Figured Magic Squares of Order 24 Using Bordered Magic Rectangles: A Systematic Procedure, **Zenodo**, November 14, 2022, pp. 1-104, *https://doi.org/10.5281/zenodo.7377779*

Figured Magic Squares of Order 24 Using Bordered Magic Rectangles: A Systematic Procedure

Inder J. Taneja[1]

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 24. 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. 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 $\mathbf{2p}$*, where* $\mathbf{p}$ *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

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

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

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 $(\mathbf{a}+\mathbf{b})^{\mathbf{2}}, \mathbf{a} \neq \mathbf{b}$.

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 explainations 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 BRM's 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. First part is one sequence and second part is another sequence. Due to **half-sequential** numbers, it is not possible to construct all orders **bordered**

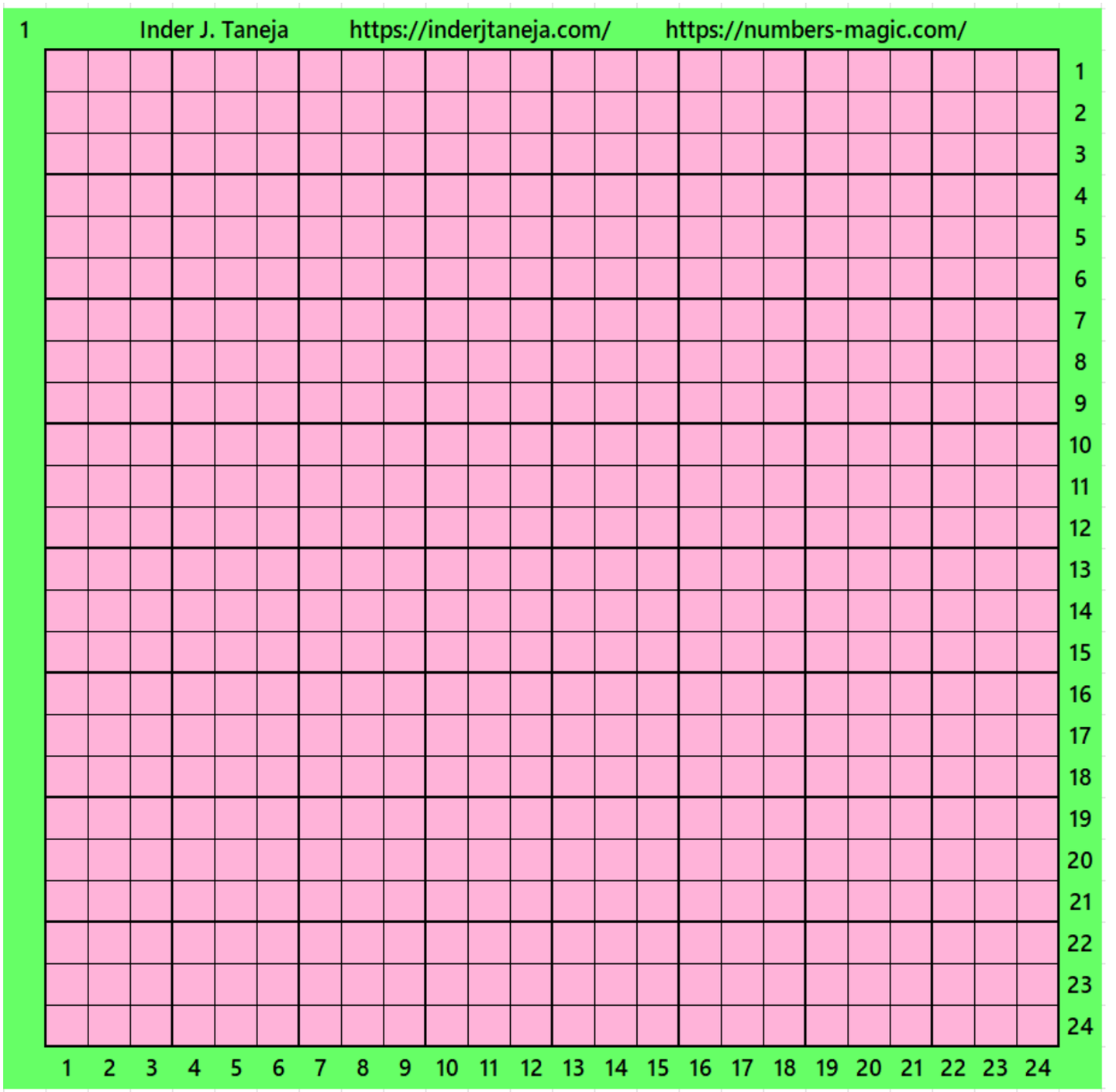
magic rectangles. In Appendix 3, there are tables showing the existence of these **bordered magic rectangles** for **half-sequential**. For simplicity, we shall write **BMR** as **bordered magic rectangle**.

2 Magic Squares of Order 24

This section brings in figures (without numbers) magic squares of order 24. In some cases the construction's ideas are given.

2.1 Block-Wise and Bordered Magic Squares of Order 24

Below are four magic squares of order 24 already known in the literature. For more details refer [22, 24].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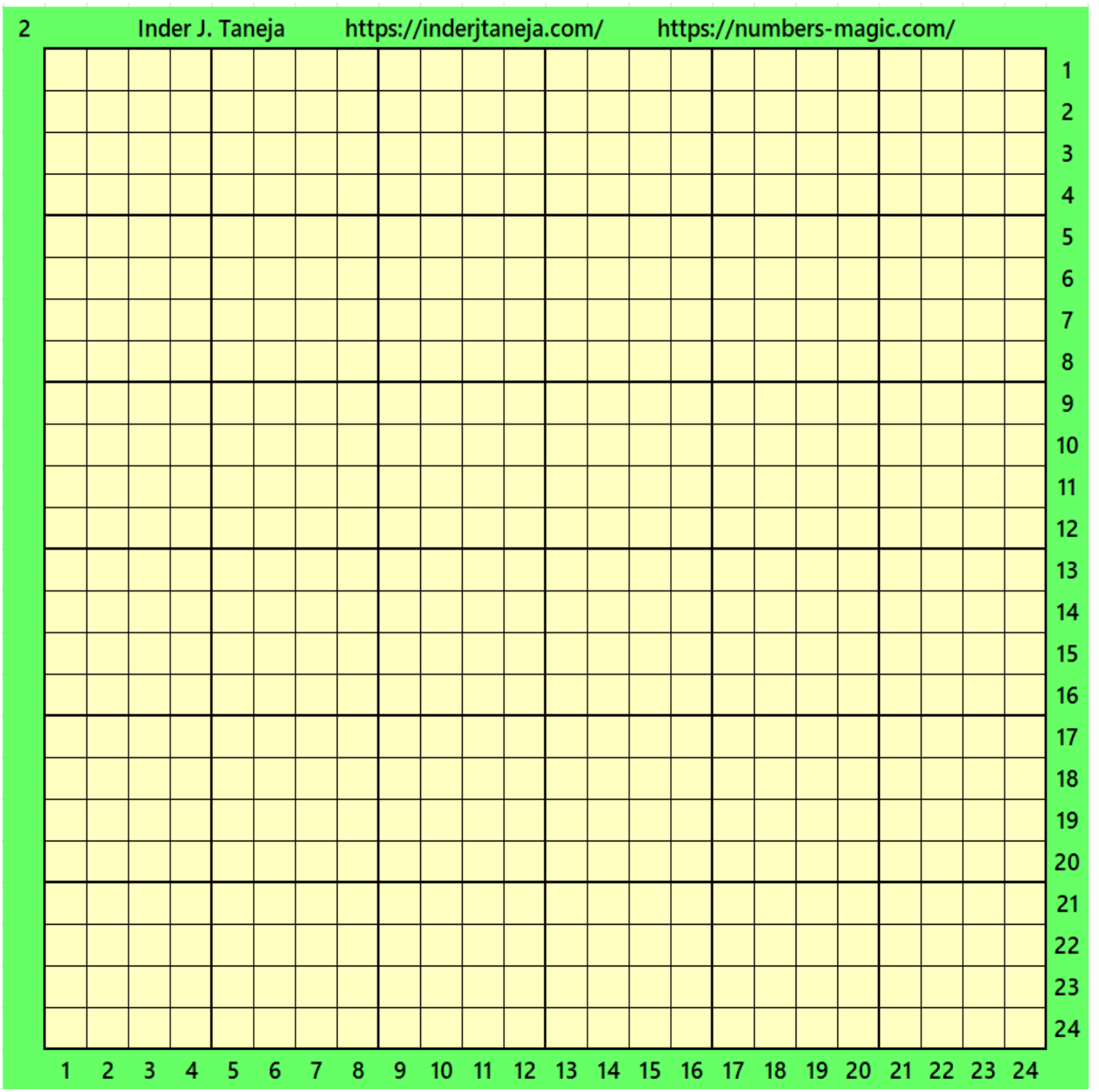
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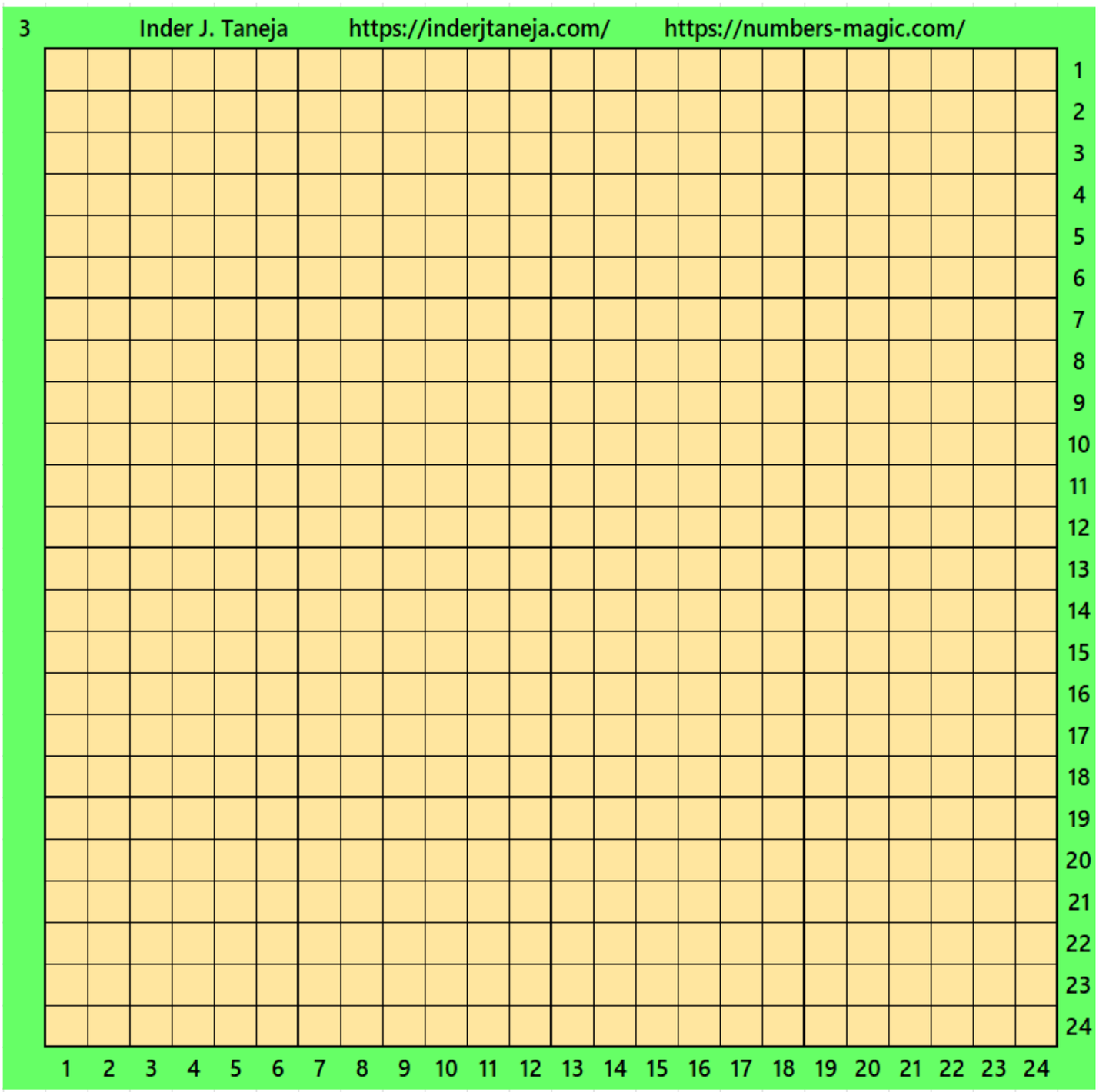
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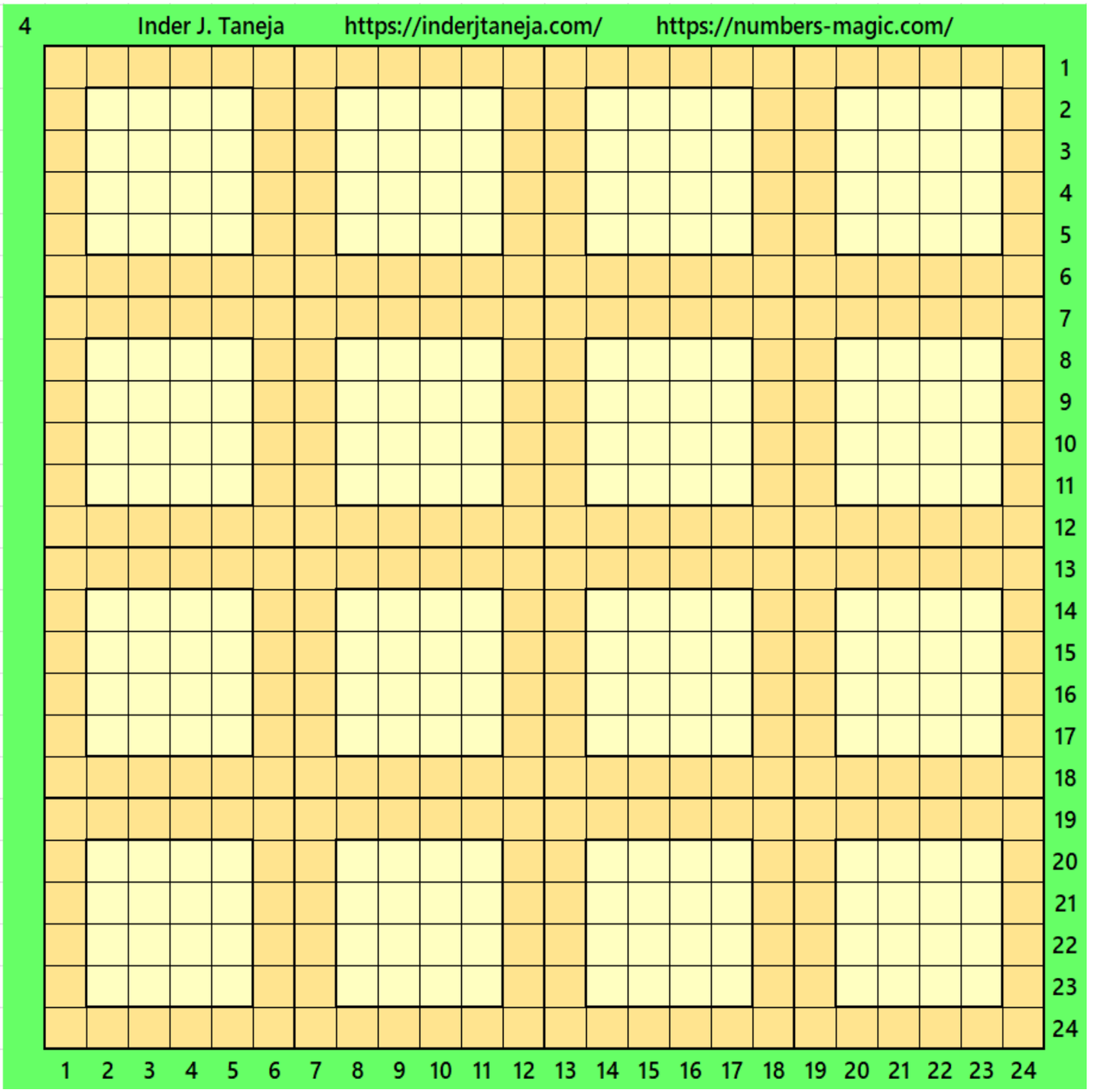
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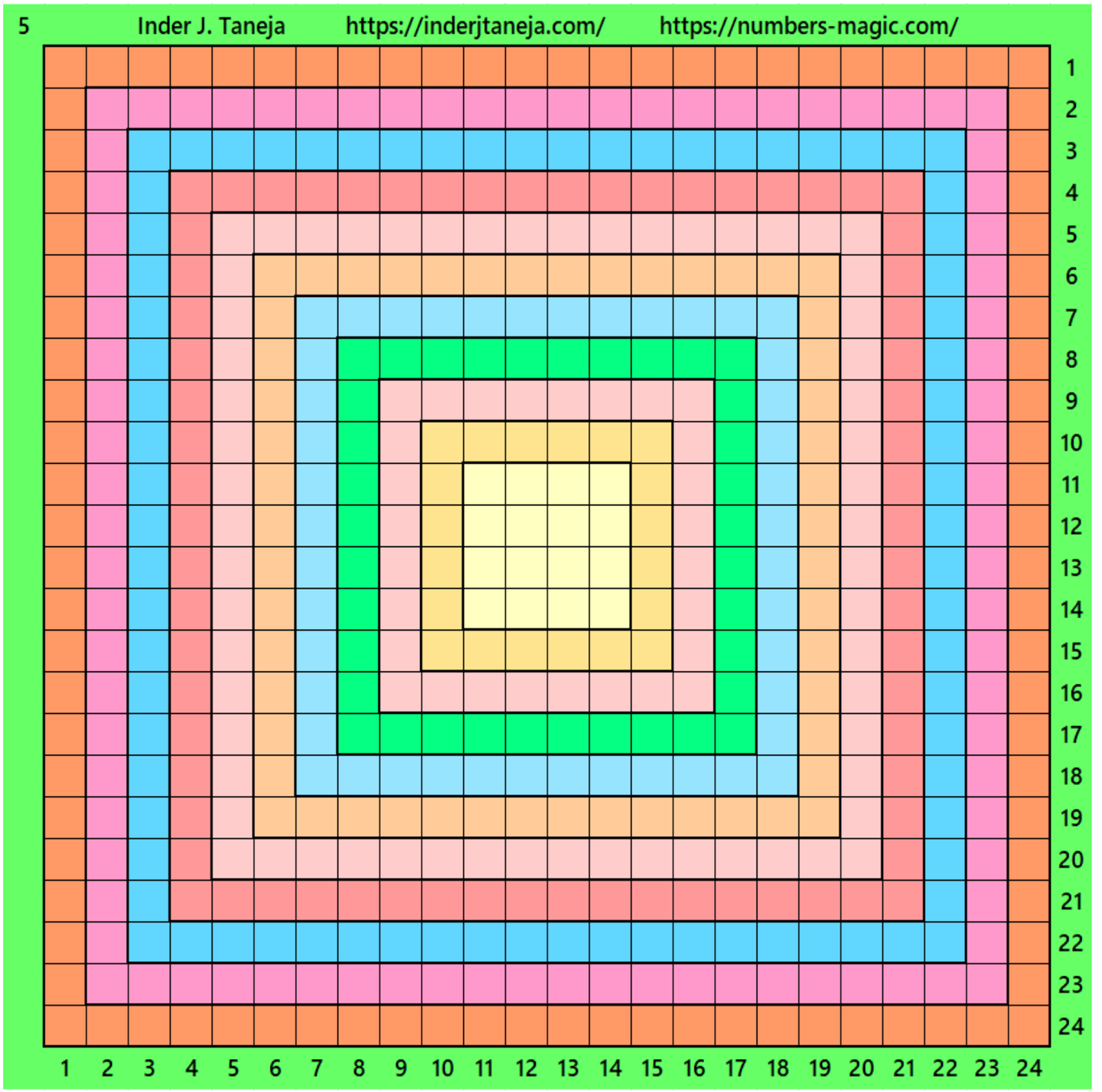
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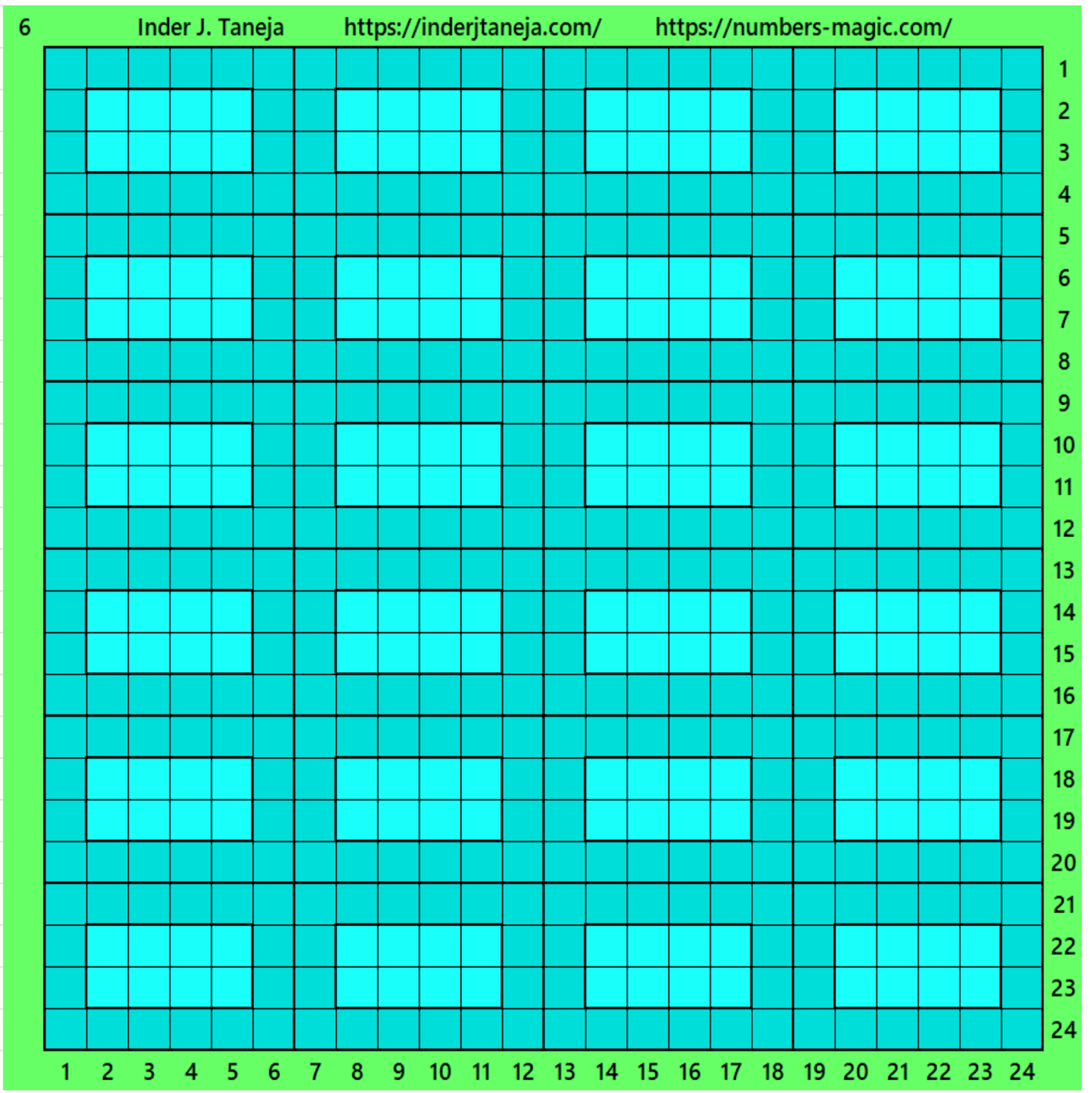
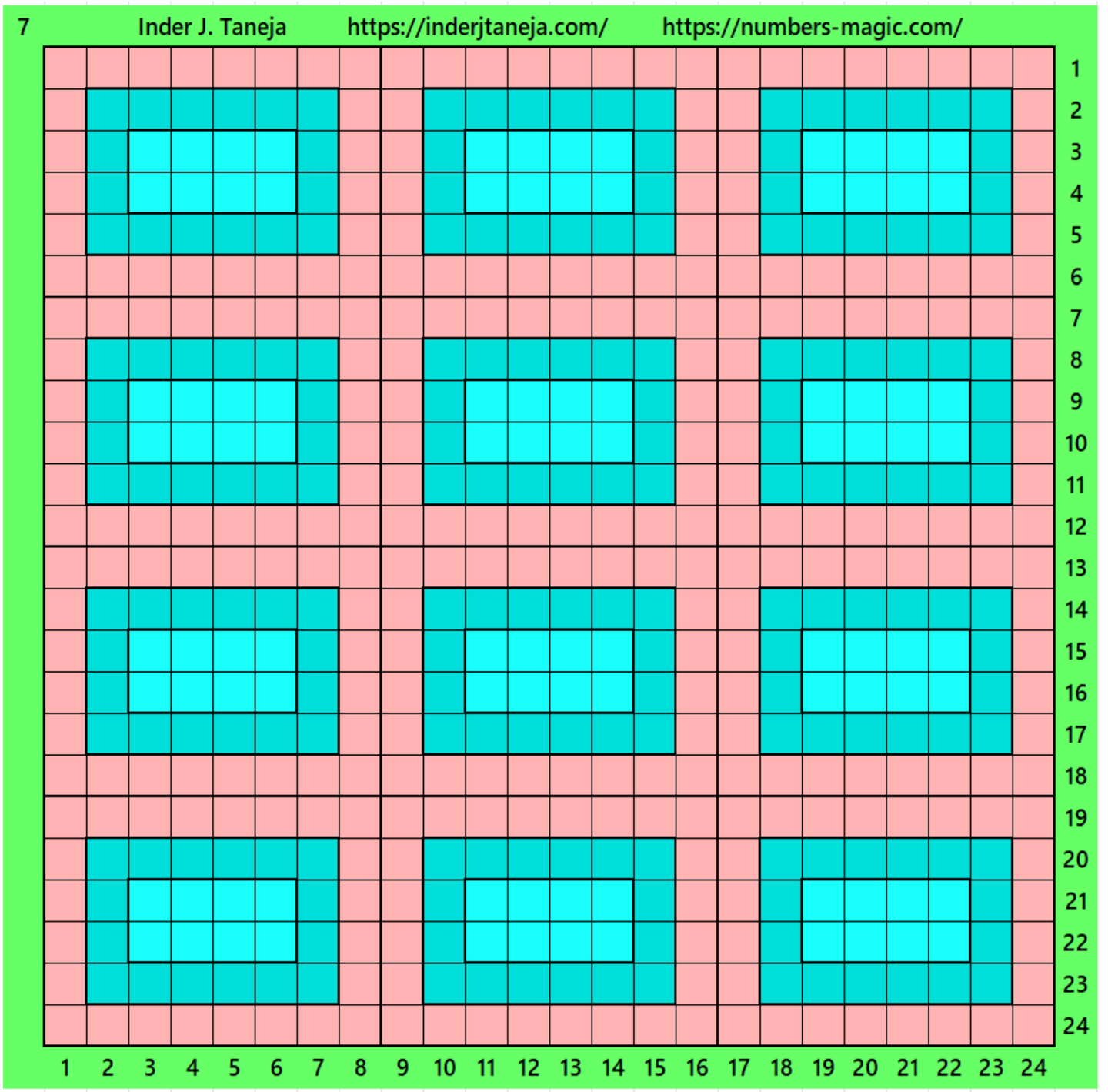
2.2 Magic Squares of Order 24 With BMR

Below are four magic squares of order 20 made with BMR. These are constructed separately. For more details with numbers refer [35].

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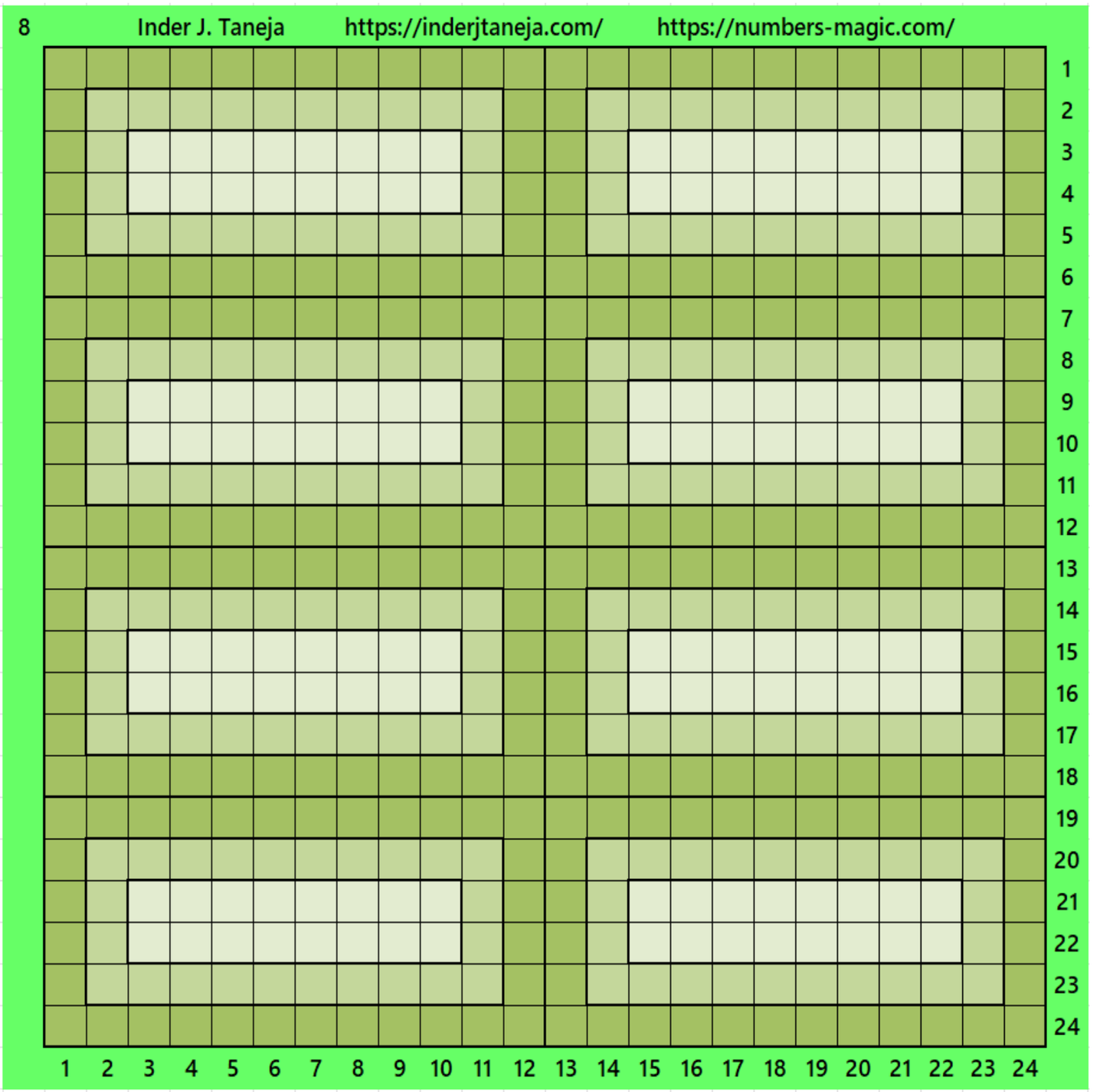
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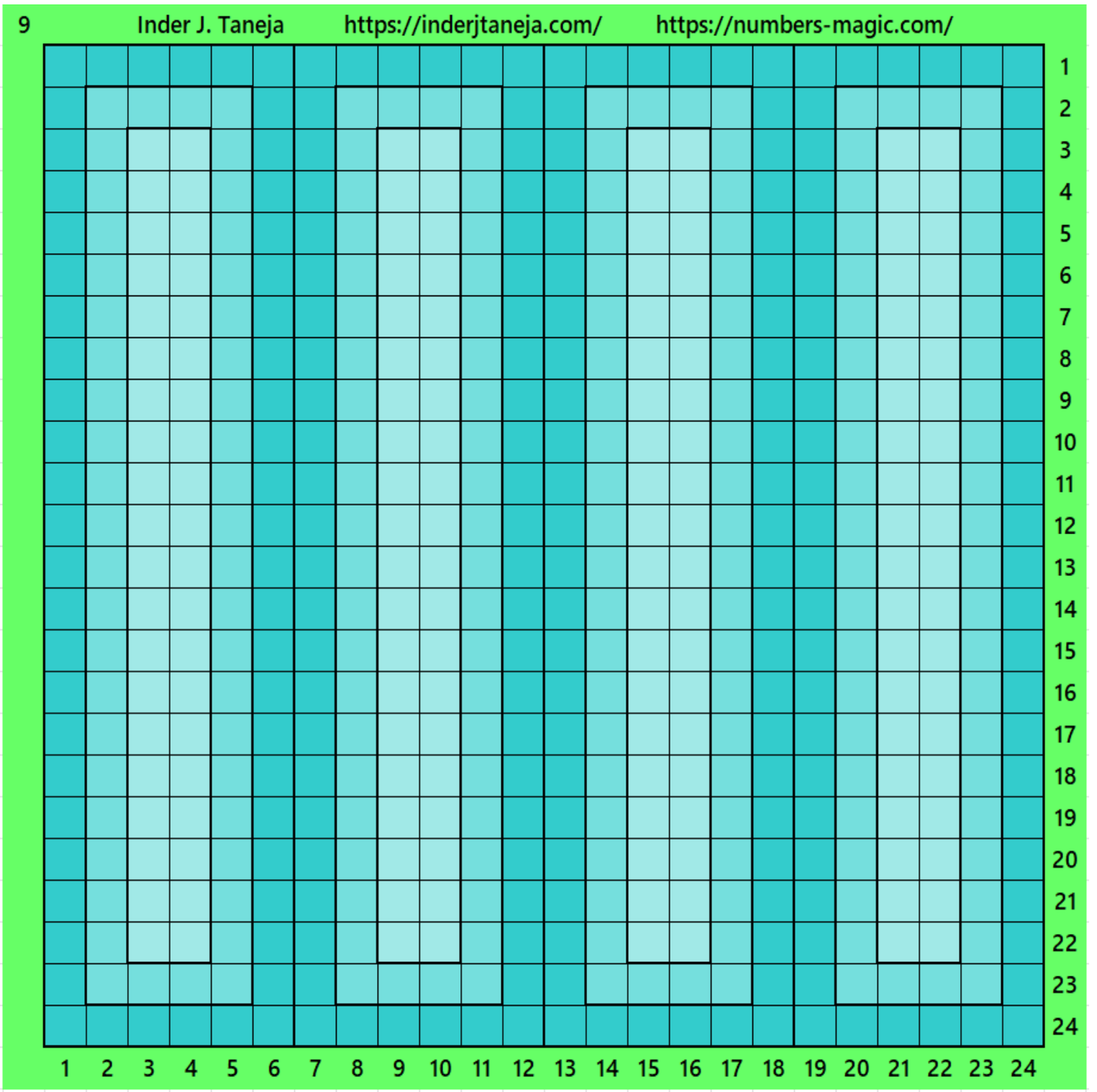
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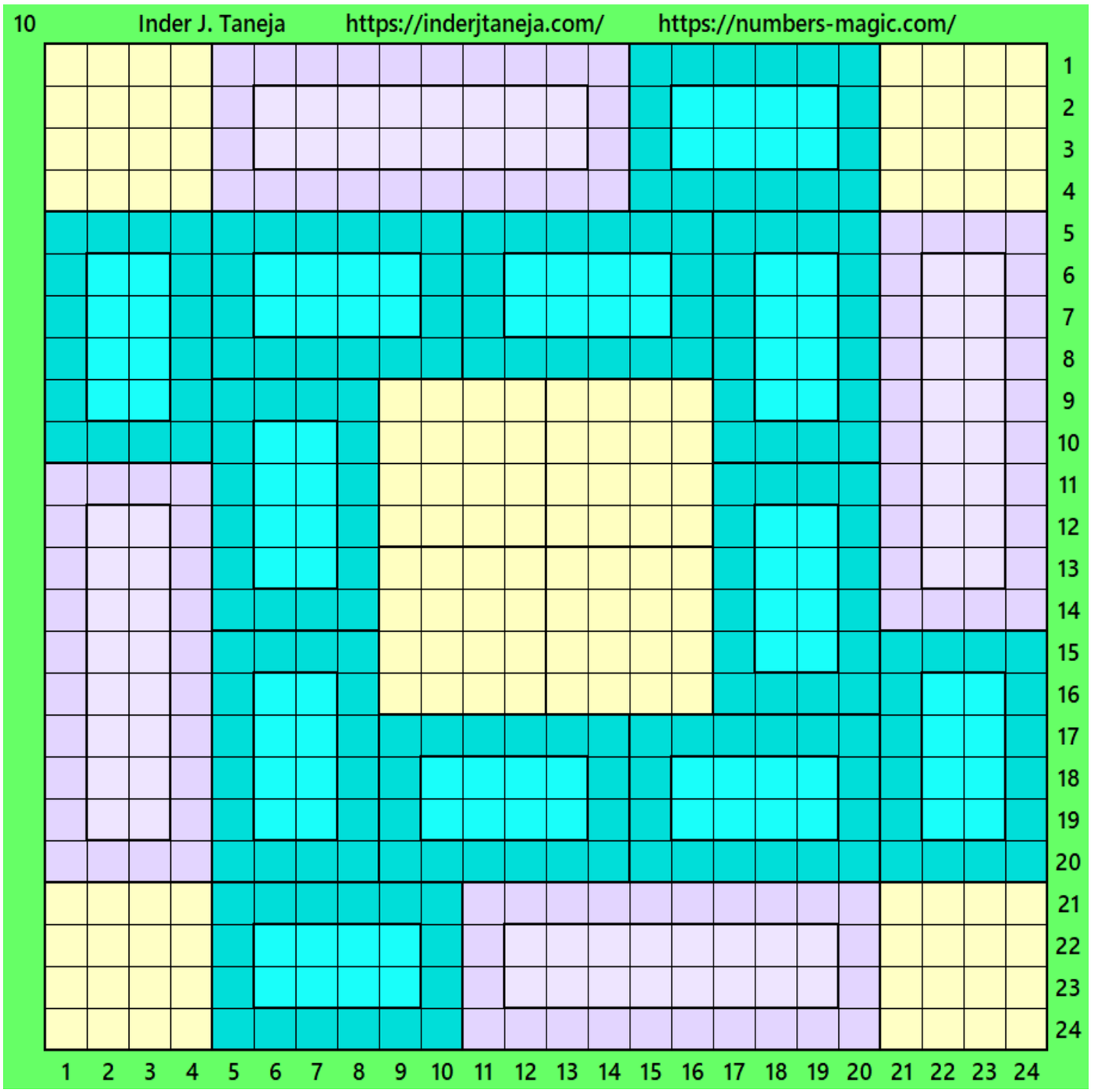
2.3 Cornered Magic Squares of Order 4

