World Open Journal of Advanced Mathematics
Vol. 2, No. 1, April 2014, PP: 01 - 32
Available online at http://scitecpub.com/Journals.php

Research article

THE FORMATION OF PRIME NUMBERS AND THE SOLUTION FOR GOLDBACH'S CONJECTURES

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Abstract

To date it had been thought that the formation of the primes within the natural numbers was not due to a definite law that could be expressed in the form of an equation. This document demonstrates that it is possible to express an equation that contains the shape of every prime number, which obeys a pattern similar to the natural numbers. Two functions for the behavior of the density of prime numbers, are presented in relation with $\frac{x}{\ln x}$ and $Li(x)$, allowing to observe the oscillating behavior of the density of primes less than a given number x, improving those proposed in Tchebychev (1852) and Sylvester (1881).
Furthermore, two of the fundamental theorems of mathematics are proven: "every composite number is formed with at least one prime and primes are infinite" in a different way. At the same time, the "strong" and "weak" Goldbach conjectures are proven.

Keywords: Prime numbers, Strong and weak Goldbach's Conjectures, Bertrand´s Postulate.

Introduction

The study on the distribution of prime numbers has fascinated mathematicians since ancient times. There are countless publications about the properties of prime numbers that can be found in all languages and theorems have been created in different ways, seeking always to find a pattern of ordering [1][2]. The inability to find an order has been eloquently documented, such as in Havil's book:

"The succession of primes is unpredictable. We don't know if they will obey any rule or order that we have not been able to discover still. For centuries, the most illustrious minds tried to put an end to this situation, but without success. Leonhard Euler commented on one occasion: mathematicians have tried in vain to this day to discover some order in the sequence of prime numbers and we have reason to believe that it is a mystery into which the human mind will never penetrate. In a lecture given by D. Zagier in 1975, he said: "There are two facts about the distribution of prime numbers of which I hope to convince you so overwhelmingly that they will be permanently engraved in your hearts. The first is that, [they are] the most arbitrary and ornery objects studied by mathematicians: they grow like weeds among the natural numbers, seeming to obey no other law than that of chance, and nobody can predict where the next one will sprout. The second fact is even more astonishing, for it states just the opposite: that the prime numbers exhibit stunning regularity, that there are laws governing their behavior, and that they obey these laws with almost military precision." (Havil, 2003, [3]*)"*

To put prime numbers into context, let´s begin by saying anecdotally, as late as 20,000 years ago humans marked the bone of Ishango with 19, 17, 13, 11 [4] and 2,000 years ago Euclid prove that there are infinitely many prime numbers [5]. Later, Euler made another formal proof of it [6].

The problem of recognizing the primality of numbers was confronted from the Sieve of Eratosthenes (circa 200 BC) [7] passing for the fast Lucas-Lehma primality test [8] until the deterministic primality test developed by Agrawal, Kayal and Saxena (2004) [9].

Many questions around prime numbers remain open. Often having an elementary formulation, many of these conjectures have withstood a proof for decades: all four of Landau's problems from 1912 [10] are still unsolved. Goldbach's conjecture: "every even integer greater than 2 can be expressed as the sum of two primes" [11], the twin prime conjecture: "there are infinitely many pairs of primes whose difference is 2" [12]. Legendre´s Conjecture: "there is a prime number between n^2 and $(n+1)^2$ for every positive integer n" [13] and that there are infinite prime numbers of the form a^2+1" (e.g. Euler, 1764) [14]. Some other famous patterns of primes have also been conjectured with like the order the French monk Marin Mersenne devised of the form $2^p - 1$, with p a prime [15] from which today the Great Internet Mersenne Prime Search (GIMPS) is looking for another even larger prime [16], the conjecture whether there are infinite Fermat's primes of the form $F_y = 2^{2^y} + 1$ [17][18], and many other proposed patterns that are not mentioned here for simplicity, but no less interesting in any way.

The Riemman Zeta function and the Riemann hypothesis are closely related to prime numbers [19], they conjecture that all (nontrivial) zeros of $\zeta(s)$ have real part ½ on every prime coordinate [20] are still a mathematical challenge. Until now, there is no known efficient formula for primes, nor a recognizable pattern or sequence the primes follow. All recent publications dealing with this issue established that primes are distributed at random and looked more to a white noise distribution [21]. However, Riemann was able to observe a fluctuation in the density of prime numbers, which allowed him to correct the error between the function $Li(x)$ and the actual number of primes less than x, which we can see through the functions $W(a(x))$ and $W(b(x))$ developed in the present study about primes.

In relationship with Goldbach's Conjecture in number theory, Christian Goldbach (1742) [11] expressed: "*every even number greater than 2 can be written as the sum of two prime numbers*" known as Goldbach's "strong" conjecture. He also postulated that "*every odd number greater than 7 can be expressed as the sum of three odd prime numbers*", known as Goldbach's "weak" conjecture. This weak conjecture has been proven for sufficiently large n solving Vinogradov´s Theorem [22][23] and more recently a solution for all odd integers greater than 7 has been presented by Helfgott (2013) [24]. Here, an alternative solution for both conjectures will be presented.

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1. The prime numbers

The prime numbers (P) fill the space left by the multiplication of natural numbers greater than 1, for example, if we denote all natural numbers greater than 1 as the product of the multiplication between them by M (composite numbers) we can affirm that all natural numbers N would be equal to:

$$N=\{1\} \cup M \cup P \quad (1)$$

The distribution of prime numbers is a recurring theme of research in the theory of numbers (for example, Riemann (1859) [25], Dudley (1978) [26], Goldfeld (2003) [27].

