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Prime numbers, infinite binary matrices and generation rules

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Abstract
The purpose of this article is going one step further, in our exploration of prime numbers, namely through a binary matrix generating valuable information about them, including the list and amount of prime numbers between 1 and n. Additionally this matrix will provide a theoretically infinite, exhaustive and orderly list of prime numbers. The special innovation of this article, is that for the first time we are able to generate a matrix providing all the information about prime numbers we have mentioned, by means of just a few rules.
Keywords: *Binary numbers, generation rules, infinite binary matrix, prime numbers.*

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I. INTRODUCTION

Prime numbers are one of the central areas of inquiry in arithmetic and number theory, and this article aims at contributing to it. What is presented in this article is an in-depth explanation of a model to find important information about prime numbers as well as generating them orderly, exhaustively and infinitely. This model has been found after some years of polishing, researching and discarding several alternatives, and it is based on calculations among binary numbers within an infinite matrix.

II. THEORETICAL FRAMEWORK

2.1 Prime numbers

Prime numbers are those numbers that have two factors, i. e., one and the number itself (Kumar & Mozar, 2020).

2.1.1 Methods to work with prime numbers

This article and its underlying research, are part of a sub-line of research on prime numbers, which is based on binary numbers. Other scholars such as Chang (2014), Mazurkin (2014) and Alvarez (2021, 2024), have worked on prime numbers using binary numbers, but not in the same way we are trying to show. In this case we work with binary numbers within binary matrices or tables.

III. DISCUSSION

After some reflection, we have found the infinite binary matrix described in the article *A simple method for finding prime numbers: An infinite model based on binary numbers* (Alvarez, 2024), can be generated by only a few rules. The outcome is thus, a binary matrix which extends to the infinite of natural numbers. Mathematically speaking, this matrix will be able to perform operations yielding the following theoretical outcomes:

a. The number of prime numbers from 1 to infinity.
b. An orderly list of all prime numbers from 1 to infinity.

We will begin this section by showing the rules by which a matrix of this kind can be generated. Likewise, this procedure will show how to generate the input to get the theoretical results mentioned in a and b, namely the number of prime numbers from 1 to n (or 1 to infinity) and an orderly and exhaustive list of prime numbers from 1 to infinity.

First rule is thus, generating an infinite row of 1s from left to right, to then assigning each of them to their corresponding orderly arithmetic position from 1 to infinity. Matrix 1 shows previous point from 1 to 15 but it works endlessly as well.

Matrix 1. Rule 1: Infinite row of 1s.

Then, through second rule, we can generate a diagonal of 1s in order to set the semi-perimeter completed by first rule previously shown.

Matrix 2. Rule 2: Diagonal of 1s.

														1
													1	
												1		
											1			
										1				
									1					
								1						
							1							
						1								
					1									
				1										
			1											
		1												
	1													
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Third rule, we fill the squares outside main zone with 1s, in order to keep the status quo of the multiplication process between 1s and 0s in a subsequent binary matrix (Alvarez, 2024). We can show this as it follows:

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1		
1	1	1	1	1	1	1	1	1	1	1	1			
1	1	1	1	1	1	1	1	1	1	1				
1	1	1	1	1	1	1	1	1	1					
1	1	1	1	1	1	1	1	1						
1	1	1	1	1	1	1	1							
1	1	1	1	1	1	1								
1	1	1	1	1	1									
1	1	1	1	1										
1	1	1	1											
1	1	1												
1	1													
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Matrix 3. Rule 3: Filling of squares outside main zone with 1s.

