STRUCTURAL SIMILARITY BETWEEN THE ORDERED PAIRS OF PRIMES AND NON-PRIMES

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Dedicated to Someone Standing on the Shoulders of Giants

Abstract. There have been various approaches to prove Goldbach’s conjecture using analytical number theory. We go back to the starting point of this famous problem and are able to show that the number of Goldbach partition is related to that of ordered pairs of non-primes. This proof is based on the world’s first dynamic model of primes and can be a key to identify the structure of prime numbers.

1. Introduction

Although a number of studies have been conducted on prime number, many parts of primes remain unknown. Riemann hypothesis, twin prime problem and Goldbach’s conjecture are typical examples of the famous unsolved problems. In 1742, Christian Goldbach suggested that every integer greater than 6 can be represented as a sum of three primes. This conjecture can be divided into two different statements: weak Goldbach’s conjecture and strong Goldbach’s conjecture. The weak Goldbach’s conjecture states that every integer greater than 5 can be written as the sum of three primes[1]. Vinogradov showed that this conjecture holds for numbers larger than $3^{315}$ and this value is reduced to $3.33 \times 10^{43000}$ by Chen. The strong Goldbach’s conjecture states that every even integer greater than 2 can be written as the sum of two primes. Unlike the weak conjecture, much of this conjecture still remain unsolved. In this study, dynamic model for Goldbach partition is suggested and the structural similarity between the ordered pairs is shown as the first step for proving the strong Goldbach conjecture.

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2. Preliminaries: Goldbach’s conjecture

Goldbach’s conjecture is one of the oldest and famous unsolved problems in mathematics which states: Every even integer greater than 2 can be expressed as the sum of two primes. It can be easily expressed as follows.

\[ 2n = p_1 + p_2 \]

where \( p_1 \) and \( p_2 \) are both primes for \( \forall n \geq 2, n \in N \).

This can be transformed as follows for using the geometric characteristics.

\[ 2n = (n - \alpha) + (n + \alpha) \]

\( \exists \alpha \in Z \text{ s.t. } (n - \alpha) \text{ and } (n + \alpha) \text{ are both primes} \)

\( \text{and } 0 \leq \alpha < n \text{ for } \forall n \geq 2, n \in N \)

This means that we have to show the existence of the integer \( \alpha \) which makes both \( (n - \alpha) \) and \( (n + \alpha) \) primes. Also it can be interpreted that there are always two pair of primes which have same distance of \( \alpha \) apart to \( n \geq 2 \).

3. The main mathematical results

Let \( G_n = \{(n - \alpha), (n + \alpha) \mid 0 \leq \alpha < n, \alpha \in Z\} \) be a set of given \( n \). It is easy to classify elements in \( G_n \) into 4 groups: \( a_n = (p, p) \), \( b_n = (p, q) \), \( c_n = (q, p) \) and \( d_n = (q, q) \). Here \( p \) is prime nad \( q \) is not prime. Now, Goldbach’s conjecture is equivalent with the following proposition.

\[ n(a_n) \neq 0 \text{ for } \forall n \geq 2 \text{ and } n \in N \]

Since \( G_n \) and its 4 small groups of element varies with a value of \( n \), now we will call \( G_n \) as a dynamic model of primes. It is necessary to observe a difference between \( G_{n+1} \) and \( G_n \) and 8 different flows \( (v_j) \) are introduced in Figure 1 as a Reactor \( n \). For representing the dynamic model in terms of each flow, the following function are used.

\[ \pi(n) = \text{the number of prime } p \text{ which satisfies } p \leq n \]

\[ \delta(n) = \begin{cases} 1, & \text{if } n \text{ is prime} \\ 0, & \text{otherwise} \end{cases} \]
Figure 1. Dynamic model of ordered pairs
Now it is possible to present the dynamic model of primes in terms of \( v_j \) and given function.

First, it is obvious that \( n(G_n) = n \), the overall balance equation can be obtained as follows.

\[
(6) \quad n(G_n) = n(a_n) + n(b_n) + n(c_n) + n(d_n) = v_1 + v_2 + v_3 + v_4 + v_5 + v_6 + v_7 + v_8 = n
\]

Second, the number of prime \( p \) such that \( 1 \leq p \leq n \) is only found in the left part of ordered pairs in \( a_n \) and \( b_n \), we can easily have the additional balance equation.

\[
(7) \quad n(a_n) + n(b_n) = v_1 + v_2 + v_3 + v_4 = \pi(n)
\]

Finally, when \( G_n \) is changed to \( G_{n+1} \) as \( n \) increases by one, we can observe the change of each flows and set the balance equation for primes which are in right part of ordered pairs in \( G_n \).

\[
(8) \quad n(a_n) + n(c_n) = v_1 + v_2 + v_5 + v_6 = \pi(2n) - \pi(n) + \delta(n)
\]

Since we have to show \( n(a_n) \neq 0 \) for \( n \geq 2 \), it is necessary to observe \( \Delta a_n \).

\[
(10) \quad \Delta n(a_n) = n(a_{n+1}) - n(a_n) = (v_1 + v_3 + \delta(n+1)) - (v_1 + v_2) = v_3 - v_2 + \delta(n+1)
\]

Similarly, \( \Delta d_n \) can be obtained.

