

Prime Analysis: Expressing Primes As Triangles

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August 2026

Abstract

Prime Numbers have been a hot topic around mathematics for centuries. Many theories have been devised such as the Riemann Hypothesis, Twin Prime Conjecture, etc. However, prime theories involve using many advanced concepts such as the imaginary number and contour integration making it hard for the layman to understand a pattern in primes. Therefore, I propose a theory where comparing the graph of prime against prime roots can help better understand the patterns in primes such as spacing and clustering. Though primes seem random I believe they can be expressed using basic geometric principles. *All in all, this research investigates a novel geometric framework utilizing coordinate-based triangular networks formed by prime values and their square roots. By analyzing the asymptotic behavior of the resulting interior angles, this study aims to quantify prime sparsity and local clustering distributions, with the final objective of deriving an alternative geometric expression for prime number distribution standing for the first 500 primes.*

1 Introduction

The analysis will first begin crediting Desmos for their state of the art graphing application which has allowed me to imagine different polygons, and patterns found between them. In this study rooted primes represent the square root of primes which is an irrational number. It is crucial that the primes and their roots are separated by one on the x-axis in order to identify the intricate patterns between each. The primes are all plotted along the y-axis and form a linear graph when you zoom out, and when rooted form a square root graph. The identification of this pattern is quite extraordinary since at the beginning the beginning 2 triangles have closely identical angles for two vertices. This is an understandable pattern since primes are closely clustered (in other words they are closer to each other) meaning difference in the exact value is not differentiable by an extreme amount compared to the triangle formed at point the 100th prime (100, 541) where angles become sparser rather than identical indicating a greater distance between each prime. On that note, throughout this whole

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study the following notation will be used to define the three points: (n, p_n) , $(n, \sqrt{p_n})$, $(n+1, \sqrt{p_{n+1}})$. In simple words, this is an (index, prime / root prime) system that helps determine each point and will be used in the equations. A key fact previously not mentioned is that all geometric shapes will be formed between twin primes (primes with a difference of two).

2 Methods

The study begins with first building both graphs until the first hundred primes because it is optimal for recognizing patterns since after one hundred they get more sparser meaning there is a lesser concentration of clusters. With a visual representation, it is possible to identify coordinates of the triangle. An example is shown below:

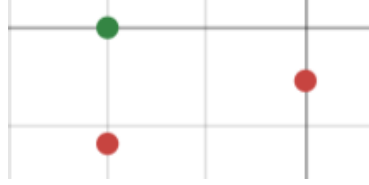


Figure 1: A visual example of triangle formed between coordinates, more specifically the first triangle. The single green coordinate represents the coordinate $A(1, 2)$ while the the two red coordinates represents $B(1, \sqrt{2})$ and $C(2, \sqrt{3})$

It is important to note that the A, B, C point label will be constant throughout where A represents the prime coordinate while B and C represent the rooted prime coordinates. The primes being on a 2-Dimensional Cartesian plane will allow us to compute side length using the distance formula for side length AC , AB , BC and angles with sine law along with cosine law.

$$AC/AB/BC = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

$$\cos(C) = \frac{BA^2 + AC^2 - AB^2}{2(BA)(AC)} \quad (2)$$

$$\frac{\sin A}{BC} = \frac{\sin B}{AC} = \frac{\sin C}{AB} \quad (3)$$

However, the use of these equations are very basic or in other words a prerequisite step that must be done. Recording the geometric split is the most important. The overall split is involves a total of 4 points that will be used to form two triangles. It is important to remember that the notation italicized at the bottom of page one will be used to define each point, but with a slight change. The first triangle formed contains notation mentioned earlier. The second triangle formed on the other hand contain two whole number twin primes

and the rooted coordinate with the greatest x-value between the two. With solving for all angles (all angles will be rounded to 2 decimal places) and side lengths (kept in exact values but rounded to 2 decimal places in calculation unless both tenths and hundredths contain zeroes), a stunning pattern begins to emerge with the number of primes between the twins. Also, the notation for the second triangle is $(n, p_n), (n, p_{n+1}), (n+1, \sqrt{p_{n+1}})$. I will now provide a figure that demonstrates how the two triangles will be formed.