Observing Fig. 2 given in subsection 2.1, we don't required external border of order 4. But as an extra option, we shall make it by considering 4 magic squares of order 4 at the corners, four BMR's of order 4×10 and four BMR's of order 4×10. Put these according to figure below. We have chossed two BMR's instead of as there is no BMR of order 4×16 for half-sequential distributions. We are left with internal block of order 16. Writing internal block of order 16 with different magic squares, we get magic squares of 24. See below few examples.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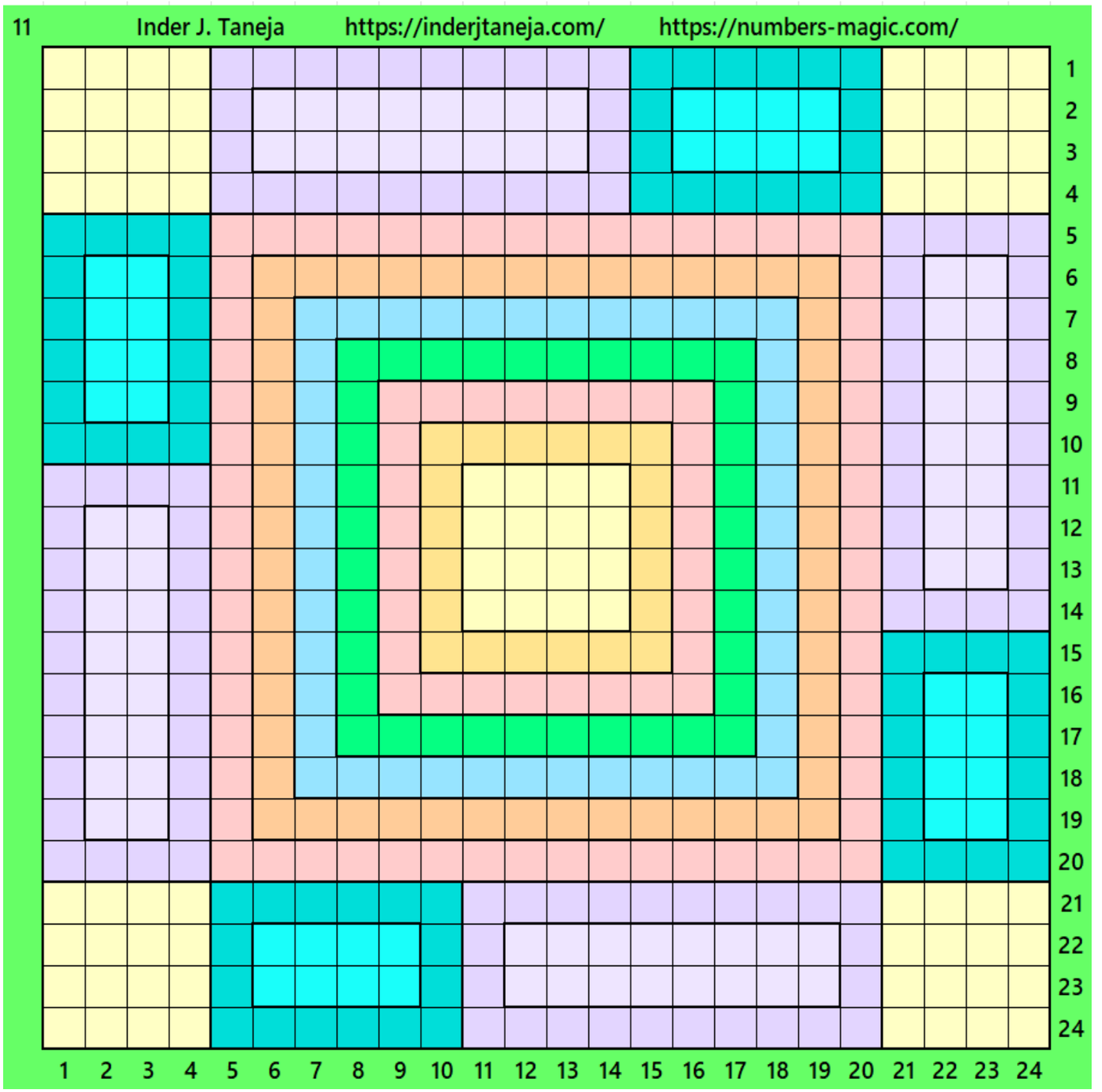

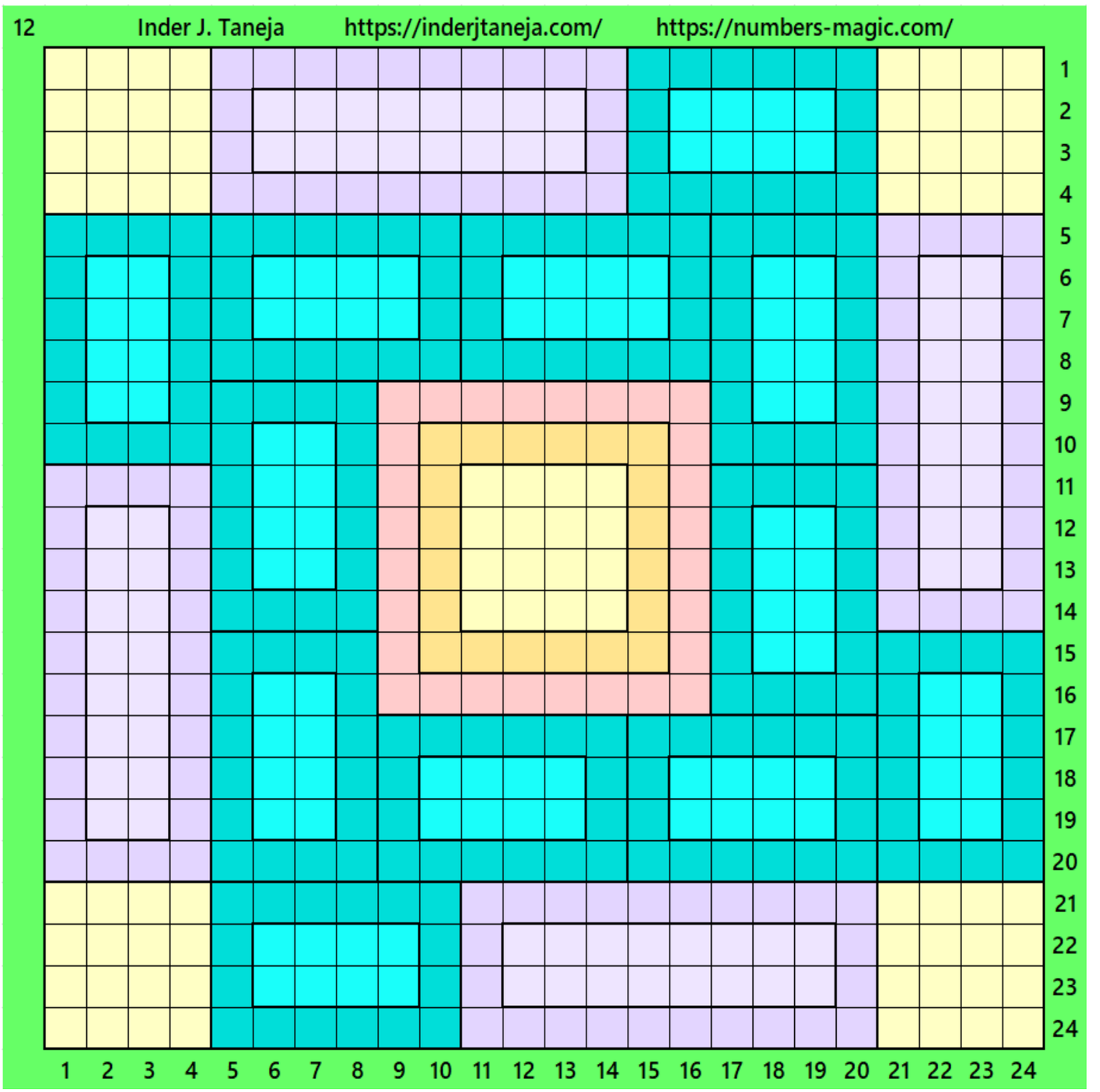
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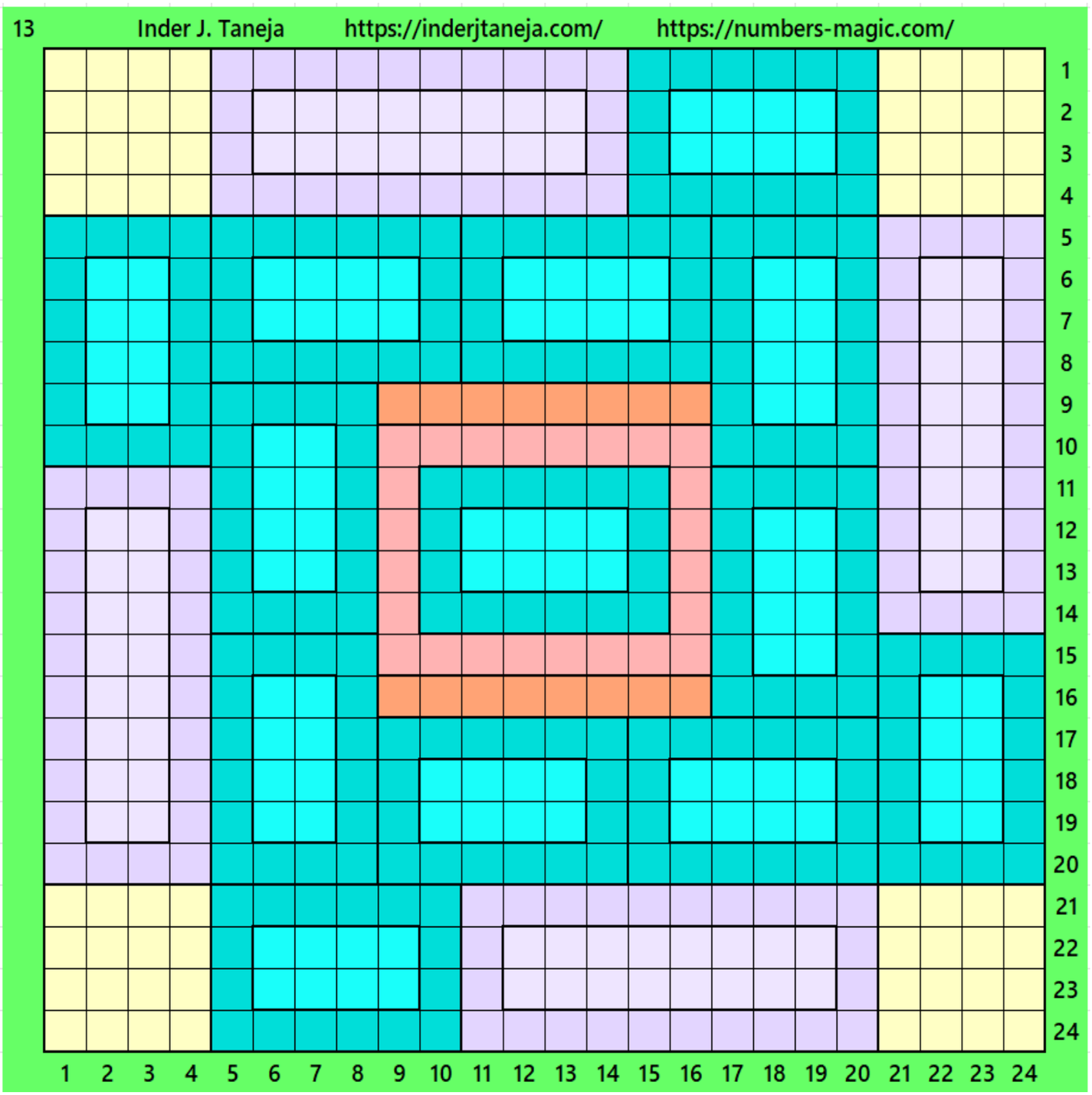
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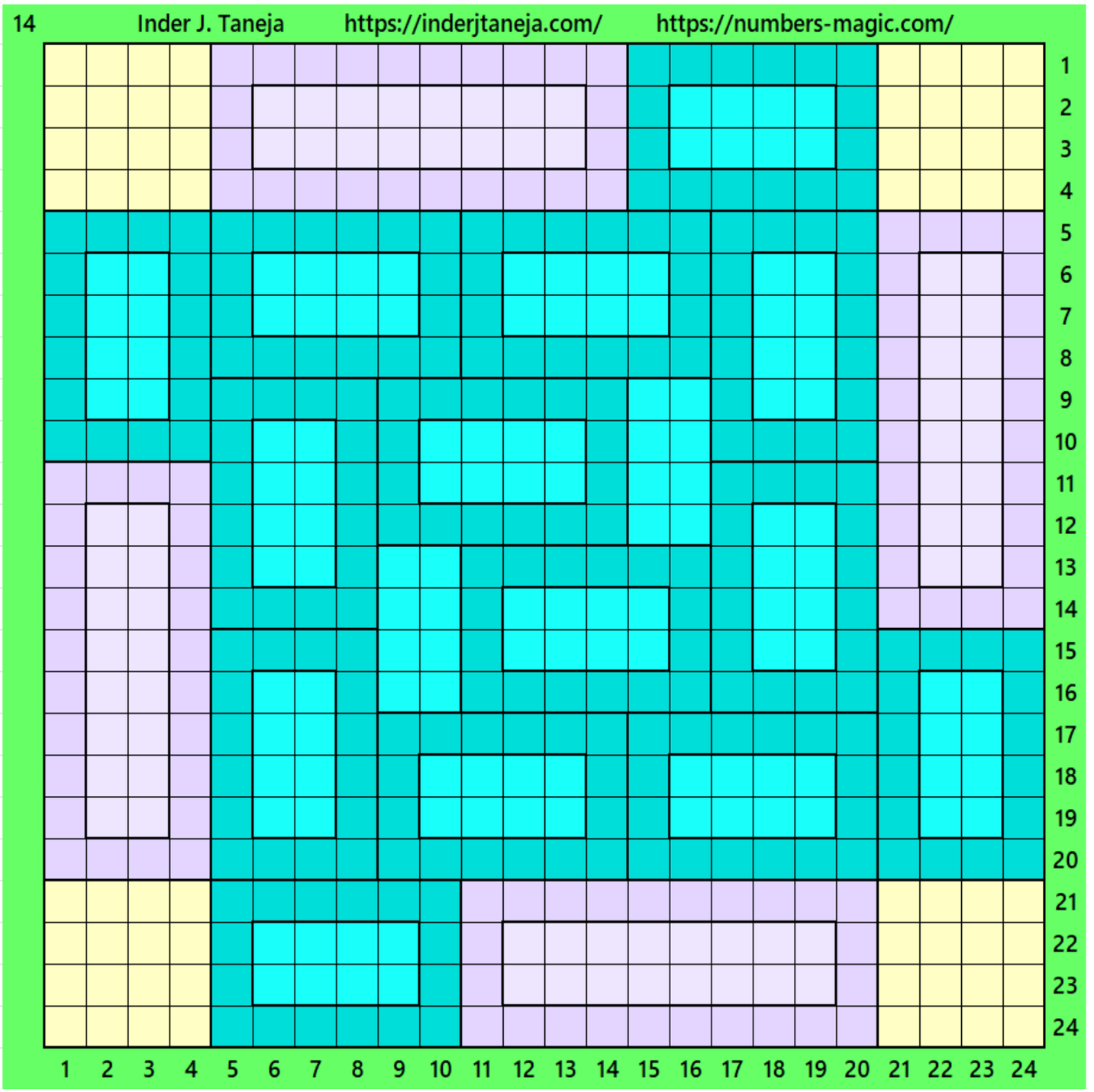
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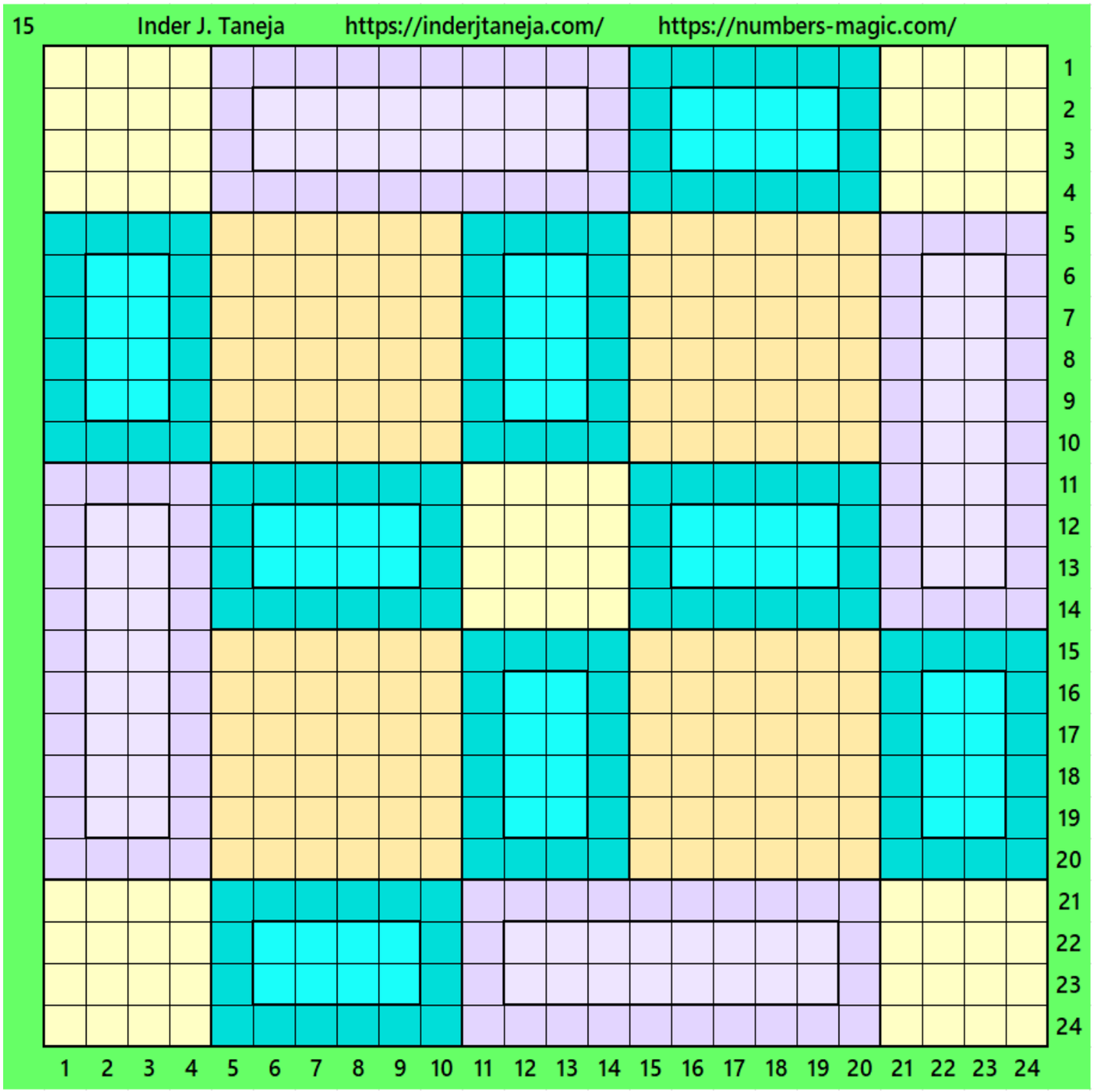
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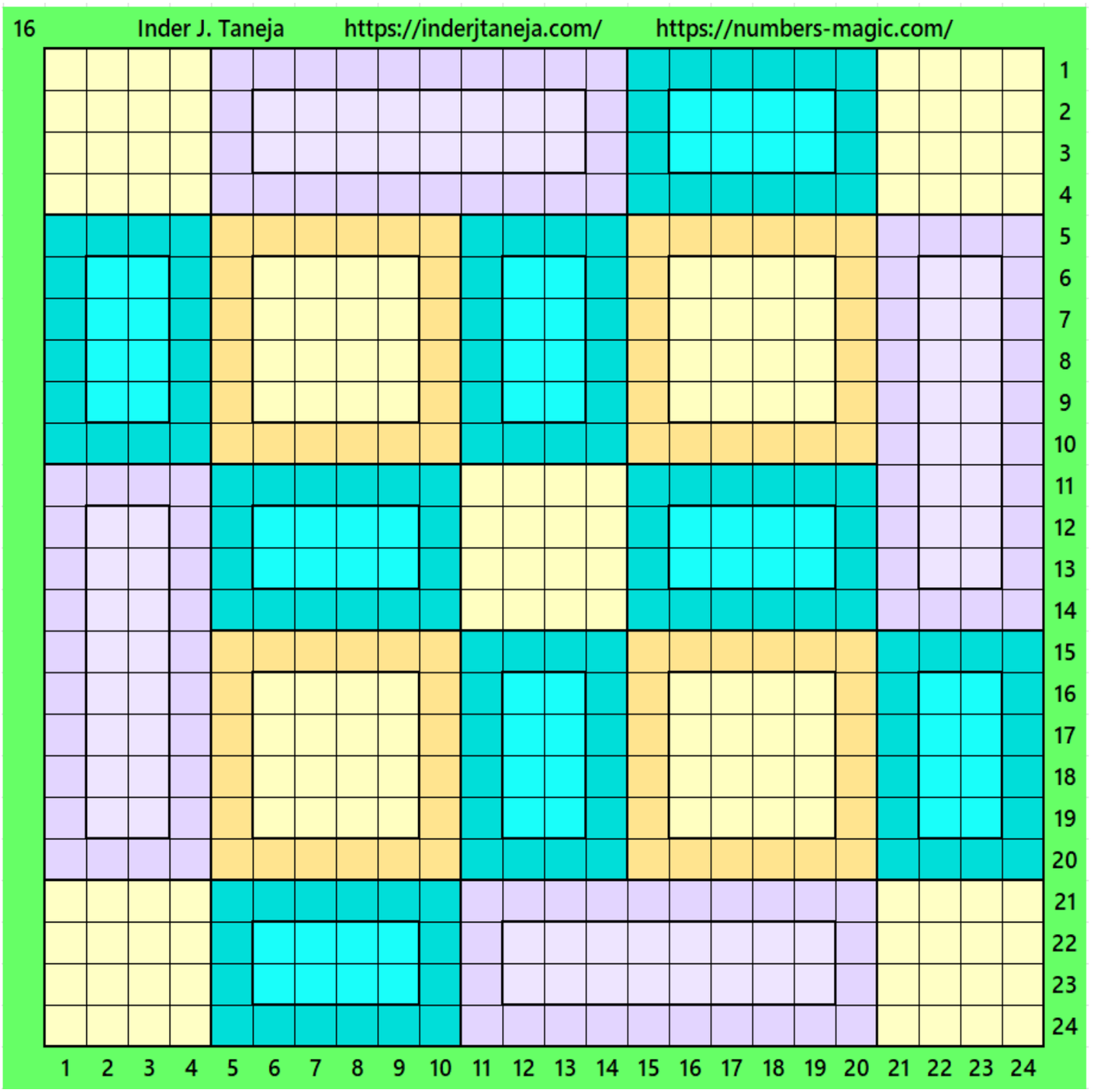
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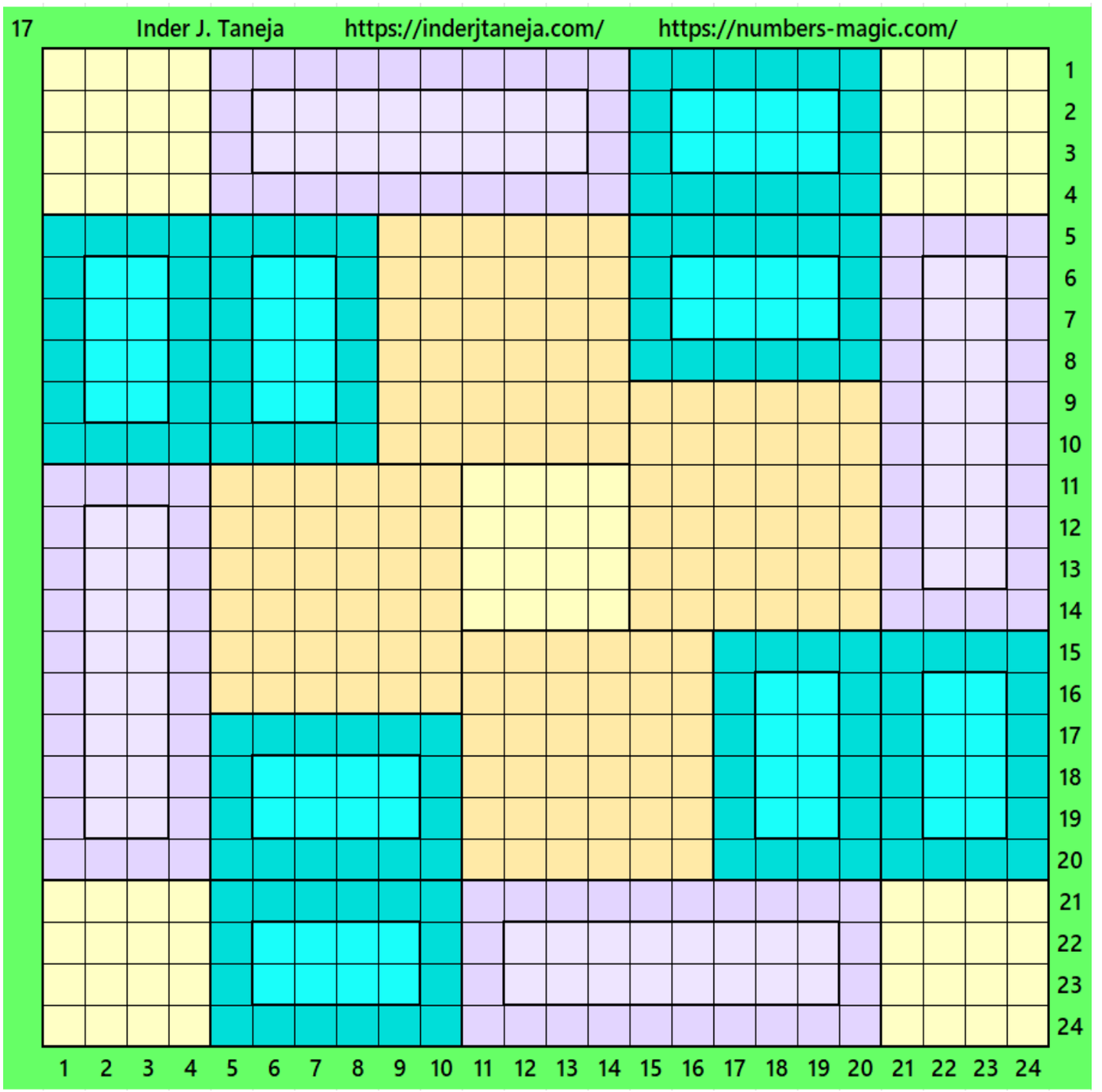
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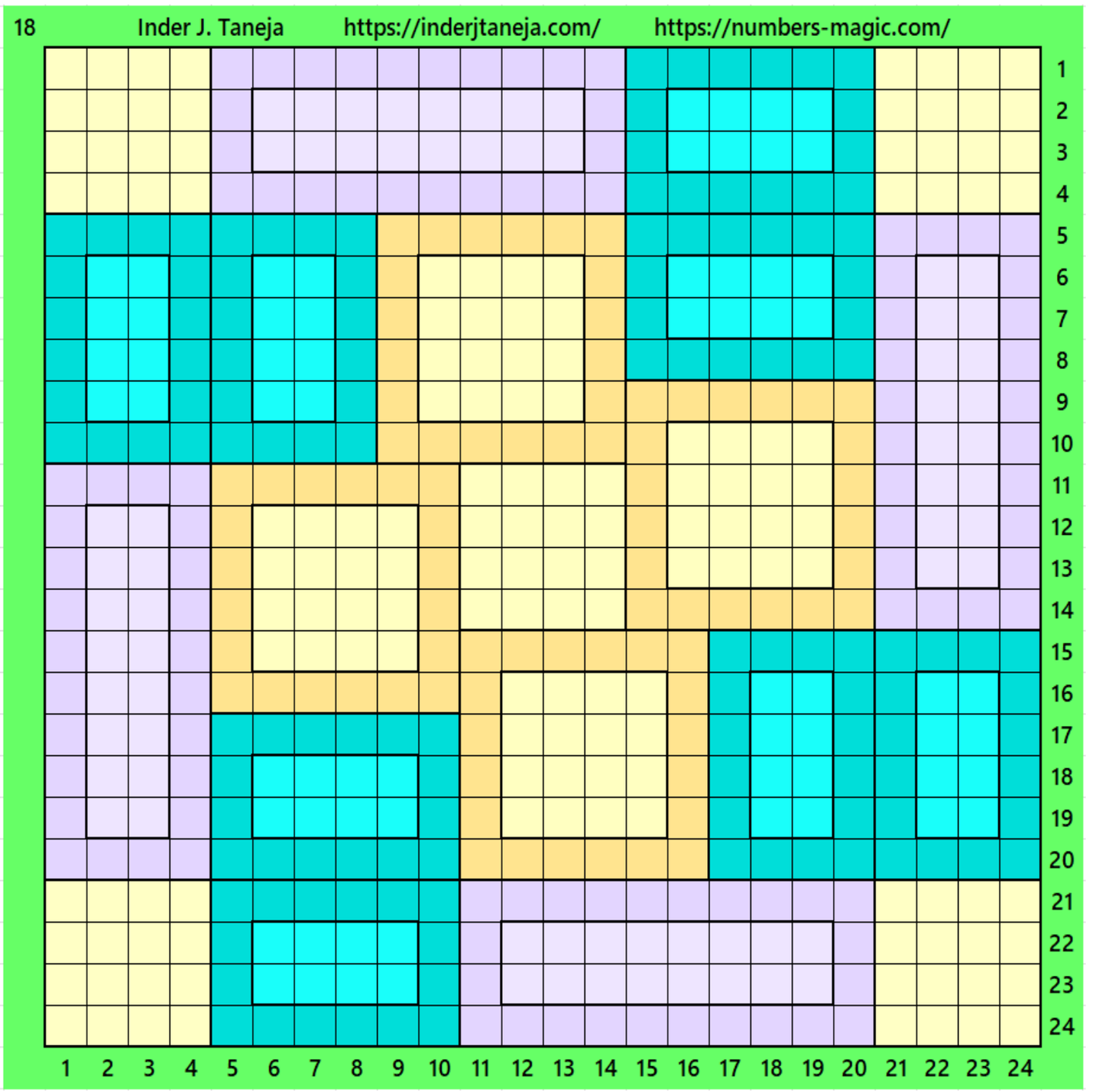
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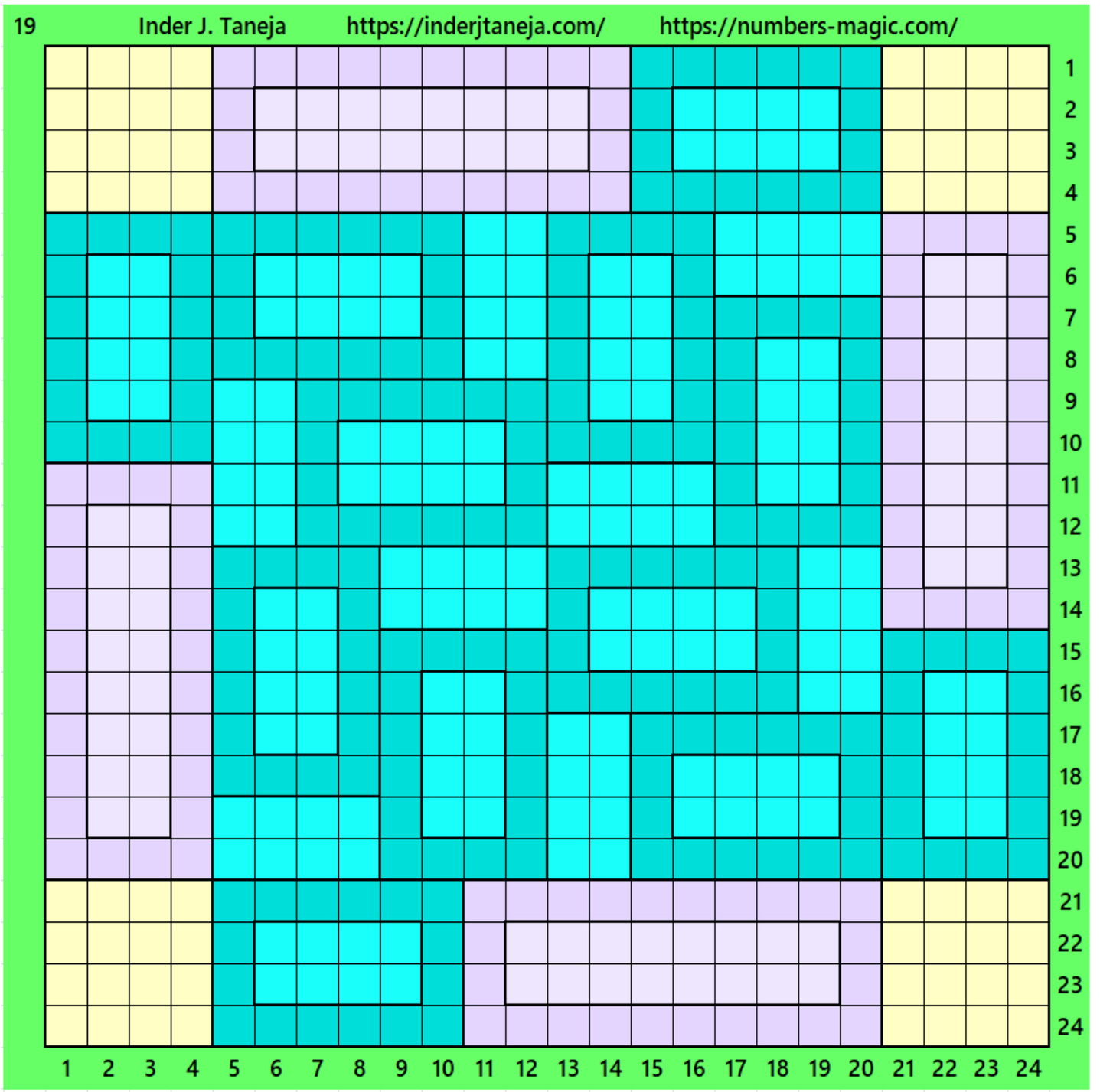
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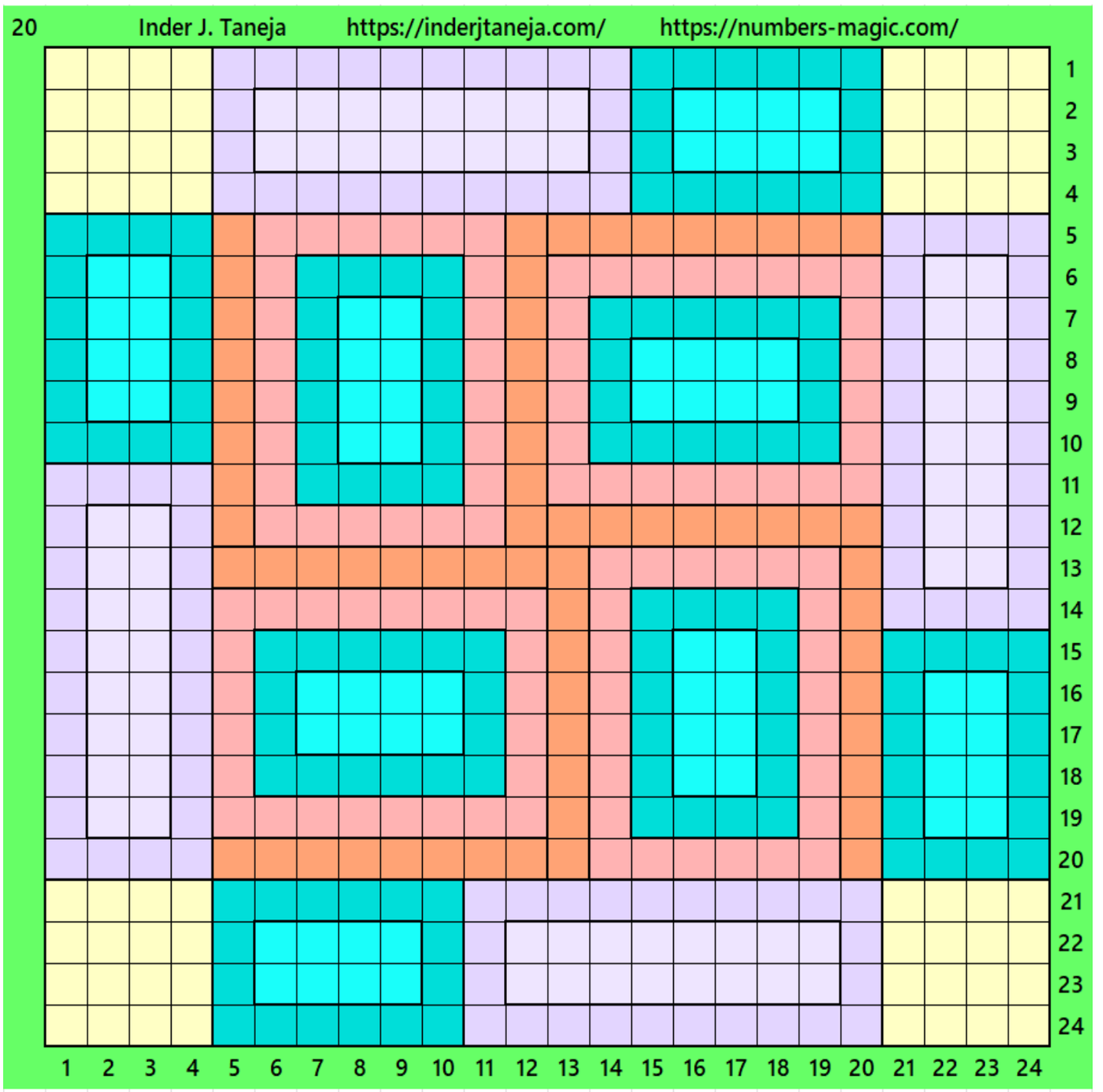
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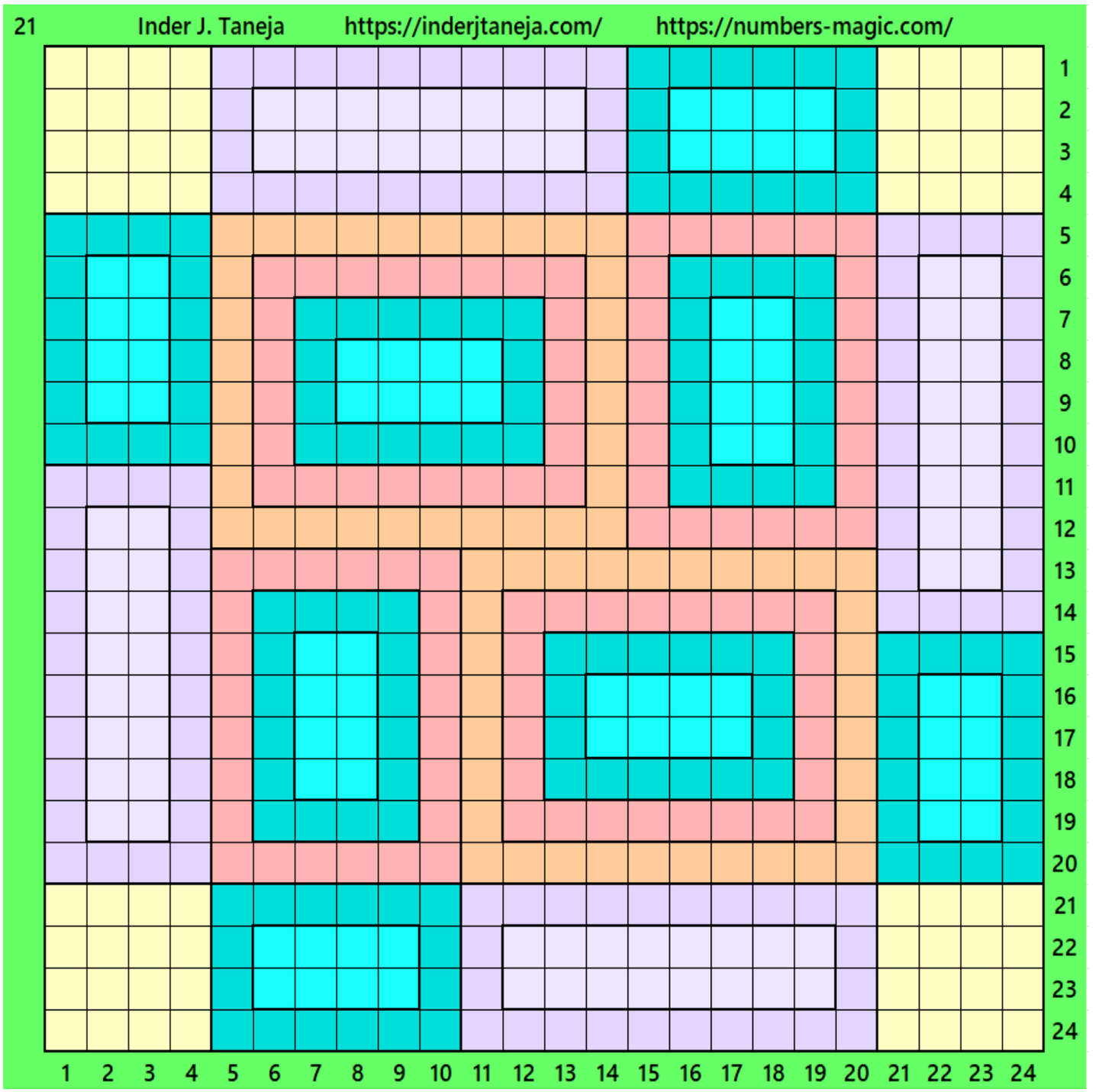
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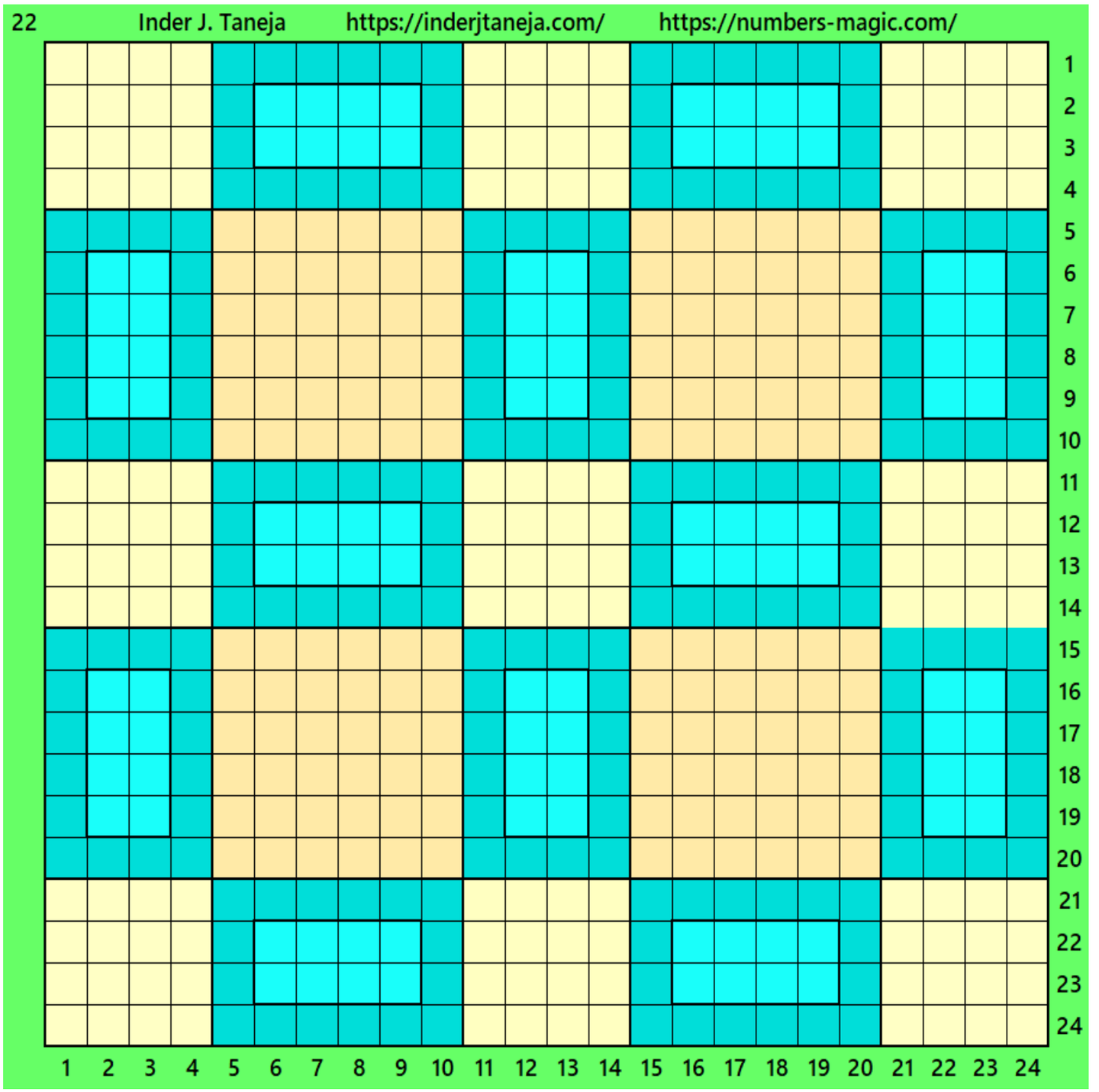
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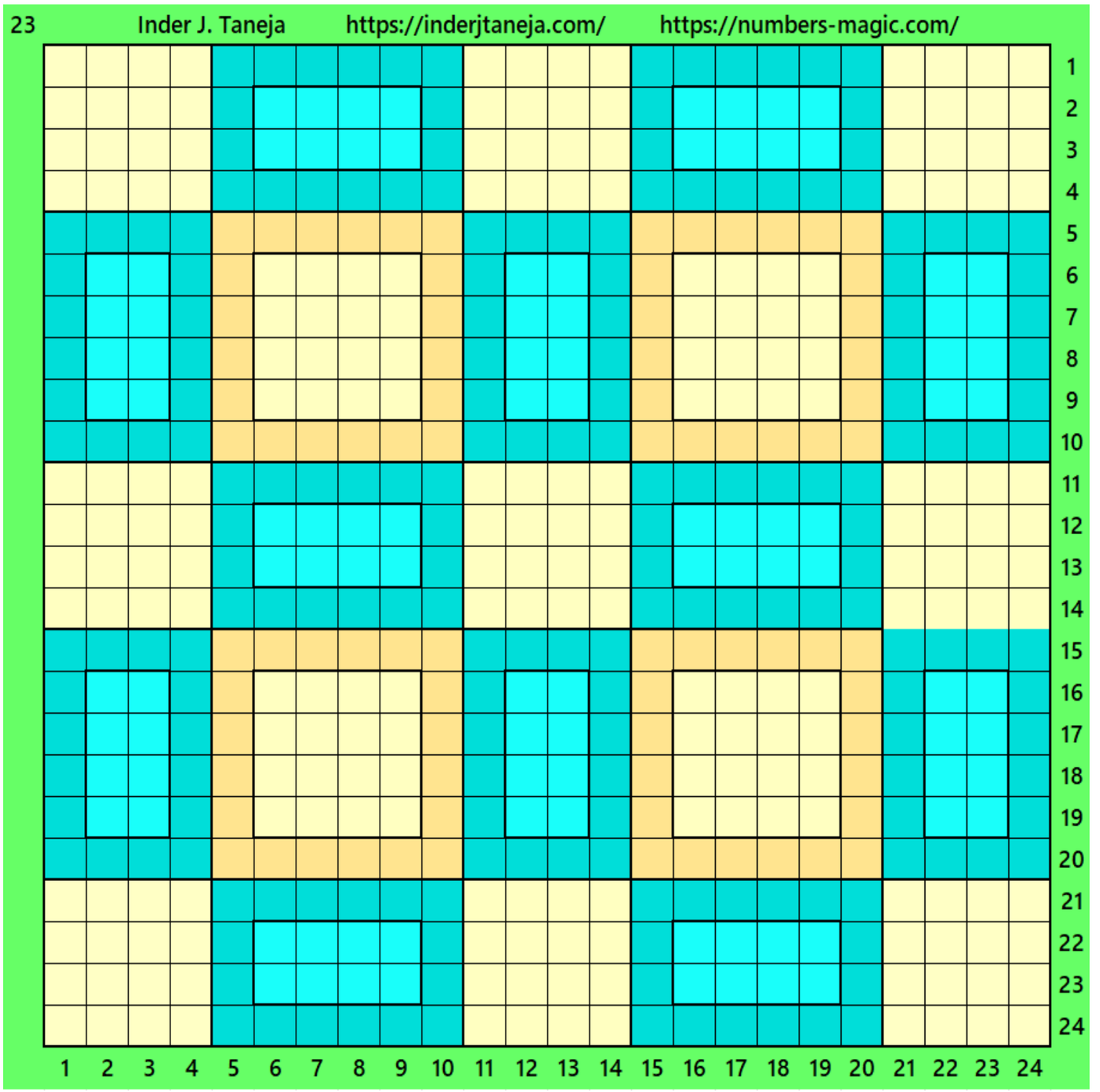

