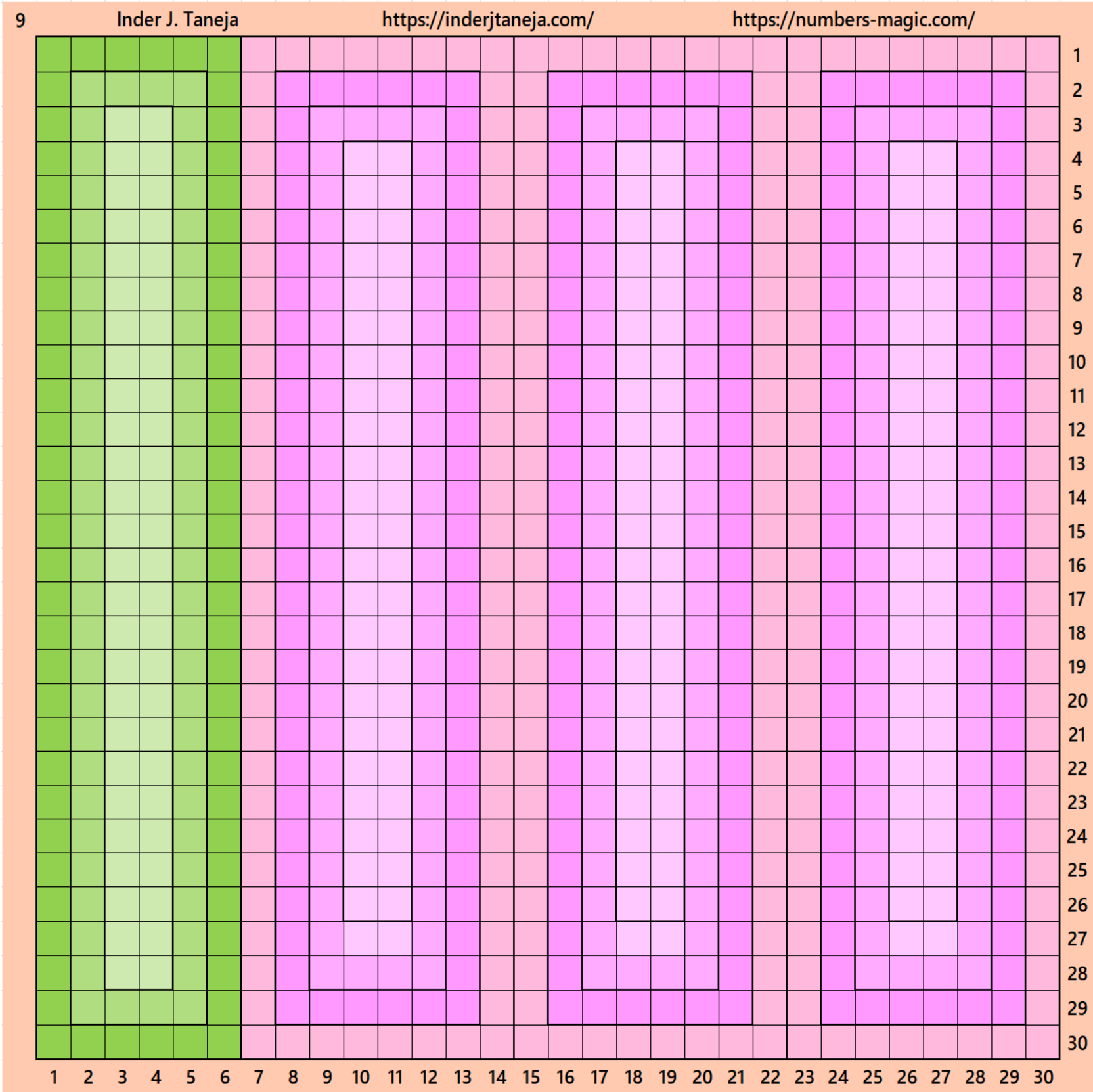
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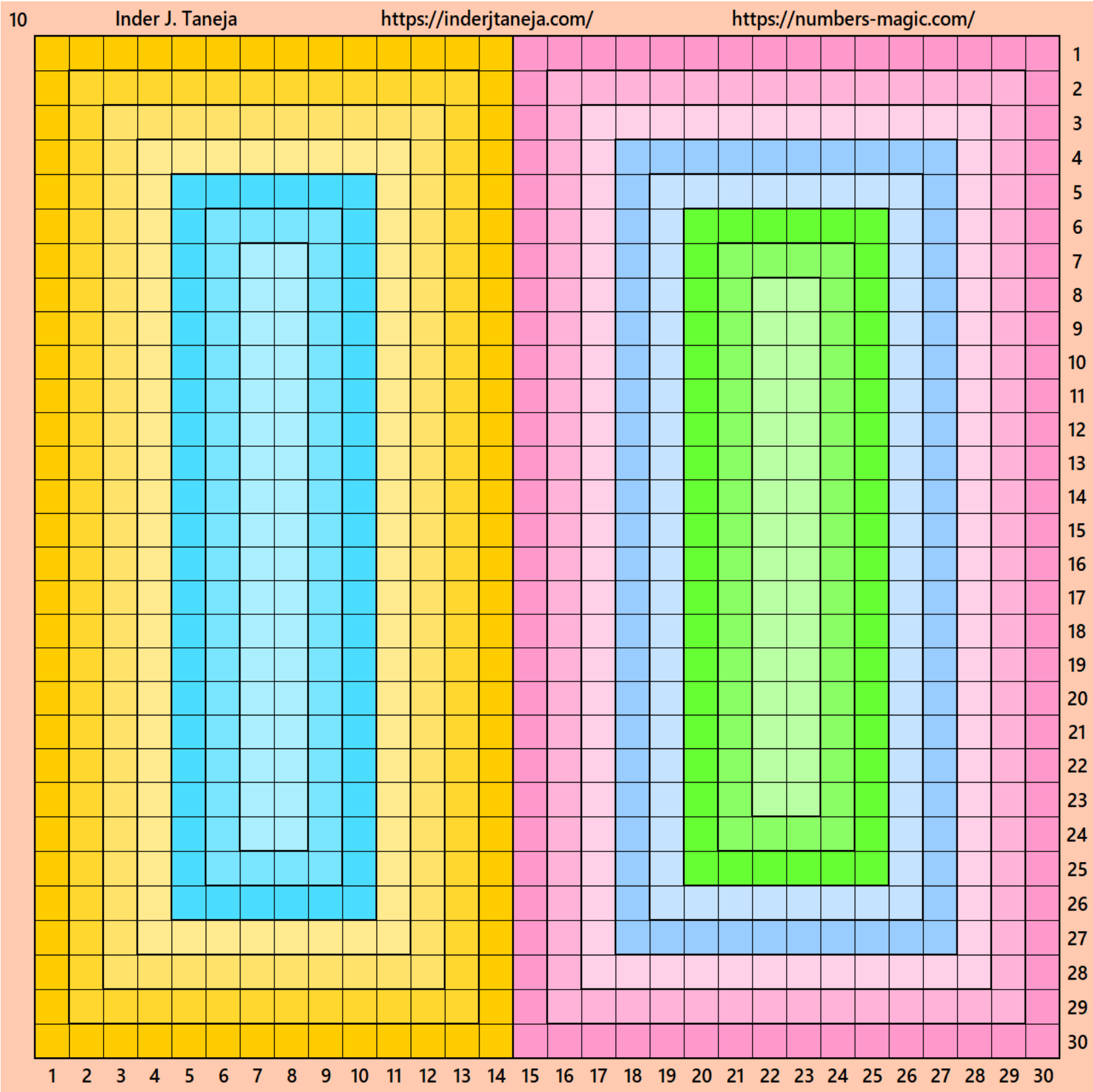


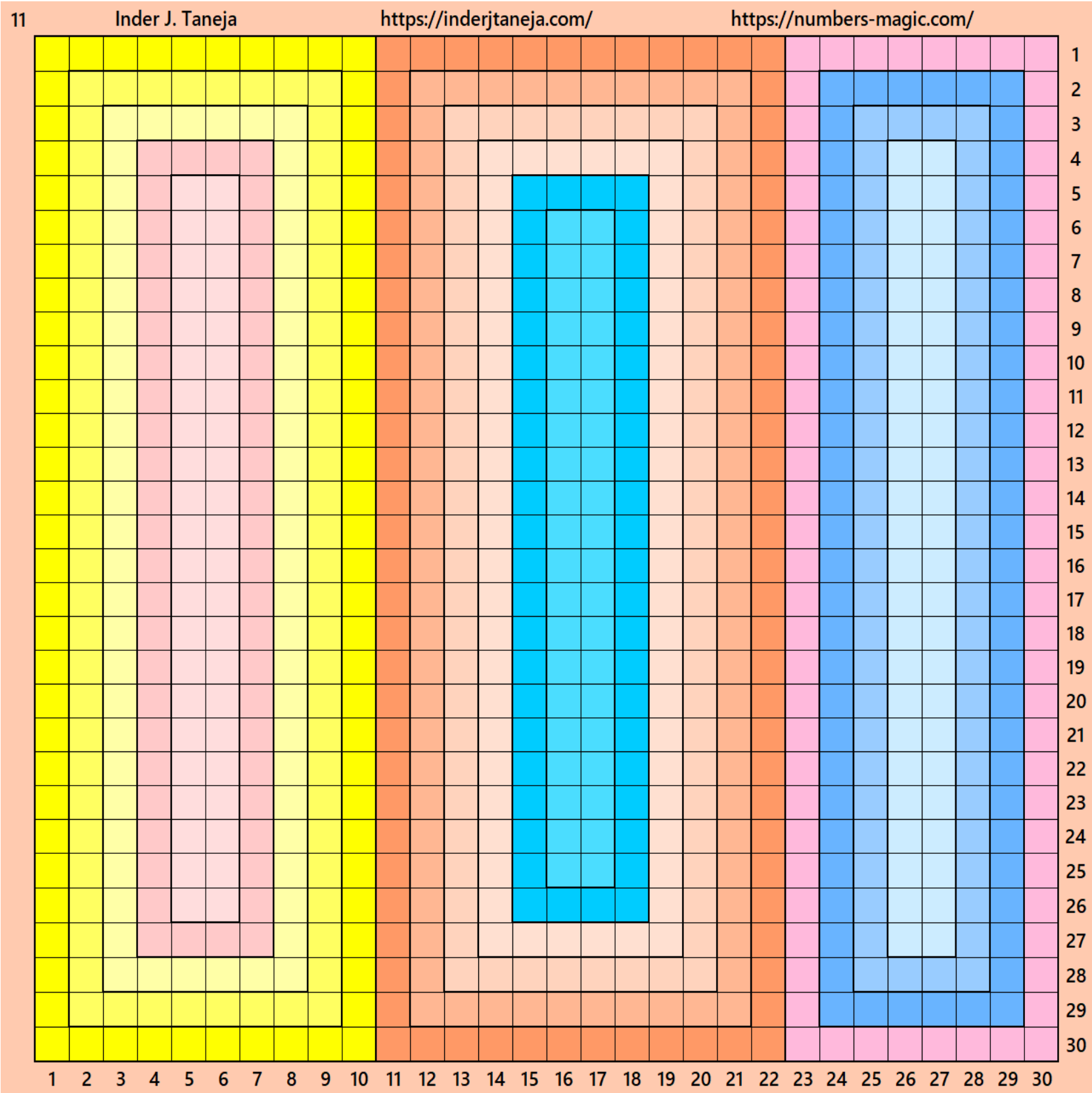
2.2 Magic Squares of Order 30 With BMRs

Below are examples of magic squares of order 28 made with BMRs. The construction in each case is individual.



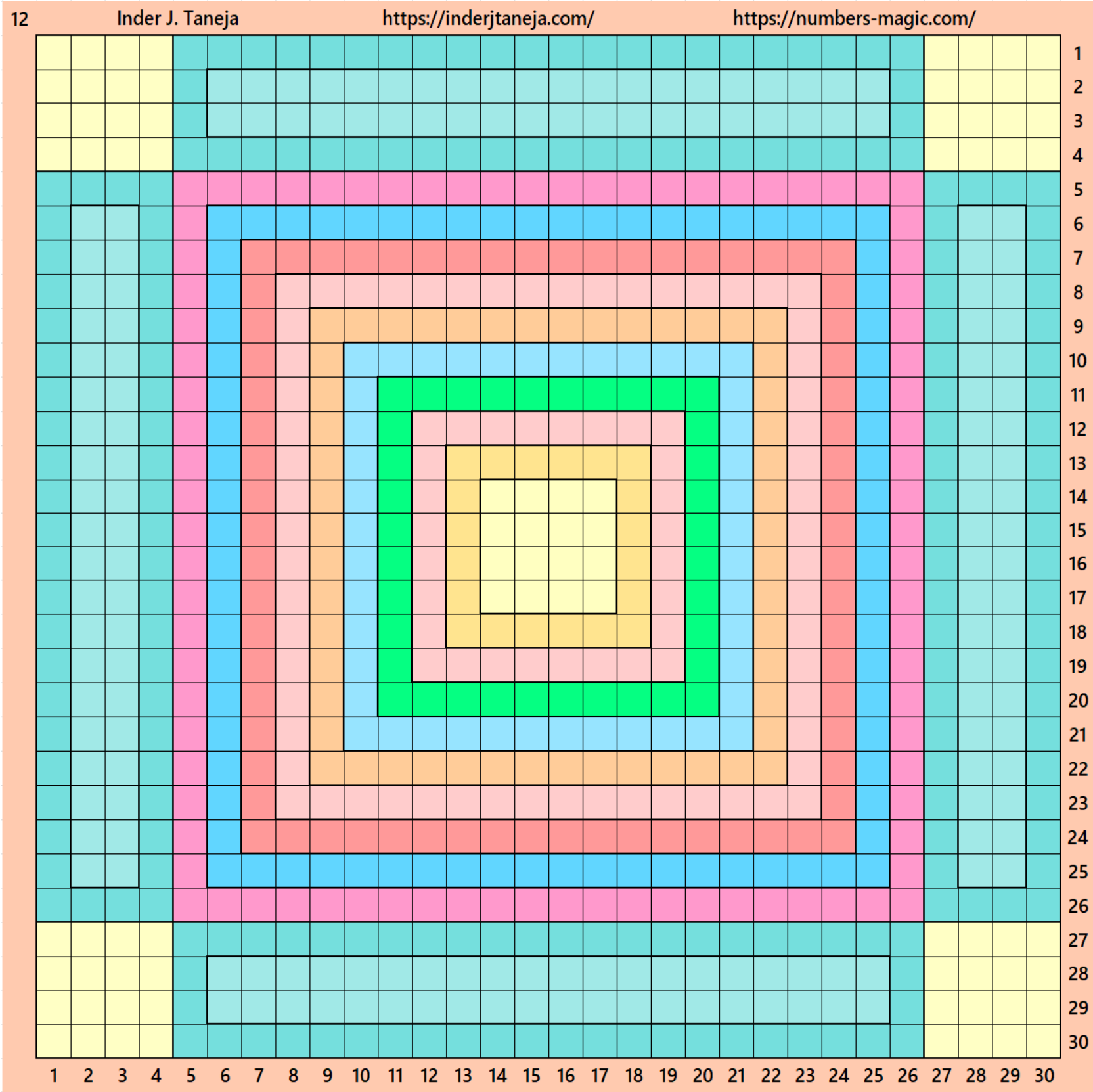


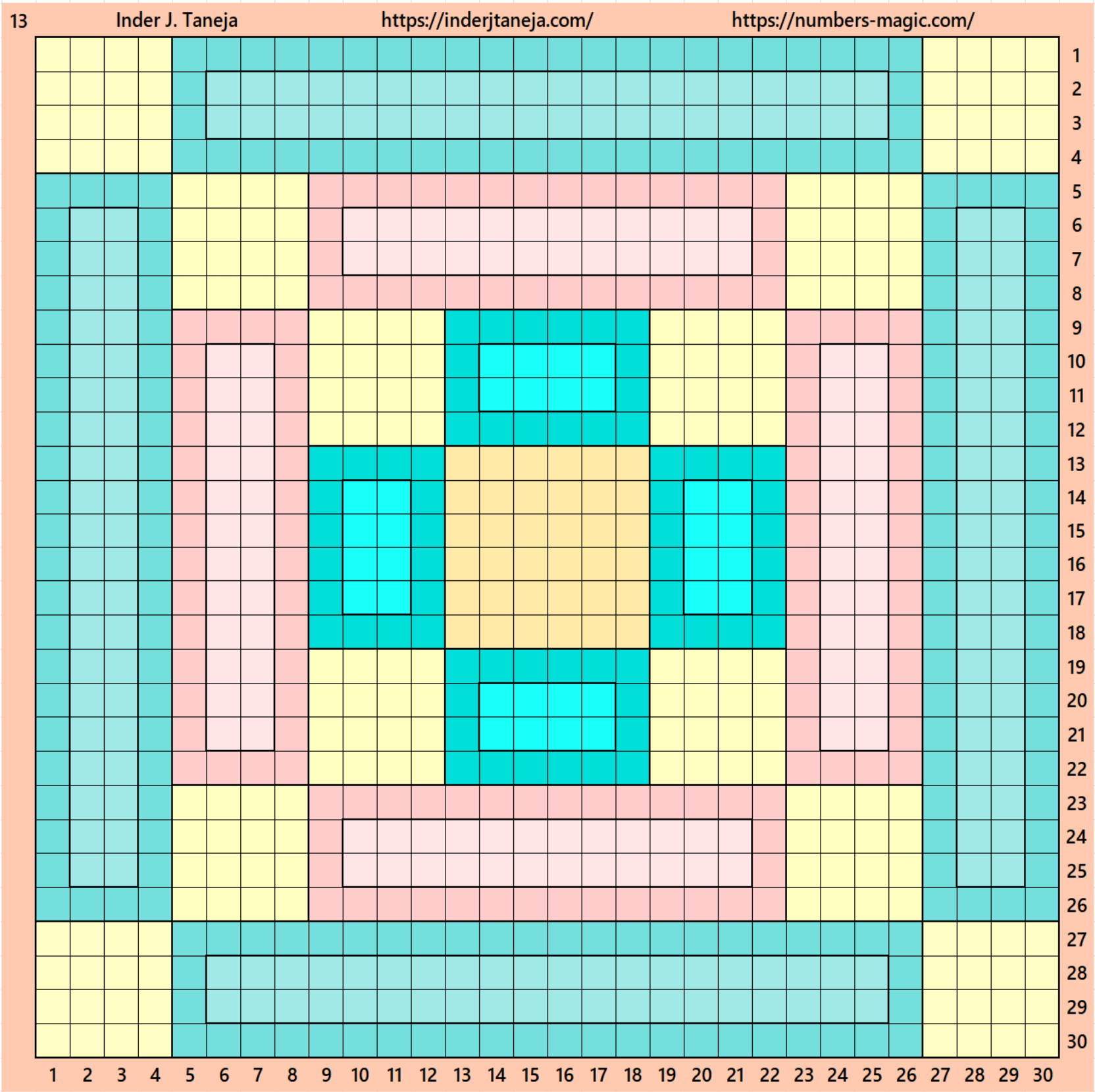


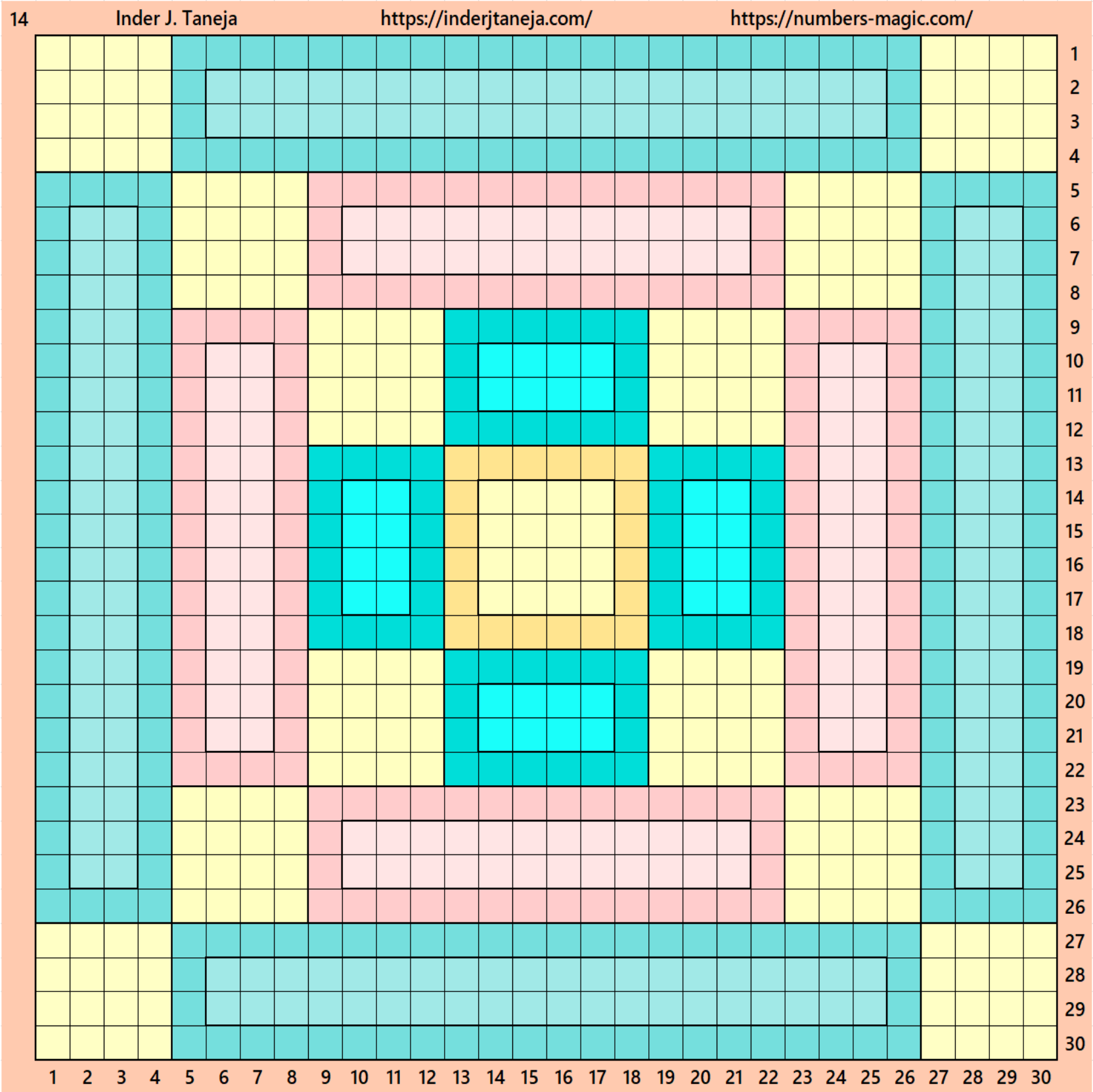


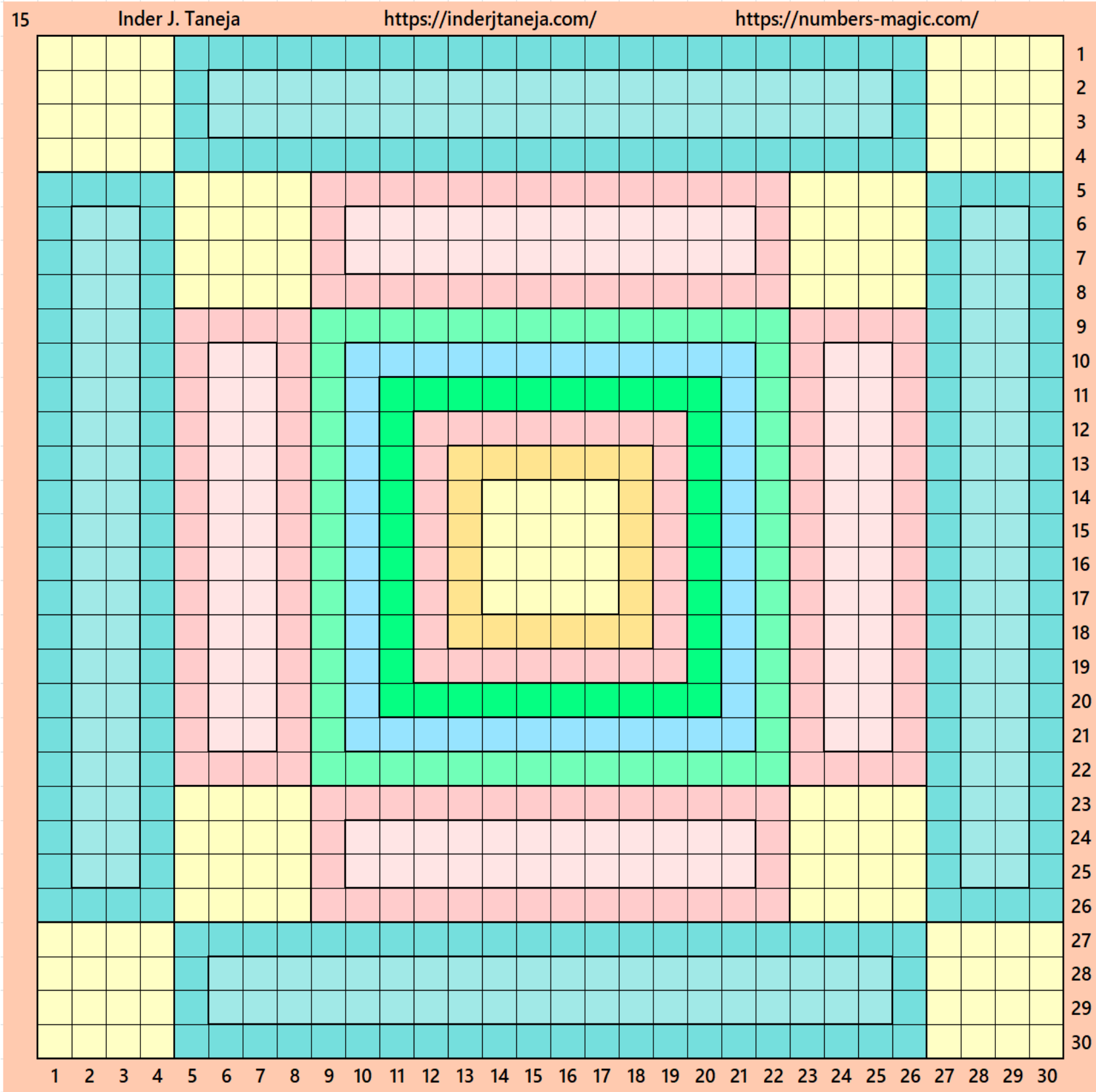
2.3 Cornered Magic Squares of Order 4

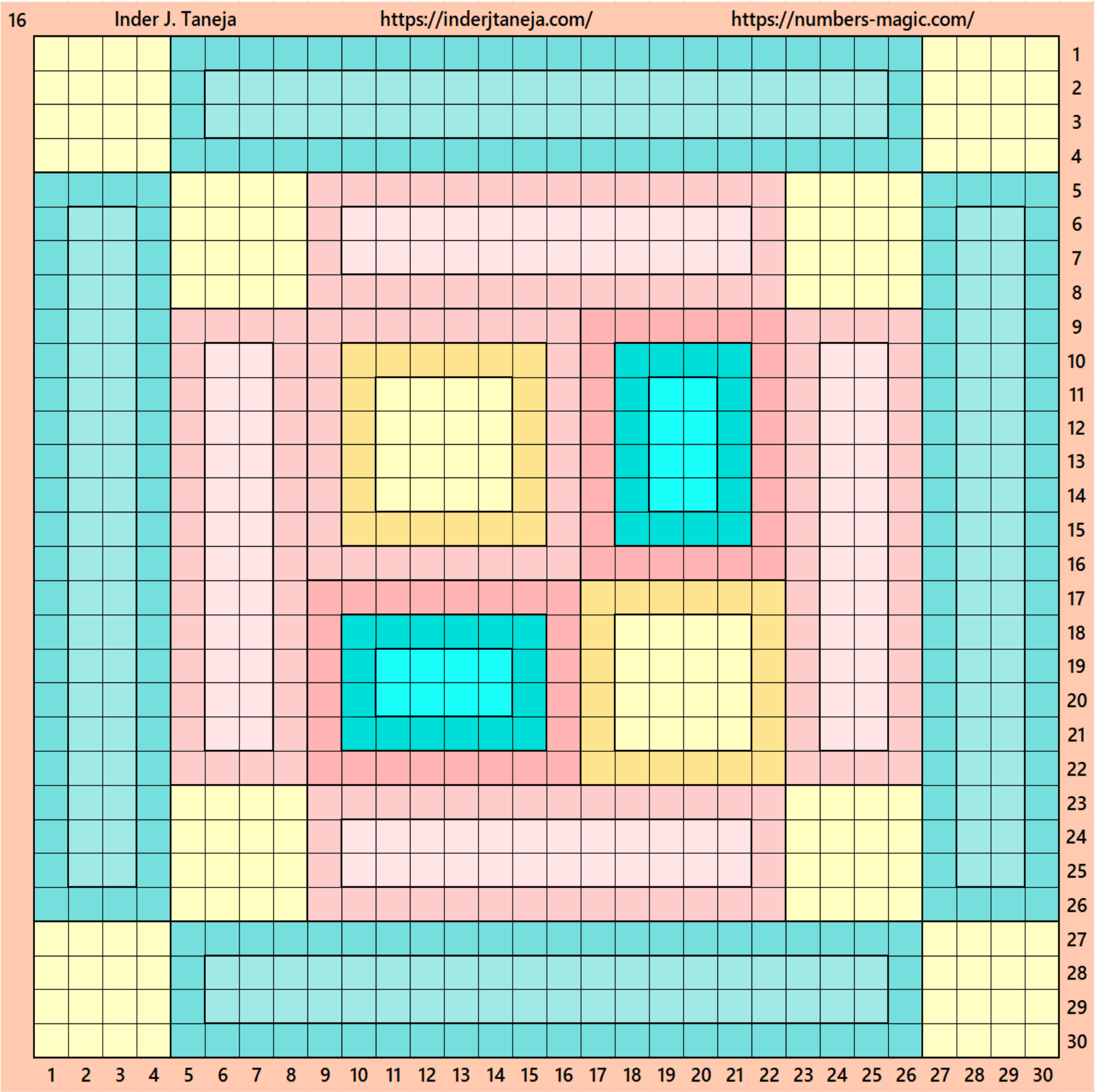
Let's consider an external border, where there are 4 magic squares of order 4 at the corners. Let's make an external border by putting BMR of order 4×22 in each row and column. In the middle we are left with block of order 22. Writing this middle blocks with different types of magic squares of order 22, we get magic squares of order 30. See below few examples:

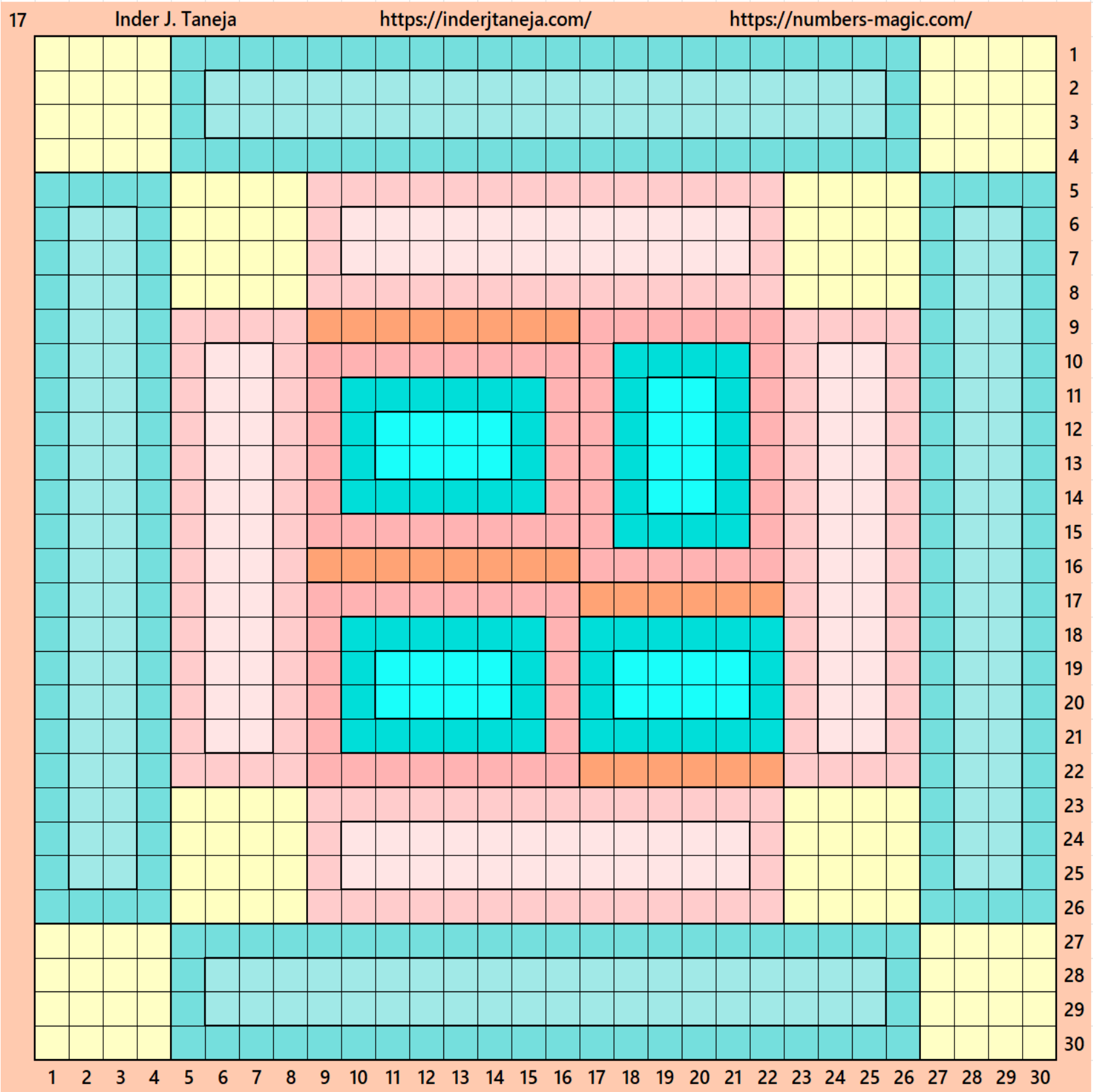


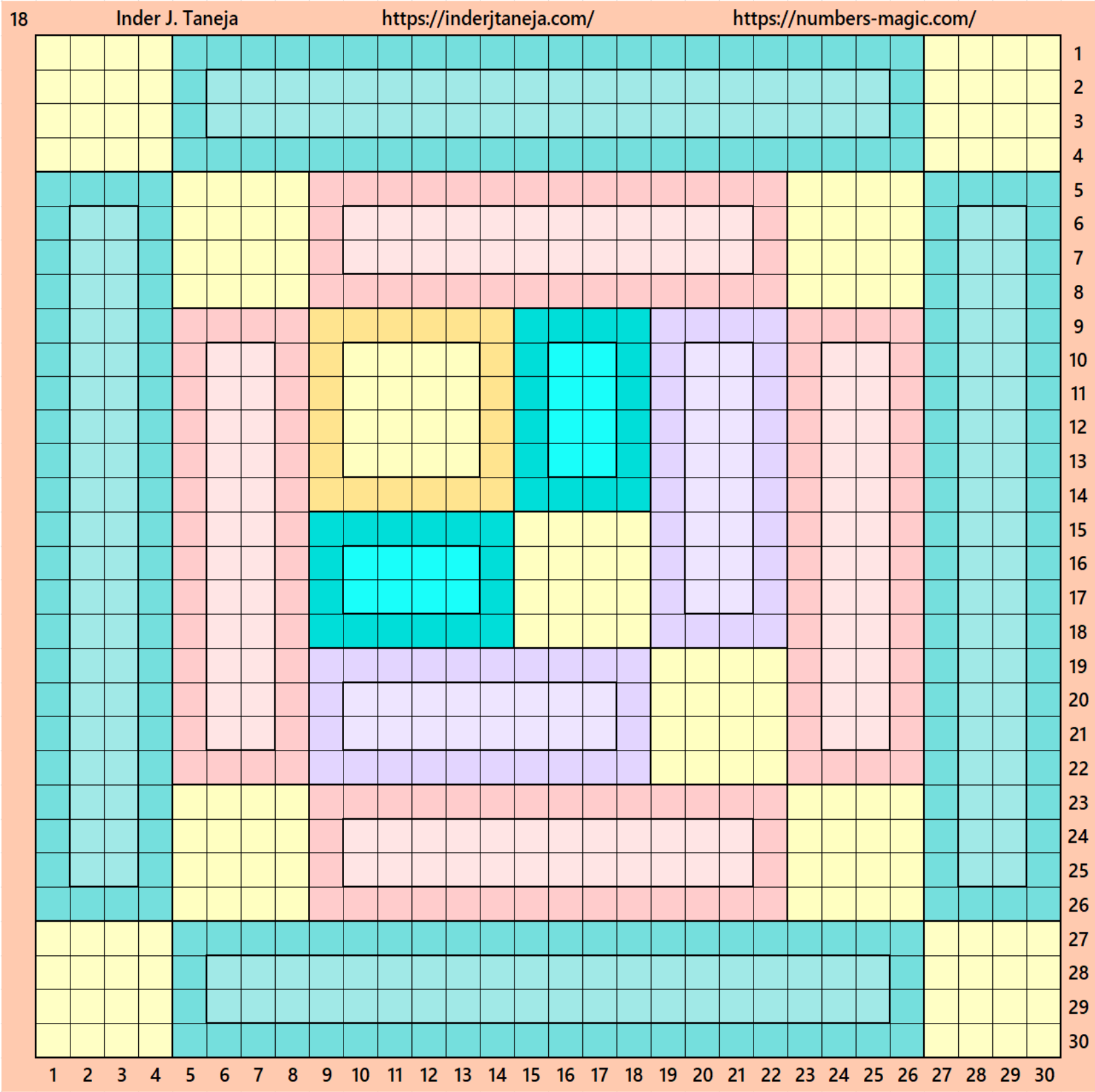


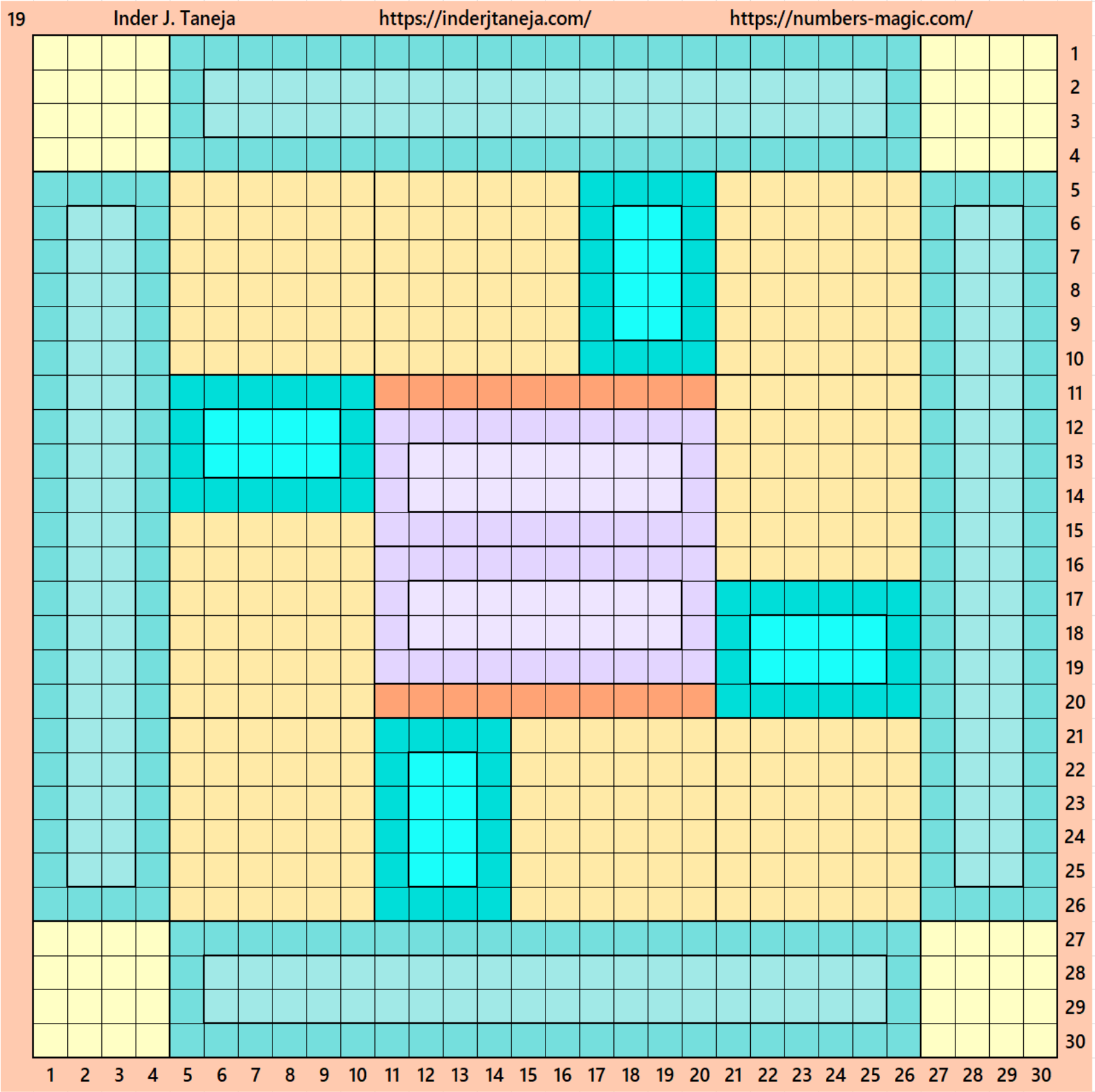


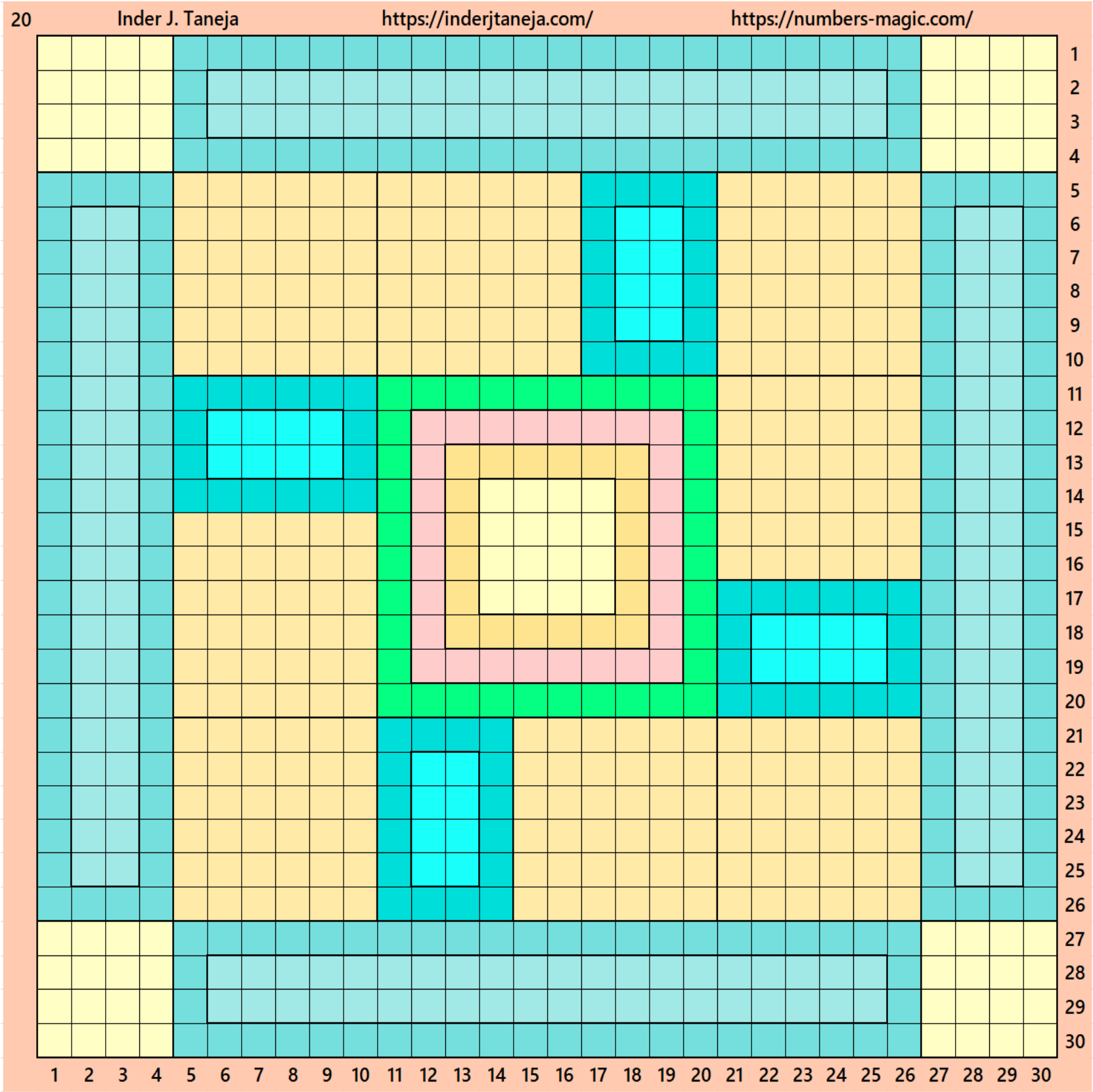


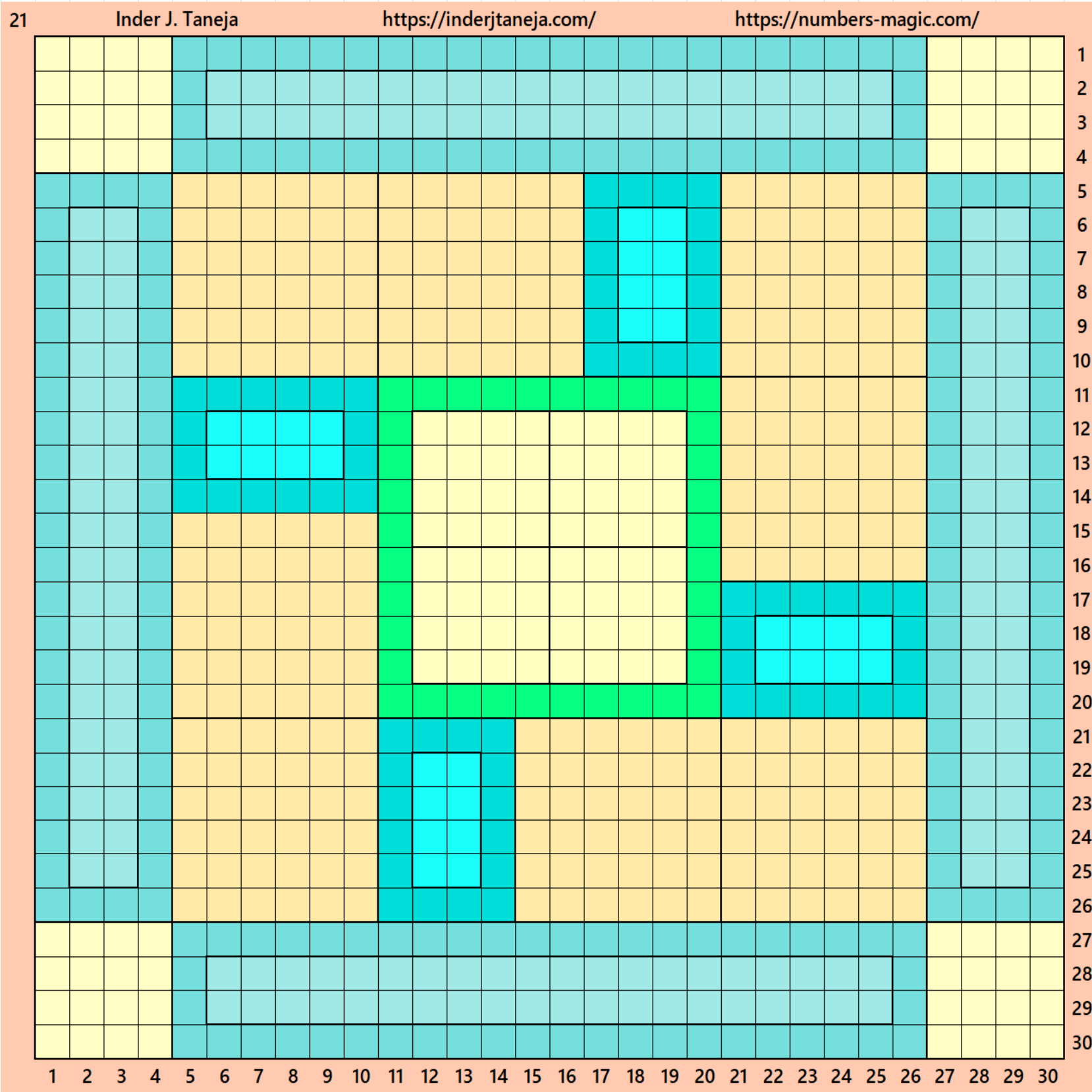


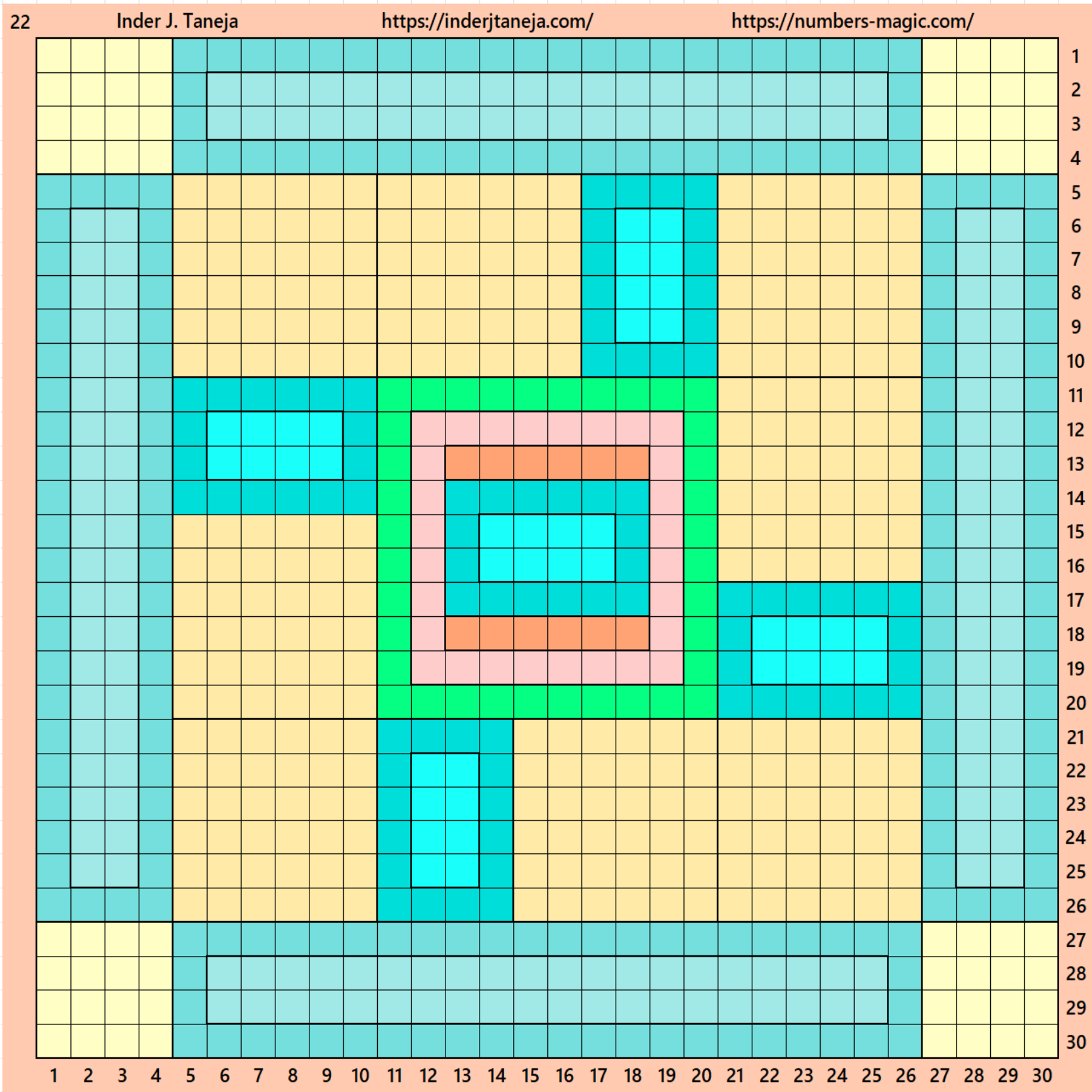


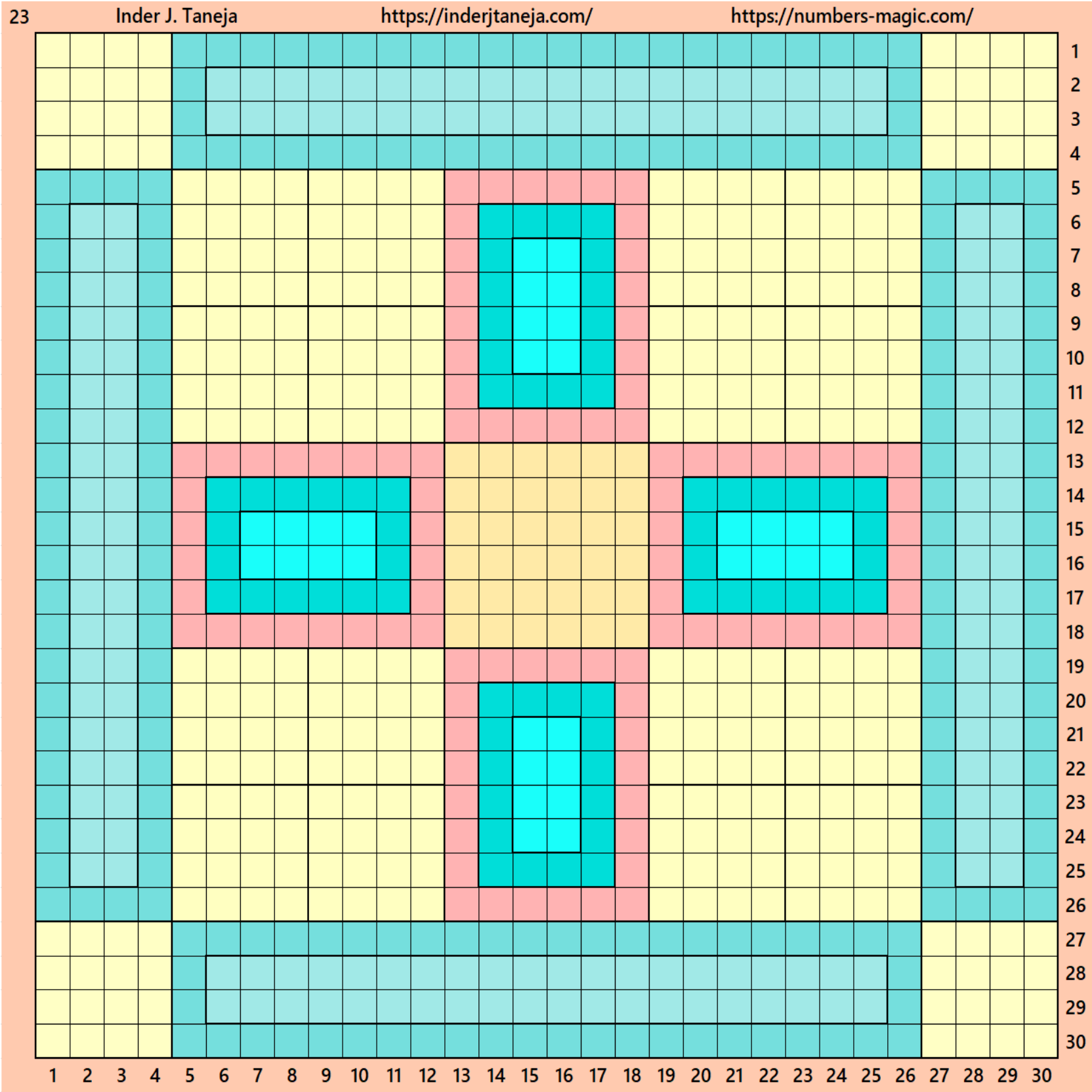


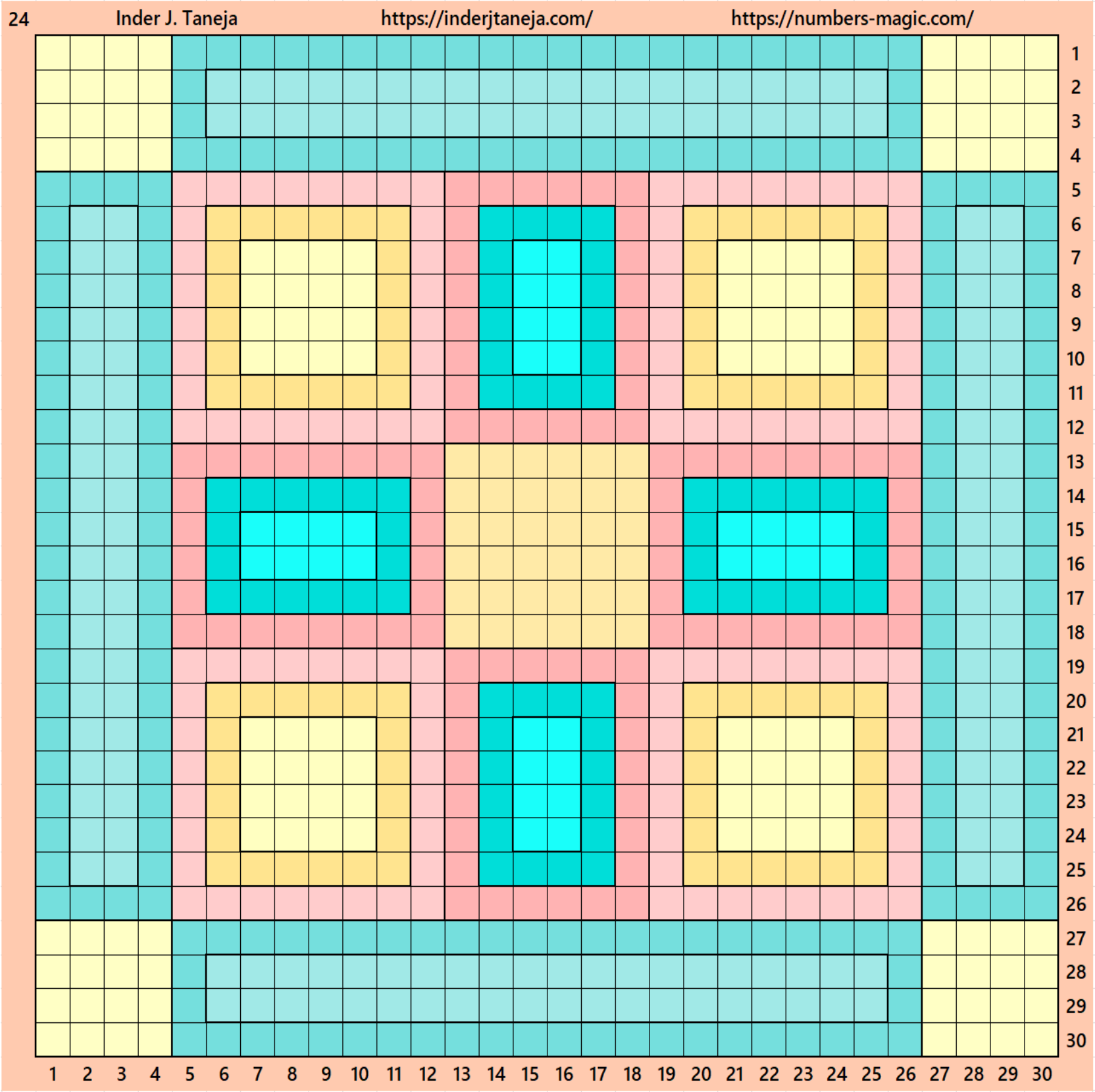


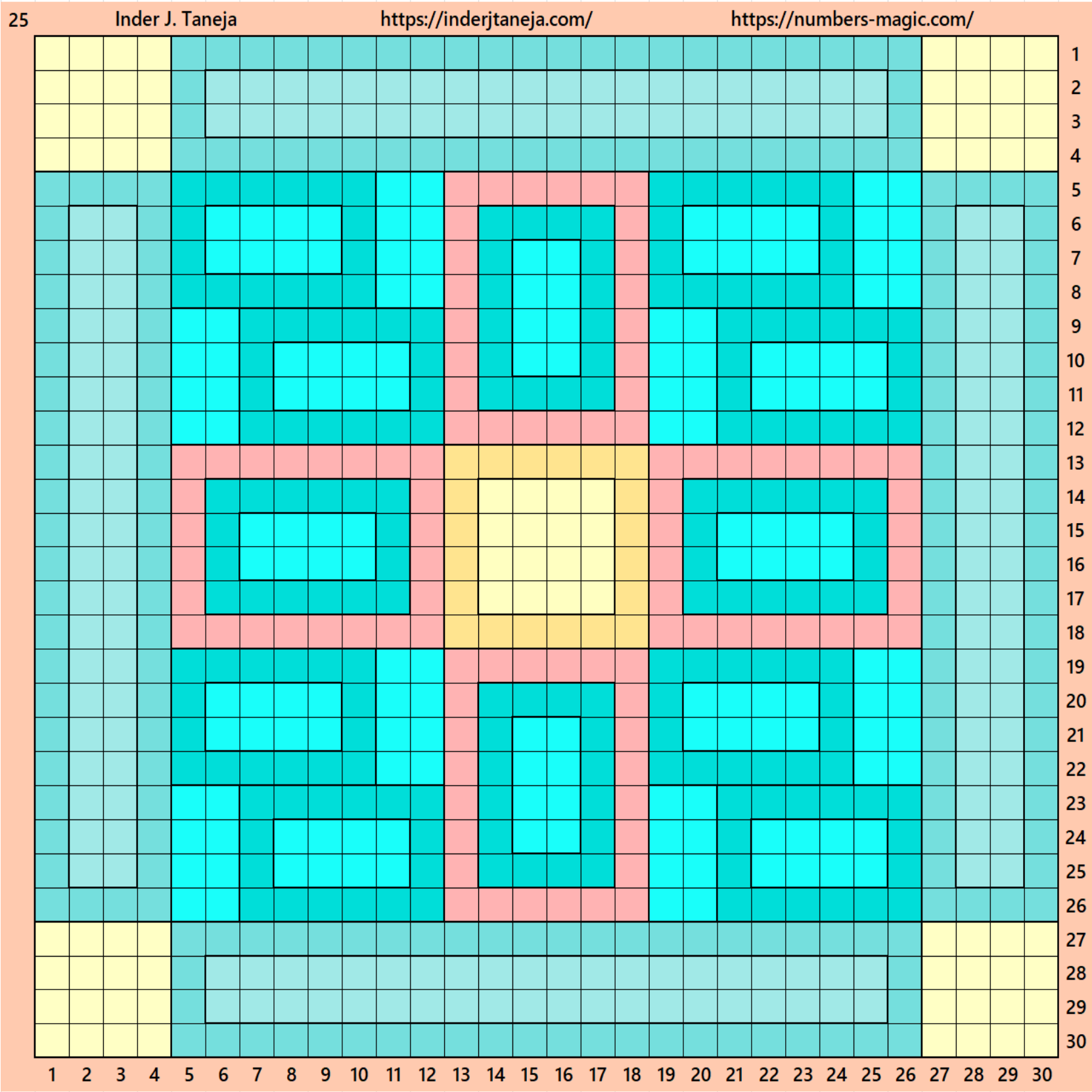


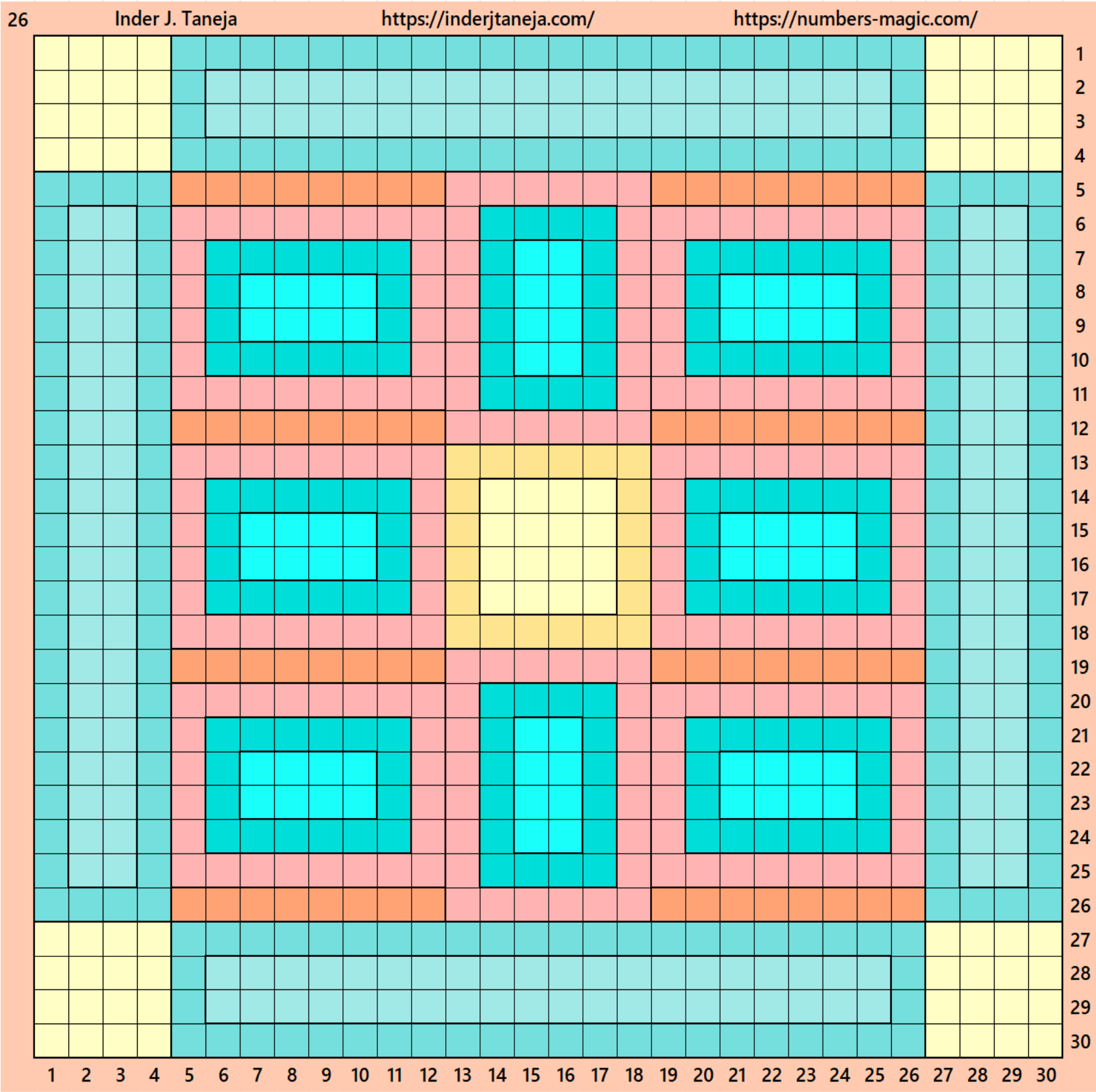


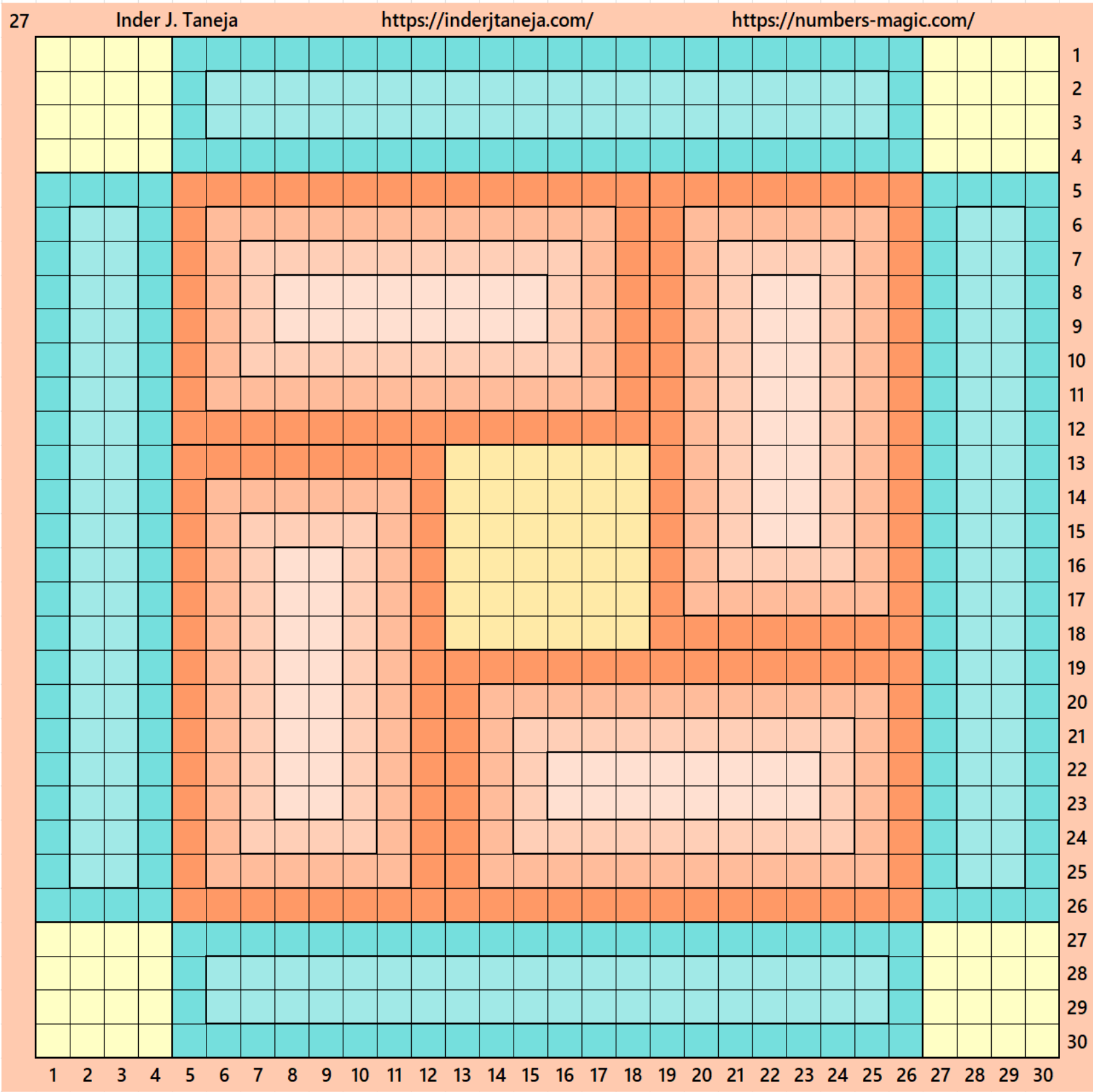


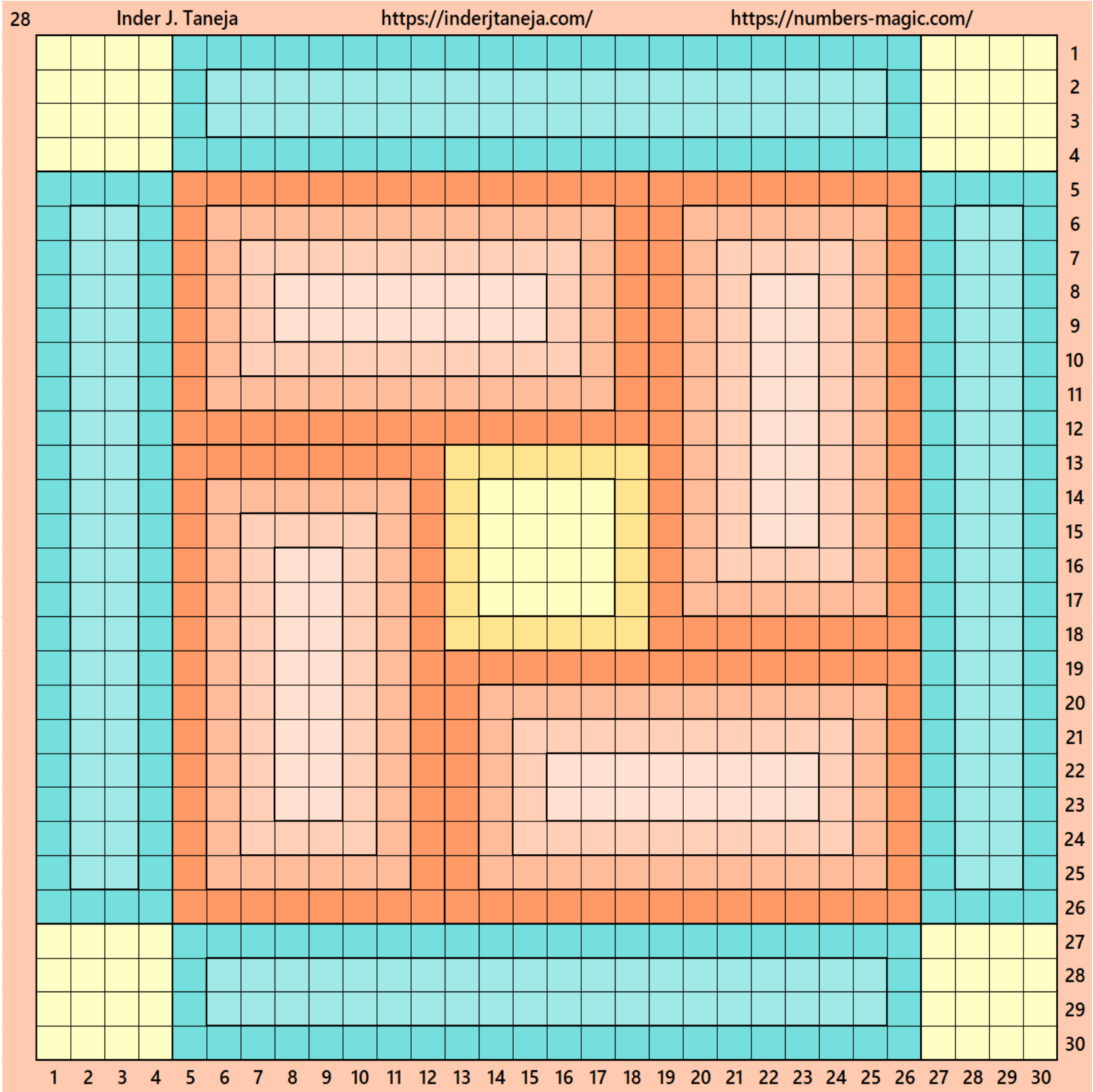


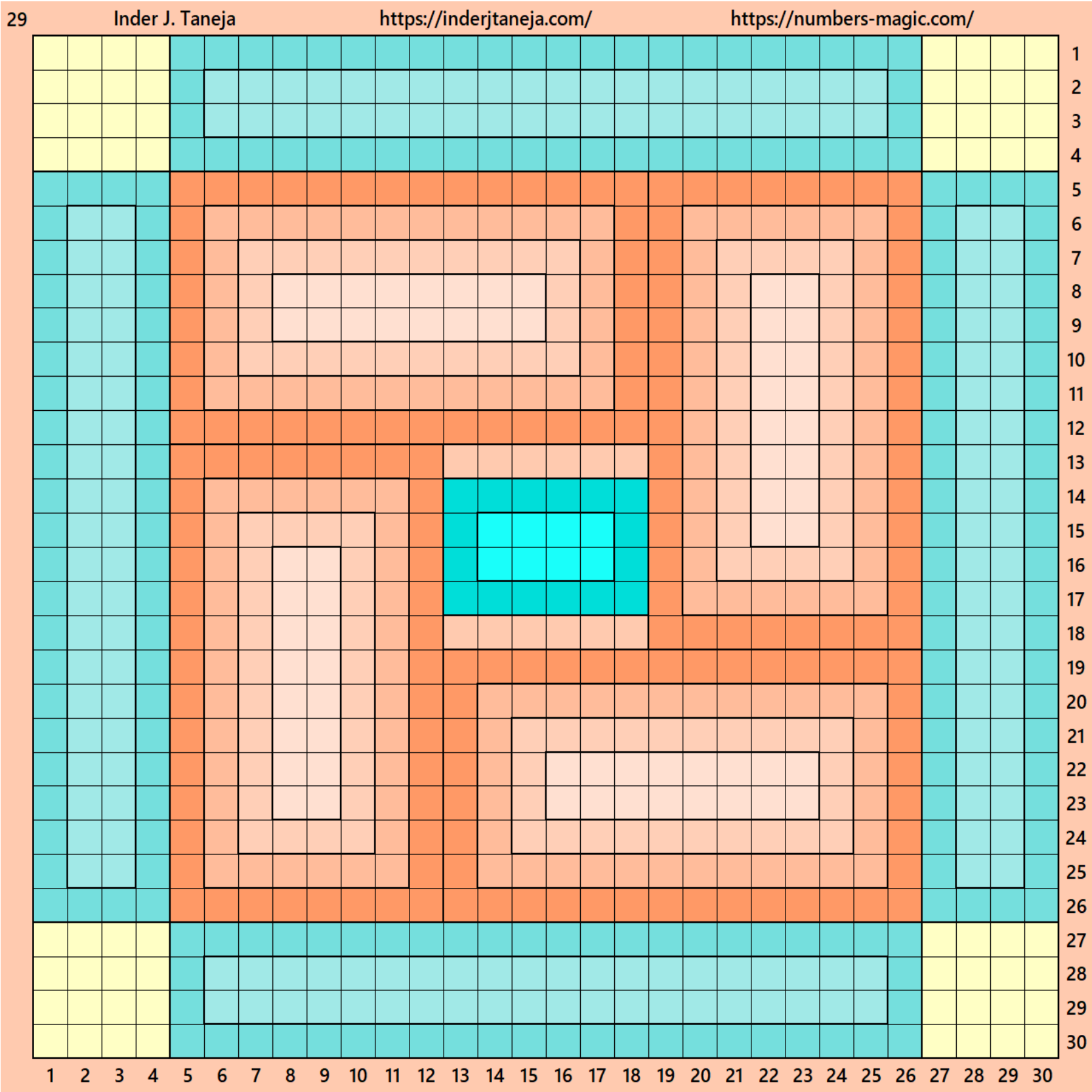


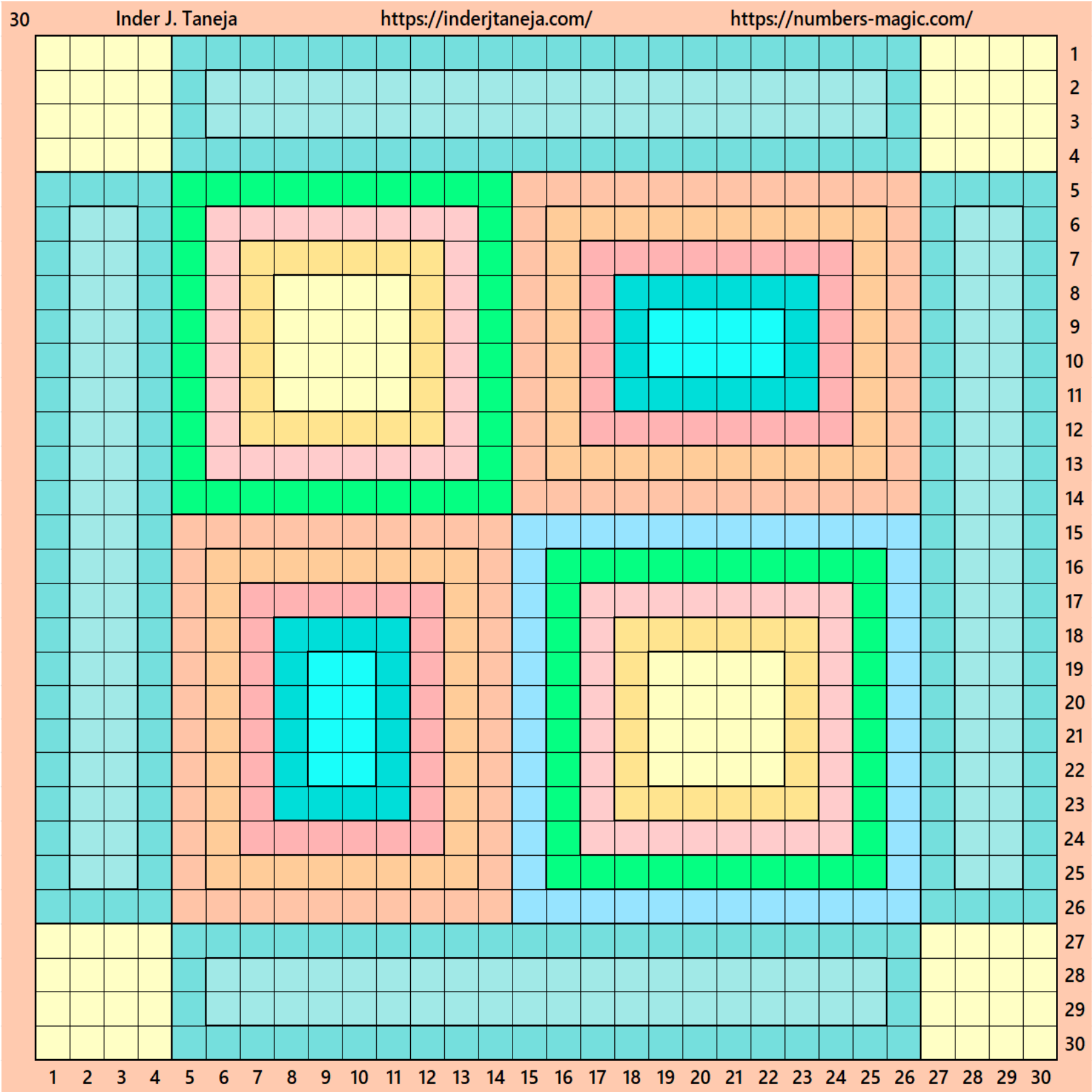


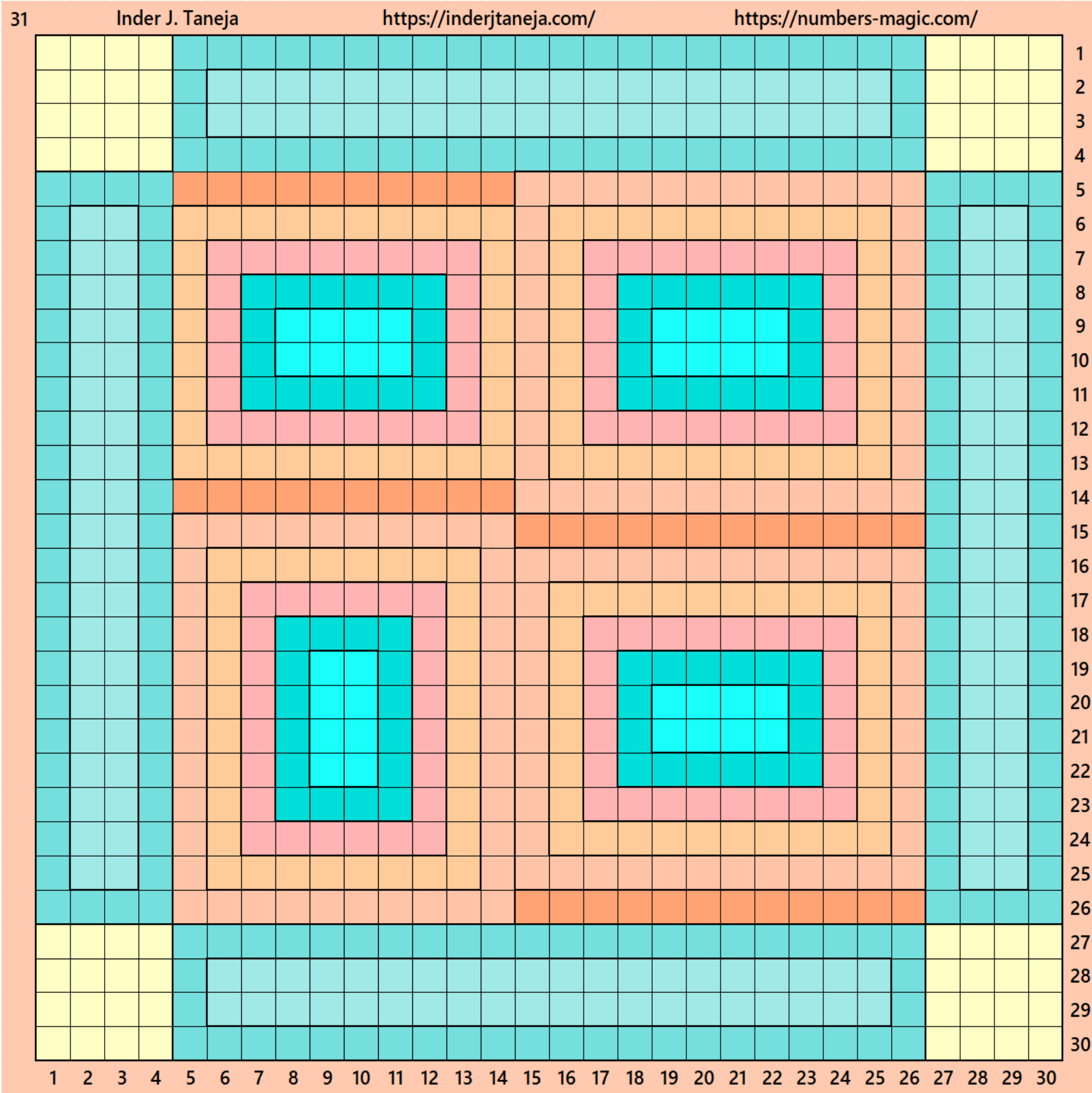


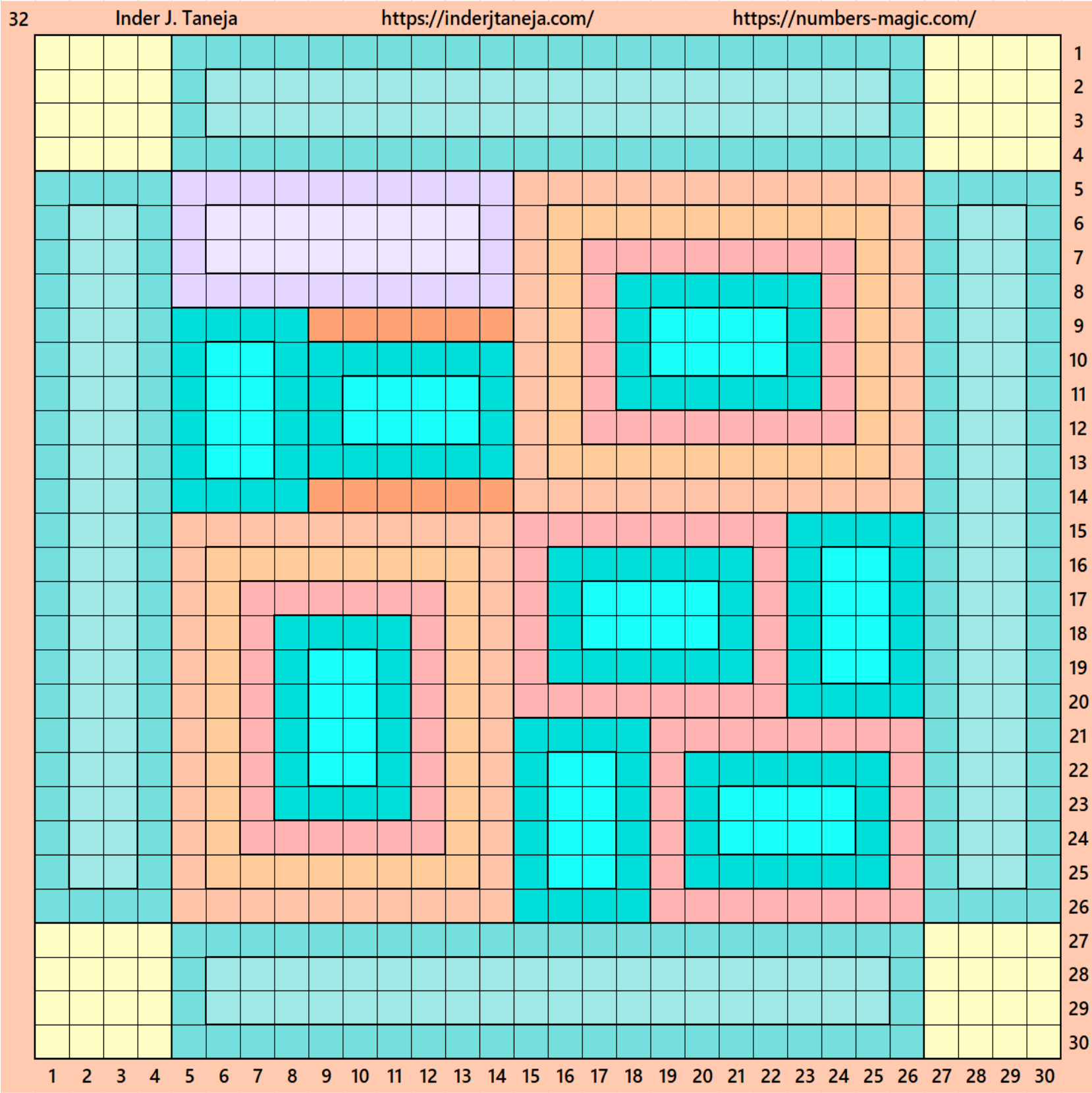


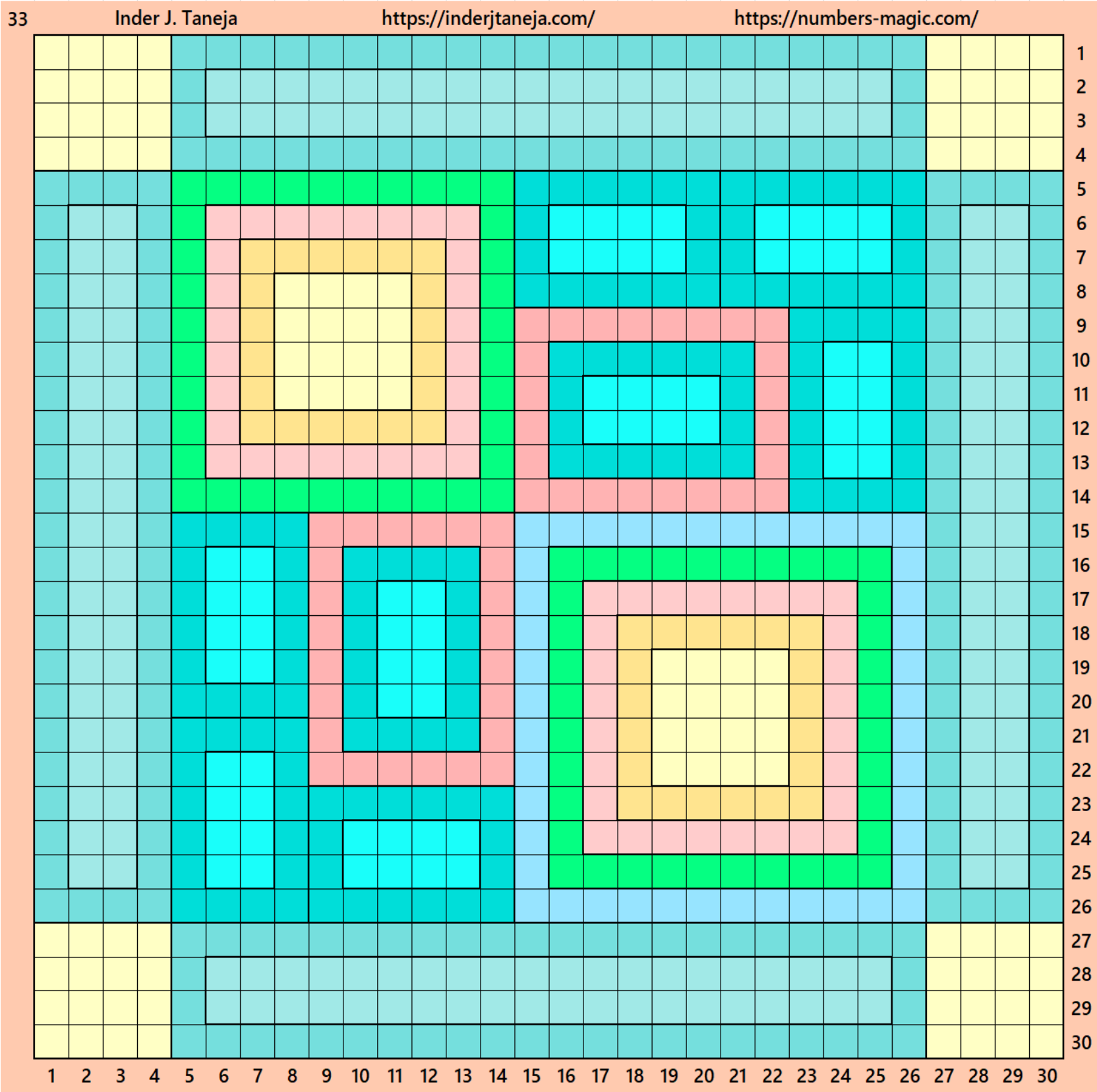


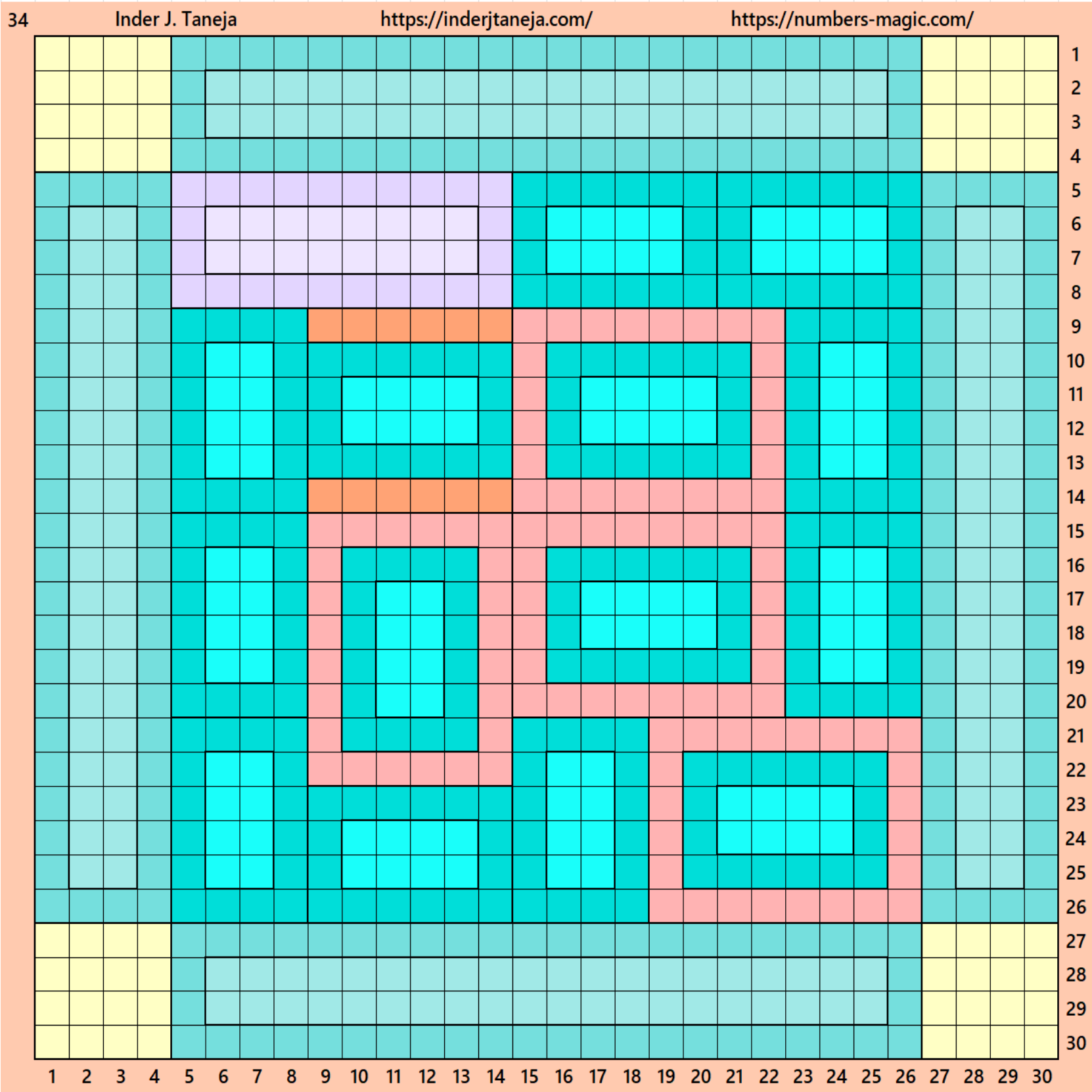


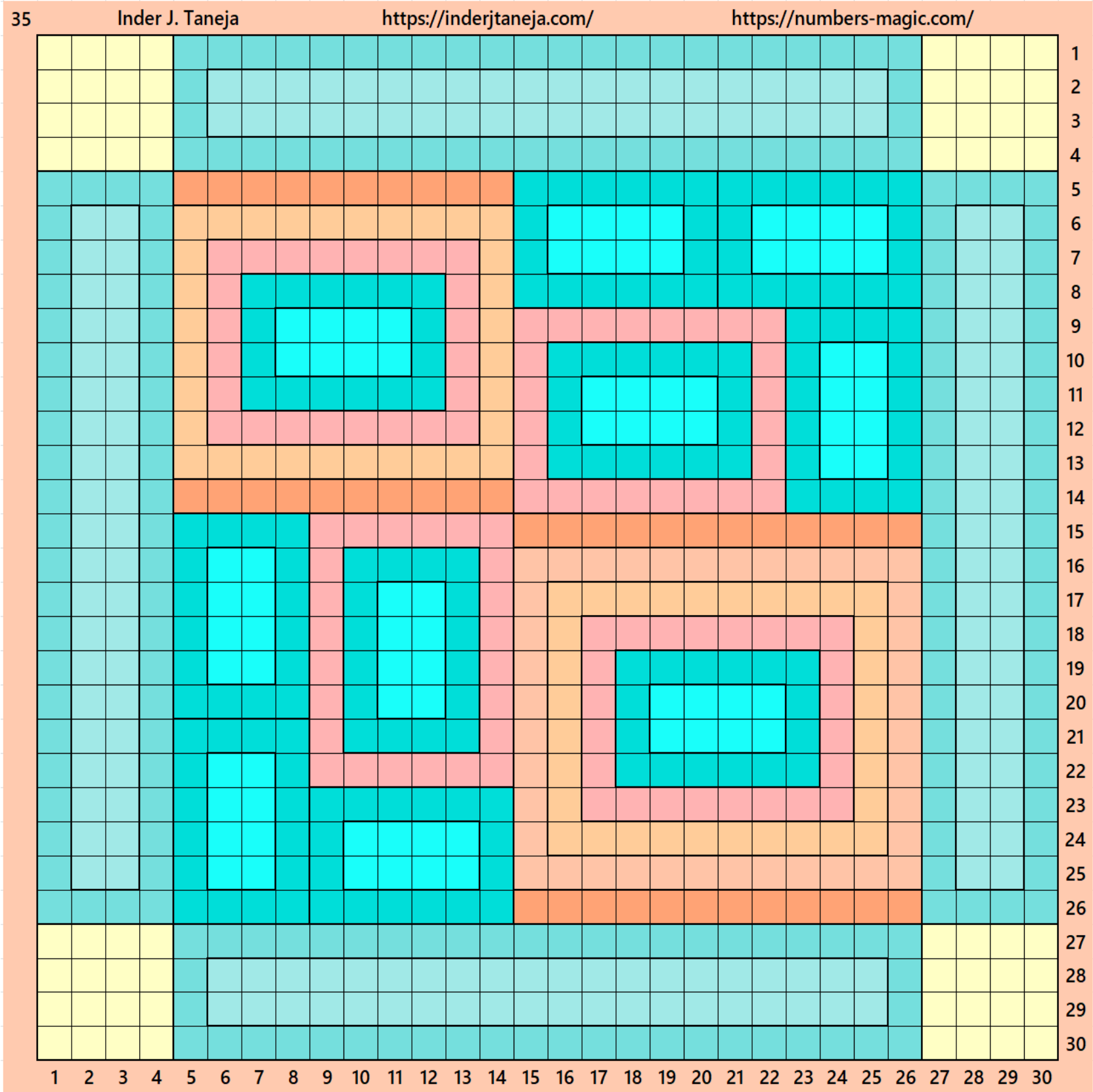


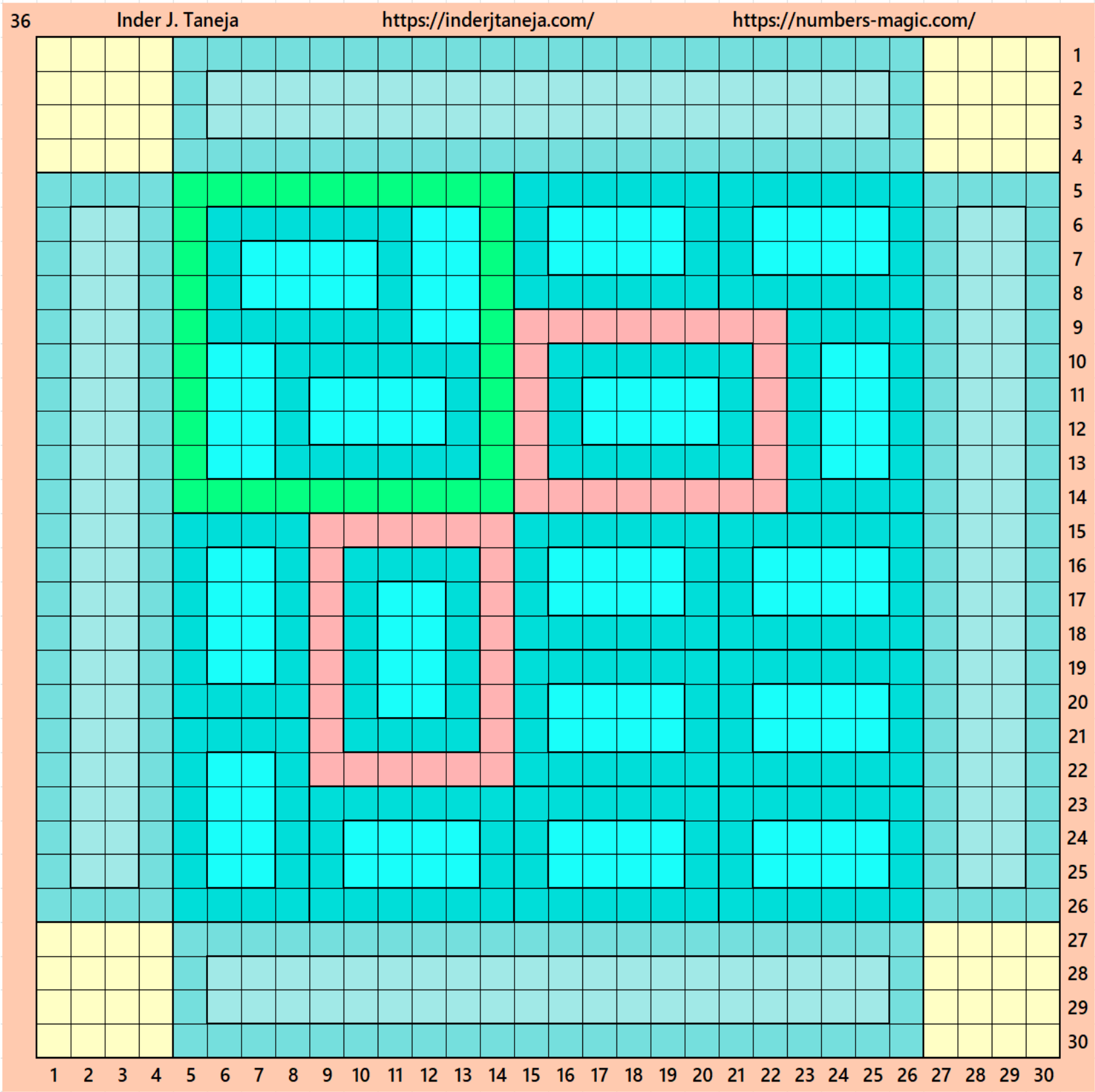


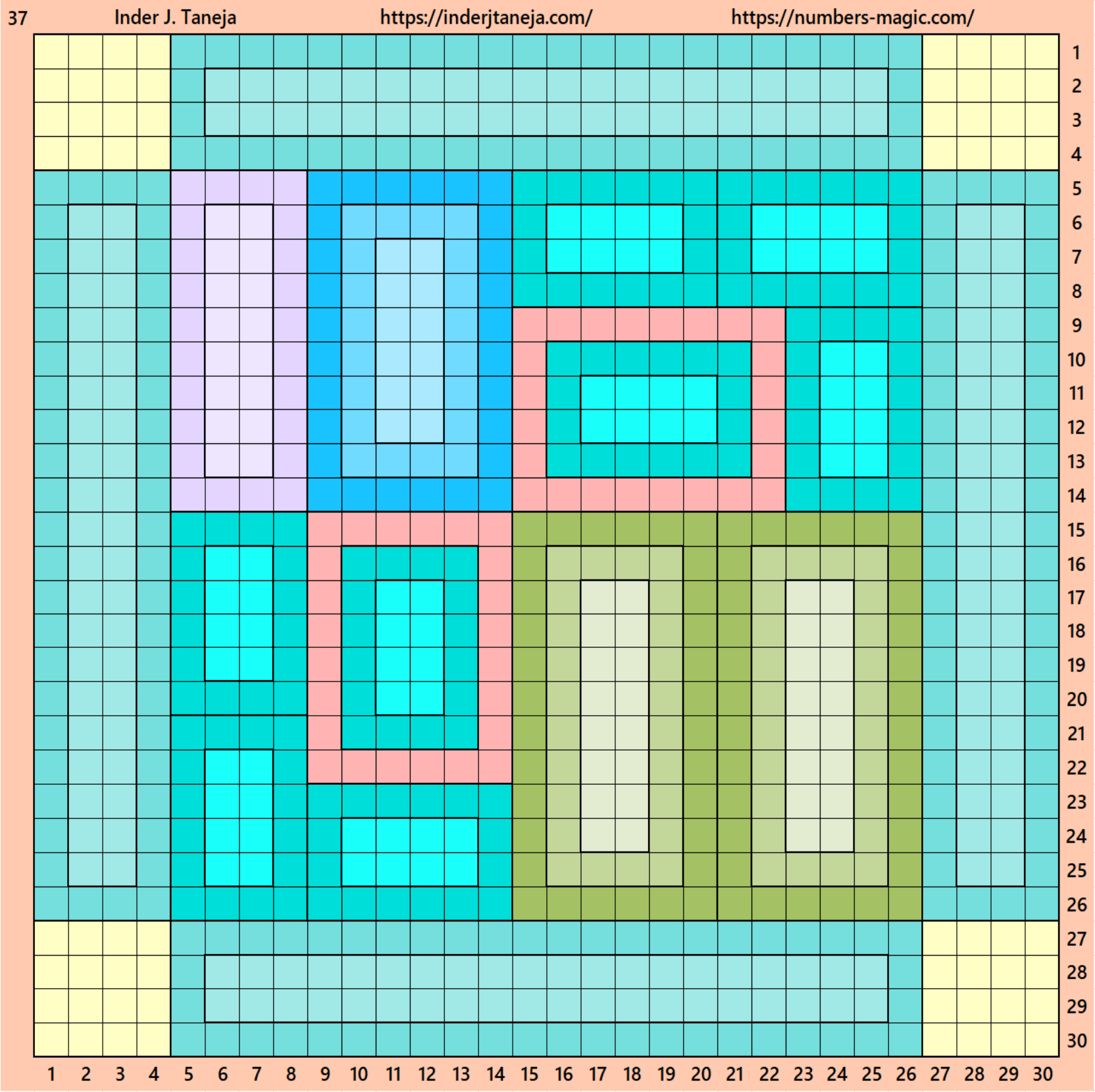








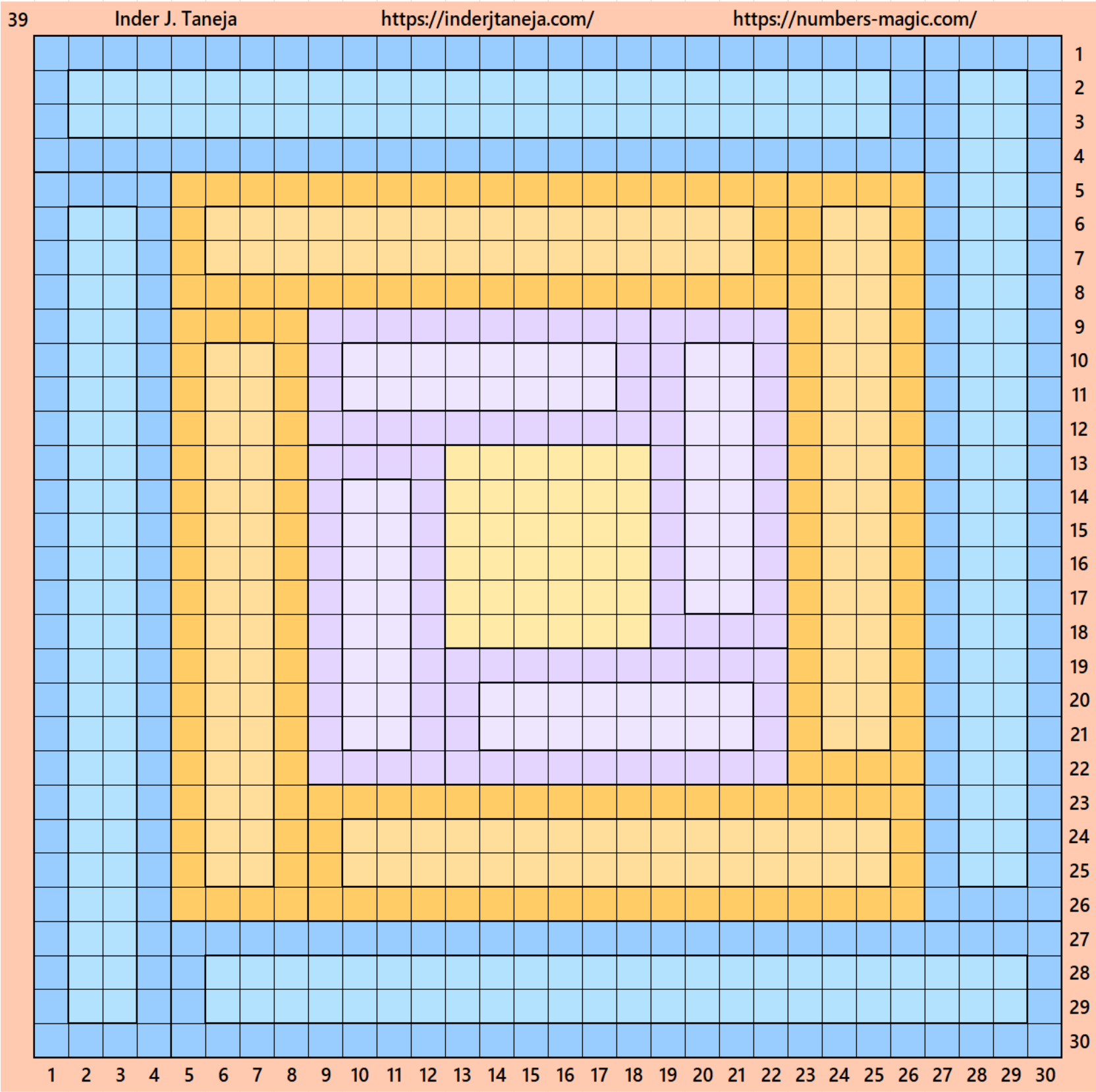


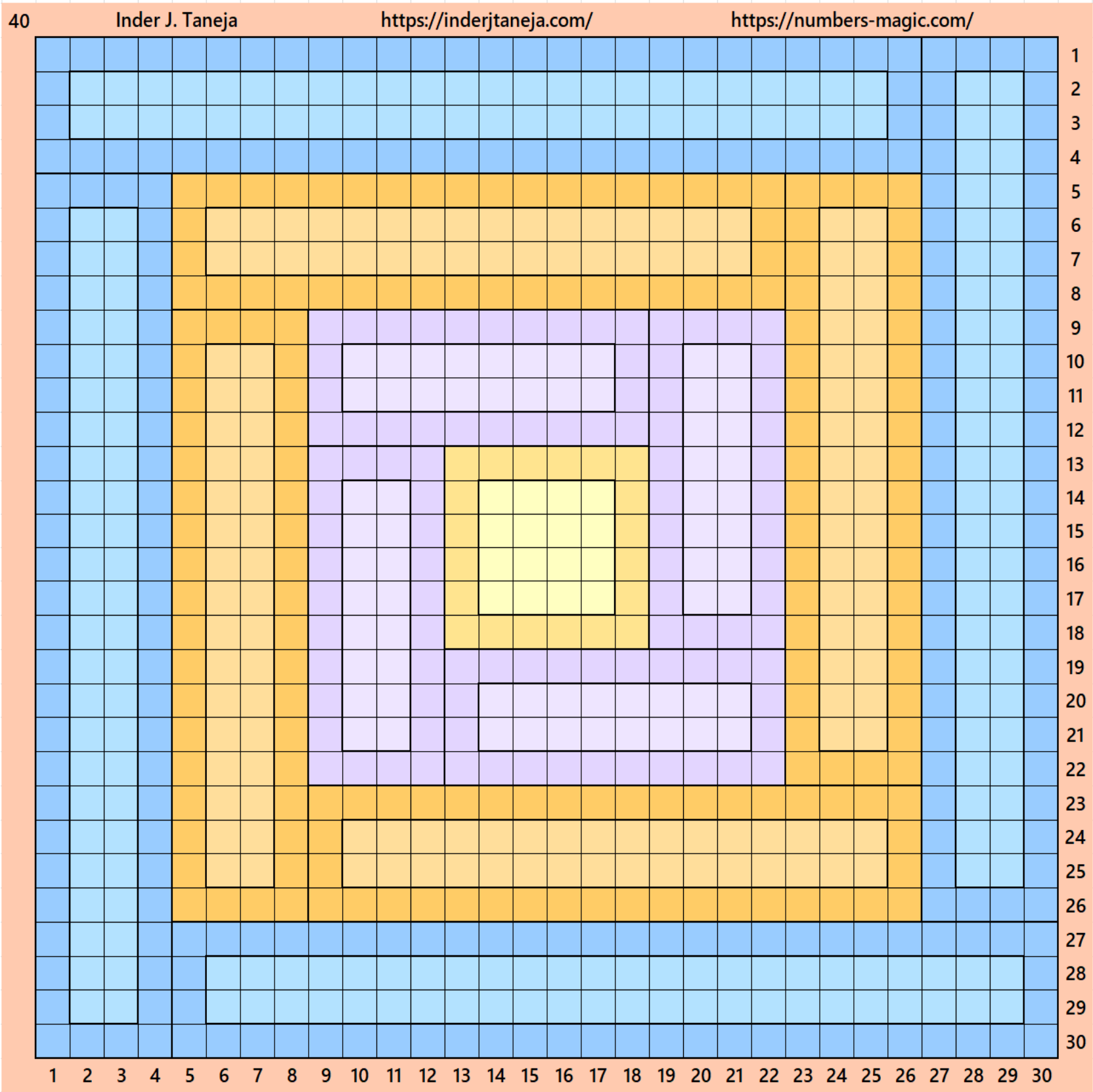


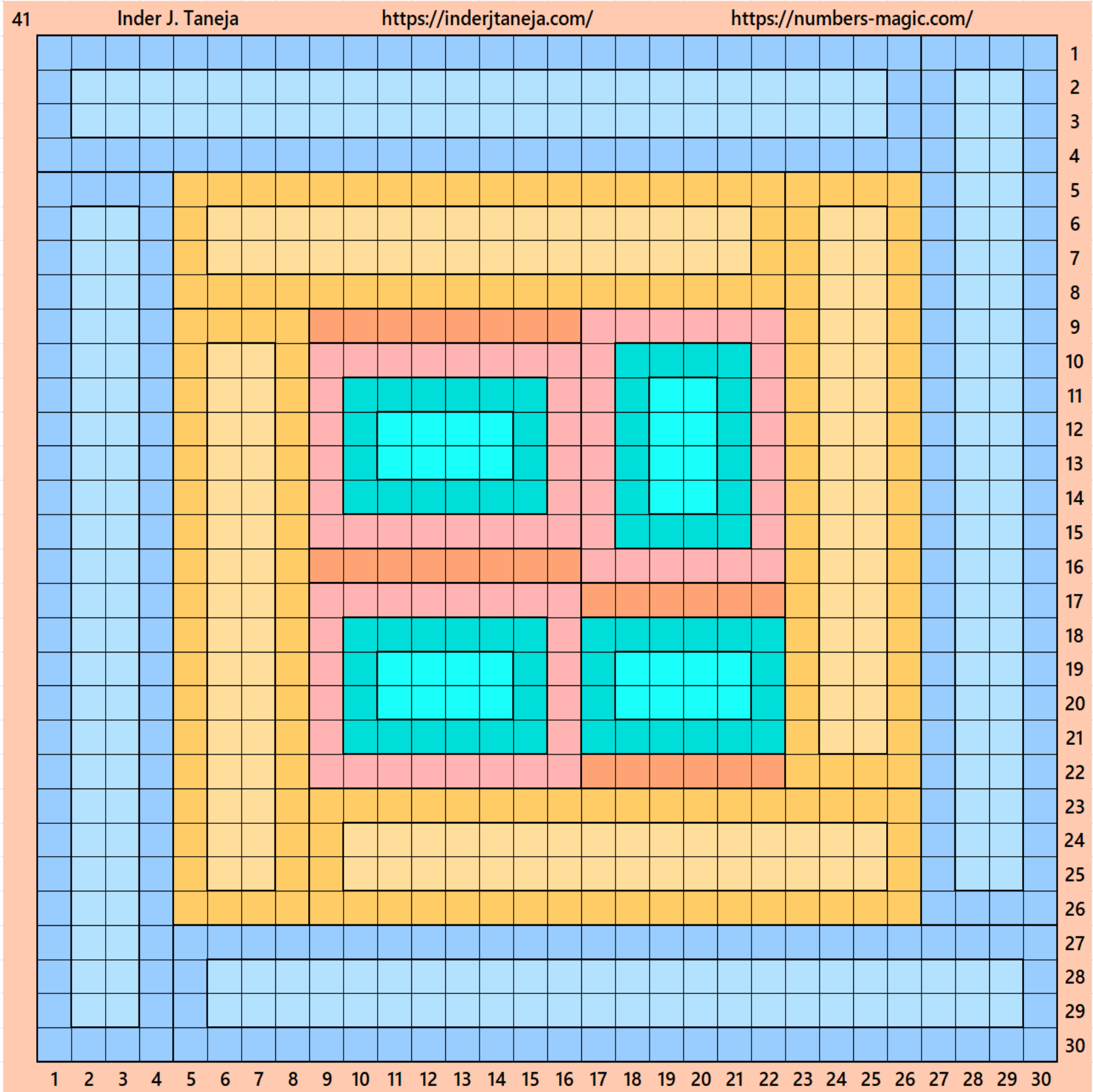
2.4 Closed Border of Order 4

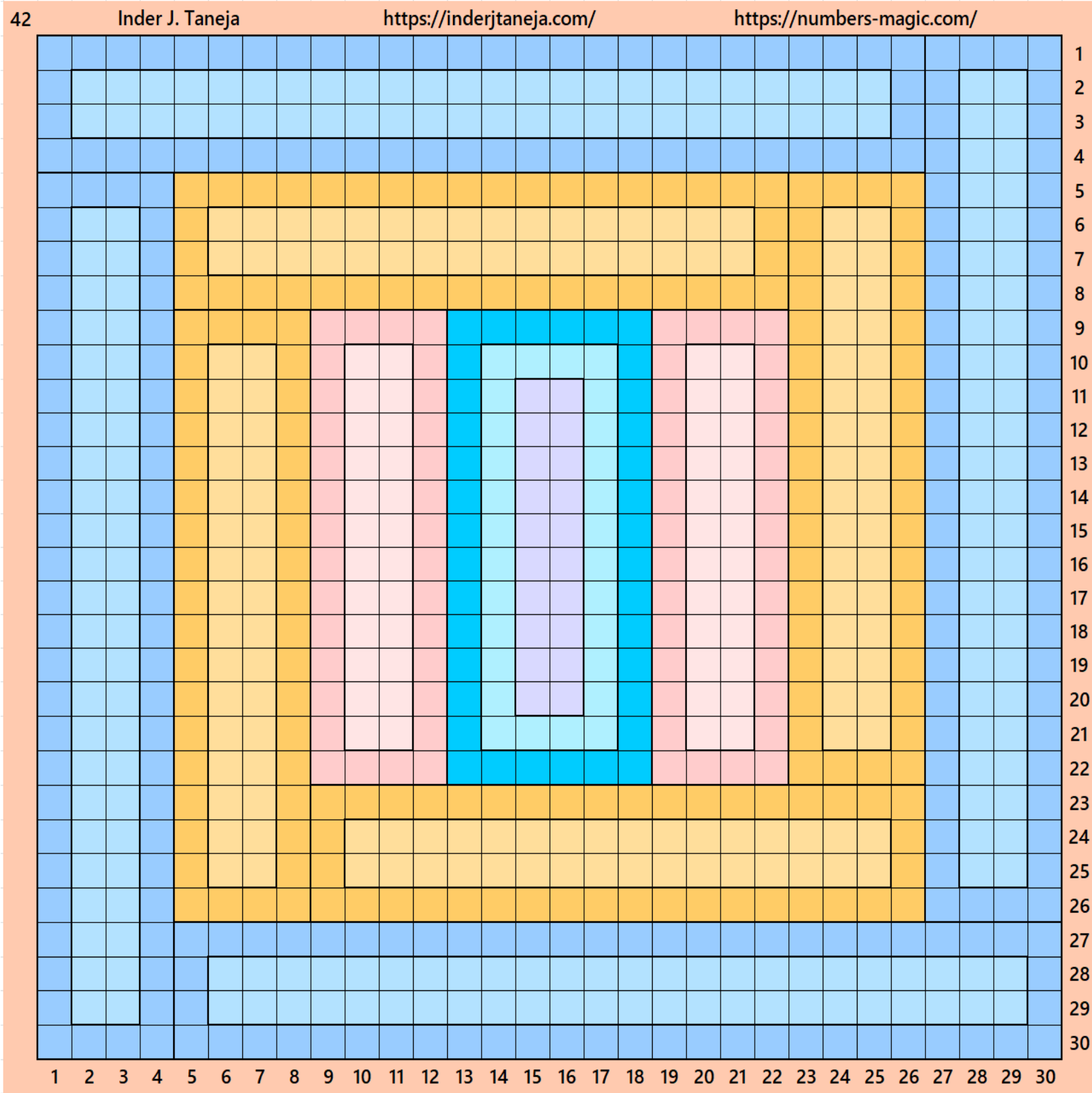
The external border is made with 4 BMRs of order 4×26 . We are left with inner block of order 22. Writing this middle blocks with different types of magic squares of order 22, we get magic squares of order 30. See below few examples:

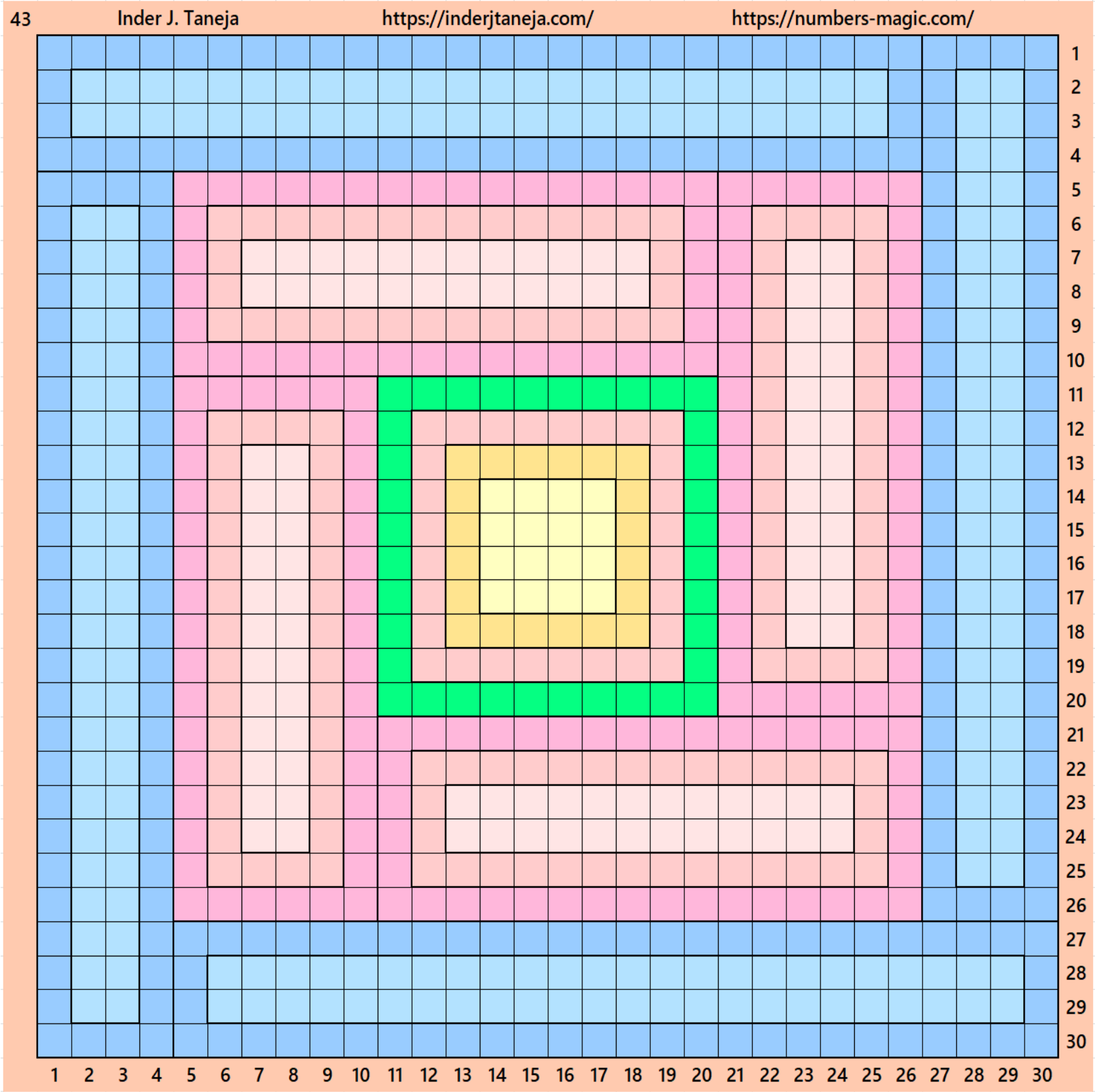


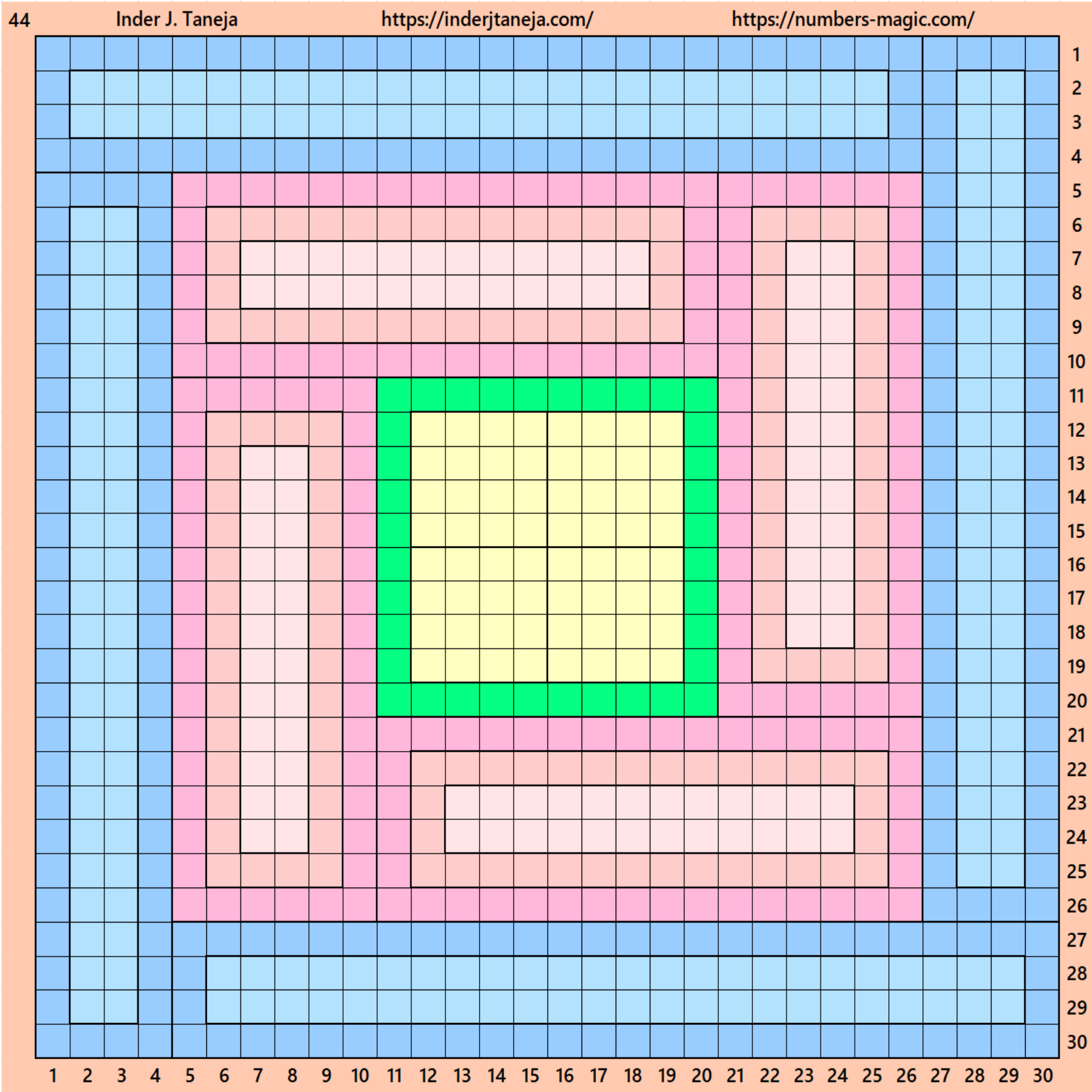


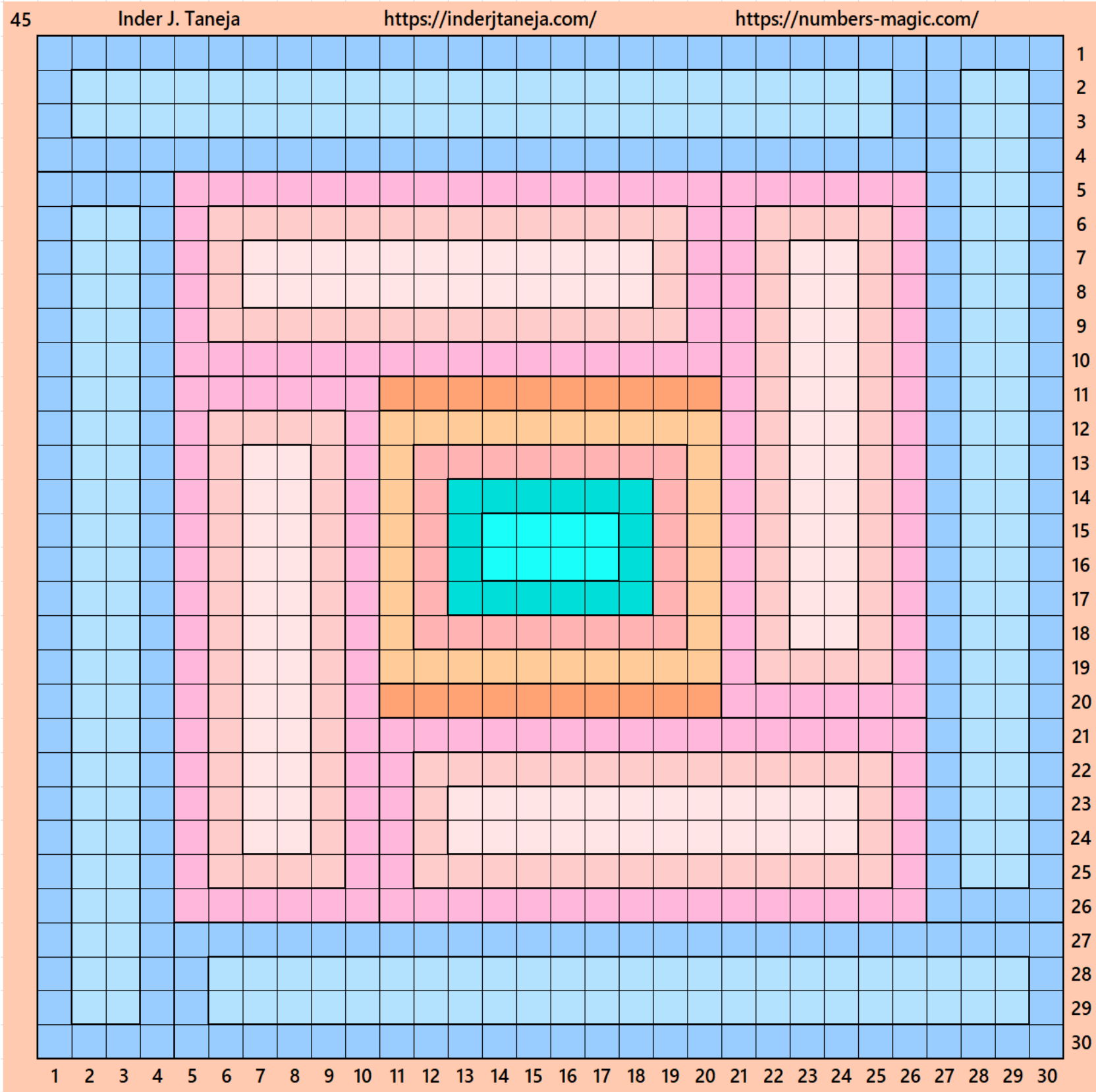


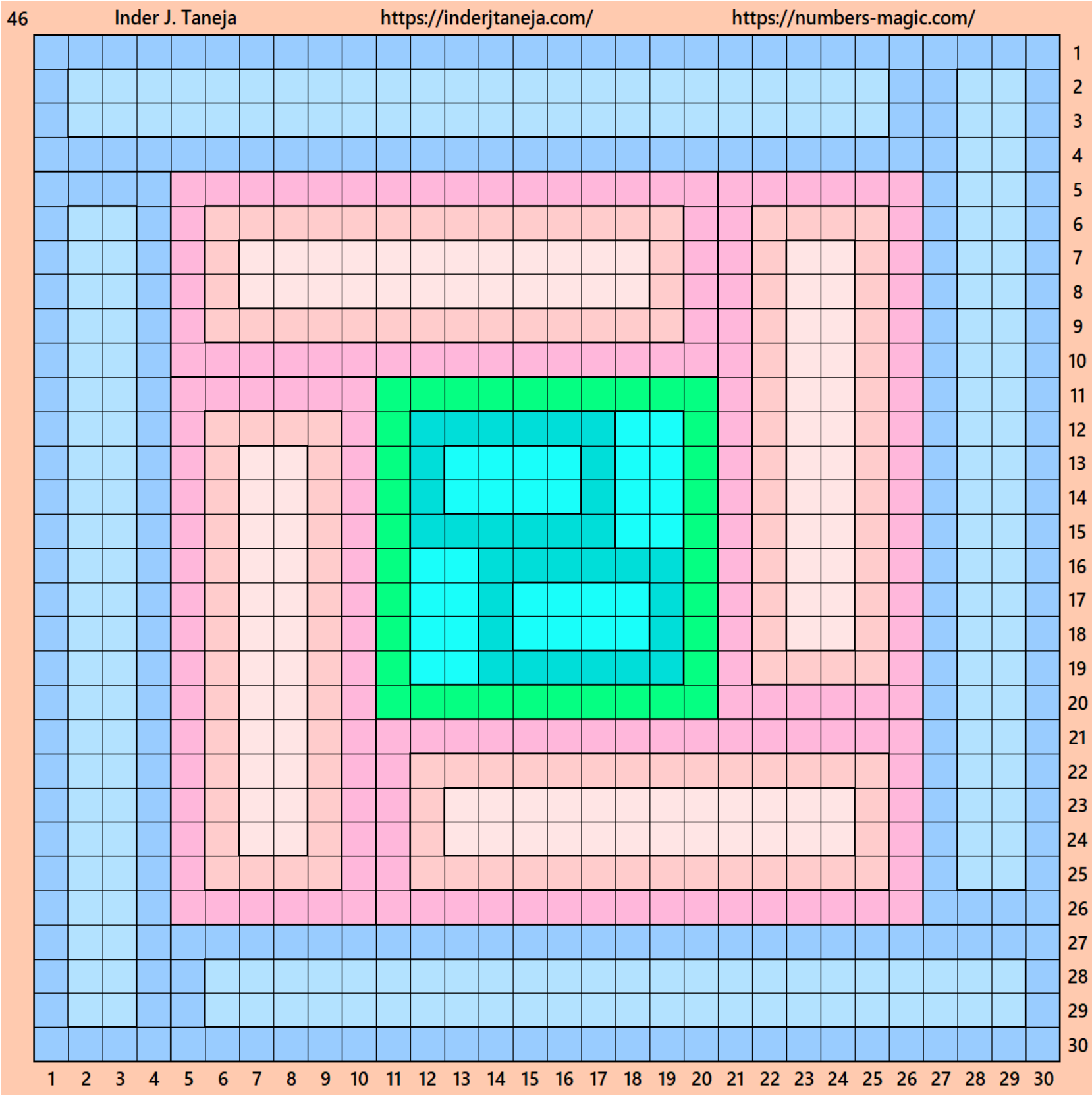


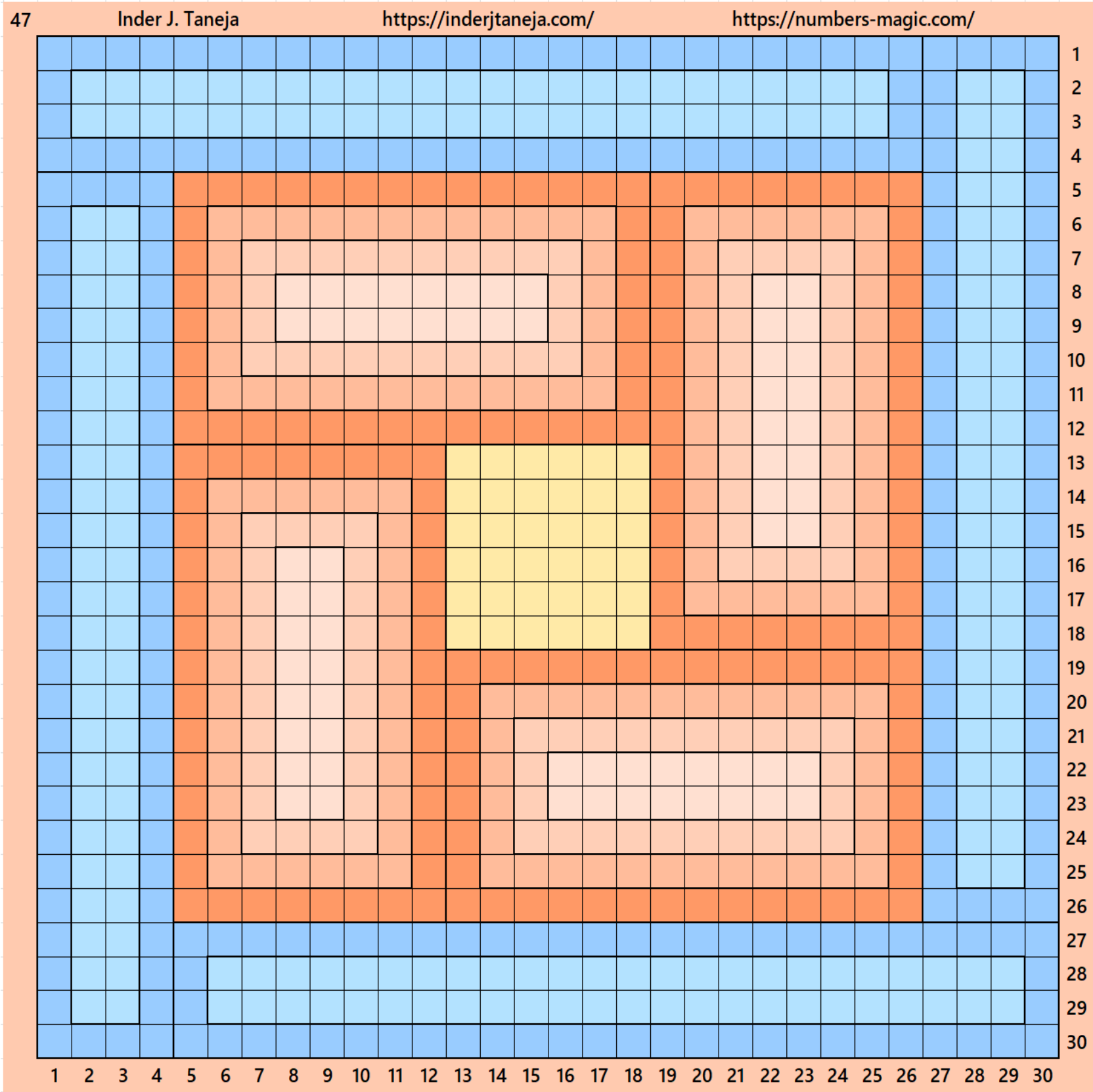


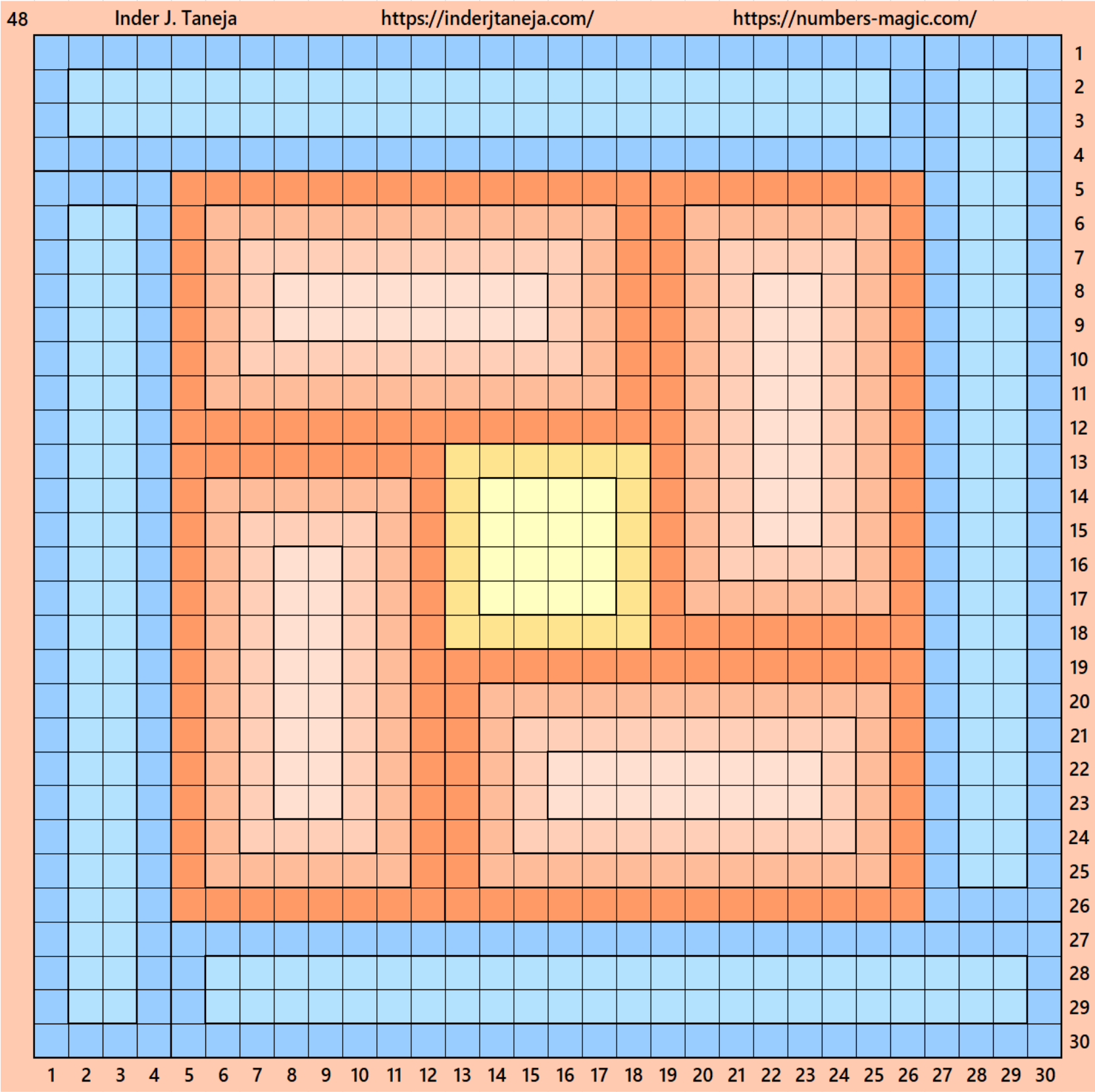


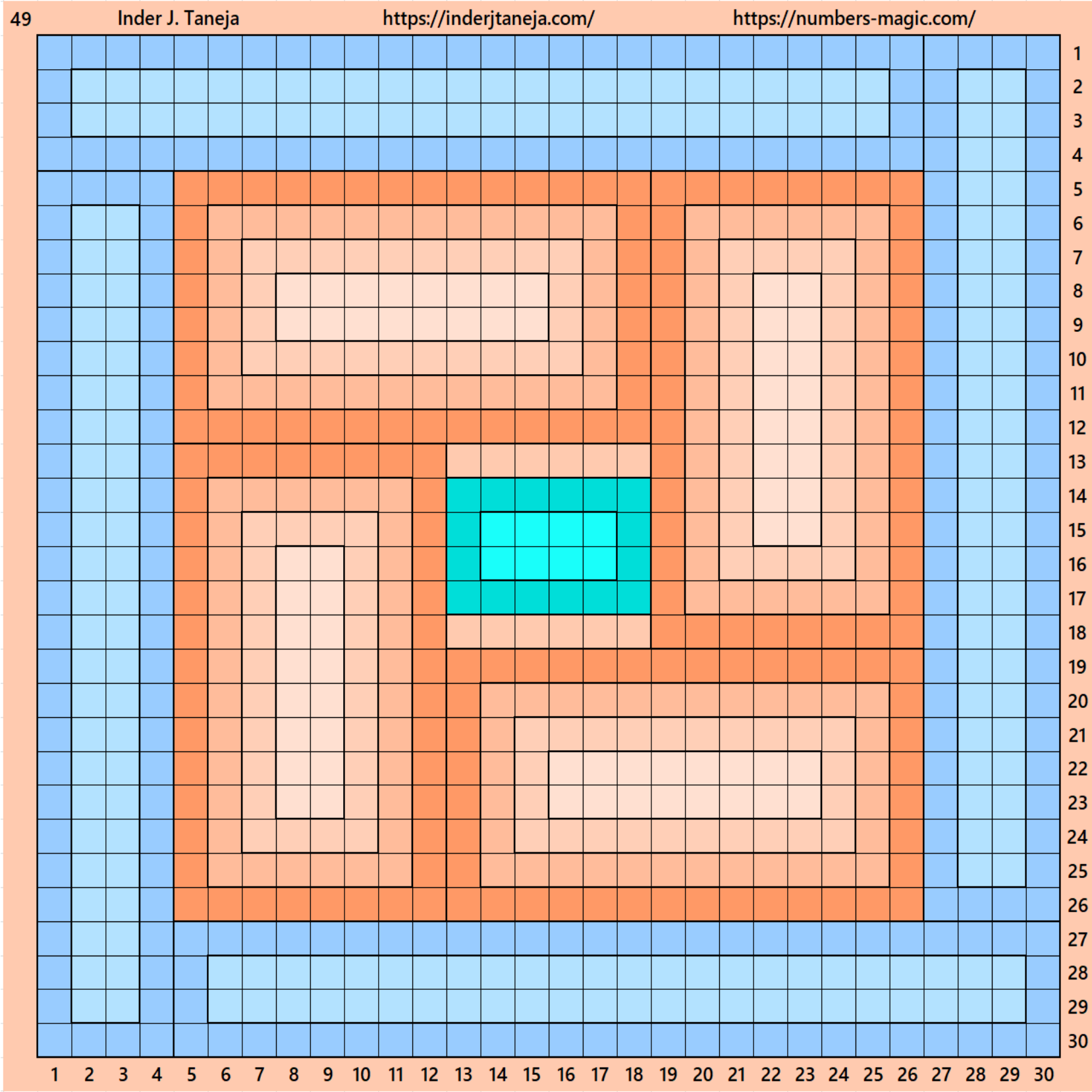


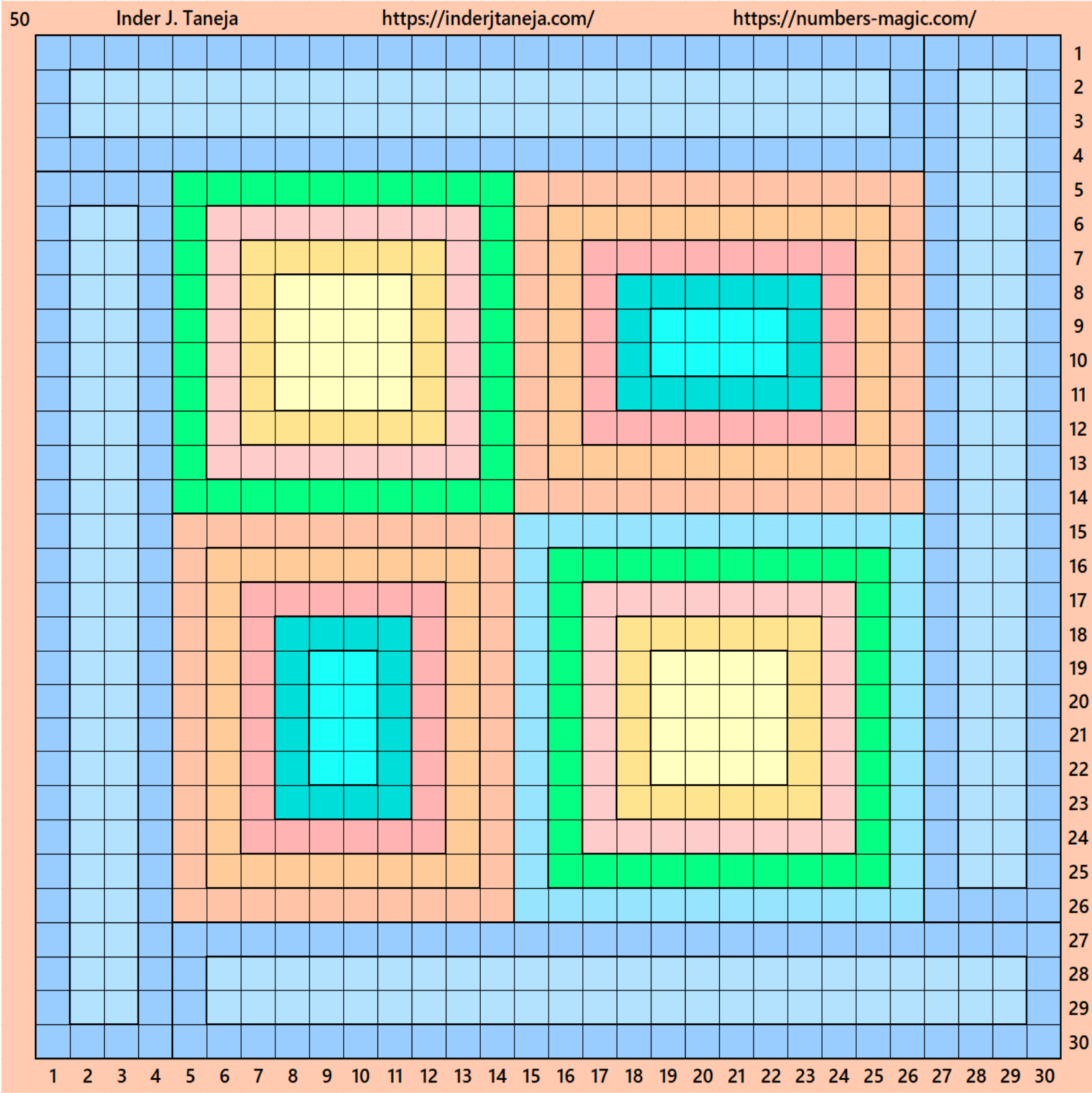


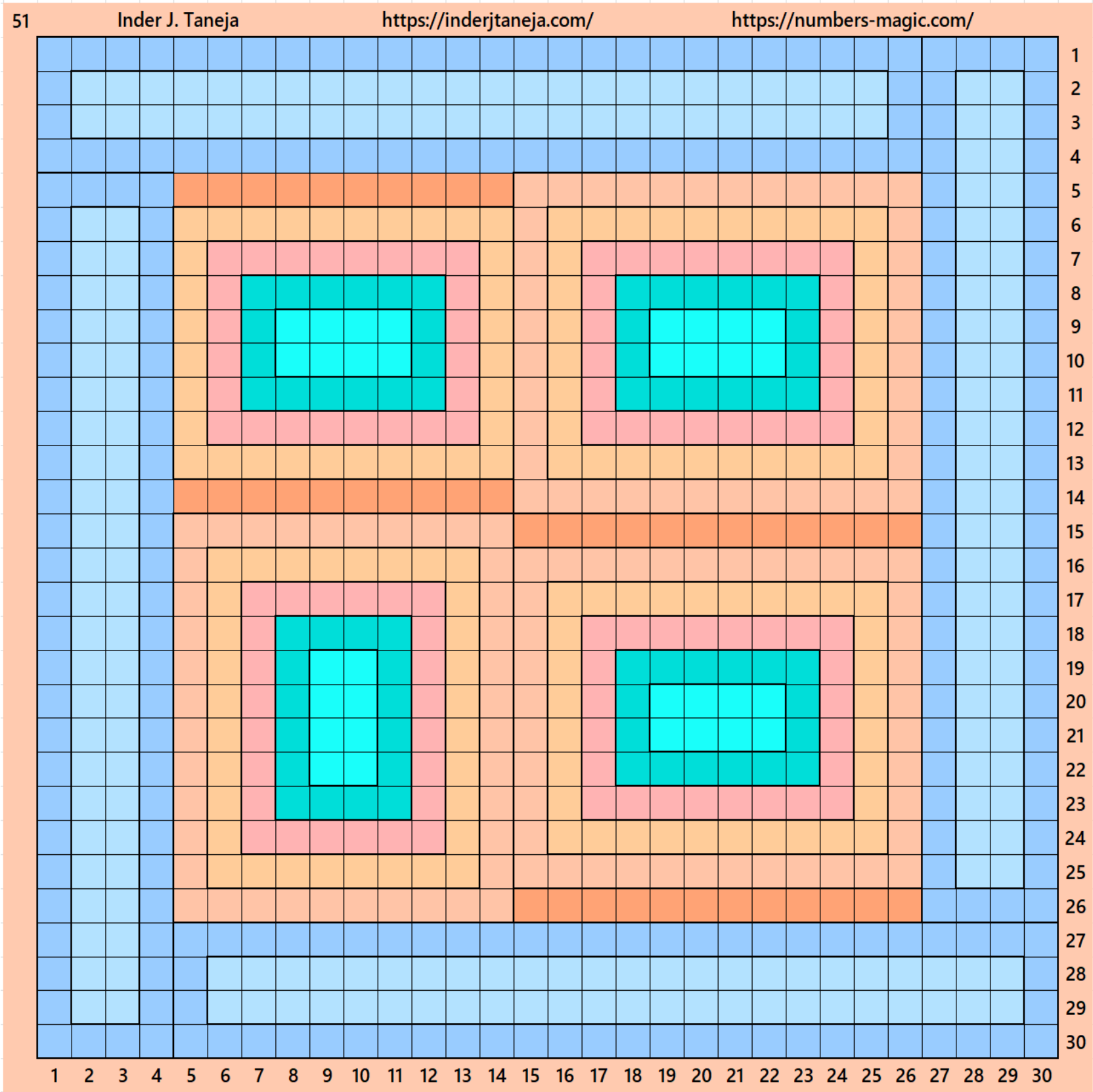




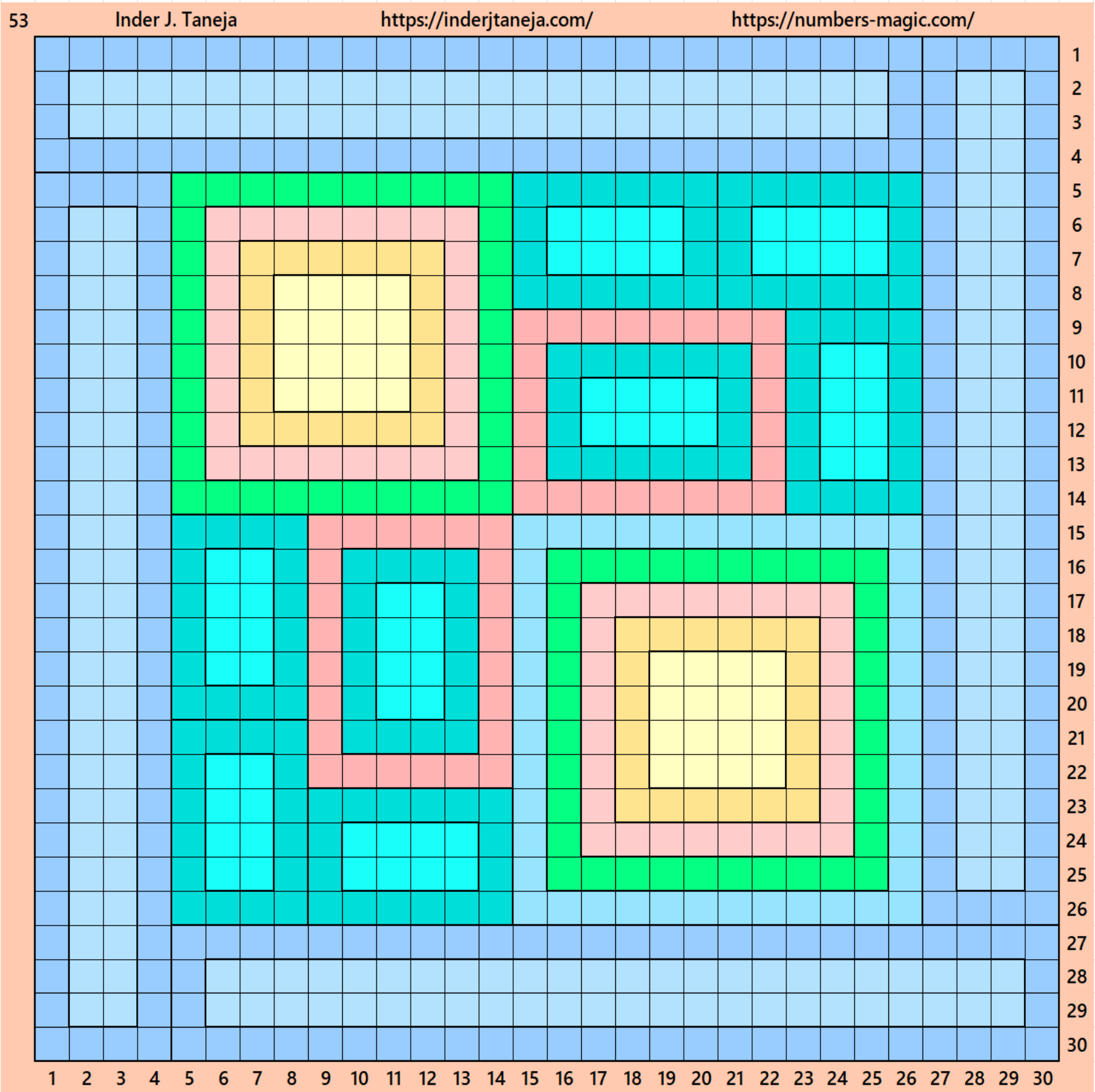


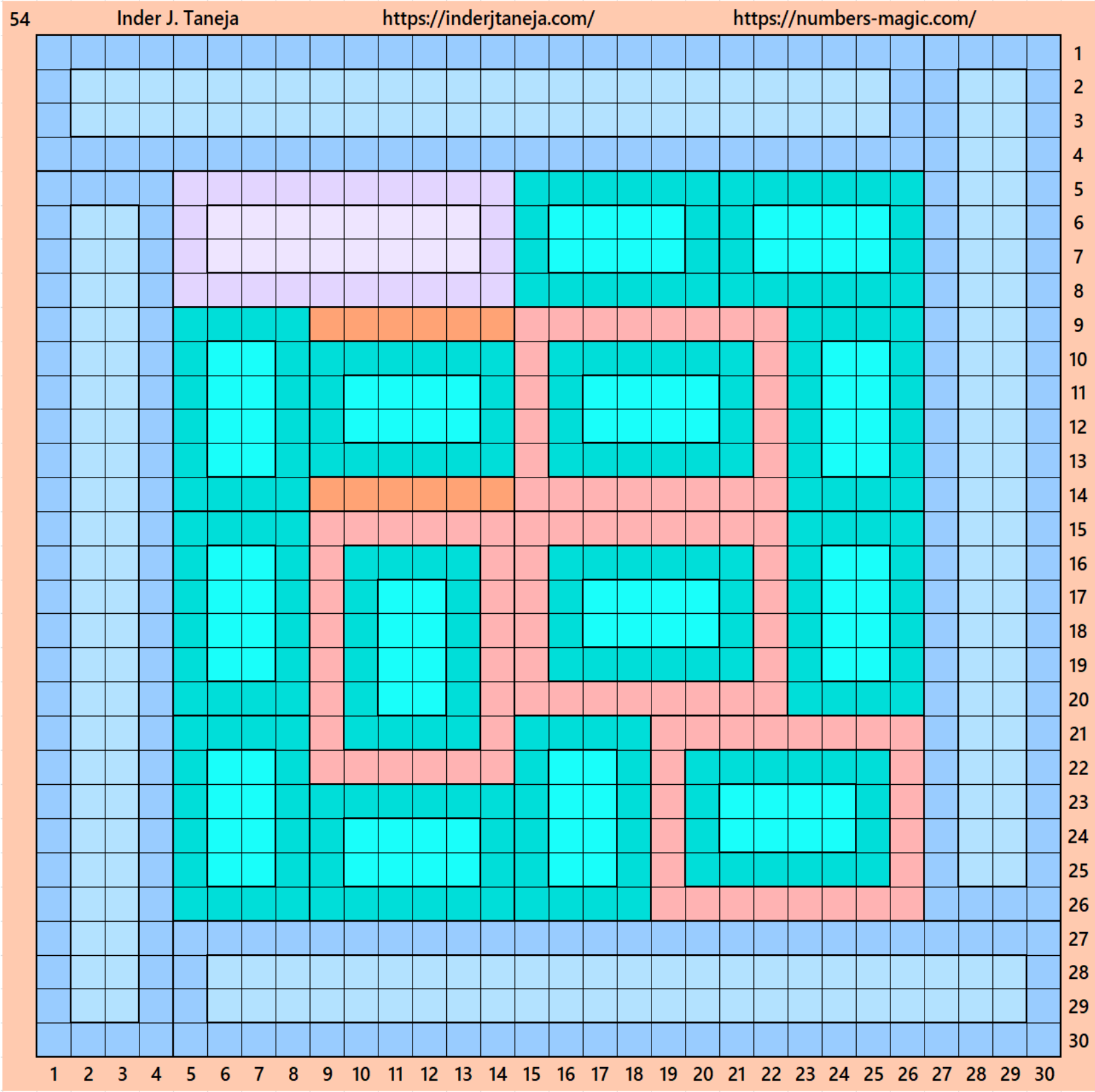


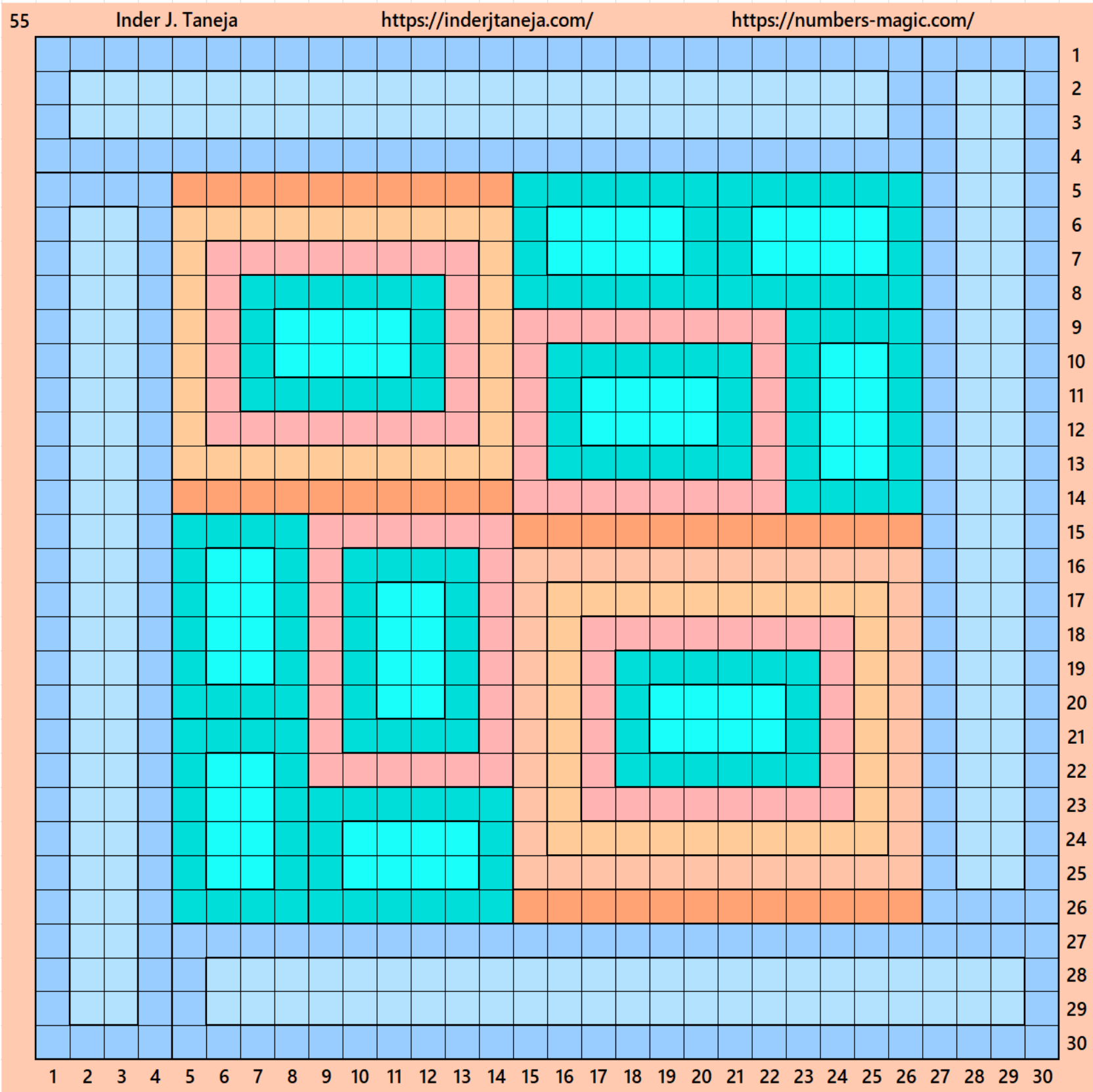


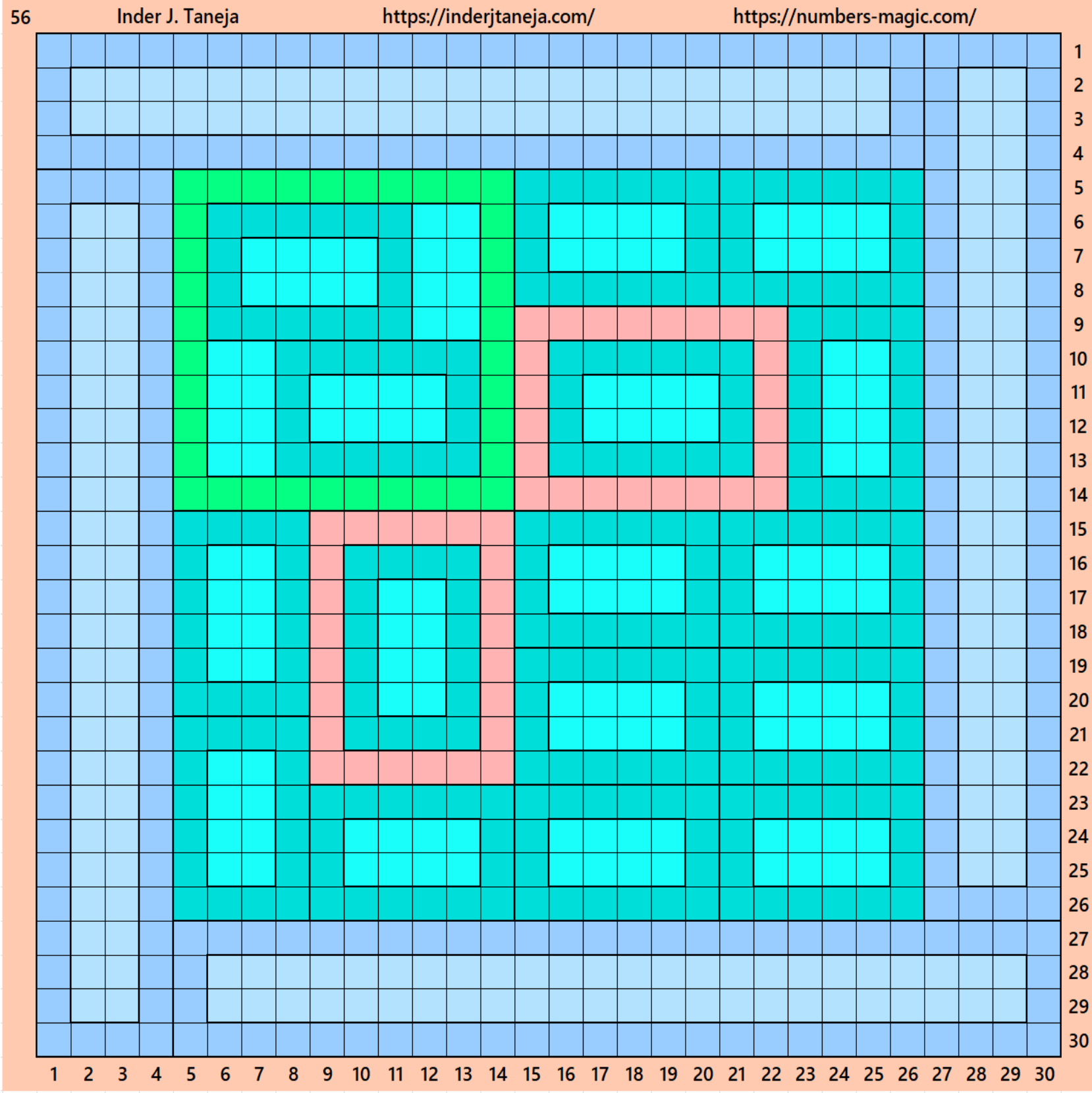


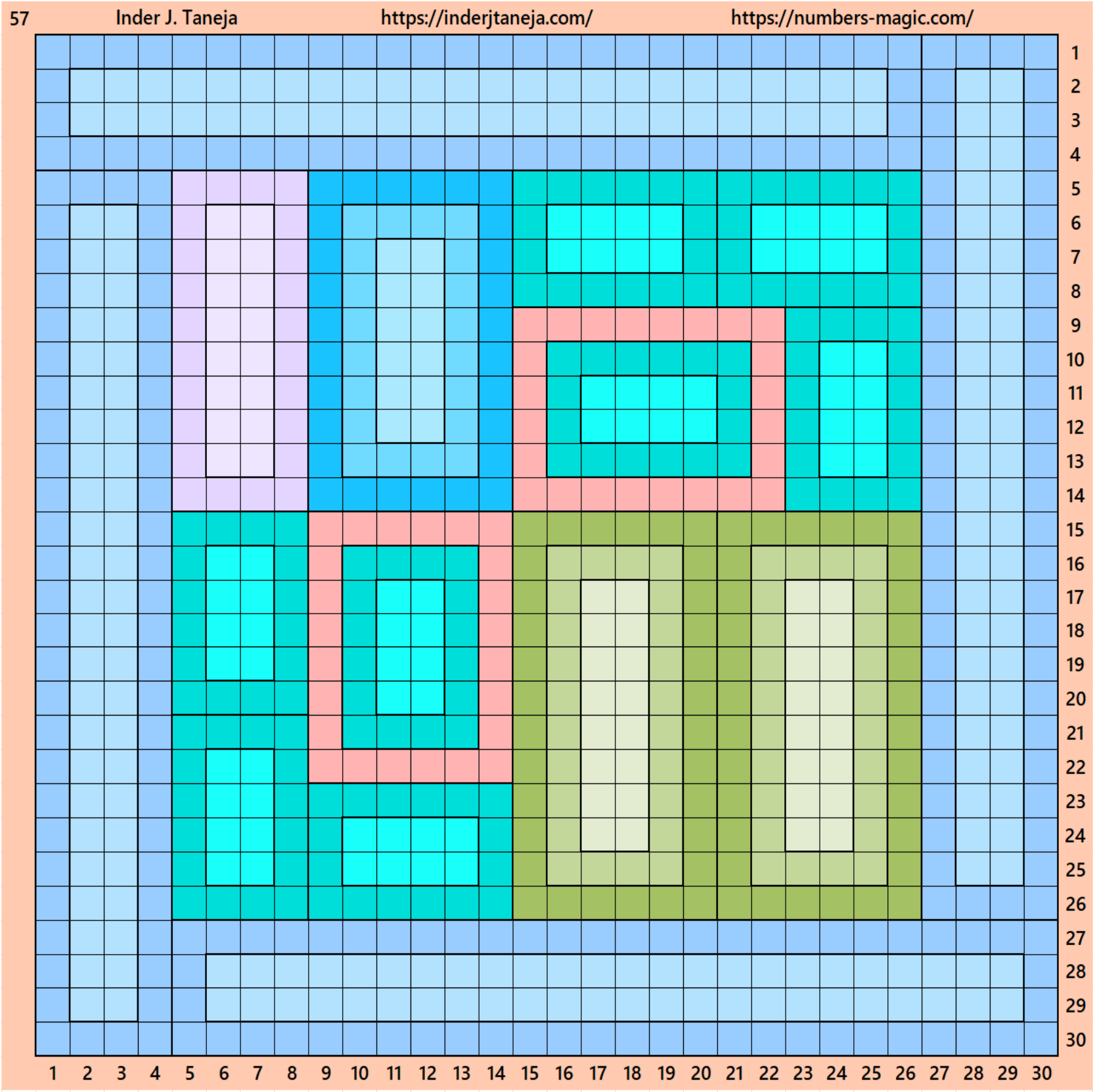






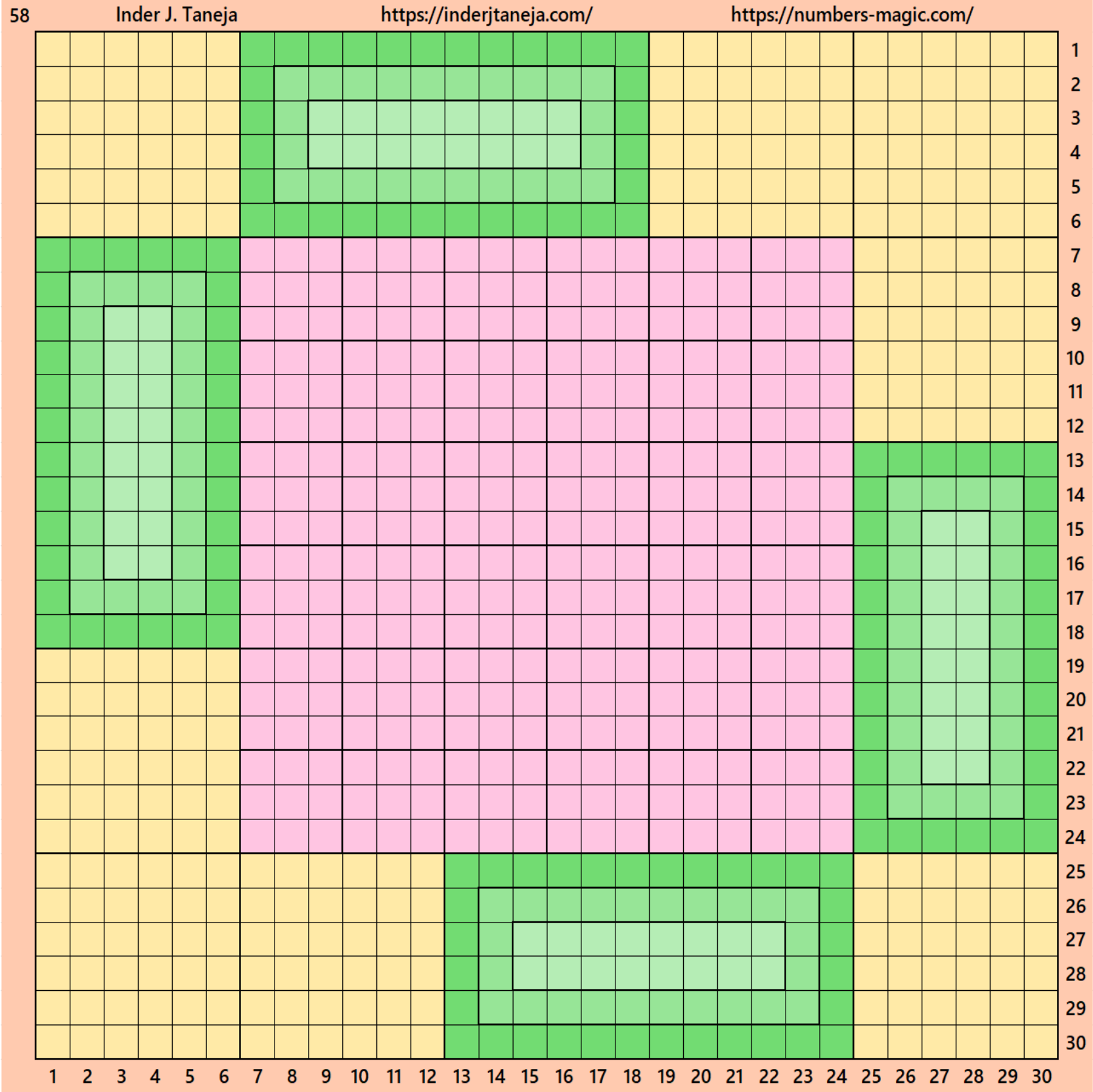


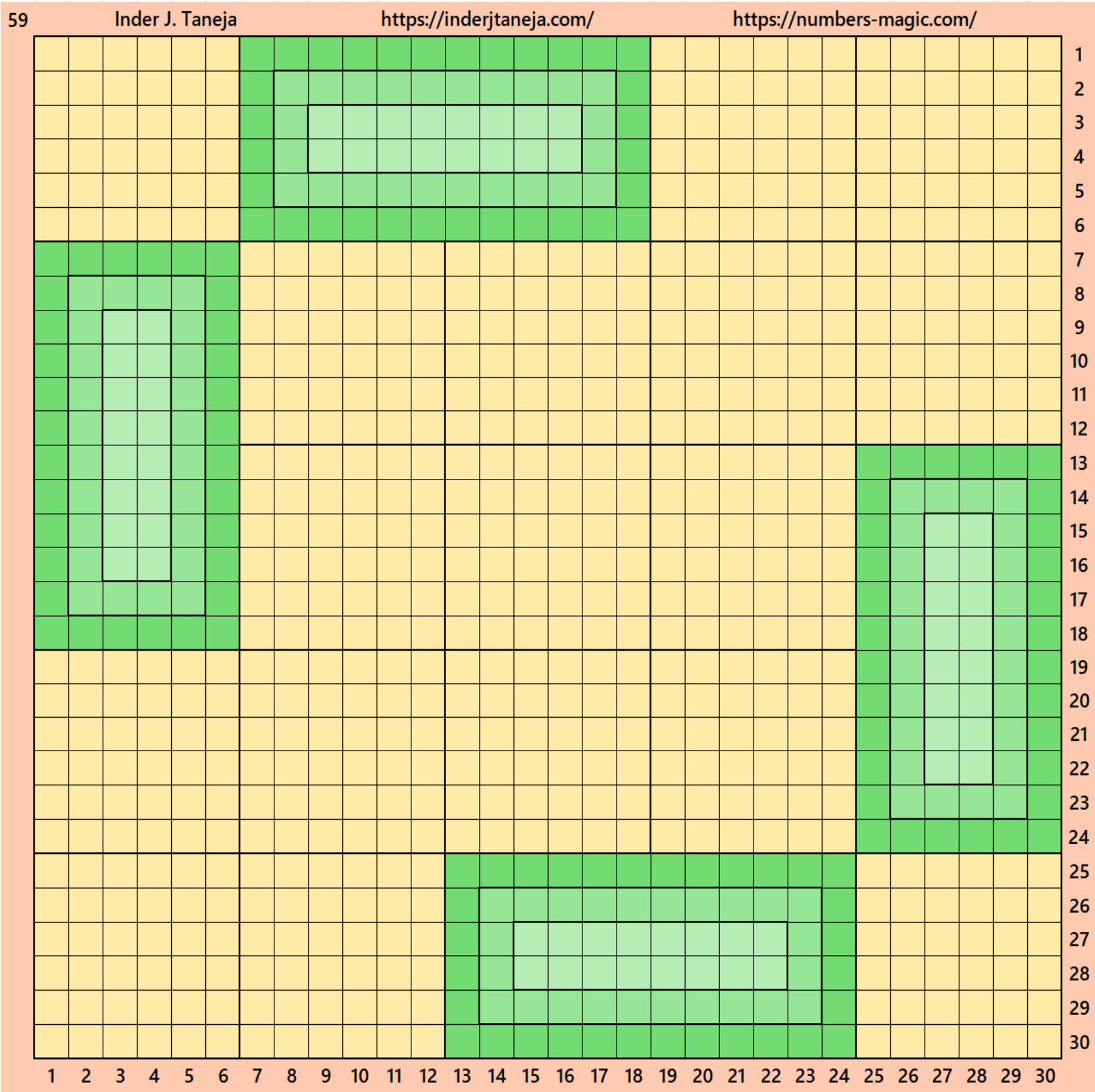


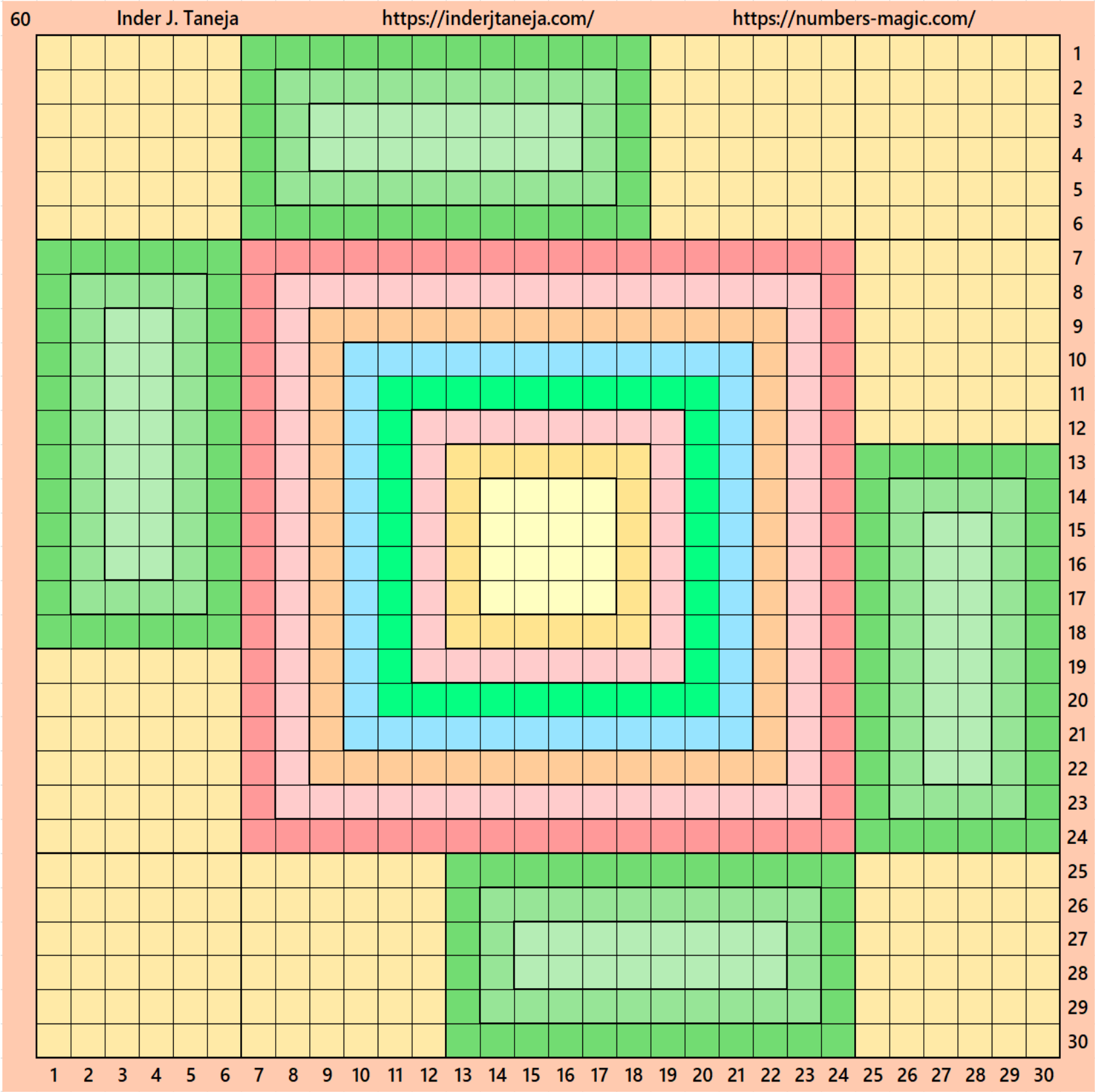


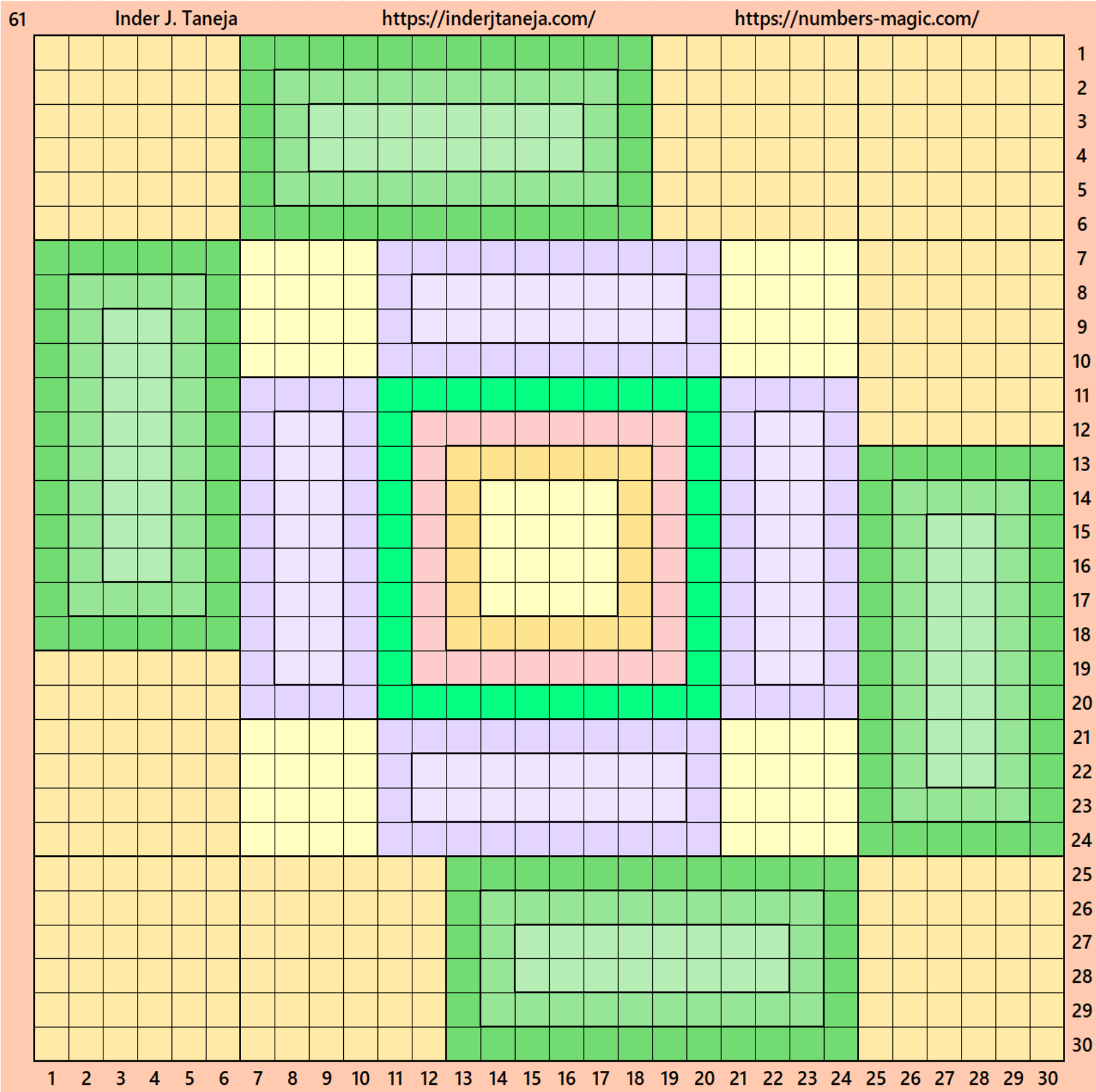
2.5 Cornered Magic Squares of Order 6

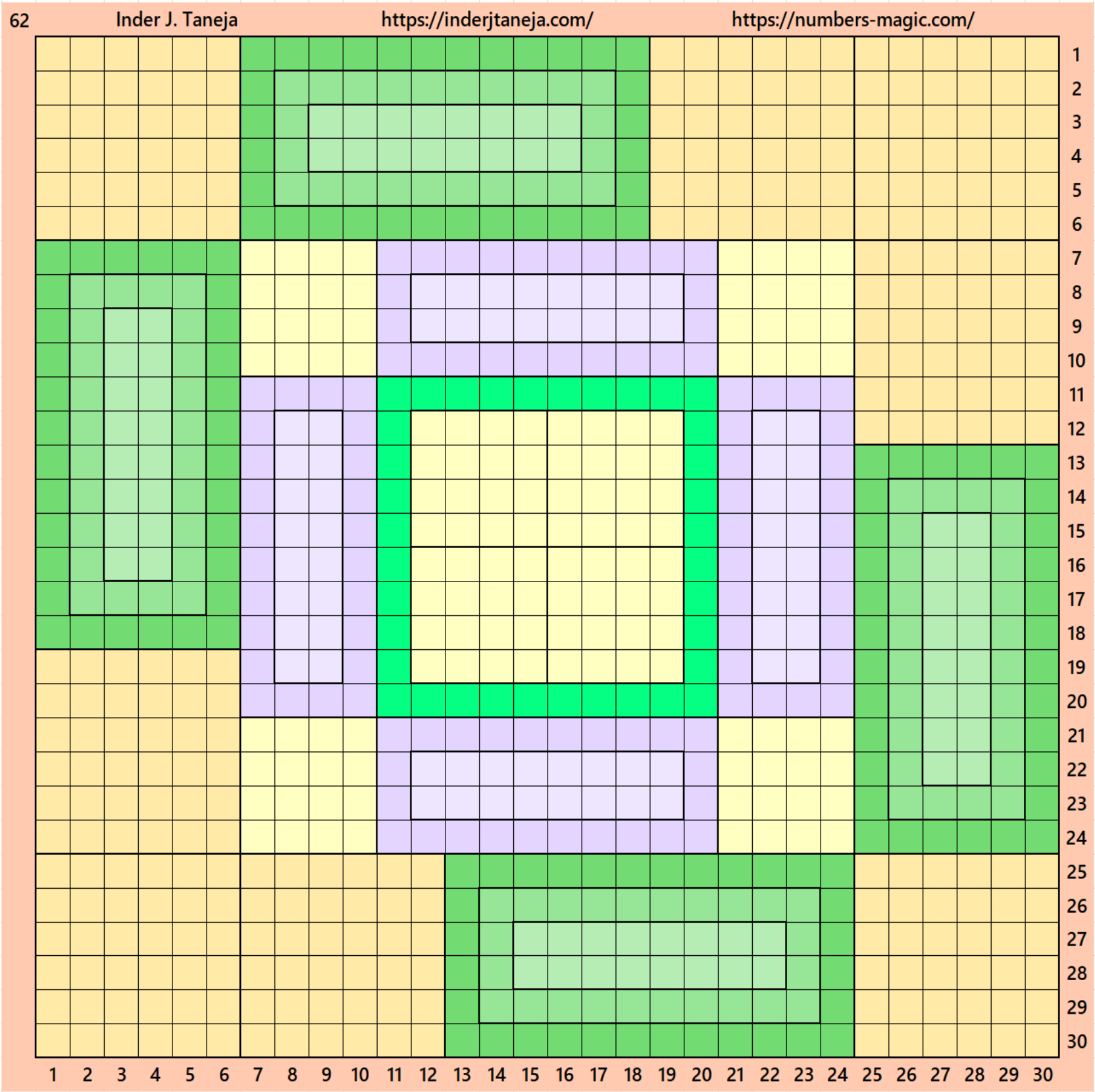
In view of Fig. 4 given in subsection 2.1, we don't require to make cornered blocks of order 6. But we have considered below just as an extra option. Let's consider an external border, where there are 8 magic squares of order 6 and 4 BMRs of order 6×12 . This gives us an external border with cornered magic squares of order 6. In the middle we are left with block of order 18. Writing this middle blocks with different types of magic squares of order 18, we get magic squares of order 30. See below few examples:

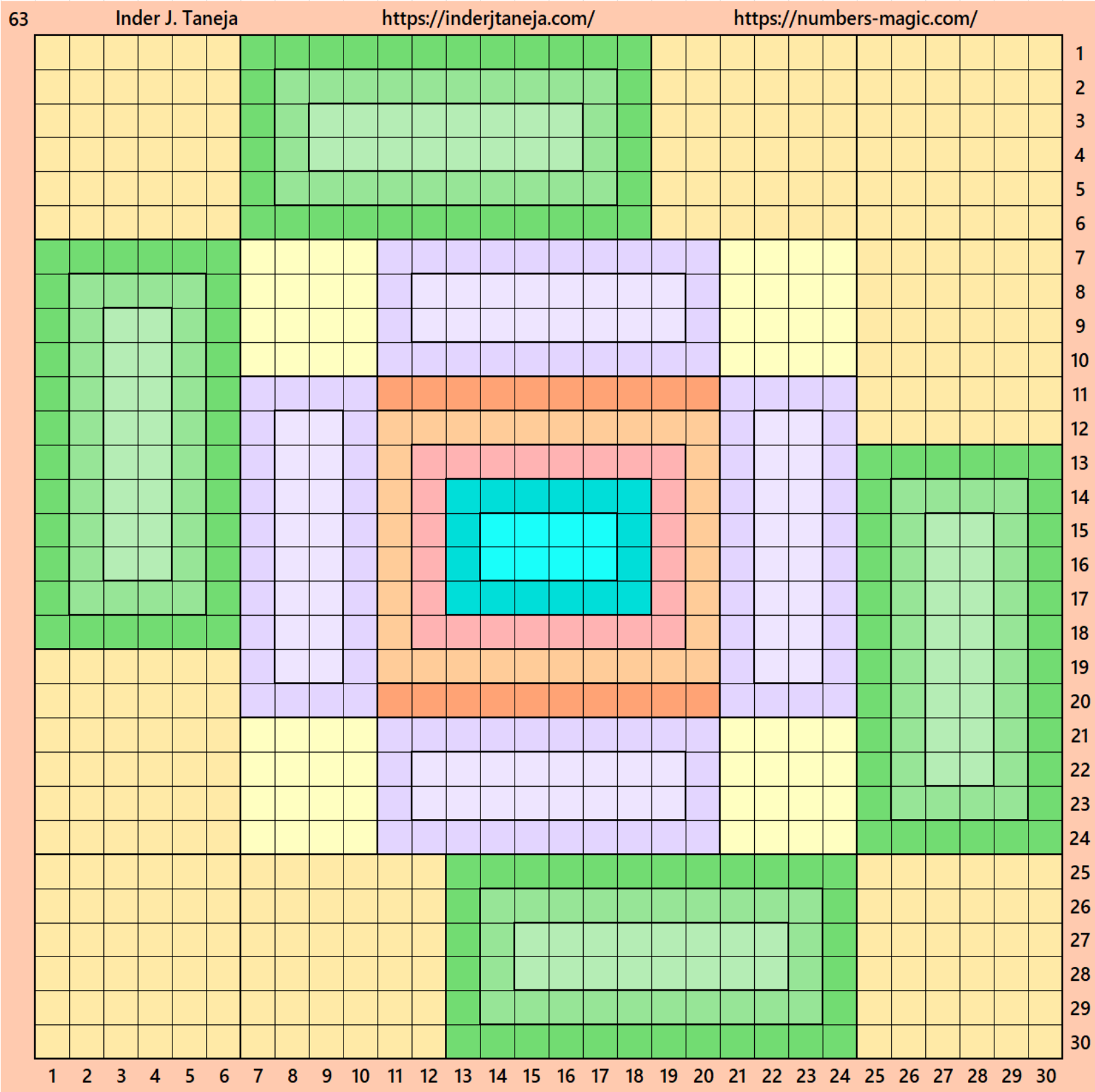


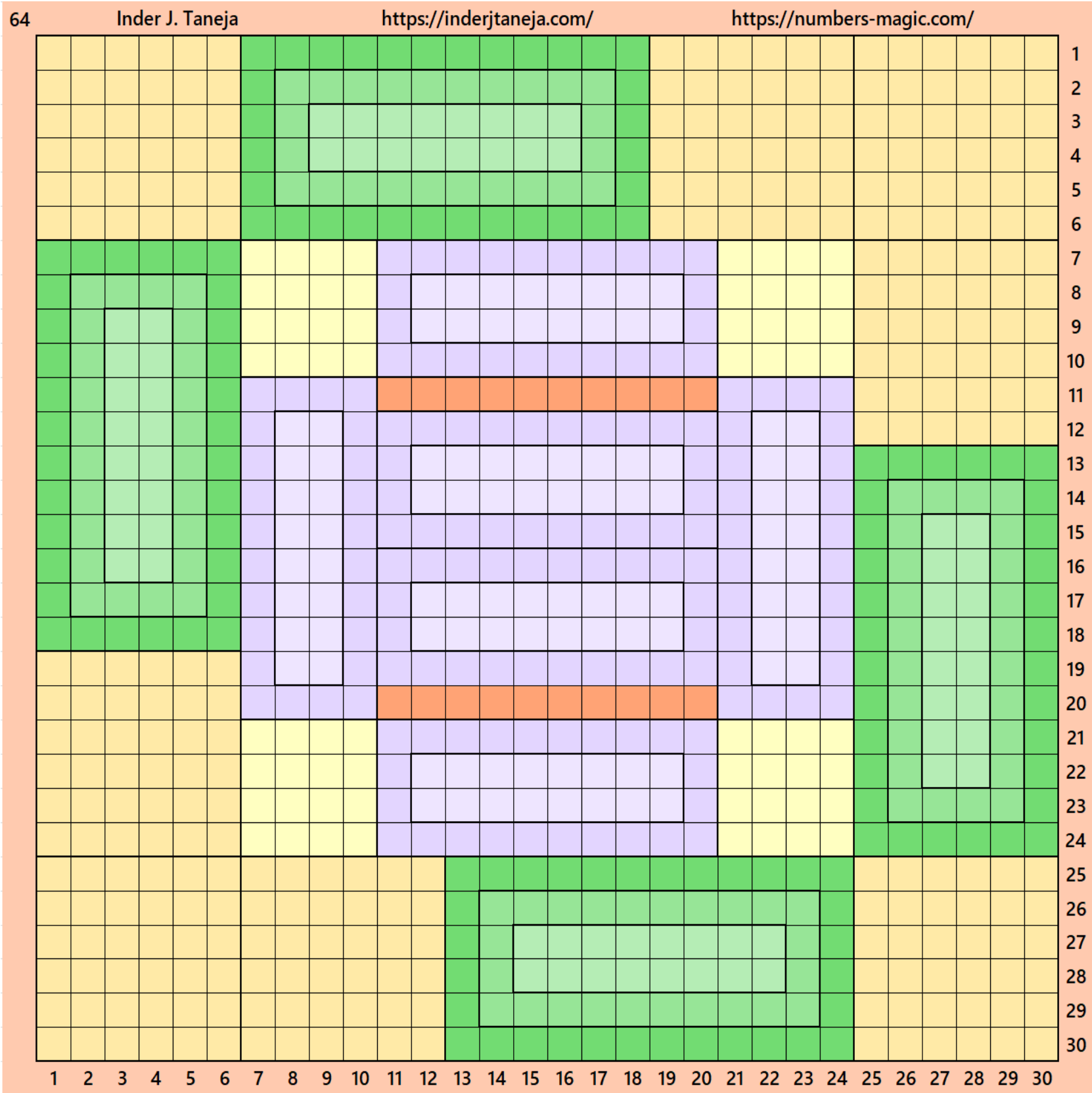


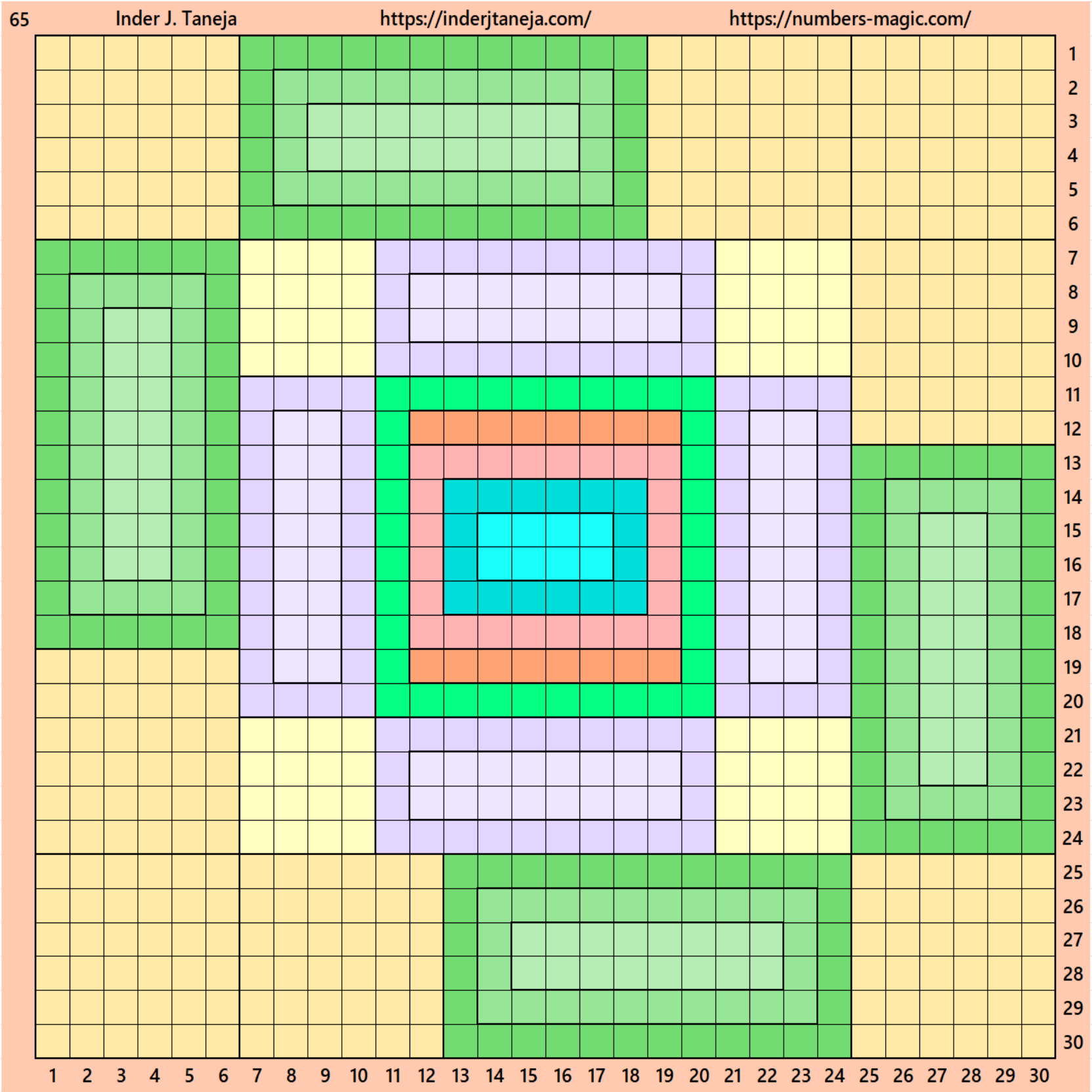


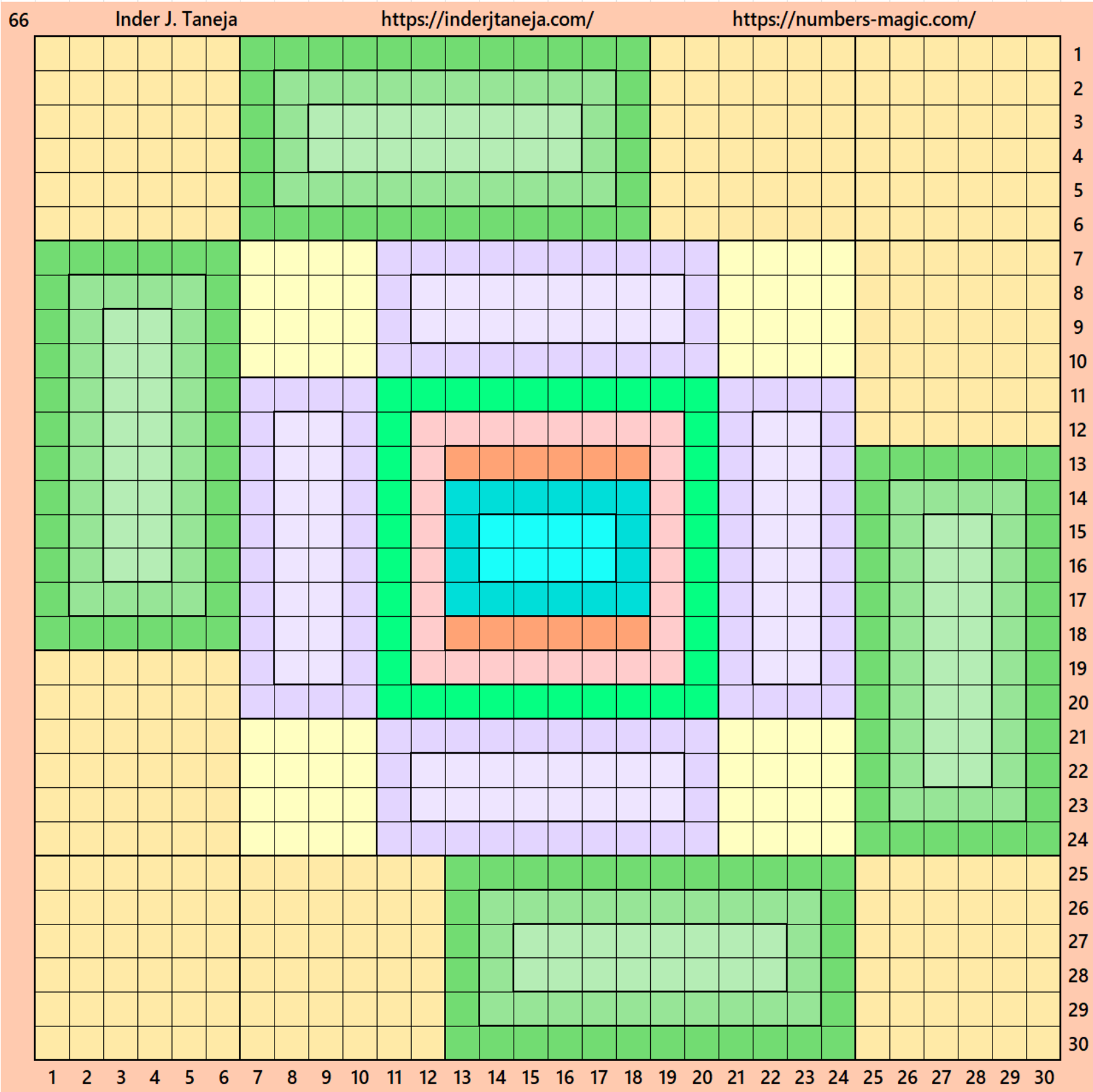


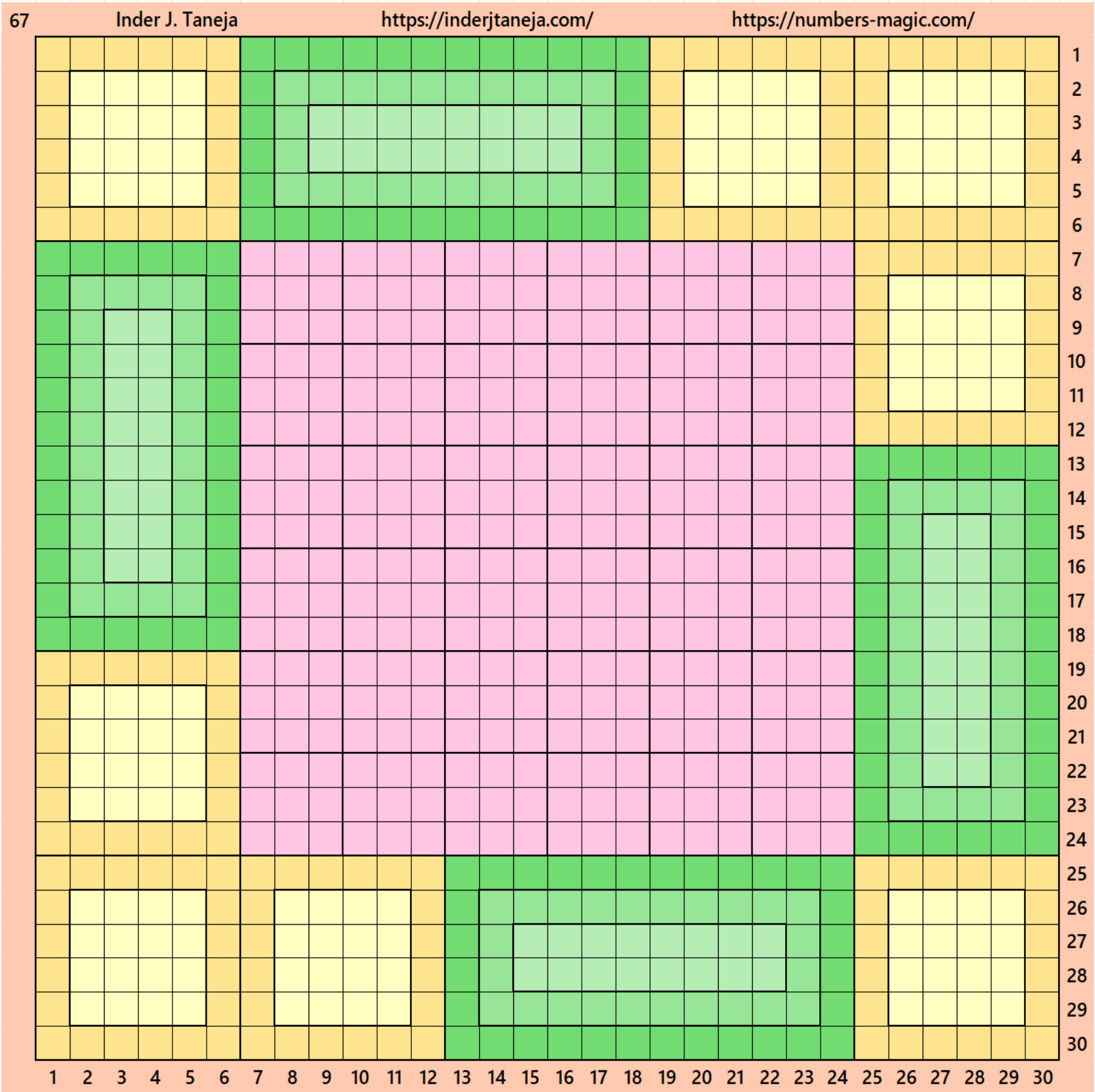


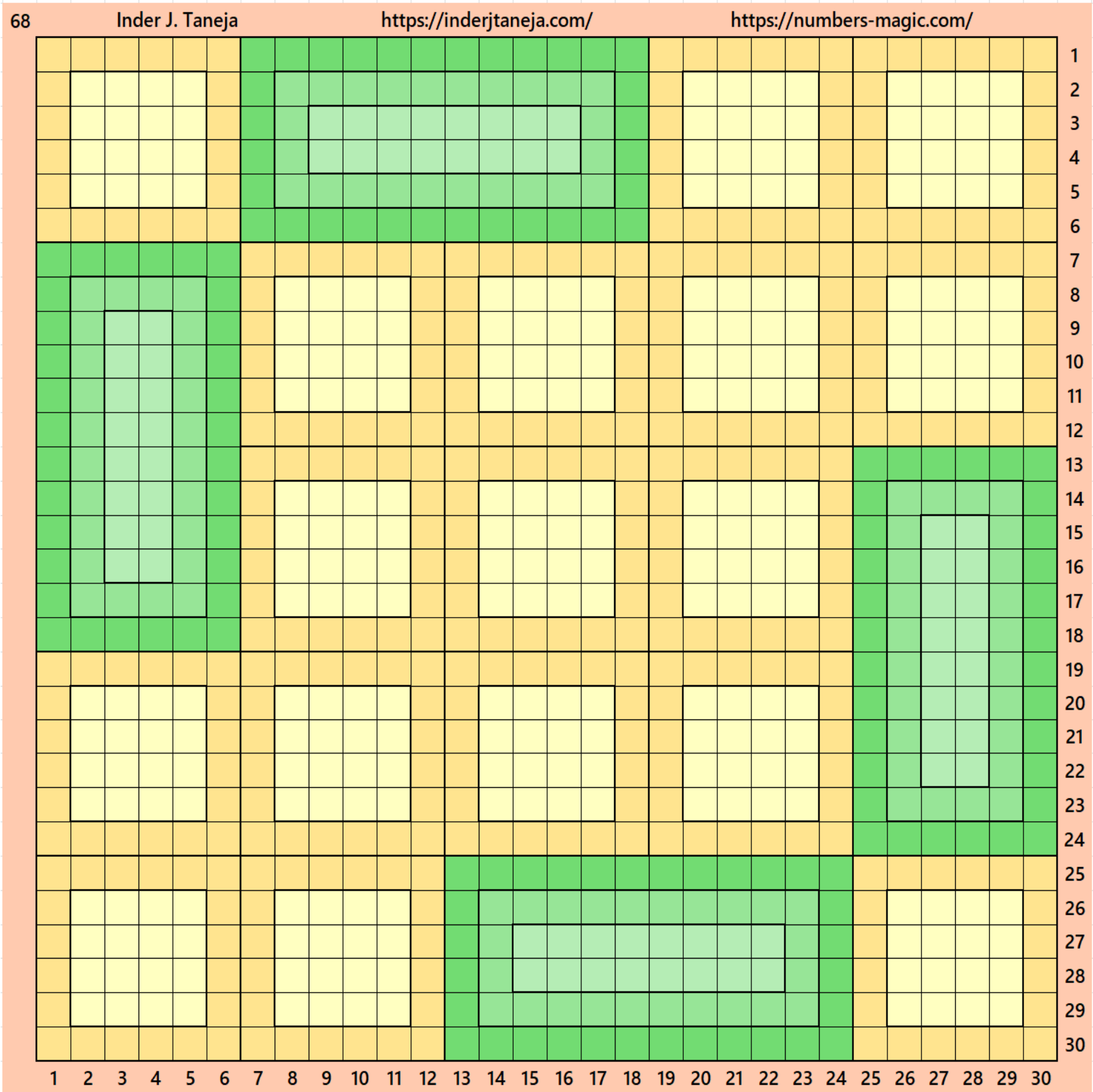


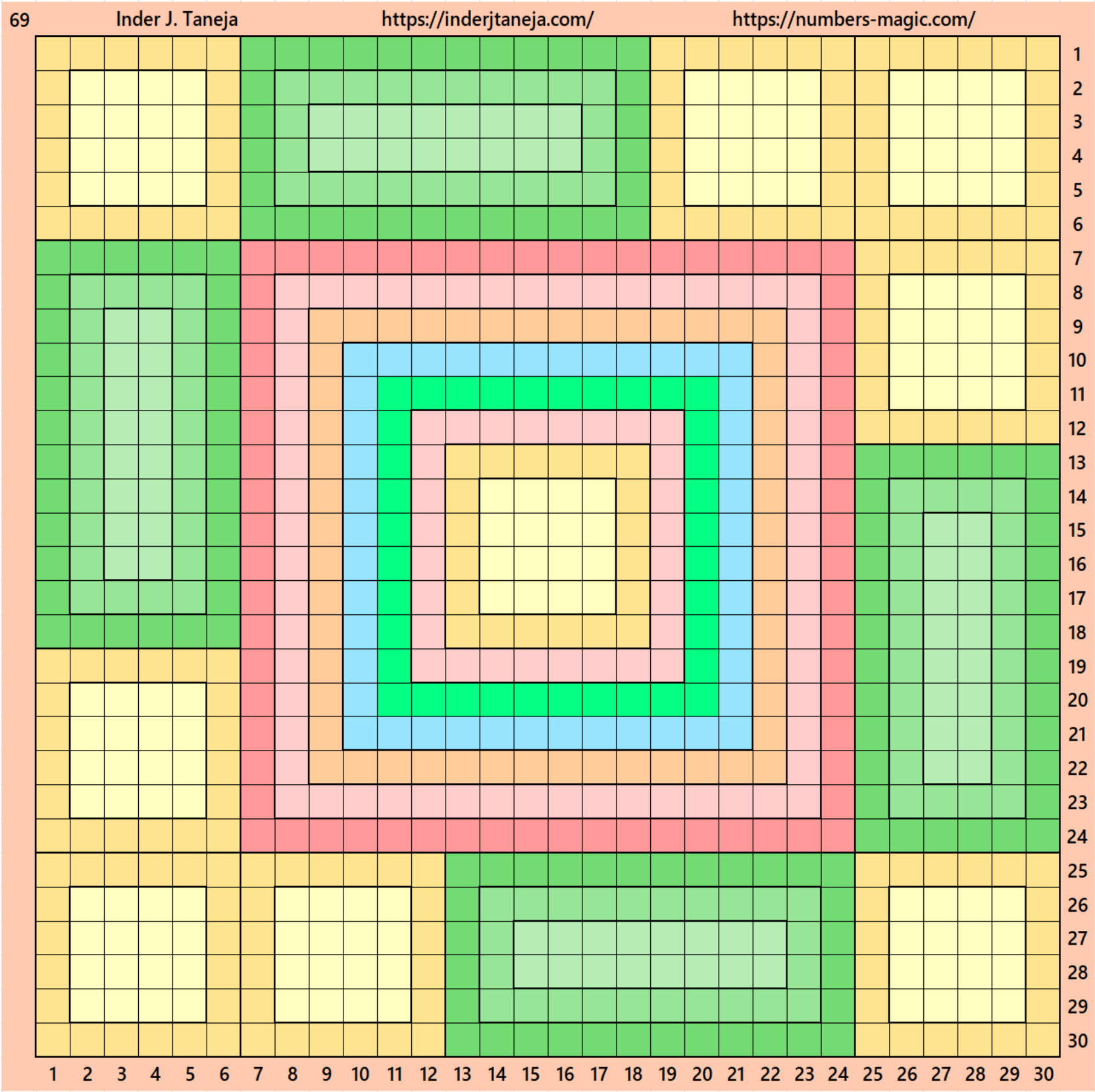


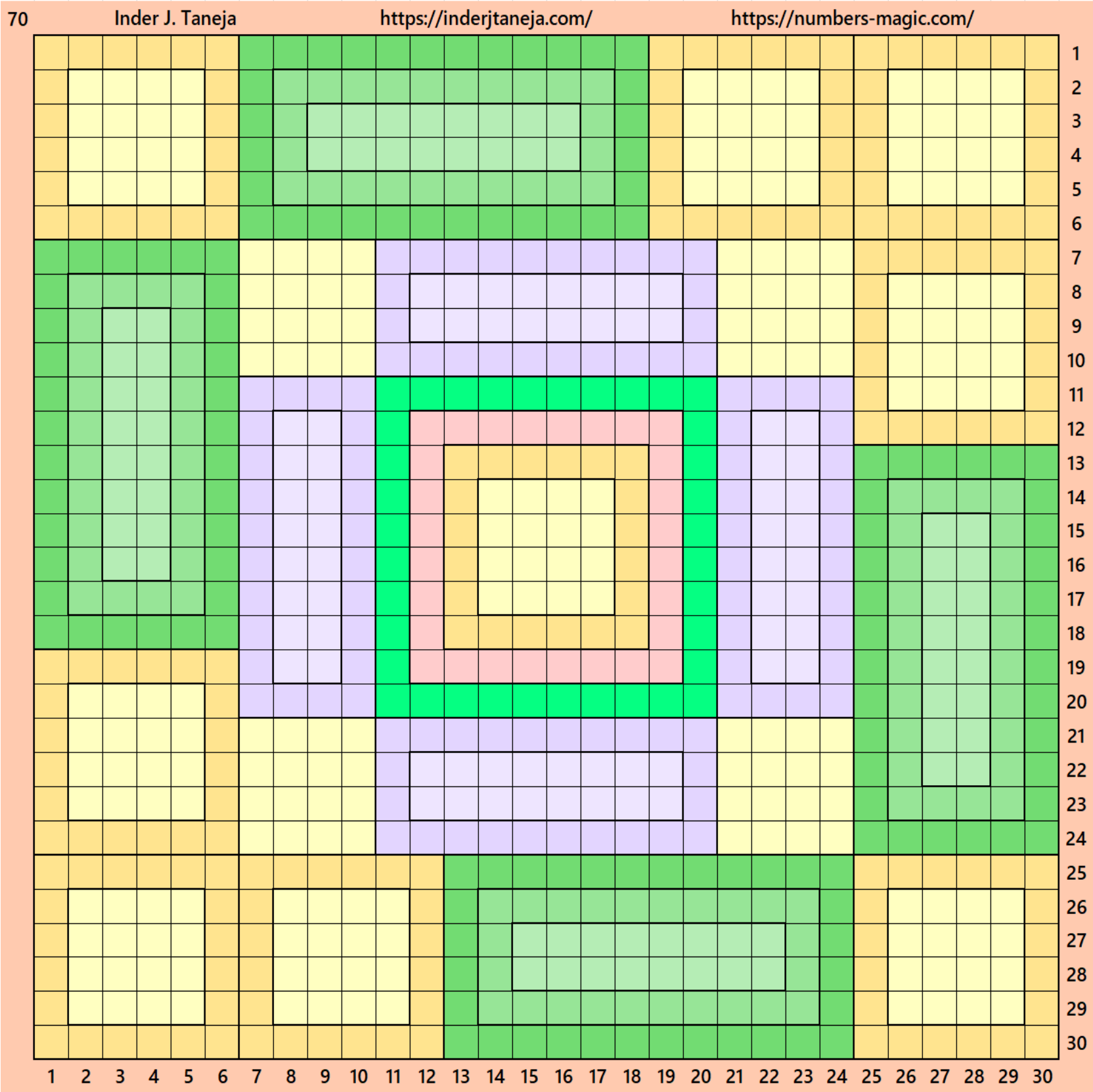


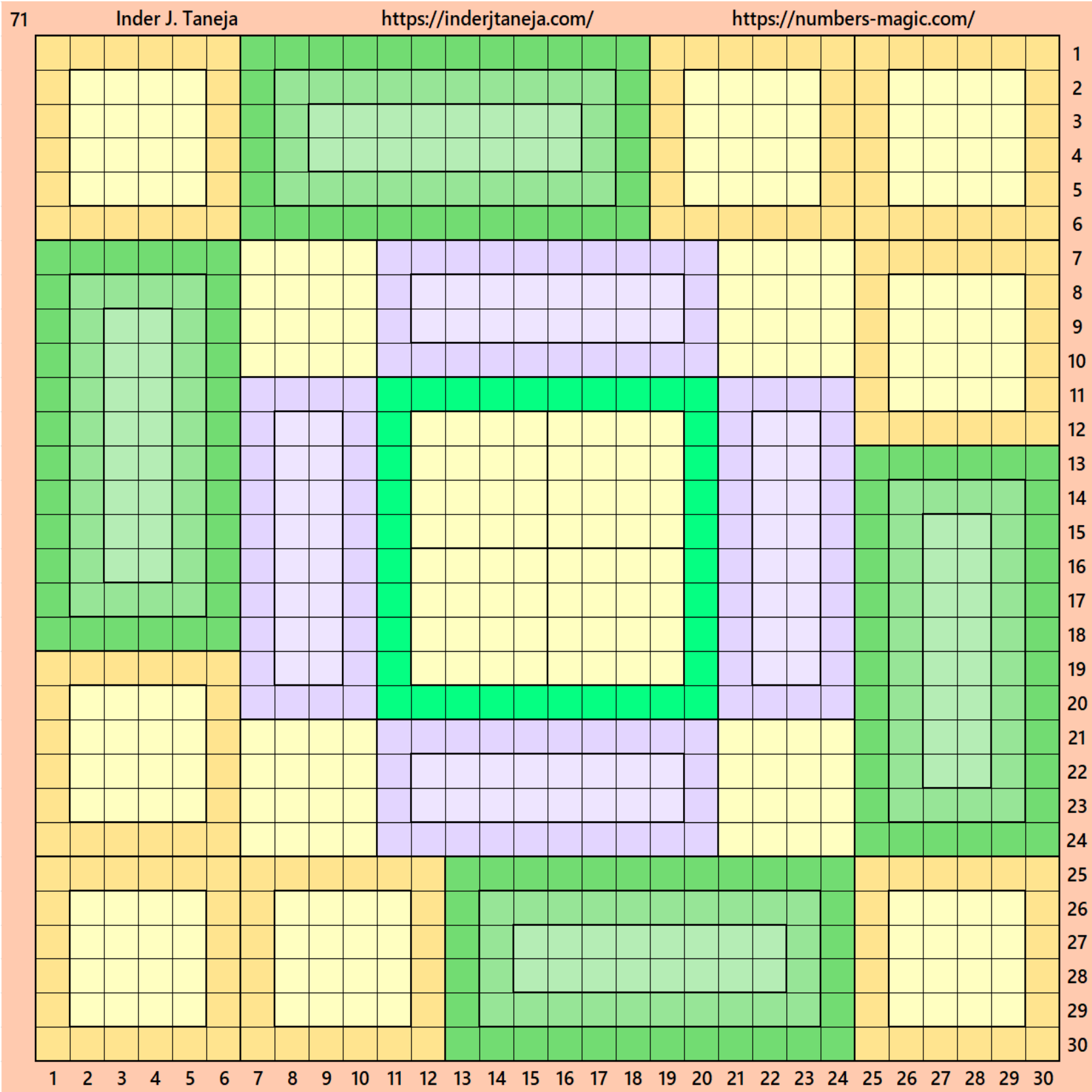


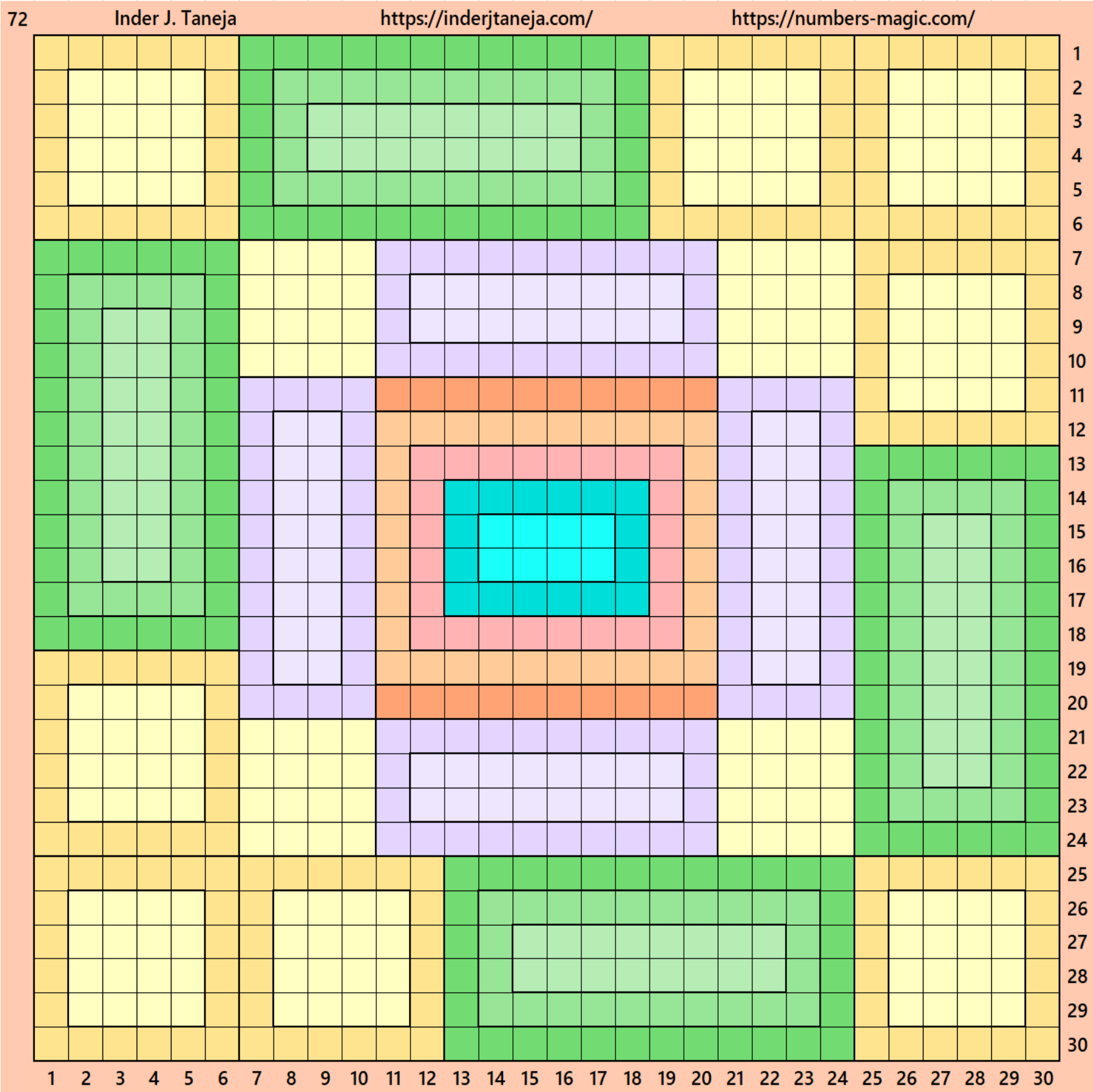


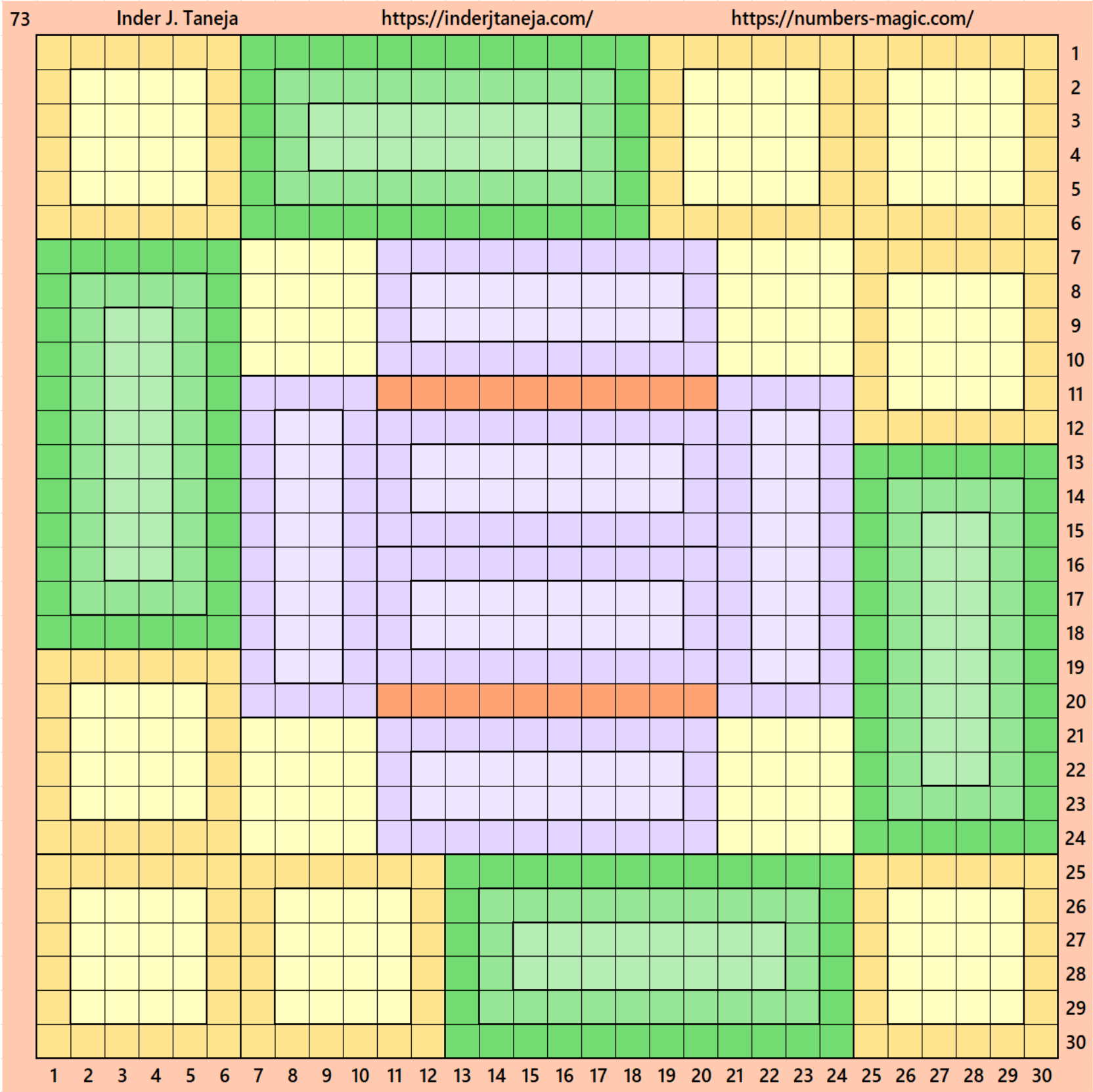


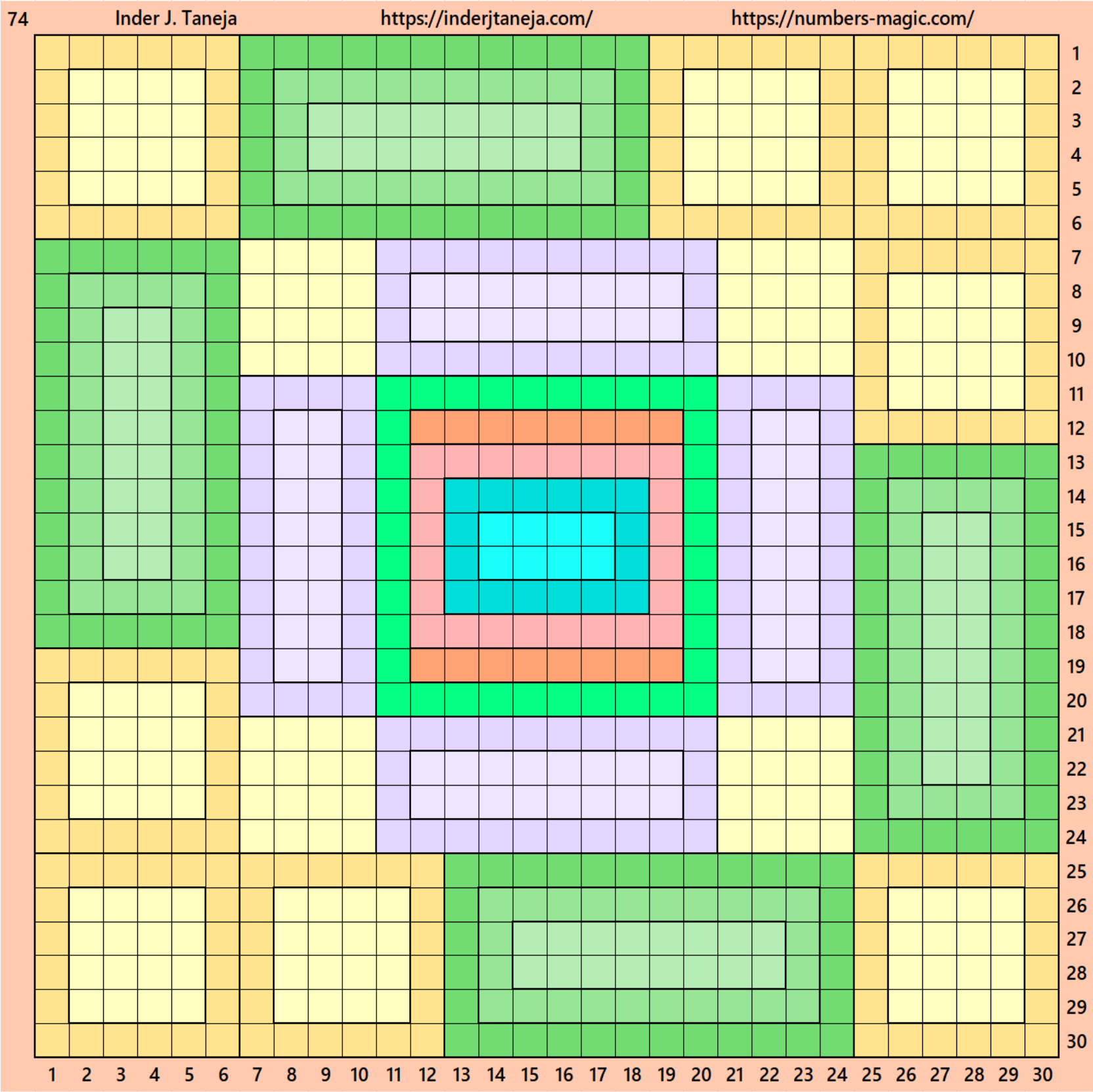


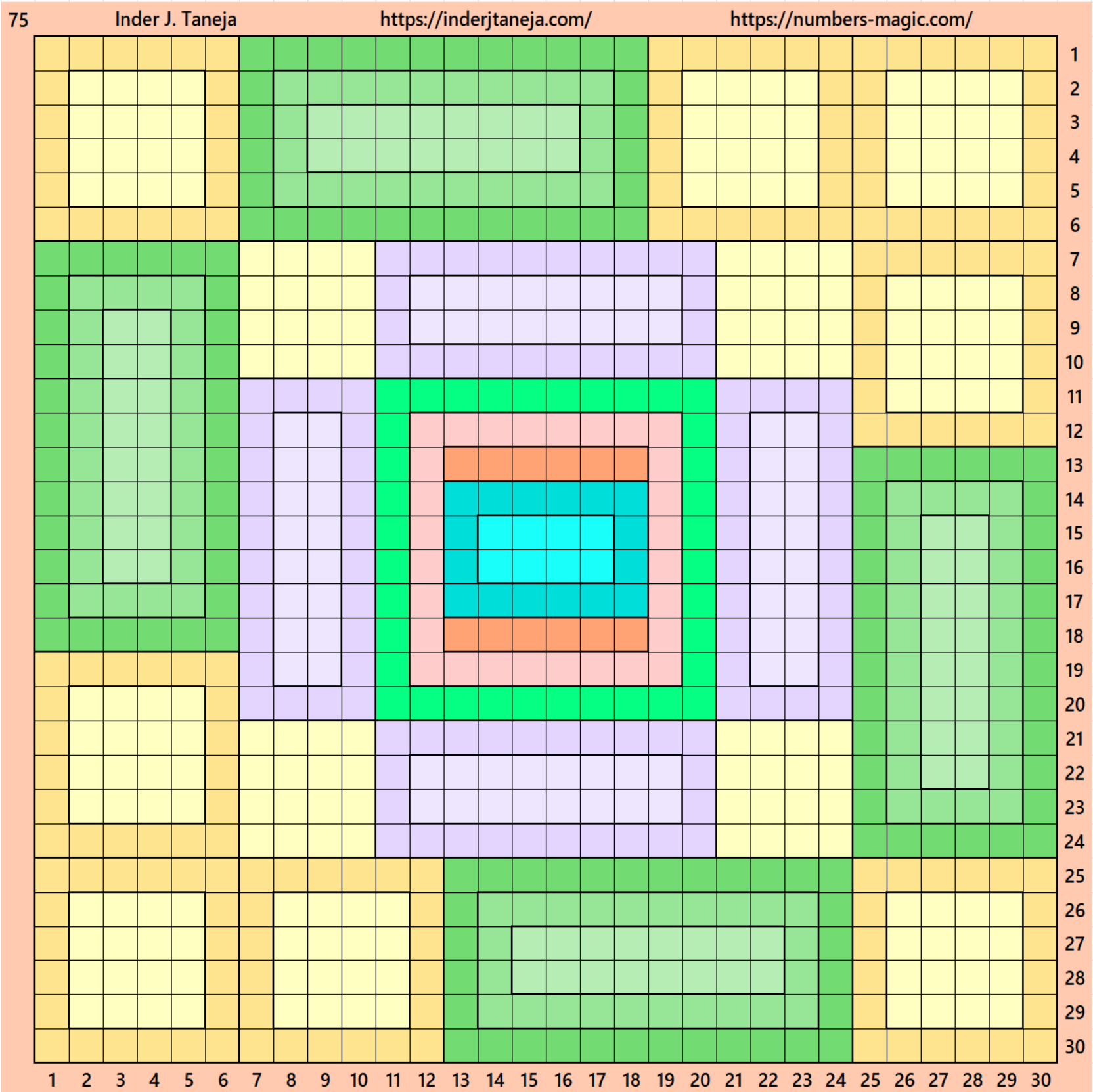






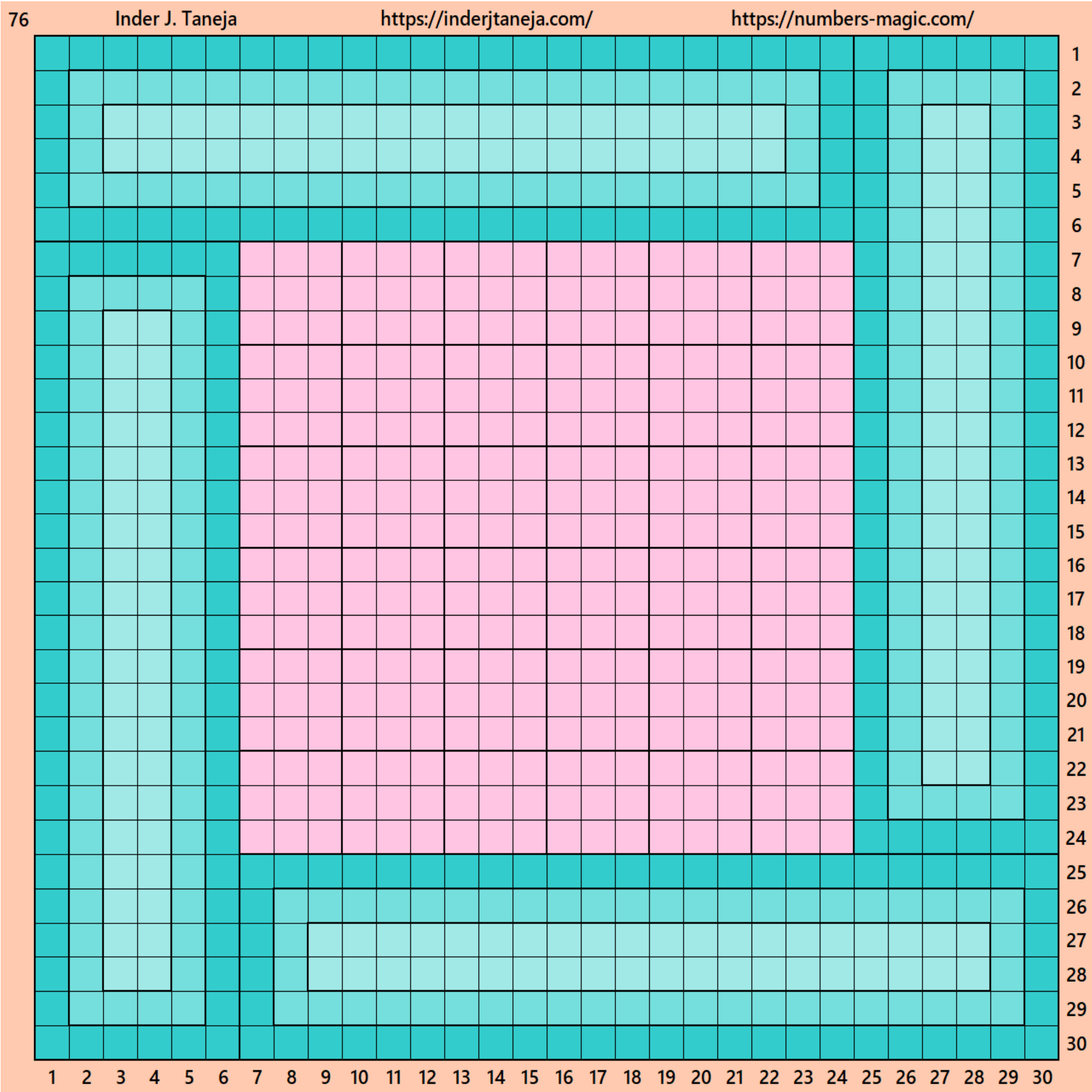






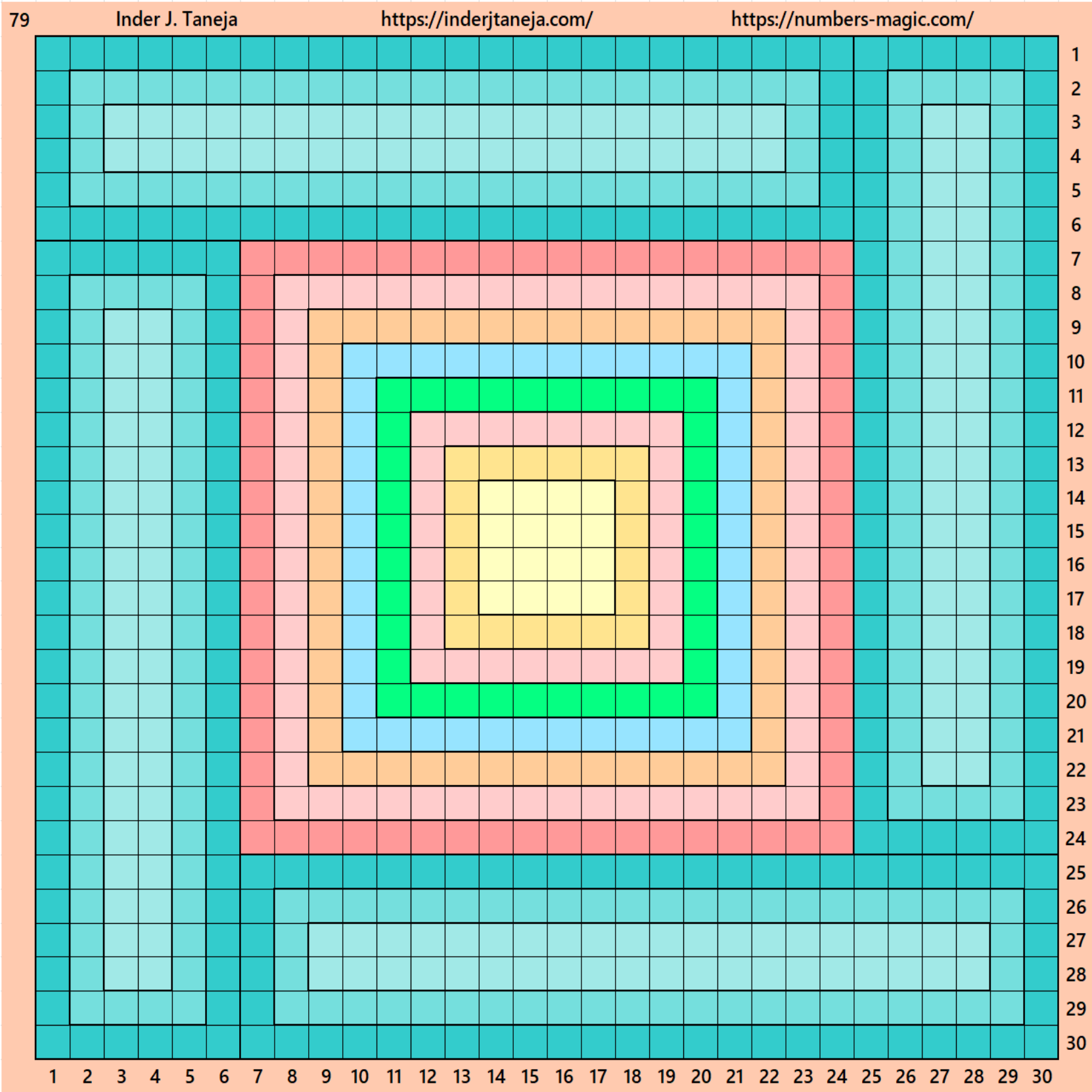
2.6 Closed Border of Order 6

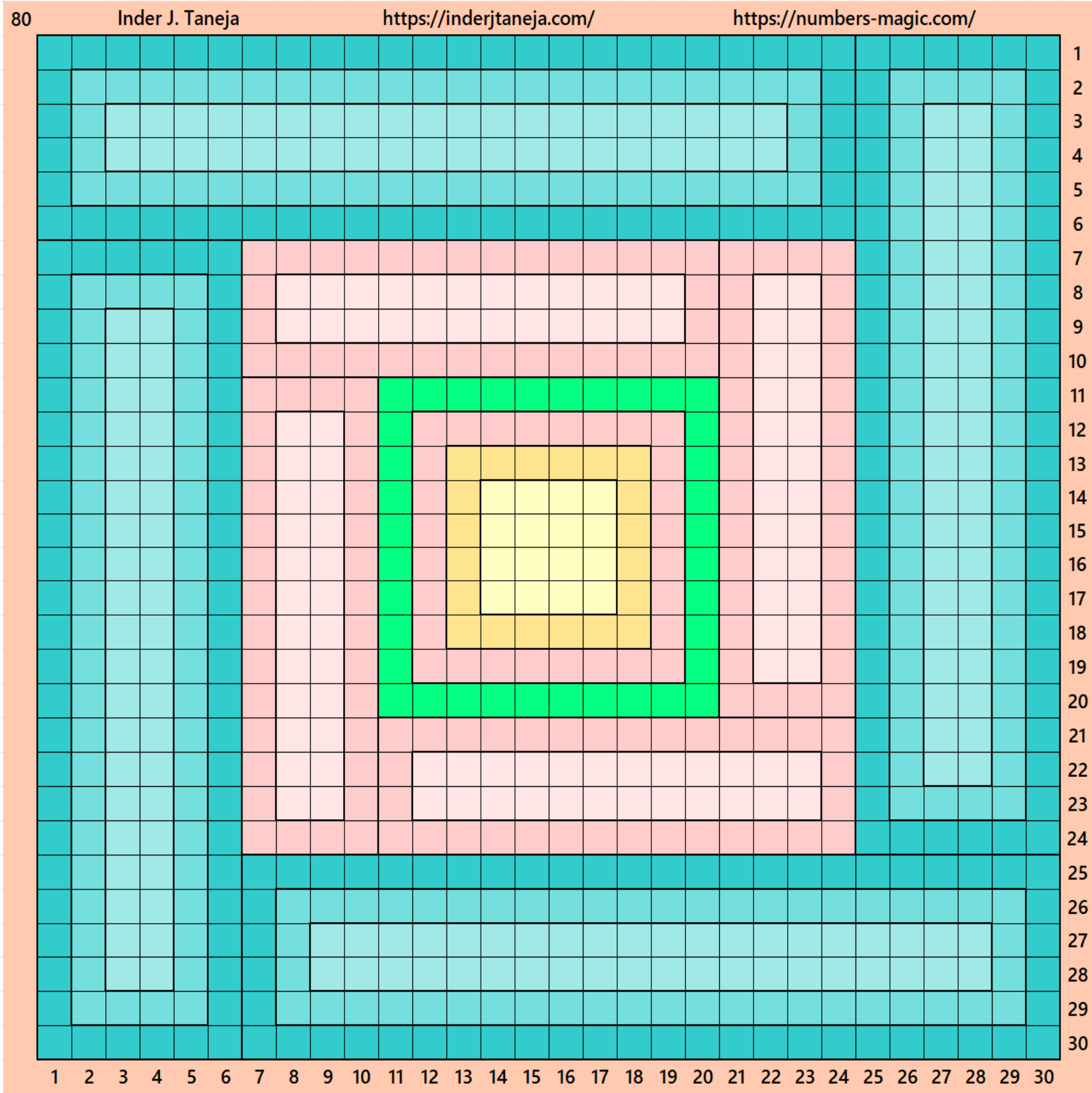
Let's write a closed external border formed by 4 blocks of equal sums BMRs of order 6×24 . In the middle we are left with blocks of order 18. Writing this middle blocks with different types of magic squares of order 18, we get magic squares of order 30. See below few examples:

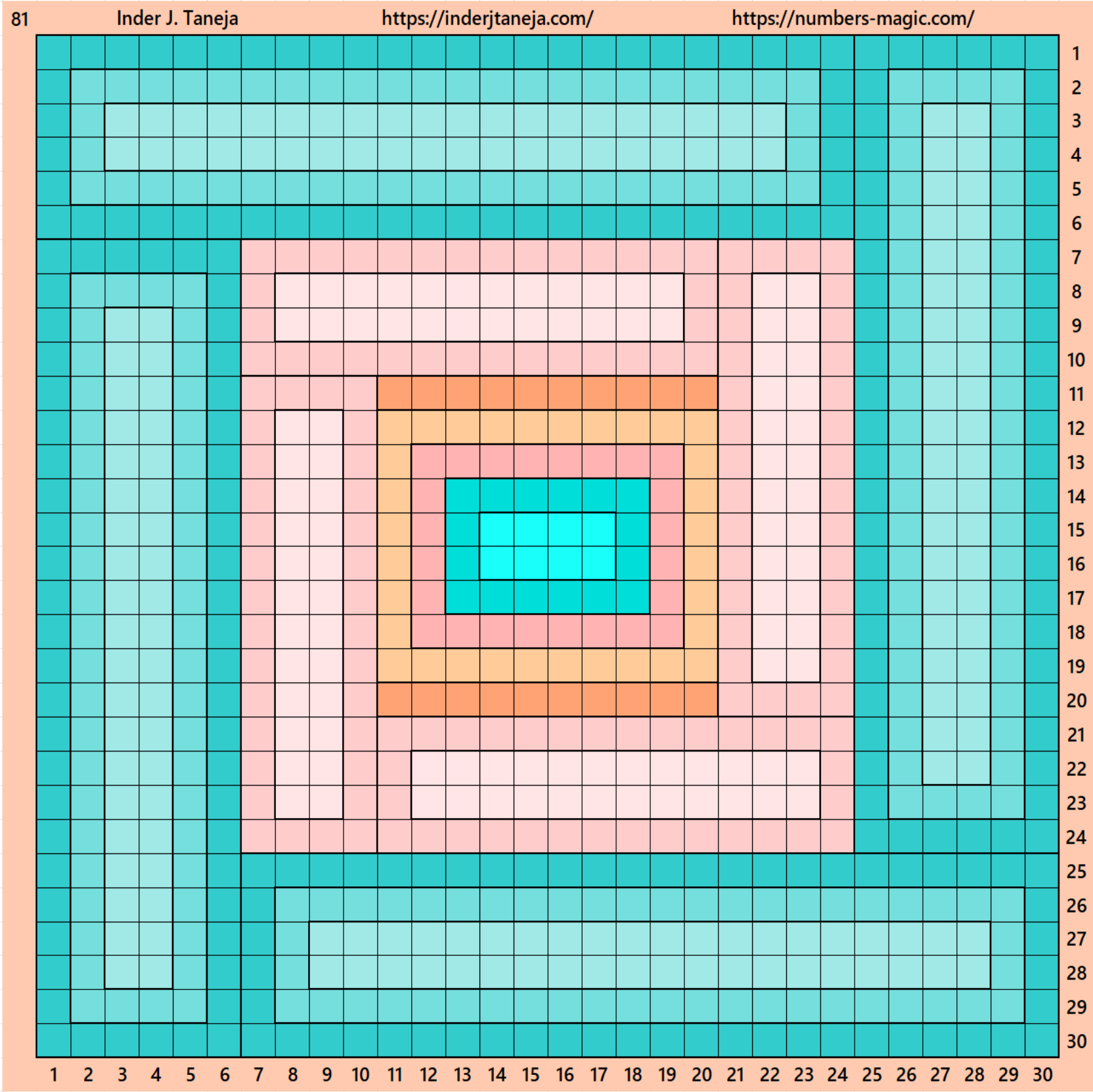


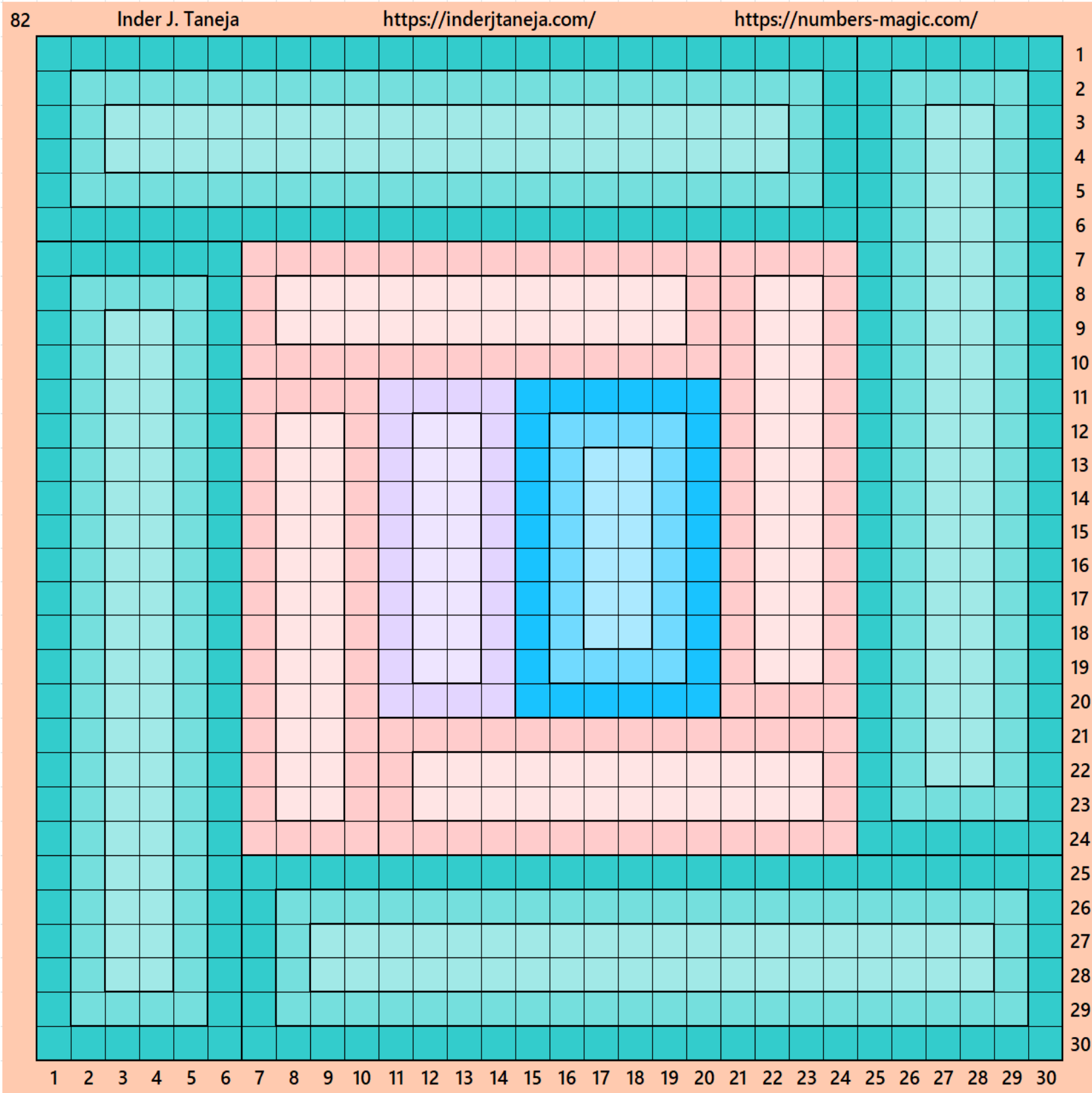


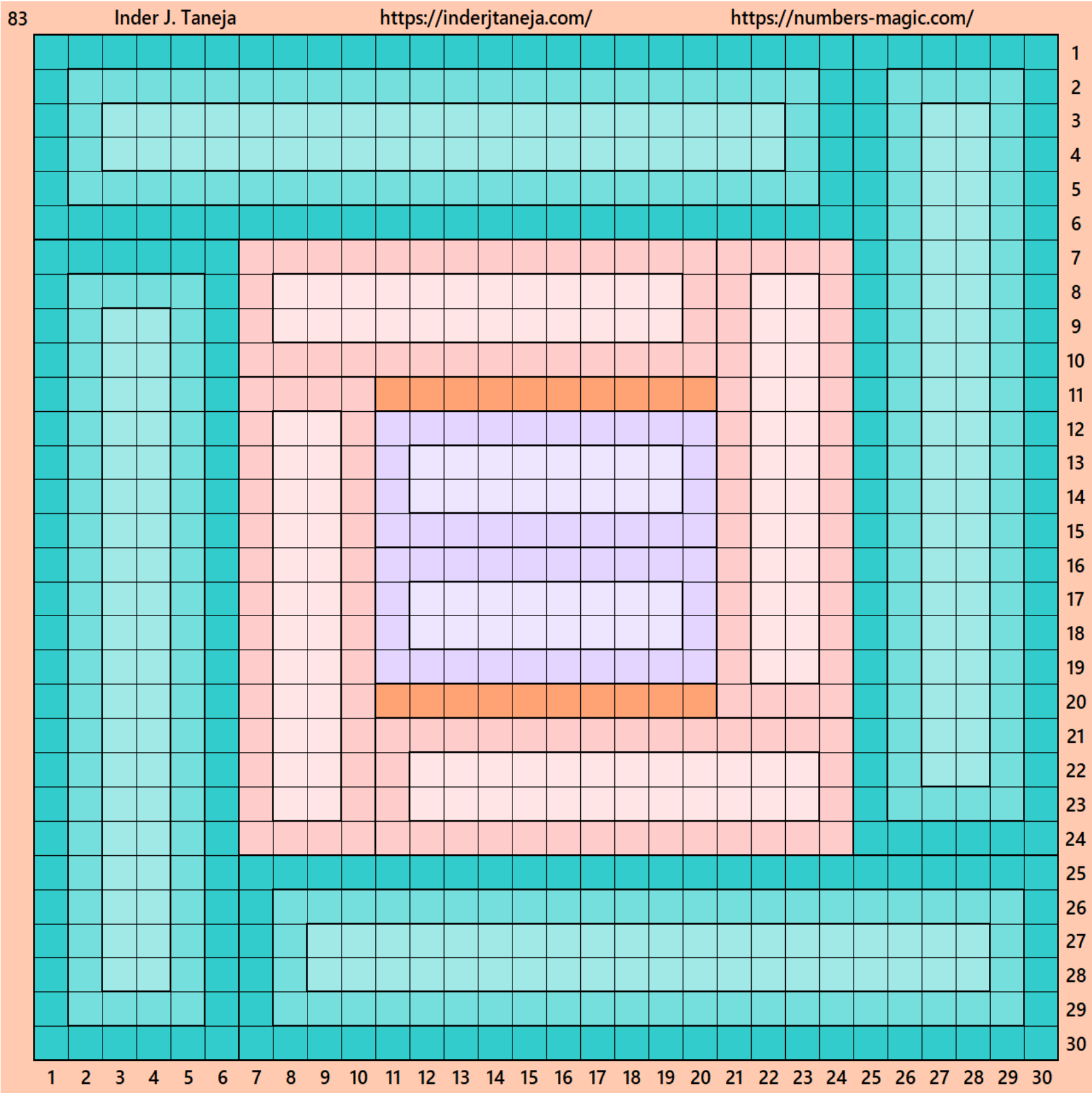


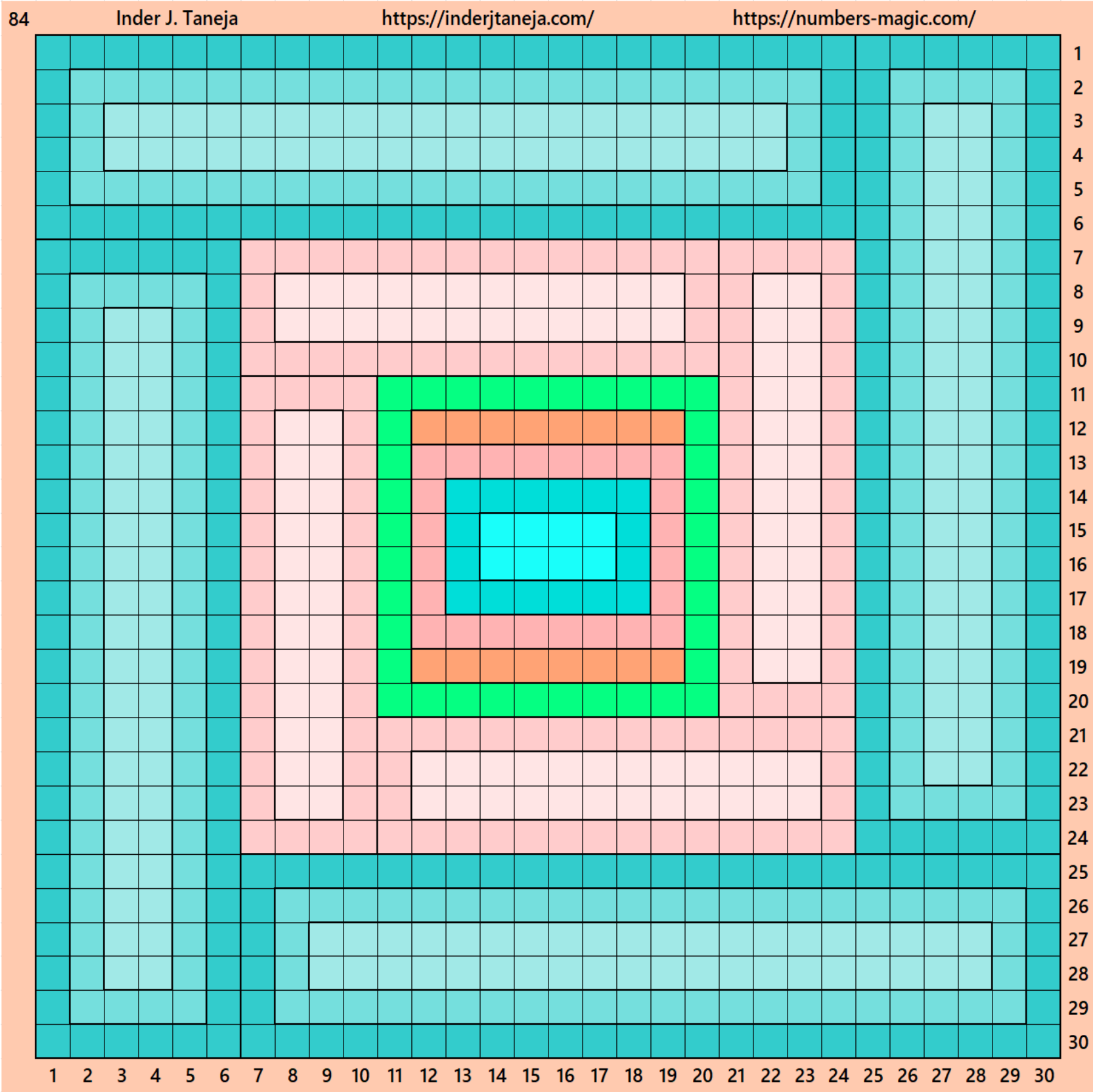


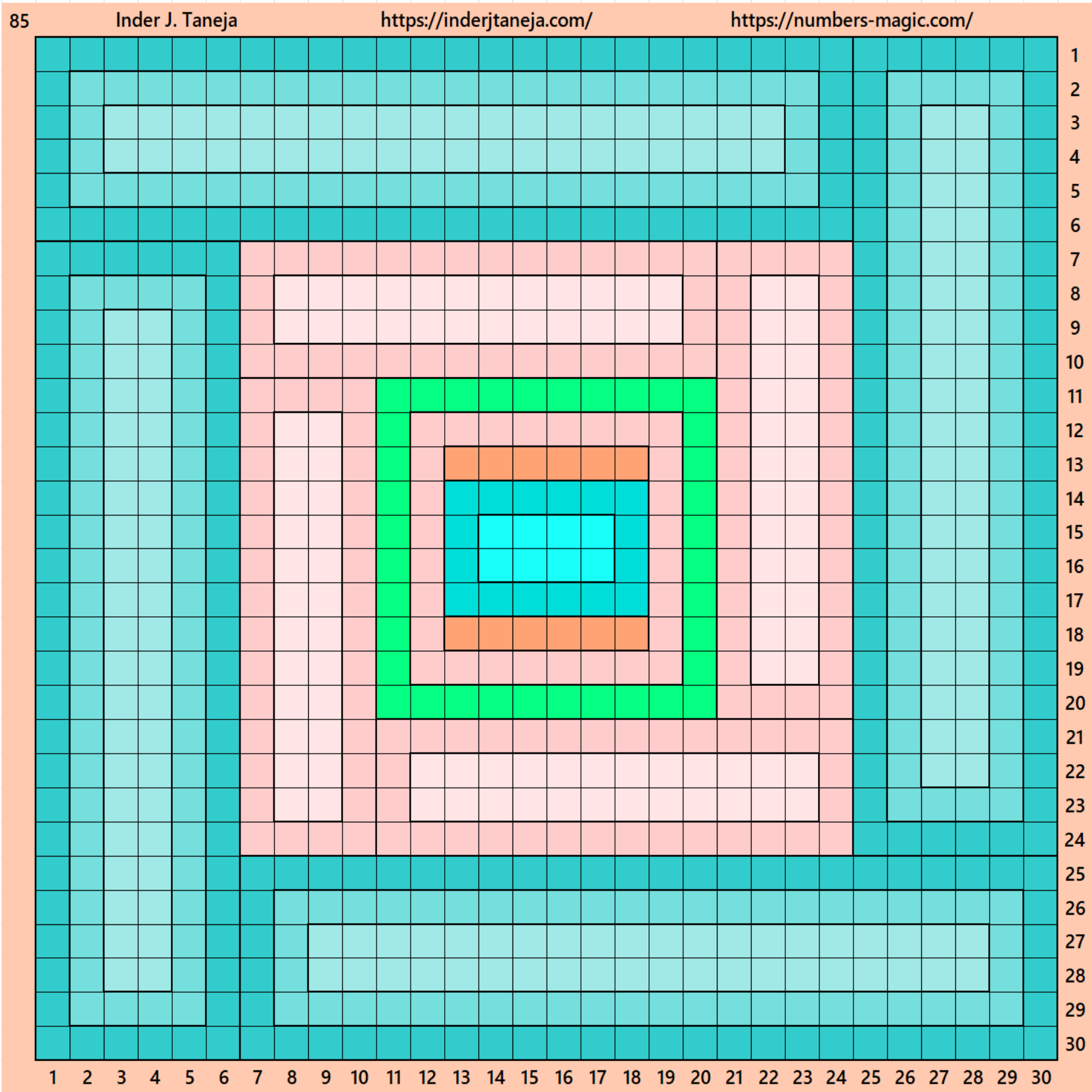








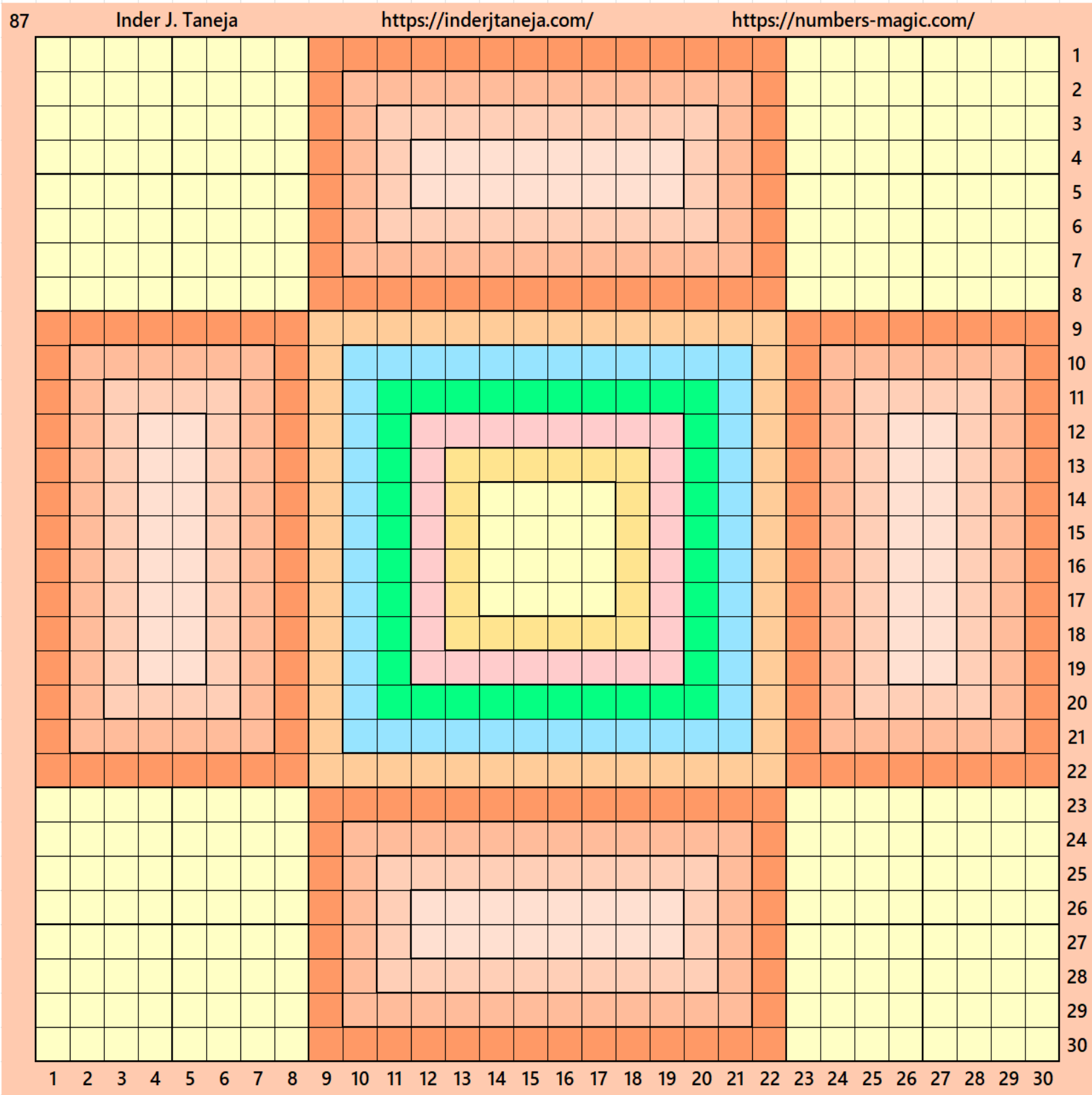


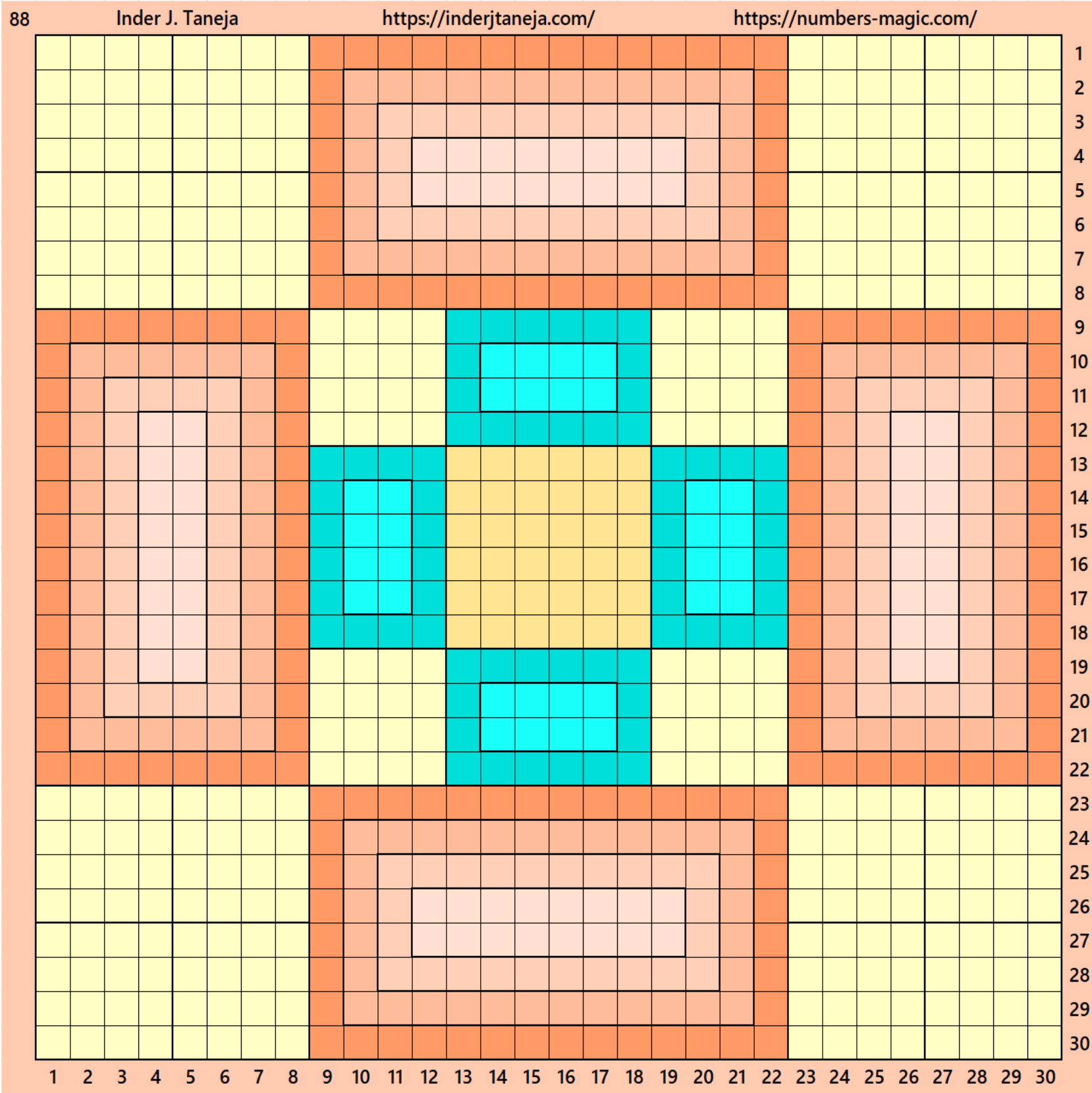


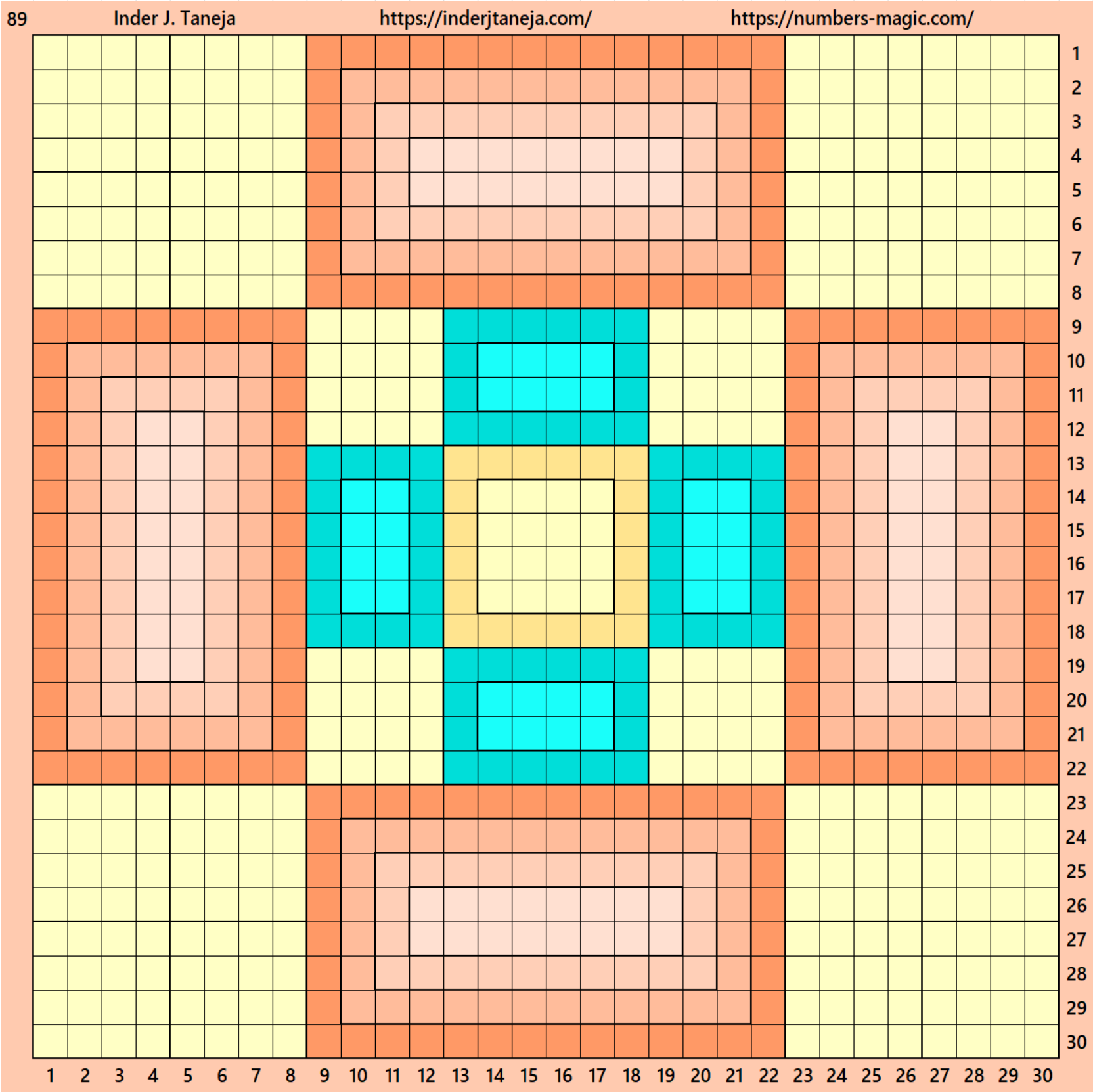


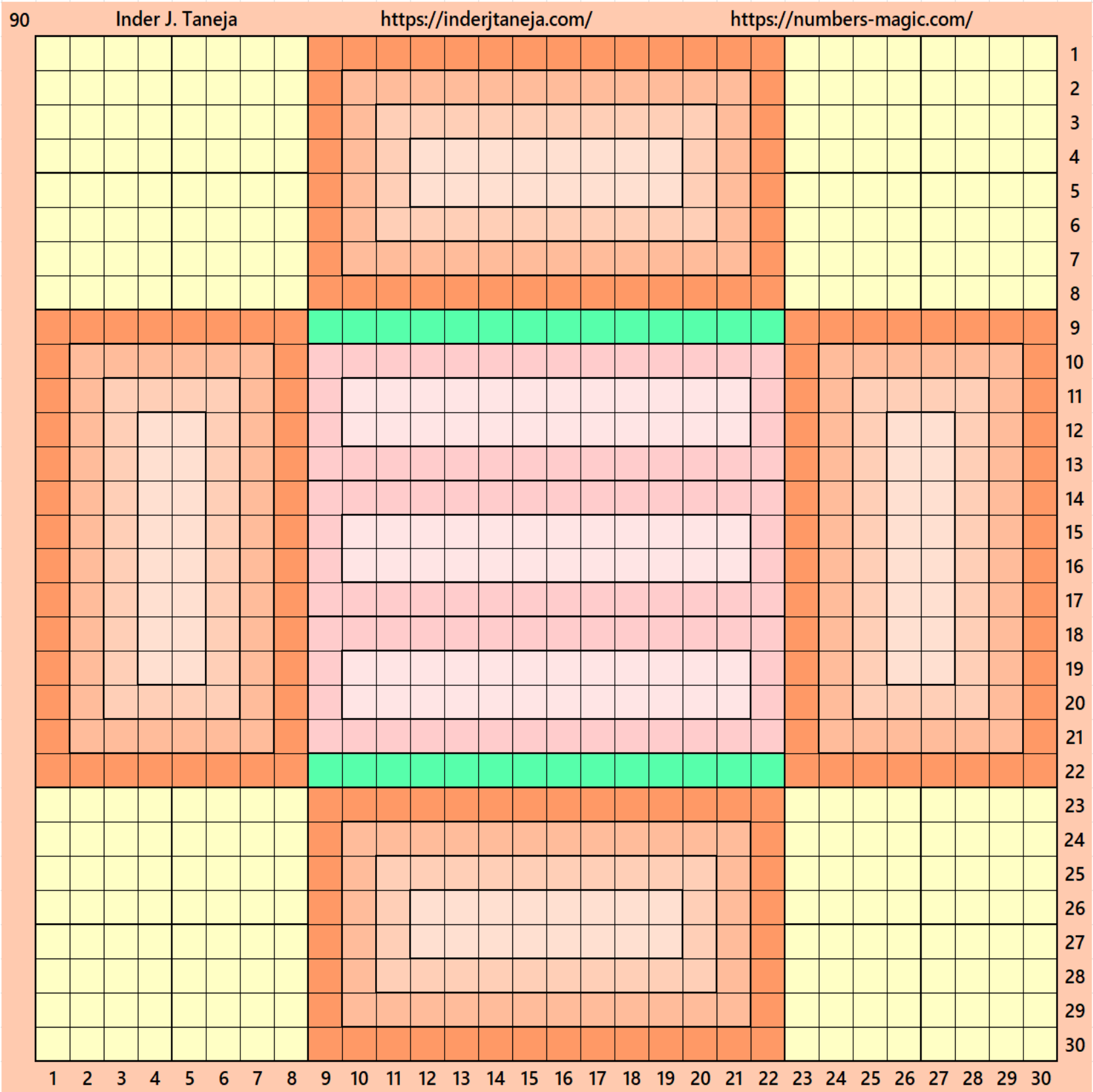
2.7 Cornered Magic Squares of Order 8

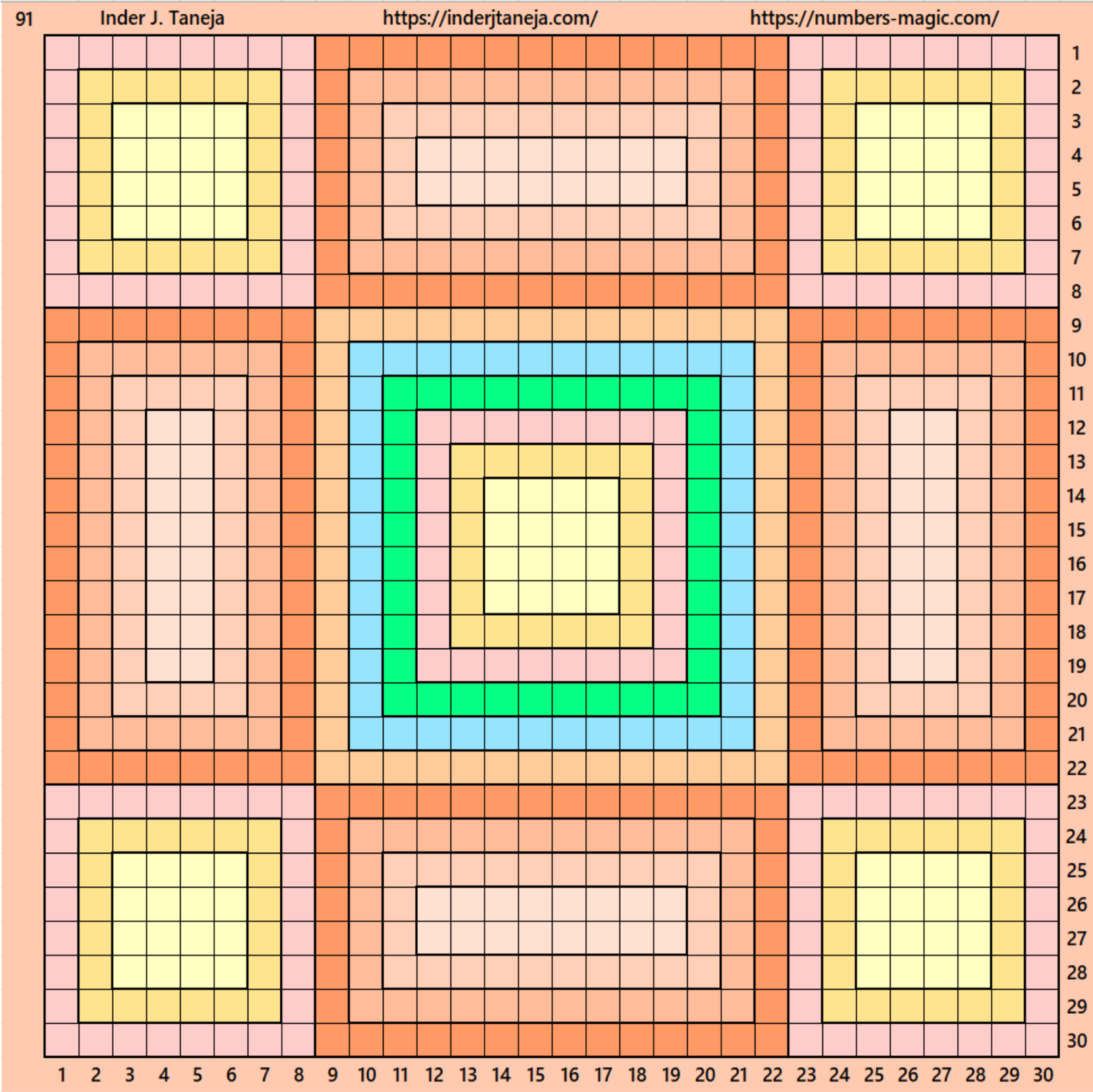
Let's consider an external border, where there are 4 magic squares of order 8 at the corners. Let's make an external border by putting BMRs of order 6×14 in each row and column. In the middle we are left with blocks of order 14. Writing this middle blocks with different types of magic squares of order 14, we get magic squares of order 30. See below few examples:

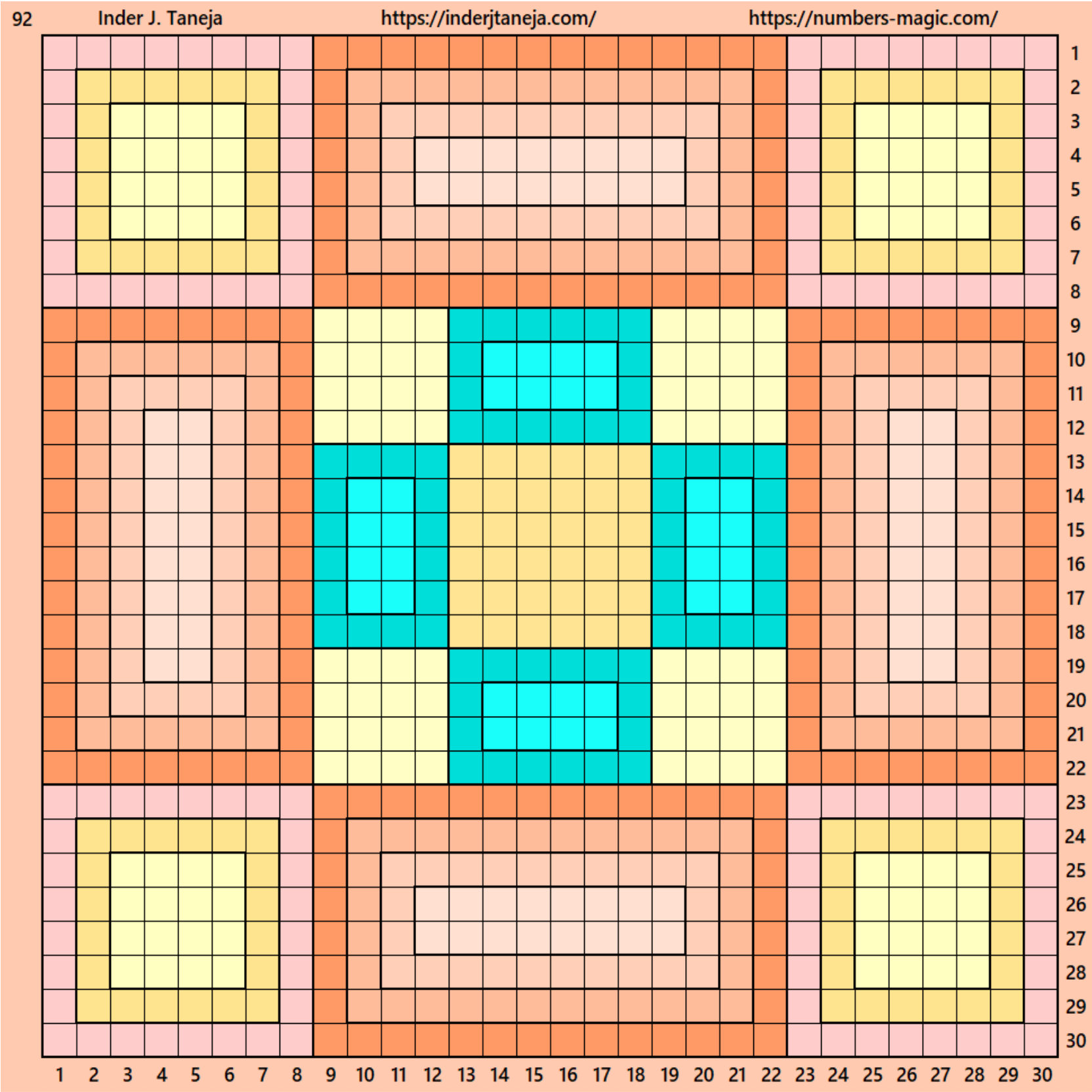


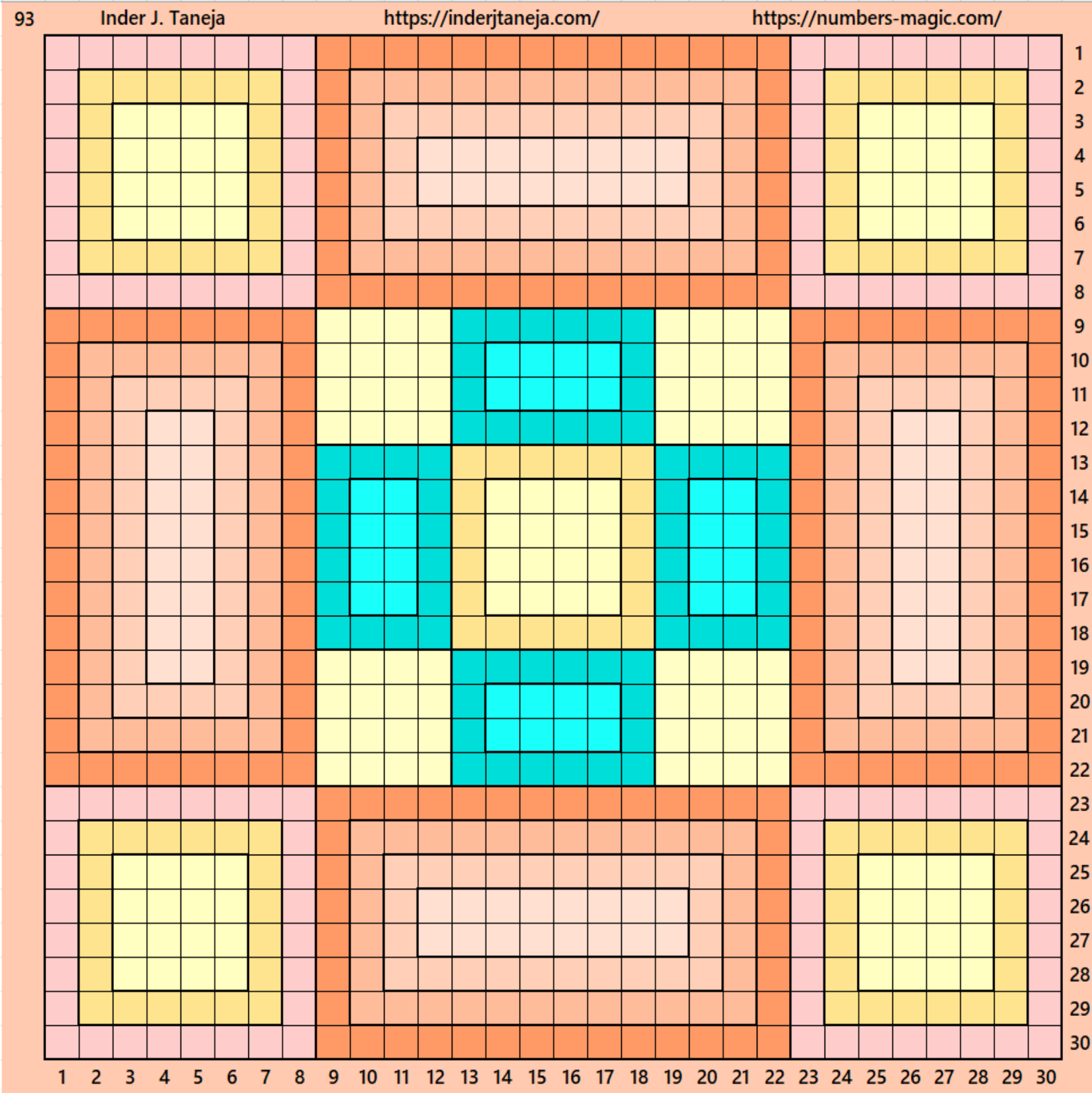


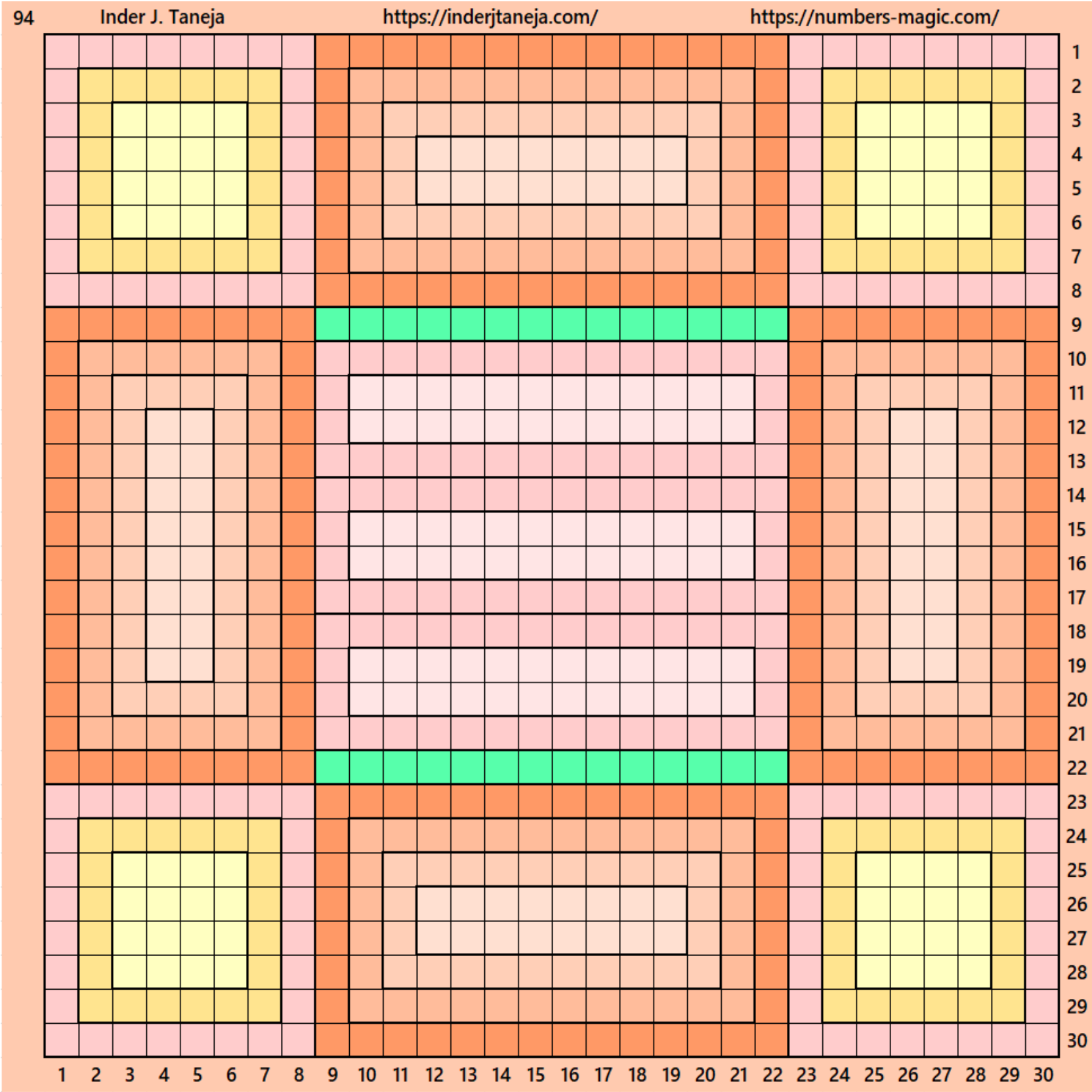


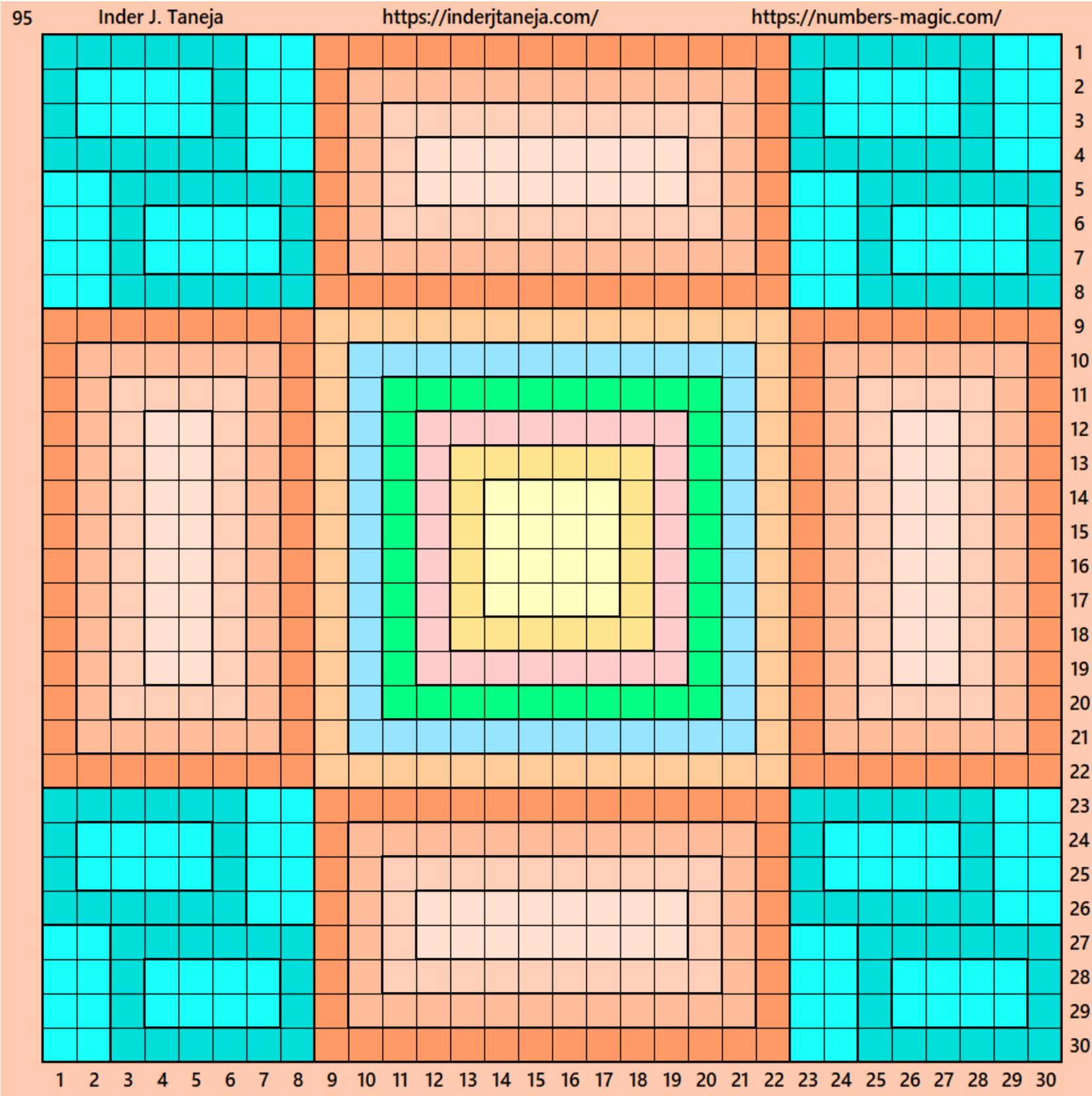


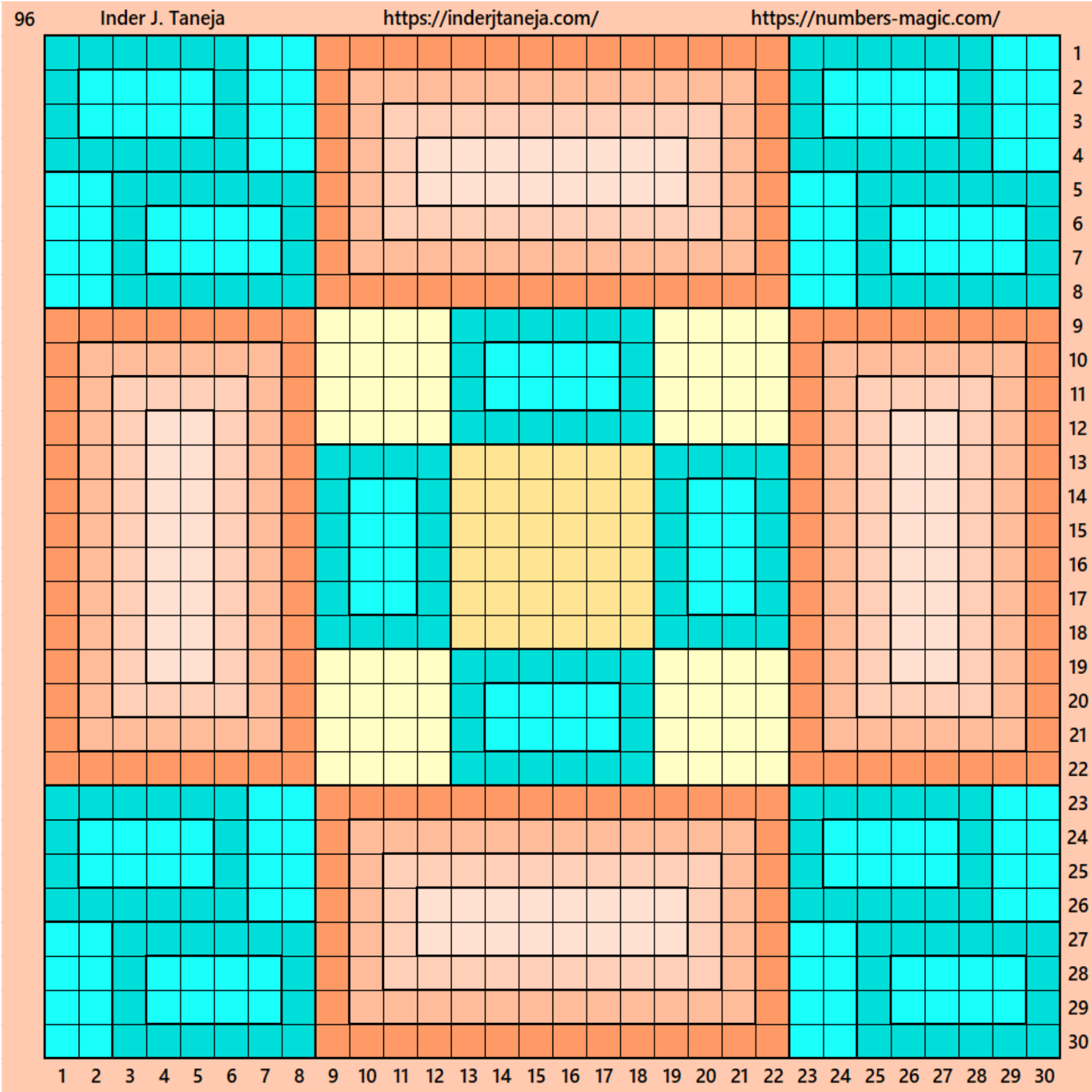


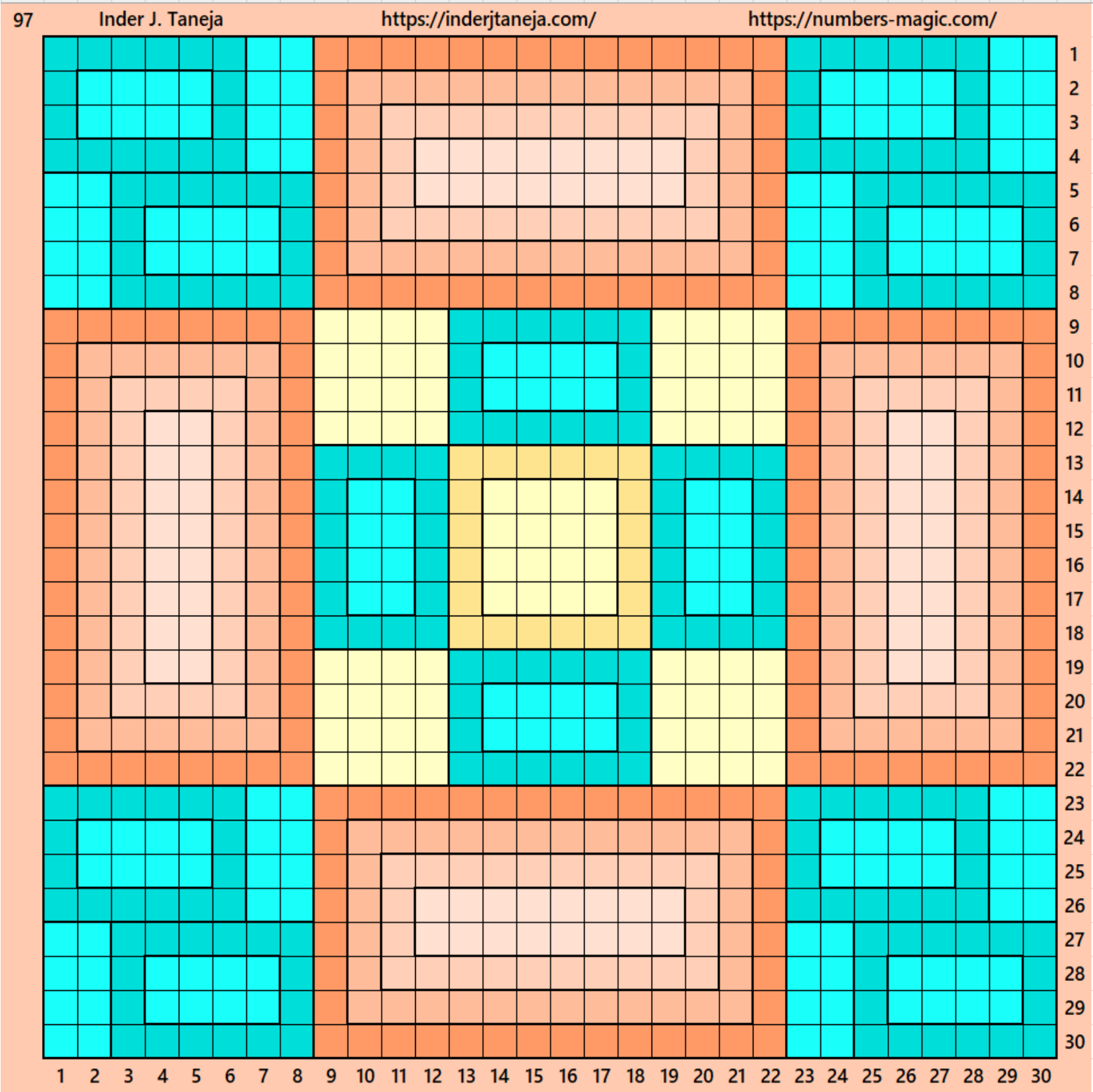


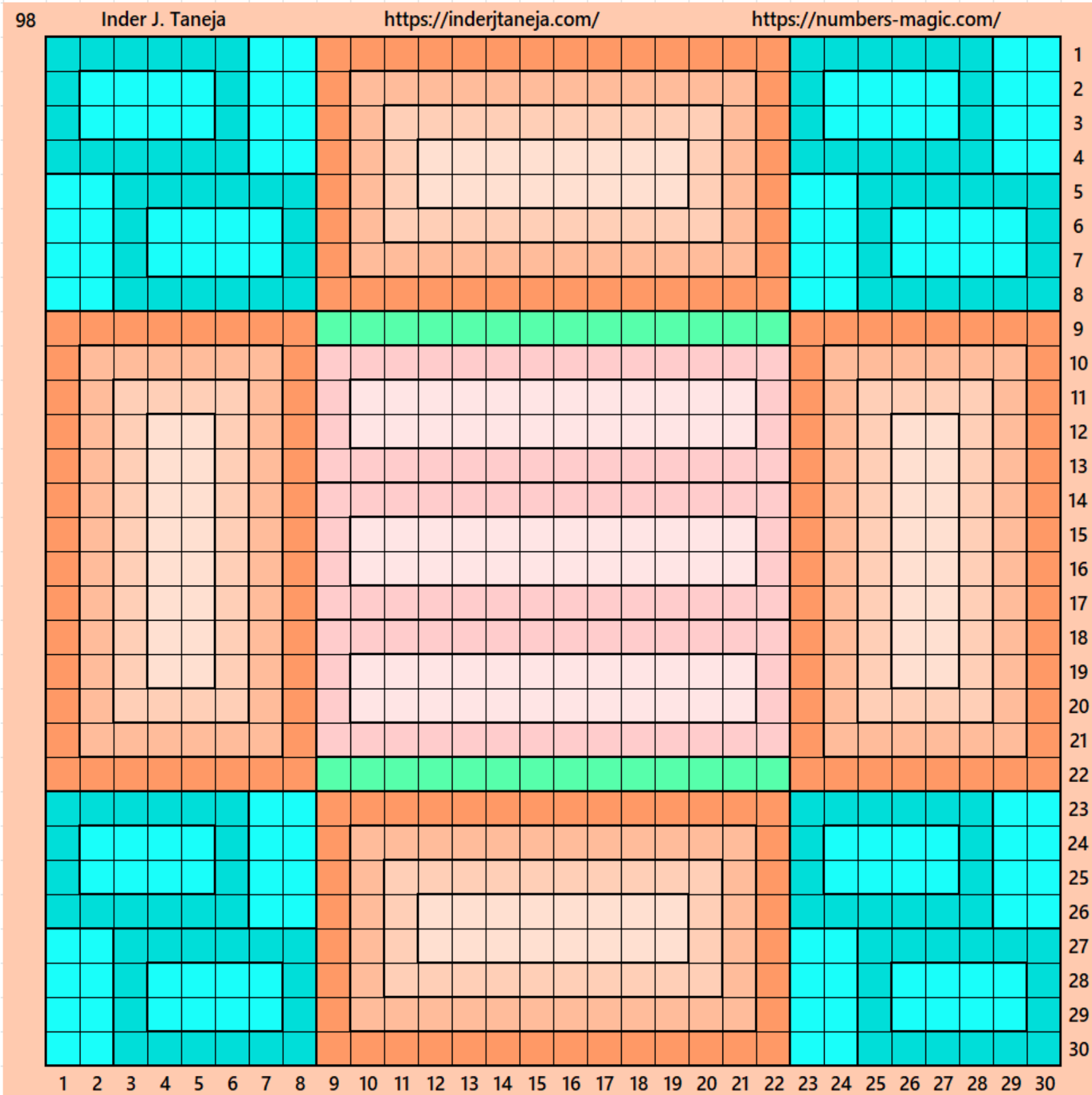


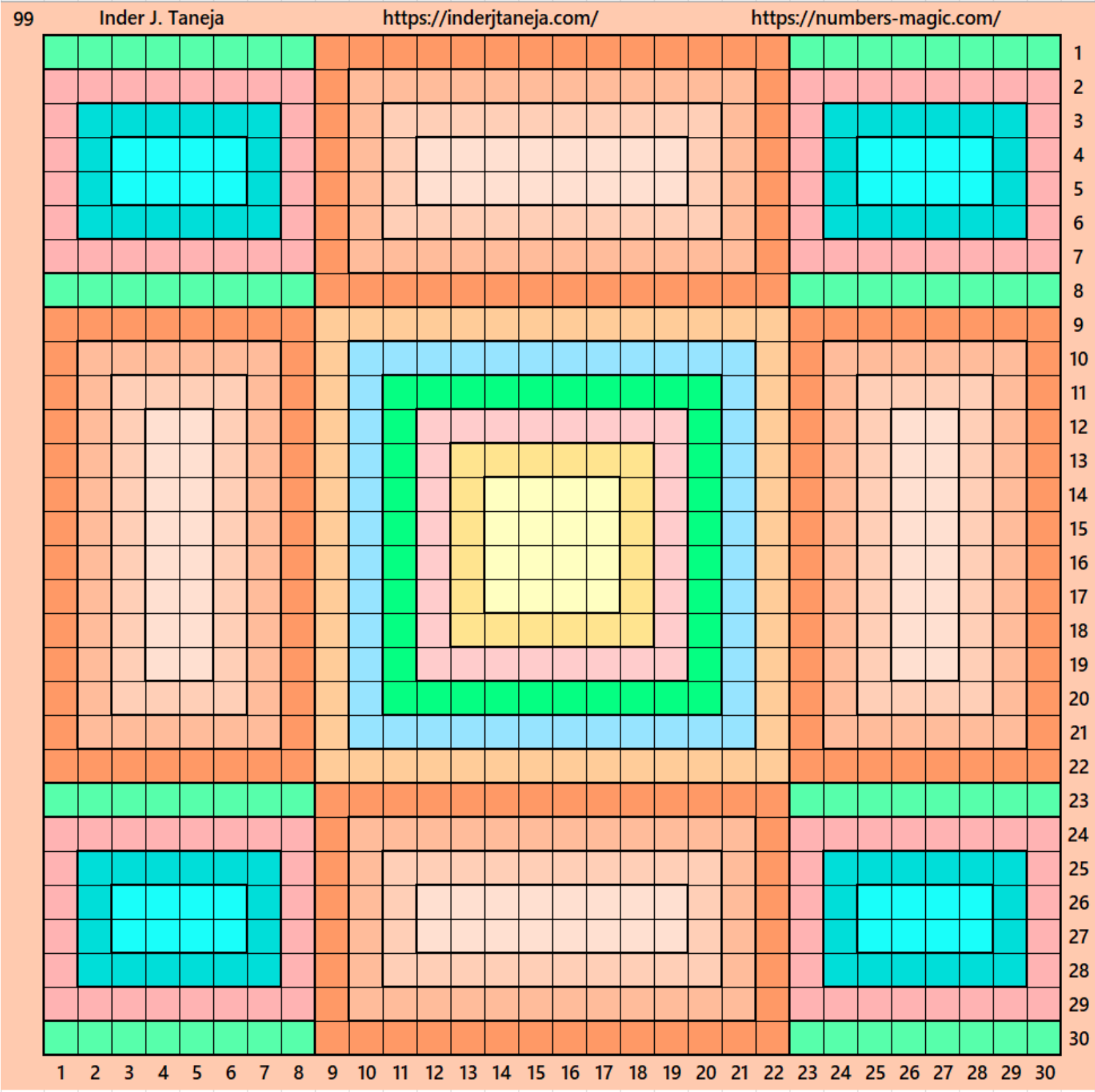


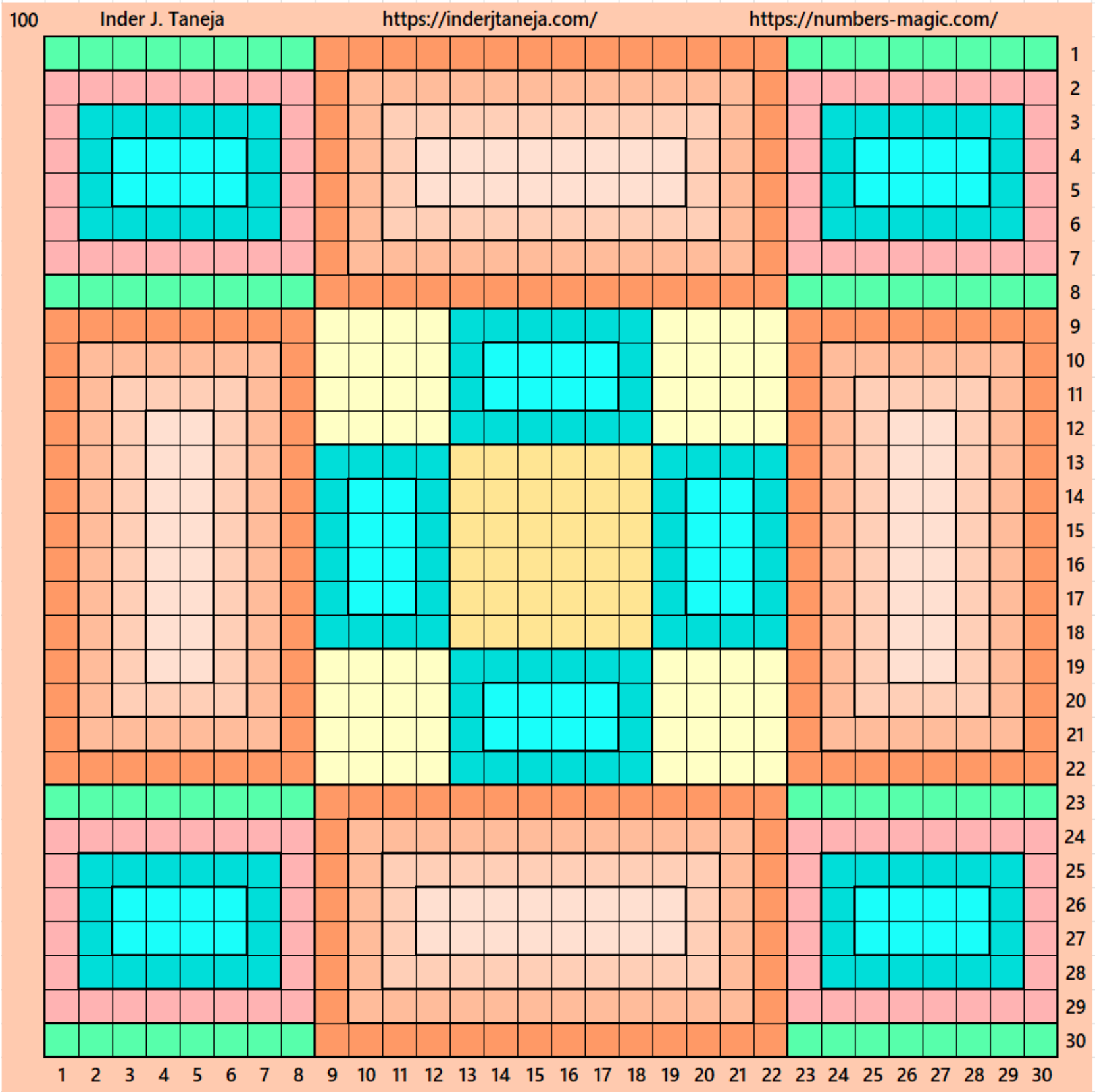


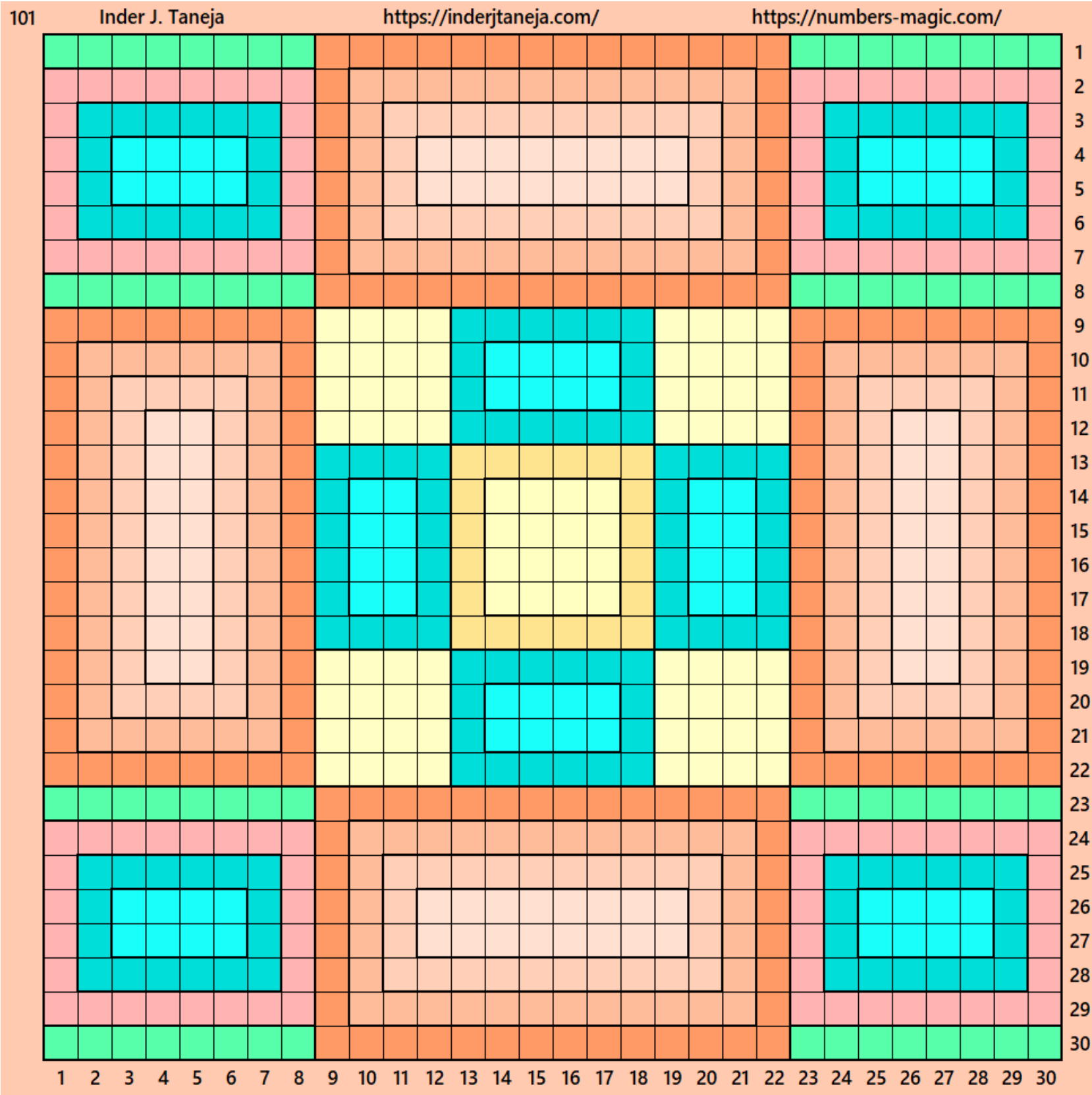


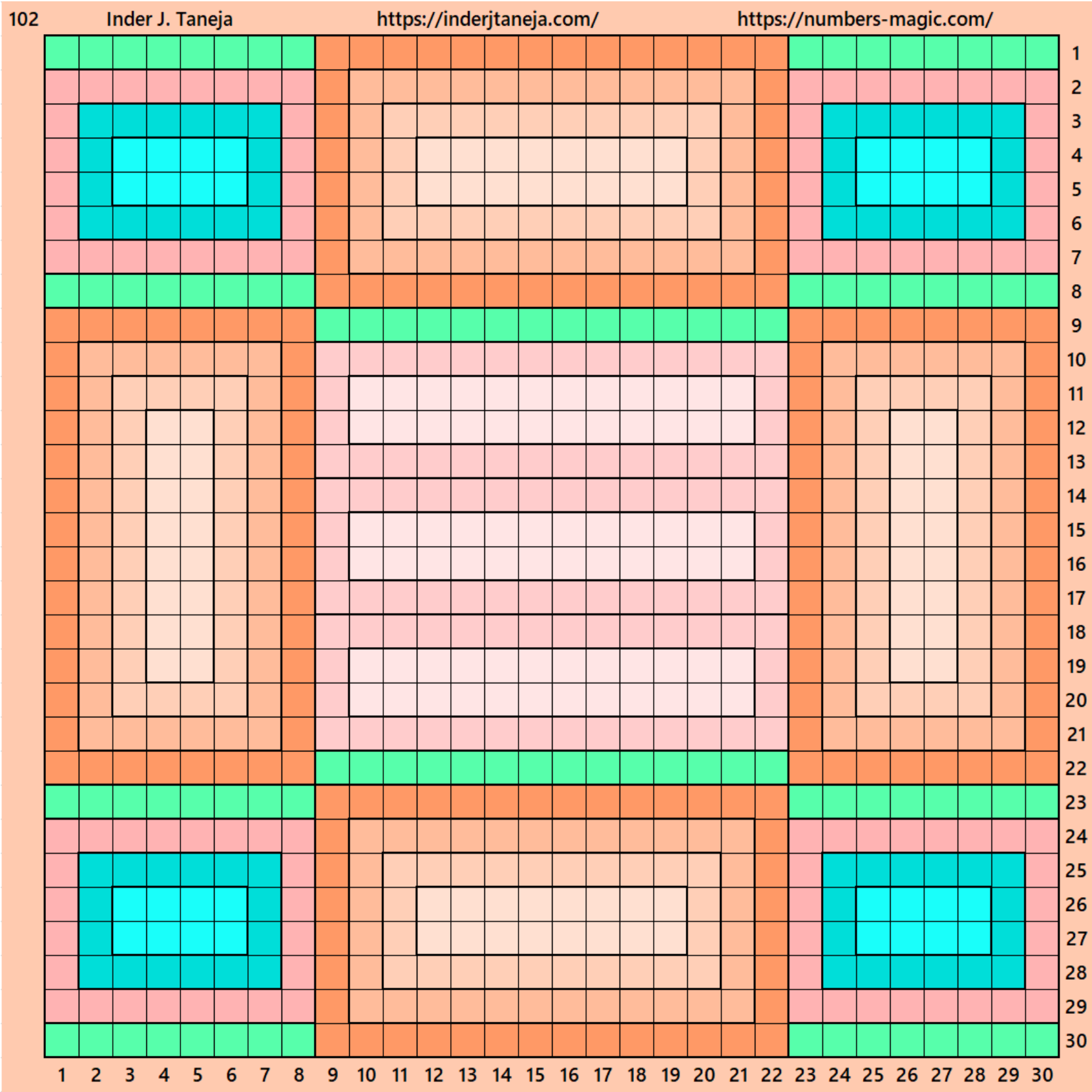






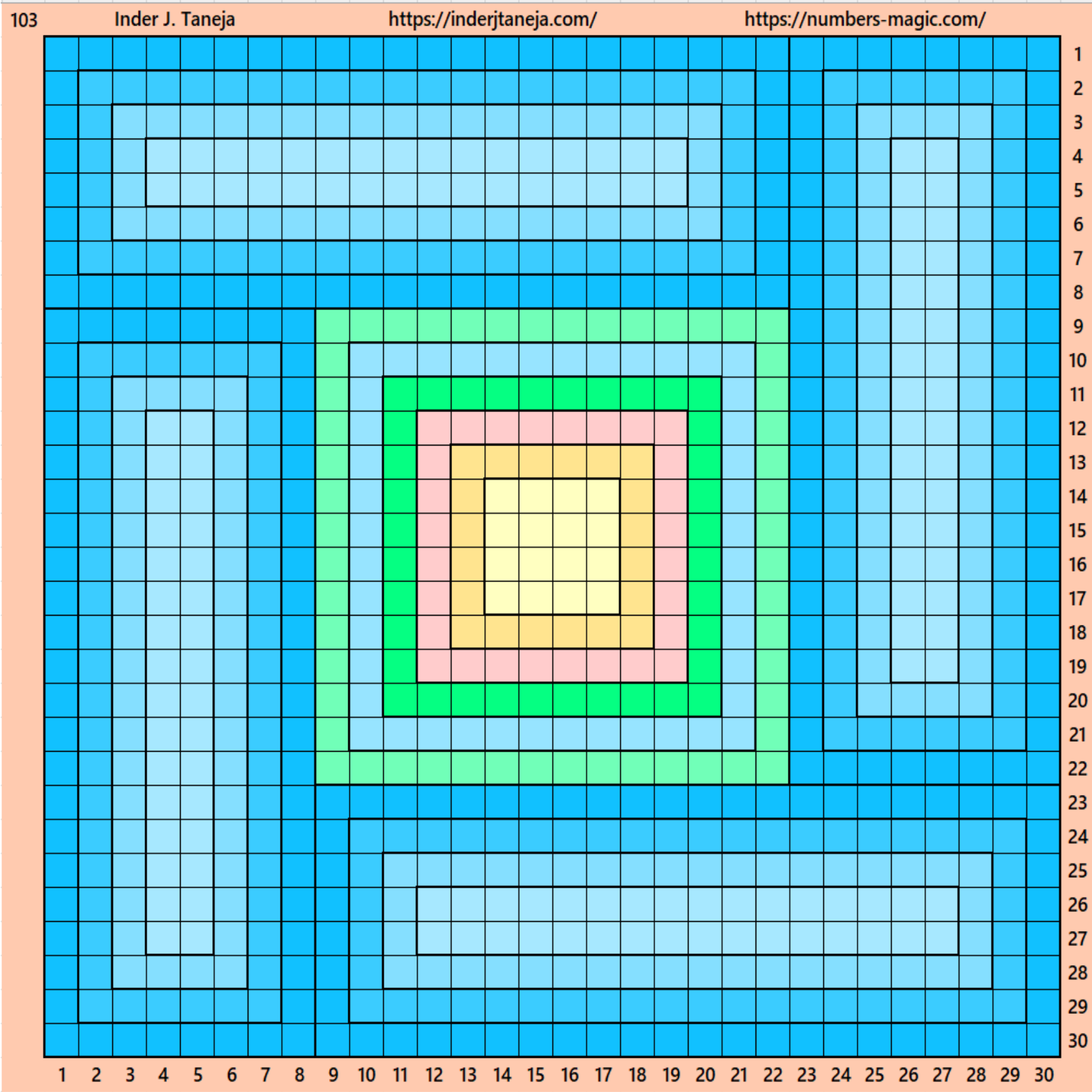


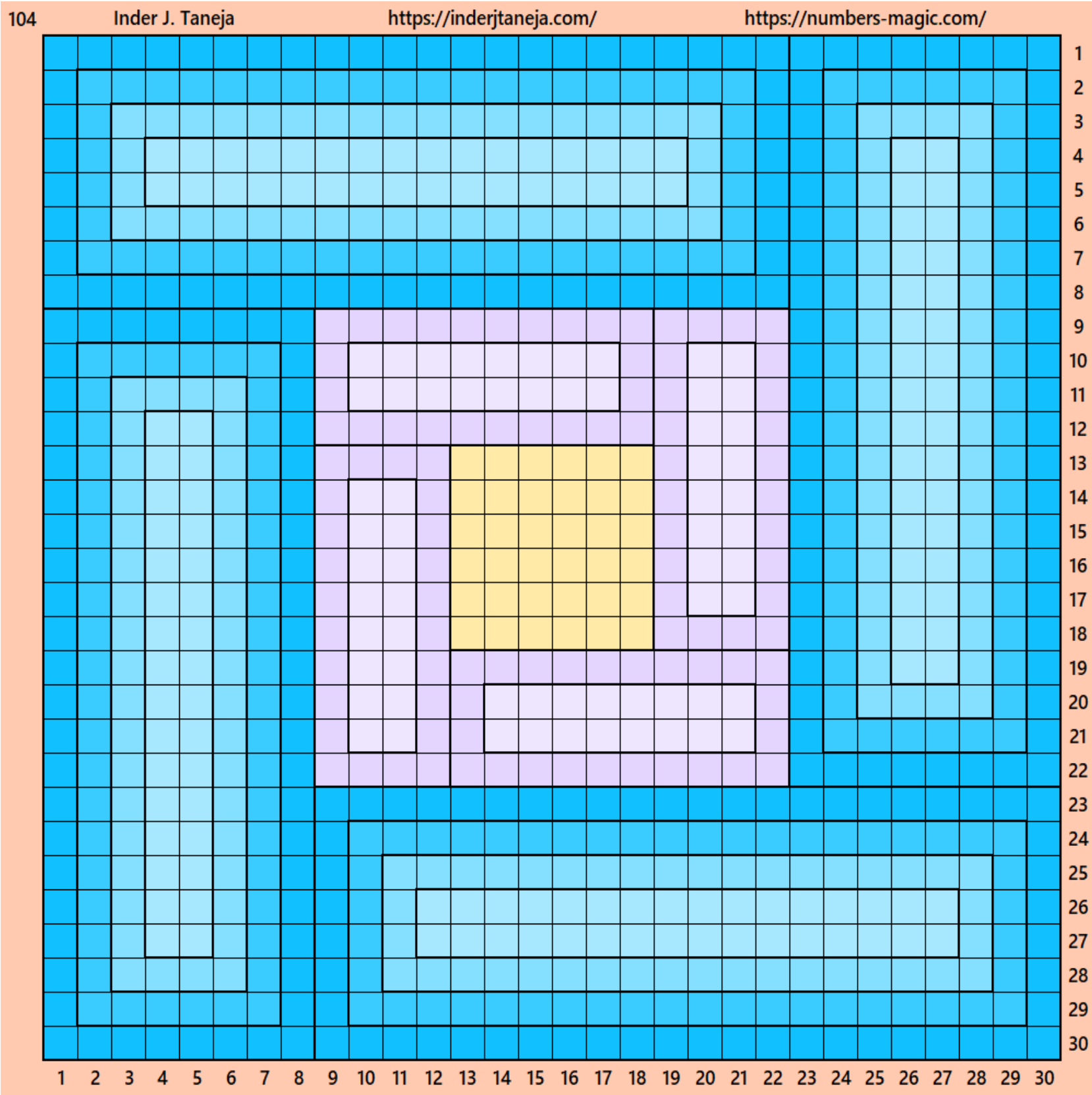


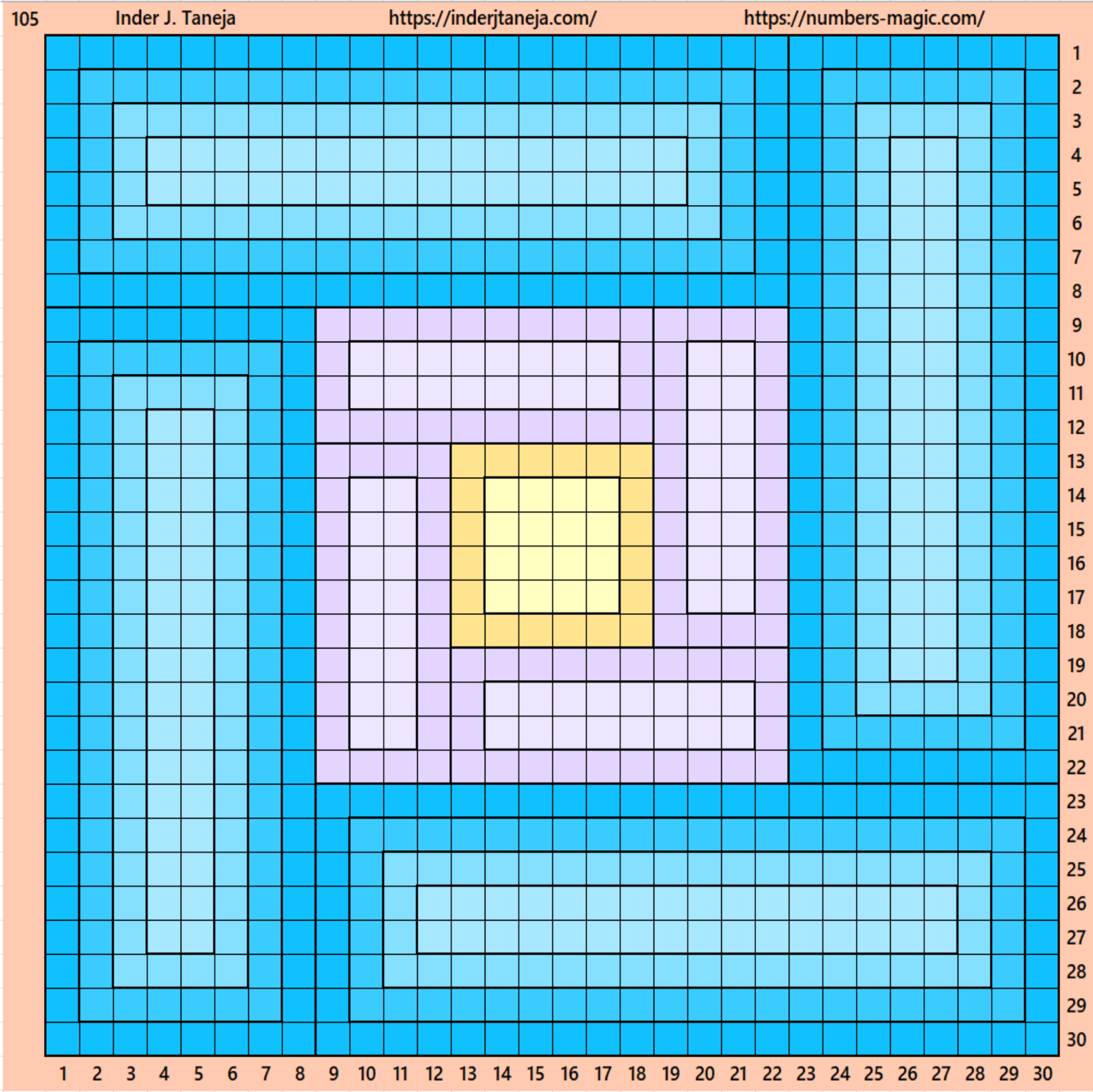


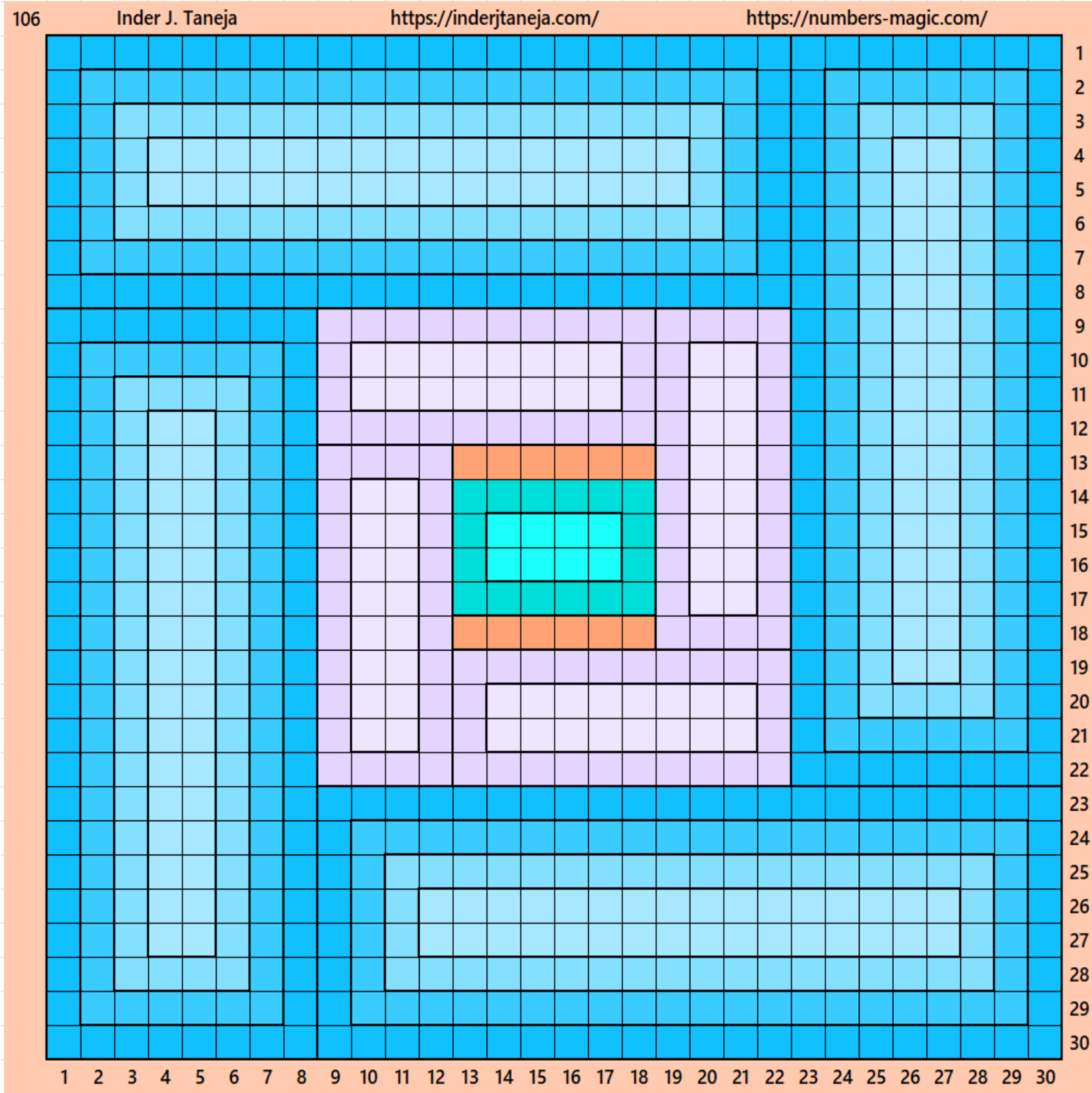
2.8 Closed Border of Order 8

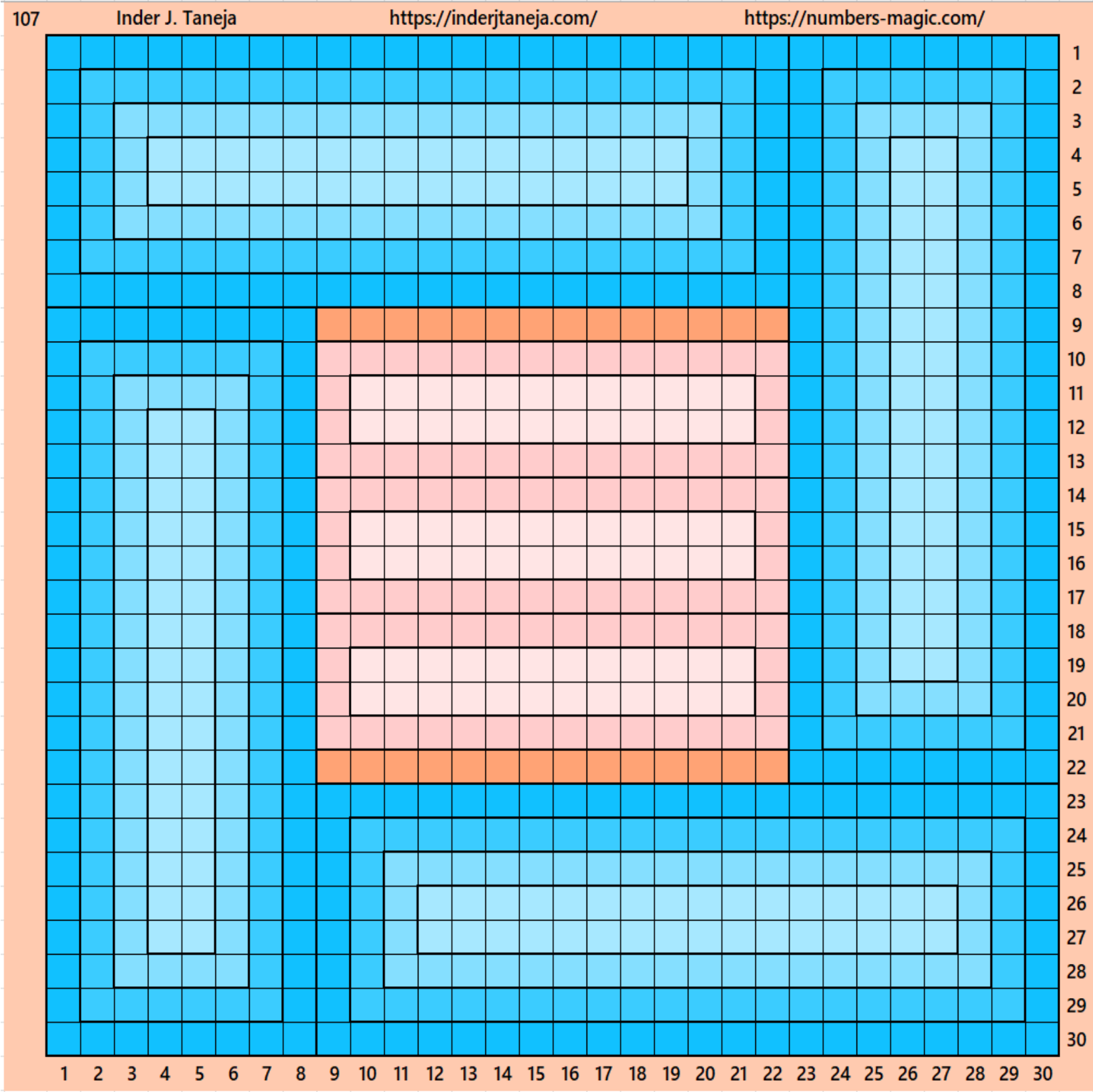
Let's consider an external border, where there are 4 BMRs of order 8×22 . Putting them in rows and columns, we get a closed border of order 8. In the middle we are left with blocks of order 14. Writing this middle blocks with different types of magic squares of order 14, we get magic squares of order 30. See below few examples:









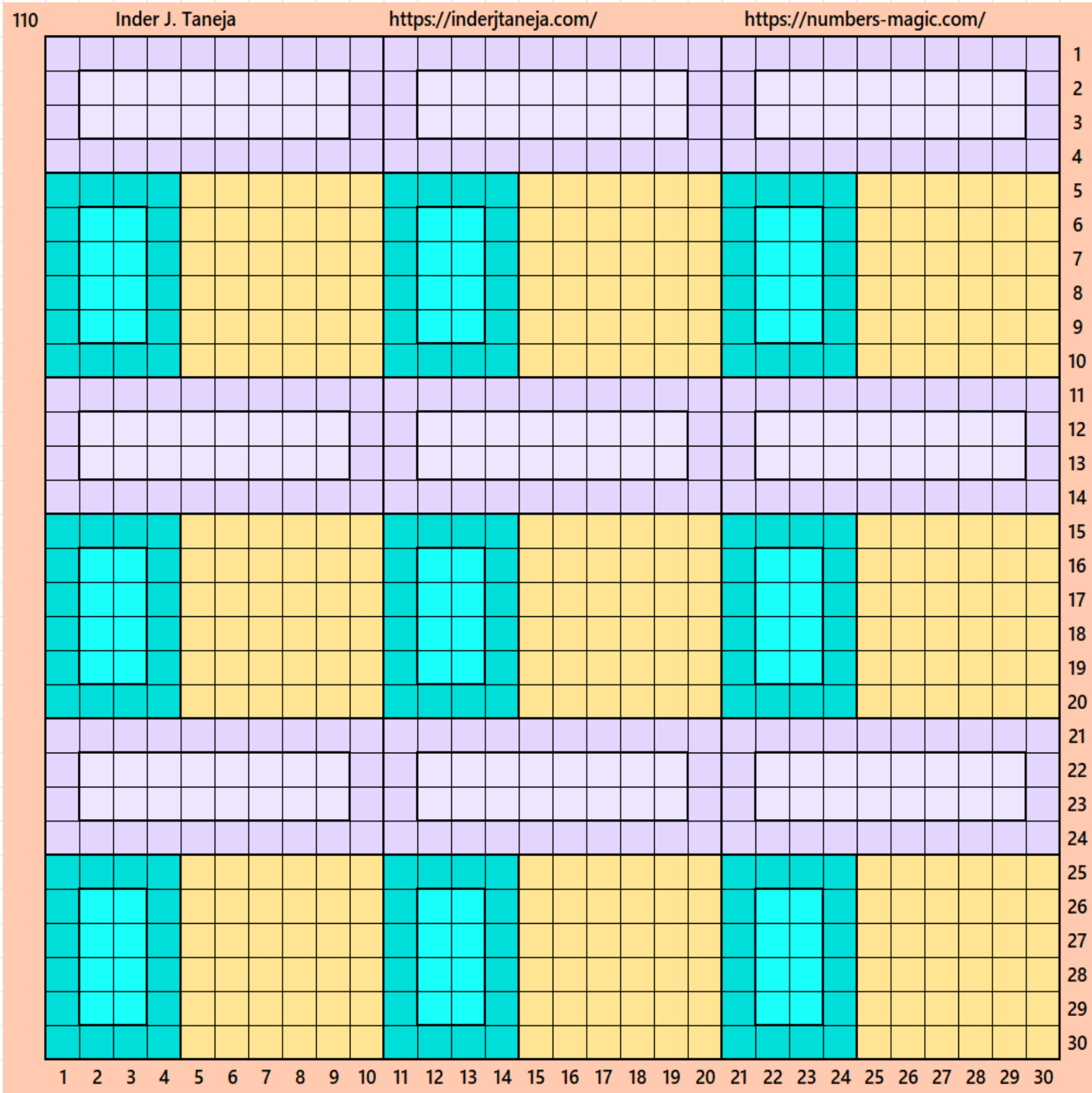


2.9 Equal Sums Blocks of Order 10

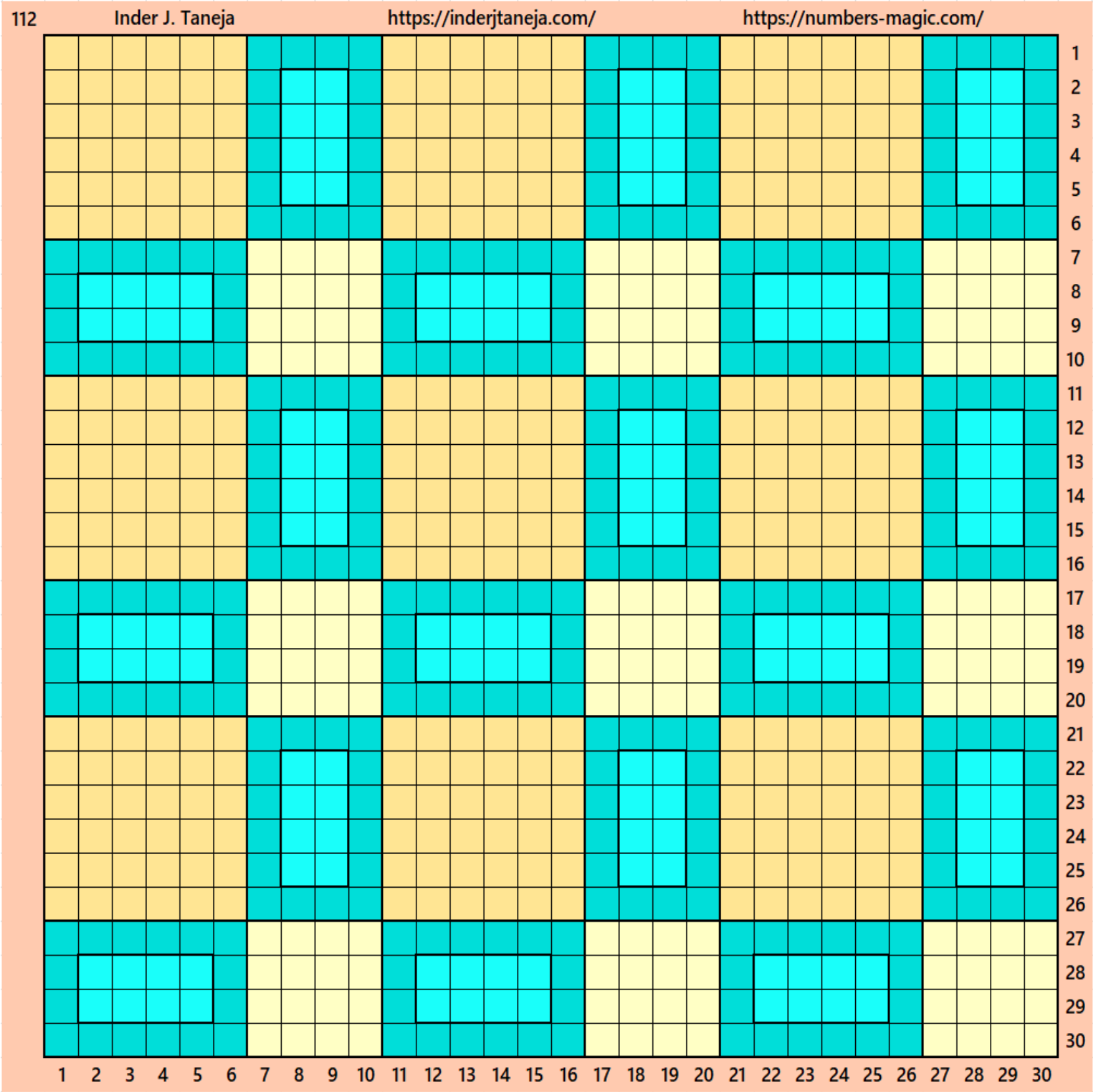
Let's consider 9 equal sums magic squares of order 10. This gives us magic squares of order 30. See below few examples:

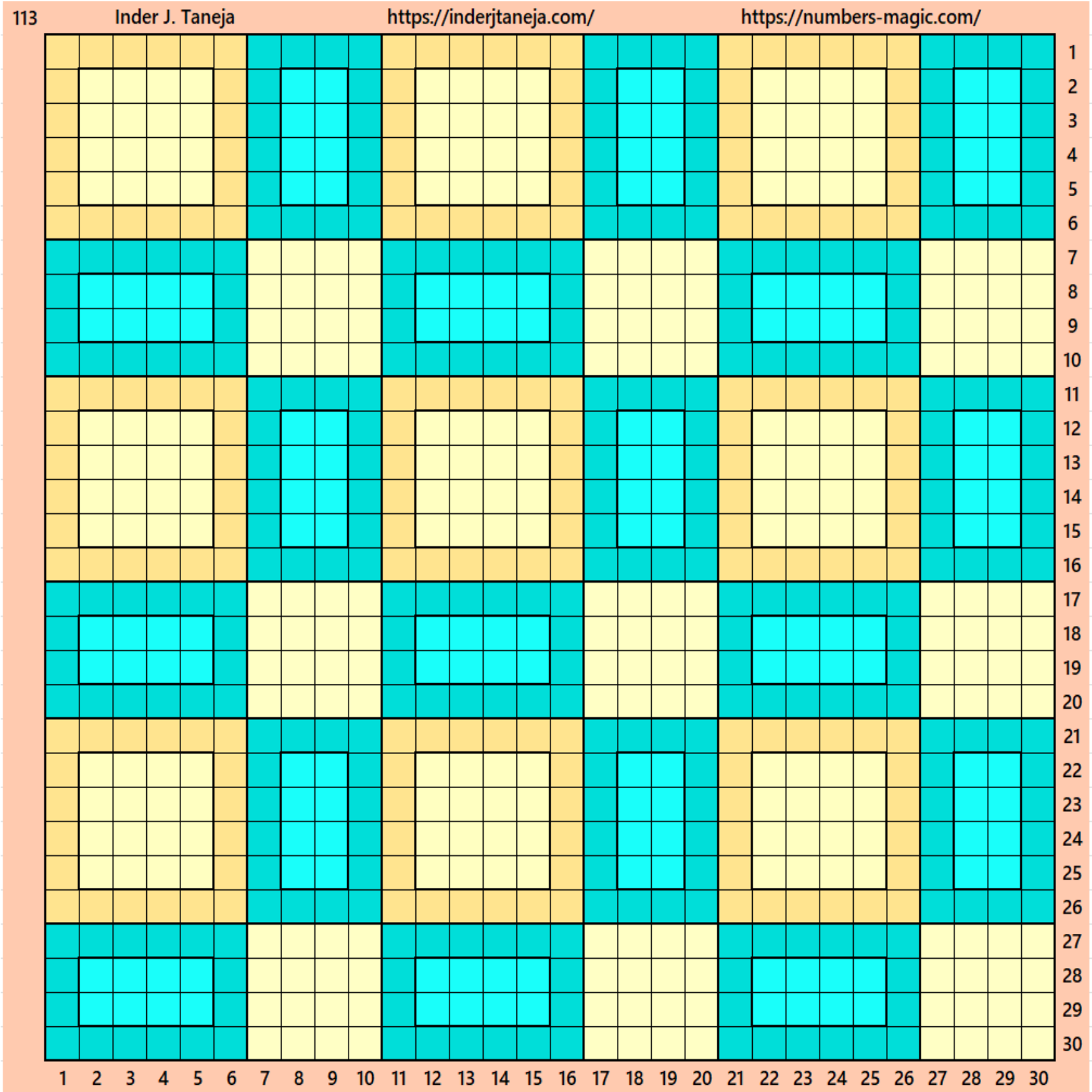


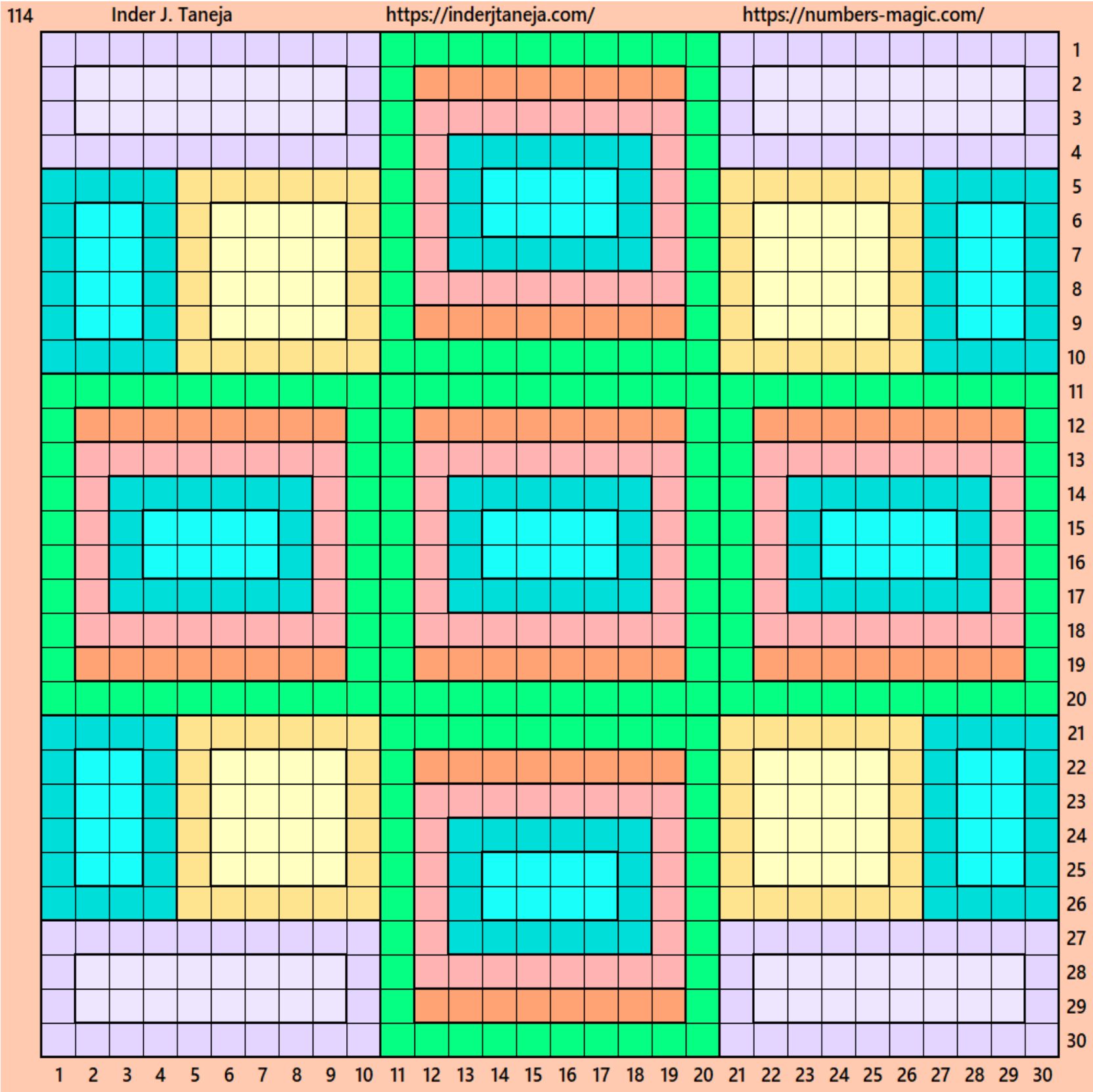
121

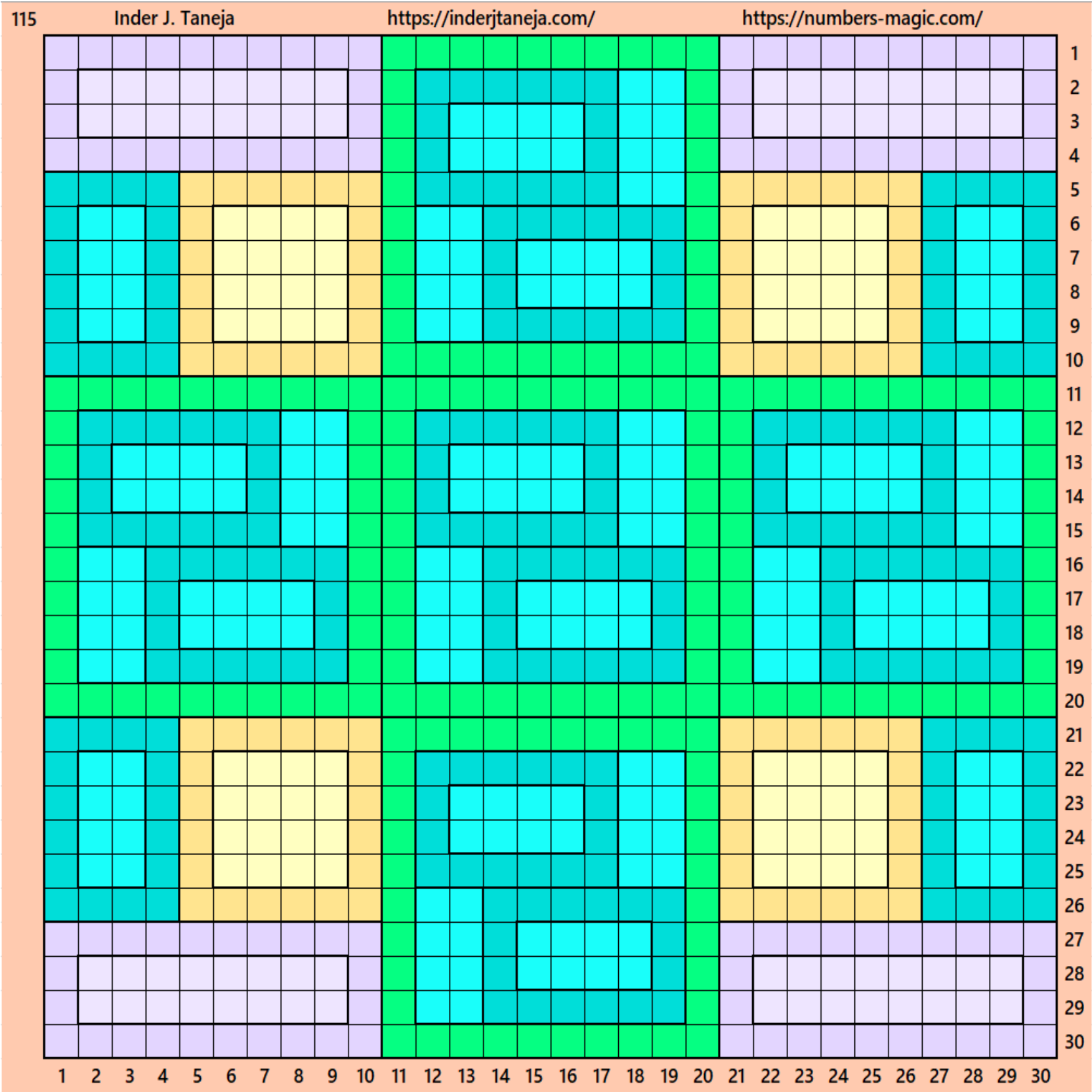


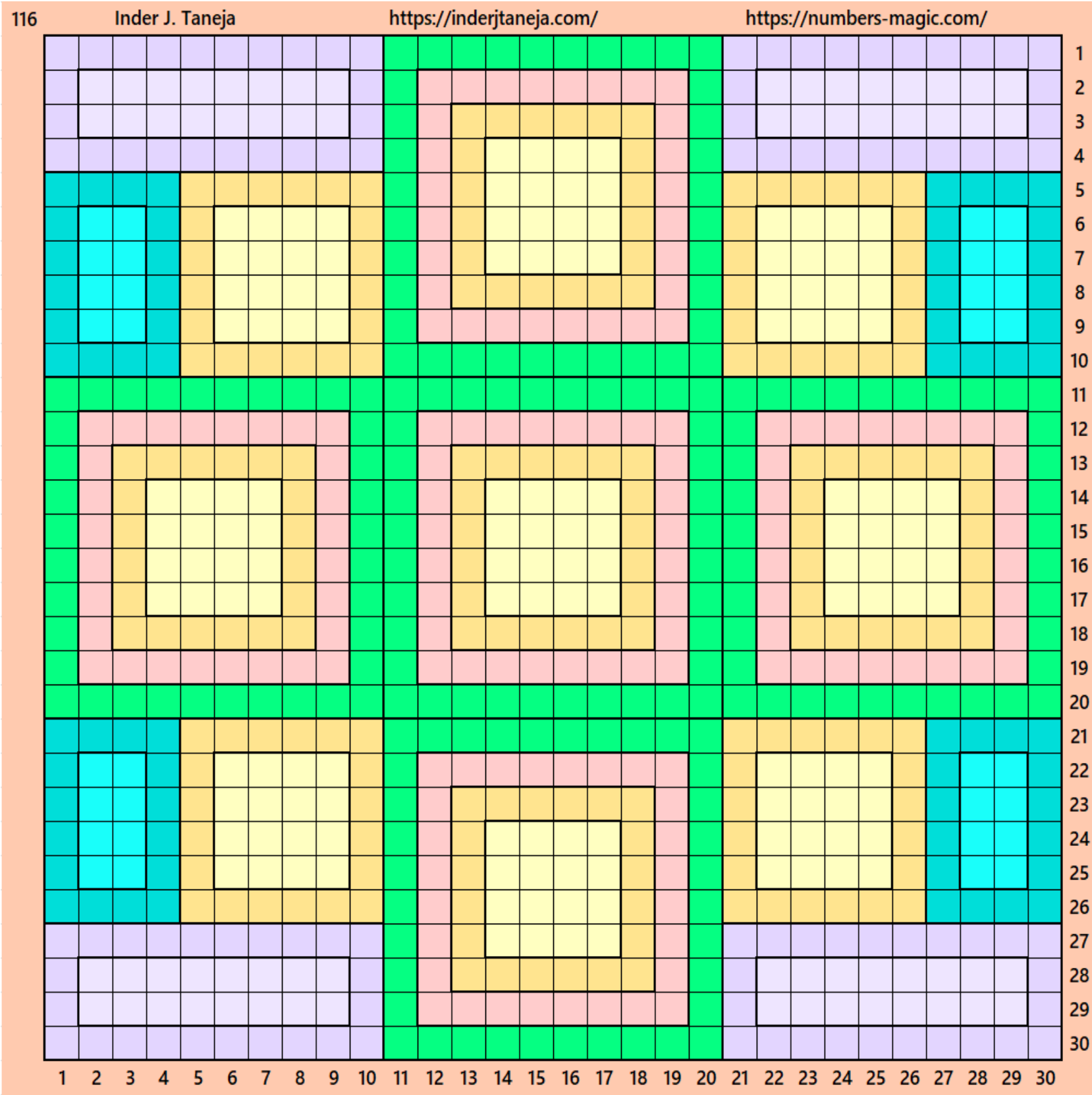


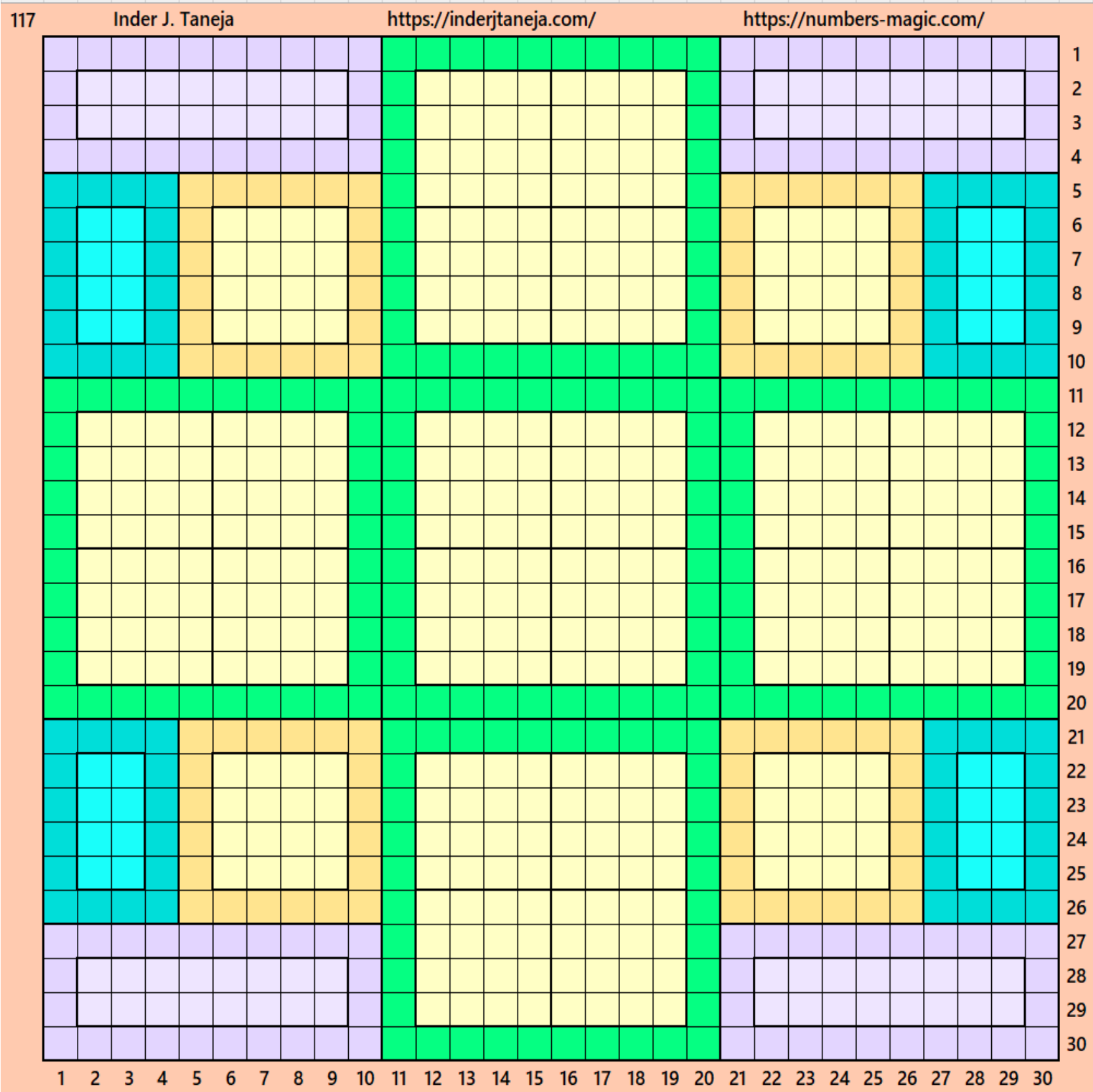






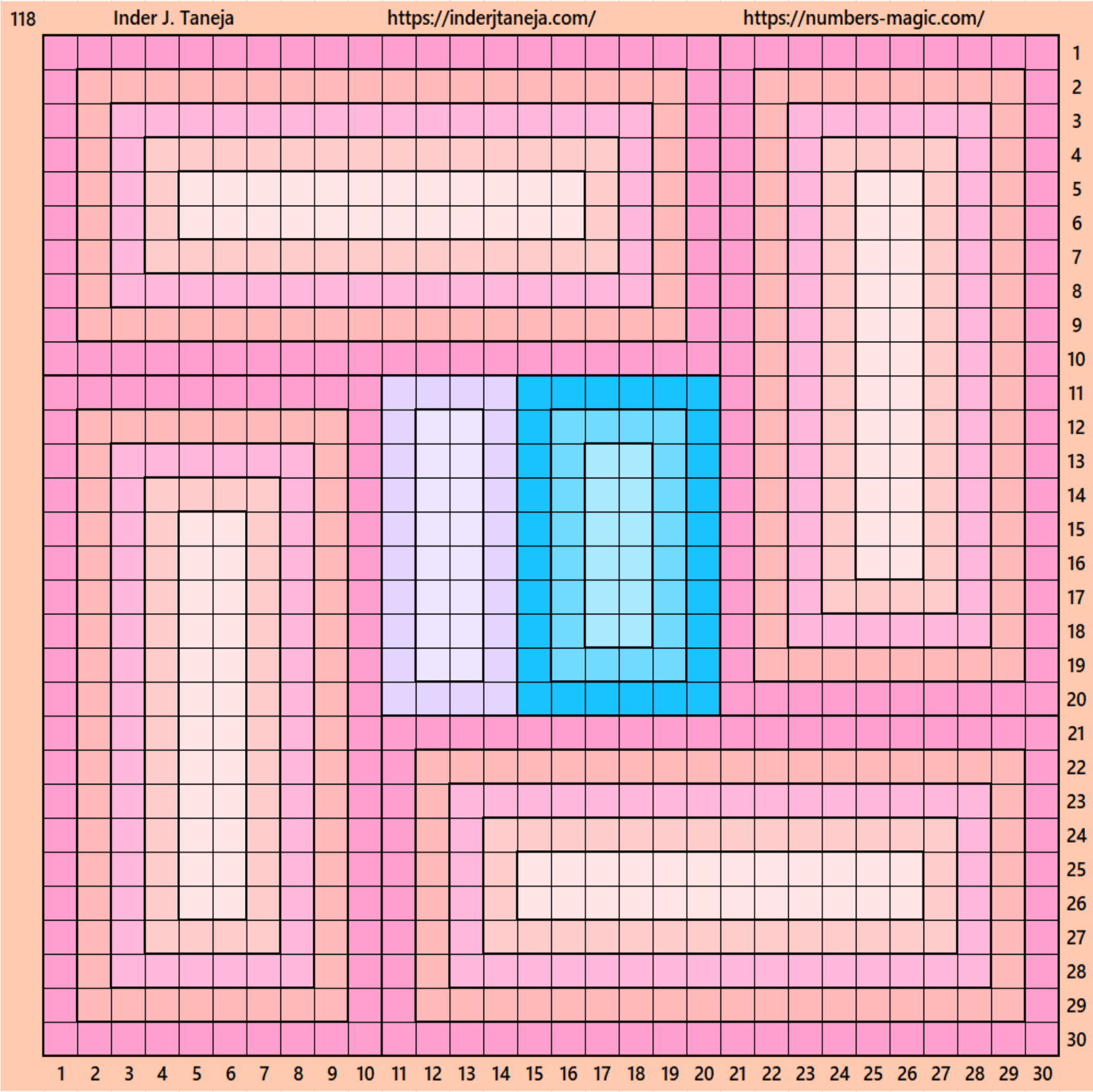


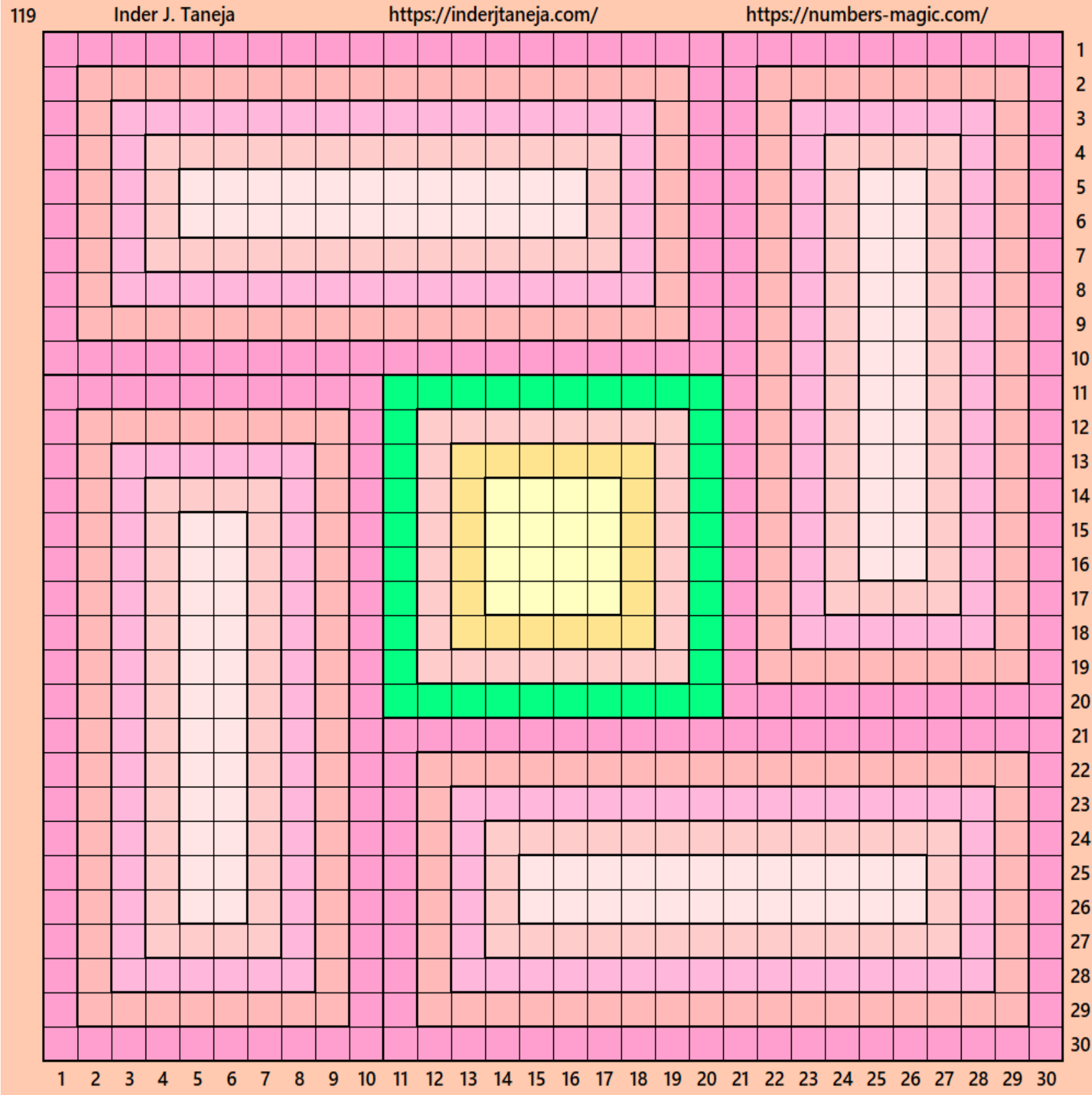




2.10 Closed Border of Order 10

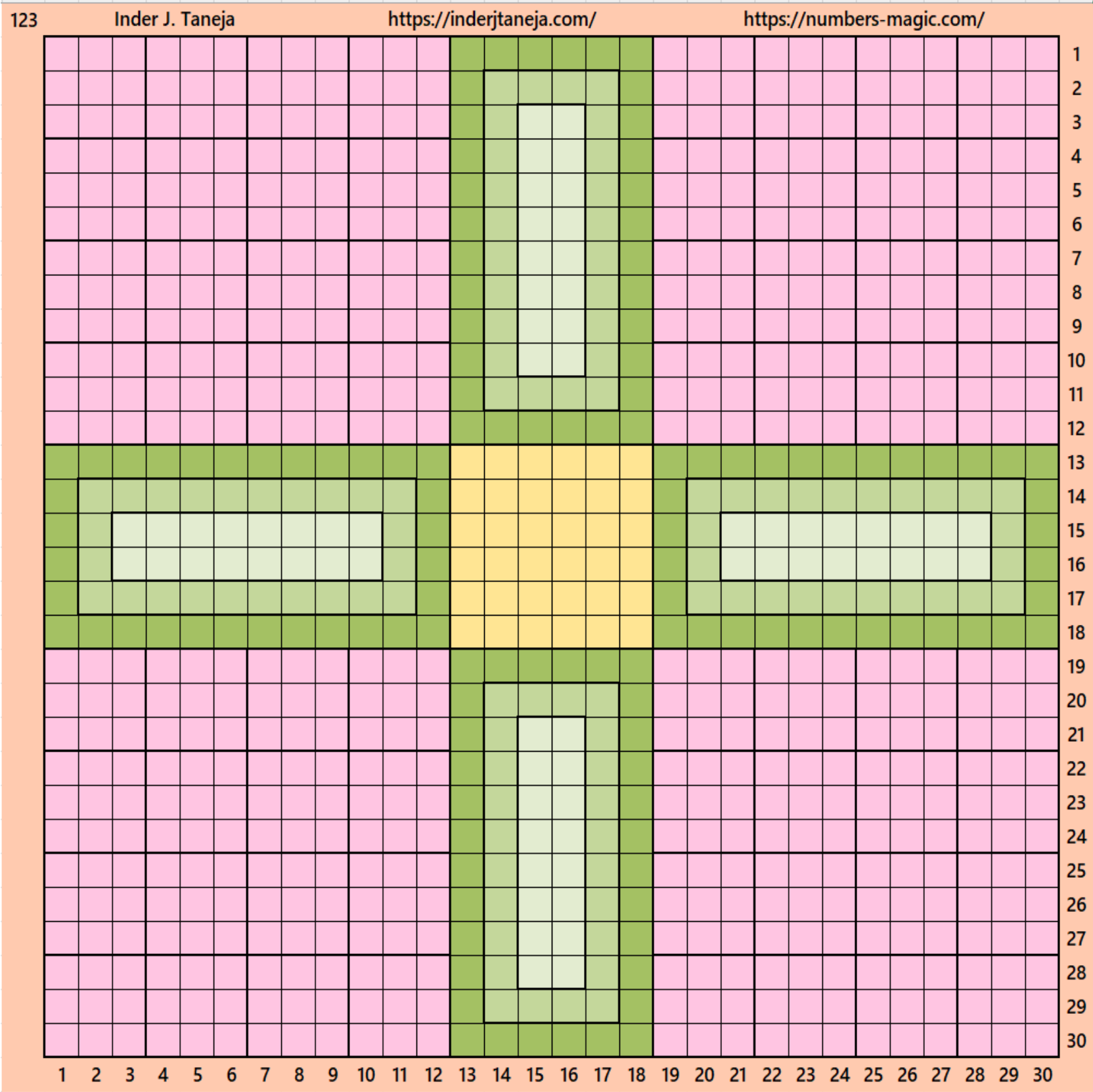
Let's consider 4 equal sums BMRs of orders 10×20 . Putting them in rows and columns, we get a closed border of order 10. In the middle we are left with blocks of order 10. Writing this middle blocks with different types of magic squares of order 10, we get magic squares of order 30. See below few examples:



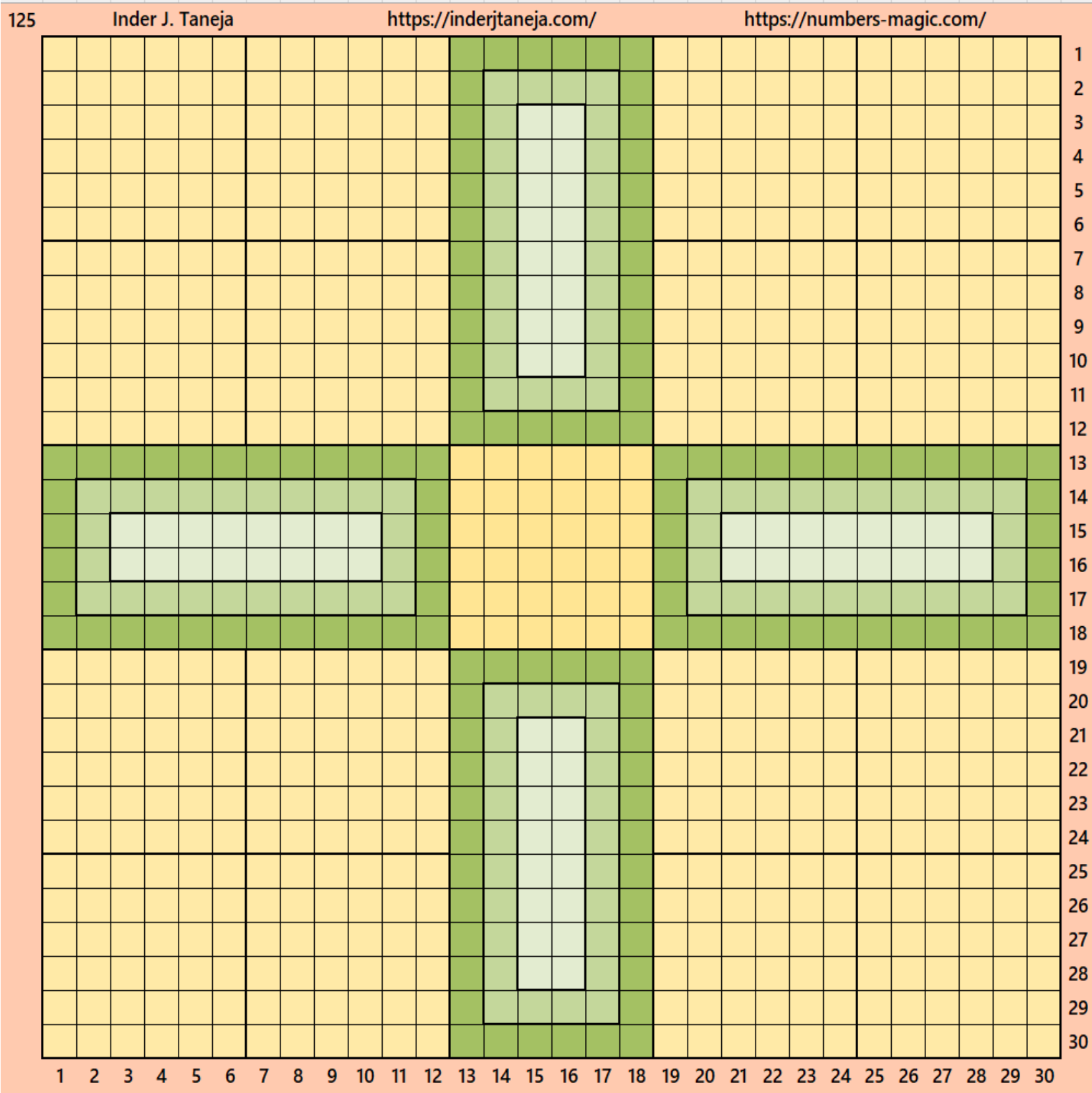


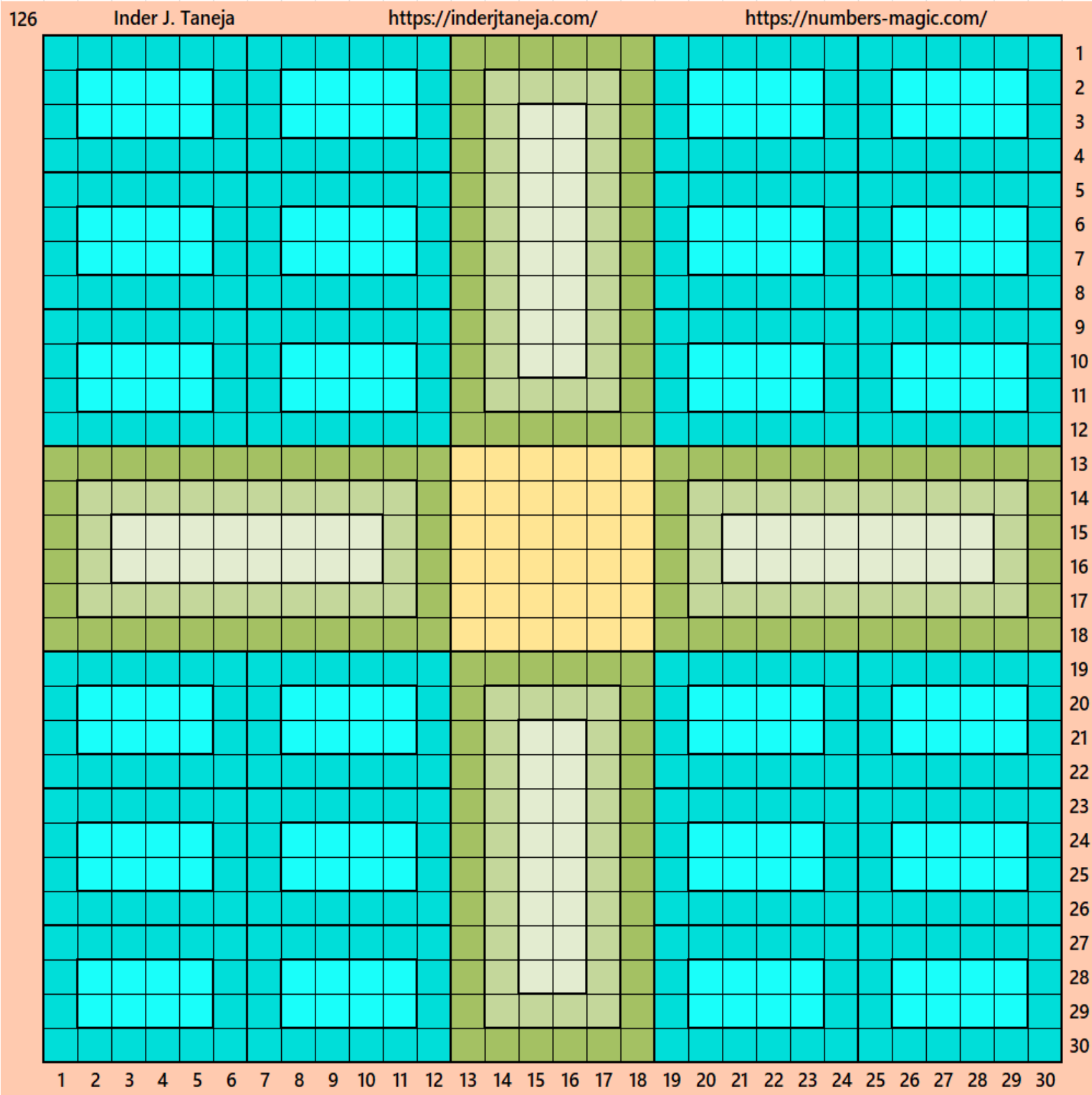
2.11 Cornered Magic Squares of Order 12

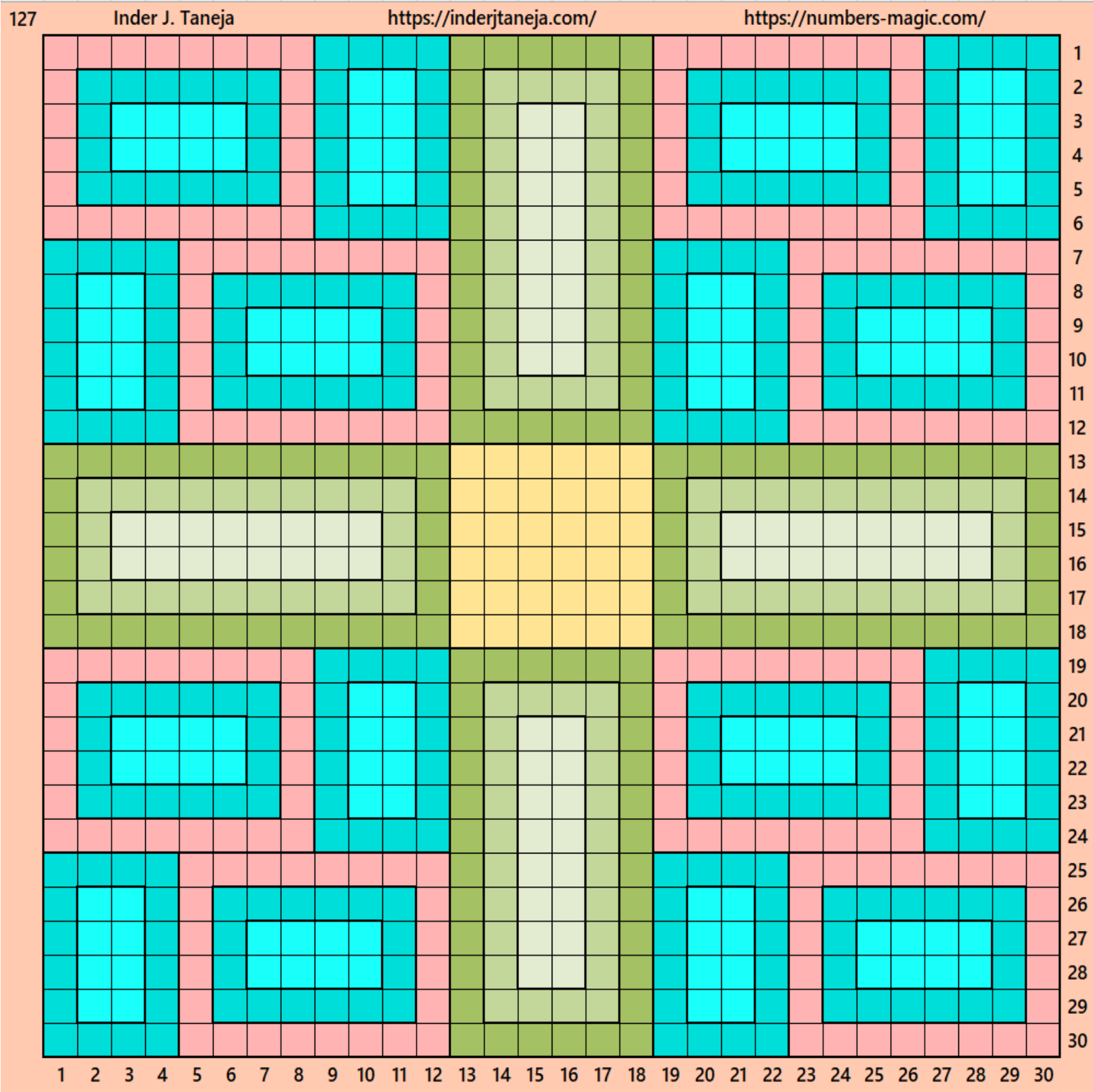
Let's consider an external border, where there are 4 magic squares of order 12 at the corners. Let's make an external border by putting 2 BMRs of order 4×6 in each row and column. In the middle we are left with blocks of order 4. Writing magic squares of order 12 in different ways, we get magic squares of order 30. See below few examples:

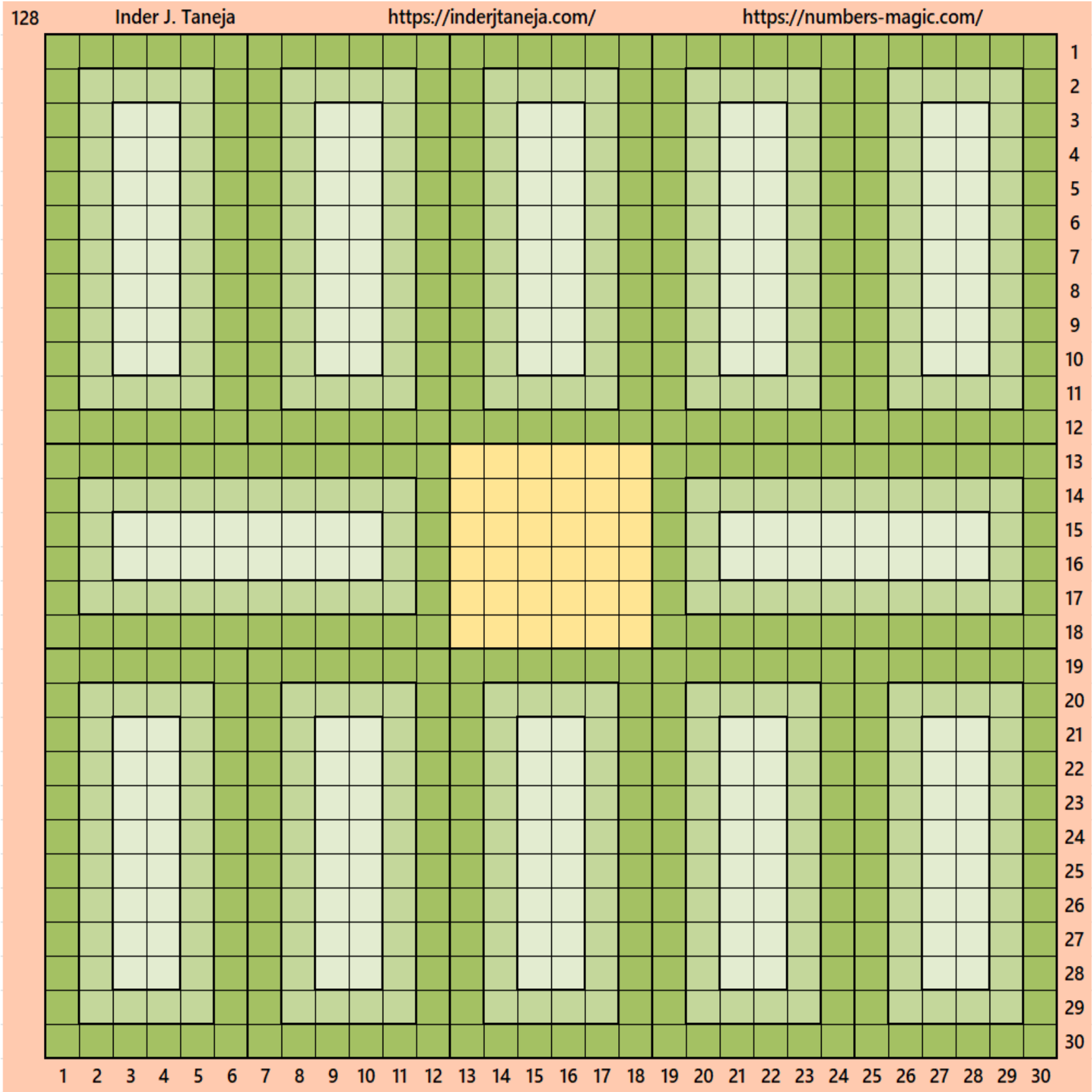


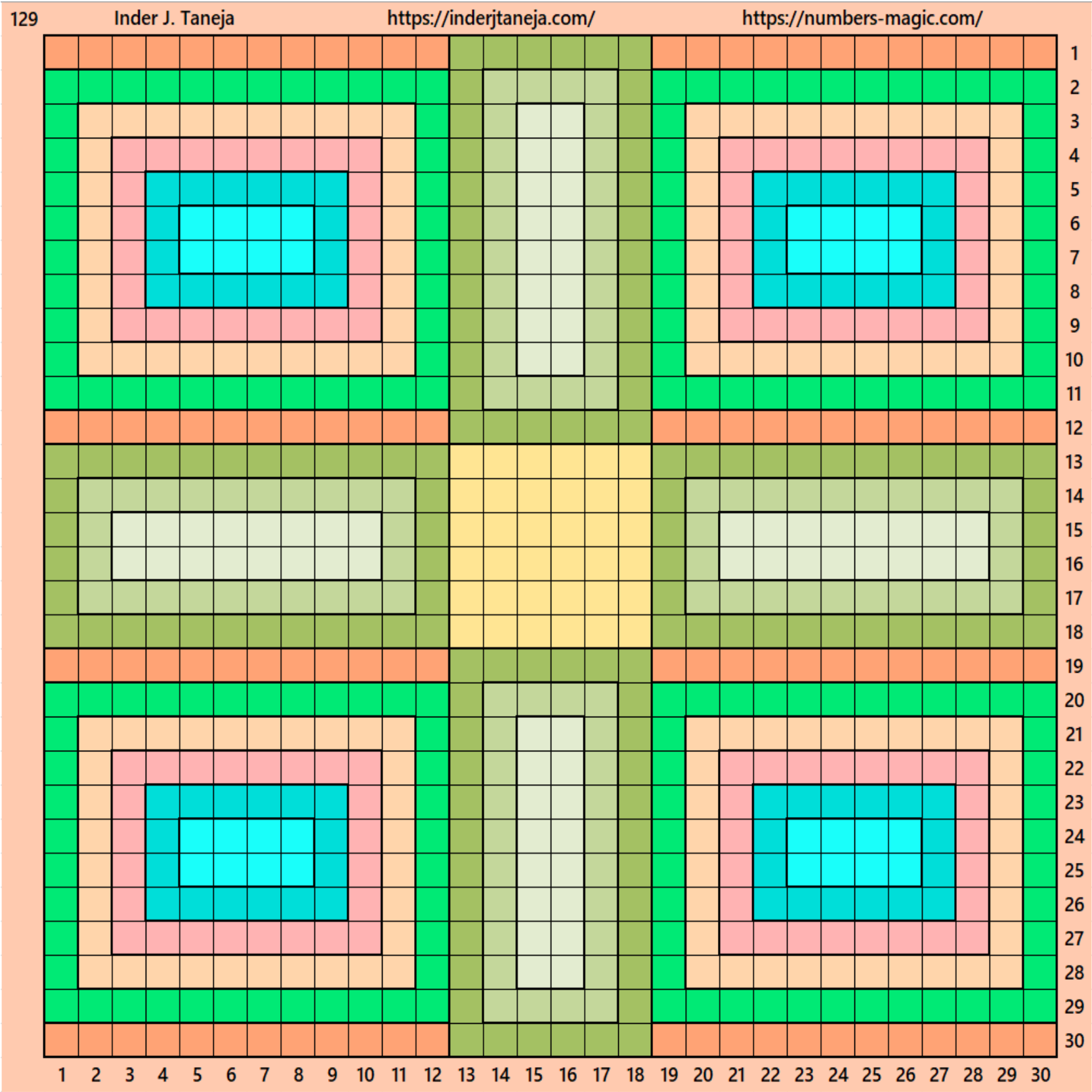


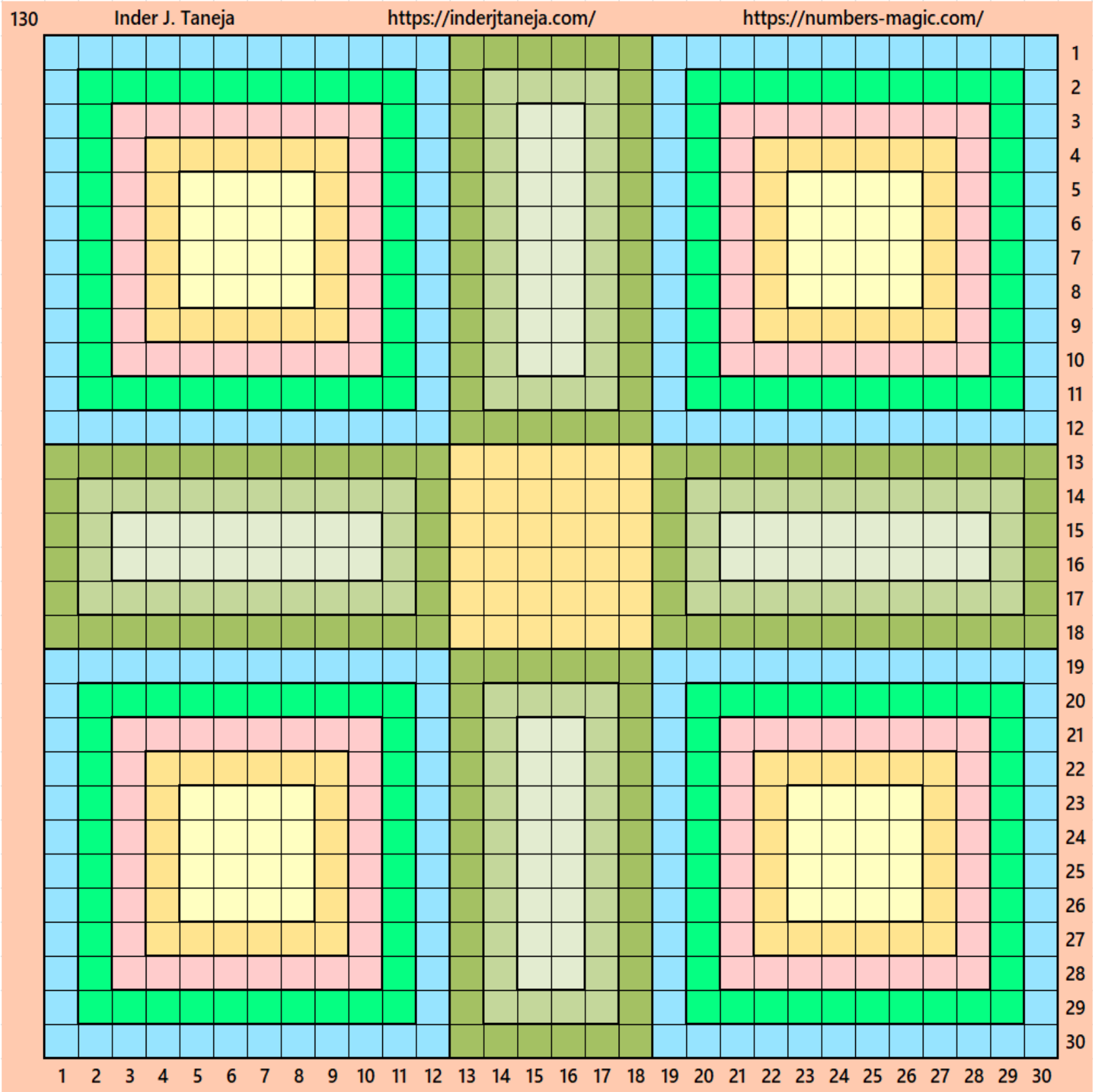


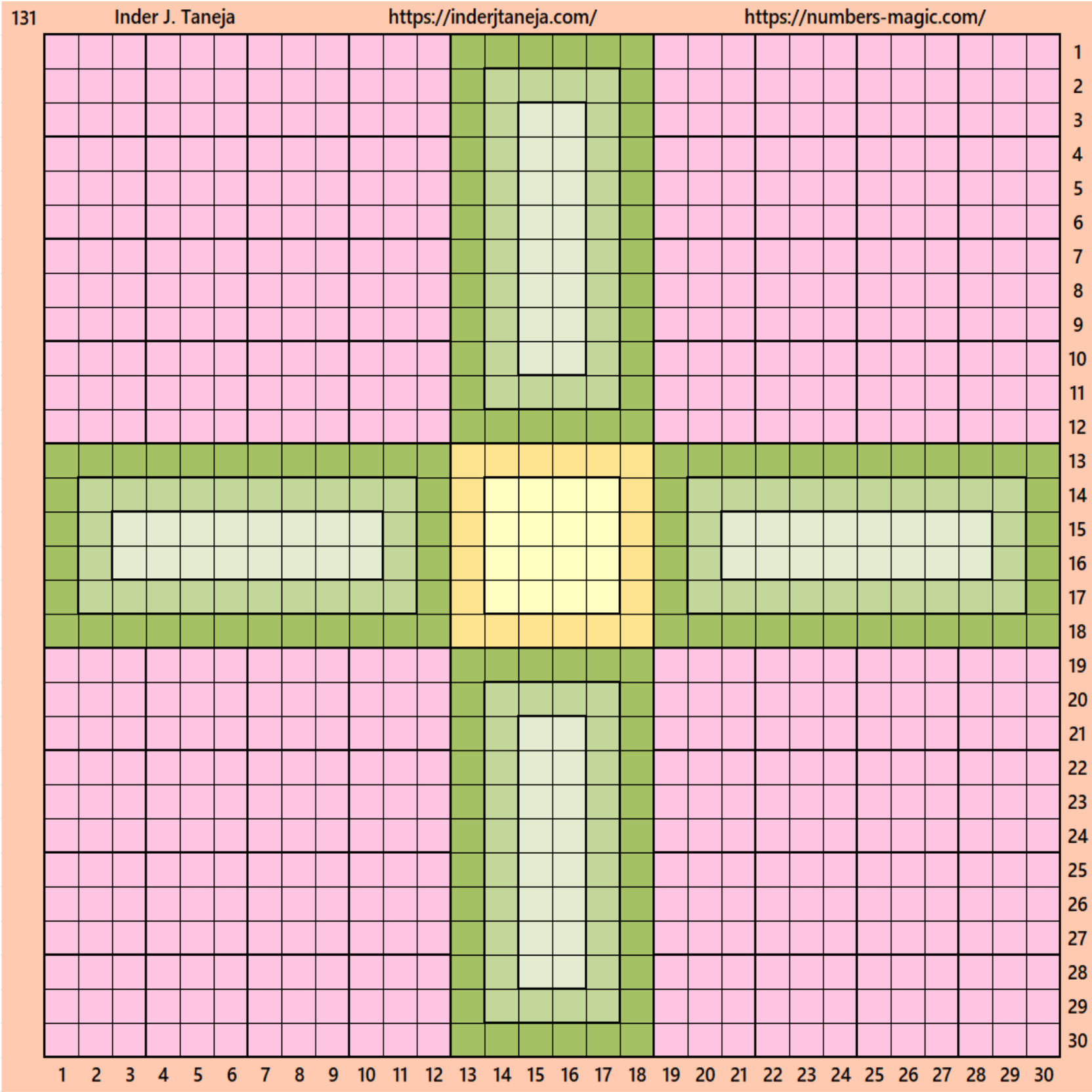


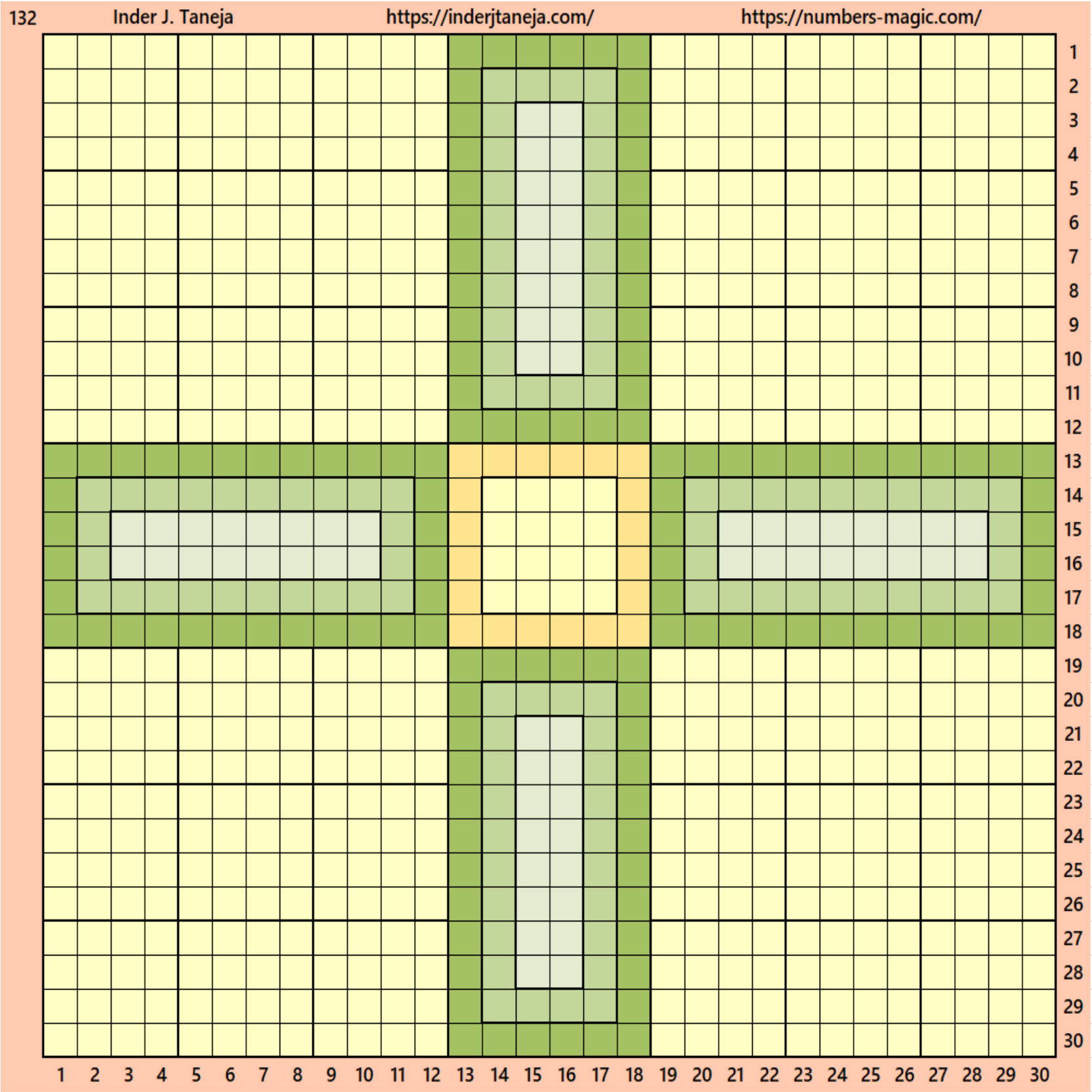


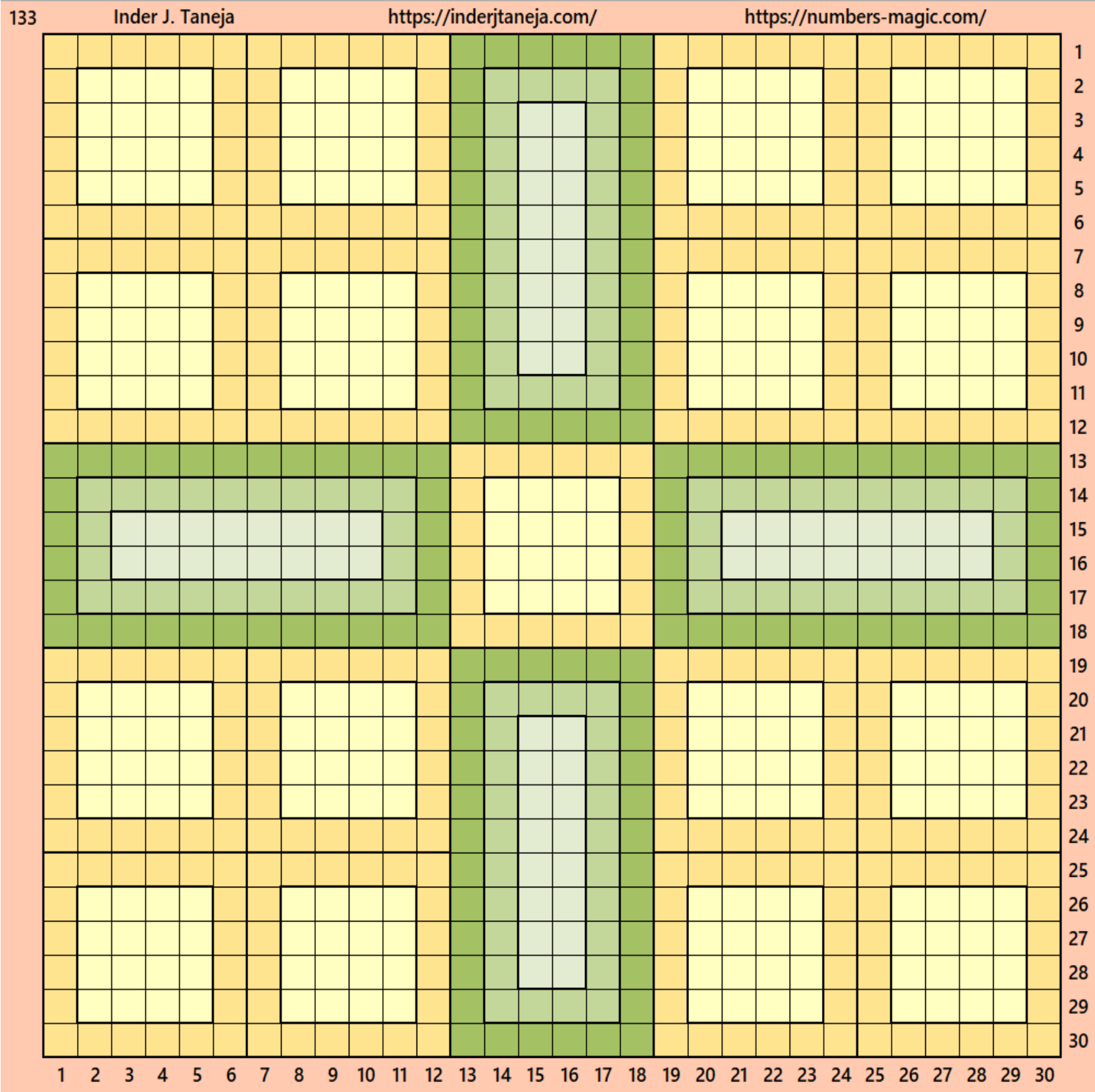


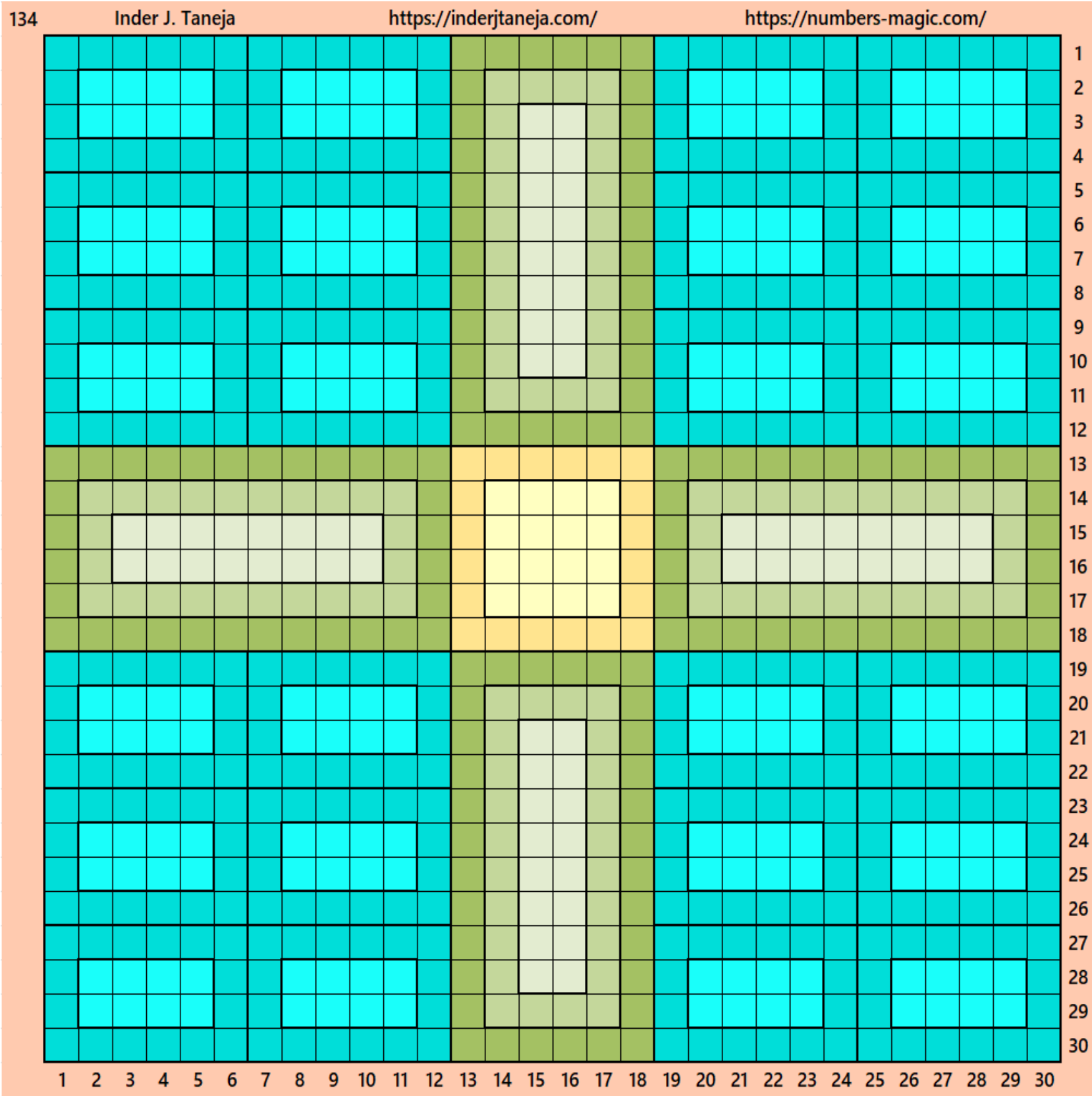


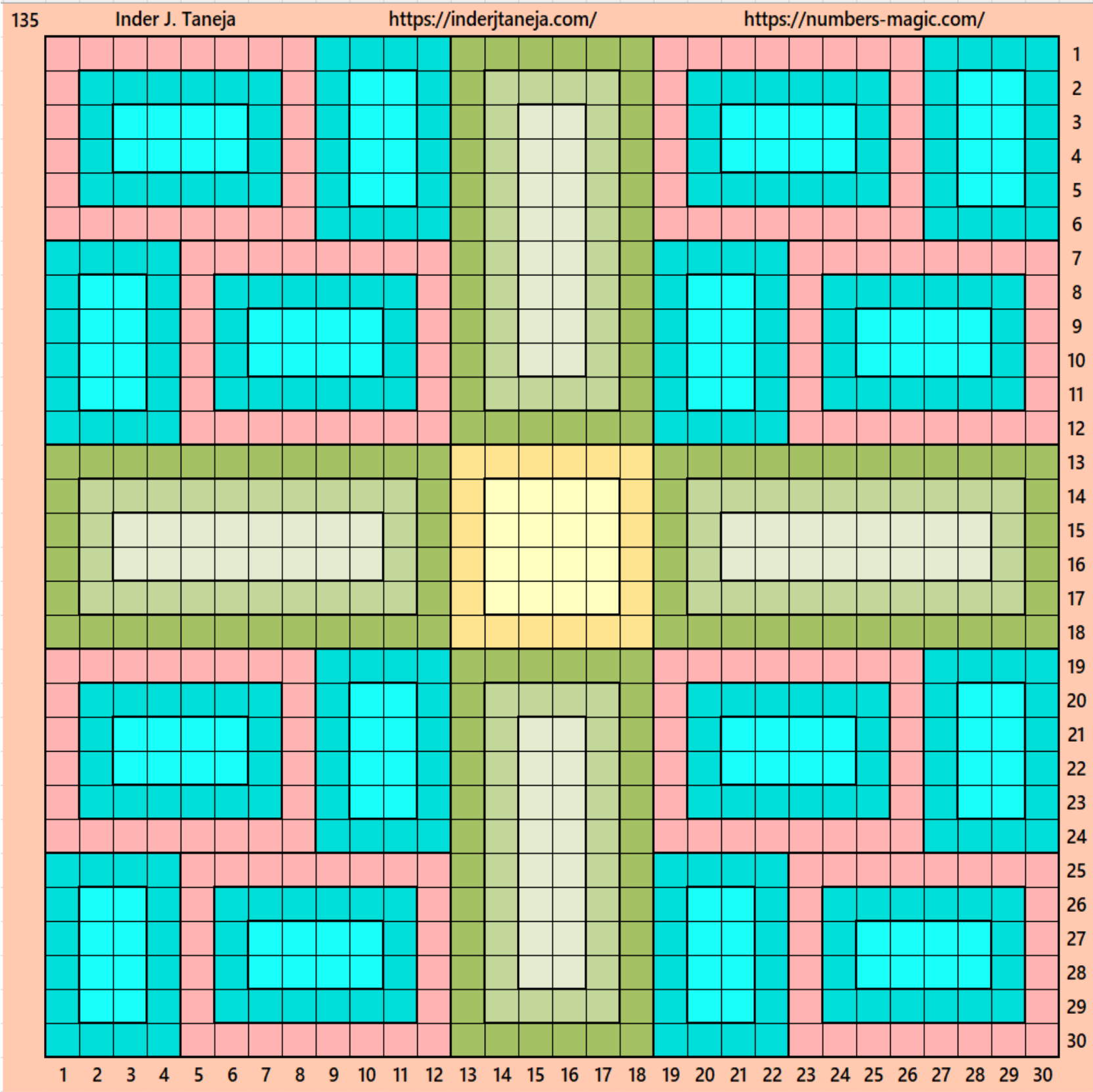




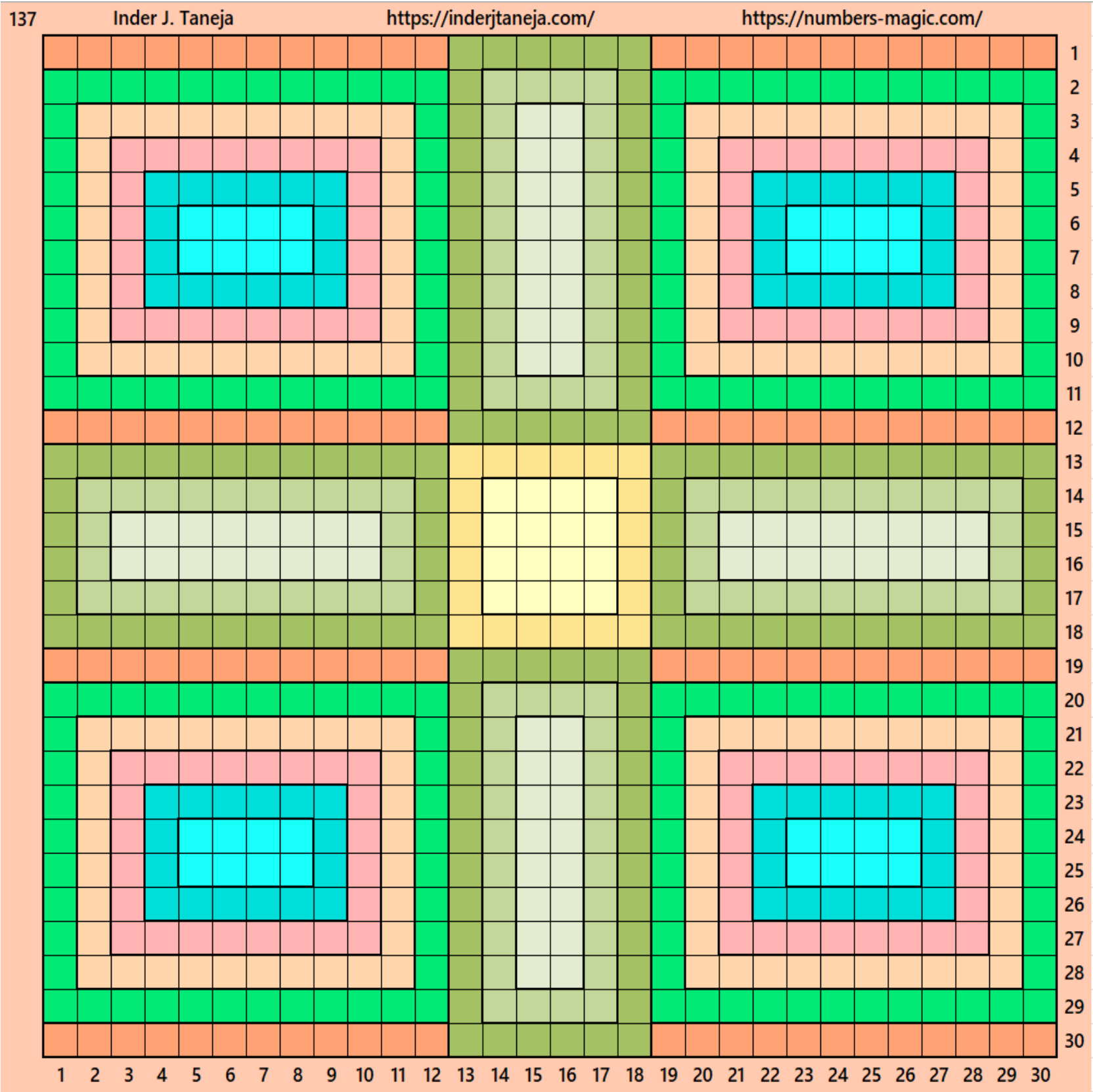


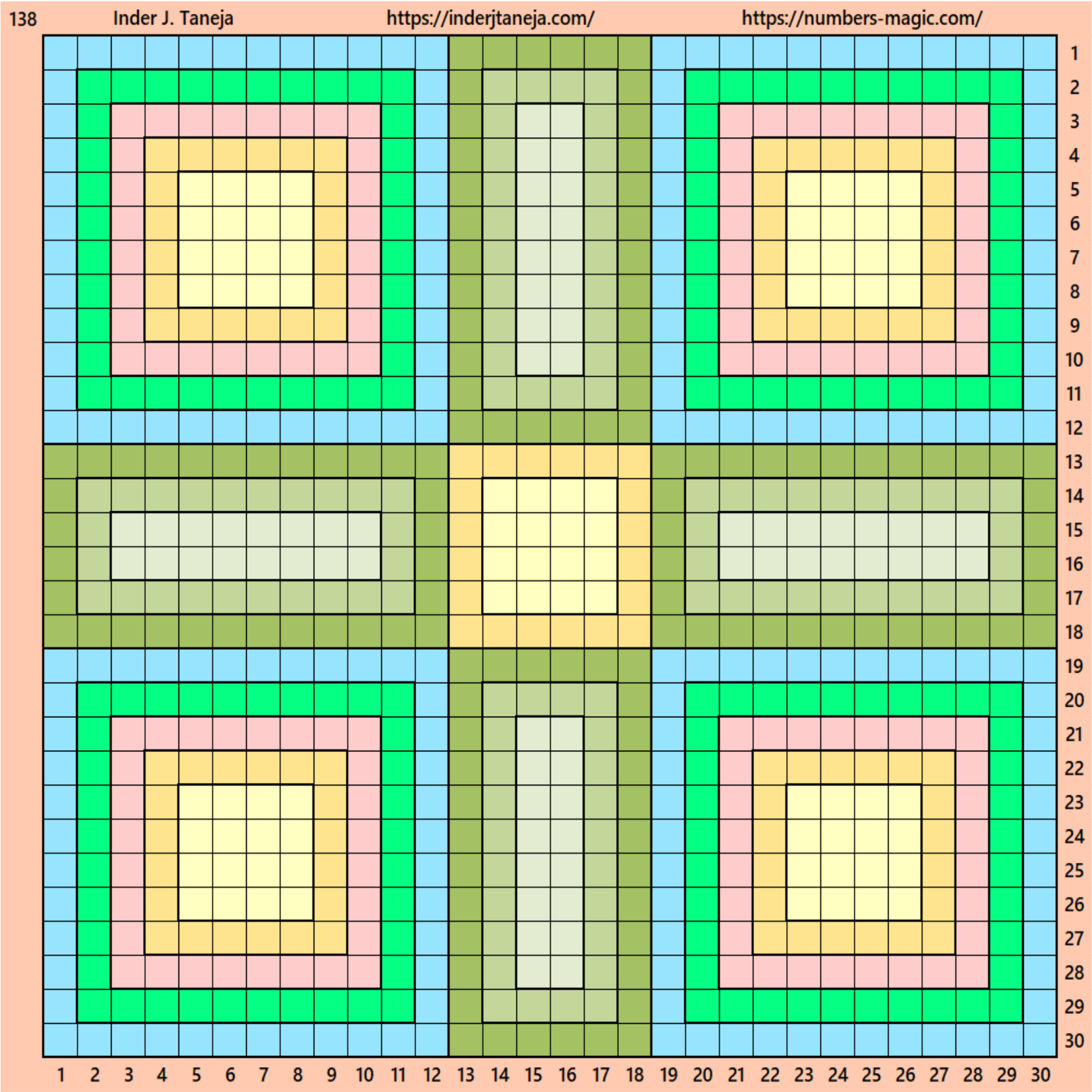


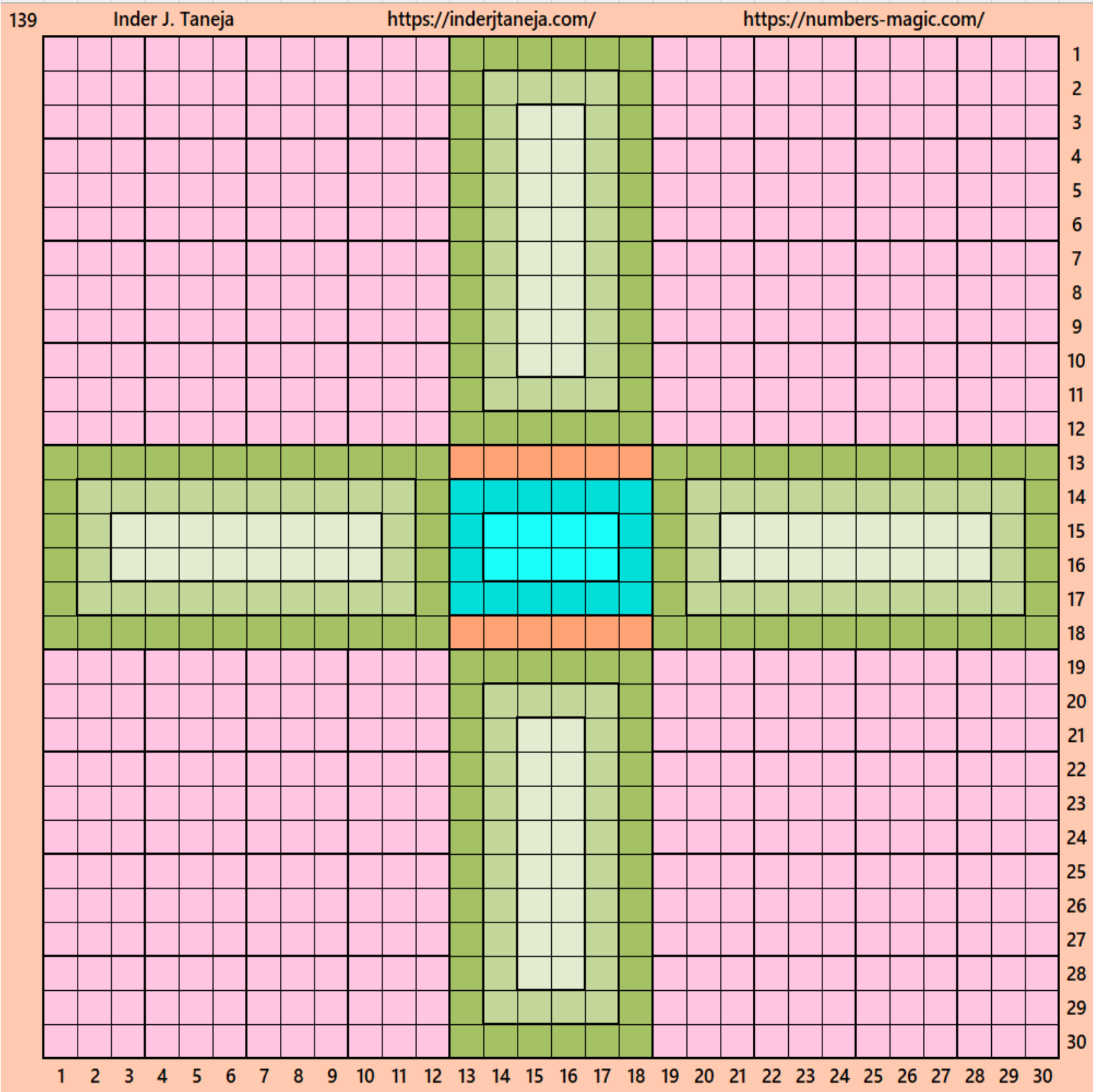




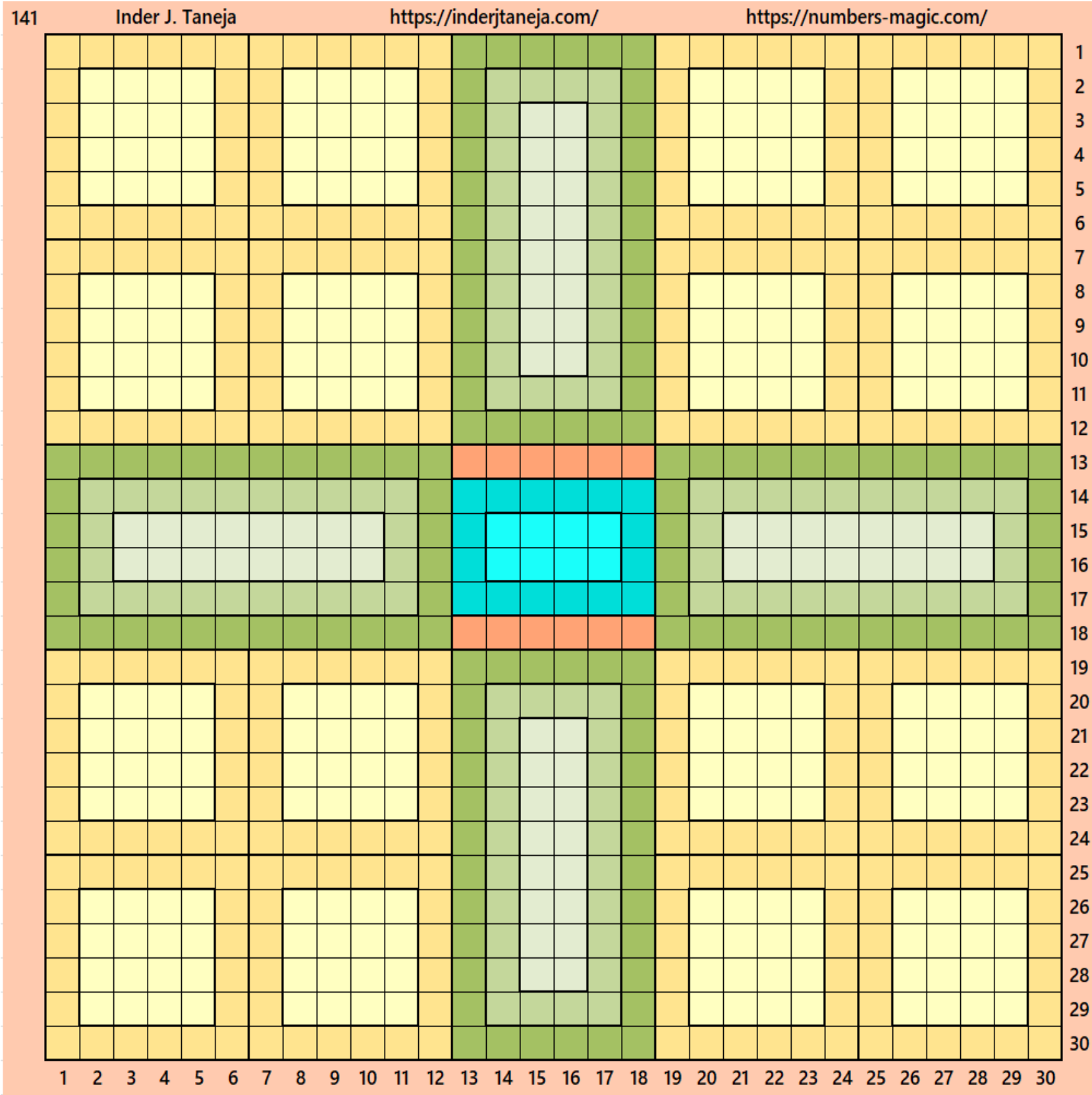


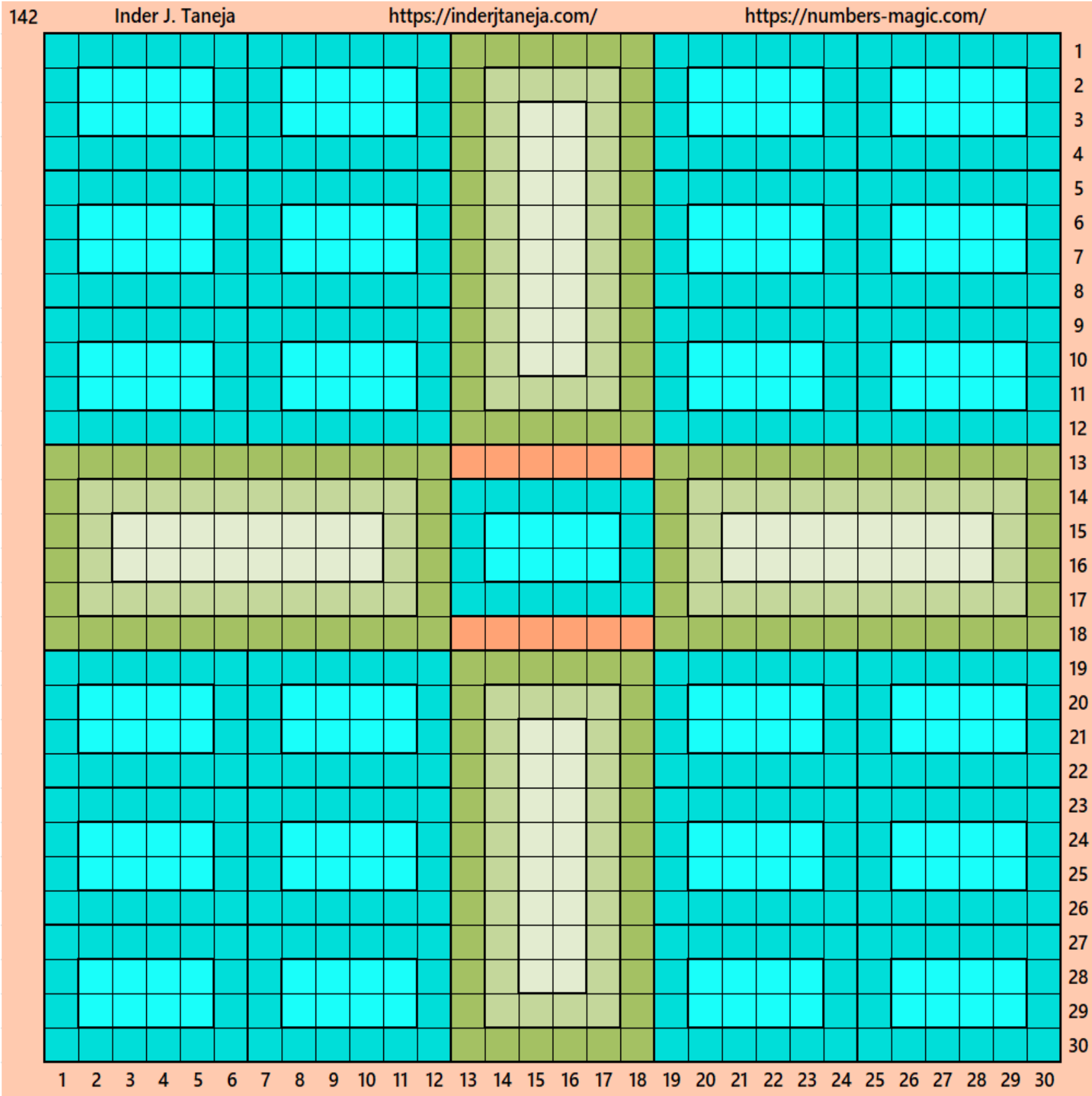


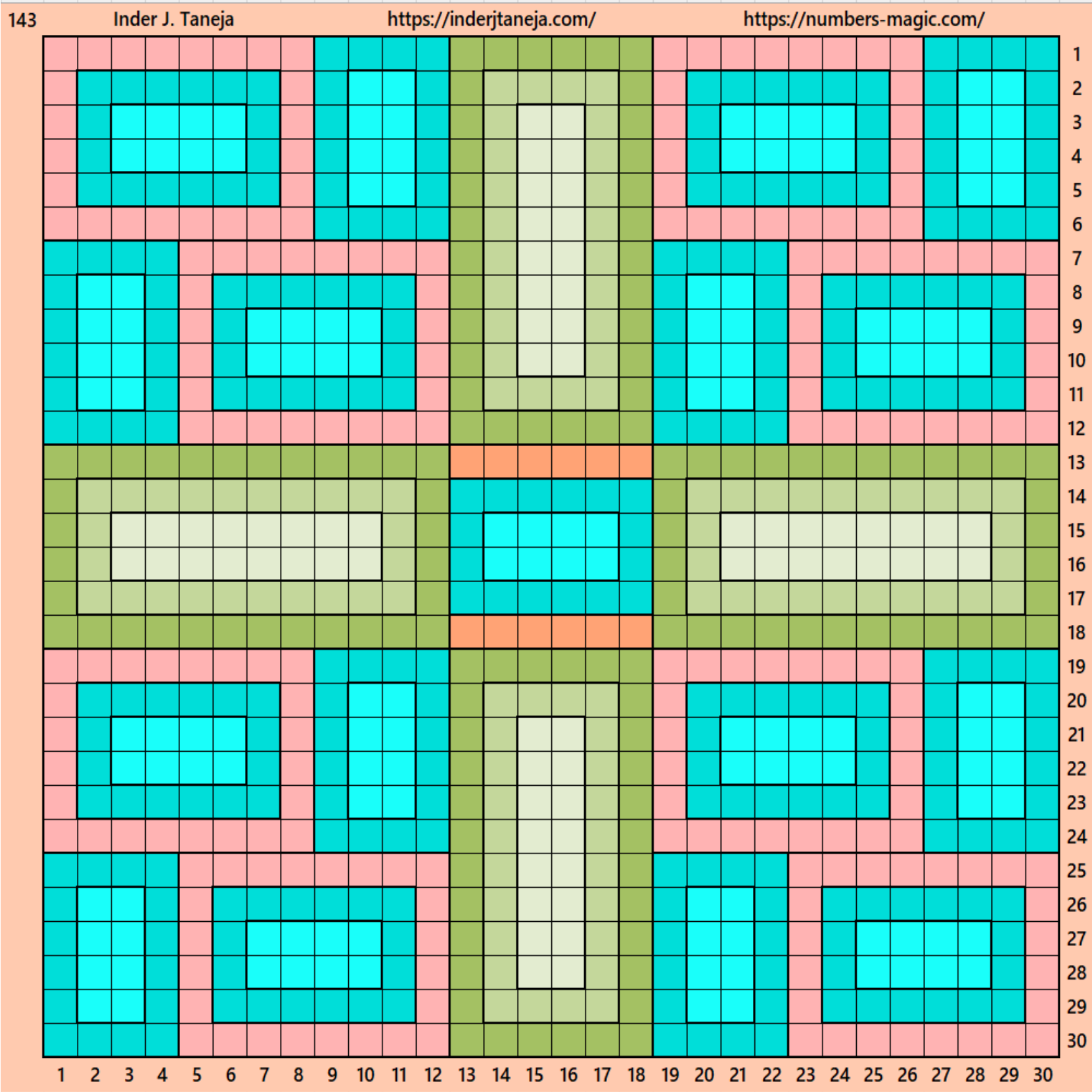




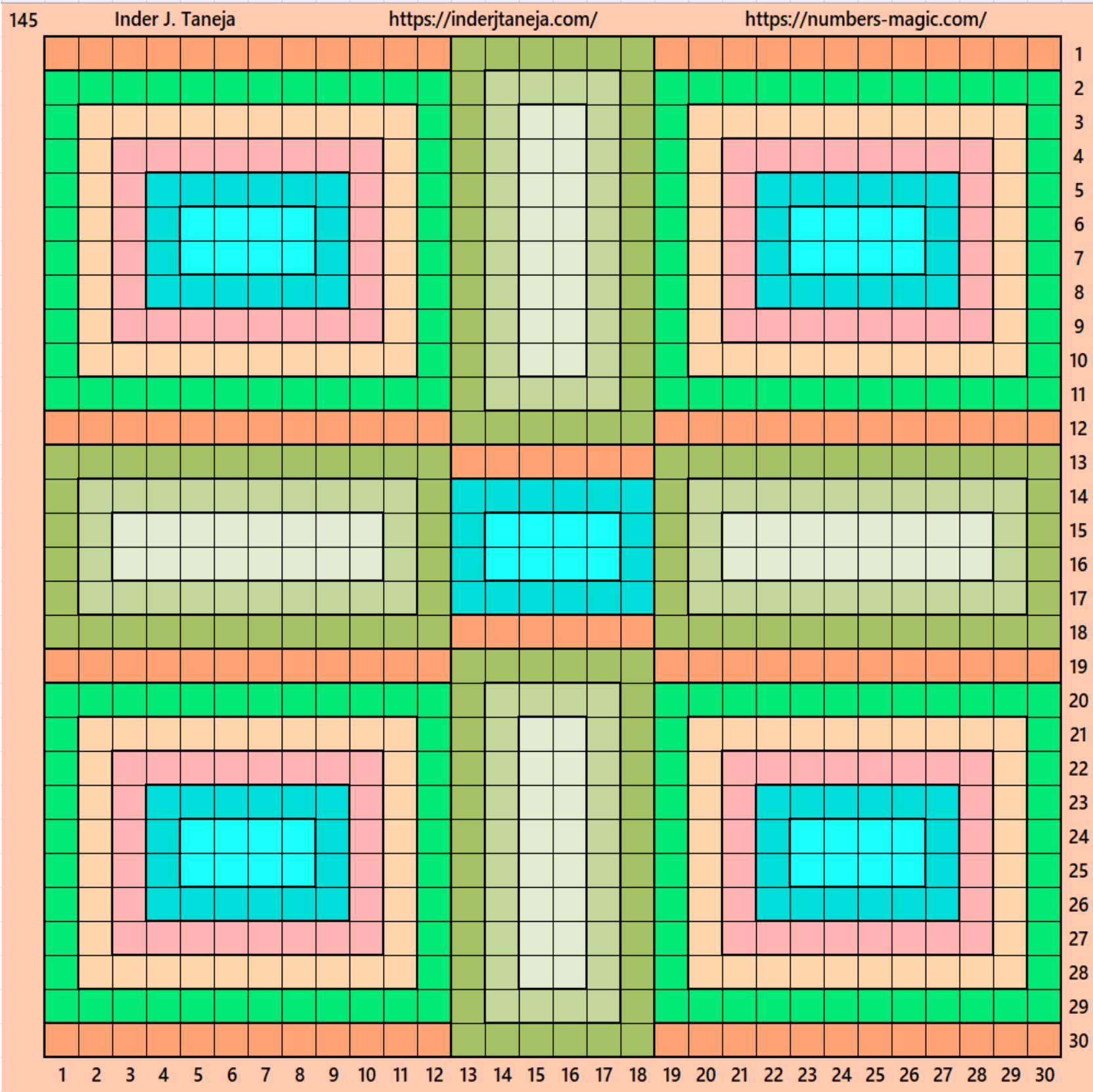


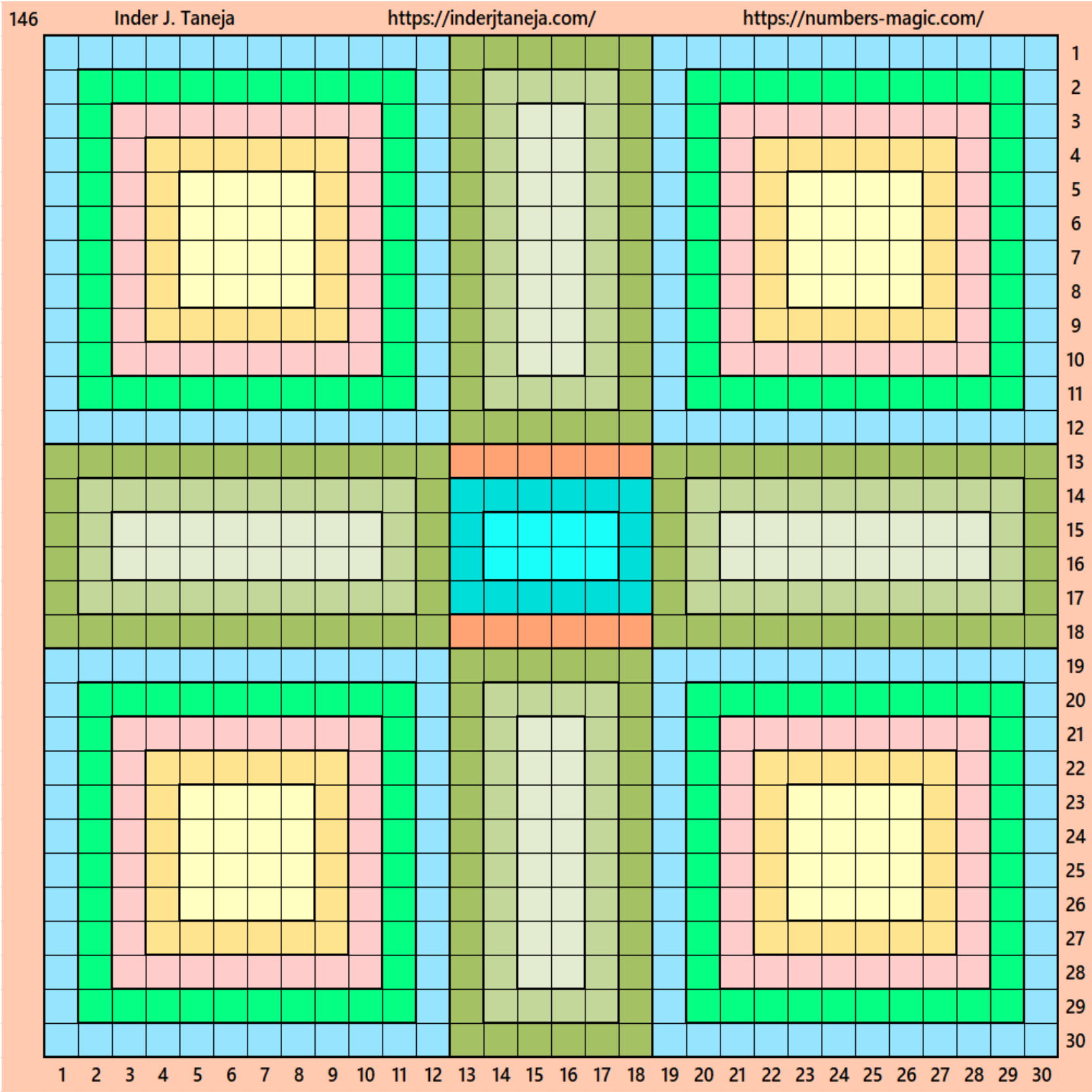






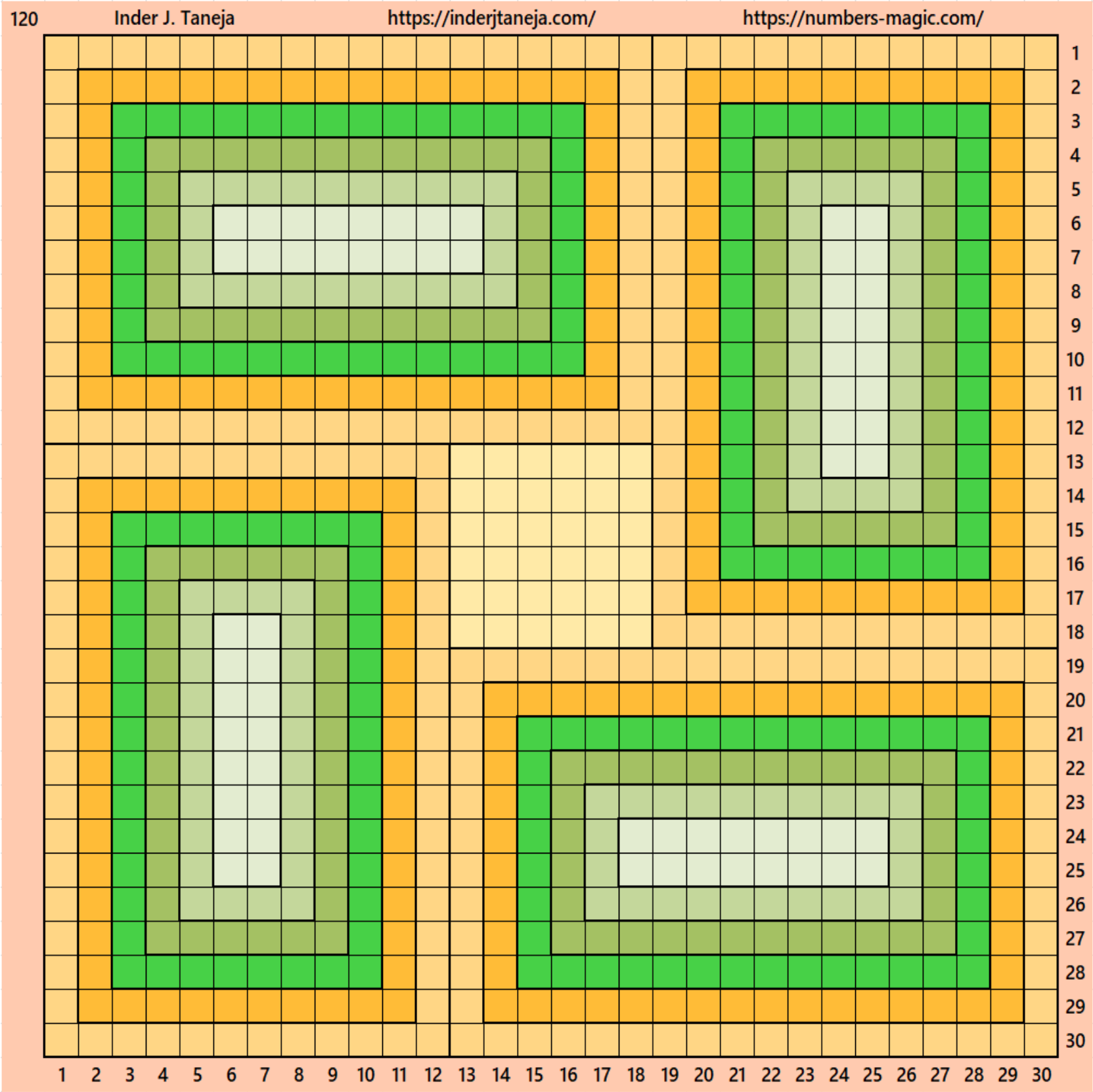


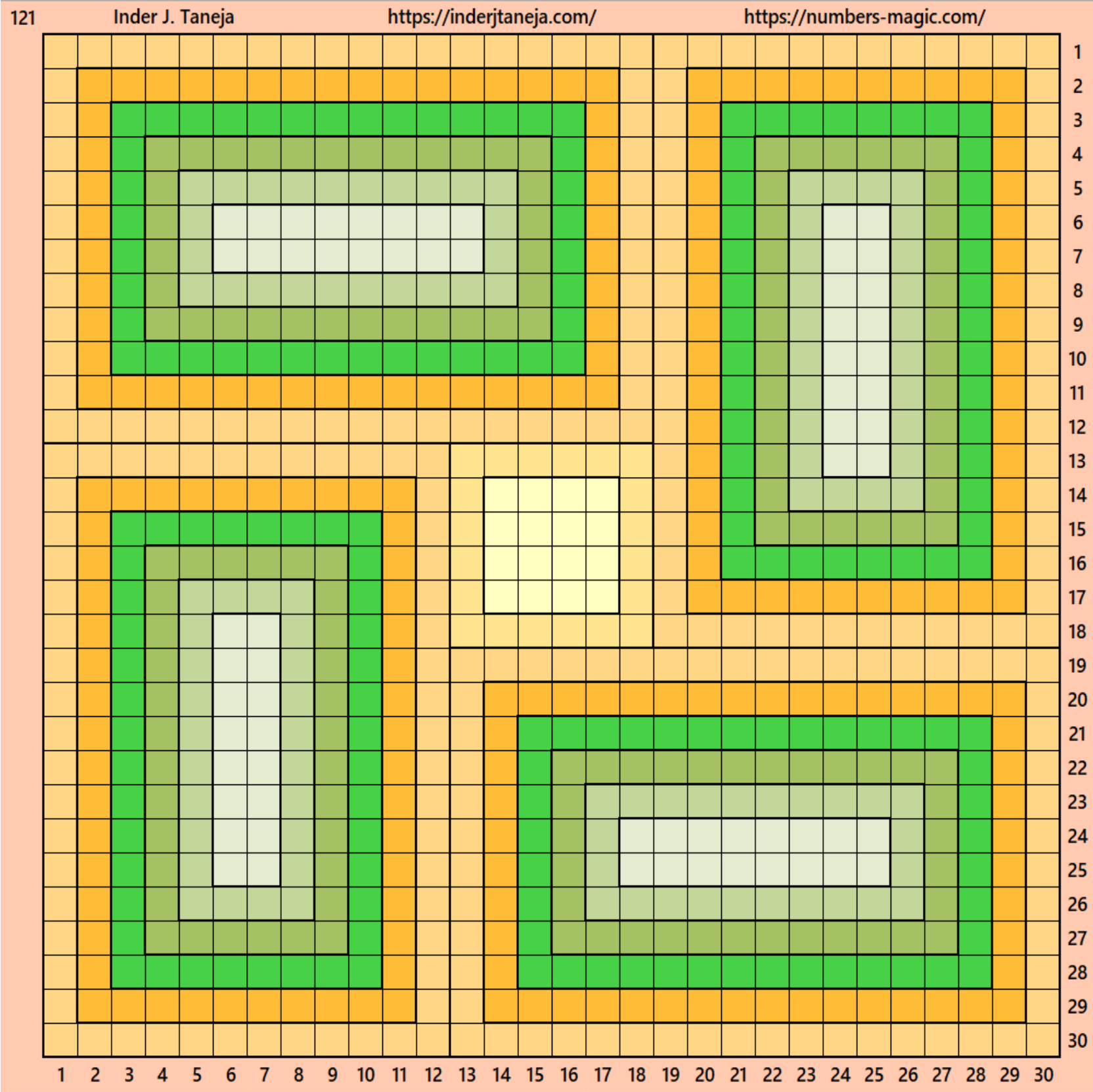


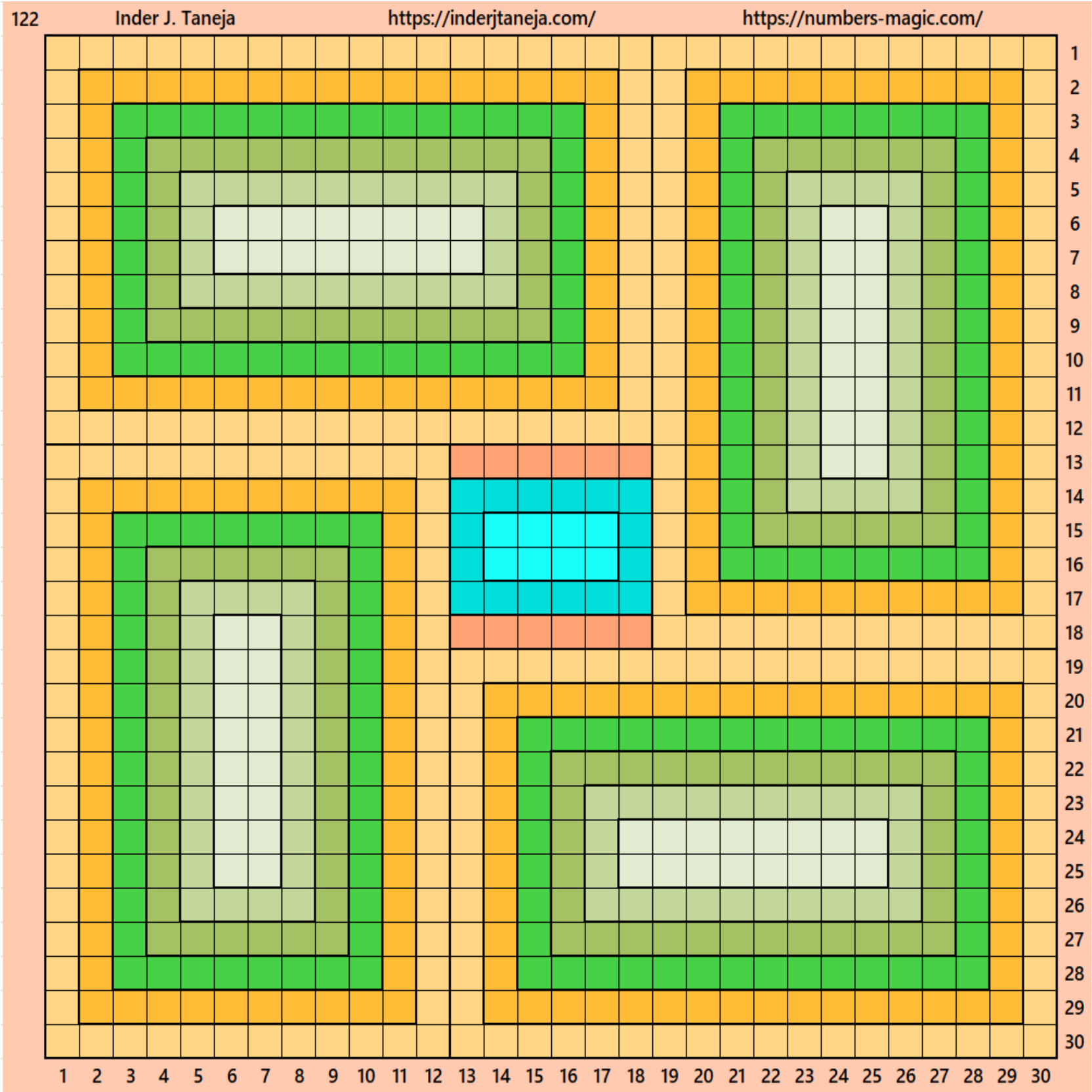


2.12 Closed Border of Order 12

Let's consider an external border with 8 BMRs of order 6×16 . In the middle we are left with blocks of order 4. It gives us a magic square of order 30. See below a single example:

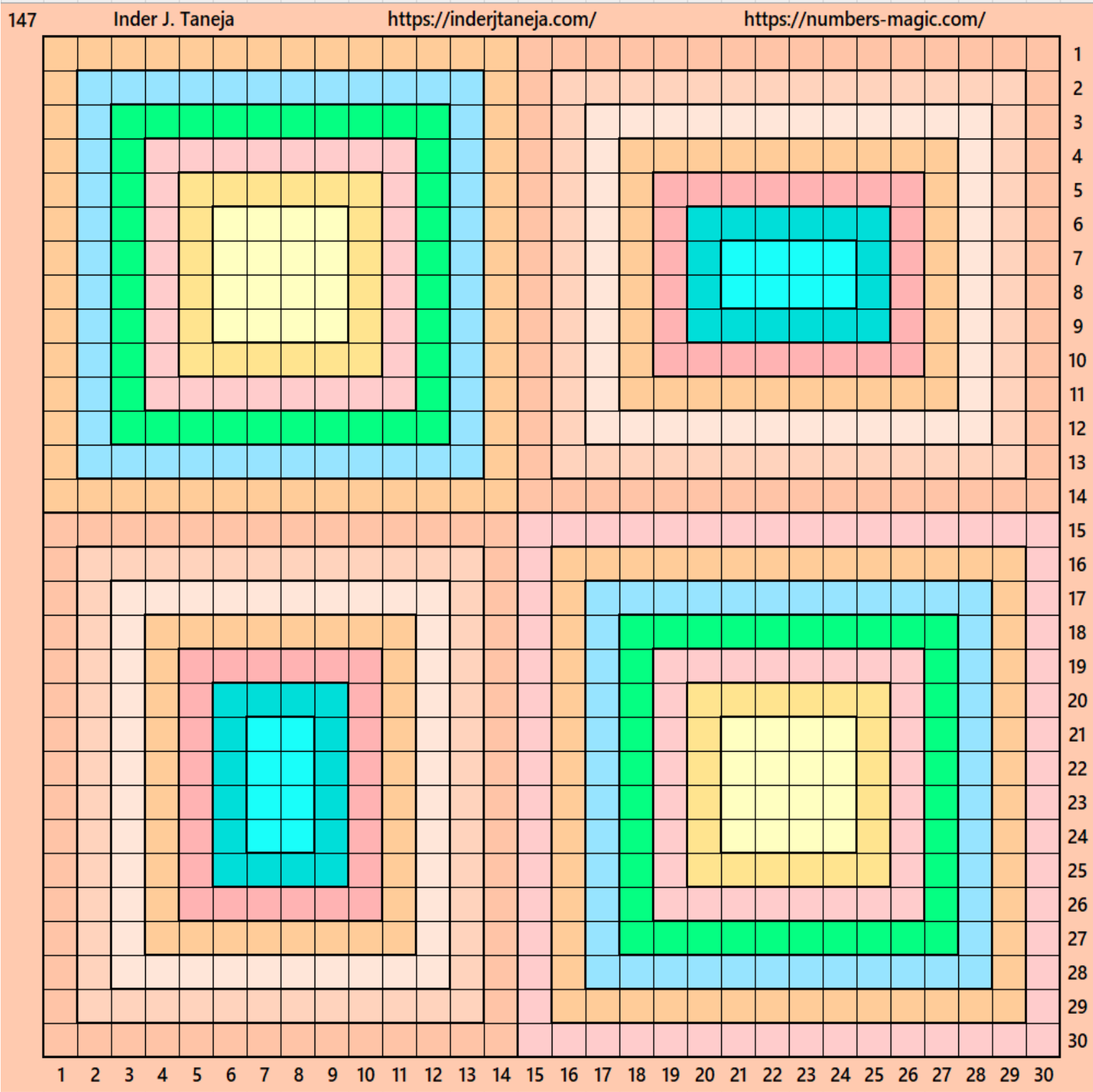


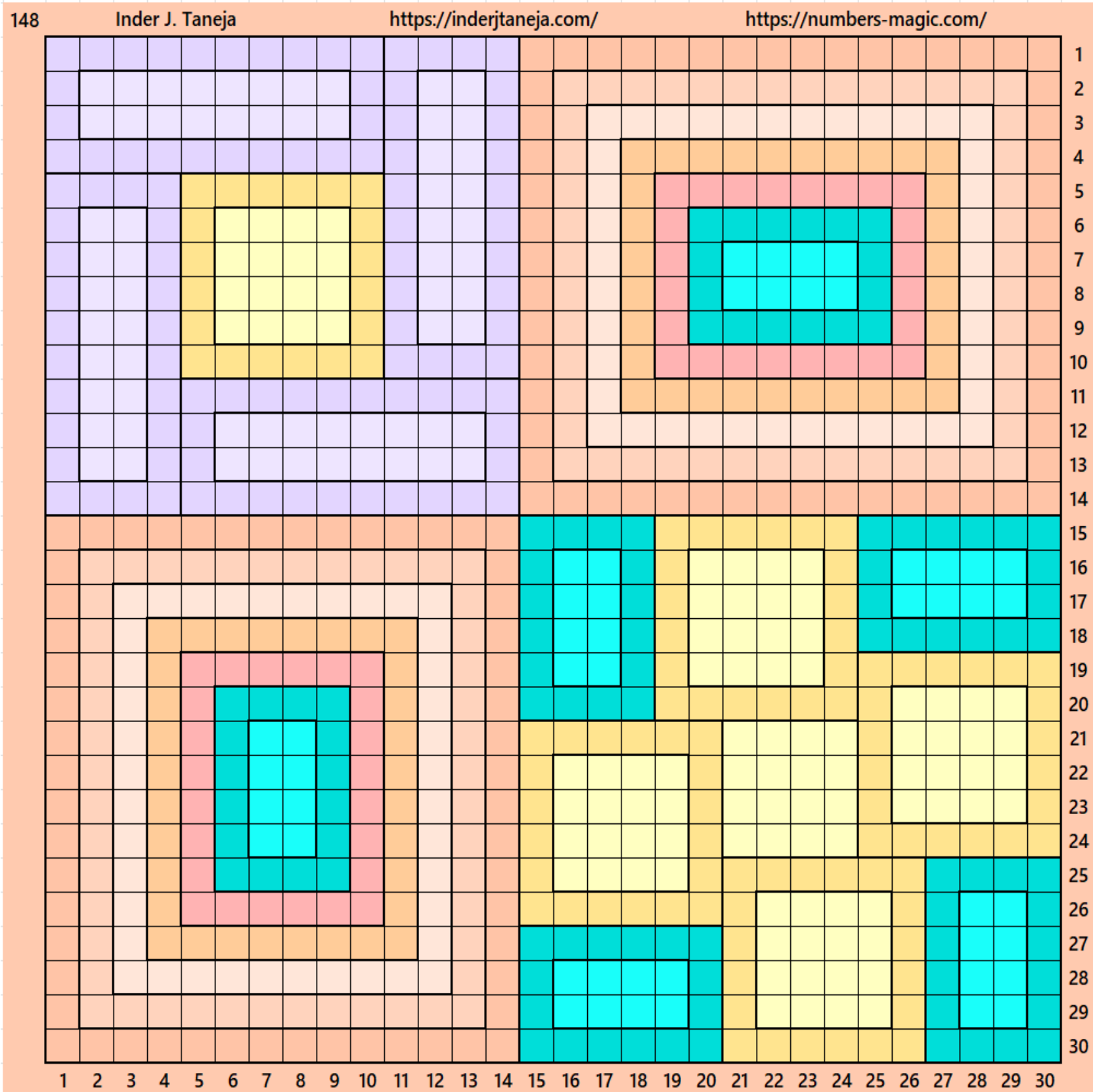


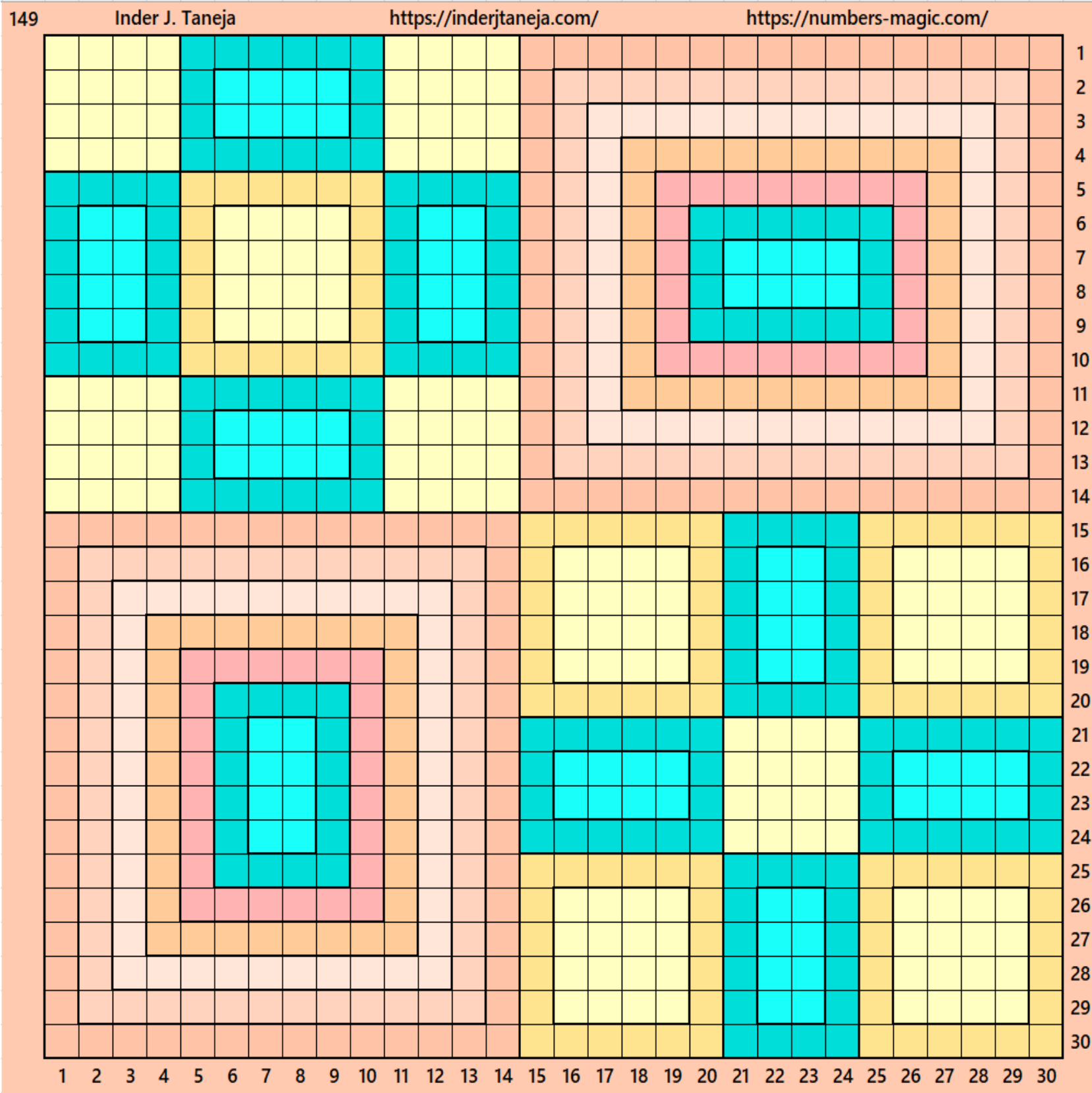


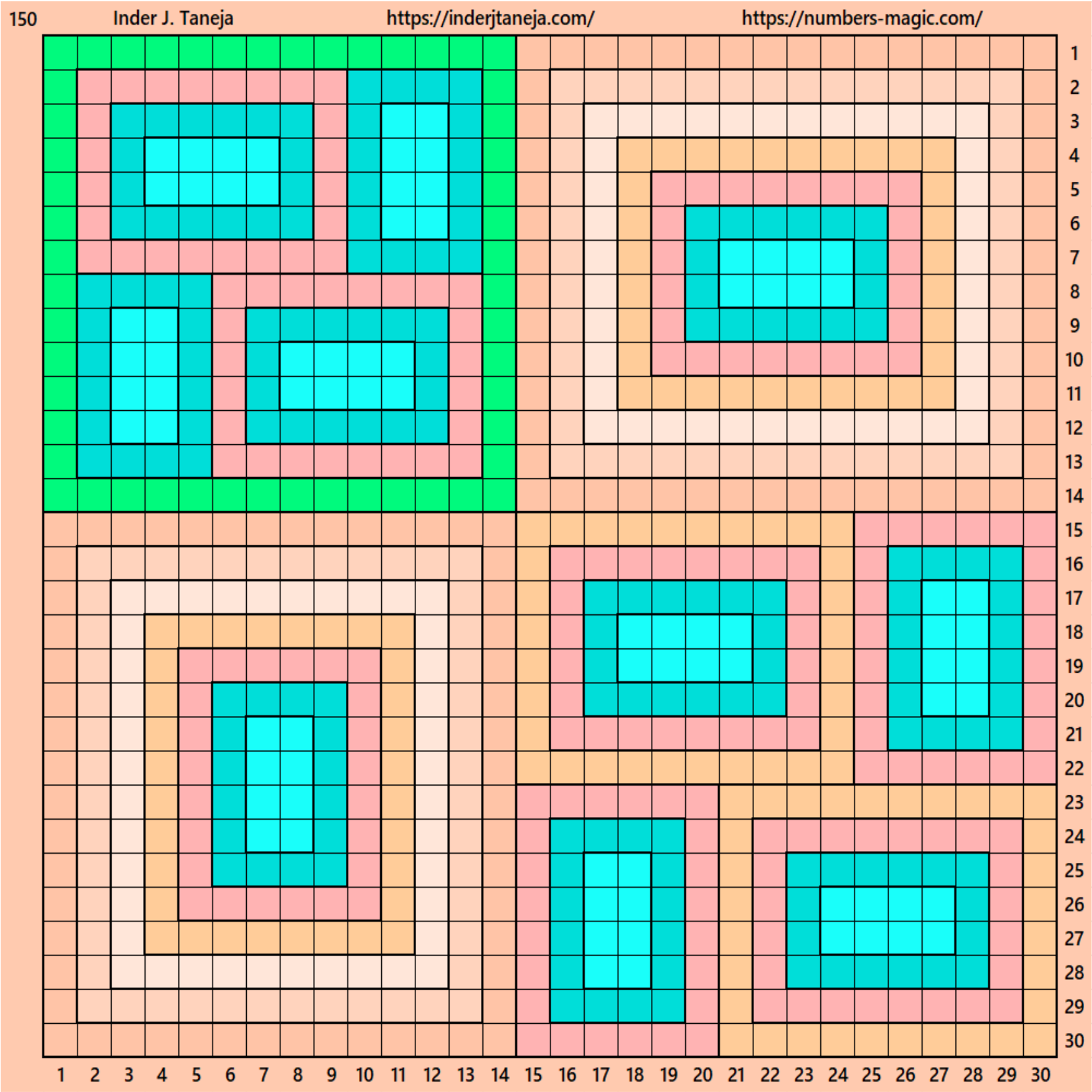
2.13 Magic Squares of Orders 14, 16 and BMRs of Order 14×16

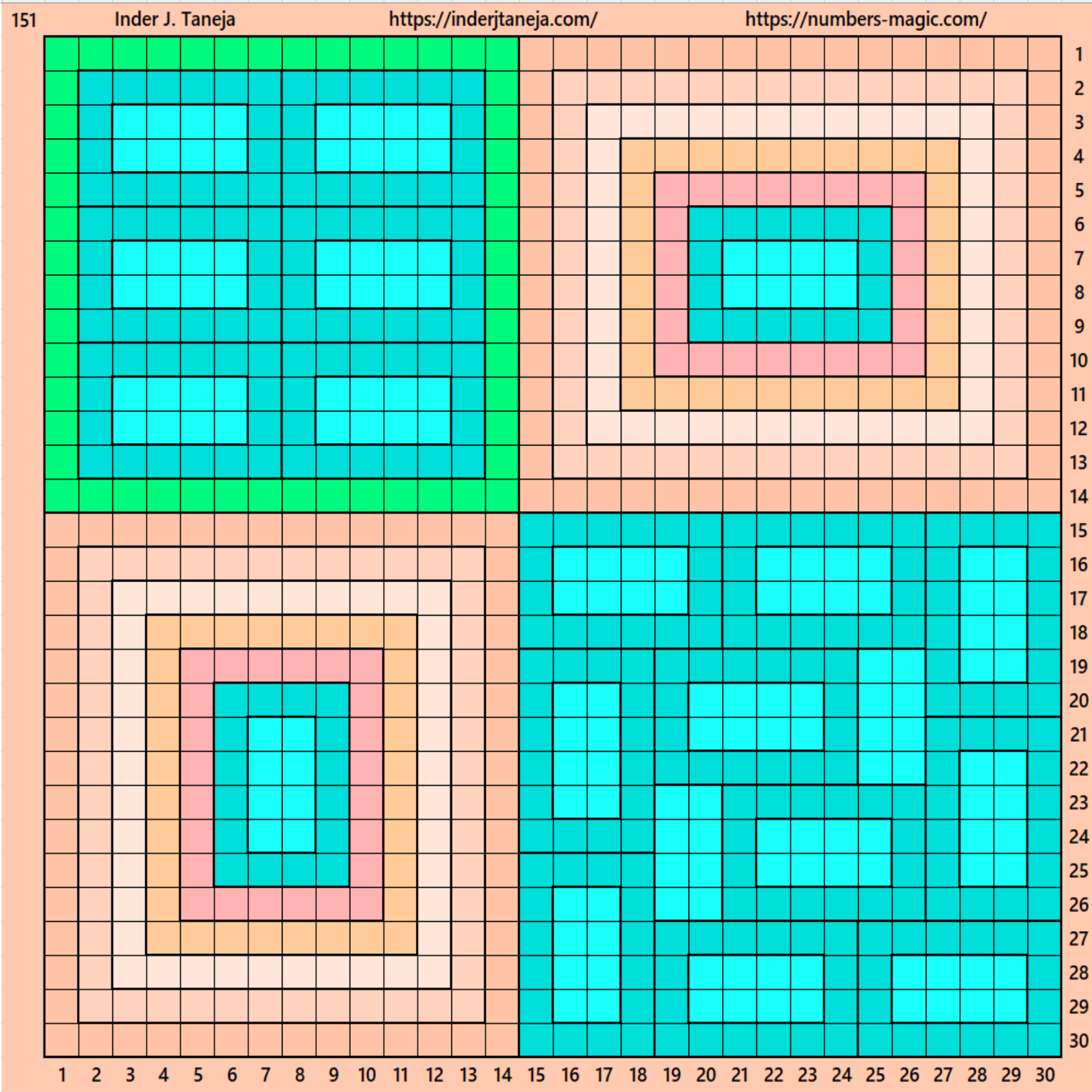
Let's consider different combinations of magic squares of order 14 and 16 with 2 BMRs of order 14×16 , we get magic squares of order 30. See below few examples:





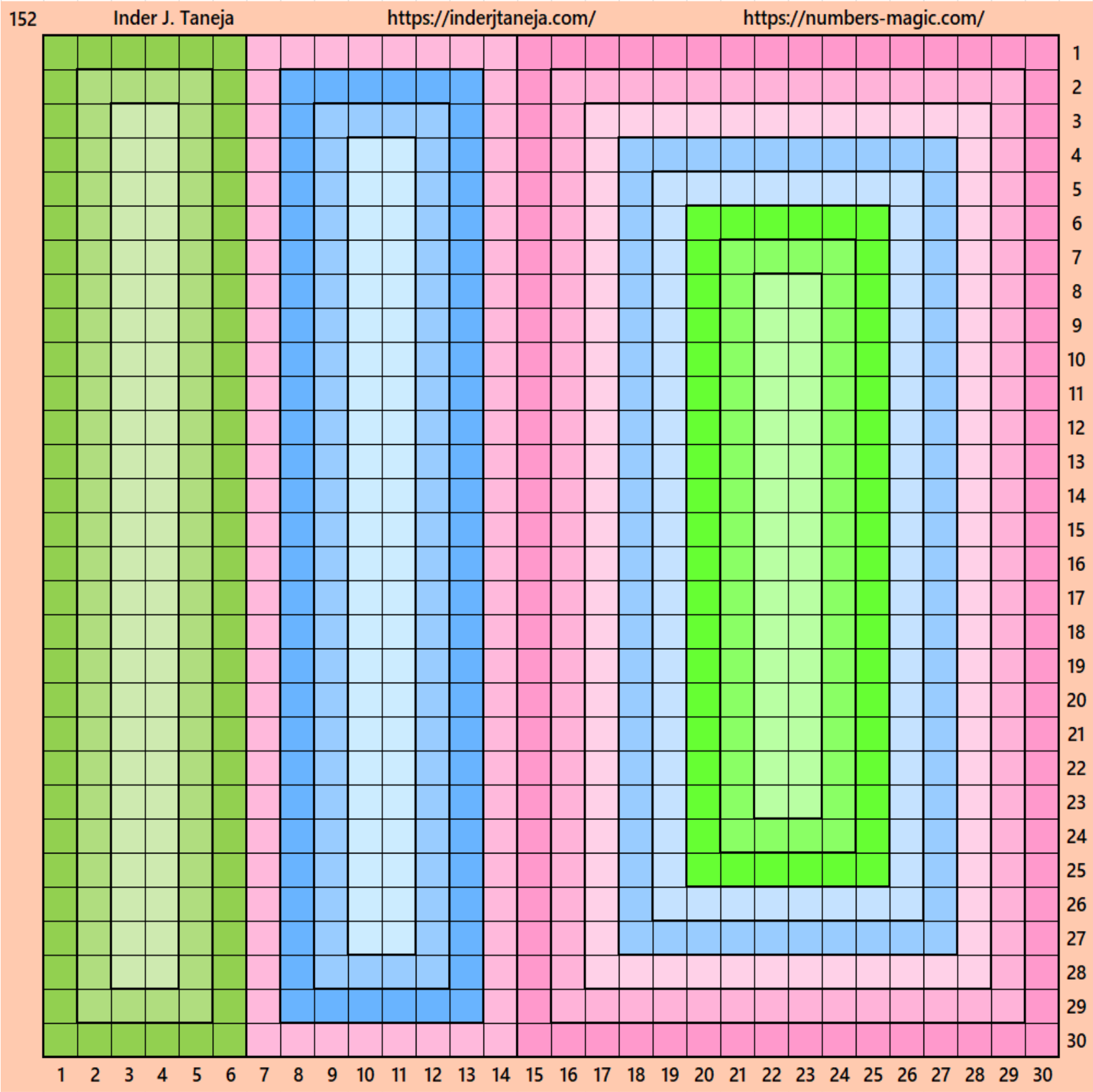


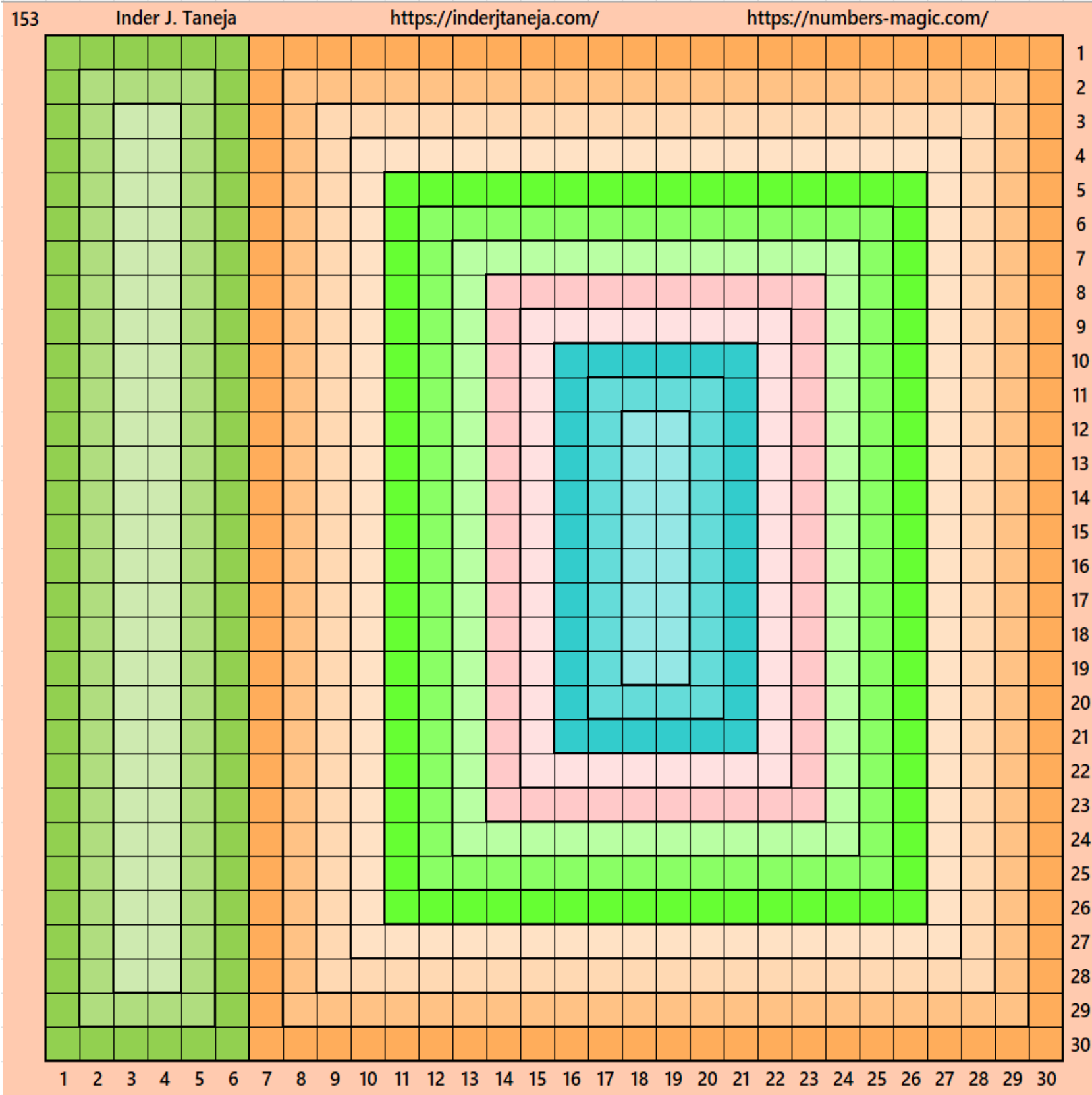


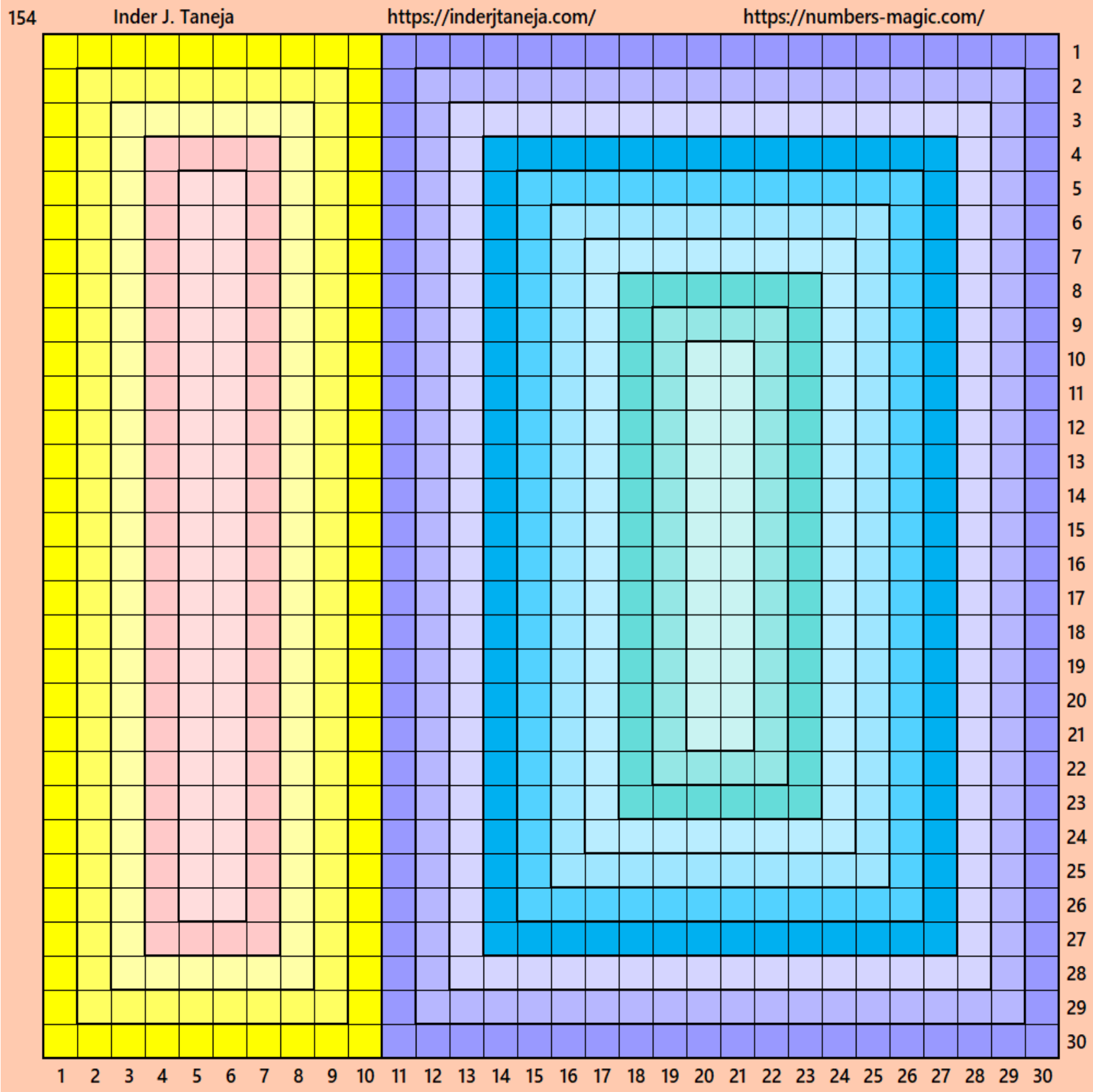


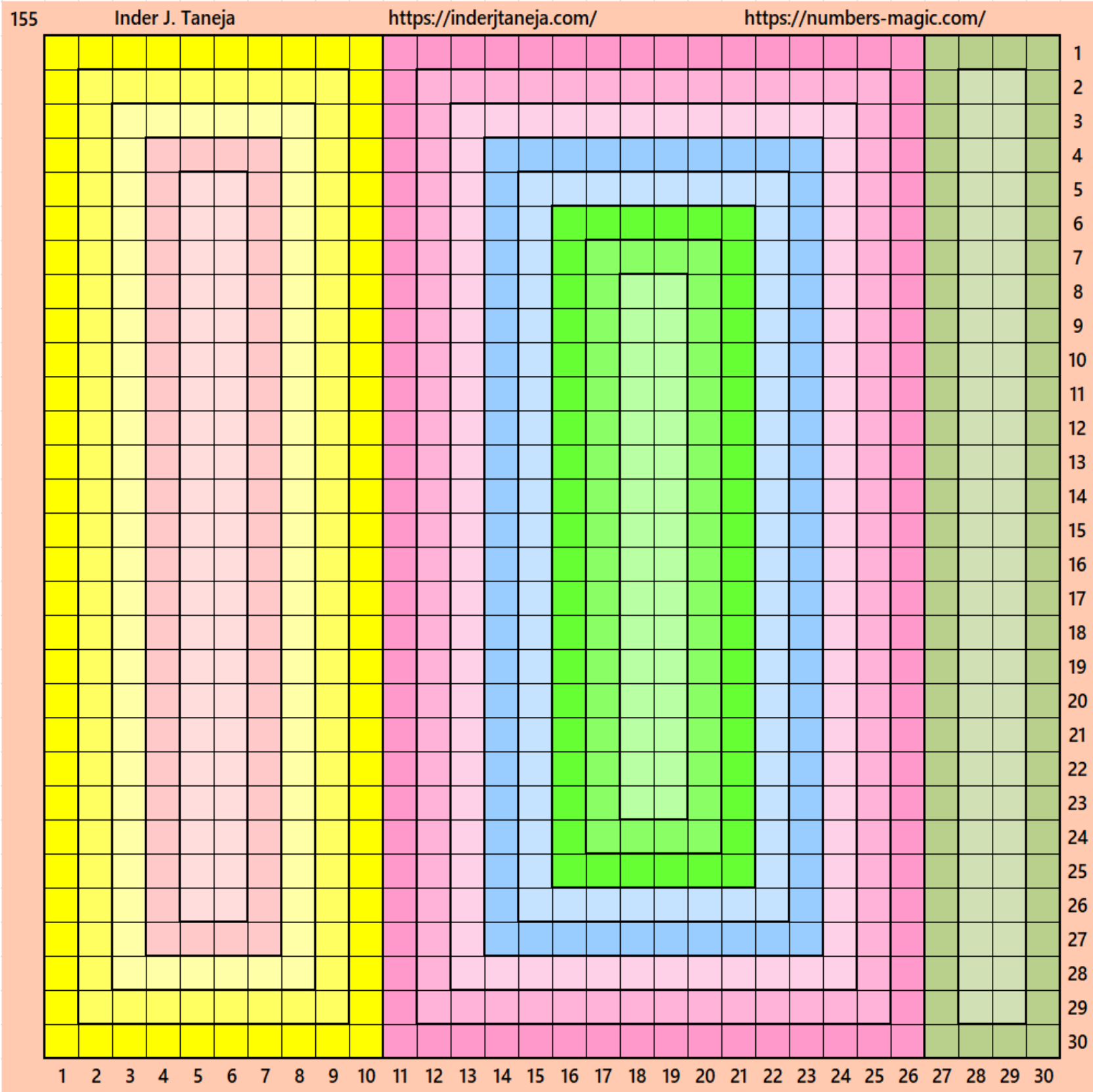
2.14 Extra Examples

Below are few extra examples of magic squares of order 30 done individually with BMRs.









3 Appendix

Below are tables giving the existence of **bordered magic rectangles** for **half-sequential** numbers.

Order of Magic Square	Bordered Magic Rectangles
6	4×6
8	6×8
10	$4 \times 10, 8 \times 10$
12	$6 \times 12, 10 \times 12$
14	$4 \times 14, 8 \times 14, 12 \times 14$
16	$6 \times 16, 10 \times 16, 14 \times 16$
18	$4 \times 18, 8 \times 18, 12 \times 18$
20	$6 \times 20, 10 \times 20, 14 \times 20, 18 \times 20$
22	$4 \times 22, 8 \times 22, 12 \times 22,$ $16 \times 22, 20 \times 22$
24	$6 \times 24, 10 \times 24, 14 \times 24,$ $18 \times 24, 22 \times 24$
26	$4 \times 26, 8 \times 26, 12 \times 26,$ $16 \times 26, 20 \times 26, 24 \times 26$
28	$6 \times 28, 10 \times 28, 14 \times 28,$ $18 \times 28, 22 \times 28, 26 \times 28$
30	$4 \times 30, 8 \times 30, 12 \times 30, 16 \times 30,$ $20 \times 30, 24 \times 30, 28 \times 30$
32	$6 \times 32, 10 \times 32, 14 \times 32, 18 \times 32,$ $22 \times 32, 26 \times 32, 30 \times 32$
34	$4 \times 34, 8 \times 34, 12 \times 34, 16 \times 34,$ $20 \times 34, 24 \times 34, 28 \times 34, 32 \times 34$

Order of Magic Square	Bordered Magic Rectangles
36	$6 \times 36, 10 \times 36, 14 \times 36, 18 \times 36,$ $22 \times 36, 26 \times 36, 30 \times 36, 34 \times 36$
38	$4 \times 38, 8 \times 38, 12 \times 38, 16 \times 38, 20 \times 38,$ $24 \times 38, 28 \times 38, 32 \times 38, 36 \times 38$
40	$6 \times 40, 10 \times 40, 14 \times 40, 18 \times 40, 22 \times 40,$ $26 \times 40, 30 \times 40, 34 \times 40, 38 \times 40$
42	$4 \times 42, 8 \times 42, 12 \times 42, 16 \times 42, 20 \times 42,$ $24 \times 42, 28 \times 42, 32 \times 42, 36 \times 42, 40 \times 42$
44	$6 \times 44, 10 \times 44, 14 \times 44, 18 \times 44, 22 \times 44, 26 \times 44,$ $30 \times 44, 34 \times 44, 38 \times 44, 42 \times 44$
46	$4 \times 46, 8 \times 46, 12 \times 46, 16 \times 46, 20 \times 46, 24 \times 46,$ $28 \times 46, 32 \times 46, 36 \times 46, 40 \times 46, 44 \times 46$
48	$6 \times 48, 10 \times 48, 14 \times 48, 18 \times 48, 22 \times 48, 26 \times 48,$ $30 \times 48, 34 \times 48, 38 \times 48, 42 \times 48, 46 \times 48$
50	$4 \times 50, 8 \times 50, 12 \times 50, 16 \times 50, 20 \times 50, 24 \times 50,$ $28 \times 50, 32 \times 50, 36 \times 50, 40 \times 50, 44 \times 50, 48 \times 50$

4 Author’s Contribution to Magic Squares and Recreation Numbers

For author’s contribution to **magic squares** and **recreation numbers** please see the links below:

- Inder J. Taneja, Magic Squares, <https://inderjtaneja.com/2019/06/27/publications-magic-squares/>
- Inder J. Taneja, Recreation of Numbers, <https://inderjtaneja.com/2019/06/27/publications-recreation-of-numbers/>

Acknowledgement

The **bordered magic rectangles** are constructed based on the software produced by H. White [1]. The author is thankful to H. White for their valuable help.

References

- [1] **H. White**, Bordered Magic Squares, <http://budshaw.ca/MagicRectangles.html>.
- [2] **Inder J. Taneja**, Magic Squares - <https://inderjtaneja.com/category/magic-squares/>.
- [3] **Inder J. Taneja**, Recreating Numbers and Magic Squares - <https://numbers-magic.com/>.

● Block-Wise Magic Squares

- [4] **Inder J. Taneja**, Block-Wise Constructions of Magic and Bimagic Squares of Orders 8 to 108, May 15, 2019, pp. 1-43, **Zenodo**, <http://doi.org/10.5281/zenodo.2843326>.
- [5] **Inder J. Taneja**, Block-Wise Equal Sums Pandiagonal Magic Squares of Order $4k$, **Zenodo**, January 31, 2019, pp. 1-17, <http://doi.org/10.5281/zenodo.2554288>.
- [6] **Inder J. Taneja**, Magic Rectangles in Construction of Block-Wise Pandiagonal Magic Squares, **Zenodo**, January 31, 2019, pp. 1-49, <http://doi.org/10.5281/zenodo.2554520>.
- [7] **Inder J. Taneja**, Block-Wise Equal Sums Magic Squares of Orders $3k$ and $6k$, **Zenodo**, February 1, 2019, pp. 1-55, <http://doi.org/10.5281/zenodo.2554895>.
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