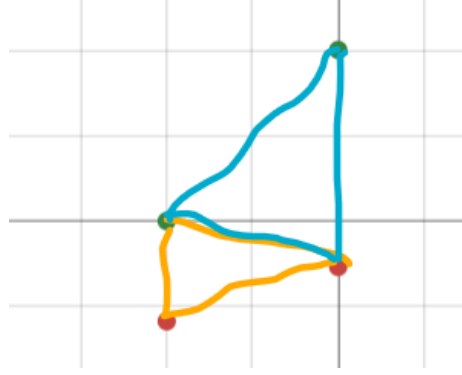


Figure 2: The outlined in orange is the triangle shown in the previous figure and the second triangle uses the second set of notation. This is the full geometric split among the coordinates.

On that note, values are rounded to 2 decimal places for angles for easier derivation and constant pattern recognition. Now with all set and stone, the final step involves deriving a formula. Let us define θ angle which is formed between sides AB and AC in the first triangle and β represents the angle formed between AB and BC (in simple terms vertex C). Moreover, through an analysis is is shown that $\theta \geq \beta$ and the inequality that can be used to explain this relationship is:

$$(\theta - \beta) + 1 \geq 1 \quad (4)$$

Now the one addition is crucial since the result of $\theta - \beta$ will have intricate values and the addition allows for defining a more accurate, sparser range based on how many primes are between the twin pairs. In mathematical terms, $\theta = \angle BAC$ with angle at Vertex A and $\beta = \angle BCA$ with angle at Vertex C . For more information on how vertex visit the google drive folder in supplemental information. It has already been indicated that even without the addition they contain a distinct sparsity. Before the end of this section, I would like to remind the θ and β represent the focus angles which have the least distance between both.

3 Results

Through the usage of the inequality theorem rounded to two (for simplicity) you land at these values solved through handheld calculations:

Number of Primes Between Two Twin Prime Pairs	Angular difference ($\theta - \beta + 1$)
0	1.00°
1	1.02°
2	1.01°
3	1.00°
4	1.01°
7	1.00°

Even without exact notation, there is a distinct pattern recognized between the two. Any odd number of primes between twin primes computed to the value of 1.00°(with the exception of "1"), while the even numbered primes all had 1.01°. Now, the pattern presented on the table shows that doing $n + 2$ gives the same angular difference. Which mirrors the twin prime conjecture since it also increases by a value of two. So in basic terms, if the angles hundredths place contains the number one, it has an even value of primes between it. However, if the angles hundredths contains zero it is an odd number. The sole exception being one since it contains two in the hundredths place. Another exception being no isolated primes between itself where the angular difference according to the theorem is one (which means that there is a zero degree difference without the +1). The inequality ensures that the value must be equal to or greater than otherwise there has been a miscalculation in the methods.

4 Discussion

Due to limiting factors in testing, the mathematics was conducted on the first 100 prime numbers where the most trickier patterns are easier to find. However, one clear limitation is the scale to which his theorem could work since twin primes (and primes in general) become less frequent. Python code would be used in the future to validate the hypothesis rather than brute force pen and paper. The computational model requires maximum compute since current tries did not work and run well. The focus angles slowly decrease and only become extremely small after 500 primes when the remaining $\angle A$ and $\angle B$ angles totals on both triangles increase decimal-points close to 180°. One finding that I was not expecting in particular was the mirroring of the twin prime theorem with angular difference which indicated that the spacing of the numbers are all connected in some way mathematicians had to think of it in a simpler manner. it is important to note that, current conjectures that still stand are so complicated that it takes

centuries to solve, some still standing today showing sheer complexity of current theorems. A check has been done those with similar motifs of primes between two twin pairs with a calculator to ensure consistency and reduce complexity in the supplemental information file.

5 Conclusion

All in all, the goal of this study was achieved (at least the author believes) expressing prime spacing and clustering with a simpler expression and methodology. The use of twin prime conjecture came into improvement use to show the amount of primes being spaced apart. To conclude, the great mathematician John von neumann once said: "If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is."

6 Supplemental Information

Desmos: <https://www.desmos.com/calculator/sd1et2qkm2> (Please zoom in for clear view of each number)

Google Drive folder with calculations (other points with similar motifs were checked with a calculator): Prime Theory: Calculations