Considering individual numbers, the primes seem to be distributed randomly, but the «global» distribution of prime numbers follows well-defined laws. For example, all prime numbers can only end in 1, 3, 7 and 9 starting from number 11, but not all the natural numbers ending in 1, 3, 7 and 9 are primes.

Some properties of primes:

- An integer $p > 1$ is prime if its only positive divisors are 1 and p.
- If an integer $q > 1$ is not prime, it is called composite number. Therefore, an integer q will be composite number if and only if there are positive integers a, b (smaller than q) such that $q = ab$.
- If p is a prime and dividing integer $a \cdot b$ product number, then p is divisor of a or b. (Euclid's Theorem, [5]).
- If p is prime and a is any natural number other than 1, then $a^p - a$ is divisible by p (Fermat's little theorem, [18]).
- If $\text{mcd}(a, b) = 1$, then a and b are primes among them or they are related primes.
- If p is prime, $p|x_1x_2x_3 \ldots x_n \Rightarrow p|x_i$ for some i.
- A number p is prime if and only if the factorial $(p-1)! + 1$ is divisible by p. (Wilson theorem) [28].
- If n is a natural number, then there will always be a prime number p such that $n < p < 2n$. Bertrand Postulate (1845) [29]).
- The number of primes smaller than a given x follows an asymptotic function $f(x) = \frac{x}{\ln x}$. (Prime number Theorem, Gauss (1801) in [30]).
- The fundamental theorem of arithmetic establishes that any integer greater than 1 is either a prime or can be expressed as a product of primes. That decomposition is unique, except the order of the factors. The theorem says that every positive integer greater than 1 can be written as a product of prime numbers [6] negating the primality of 1 in the Totien function (Euler, 1760) [31].
- If a number n is composite, it is verified that it must have a prime divisor less than or equal to its square root.
- The root n>1 of a prime number p, is always irrational [32].
- There are infinite primes. (Euclid, [5]).

1.1 The prime number Theorem

The prime number theorem states that:

$$\Pi(x) / x \quad \cong \quad 1 / \ln x \quad (2)$$

For large values of x.

Where $\Pi(x)$, is the amount of prime numbers that can be below an x value, Gauss (1801) [30].

One of the most important consequences in (2) is that the value of $\Pi(x)$ approximates to $x/\ln x$ as $x \to \infty$.

Hadamard (1893) [33] and De la Vallée Poussin (1896) [34] independently demonstrated the theorem. Both demonstrations were based on the notion that the Riemann $\xi(z)$ Zeta Function only has zeros in the form $\frac{1}{2}+it$ with $t > 0$ obtaining independently of the other, a definitive demonstration of:

$$\Pi(x) \approx Li(x) \quad (3)$$

Where *Li(x),* is the integral logarithm function:

$$Li(x) = \int_2^x \frac{dy}{ln\,(y)} \quad (4)$$

Subsequently, Helge Von Koch (1901) [35] showed that if the Riemann's hypothesis was true, there was a more accurate estimate:

$$\Pi(x) = Li(x) + O(\sqrt{x} lnx)$$

The best current approximation [36] given by:

$$\Pi(x) = Li(x) + O\left[x \,.\, exp(-\frac{A(ln\,x)^{3/5}}{(ln\,ln\,x)^{1/5}})\right] \quad (5)$$

Where *O[f(x)]* is defined as a function of equal order that *f(x)* and *A* is an undetermined constant.

On the other hand, Tchebychev (1852) [37] showed that *p*(*x*)/(*x/ln_x*) for large *x* was in between:

$$0.92129 \leq \frac{\Pi(x)}{\frac{x}{ln\,x}} \leq 1.10555 \quad (6)$$

Likewise Sylvester (1881) [38] improved the result above and was able to demonstrate that the limit established in [37] for *Π*(*x*)/(*x/ln x*) was in the interval:

$$0.956 \leq \frac{\Pi(x)}{\frac{x}{ln\,x}} \leq 1.045 \quad (7)$$

1.2 The function $W(a(x)) = ln\,(a(x))$

Given the difficulty to find the true value of the amount of primes $\Pi(x)$ in a different form of the function $\frac{x}{\ln x}$, $Li(x)$ proposed by Gauss, or those found from the Riemann function $F(x)$, here it is proposed that the true value lies in:

$$\Pi(x) = \frac{x\,W(a(x))}{\ln x} = \frac{x \cdot ln\,(a(x))}{\ln x} \quad (8)$$

Where $3.50805 > a(x)$ and $a(x) \to e$ when $x \to \infty$, e is the Napier constant or Euler number (2.71828182845905 ..., the base for natural logarithms). The function $W(x)$ allowed better analysis of the oscillating movement of the density of prime numbers, depending on the separation between two consecutive primes and the limit values found in [37] and [38].

With equation (8) Table I was constructed giving values to x and $a(x)$ to get the exact value for $\Pi(x)$ less or equal to x. It is possible to see how $a(x) \to e$ when $x \to \infty$, which is consistent with the theorem of primes, taking into account that if $a(x) \to e$ when $x \to \infty$, $\lim_{a \to e} \ln a(x) = \ln e = 1$.