The last two examples Figs. 22 and 23 are just with BMR's of order 4×6.

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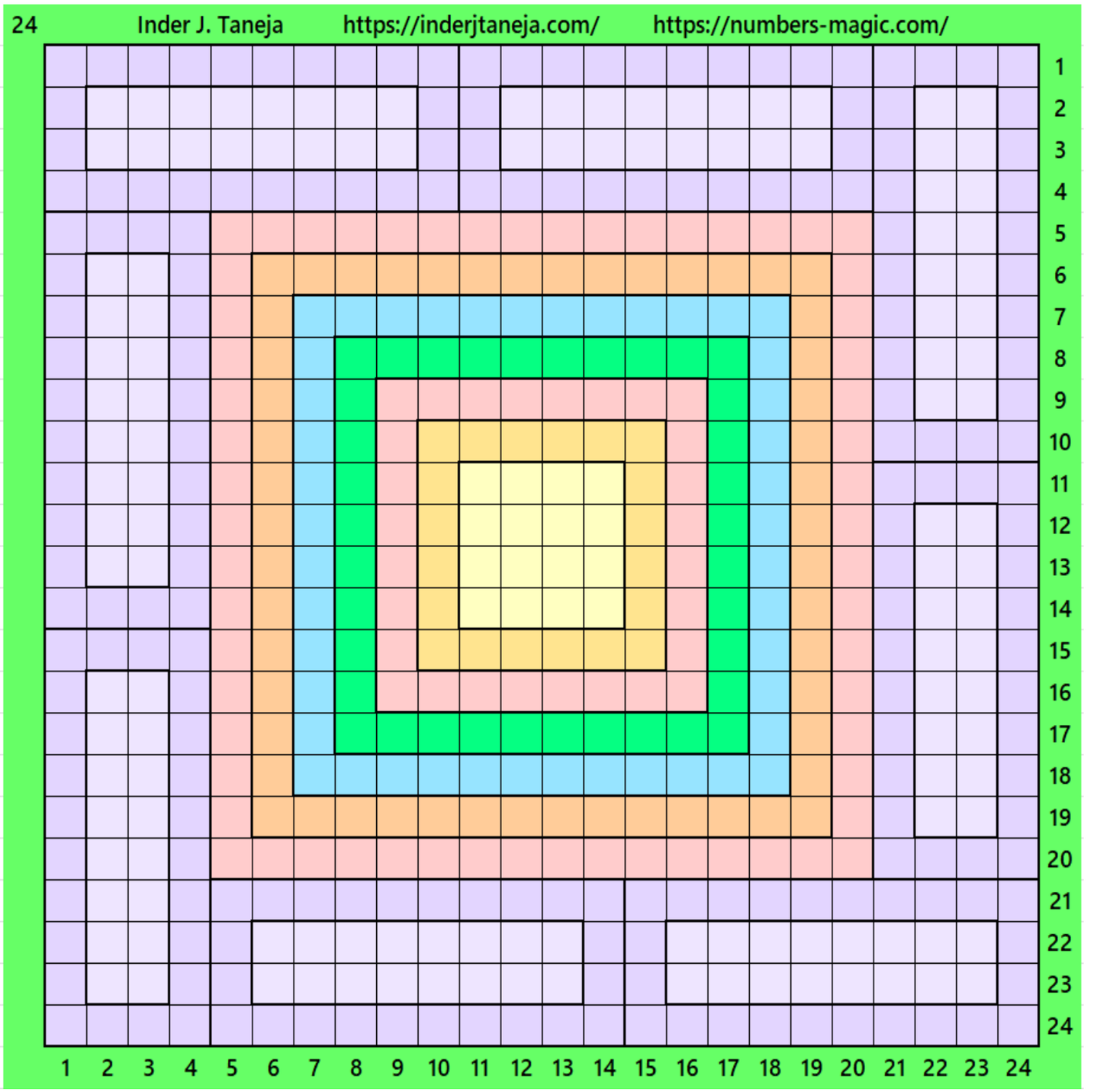
2.4 Closed Border of Order 4

Above we have given open external border of order 4. Let's consider 8 equal sums BMR of order 4×10. Let's put them in external rows and columns forming an external border of order 4. Then we are left with internal block of order 16. Writing internal block of order 16 with different magic squares, we get magic squares of 24. See below few examples.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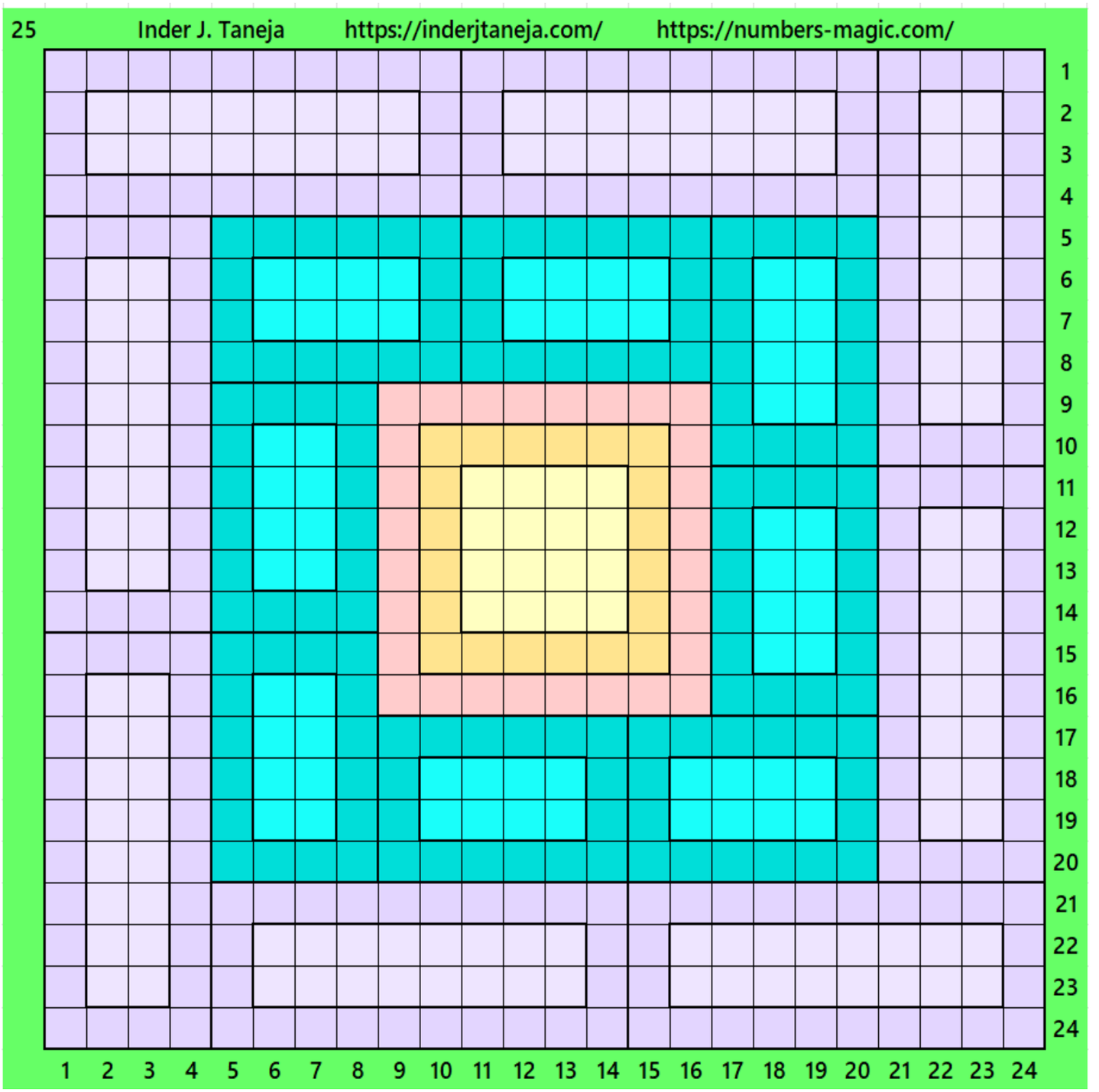
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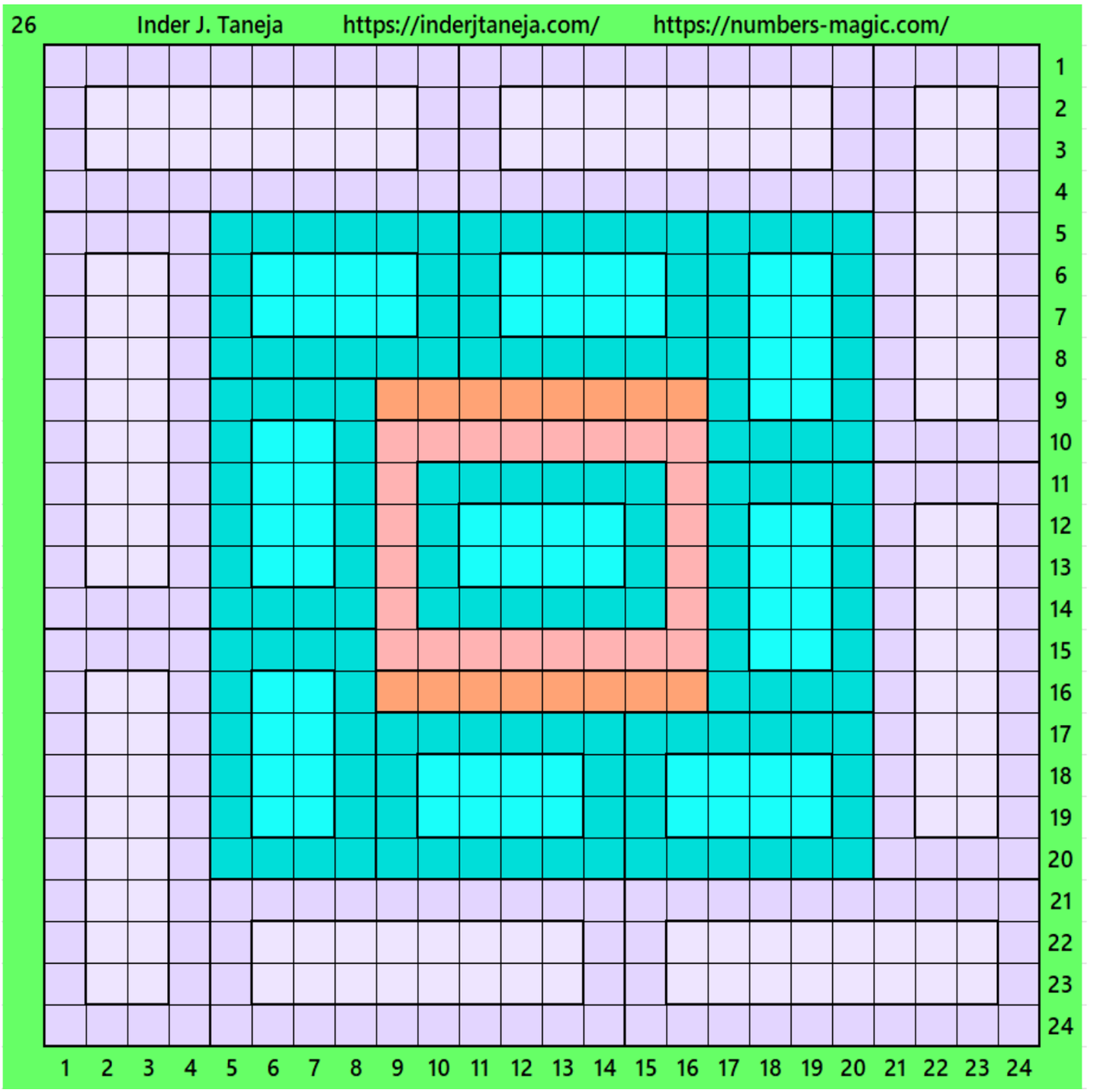
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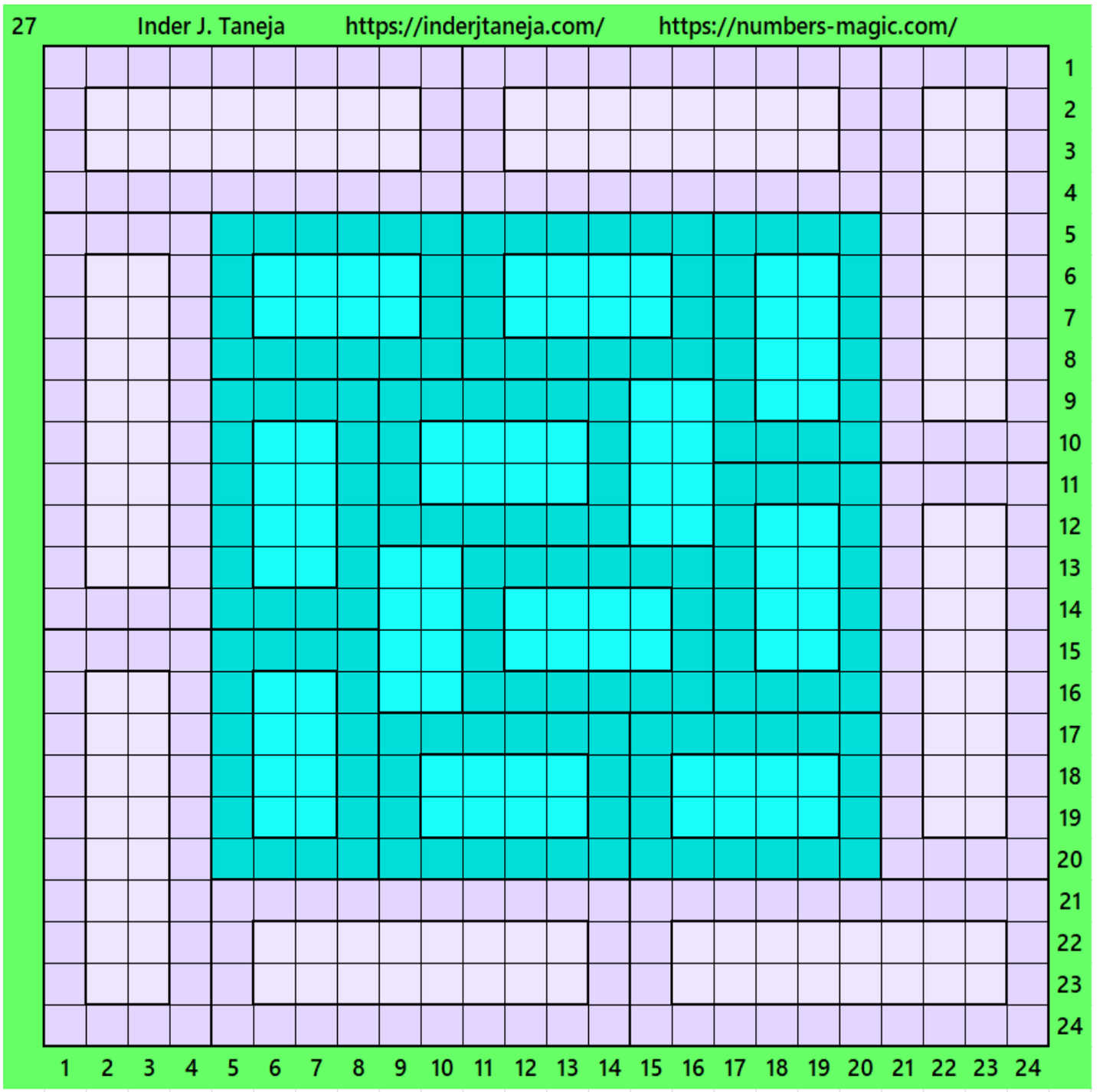
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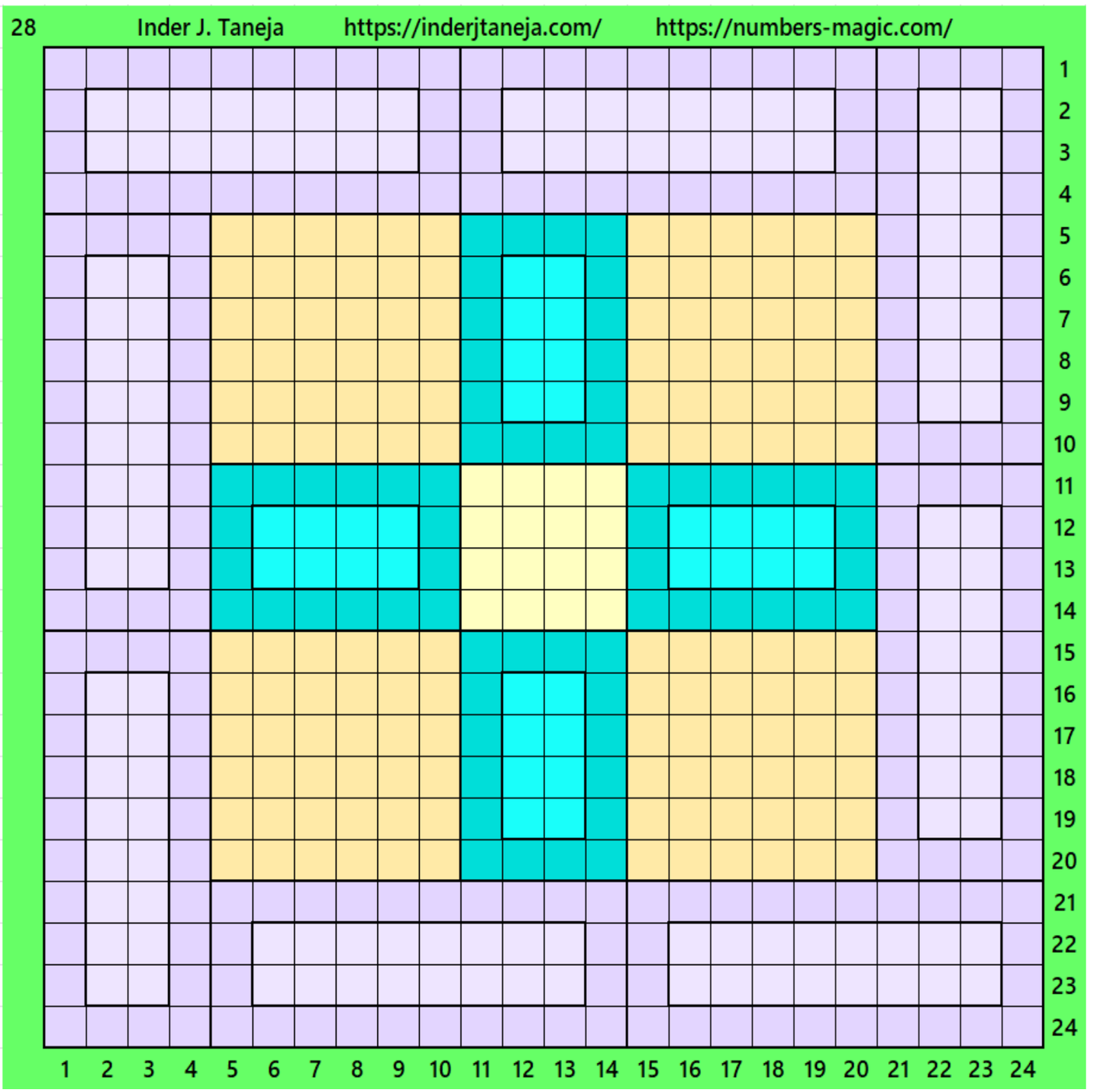
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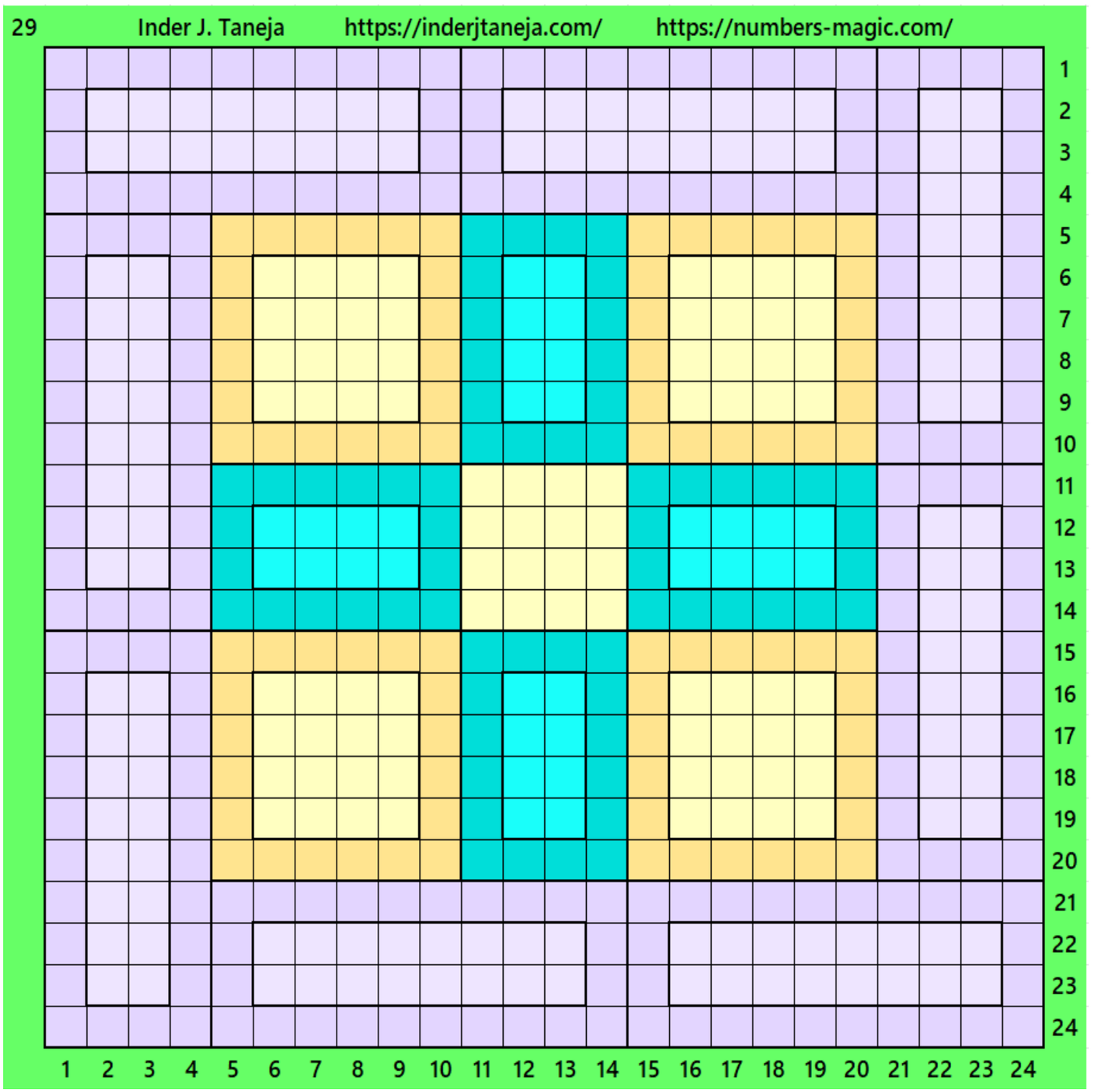
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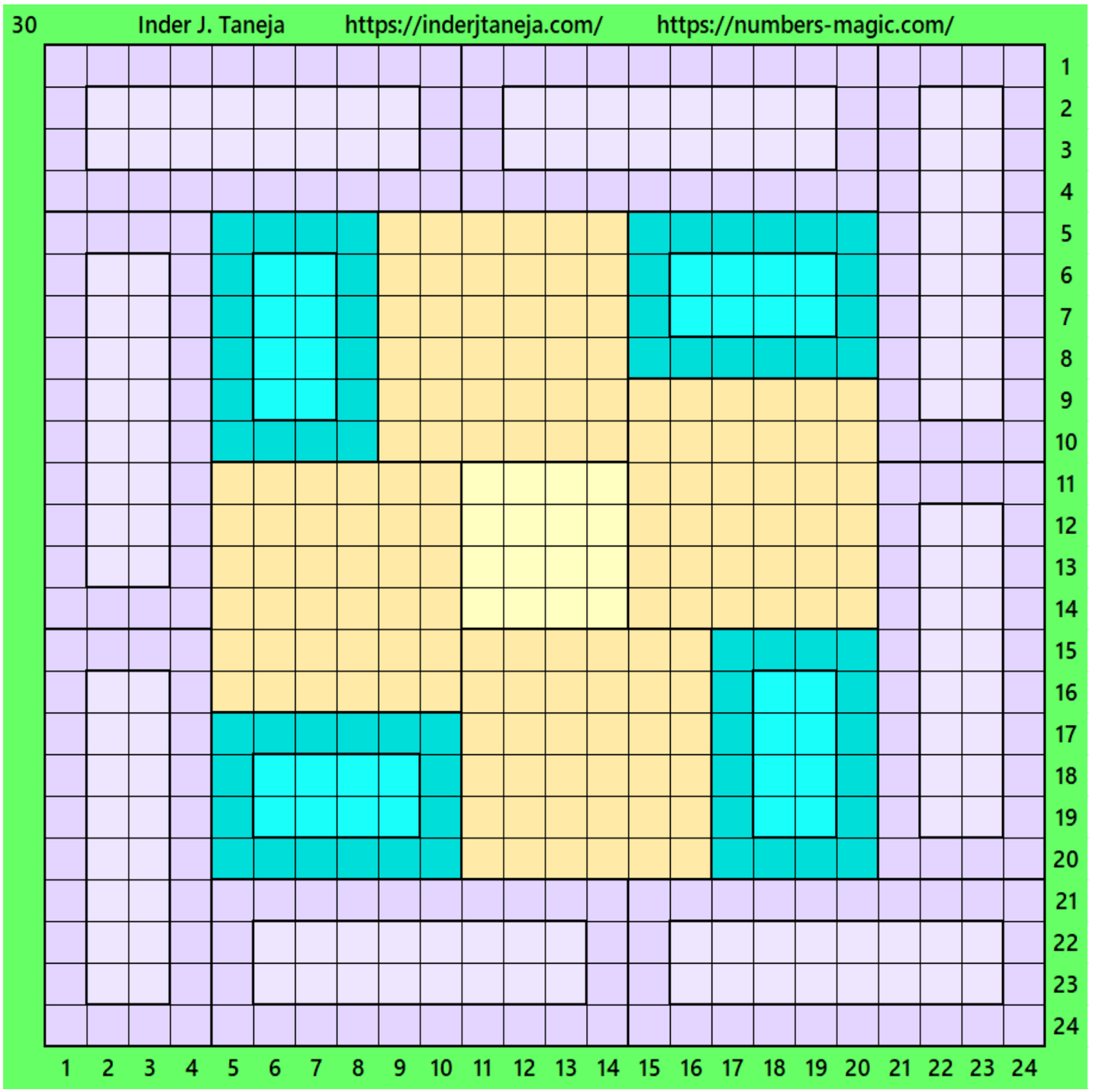
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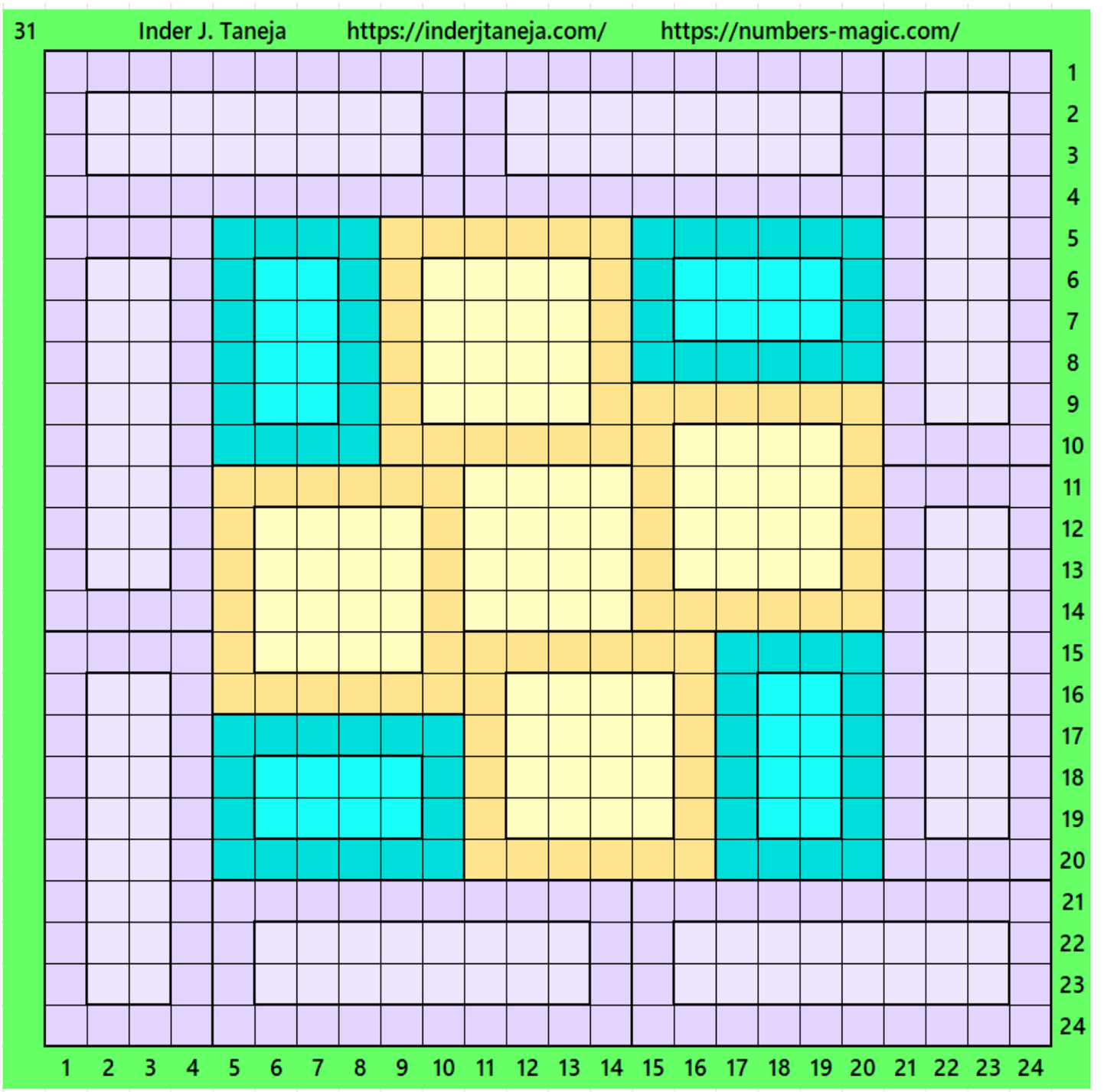
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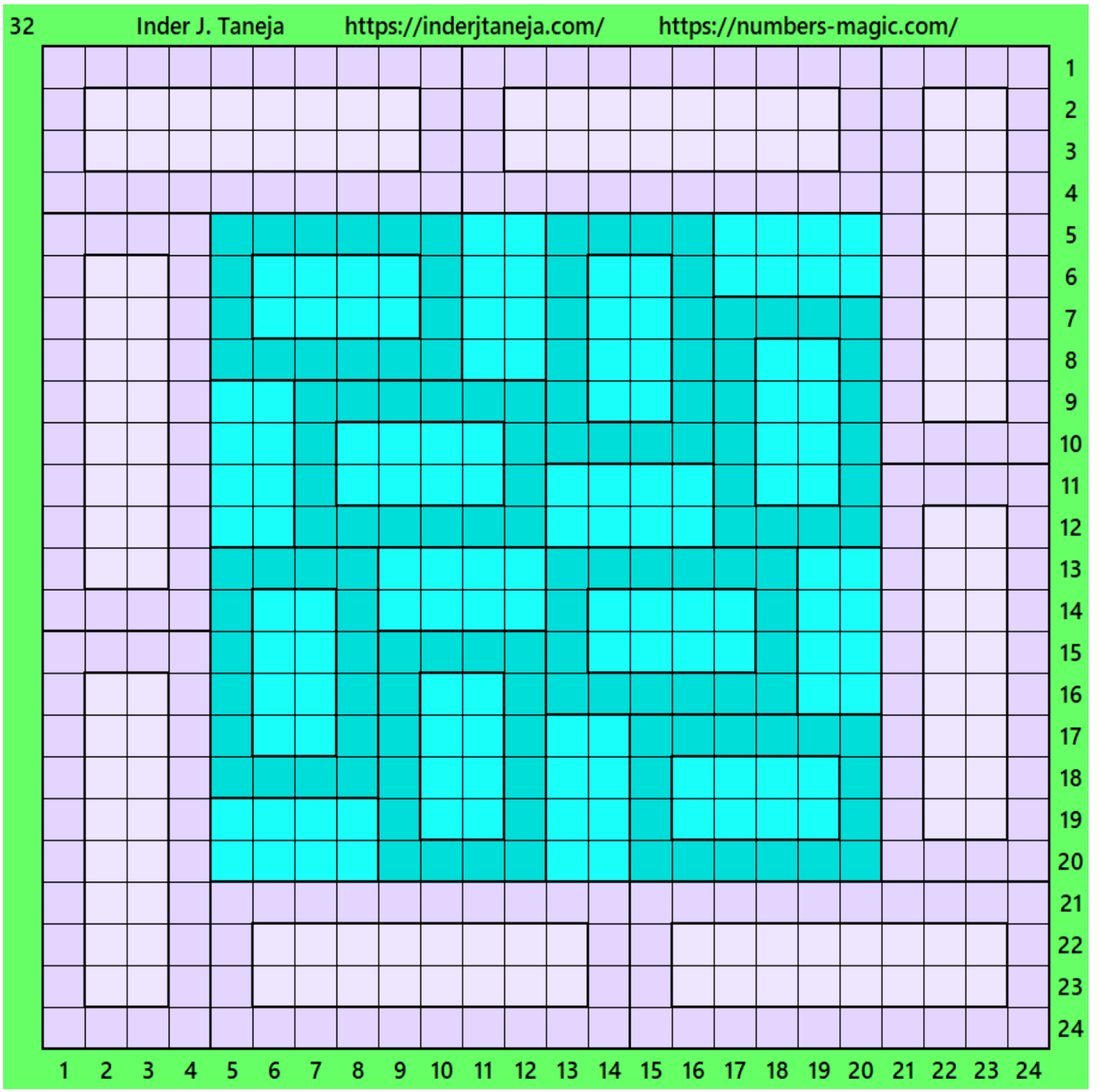
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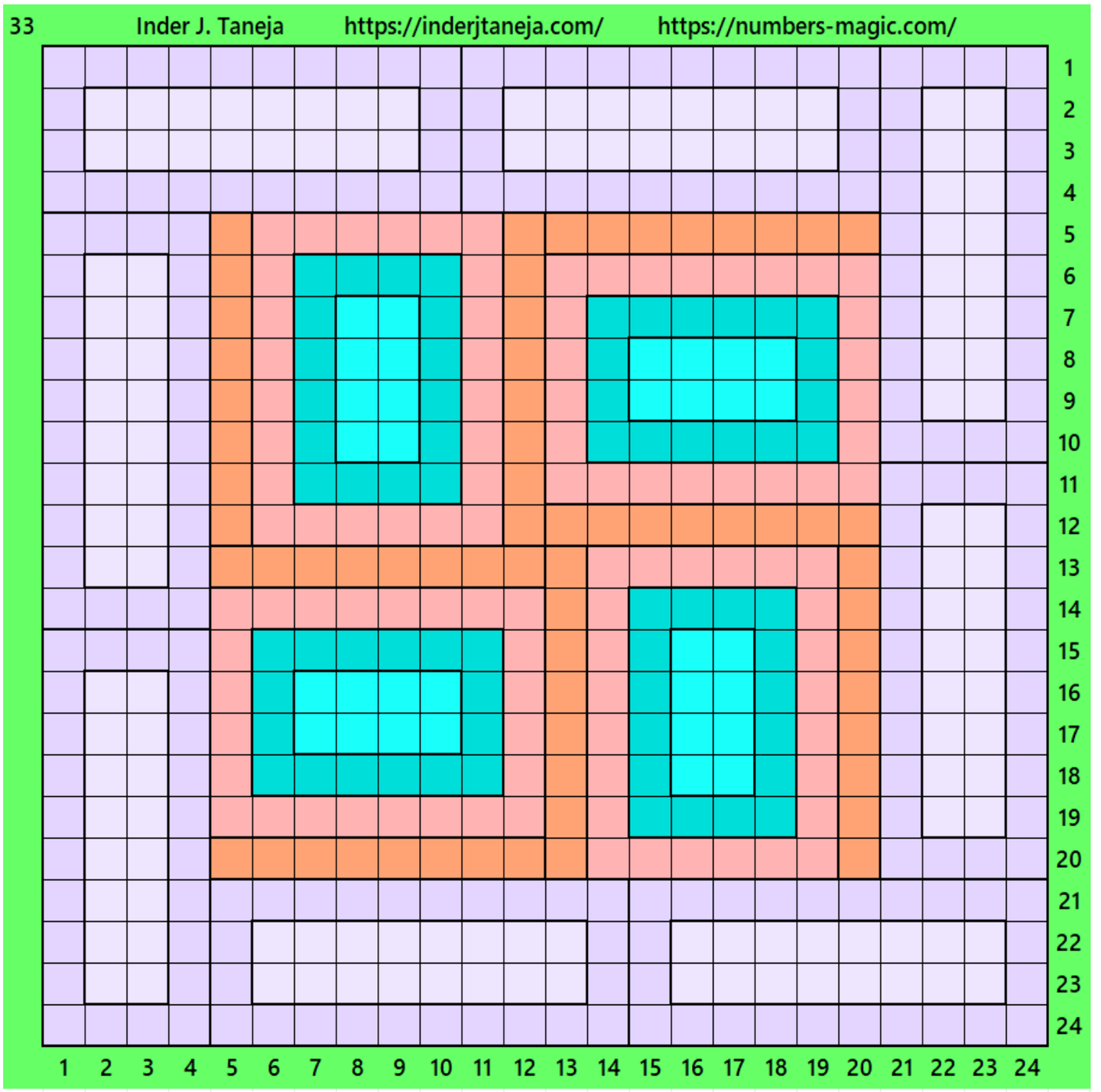
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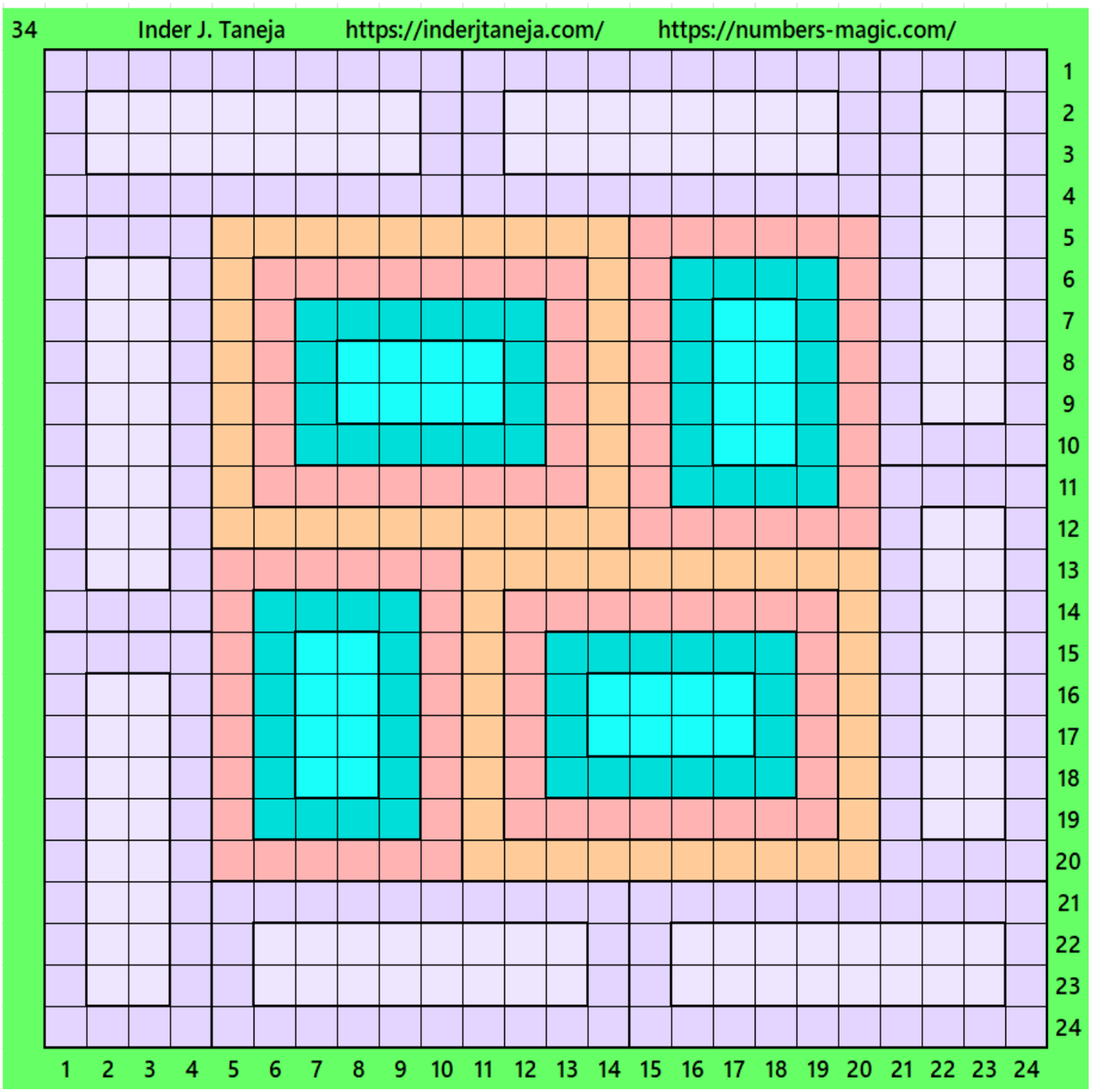
34
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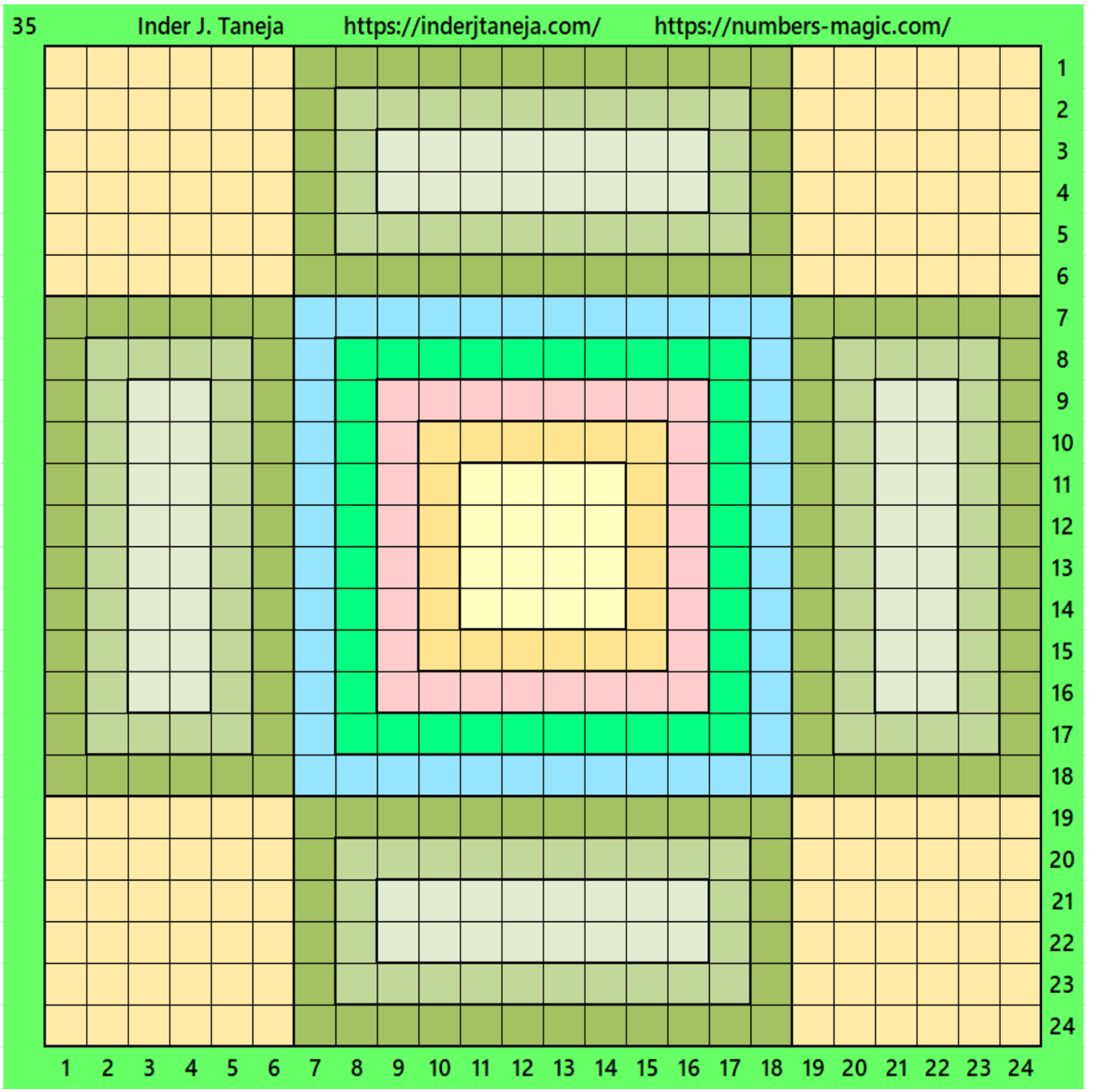
2.5 Cornered Magic Squares of Order 6