\[
(11) \quad \Delta n(d_n) = n(d_{n+1}) - n(d_n) = (v_6 + v_8 + 1 - \delta(n+1)) - (v_7 + v_8) = v_6 - v_7 + 1 - \delta(n+1)
\]

If we combine the Eq.10 and Eq.11, the relation between \( \Delta a_n \) and \( \Delta d_n \) can be represented as a function of \( n \) and \( v_j \).

\[
(12) \quad \Delta n(a_n) = \Delta n(d_n) + v_3 - v_2 + v_7 - v_6 + 2\delta(n+1) - 1
\]
To convert \((v_3 - v_2 + v_7 - v_6)\) to a function of \(n\), we can use Eq.8 and Eq.9. Then Eq.12 can be reduced as follows.

\[
(13) \quad \Delta n(a_n) = \Delta n(d_n) + \delta(2n+1) + \delta(n+1) - \delta(n) - 1 = \Delta n(d_n) + \eta(n)
\]

Here \(\eta(n) = \delta(2n+1) + \delta(n+1) - \delta(n) - 1\).

Since both \(n\) and \((n+1)\) cannot be primes except \(n = 2\), it is easy to find the value of \(\eta(n)\) based on the observation of 6 cases of possible when \(n \geq 3\).

\[
\eta(n) = \begin{cases} 
1 & \text{if } 2n+1, n+1 \in P \text{ and } n \in Q \\
0 & \text{if } 2n+1, n \in Q \text{ and } n \in P \text{ or if } 2n+1 \in P \text{ and } n+1, n \in Q \\
-1 & \text{if } 2n+1, n+1, n \in Q \text{ or if } 2n+1, n \in P \text{ and } n+1 \in Q \\
-2 & \text{if } 2n+1, n+1 \in Q \text{ and } n \in P
\end{cases}
\]

This relation can be seen in table I and it can be found that the similar shape in graph of \(n(a_n)\) and \(n(d_n)\) is due to the function \(\eta(n)\). Figure 2 represents the graph of \(n(a_n)\) and \(n(d_n)\). Although the \(n(d_n)\) has values greater than \(n(a_n)\), when we focus on \(\Delta n(a_n)\) and \(\Delta n(d_n)\), the relation \(\Delta n(a_n) - \Delta n(d_n) = \eta(n)\) holds for all \(n \geq 3\). The similar tendency of the dark band in both \(n(a_n)\) and \(n(d_n)\), which is generated from the bottom to the top, can be explained by this.
**Table 1.** Relation between ordered pairs of primes and non-primes

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STRUCTURAL SIMILARITY BETWEEN THE ORDERED PAIRS OF PRIMES AND NON-PRIMES

Figure 2. Graphs of $n(a_n)$ and $n(d_n)$
Likewise, the relation between \(n(b_n)\) and \(n(c_n)\) can be derived easily.

\[
\Delta n(b_n) = v_3 - v_2 = -\Delta n(a_n) + \delta(n + 1)
\]

\[
\Delta n(c_n) = v_7 - v_6 = -\Delta n(d_n) - \delta(n + 1) - 1
\]

From Eq.13, Eq.14 and Eq.15,

\[
\Delta n(b_n) = \Delta n(c_n) - \delta(2n + 1) + \delta(n + 1) + \delta(n) = \Delta n(c_n) + \theta(n)
\]

Here \(\theta(n) = -\delta(2n + 1) + \delta(n + 1) + \delta(n)\).

Since both \(n\) and \((n + 1)\) cannot be primes except \(n = 2\), it is easy to find the value of \(\theta(n)\) based on the observation of 6 cases of possible when \(n \geq 3\).

\[
\theta(n) = \begin{cases} 
1 & \text{if } 2n+1, n \in Q \text{ and } n+1 \in P \text{ or if } 2n+1, n+1 \in Q \text{ and } n \in P \\
0 & \text{if } 2n+1, n, n+1 \in Q \text{ or if } 2n+1, n \in P \text{ or if } 2n+1, n+1 \in P \\
-1 & \text{if } 2n+1 \in P \text{ and } n, n+1 \in Q
\end{cases}
\]

This relation can be seen in Figure 3 and it can be found that the similar shape in graph of \(n(b_n)\) and \(n(c_n)\) is due to the function \(\theta(n)\). When we focus on \(\Delta n(b_n)\) and \(\Delta n(c_n)\), the relation \(\Delta n(b_n) - \Delta n(c_n) = \theta(n)\) holds for all \(n \geq 3\). The similar tendency of the dark band in both \(n(a_n)\) and \(n(d_n)\), which is generated from the top to the bottom, can be explained by this.
Figure 3. Graphs of $n(b_n)$ and $n(c_n)$
4. Conclusions

We have shown that there is a structural similarity between the ordered pairs in \( G_n \). Goldbach partition, \( n(a_n) \), and the number of expression for even number as the sum of the two composite number, \( n(d_n) \) have a similar structure which can be described as \( \Delta n(a_n) = \Delta n(d_n) + \eta(n) \). From this, it is possible to explain the similar tendency in the graph of both \( n(a_n) \) and \( n(d_n) \) quantitatively. Meanwhile, it can be also found that the number of Goldbach partition has a special periodicity based on the suggested dynamic model. This will be discussed further in next paper.

REFERENCES


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