Table I. Behavior of $a(x)$ when $x \to \infty$

x	*Π*(*x*)	*a*(x)	*x ln a*(*x*)/ln x	ln *a*(*x*)
2	1	*2*	2.000	0.6931
10	4	2.5100000000	4.00	0.9203
19	8	3,4548000000	8.00	1.2398
113	30	3.5080000000	30.00004	1.2550
1,000	168	3.1916000000	168,00	1.1605
10,000	1,229	3.1017000000	1,229.00	1.1320
100,000	9,592	3.0171800000	9,592.00	1.1043
1,000,000	78,498	2.9579308000	78,498.00	1.0845
10,000,000	664,579	2.9188064500	664,579.00	1.0712
100,000,000	5,61,455	2.8901234900	5,761,455.00	1.0613
200,000,000	11,078,937	2.8829223270	11,078,937.00	1.0588
300,000,000	16,252,325	2.8790095070	16,252,325.00	1.0574

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x	$\Pi(x)$	$a(x)$	$x \ln a(x)/\ln x$	$\ln a(x)$
400,000,000	21,336,326	2.8763444360	21,336,326.00	1.0565
500,000,000	26,355,867	2.8743377120	26,355,867.00	1.0558
600,000,000	31,324,703	2.8726869450	31,324,703.00	1.0552
700,000,000	36,252,931	2.8713541130	36,252,931.00	1.0548
800,000,000	41,146,179	2.8701868336	41,146,179.00	1.0544
900,000,000	46,009,215	2.8691480938	46,009,215.00	1.0540
1,000,000,000	50,847,534	2.8683213529	50,847,534.00	1.0537
10,000,000,000	455,052,512	2.8513630145	455,052,512.00	1.0478

The corresponding values of a graph $a(x)$ with respect to x, (Table I), are shown in Figure 1.

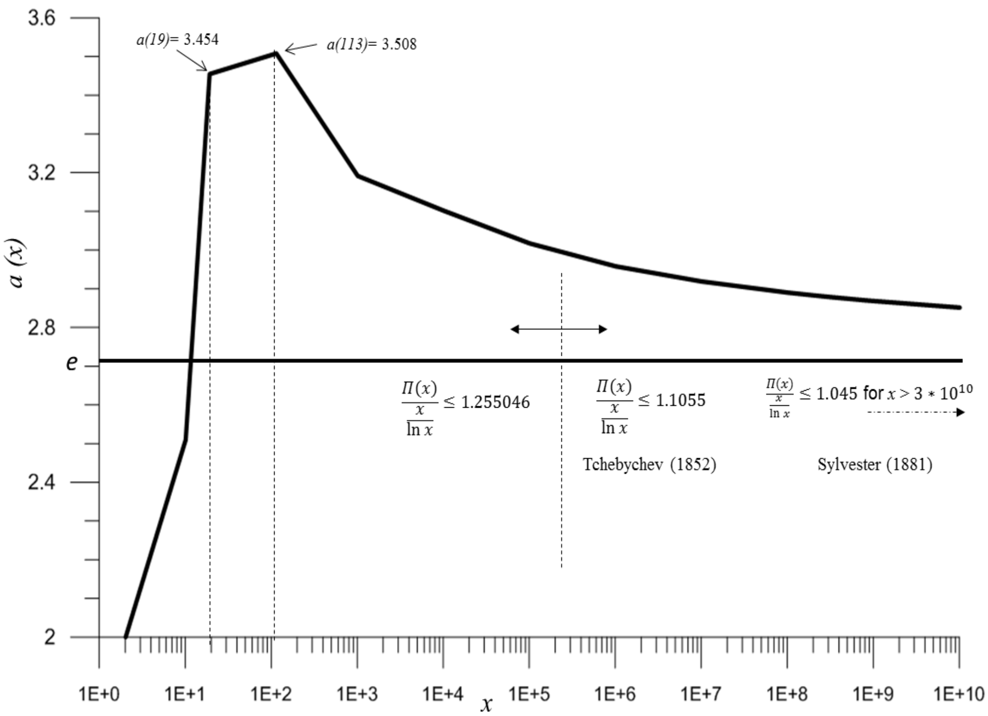

Fig. 1: The behavior $a(x)$ when $x \to \infty$ $(10 \leq x \leq 10^{10})$

In Figure 1, it is possible to see that the maximum value of $a(113) = 3{,}3508$ (absolute maximum), is obtained with $x = 113$ (113 is prime) and as $a(x) \to e$, as $x \to \infty$. This function also checked the limits set by Tchebychev (1852) and Sylvester (1881) in the sense that there are three regions of the behavioral boundary of $\frac{\Pi(x)}{\frac{x}{\ln x}}$. The first region is for values of $x \leq 10^5$, where $\frac{\Pi(x)}{\frac{x}{\ln x}} \leq 1.255046$. The second is to the limit set in [37], $10^5 < x$, where $\frac{\Pi(x)}{\frac{x}{\ln x}} \leq 1.1055$. The third is established in [38], which corresponds to large values of x above $3 * 10^{10}$, where $\frac{\Pi(x)}{\frac{x}{\ln x}} \leq 1.045$. Those limits tend to 1, when $x \to \infty$.

There is another interesting fact about the behavior of $a(x)$, which is that whenever the value of x coincides with a prime number, the value of $a(x)$ is a point maximum (relative maxima), this is the error $E(x)$ between $\frac{x}{\ln x}$ and $\Pi(x)$. Whenever x is prime, $a(x)$ reaches a maximum (absolute maximum with $p = 113$ and relative maximum with $x = p_n$ where p_n are the rest of primes.)