Again according to Fig. 3 (order 24), we don't require external border of order 6. But as an extra option, we consider 4 magic squares of order 6 and 4 BMR's of orders 6×12 to make external border of order 6. Then we are left with internal block of order 12. Writing internal block of order 12 with different magic squares, we get magic squares of 24. See below few examples.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https://numbers-magic.com/
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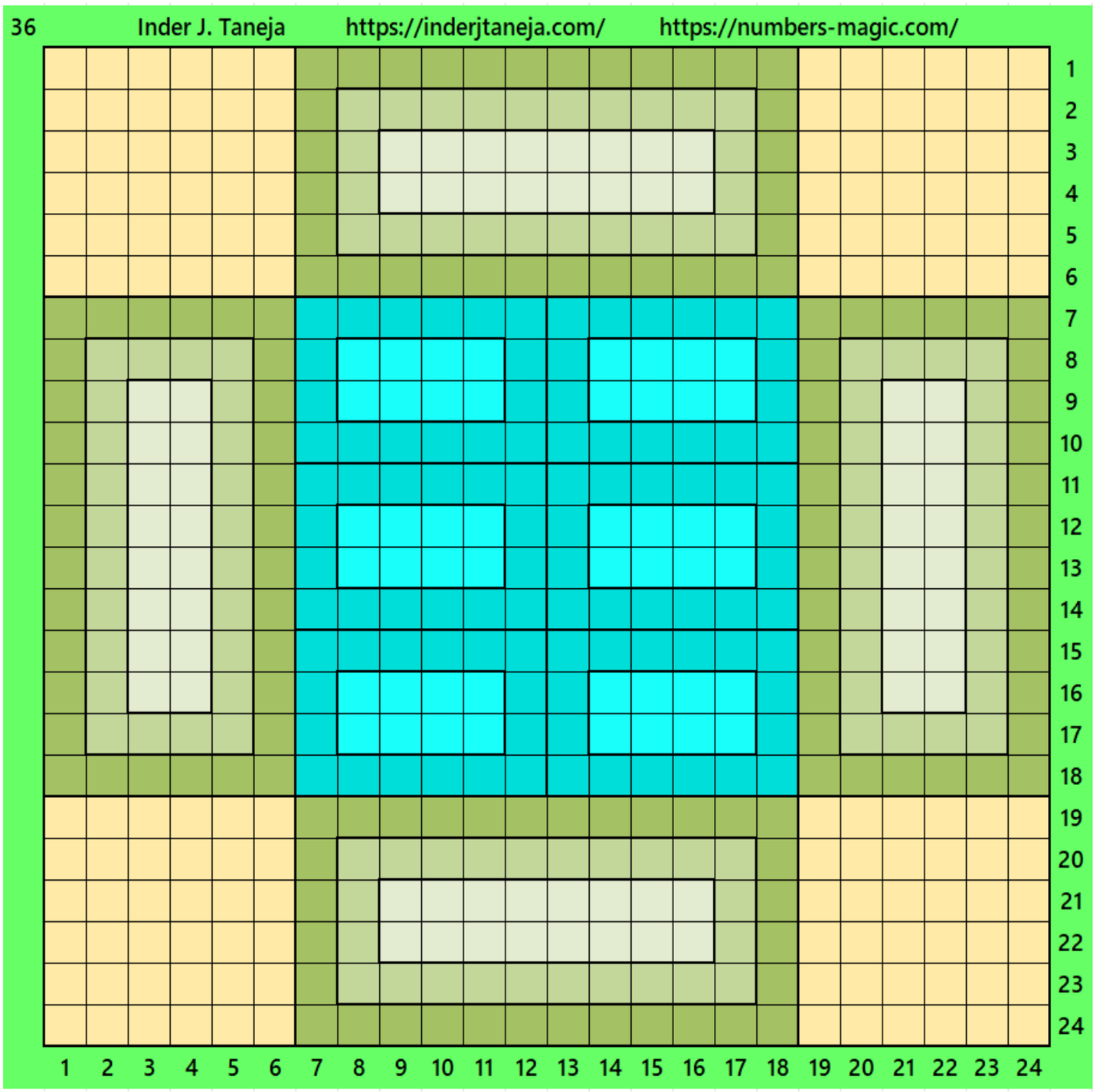
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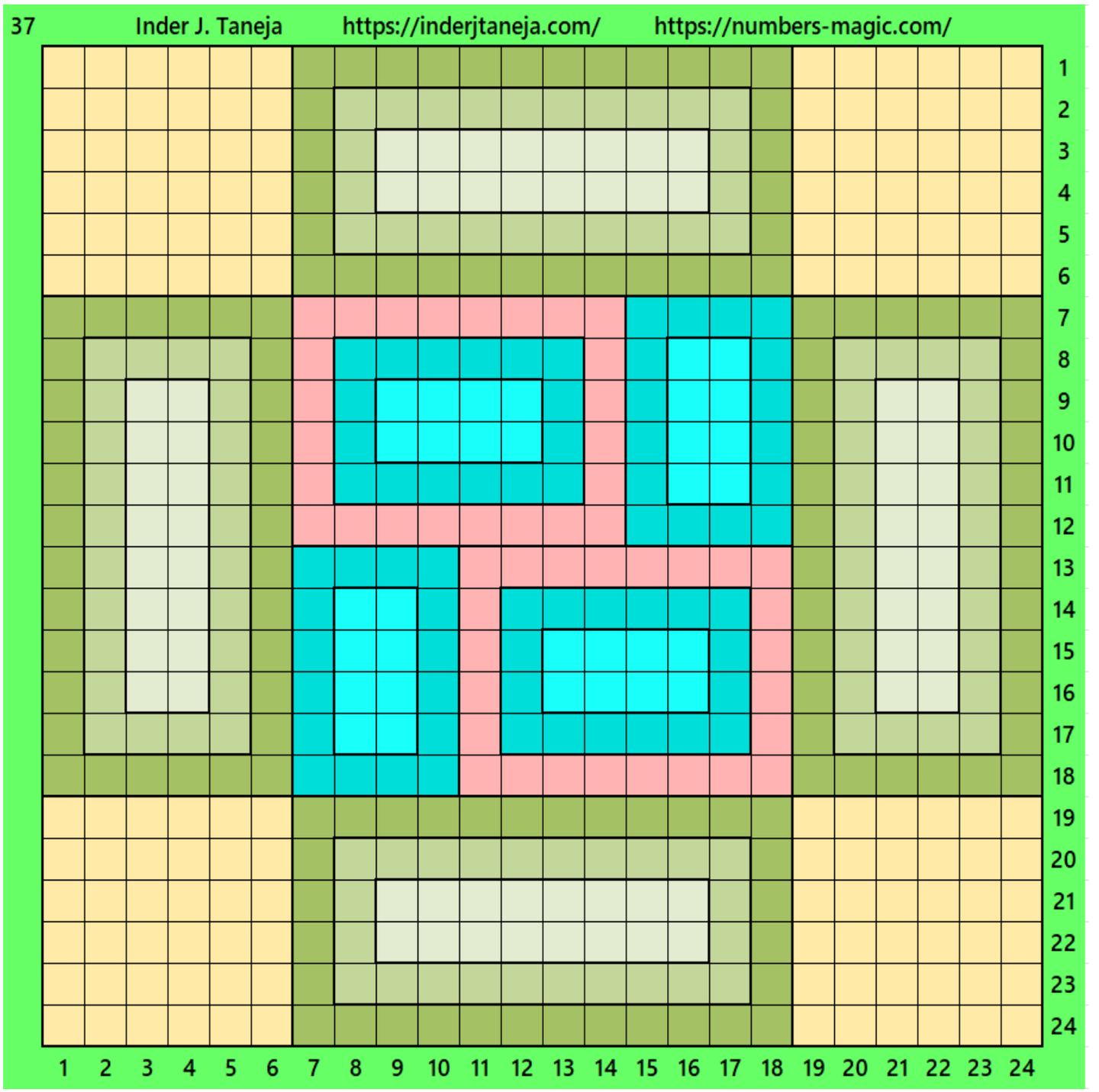
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https://numbers-magic.com/
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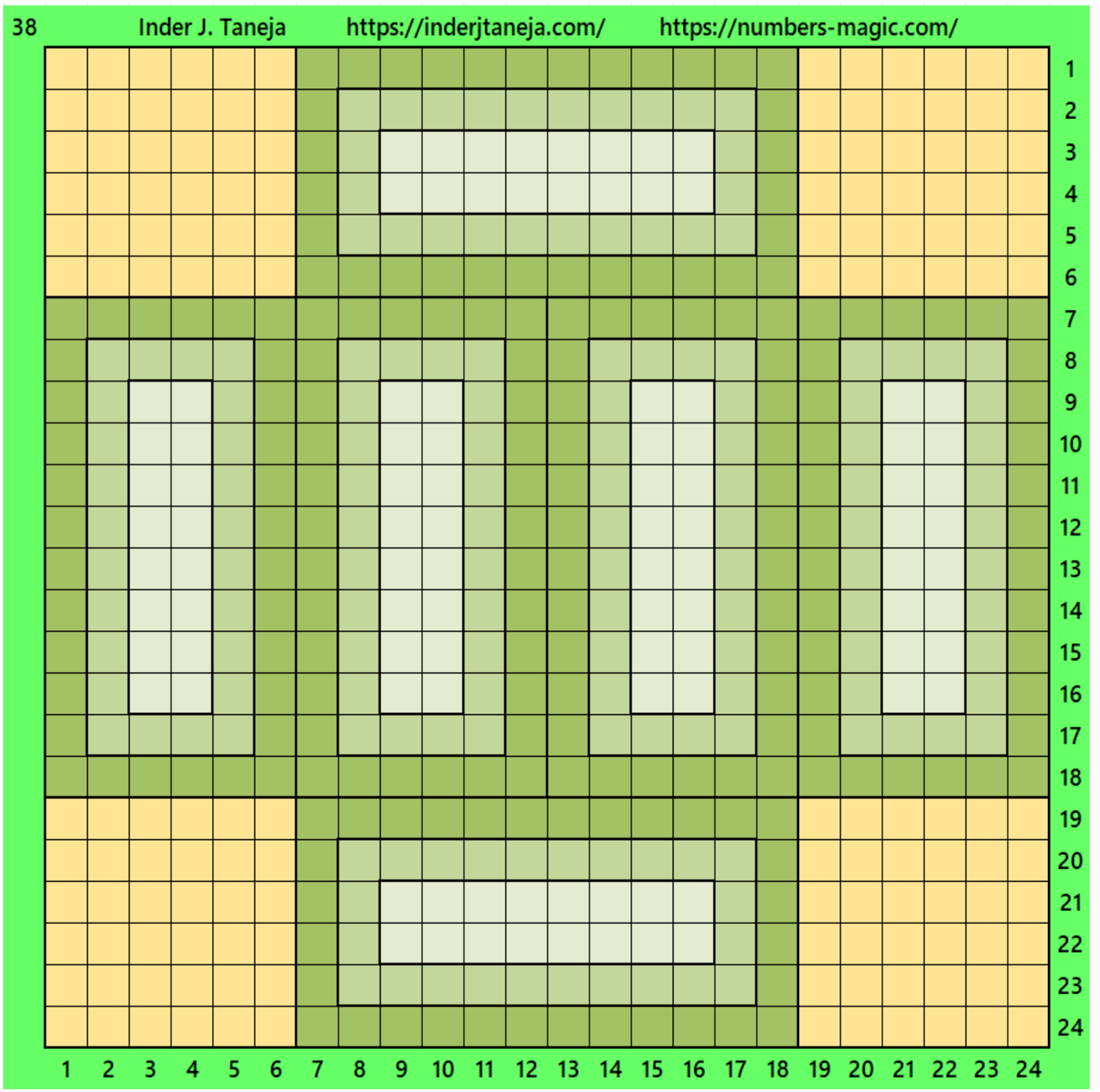
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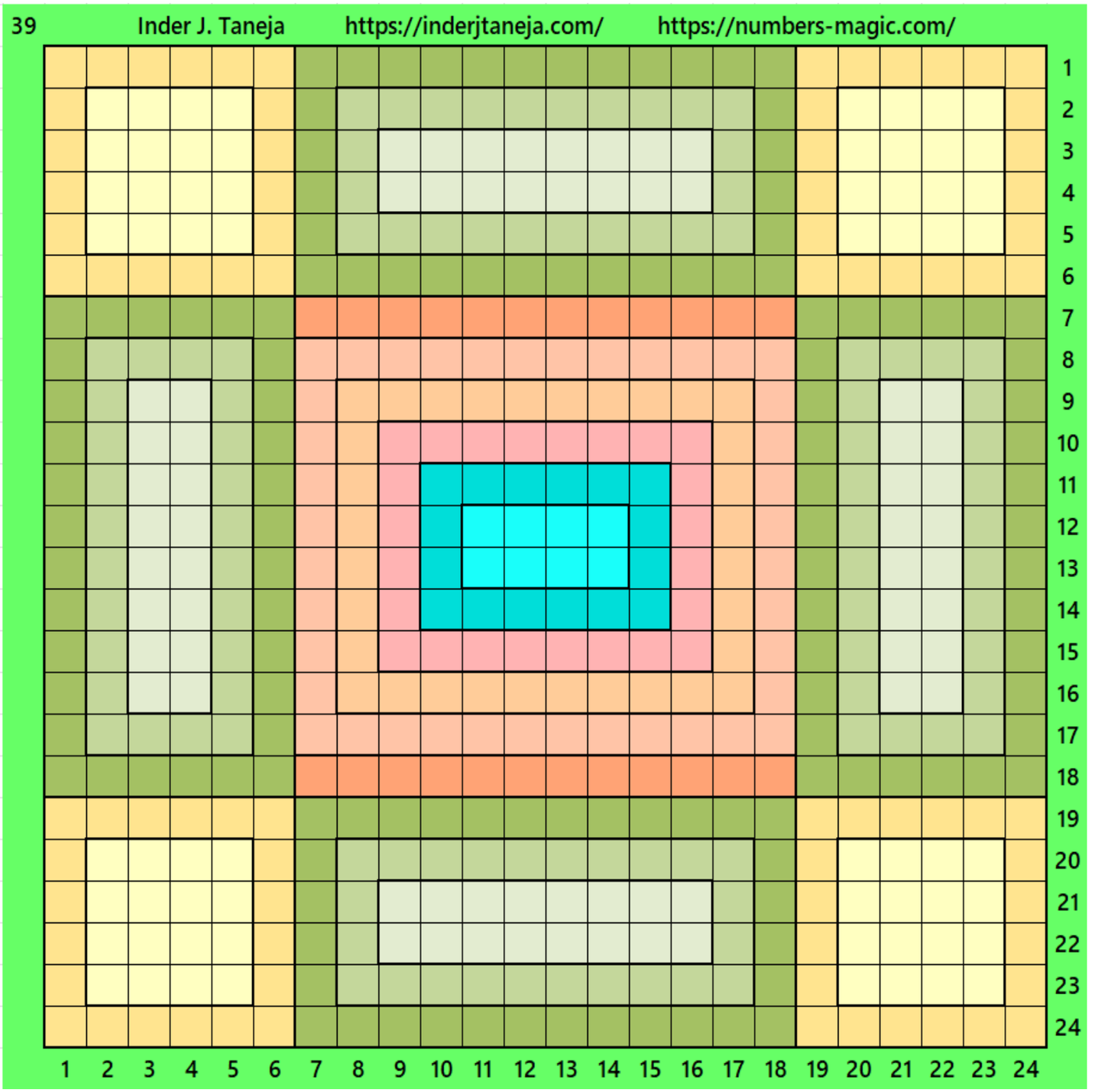
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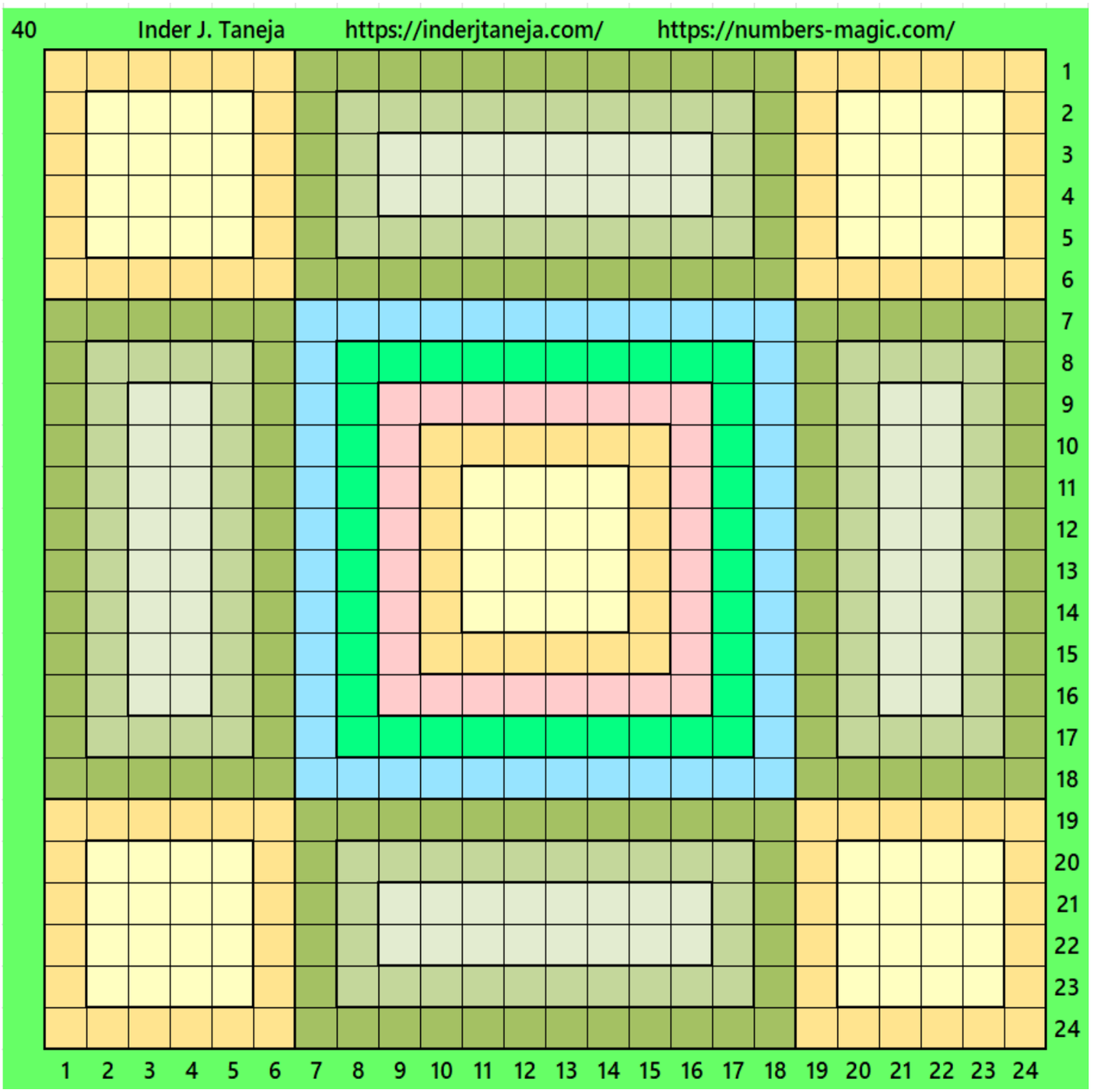