After that, we can apply rule 4 by filling the main zone, subsequently and correspondingly with sequences of 1s and 0s in the order 10-10-10, 110-110-110, 1110-1110, ascendingly and in rows, from bottom to top. Additionally, this process takes place endlessly and following the multiple-based sequencing inherent to the arithmetic system. It is important to note all these considerations have an infinite reach. This means the limitations or finite nature this system may show, are just apparent and what we actually have is an arithmetical prime number theory with a computational component. Additionally, we are already in position to delete first column, since 1 is not a prime number. This is shown in the following matrix:

1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	**1**
1	1	1	1	1	1	1	1	1	1	1	1	**1**	**1**
1	1	1	1	1	1	1	1	1	1	1	**1**	**1**	**1**
1	1	1	1	1	1	1	1	1	1	**1**	**1**	**1**	**1**
1	1	1	1	1	1	1	1	1	**1**	**1**	**1**	**1**	**1**
1	1	1	1	1	1	1	1	**1**	**1**	**1**	**1**	**1**	**1**
1	1	1	1	1	1	1	**1**	**1**	**1**	**1**	**1**	**1**	**1**
1	1	1	1	1	1	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**1**
1	1	1	1	1	**1**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**
1	1	1	1	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**0**
1	1	1	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**
1	1	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**1**	**0**
1	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**
1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	3	4	5	6	7	8	9	10	11	12	13	14	15

Matrix 4. Rule 4: Filling of squares within main zone with 1s and 0s.

At this point we can see that the upper middle zone within the perimeter, is only filled with 1s, which makes the task of filling squares with 1s and 0s, a bit easier. We still need to perform a final task, in this case inserting a row yielding the 1 or 0 output (prime or non-prime number), and adding another row with the multiplication product between 1 or 0 and the prime or non-prime number, just below last row filled with 1s. This shows in the following matrix:

1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	0	1
1	1	1	1	1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1	0	1	1	1	1	0
1	1	1	1	1	1	0	1	1	1	0	1	1	1
1	1	1	1	0	1	1	0	1	1	0	1	1	0
1	1	0	1	0	1	0	1	0	1	0	1	0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**
2	3	4	5	6	7	8	9	10	11	12	13	14	15

As we can see, we have generated an additional row, showing the multiplication product yielded by the 1s and 0s of each column. In turn, the product mentioned can be only 1 or 0, thus showing the prime/non-prime status of each natural number. If we perform a total addition operation among 1s and 0s in final row, we will get the number of prime numbers from 1 to *n*. To this point, we have accomplished binary matrix's first goal: telling how many prime numbers there are from 1 to *n* or 15 in this case (and infinity). We can see this in full in the following binary matrix.

1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	0	1	
1	1	1	1	1	1	1	1	1	1	0	1	1	1	
1	1	1	1	1	1	1	1	0	1	1	1	1	0	
1	1	1	1	1	1	0	1	1	1	0	1	1	1	
1	1	1	1	0	1	1	0	1	1	0	1	1	0	
1	1	0	1	0	1	0	1	0	1	0	1	0	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	0	1	0	1	0	0	0	1	0	1	0	0	6
2	3	4	5	6	7	8	9	10	11	12	13	14	15	
2	3	0	5	0	7	0	0	0	11	0	13	0	0	

From this table, if we delete the 0s from final row, we will get a theoretical, orderly list of all prime numbers. That being said, we have accomplished binary matrix's second goal: having an orderly list of all prime numbers from 1 to infinity. The following matrix shows everything discussed in this article.

1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1	1	0	1	
1	1	1	1	1	1	1	1	1	1	0	1	1	1	
1	1	1	1	1	1	1	1	0	1	1	1	1	0	
1	1	1	1	1	1	0	1	1	1	0	1	1	1	
1	1	1	1	0	1	1	0	1	1	0	1	1	0	
1	1	0	1	0	1	0	1	0	1	0	1	0	1	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	
1	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**6**
2	3	4	5	6	7	8	9	10	11	12	13	14	15	
2	**3**	**0**	**5**	**0**	**7**	**0**	**0**	**0**	**11**	**0**	**13**	**0**	**0**	
2	**3**	**5**	**7**	**11**	**13**					∞				

IV. CONCLUSION

Through this article we have explored some important information about prime numbers, by means of binary numbers and rules of generation. It was found a few rules can generate an infinite binary matrix that yields an orderly list of all prime numbers as well as the amount of primes between 1 and *n*, in theoretical terms.

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