This is shown in an enlargement of the Table I, given in Table II, for $a(x)$ in $2 \leq x \leq 34$ and Figure 2.

Table II. The behavior of $a(x)$ between $2 \leq x \leq 34$.

x	*Π*(x)	*a*(*x*)	x ln (*a*(*x*))/ln *x*
2	1	2.000	2.00
3	2	2.080	2.00
4	2	2.000	2.00
5	3	2.623	3.00
6	3	2.450	3.00
7	4	3.040	4.00
8	4	2.830	4.00
9	4	2.658	4.00
10	4	2.510	4.00
11	5	2.975	5.00
12	5	2.815	5.00
13	6	3.264	6.00
14	6	3.100	6.00
15	6	2.956	6.00
16	6	2.830	6.00
17	7	3.210	7.00
18	7	3.078	7.00
19	8	3.4548	8.00
20	8	3.316	8.00
21	8	3.190	8.00
22	8	3.077	8.00
23	9	3.410	9.00
24	9	3.295	9.00
25	9	3.185	9.00
26	9	3.090	9.00
27	9	3.000	9.00
28	9	2.9200	9.00
29	10	3.195	10.00
30	10	3.107	10.00
31	11	3.384	11.00
32	11	3.290	11.00

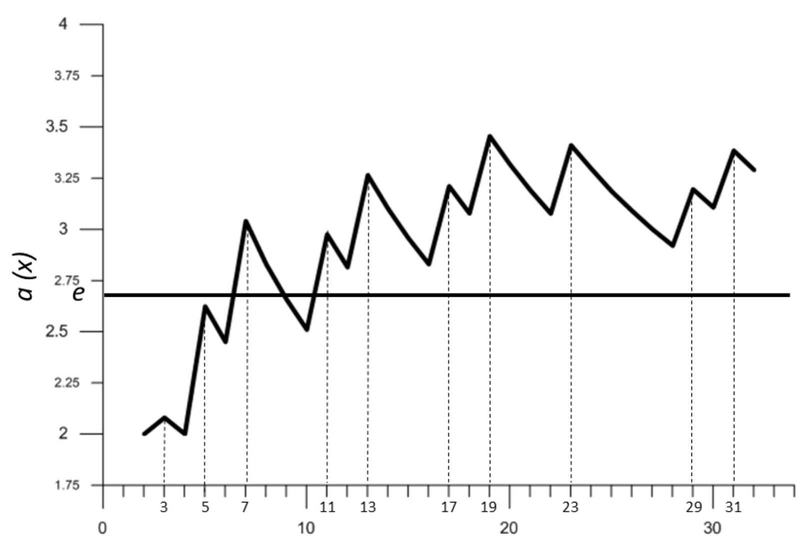

Fig. 2: Graph of the behavior of $a(x)$ on the interval ($0 \leq x \leq 32$). The graph shows the coincidence between relative maximum of *a(x)* and *x*= prime.

Additionally Figure 2 shows how the separation between two consecutive primes change the oscillation of $a(x)$. For example, if there are two double twin primes in a row, then $a(x)$ oscillates faster in ascending order than if there is a large gap between followed primes, where the swing is slower and the values of $a(x)$ decreases, keeping the slope of $a(x)$ constant. The above is shown in Figure 3. For example, if there are not infinite twin primes when $x \to \infty$, then will be impossible that $\lim_{x\to\infty} a(x) = e$, because the value of $a(x)$ would continue to decrease and the prime number theorem would be false.

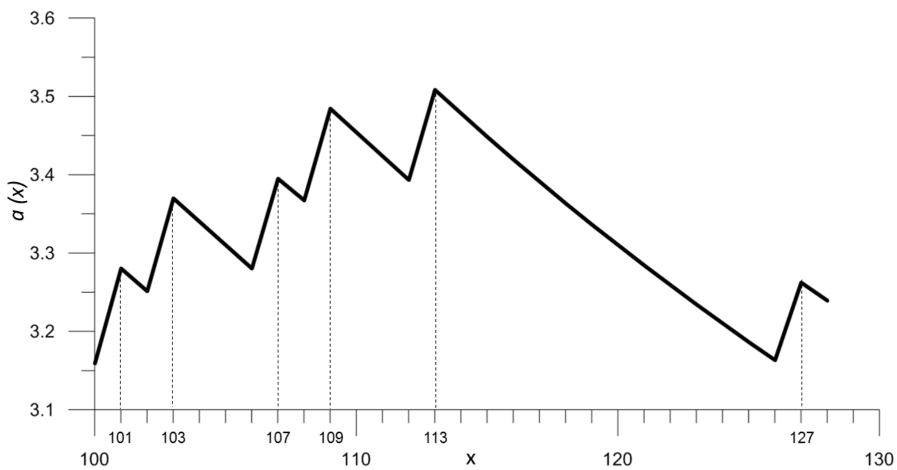

Fig. 3: Graph of the behavior of $a(x)$ on $(100 \leq x \leq 128)$

1.3 The function $W\big(b(x)\big) = ln\ (b(x))$

In relation to the error E (x) between the integral logarithm functions $Li(x)$ and $\Pi(x)$, there can be found a corrector term called $W\big(b(x)\big) = \ln(b(x))$ in such a way that:

$$\Pi(x) = W(b(x))\cdot Li(x) = \ln(b(x)) \int_2^x \frac{dt}{\ln t} \quad (9)$$

Where $b(x) \to e$ when $x \to \infty$.