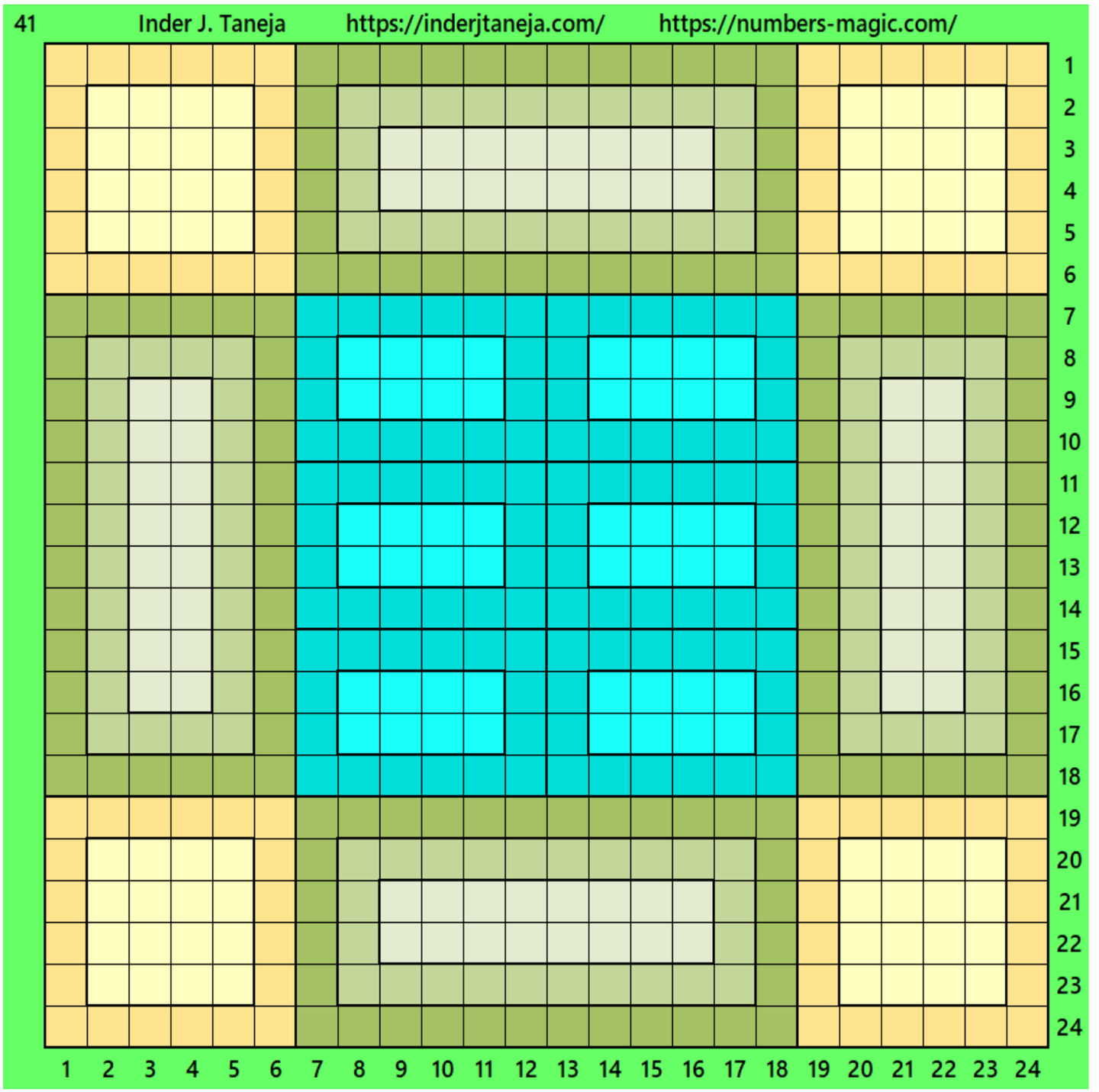
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https://numbers-magic.com/
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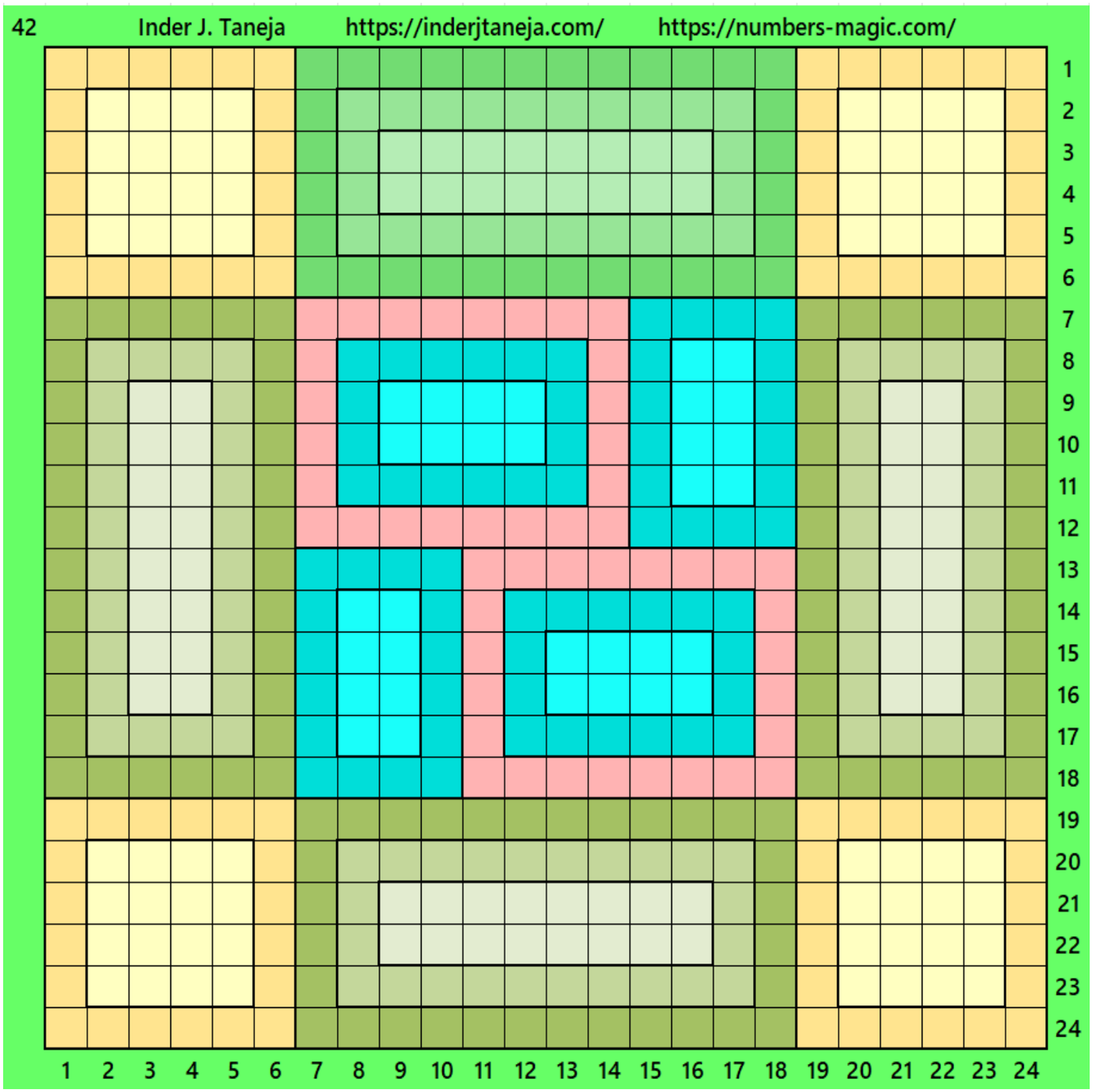
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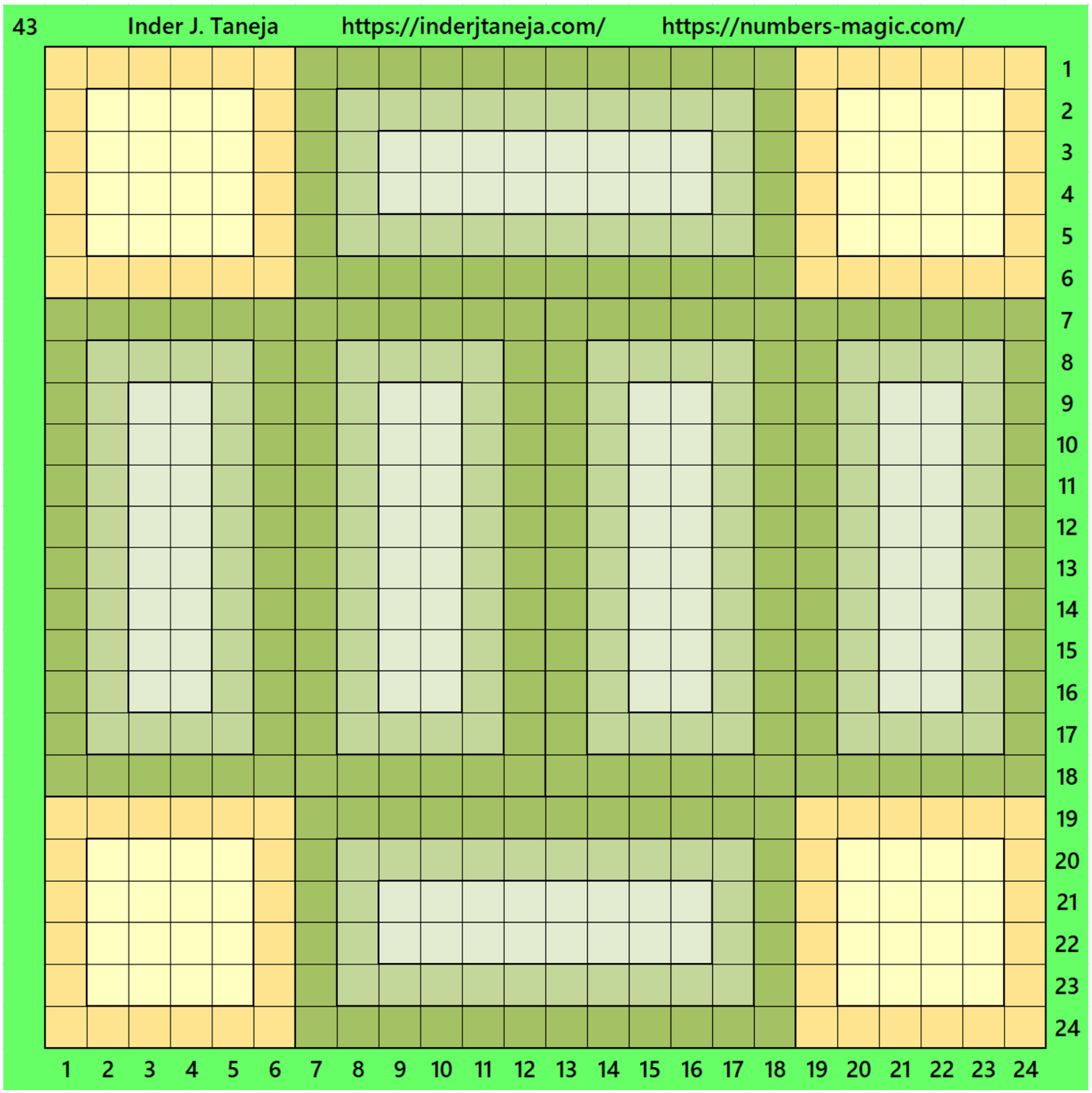
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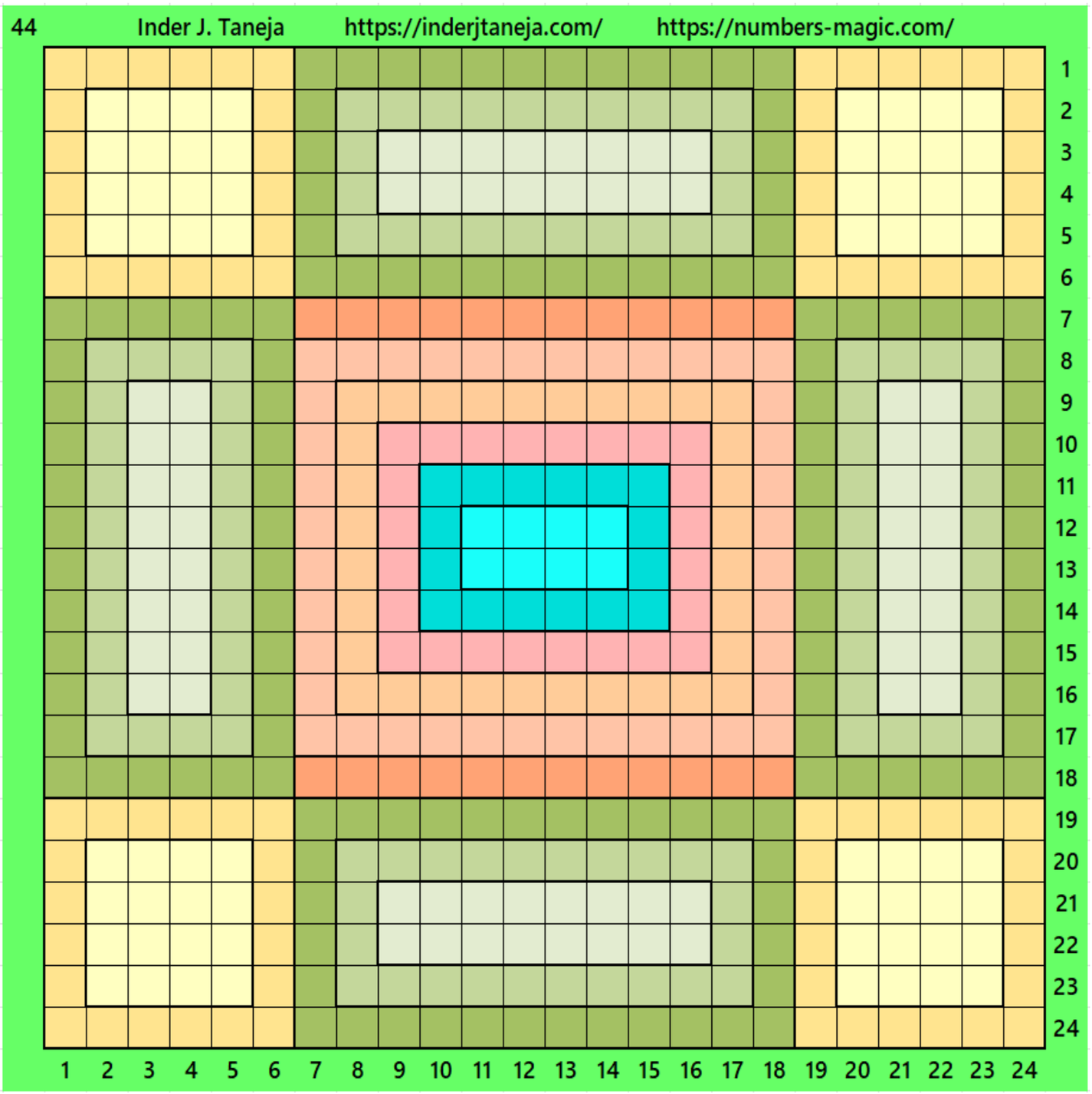
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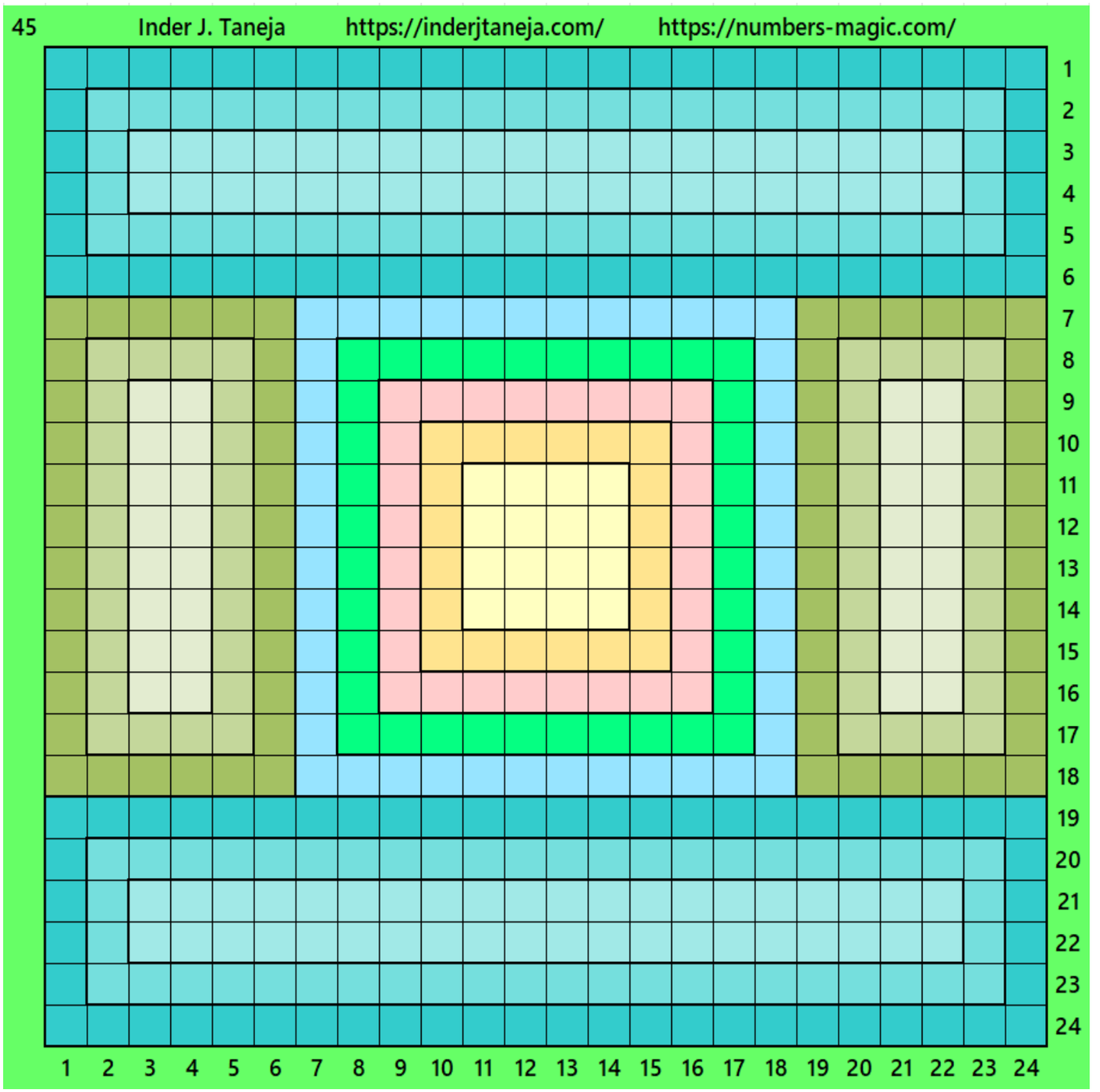
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

2.6 Closed Border of Order 6

Let's consider 2 BMR of order 6×24 and two of order 6×12. This gives us a closed external border of order 6. We are left with inner block of order 12. Writing middle block of order 12 in different ways, below are few examples of magic squares of order 24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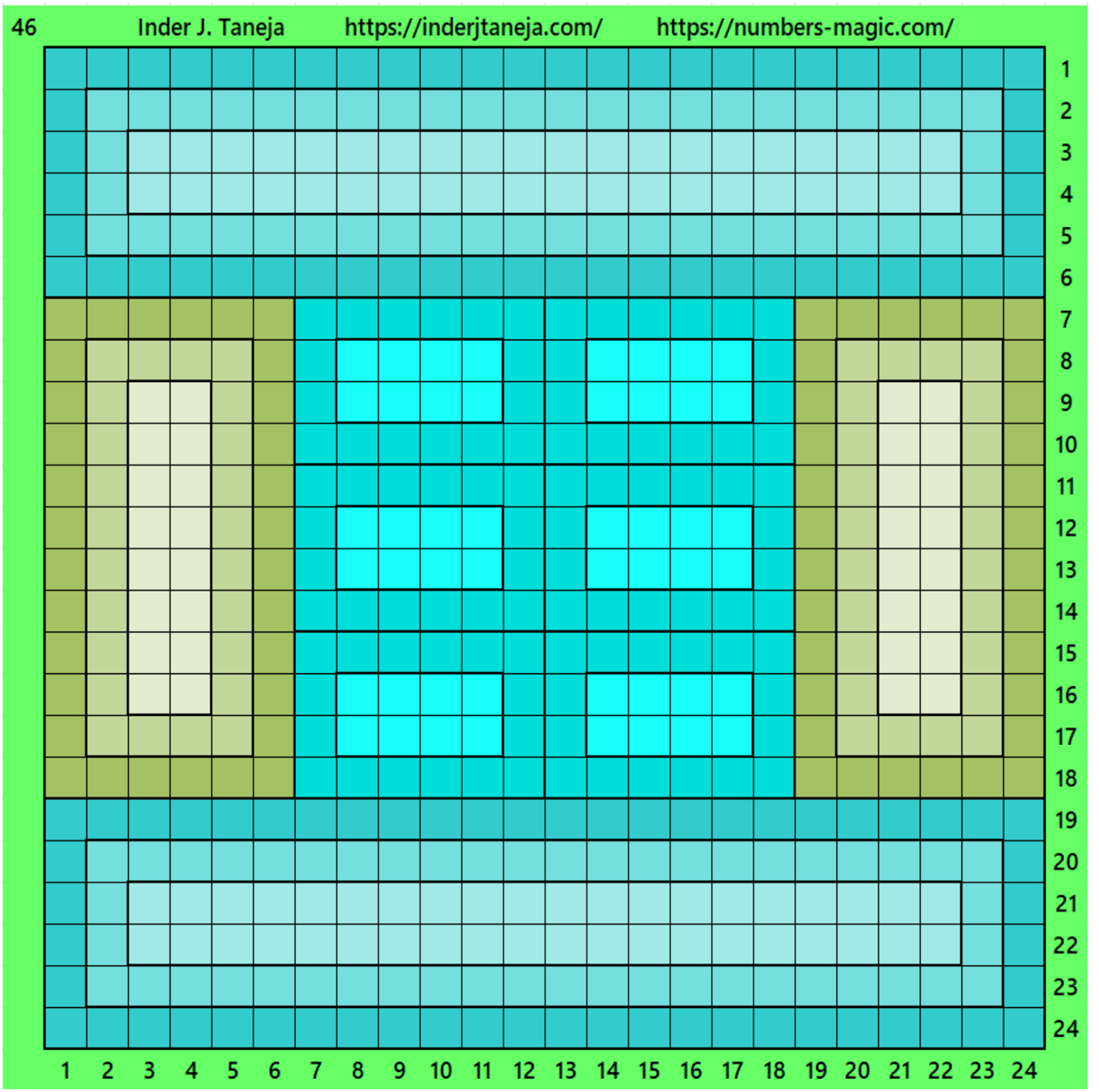
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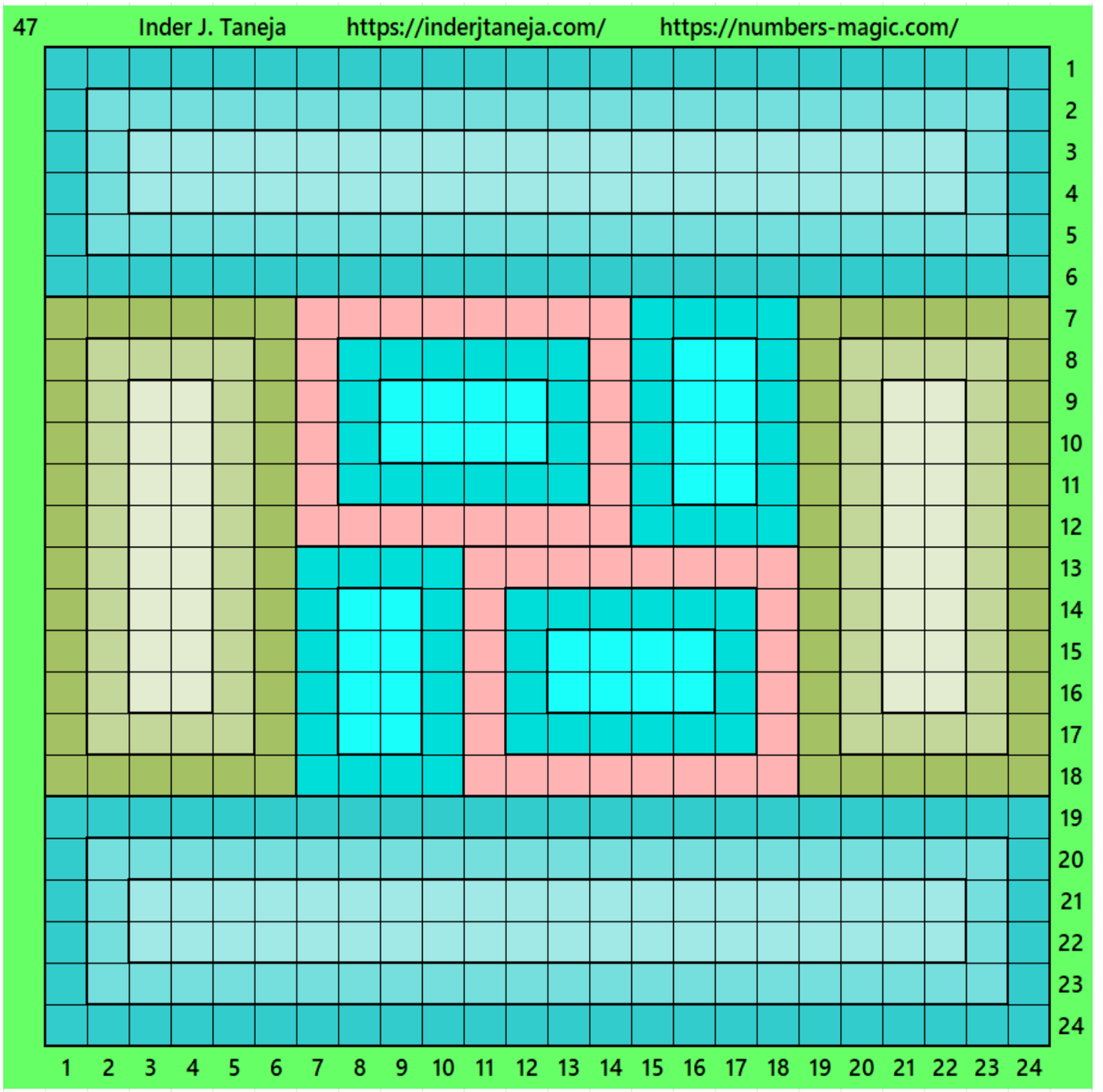
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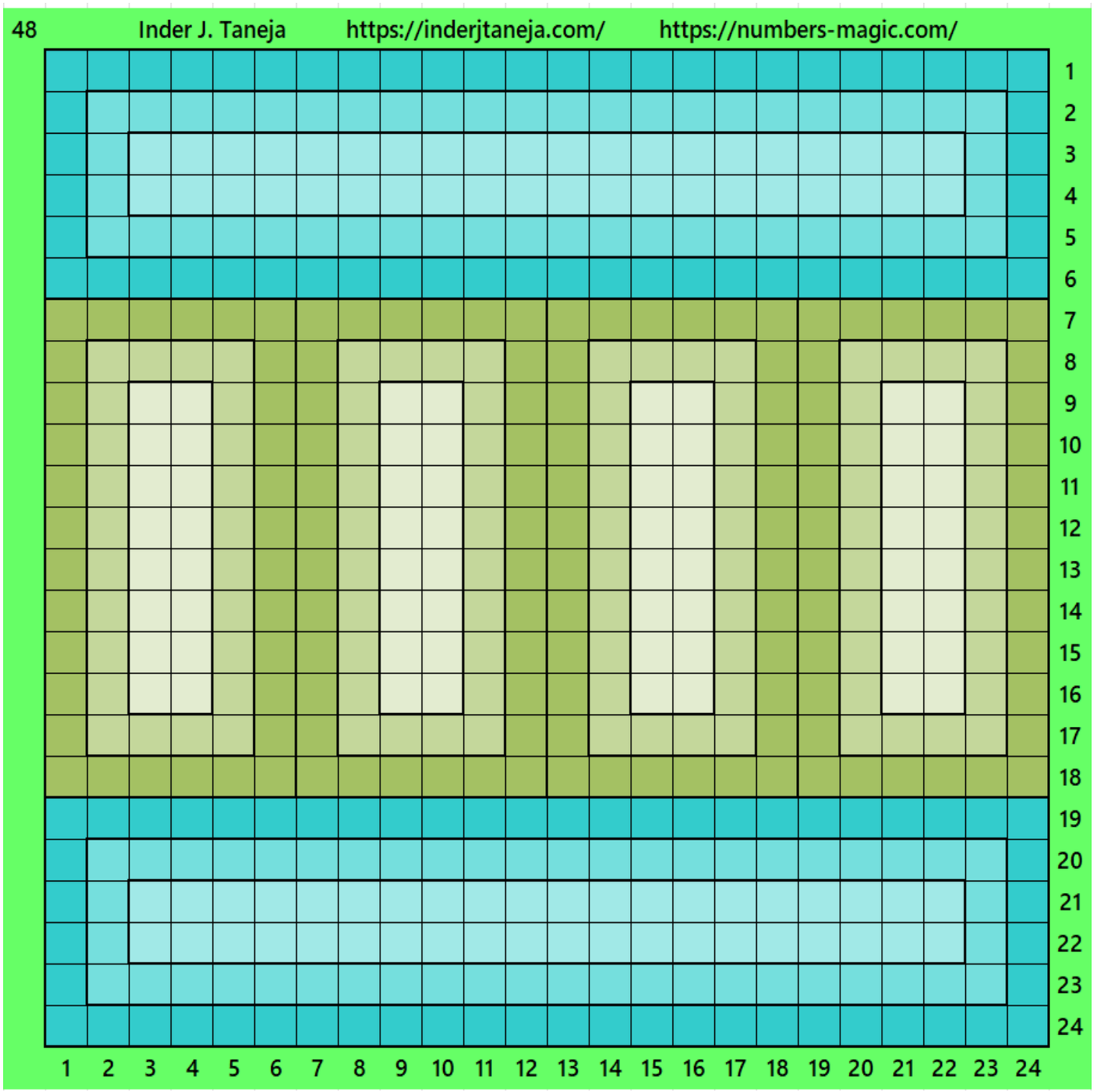
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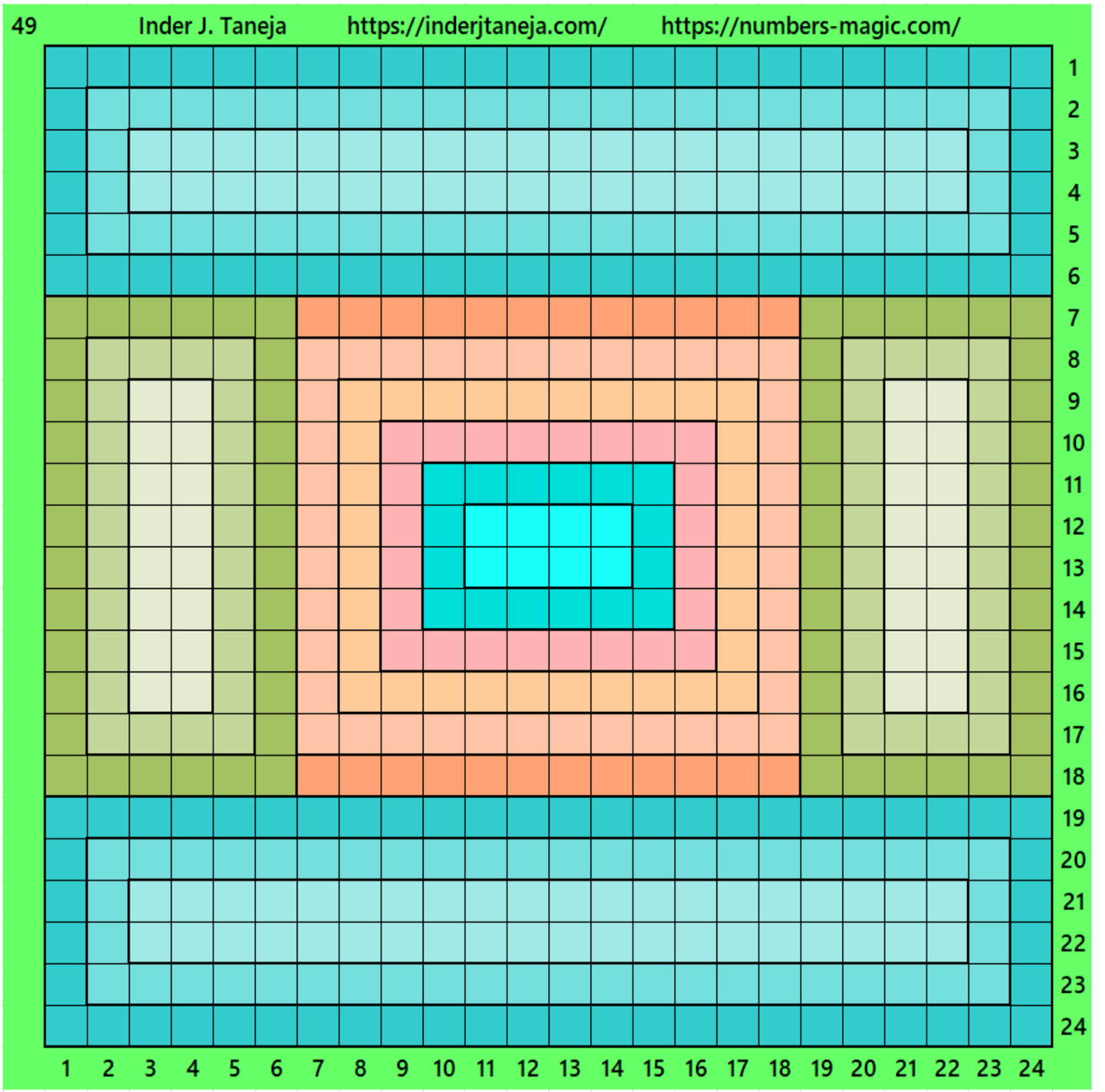
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

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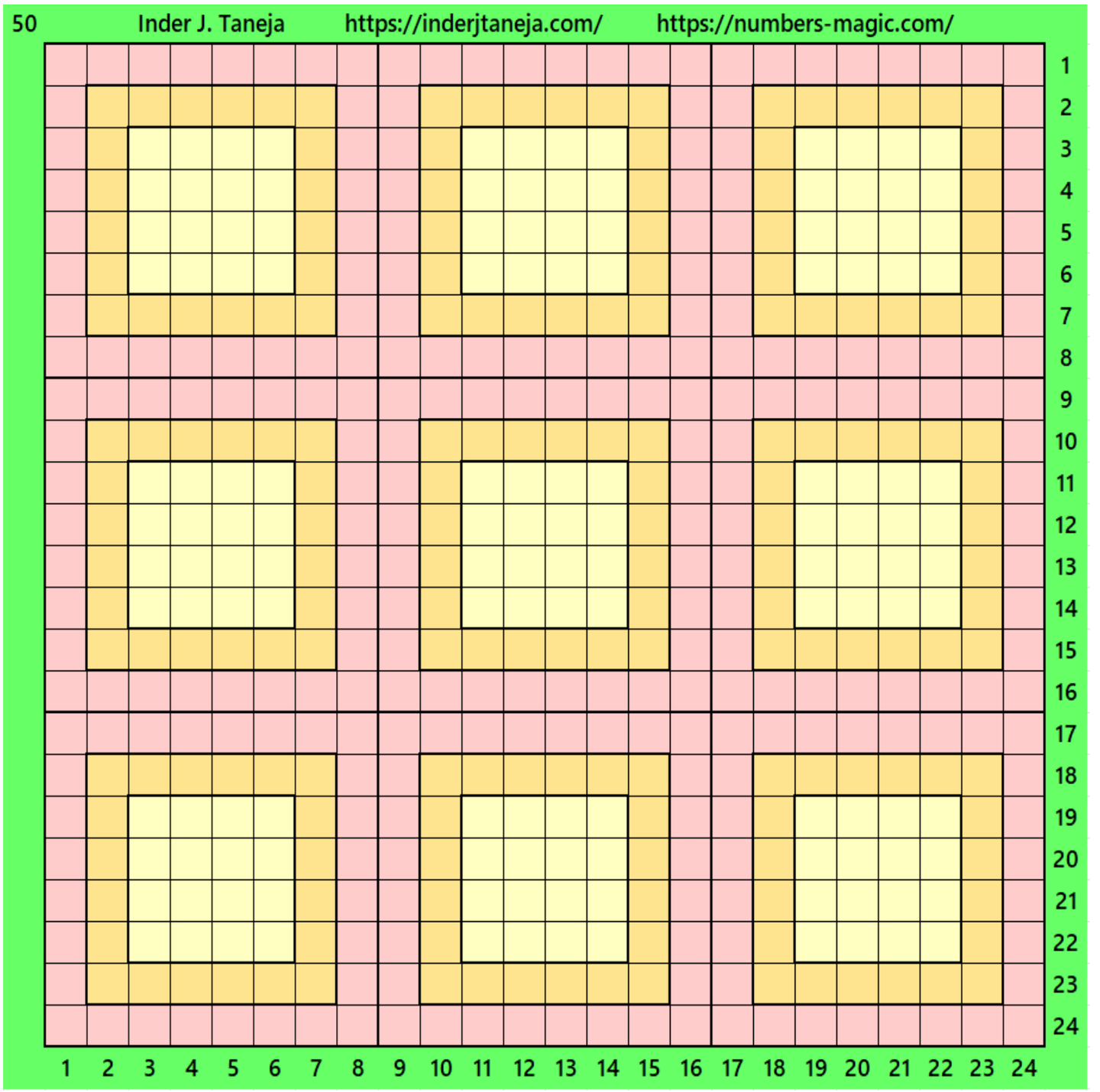
2.7 Blocks of Order 8

We can write magic square of order 24 in with 9 equal sums magic squares of order 8. This gives different type of magic squares of order 24. See below: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https://numbers-magic.com/
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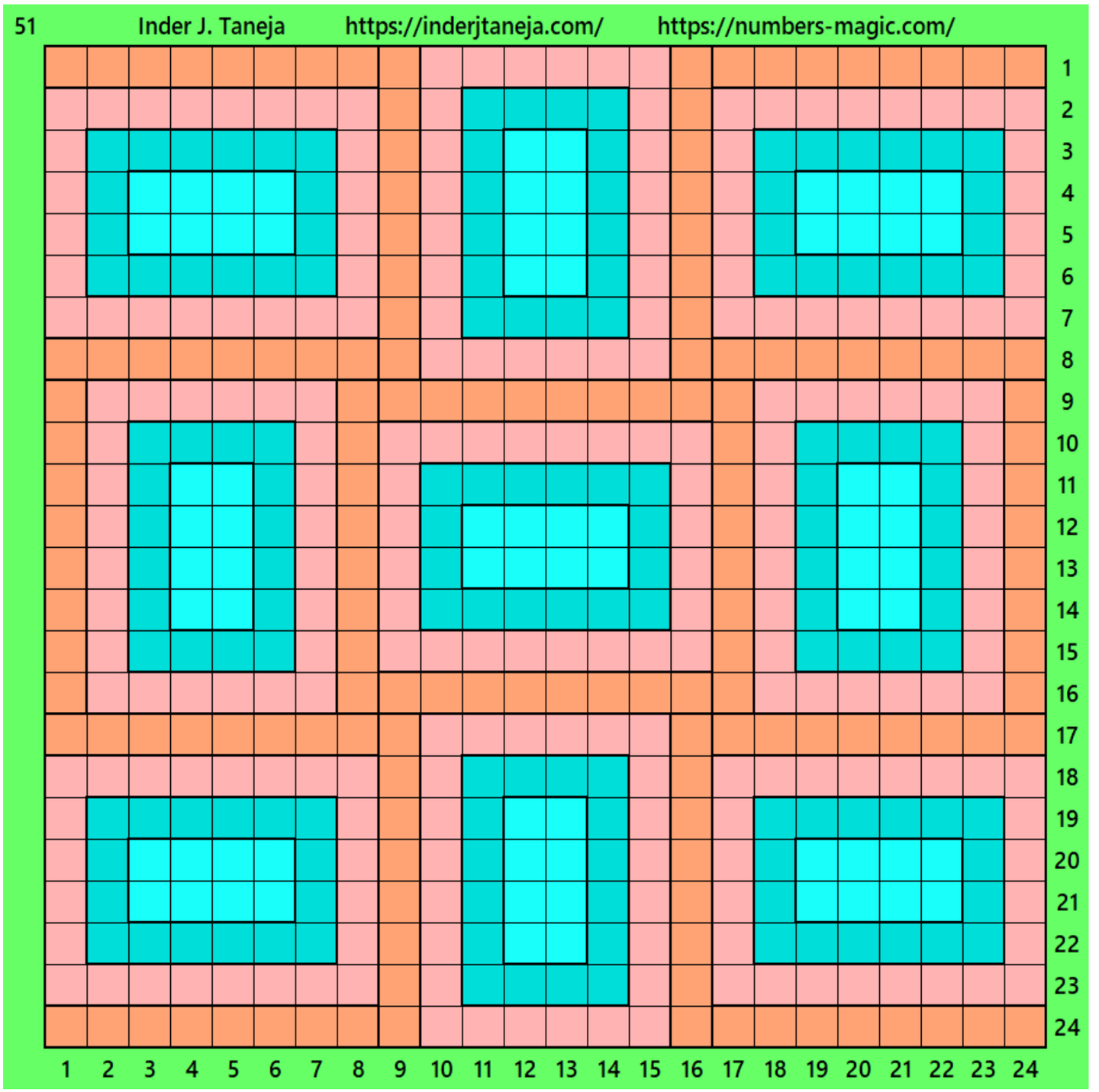
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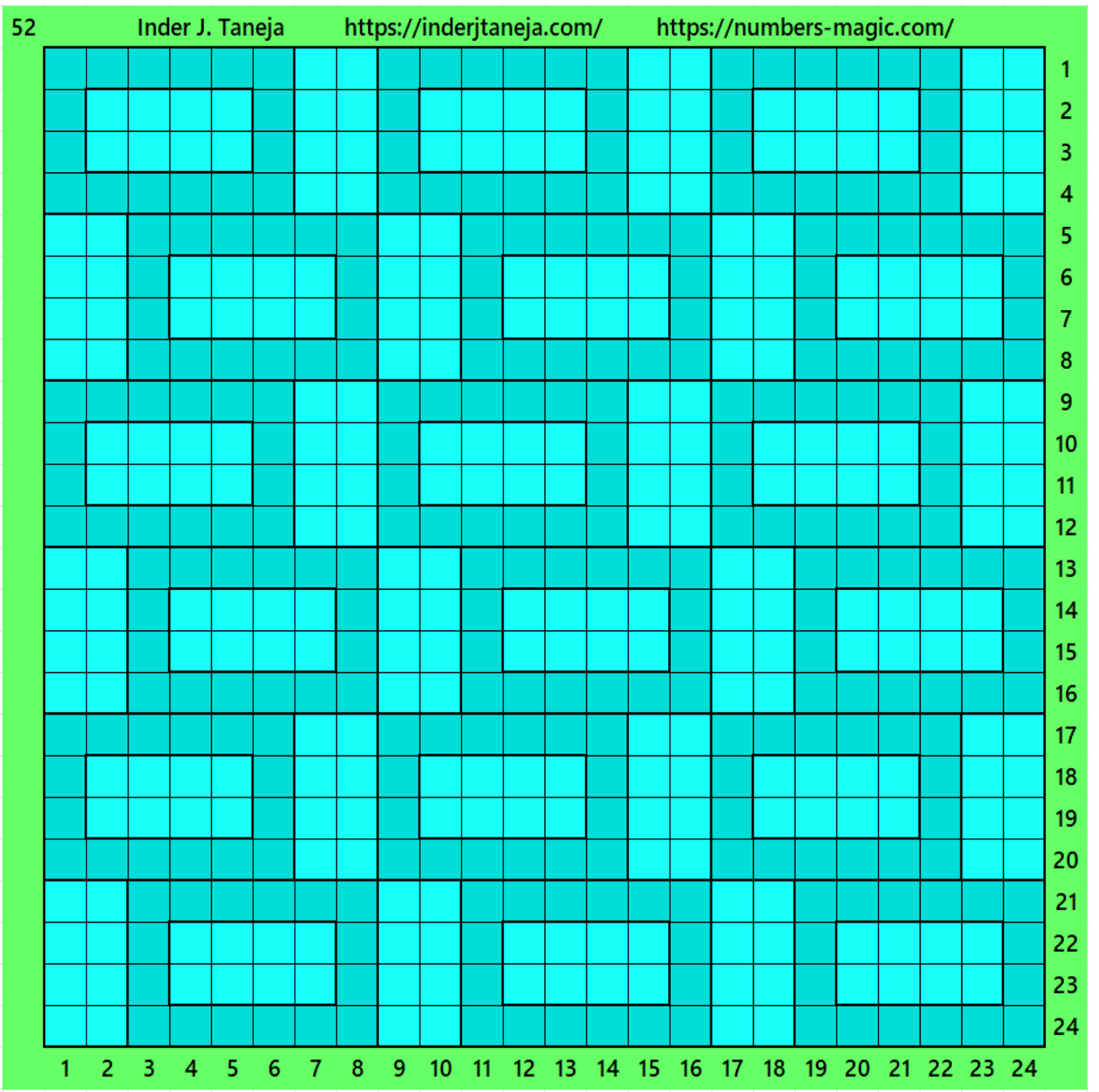
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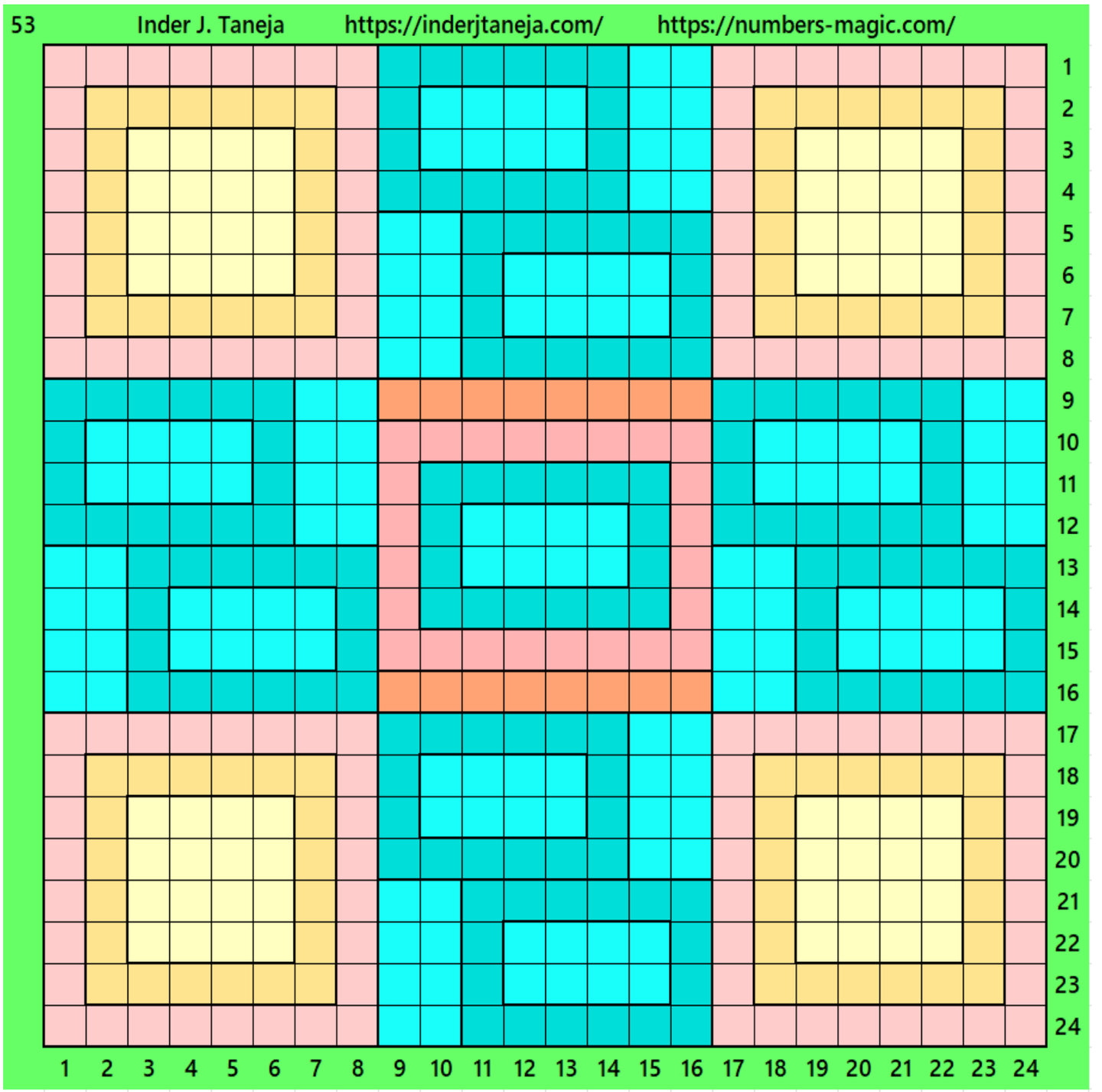
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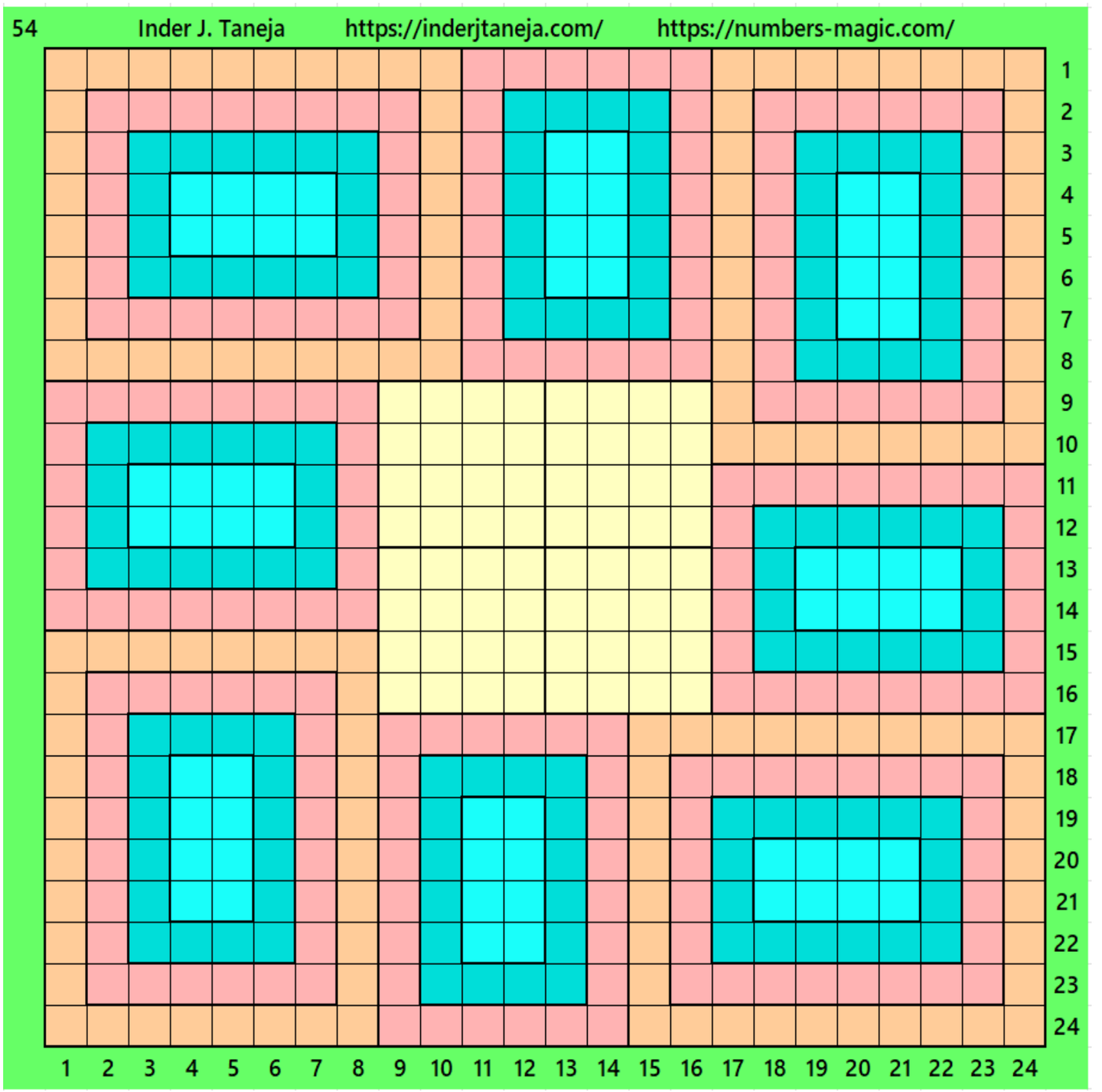
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