The corresponding graph of the values of $b(x)$ with respect to x in Table III is shown in Figure 4, where it is possible to see that the maximum value is that of $b(3) = 5{,}964$ (absolute maximum). As happened with function $a(x)$, the $b(x)$ relative maximum match when x is a prime number.

Table III. Values of $\Pi(x), b(x), Li(x)$ and $\ln b(x) \cdot Li(x)$ for $3 \leq x \leq 8 \cdot 10^8$

x	$\Pi(x)$	$b(x)$	$Li(x)$	$\ln b(x) \cdot Li(x)$
3	2	5.964	1.12	2.00
10	4	2.184201	5.12	4.00
13	6	2.57251	6.35	6.00
18	7	2.35313	8.18	7.00
19	8	2.557339	8.52	8.00
41	13	2.37077	15.06	13.00
100	25	2.36244568	29.08	25.00
113	30	2.56413089	31.86	30.00
1,000	168	2.5896376	176.56	168.00
10,000	1,229	2.68338	1,245.09	1,229.00
100,000	9,592	2.707923	9,628.76	9,592.00
1,000,000	78,498	2.713843	78,626.50	78,498.00
10,000,000	664,579	2.716899	664,917.34	664,579.00
100,000,000	5,761,455	2.717926526	5,762,208.22	5,761,455.00

x	$\Pi(x)$	$b(x)$	$Li(x)$	$\ln b(x) \cdot Li(x)$
200,000,000	11,078,937	2.718027535	11,079,973.57	11,078,937.00
400,000,000	21,336,326	2.718147975	21,337,376.72	21,336,326.00
600,000,000	31,324,703	2.718165462	31,326,044.06	31,324,703.00
800,000,000	41,146,179	2.718170704	41,147,861.18	41,146,179.00

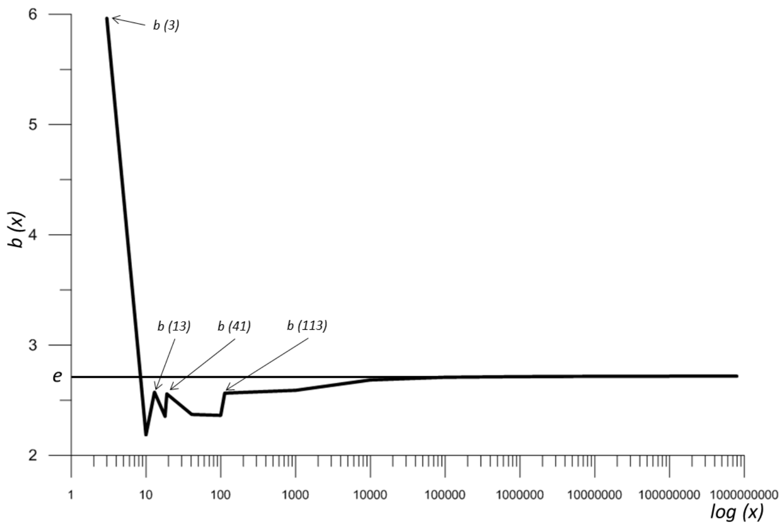

Fig. 4: Graph of (x) for $3 \leq x \leq 8 \cdot 10^8$. The graph shows the relative maximum values of *b(x)* tending to *e* for large values of *x*.

Figure 5 compares $a(x)$ vs. $b(x)$ for large values of x ($10^8 \leq x \leq 8 \cdot 10^8$) with data obtained from Table I for $a(x)$ and Table III for $b(x)$. Vertical values have different scales in order to present both curves in the same figure. It is possible to see how $a(x)$ and $b(x)$ tend to e when $x \to \infty$. The first curve above e tends toward e more slowly, and the second curve below e more quickly.

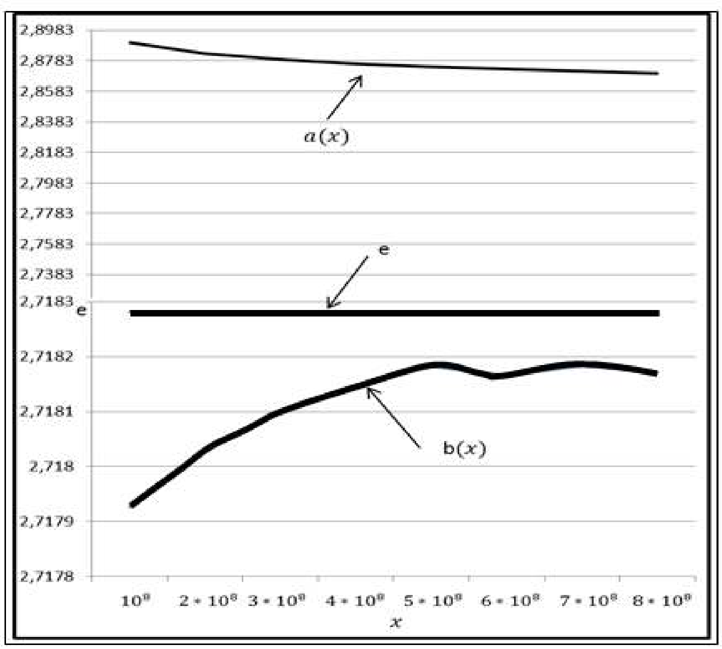

Fig. 5: Graph of $a(x)$ and $b(x)$ for $10^8 \leq x \leq 8 \cdot 10^8$. Both curves tend to e when $x \to \infty$.