2.8 Closed Border of Order 8

Let's consider 4 BMR's of orders 6×8 and 4 of order 8×10 forming a closed border of order 8. Internally we are left with block of order 8. This gives us magic squares of order 24. See below few examples: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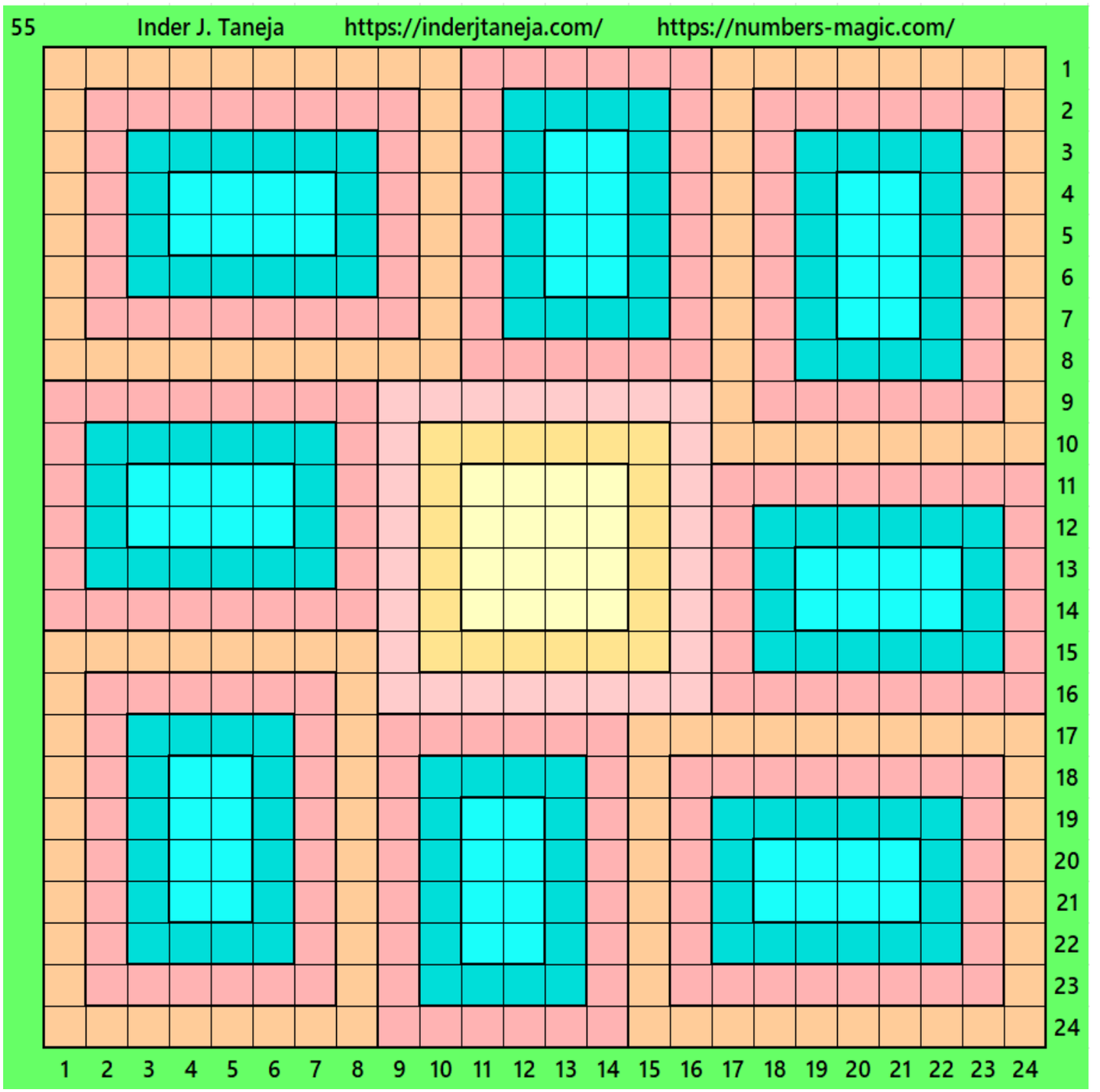
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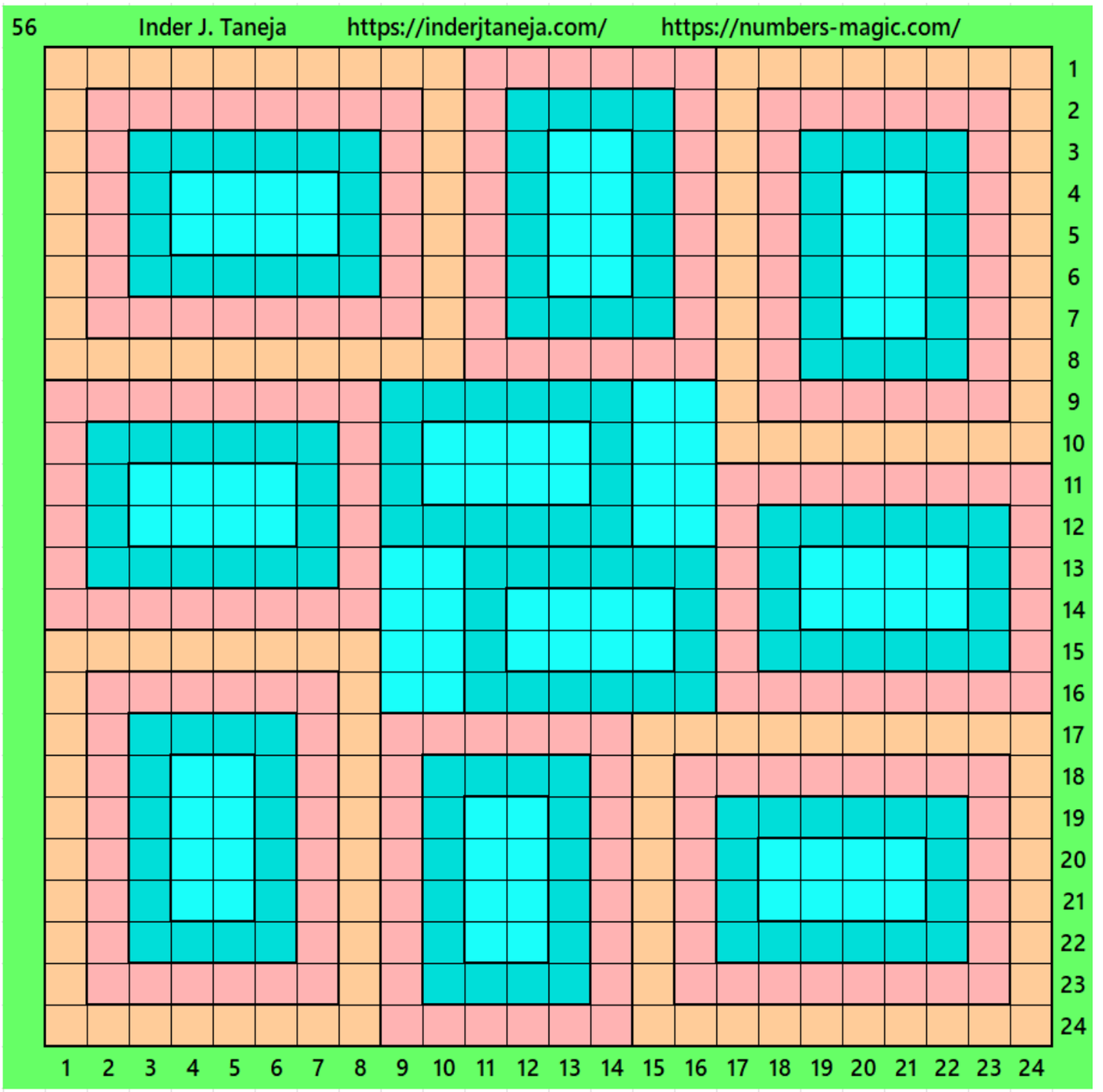
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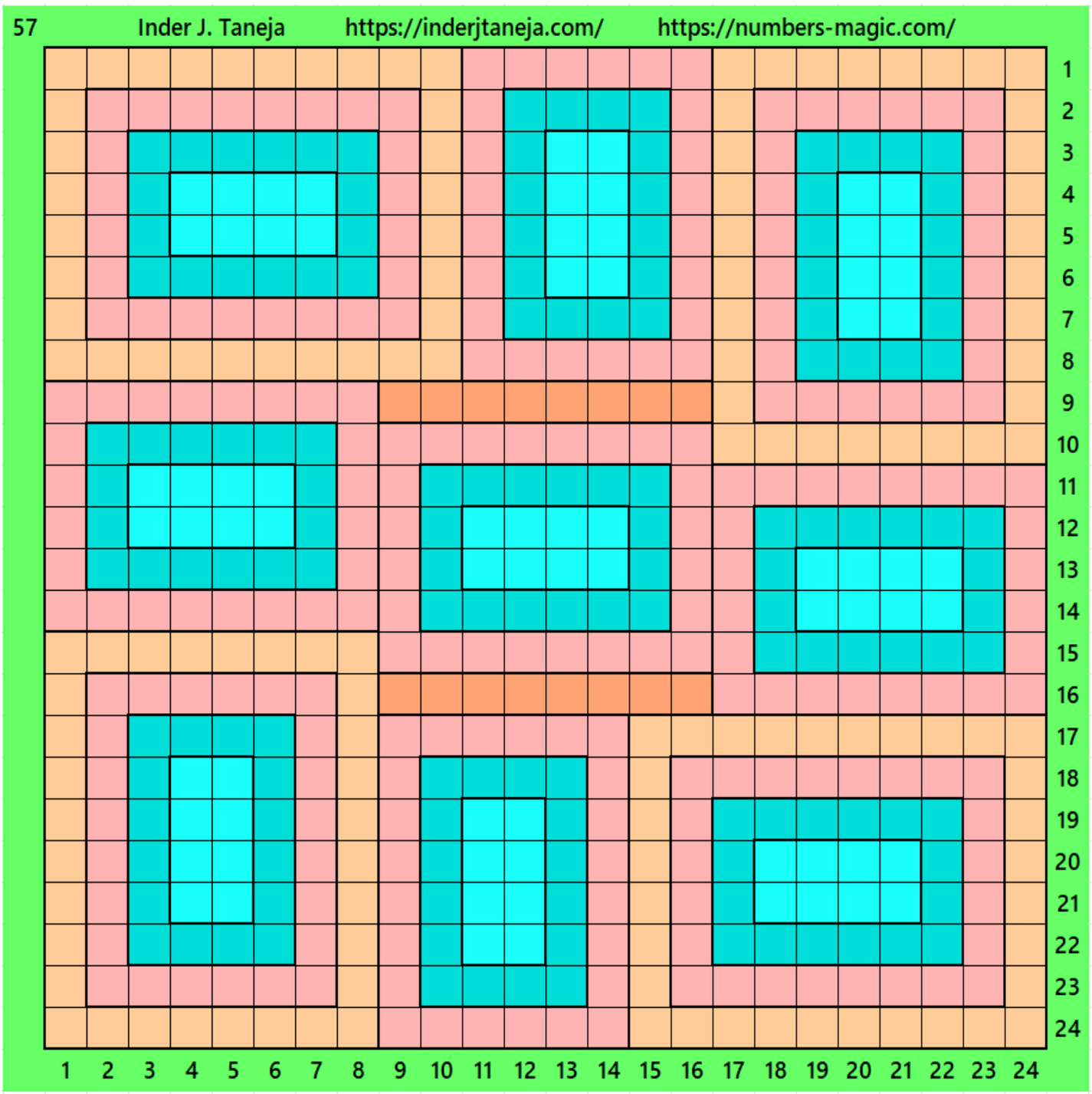
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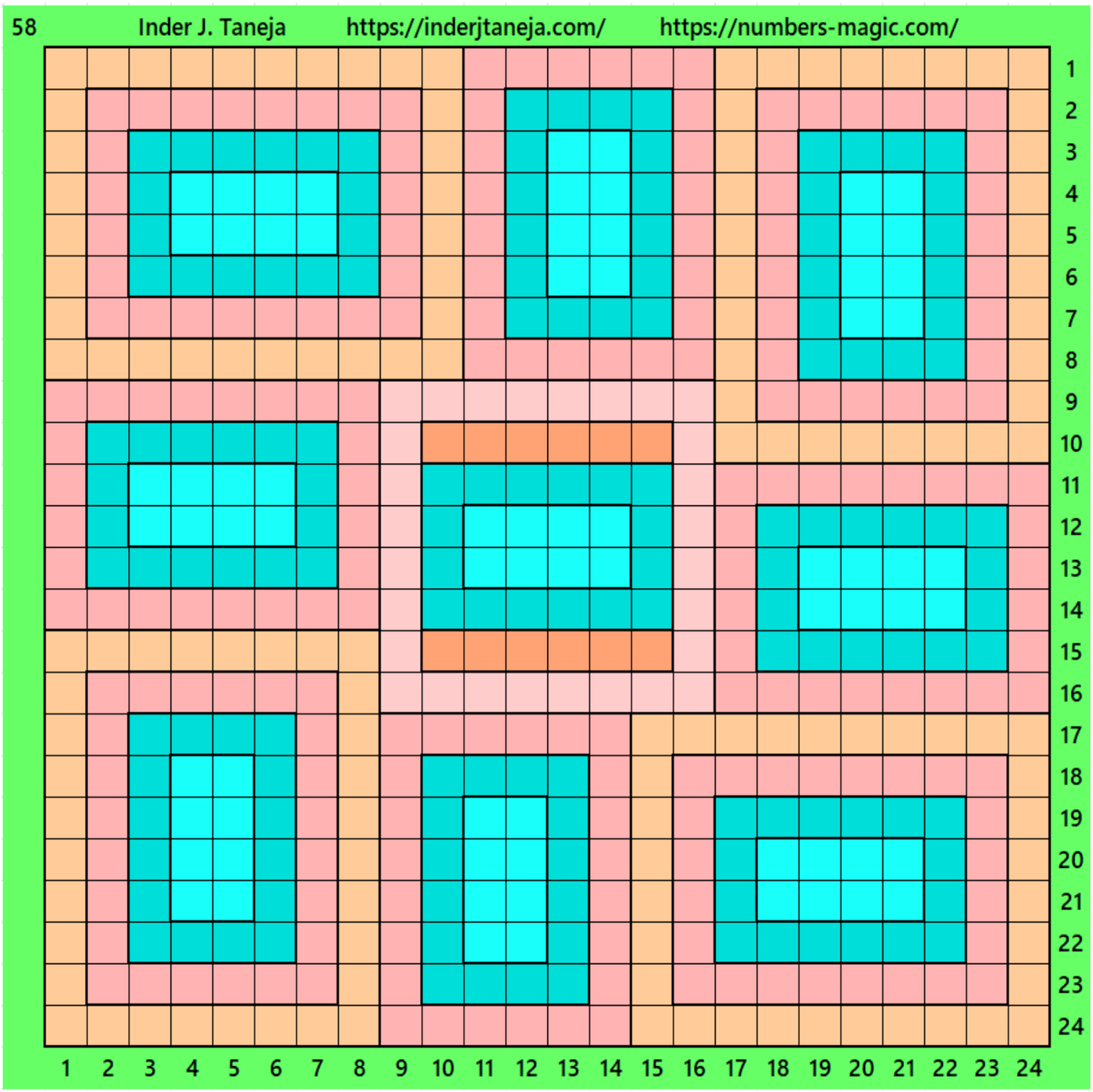
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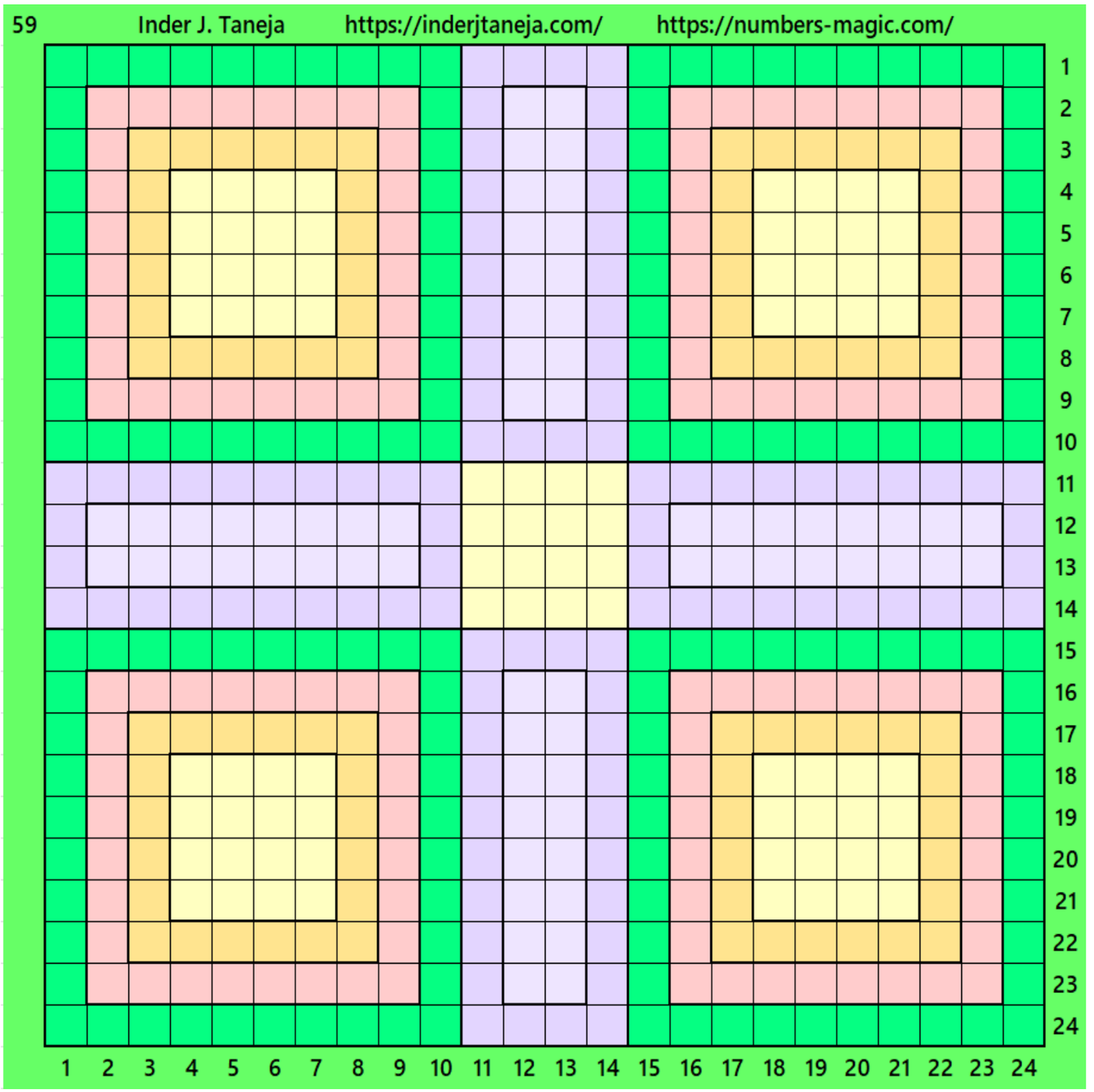
2.9 Cornered Magic Squares of Order 10

Let's consider 4 magic squares of order 10 and 4 BMR's of order 4×10. This gives us an external border of order 10. We are left with internal block of order 4 resulting in a magic square of order 24. See below few examples: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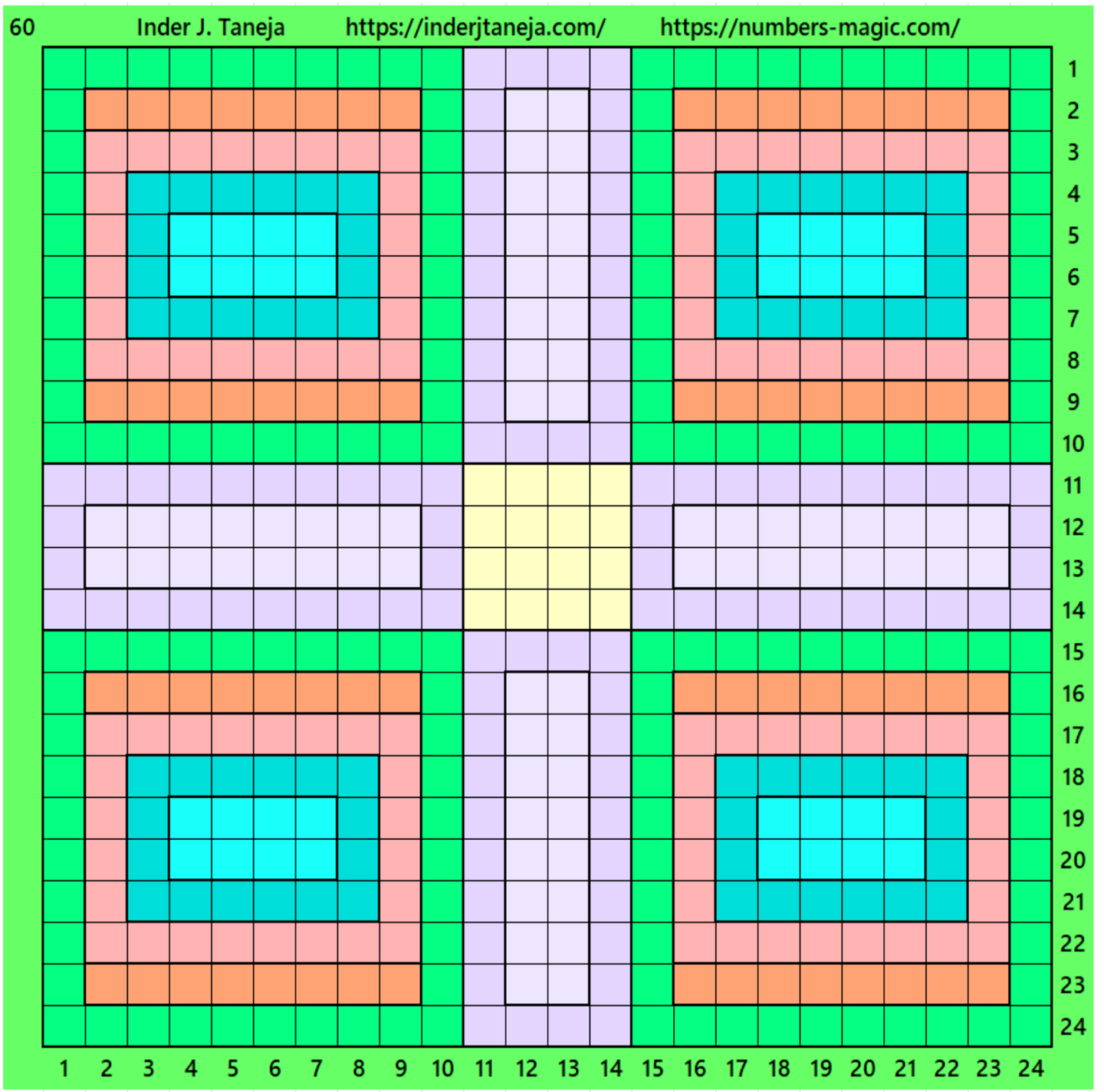
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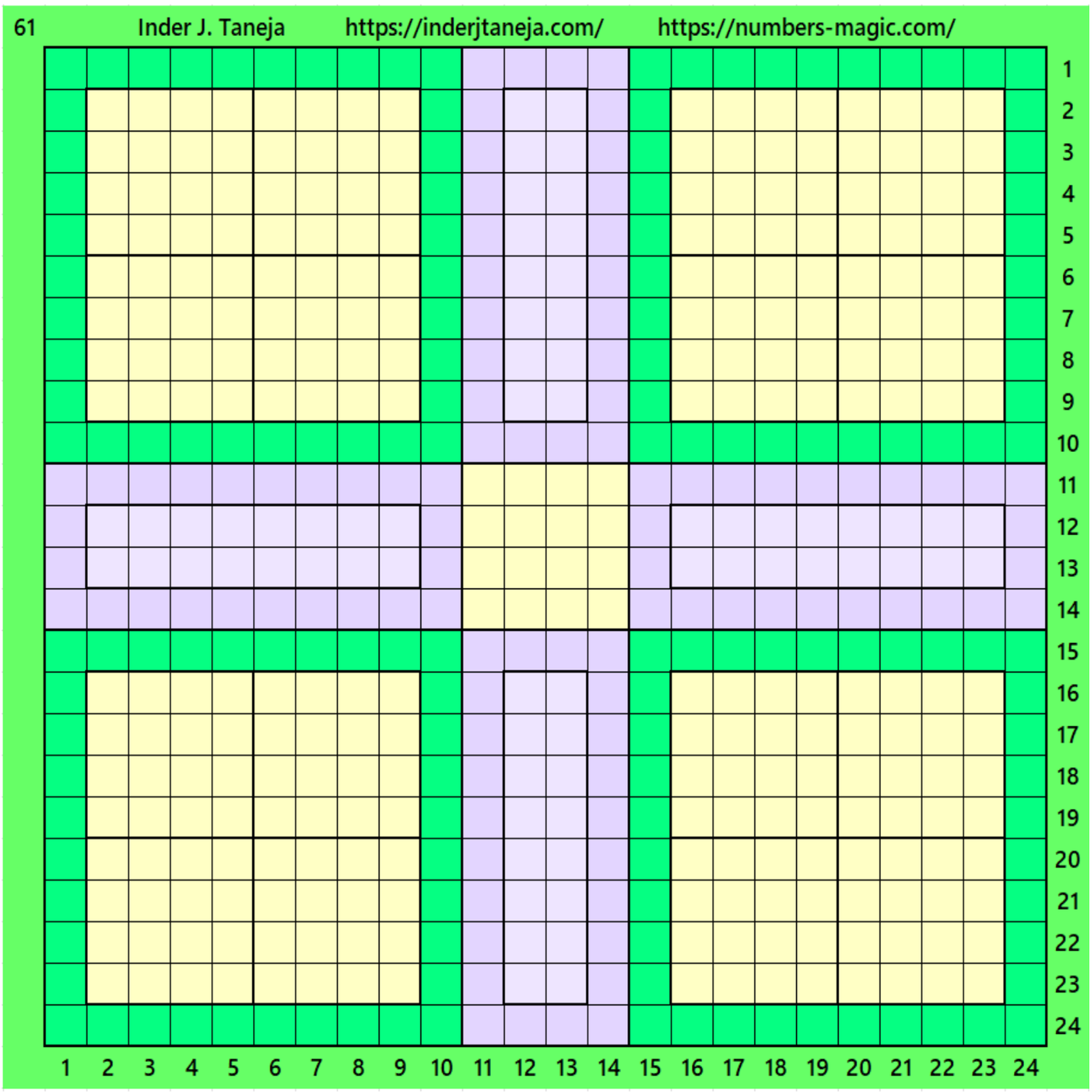
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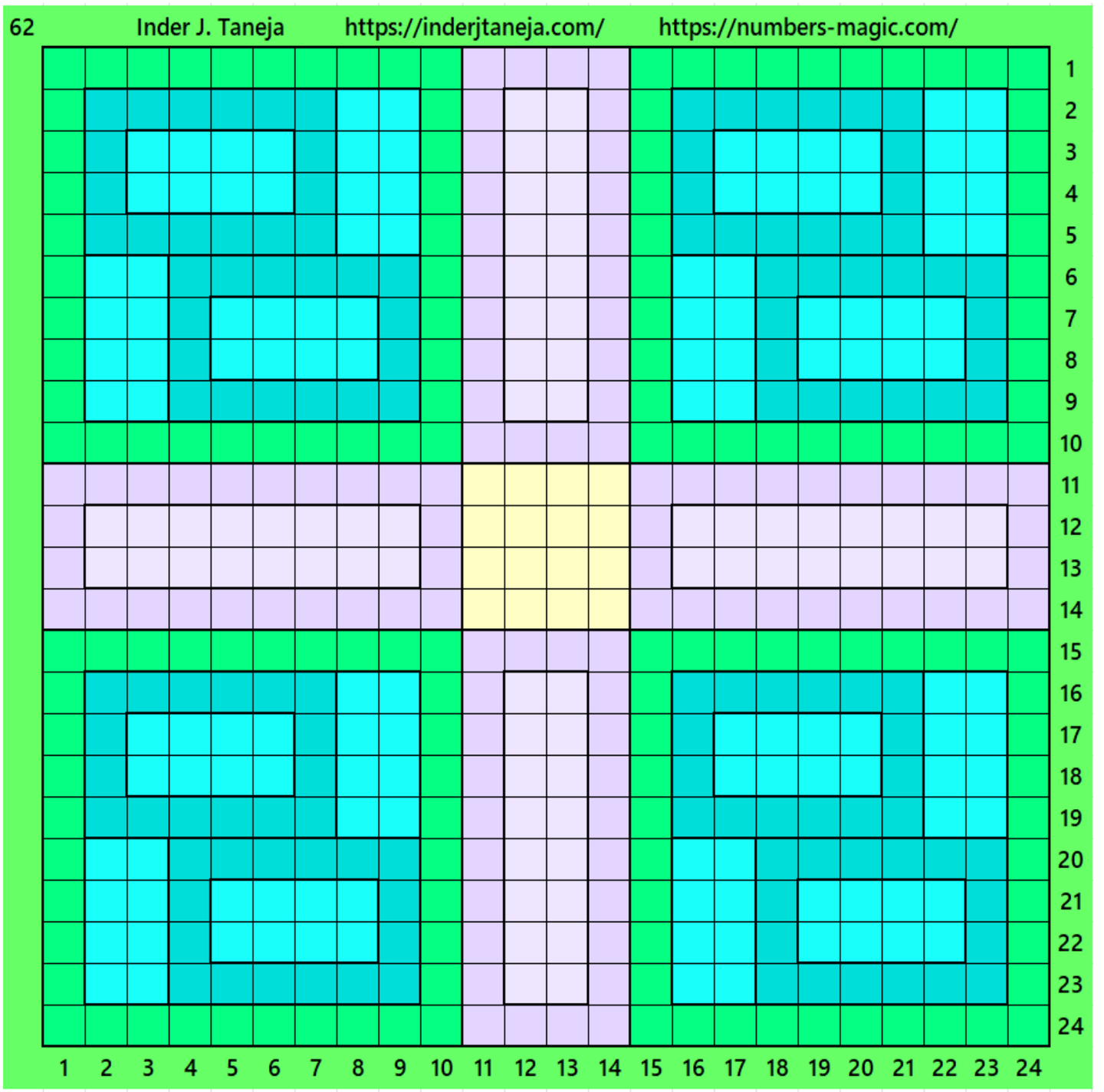
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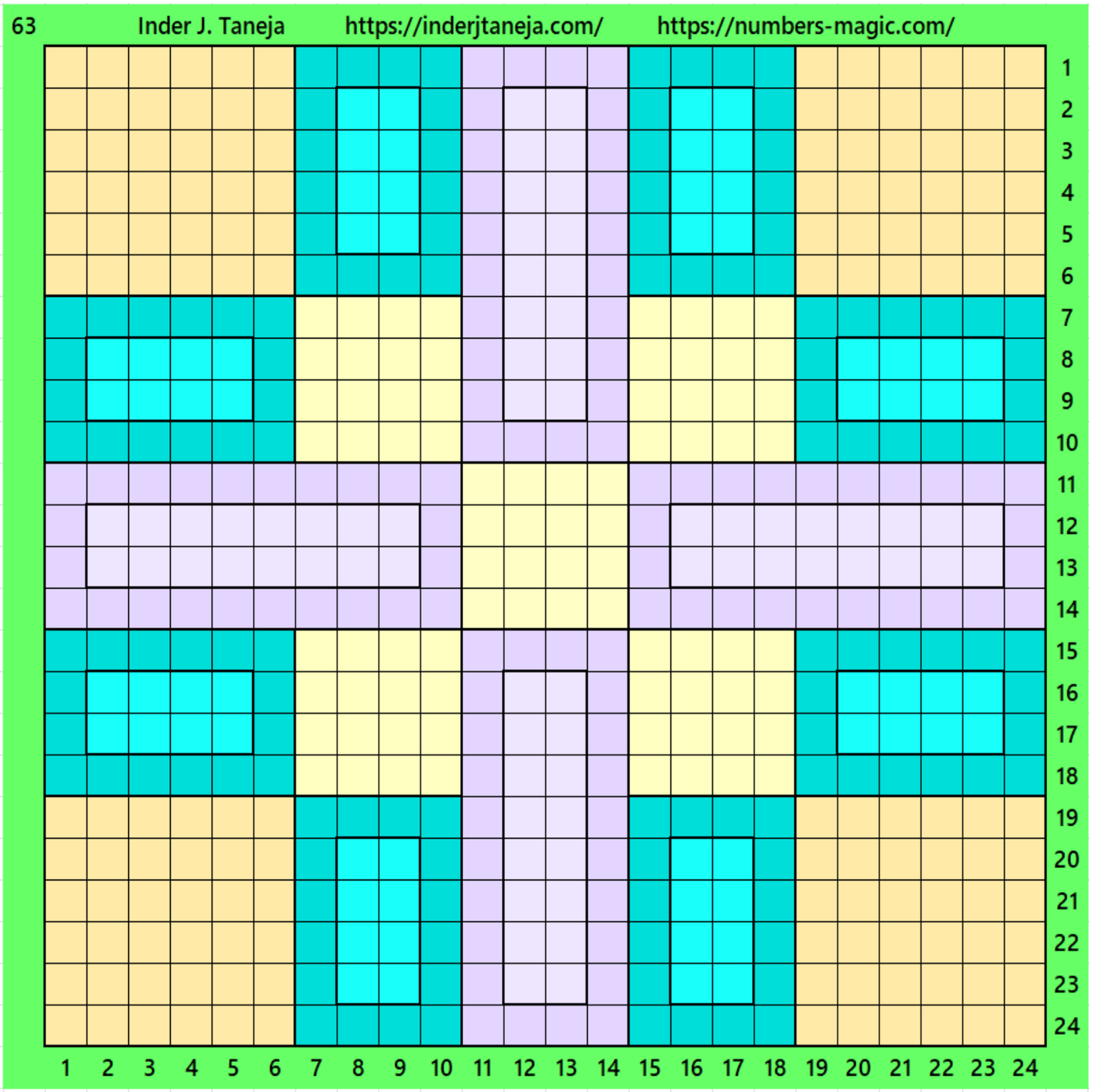
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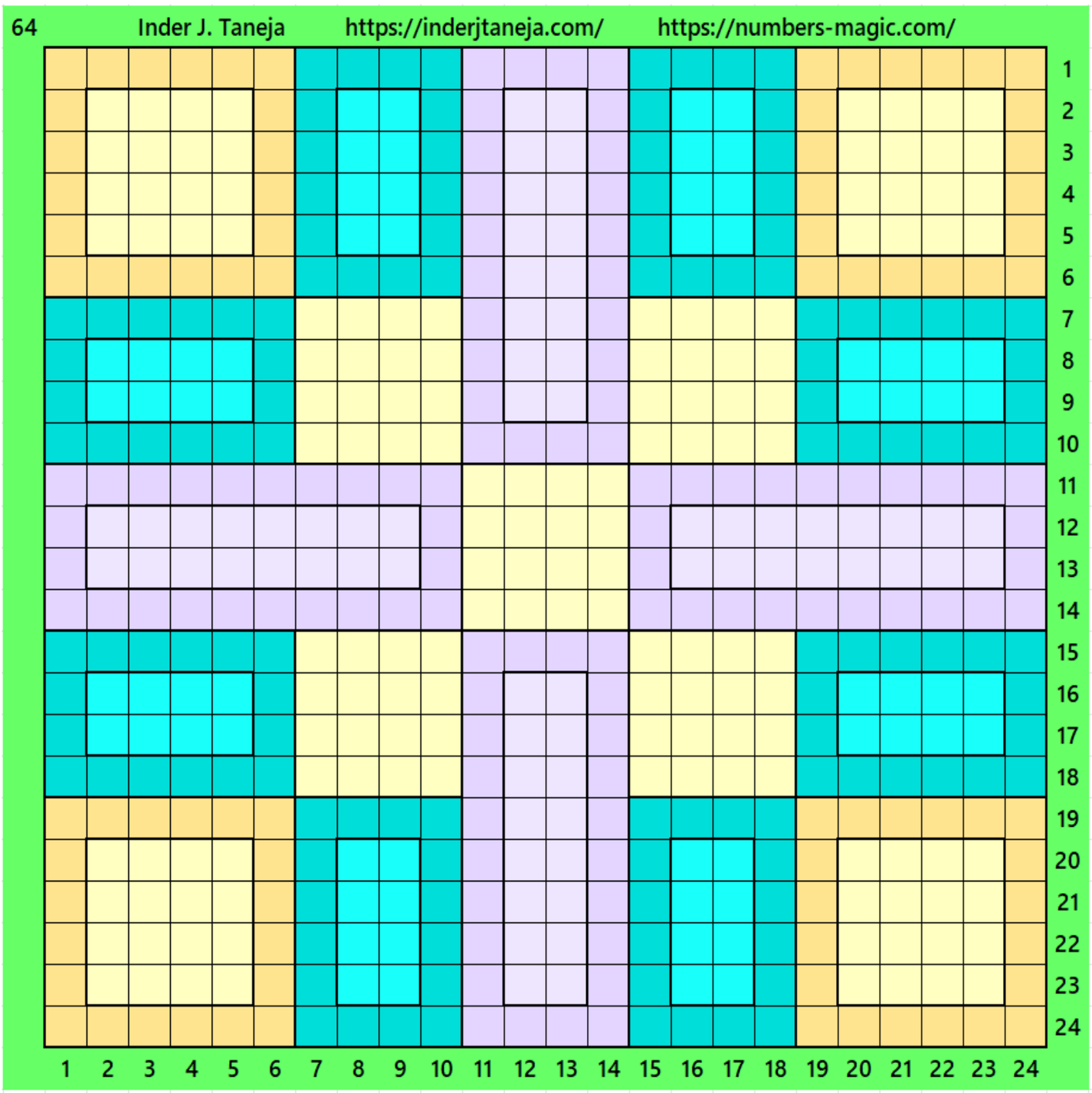
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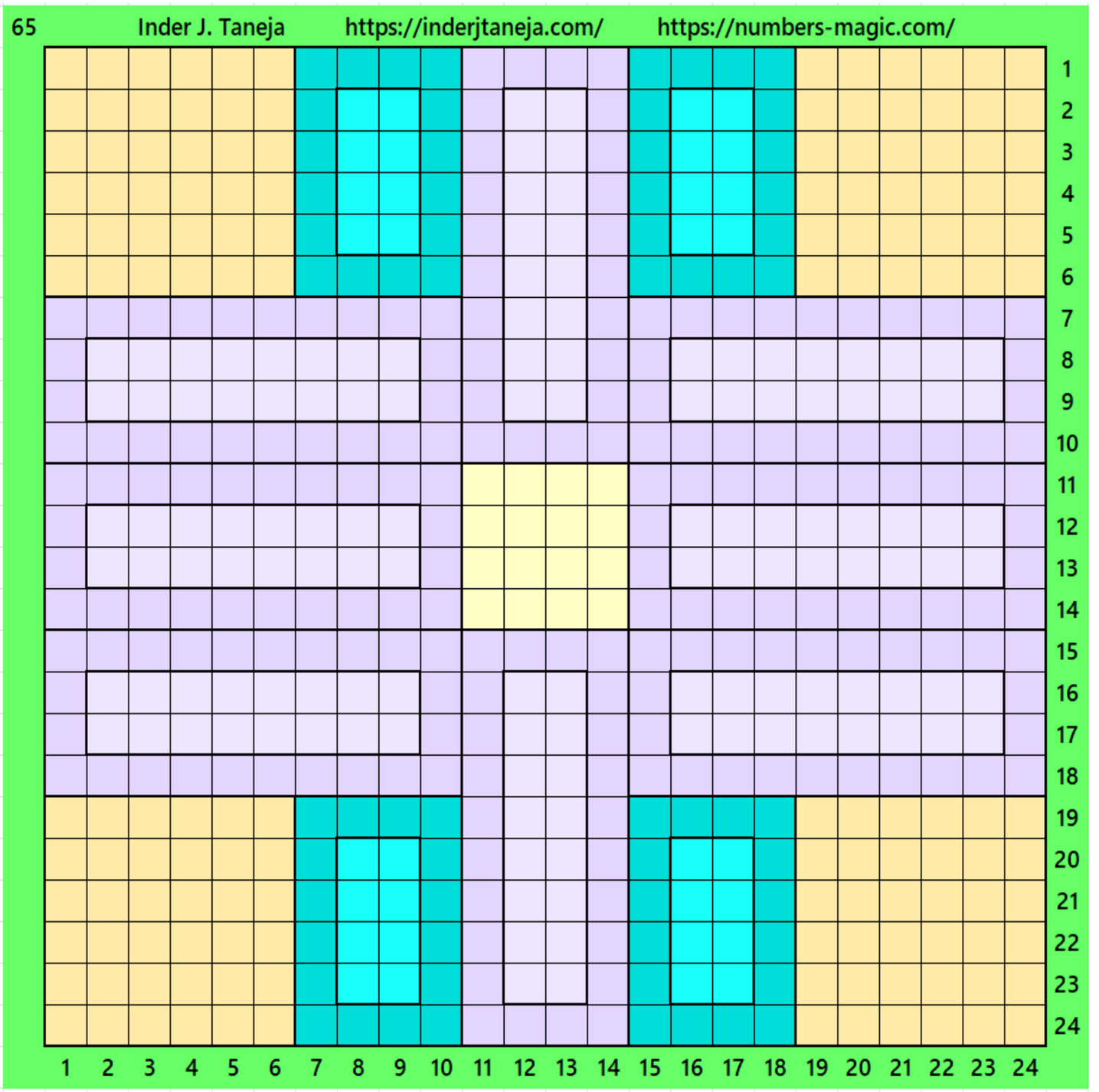
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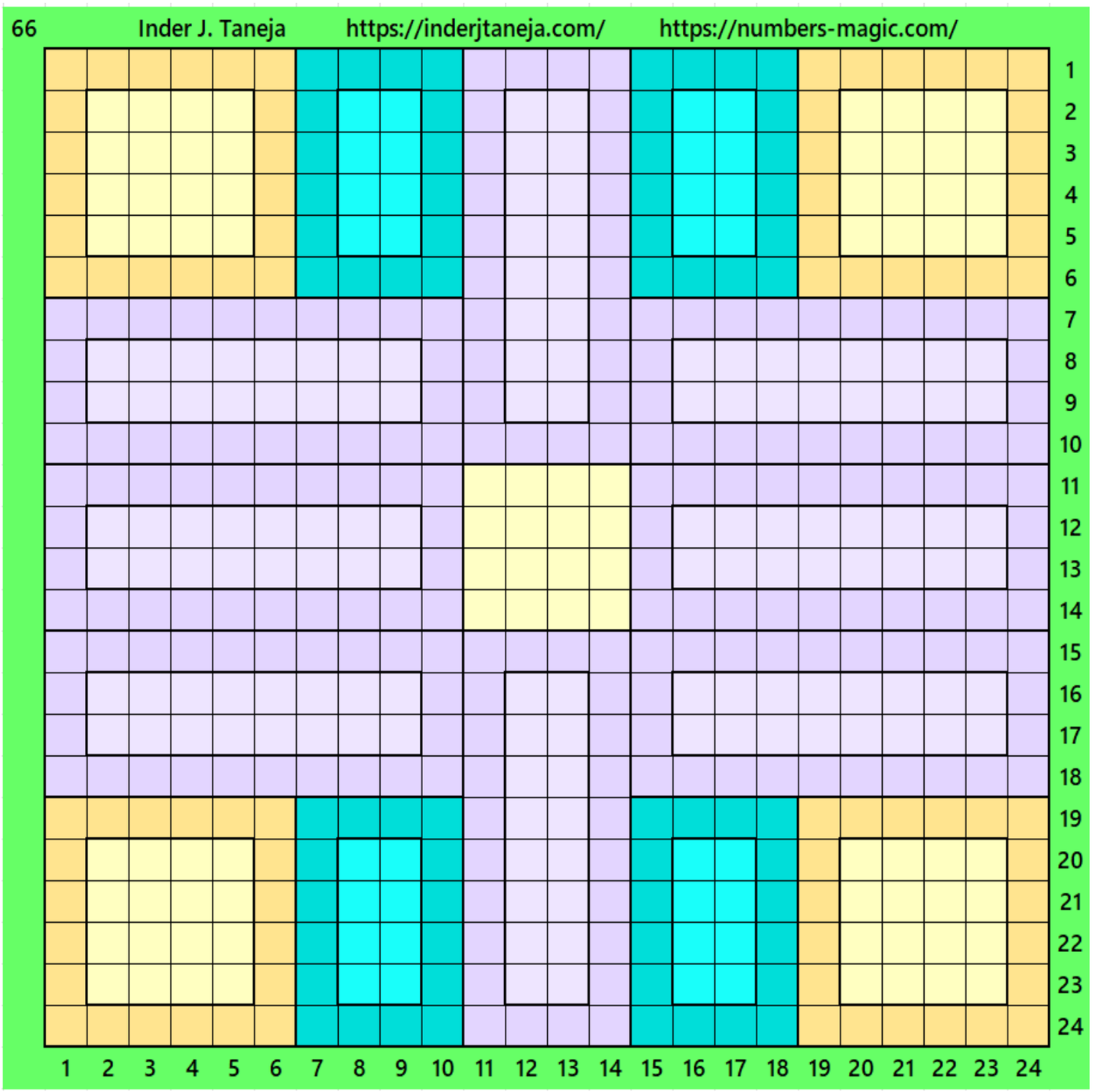
66
Inder J. Taneja
https://inderjtaneja.com/
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

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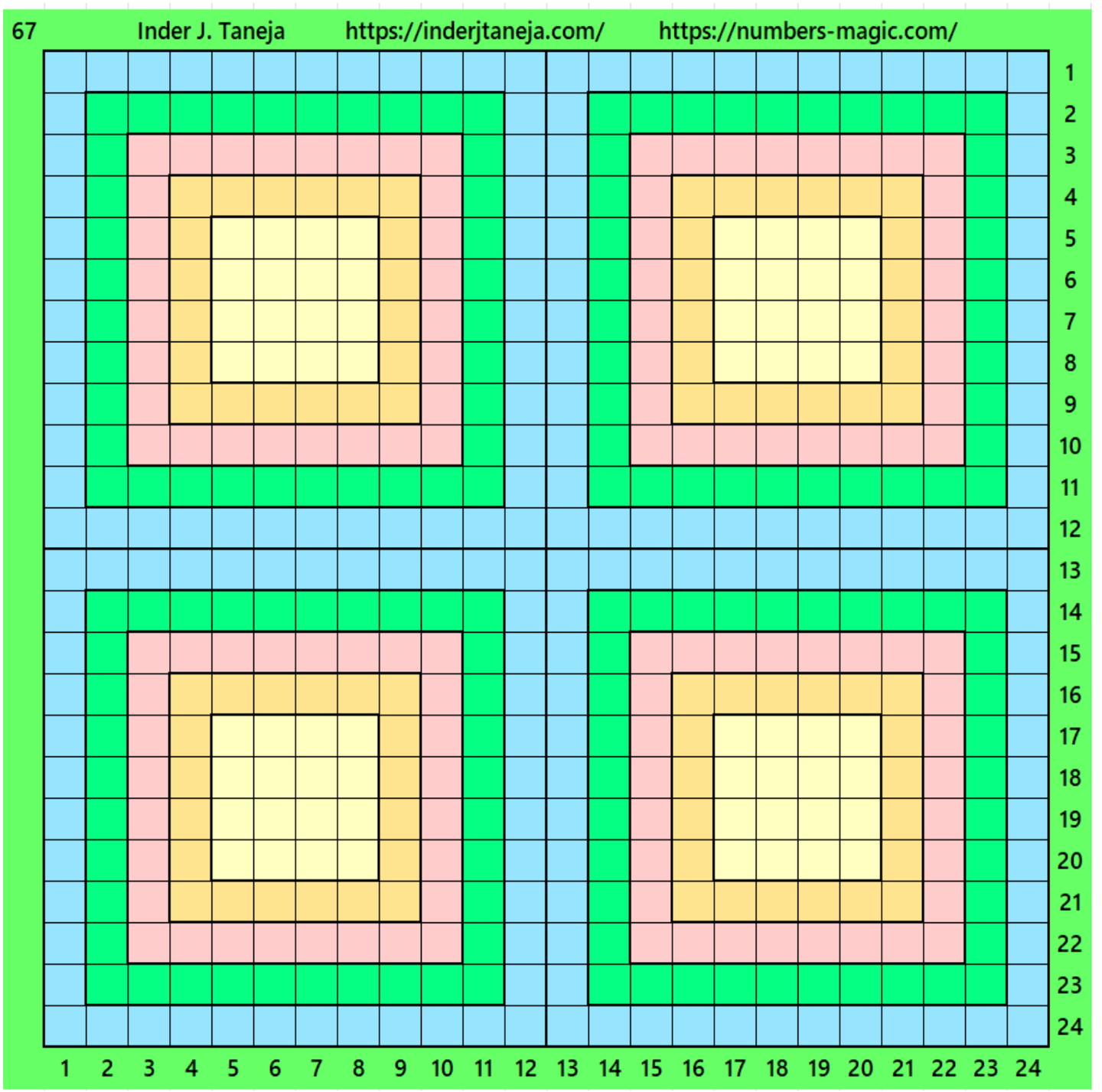
2.10 Blocks of Order 12

We can write magic square of order 24 as four equal sums magic squares of order 12. See below few examples: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https://inderjtaneja.com/
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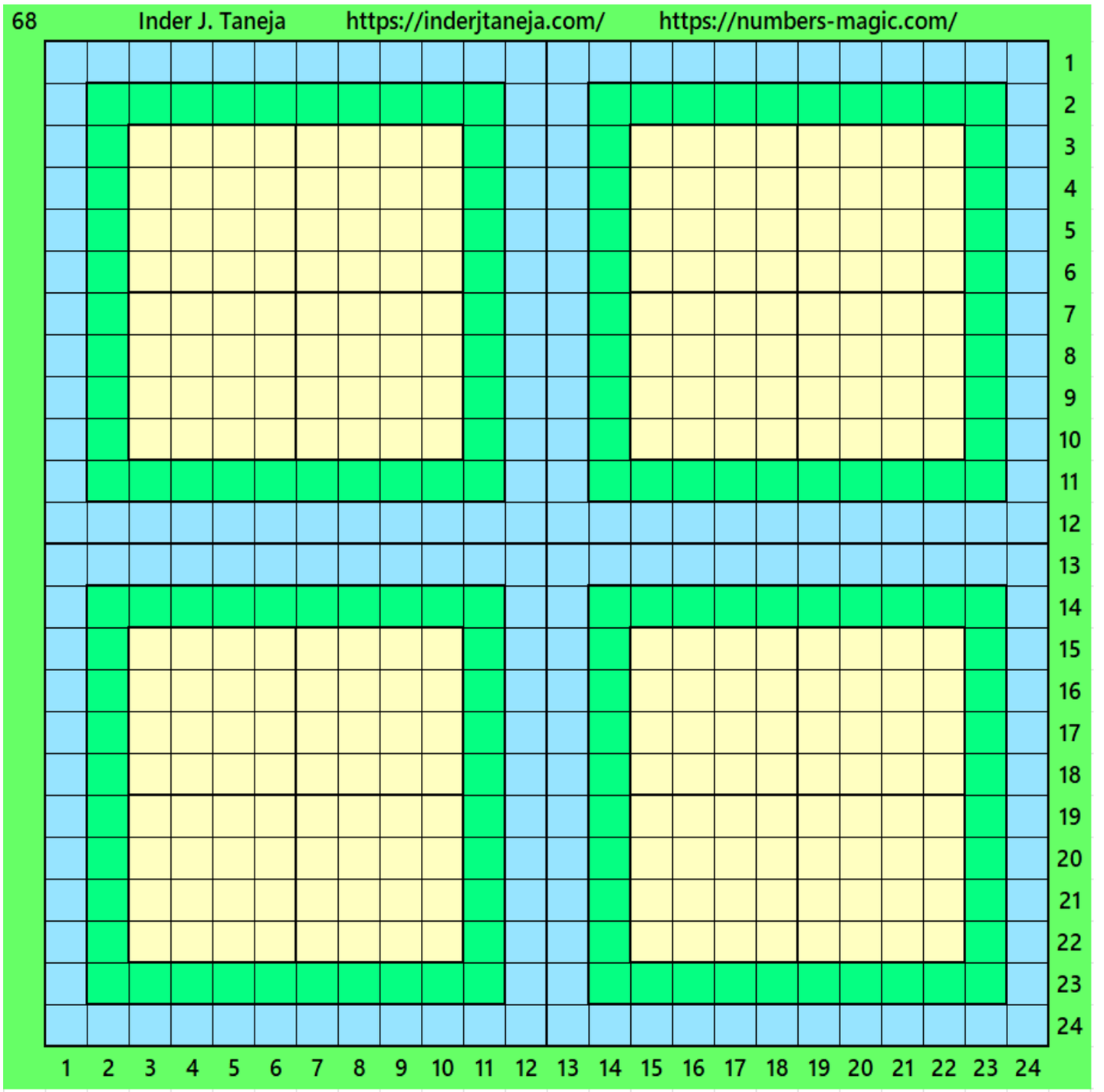
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


68
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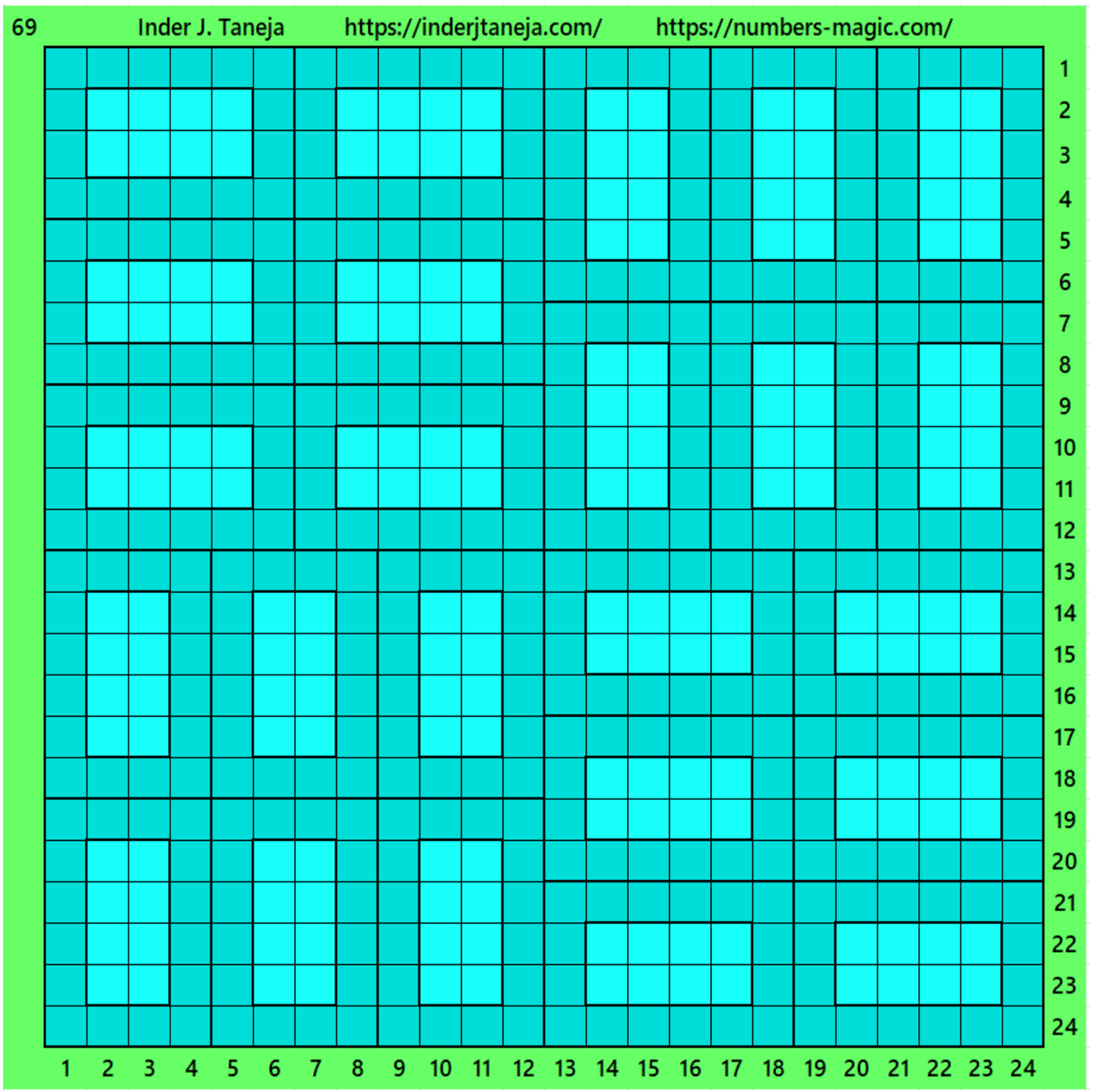
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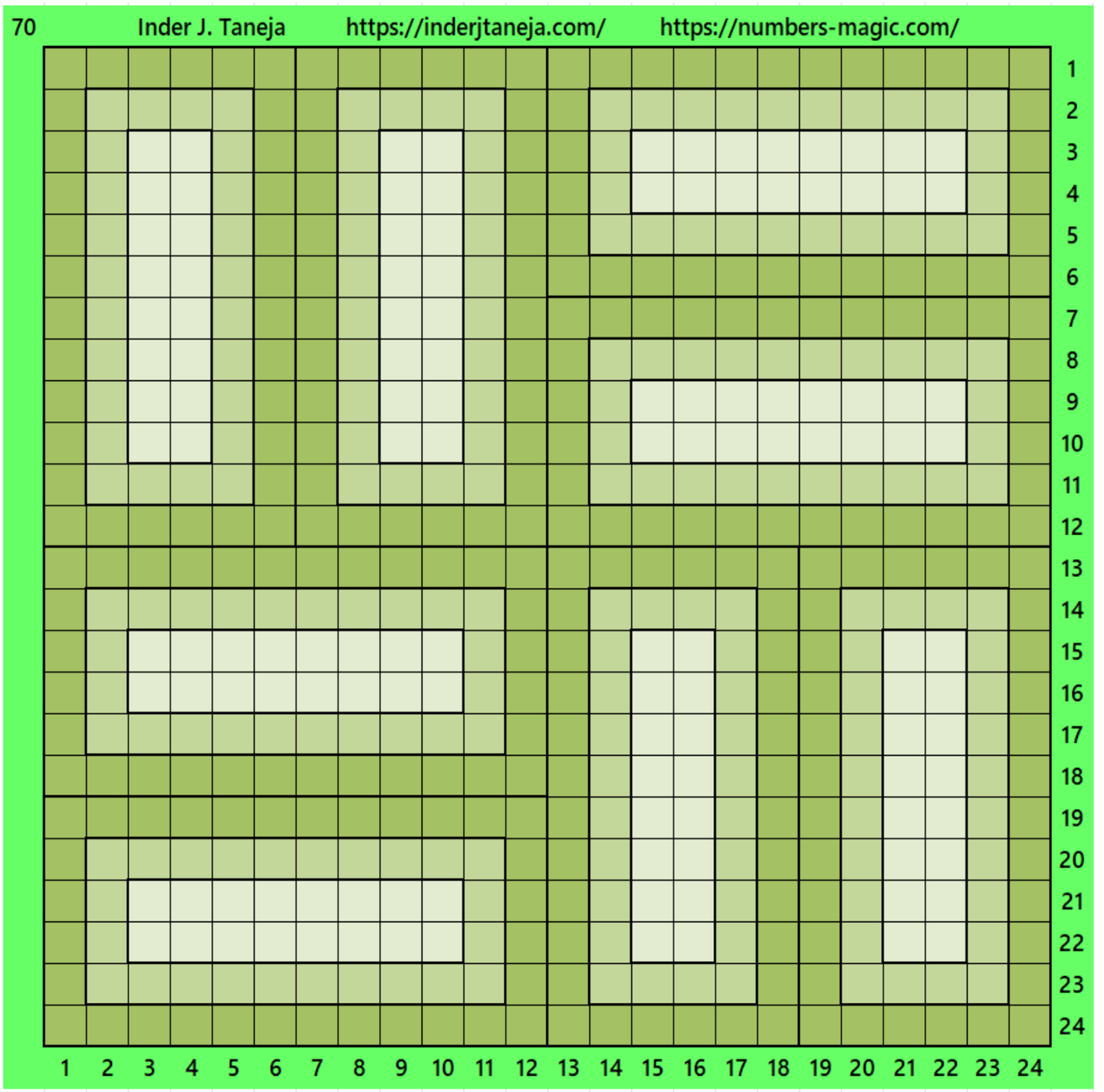
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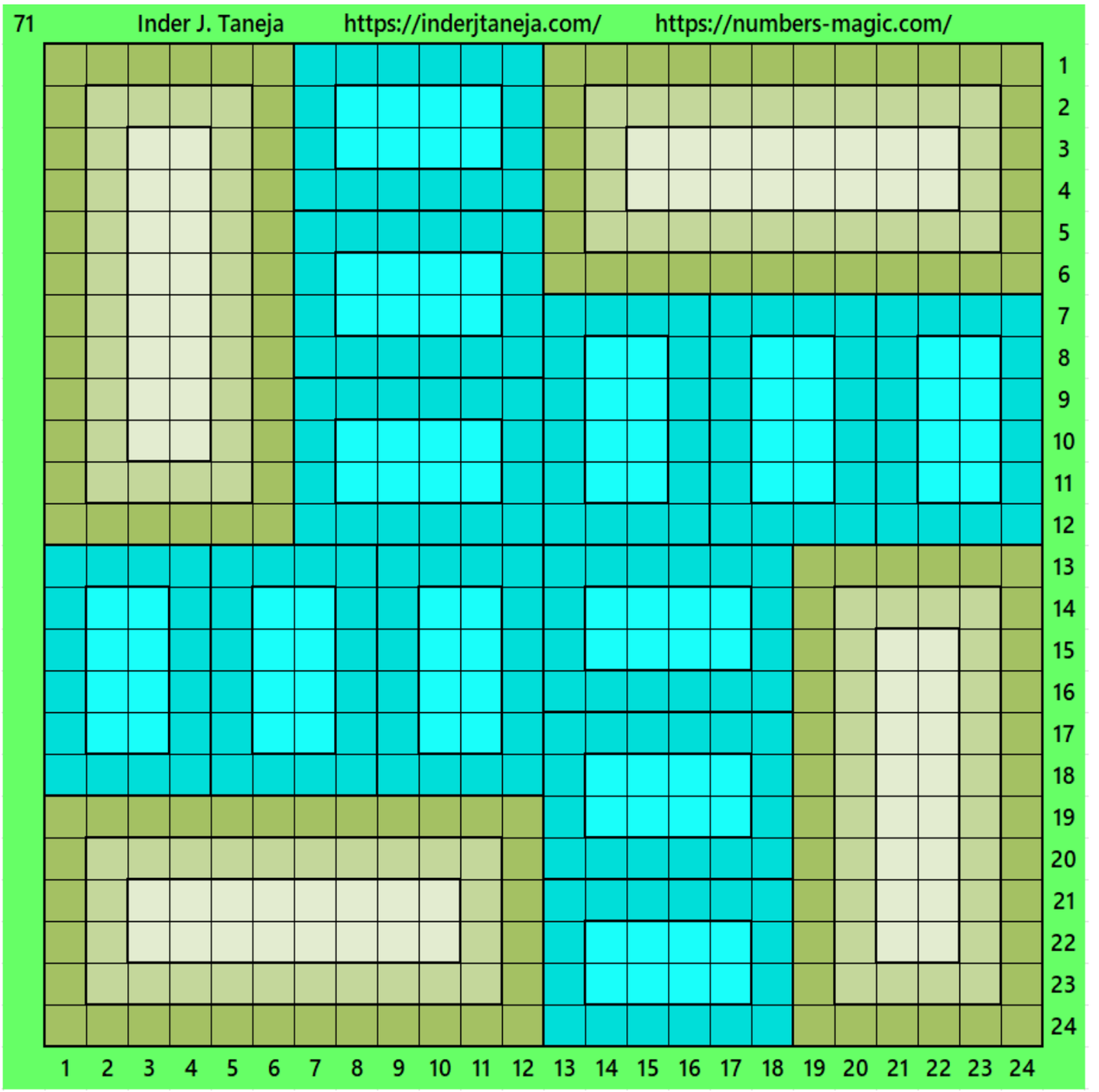
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https://inderjtaneja.com/
https://numbers-magic.com/
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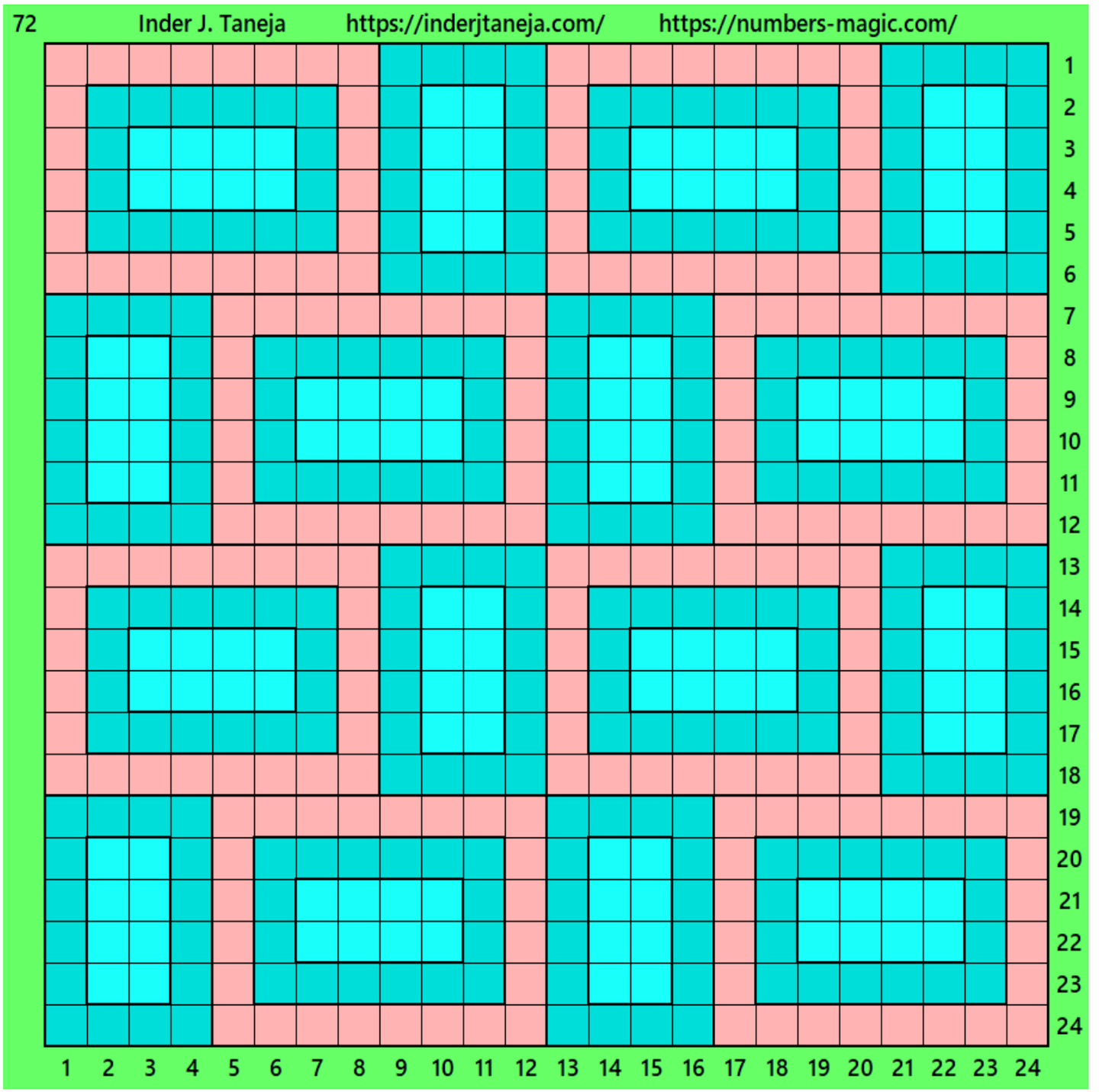
72
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https://inderjtaneja.com/
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

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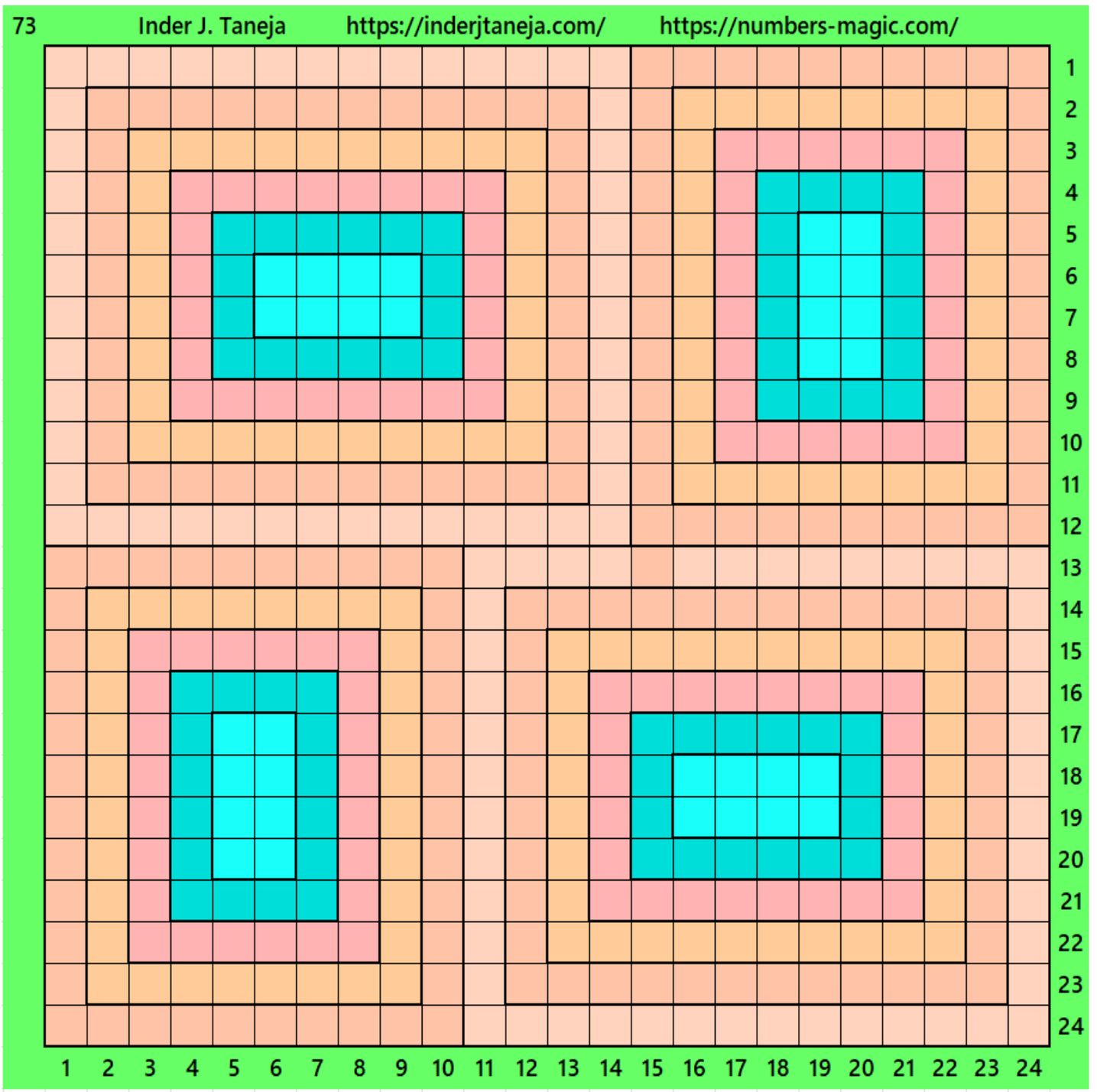
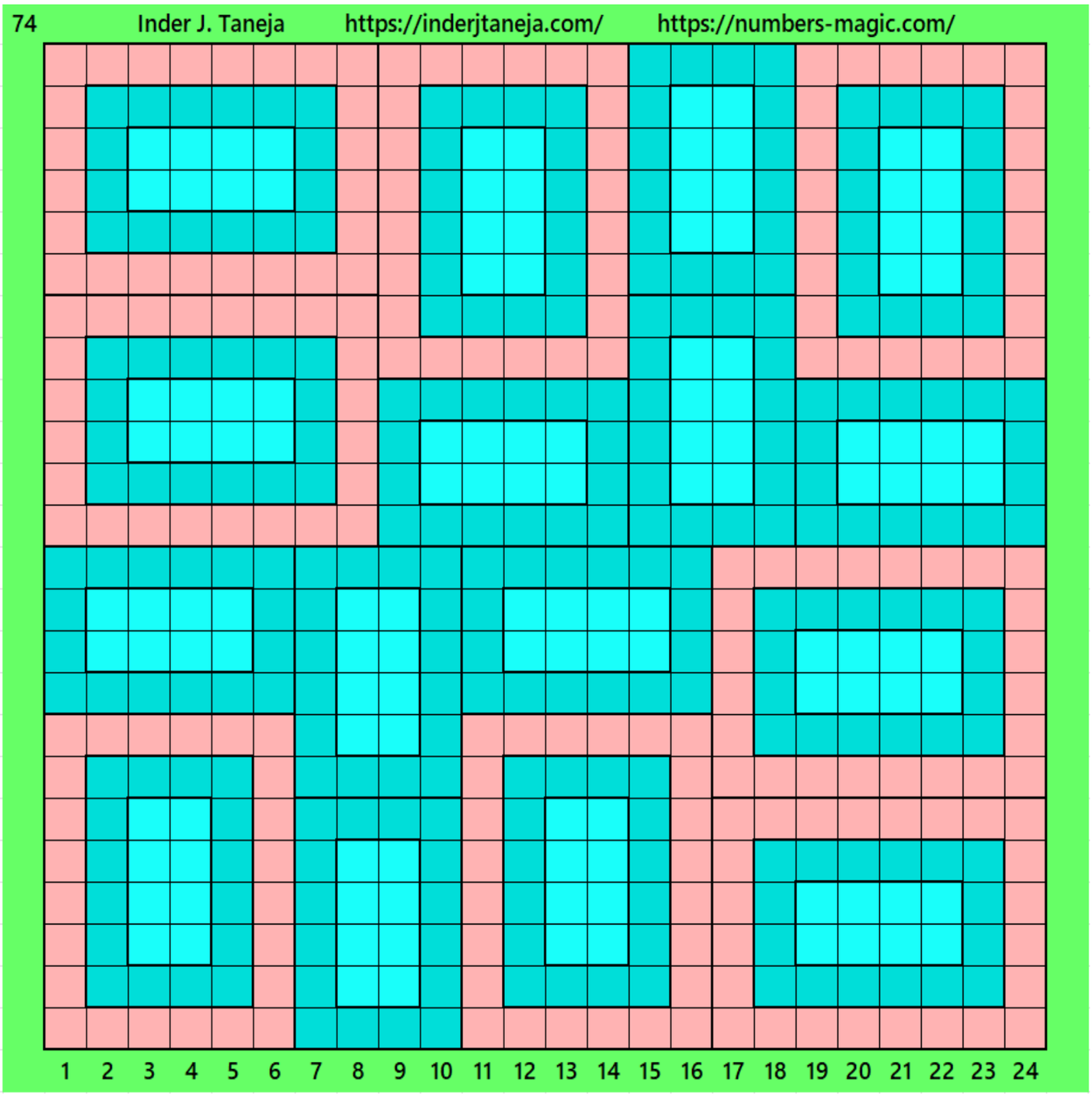
2.11 Two Consecutive BMR of Orders 10×12 and 12×14