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2. The formation of the prime numbers

It would seem that it is not possible to obtain more information on the formation of the primes, however sorting them, in a table of 30 columns by endless rows as shown in Table IV and V, there are valuable conclusions of how to obtain prime numbers, without the need to resort to the Sieve of Eratosthenes, established by Eratosthenes in the 3rd century BC [7].

Table IV. The formation of prime numbers ($n = 0$ to 33). The prime numbers organized in a 30 column table form precisely along eight columns (1,7,11,13,17,19, 23 and 29)

n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Total
0			2	3		5		7				11		13				17		19				23						29	10
1		31						37				41		43				47						53						59	7
2		61						67				71		73						79				83						89	7
3								97				101		103				107		109				113							6
4								127				131						137		139										149	5
5		151						157						163				167						173						179	6
6		181										191		193				197		199											5
7		211												223				227		229				233						239	6
8		241										251						257						263						269	5
9		271						277				281		283										293							5
10								307				311		313				317													4
11		331						337										347		349				353						359	6
12								367						373						379				383						389	5
13								397				401								409										419	4
14		421										431		433						439				443						439	6
15								457				461		463				467												479	5
16								487				491								499				503						509	5
17												521		523																	2
18		541						547										557						563						569	5
19		571						577										587						593						599	5
20		601						607						613				617		619											5
21		631										641		643				647						653						659	6
22		661												673				677						683							4
23		691										701								709										719	4
24								727						733						739				743							4
25		751						757				761								769				773							5
26								787										797												809	3
27		811										821		823				827		829										839	6
28														853				857		859				863							4
29								877				881		883				887													4
30								907				911								919										929	4
31								937				941						947						953							4
32								967				971						977						983							4
33		991						997												1009				1013						1019	5
Total		18	1	1		1		24				22		20				22		19				22						21	171

Table V. The formation of prime numbers ($n = 34$ to 67)

n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Total
34		1021										1031		1033						1039										1049	5
35		1051										1061		1063						1069											4
36								1087				1091		1093				1097						1103						1109	6
37								1117						1123						1129											3
38												1151		1153										1163							3
39		1171										1181						1187						1193							4
40		1201												1213				1217						1223						1229	5
41		1231						1237												1249										1259	4
42																		1277		1279				1283						1289	4
43		1291						1297				1301		1303				1307												1319	5
44		1321						1327																							2
45												1361						1367						1373							3
46		1381																		1399										1409	3
47														1423				1427		1429				1433						1439	5
48								1447				1451		1453						1459											4
49		1471										1481		1483				1487		1489				1493						1499	7
50												1511												1523							2
51		1531												1543						1549				1553						1559	5
52								1567				1571								1579				1583							4
53								1597				1601						1607		1609				1613						1619	6
54		1621						1627										1637													3
55								1657						1663				1667		1669											4
56														1693				1697		1699										1709	4
57												1721		1723										1733							3
58		1741						1747						1753						1759											4
59								1777						1783				1787		1789											4
60		1801										1811												1823							3
61		1831																1847													2
62		1861						1867				1871		1873				1877		1879										1889	7
63												1901						1907						1913							3
64												1931		1933																1949	3
65		1951												1973																1979	3
66																		1997		1999				2003							3
67		2011						2017										2027		2029										2039	4
Total		17						14				17		19				18		19				16						16	136

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The study of tables IV and V, allows obtain the following information:

In columns: 0, 2, 3, 4, 5, 6, 8, 9, 10, 12, 14, 15, 16, 18, 20, 21, 22, 24, 25, 26, 27 and 28, there are not "formation" of primes, with the exception of the first row of columns 2, 3 and 5, where 2, 3 and 5 are prime numbers. The reason is that in these columns are situated composite numbers only for some $n \in \mathbb{Z}_0^+$:

1. Column 0 have composite numbers of the form $0 + 30n \equiv 0\ (mod\ 2), (mod\ 3), (mod\ 5)$
2. Column 2 have composite numbers of the form $2 + 30n \equiv 0\ (mod\ 2)$
3. Column 3 have composite numbers of the form $3 + 30n \equiv 0\ (mod\ 3)$
4. Column 4 have composite numbers of the form $4 + 30n \equiv 0\ (mod\ 2)$
5. Column 5 have composite numbers of the form $5 + 30n \equiv 0\ (mod\ 5)$
6. Column 6 have composite numbers of the form $6 + 30n \equiv 0\ (mod\ 2), (mod\ 3)$
7. Column 8 have composite numbers of the form $8 + 30n \equiv 0\ (mod\ 2)$
8. Column 9 have composite numbers of the form $9 + 30n \equiv 0\ (mod\ 3)$
9. Column 10 have composite numbers of the form $10 + 30n \equiv 0\ (mod\ 2), (mod\ 5)$
10. Column 12 have composite numbers of the form $12 + 30n \equiv 0\ (mod\ 2), (mod\ 3)$
11. Column 14 have composite numbers of the form $14 + 30n \equiv 0\ (mod\ 2)$
12. Column 15 have composite numbers of the form $15 + 30n \equiv 0\ (mod\ 3), (mod\ 5)$
13. Column 16 have composite numbers of the form $16 + 30n \equiv 0\ (mod\ 2)$
14. Column 18 have composite numbers of the form $18 + 30n \equiv 0\ (mod\ 2), (mod\ 3)$
15. Column 20 have composite numbers of the form $20 + 30n \equiv 0\ (mod\ 2, (mod\ 5)$
16. Column 21 have composite numbers of the form $21 + 30n \equiv 0\ (mod\ 3)$
17. Column 22 have composite numbers of the form $22 + 30n \equiv 0\ (mod\ 2)$
18. Column 24 have composite numbers of the form $24 + 30n \equiv 0\ (mod\ 2), (mod\ 3)$
19. Column 25 have composite numbers of the form $25 + 30n \equiv 0\ (mod\ 5)$
20. Column 26 have composite numbers of the form $26 + 30n \equiv 0\ (mod\ 2)$
21. Column 27 have composite numbers of the form $27 + 30n \equiv 0\ (mod\ 3)$
22. Column 28 have composite numbers of the form $28 + 30n \equiv 0\ (mod\ 2)$