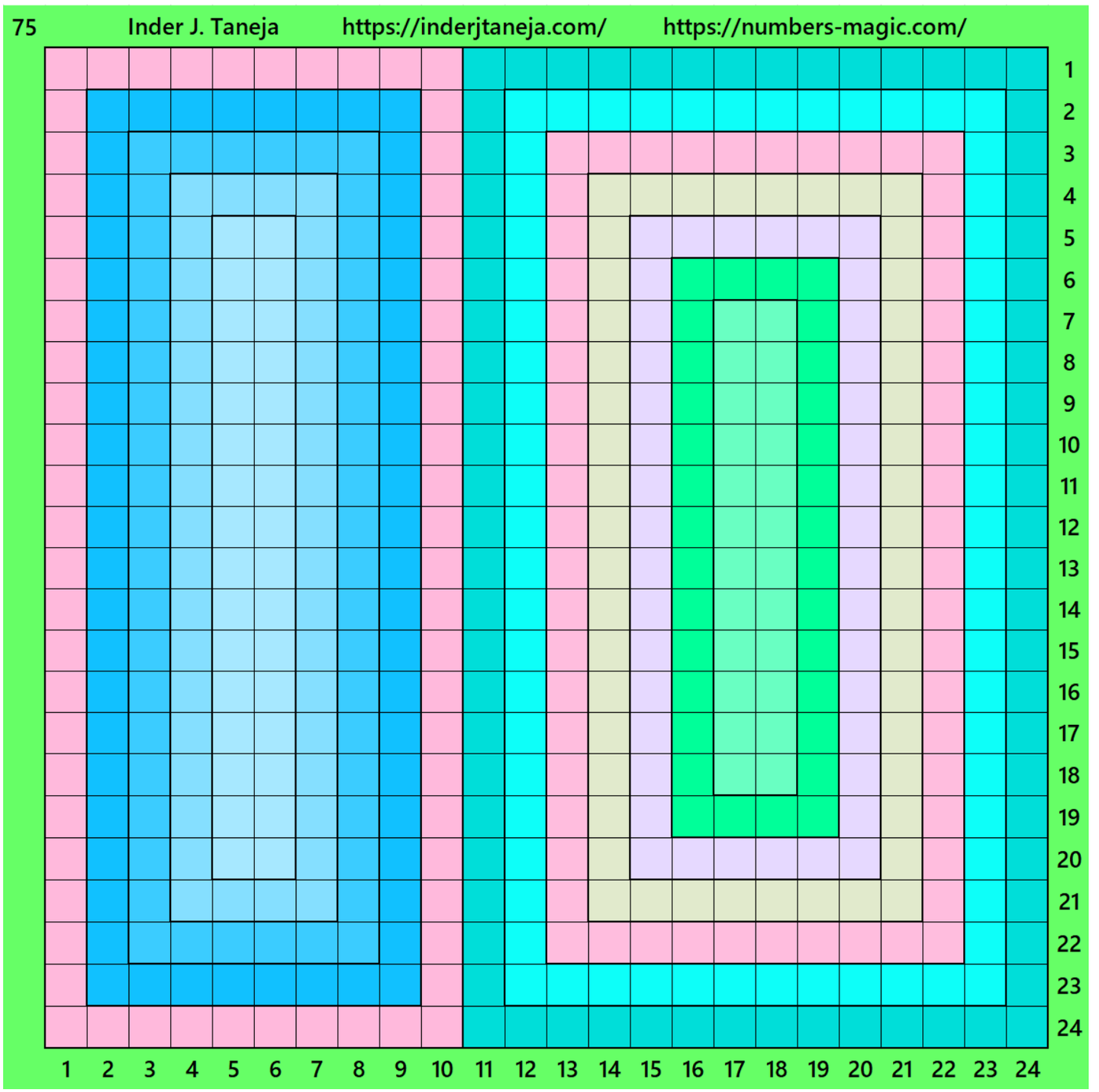
Below are two examples of magic squares of order 24 made based on two consecutive BMR's of orders 10×12 and 12×14.

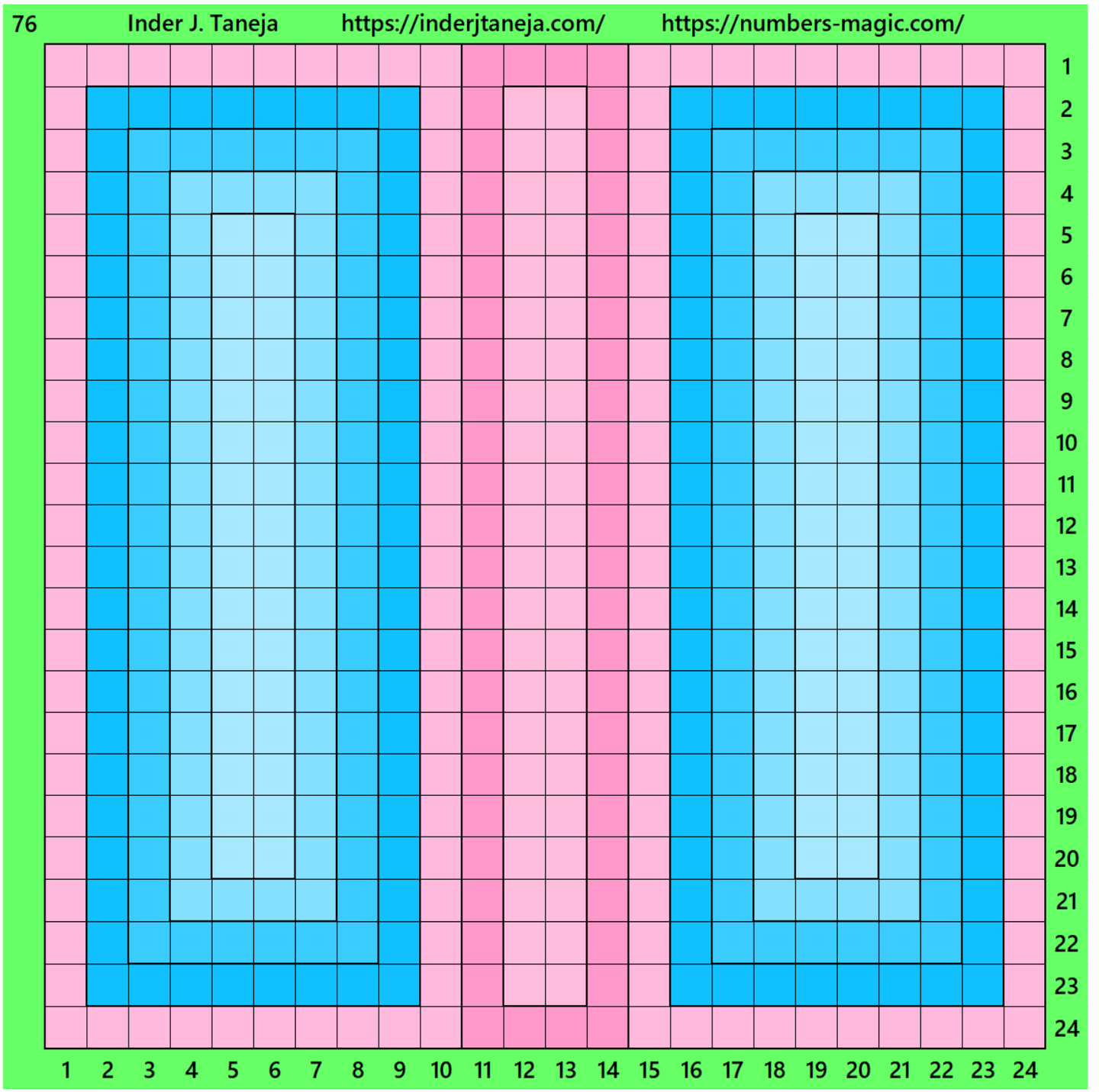


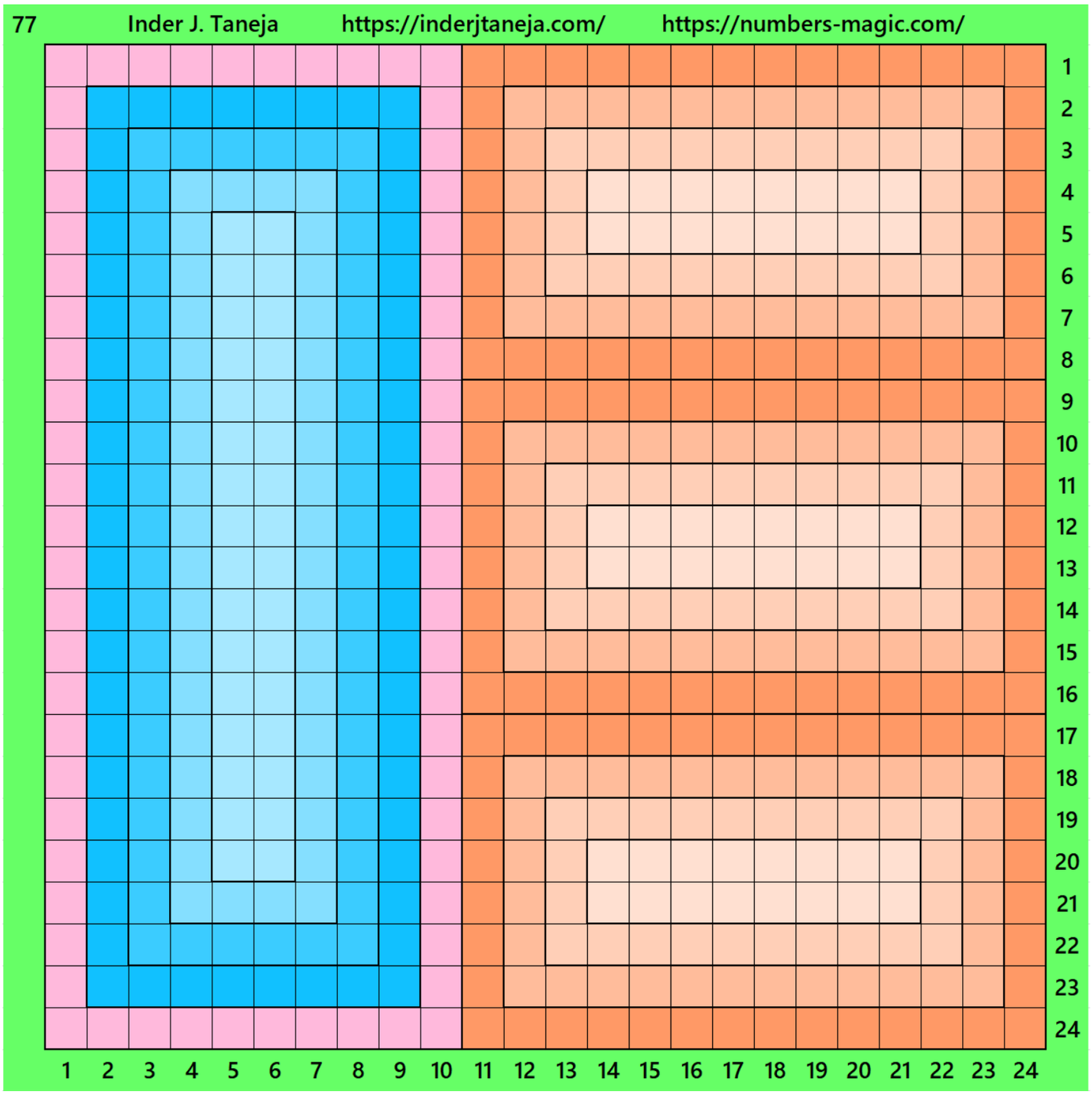


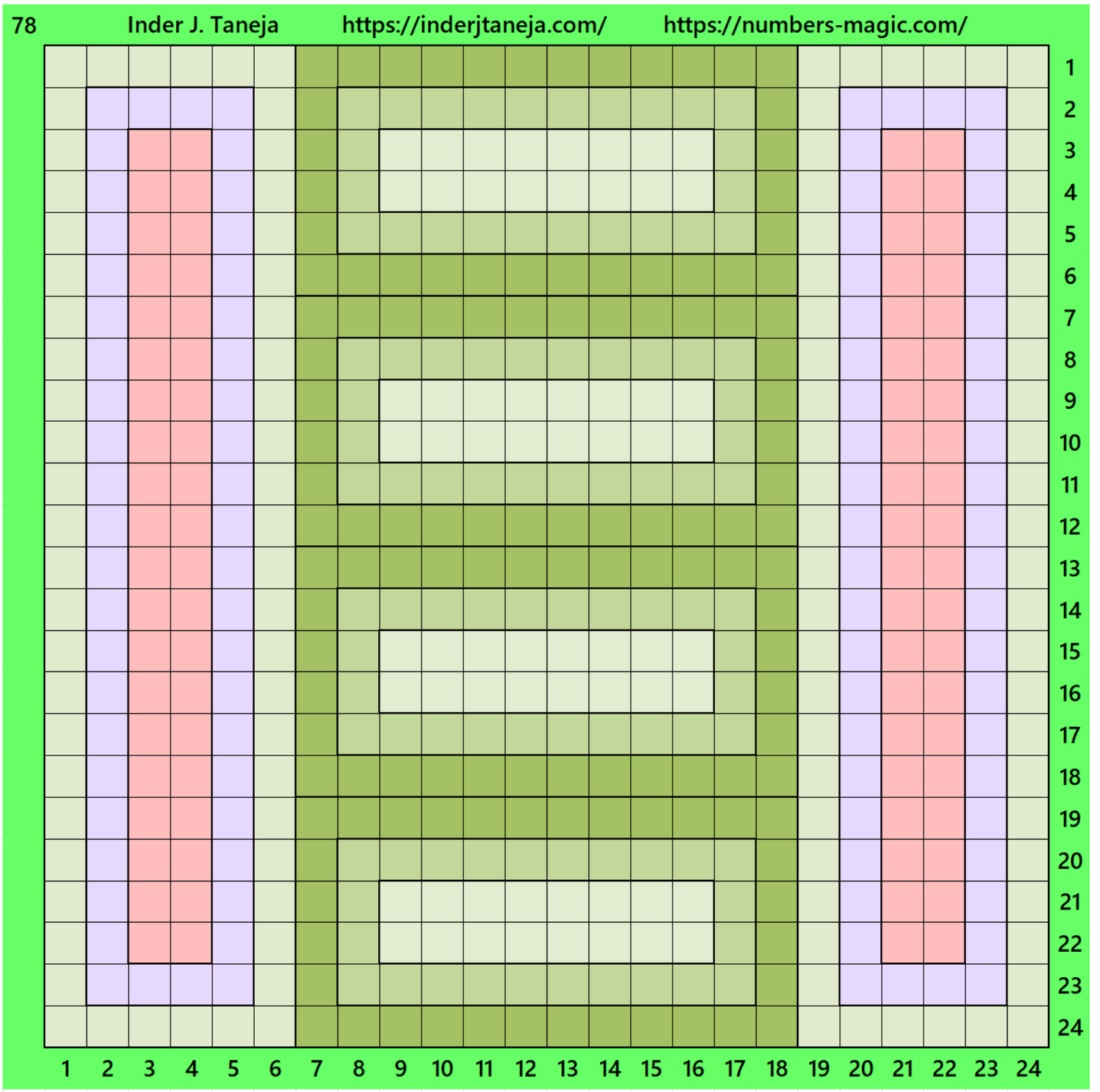
2.12 Extra Results

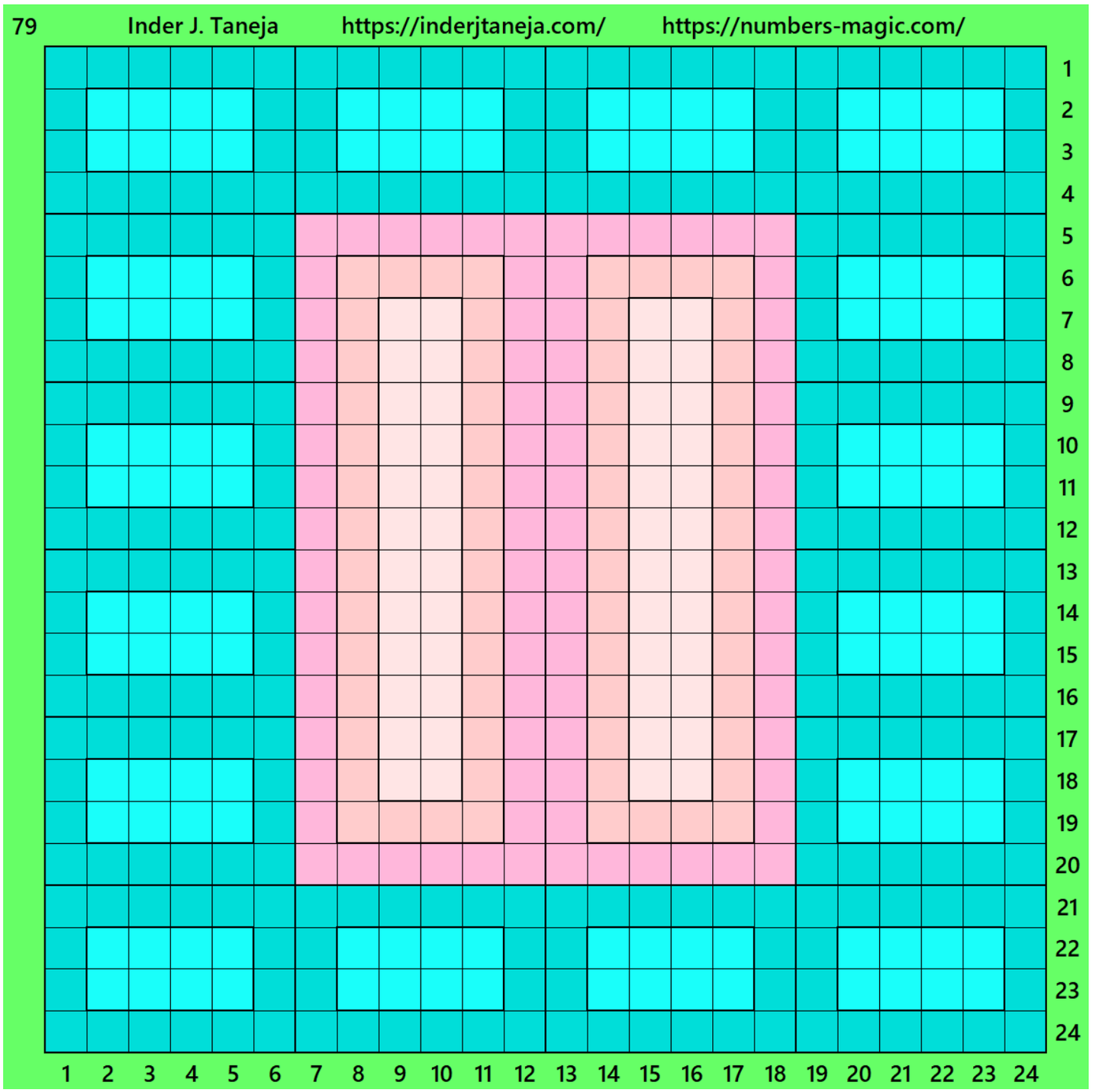
Below are some extra magic squares of order 24 made individually using BMRs.

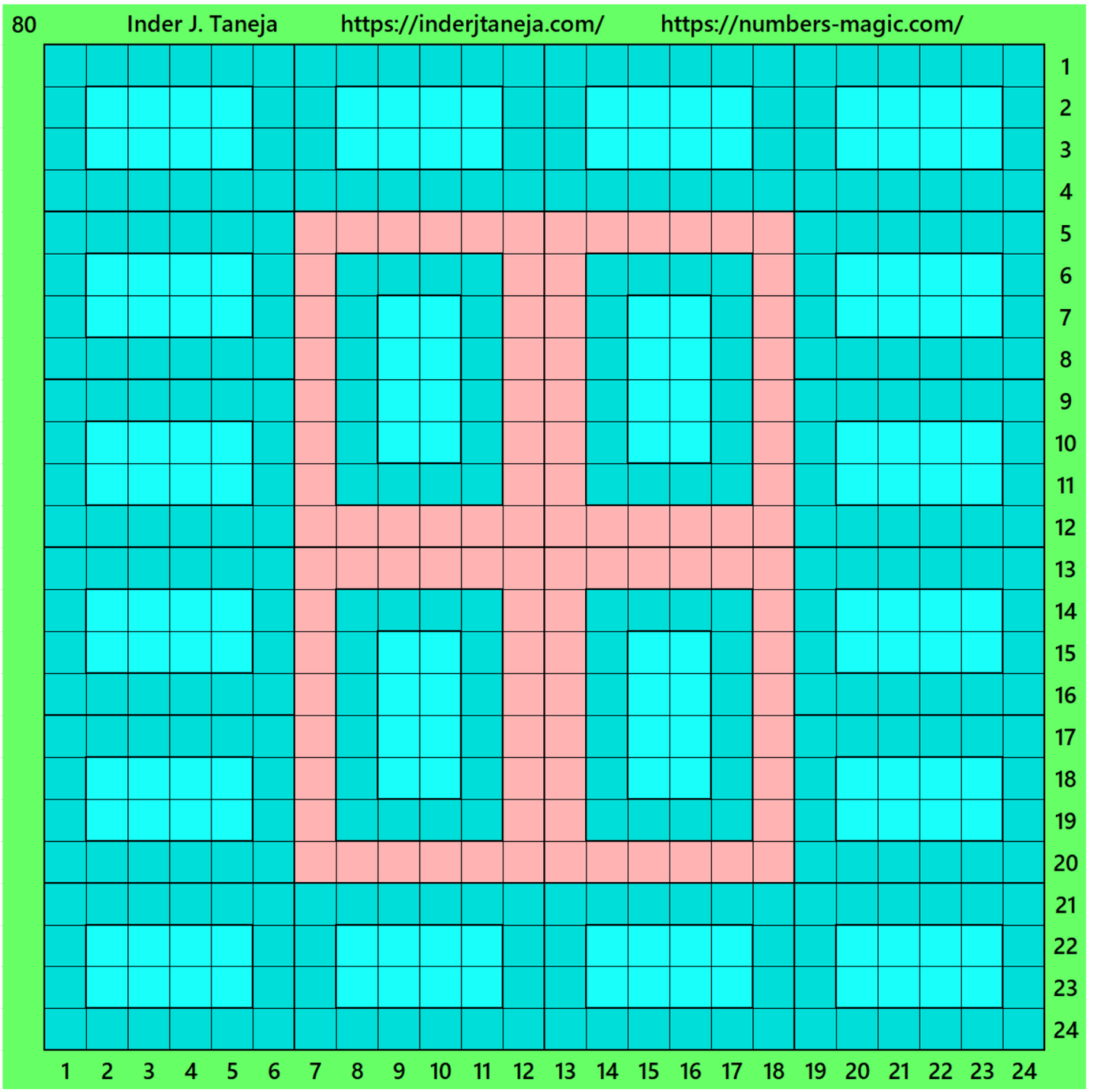

75
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


76
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


77
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


78
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


79
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

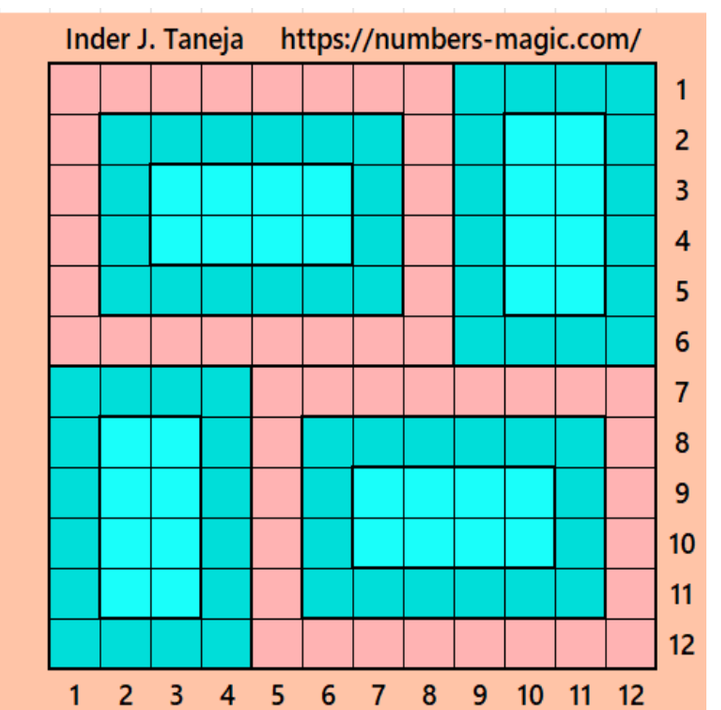

80
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Figured Magic Squares of Order 24 Using Bordered Magic Rectangles: A Systematic Procedure, **Zenodo**, November 14, 2022, pp. 1-104, *https://doi.org/10.5281/zenodo.7377779*

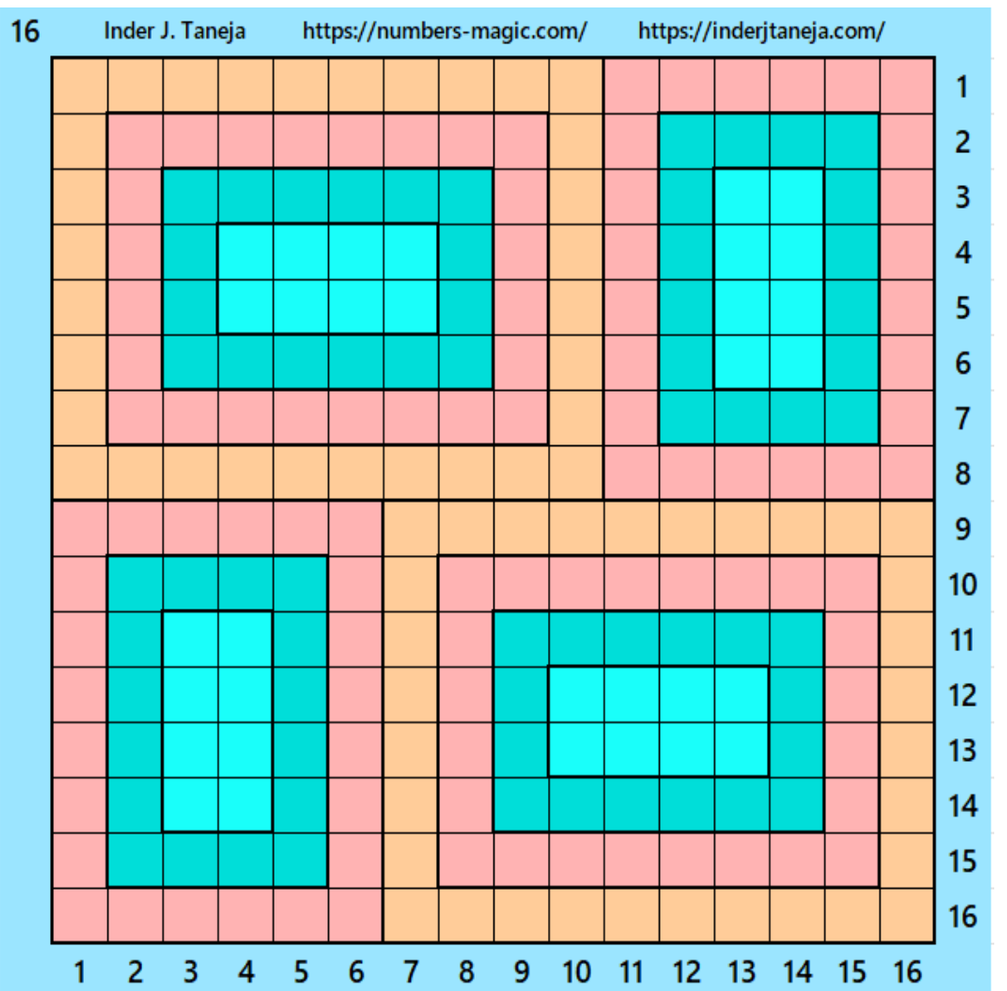
2.13 Similarity With Previous Results

The examples below of orders 12, 16, 20 and 24 are made with two consecutive BMRs given very much similarity.

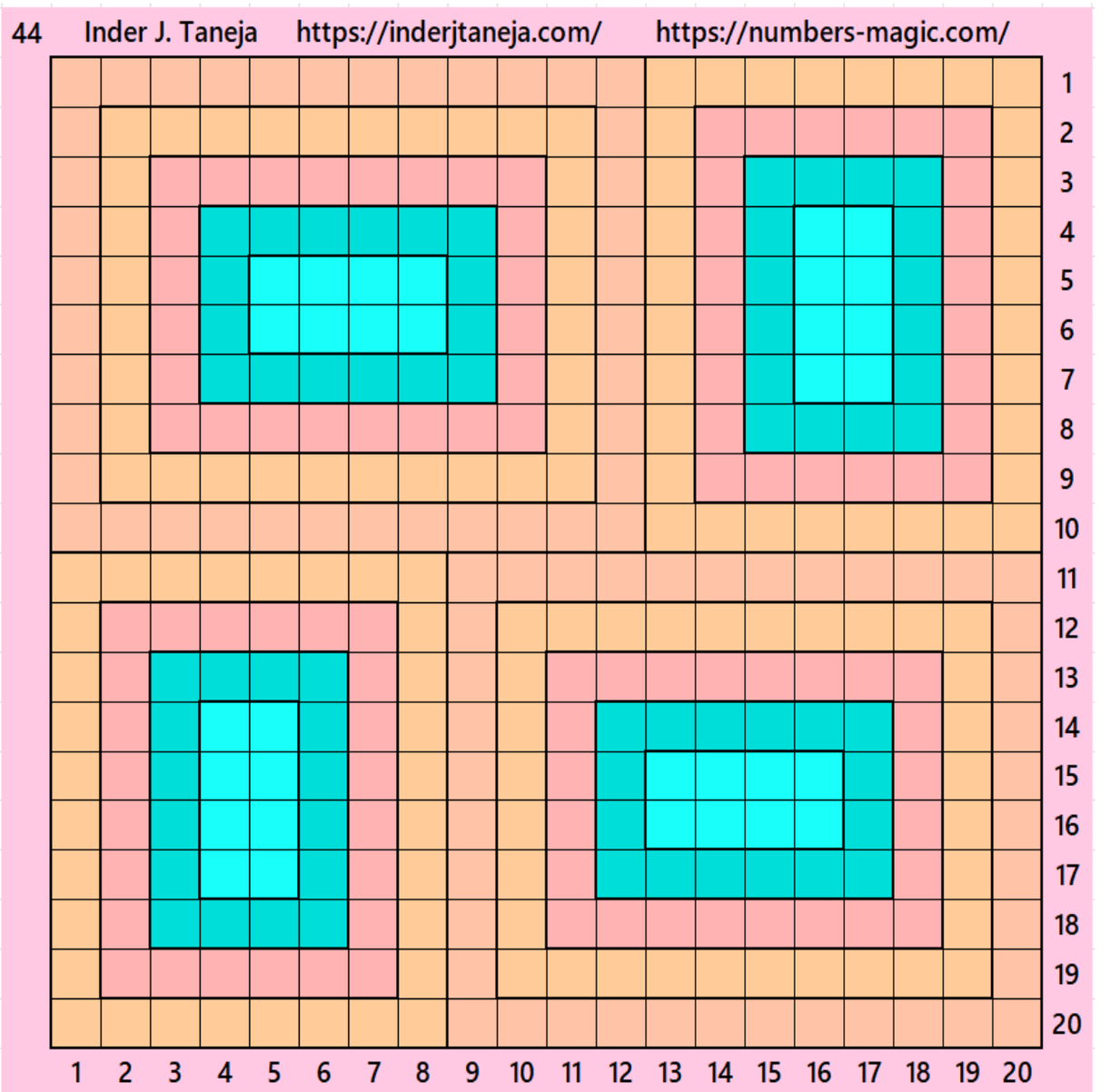
• Order 12



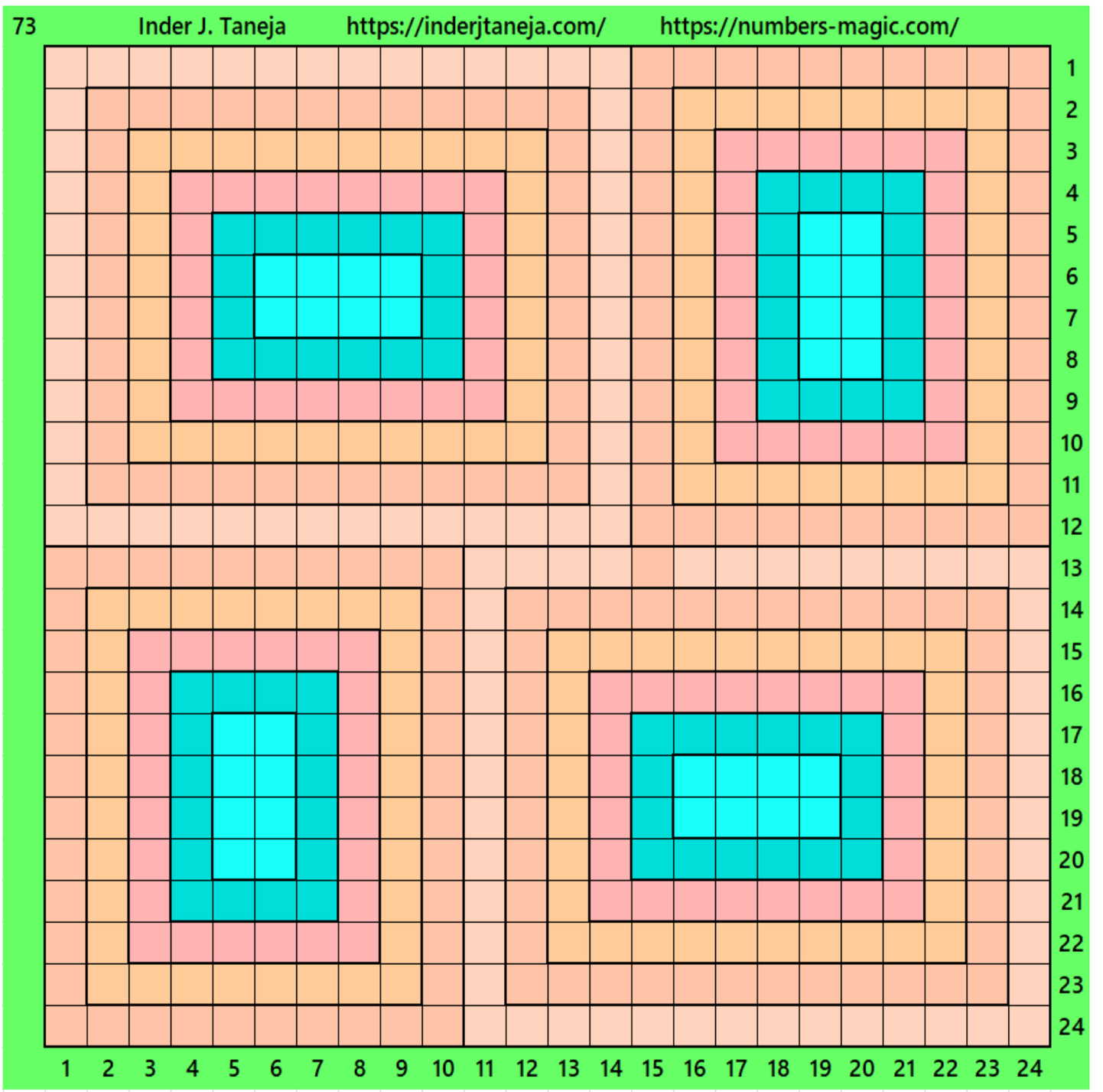
• Order 16


16
Inder J. Taneja
https://numbers-magic.com/
https://inderjtaneja.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

• Order 20


44
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

- **Order 24**


73
Inder J. Taneja
https://inderjtaneja.com/
https://numbers-magic.com/
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Figured Magic Squares of Order 24 Using Bordered Magic Rectangles: A Systematic Procedure, **Zenodo**, November 14, 2022, pp. 1-104, *https://doi.org/10.5281/zenodo.7377779*

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	6×36, 10×36, 14×36, 18×36, 22×36, 26×36, 30×36, 34×36
38	4×38, 8×38, 12×38, 16×38, 20×38, 24×38, 28×38, 32×38, 36×38
40	6×40, 10×40, 14×40, 18×40, 22×40, 26×40, 30×40, 34×40, 38×40
42	4×42, 8×42, 12×42, 16×42, 20×42, 24×42, 28×42, 32×42, 36×42, 40×42
44	6×44, 10×44, 14×44, 18×44, 22×44, 26×44, 30×44, 34×44, 38×44,42×44
46	4×46, 8×46, 12×46, 16×46, 20×46, 24×46, 28×46, 32×46, 36×46, 40×46, 44×46
48	6×48, 10×48, 14×48, 18×48, 22×48, 26×48, 30×48, 34×48, 38×48, 42×48, 46×48
50	4×50, 8×50, 12×50, 16×50, 20×50, 24×50, 28×50, 32×50, 36×50, 40×50, 44×50, 48×50

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 his valuable help.

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