The remaining eight columns 1, 7, 11, 13, 17, 19, 23 and 29 are the only ones where primes are formed, except primes 2, 3 and 5 that are the unique primes formed in these columns. All other primes can only have the following form (not in all n rows):

1. Column 1 have prime numbers $1 + 30n$ to $n > 0$ since 1 is not prime
2. Column 7 have prime numbers $7 + 30n$
3. Column 11 have prime numbers $11 + 30n$
4. Column 13 have prime numbers $13 + 30n$
5. Column 17 have prime numbers $17 + 30n$
6. Column 19 have prime numbers $19 + 30n$
7. Column 23 have prime numbers $23 + 30n$
8. Column 29 have prime numbers $29 + 30n$

If all primes formed in their respective columns, are subtracted by the first number 1, 7, 11, 13, 17, 19, 23 and 29, they all have a common factor equal to 30n, which indicates a well-defined pattern in their formation. As well as all natural numbers N have a well-defined pattern to $n \geq 0$ given by:

$$N = [0, 1, 2, 3, 4, 5, 6, 7, 8\ y\ 9] + 10n \qquad (10)$$

All prime numbers P from $n \geq 0$, except 2, 3, 5 (are primes) and 1 (is not prime) for $n = 0$, have a defined pattern given by:

$$P = [1, 7, 11, 13, 17, 19, 23, 29] + 30n \qquad \text{for some } n \in \mathbb{Z}_0^+ \qquad (11)$$

Additionally, some other conclusions on the regularity of the primes can be drawn:

1. The twin primes p_t (highlighted in yellow and blue in Tables IV and V), can only be formed in columns (11, 13), (17, 19) and (29, 1). i.e. all p_t (except 3, and 5) would have the following form:

$$[11, 13] + 30n = p_t$$
$$[17, 19] + 30n = p_t$$
$$[29, 31] + 30n = p_t$$

2. The central columns (11, 13, 17, 19), are the only ones where the consecutive doubles twin primes p_{td} are formed and have the following form:

$$[11, 13, 17, 19] + 30n = p_{td} \tag{12}$$

3. There are two solitary columns where primes are formed: columns (7 and 23).

4. Columns (1, 11), (7, 17) and (19, 29), where primes are formed, are separated by 10 columns.
5. There is a regularity in the percentage of primes ending in 1, 3, 7 and 9 as shown in Table VI and it is approximately 25%, (the Primes 2 and 5 are not included because they are the only ones that end in 2 and 5):

Table VI. Percentages of primes ending in 1, 3, 7, 9 from Tables 1 and 2

Primes ending in:	Until n=33	% until n=33	From n=34 until n=67	% from n=34 until n=37	From n=0 until n=67	% from n=0 until n=67
1	40	23.67	34	25,00	74	24.26
3	43	25.44	35	25.74	78	25.57
7	46	27.22	32	23.53	78	25.57
9	40	23.67	35	25.74	75	24.59
Total	169	100	136	100	305	100

6. There is not a complete row in which the cells in all 8 columns have primes.

7. The composite numbers N_c of the cells of the columns where the primes are formed (therefore there are not primes there), can contain one, two, or more different prime factors (which come from the columns where primes are formed) that produce other cells n where there are no primes. For example, take the eight columns as shown in Tables IV and V, where there are composite number:
$$N_c = (1, 7, 11, 13, 17, 19, 23, 29) + 30n \qquad \text{for some } n \in \mathbb{Z}_0^+ \tag{13}$$

These composite numbers are decomposed into its prime factors $p_1, p_2, \ldots, p_n$ and there won't exist prime numbers in cells:

$$n = \begin{bmatrix} n_1 + p_1 k \\ n_1 + p_2 k \\ n_1 + p_m k \end{bmatrix} \Rightarrow k \in \mathbb{Z}_0^+ \tag{14}$$

Where n would be the row number where there are not primes, n_1 the first row in any of the 8 columns where primes are formed and where for the first time N_c appears decomposed into its prime factors $p_1, p_2, \ldots, p_n$. From the n_1 cell, the table of multiplication of the $p_1, p_2, \ldots, p_n$ primes start to create conforming the composite number N_c.

8. Prime numbers p that originate in the respective column and row n_1, removes the cells $n = n_1 + pk \; to \; k \geq 1$ where there are no primes. For example the prime $p = 47$ (row 1 of the column 17),

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removes the cells $n = 1 + 47k \ to \ k \geq 1$. The prime $p = 1229$ (row 40 of the column 29), removes the cells $n = 40 + 1229k \ to \ k \geq 1$.

The above allows to quickly "remove" all cells n in their respective column where there are no primes, allowing the calculation in simple way, n cells, where there are primes and applying equation (11) for the n value, to obtain the respective value of the corresponding prime.

Table VII. The "elimination" of n cells where there are no primes, using the equation (12)

n Column 1	Composite number	Prime factors	n equation $\rightarrow k \in Z^+ + \{0\}$
3	91	7 - 13	$n = 3 + 7k$ $n = 3 + 13k$
4	121	11	$n = 4 + 11k$
10	301	7 - 43	$n = 3 + 7k$ $n = 10 + 43k$
12	361	19	$n = 12 + 19k$
13	391	17 - 23	$n = 13 + 17k$ $n = 13 + 23k$
15	451	11 - 41	$n = 4 + 11k$ $n = 15 + 41k$
16	481	13 - 37	$n = 3 + 13k$ $n = 16 + 37k$
17	511	7 - 73	$n = 3 + 7k$ $n = 17 + 73k$
24	721	7 - 103	$n = 3 + 7k$ $n = 24 + 103k$
26	781	11 - 71	$n = 4 + 11k$ $n = 26 + 71k$
28	841	29	$n = 28 + 29k$
29	871	13 - 67	$n = 3 + 13k$ $n = 29 + 67k$
30	901	17 - 53	$n = 13 + 17k$ $n = 30 + 53k$
31	931	7 - 19	$n = 3 + 7k$ $n = 12 + 19k$
32	961	31	$n = 32 + 31k$

This process facilitates very efficiently, how to get primes by computer (Annex "C" and "D", in a different way from Riesel, 1994, [40] and Crandall, 2001, [21]). For example taking the equations from Table VII, the following cells in column 1 to row 35 does not contain primes for $k \geq 0$ and the rest of the cells from the row 35 that match equation (15):

$$n = \begin{bmatrix} 3 + 7k \\ 3 + 13k \\ 4 + 11k \\ 10 + 43k \\ 12 + 19k \\ 13 + 17k \\ 13 + 23k \\ 15 + 41k \\ 16 + 37k \\ 17 + 73k \\ 24 + 103k \\ 26 + 71k \\ 28 + 29k \\ 29 + 67k \\ 30 + 53k \\ 32 + 31k \end{bmatrix} \quad (15)$$

In the array above:

1. All primes 7, 11, 13, 17, 19, 23 and 29 in row 0 appear in equation (13) at some point to generate cells that do not contain primes. The same thing happens with the primes of row 1, and so on.
2. The n row where primes are not generated can be predicted using the remainder to take it to 0. Examples for $p = 7$ and $p = 17$:
   a. In row 1 column 1: $31 \div 7 \equiv 3$ $(mod\ 7)$. In row 2 column 1: $61 \div 7 \equiv 5$ $(mod\ 7)$. That is the increment factor is $5 - 3 = 2$. The remainder 3 becomes 0 in $\frac{7-3}{2} = 2$, i.e. in the row $n = 1 + 2 = 3$ there is a multiple of 7 and $n = 3 + 7k\ to\ k \geq 0$, therefore there will be no prime numbers.
   b. In row 1 column 1: $31 \div 17 \equiv 14$ $(mod\ 17)$. In row 2 column 1: $61 \div 17 \equiv 10$ $(mod\ 17)$. That is the reduction factor is $14 - 10 = 4$. The remainder 14 becomes 0 in $\frac{2*17+14}{4} = 12$ i.e. in the row $n = 1 + 12 = 13$ there is a multiple of 17 and in $n = 13 + 17k\ to\ k \geq 0$ there are no prime numbers. Note: Here it was required to multiply 17 by 2, since the number of rows is always an integer.
   c. The procedure to find the rows where there are no primes is as follows:
   In row x, find the remainder or residue r_x, dividing [1, 7, 11, 13, 17, 19, 23, 29] $+30x$ by the prime p, where $p <$[1, 7, 11, 13, 17, 19, 23, 29]$+30x$; i.e. [1, 7, 11, 13, 17, 19, 23, 29]$+30x \equiv r_x\ (mod\ p)$; then the increase or reduction factor is calculated for row $x + 1$ where $a =| r_x - r_{x+1}$ |. The row $n_1 = x + \frac{bp \pm r_x}{a}$ do not have primes and generally in $n = n_1 + pk\ to\ k \geq 0$ there are no primes. The factor b is the smallest integer that makes $\frac{bp \pm r_x}{a}$ integer, as explained in example for $p = 17$. The sign (±) depend on: If the factor is increased then the sign is $(-)$ and if reduction then the sign is $(+)$. See examples a. and b.

With these recognized behavior of prime numbers most conjectures related to their rhythm can be easily evaluated and the velocity on producing them may speed up by many fold factors, thus improving all capacities for future use of prime numbers.

Further simplification of the equation (11) can be achieved to only two possibilities of how prime numbers are formed. With the exception of the primes 2 and 3, by means of Equation (16), taking into account that the primes p = [5, 7, 11, 13, 17, 19, 23, 29], can be transformed to two forms, $(5 + 6m)$, $(7 + 6m)$ and $30n = 6m$, then:

$$p_n = [5, 7] + 6m \text{ for some } m \in \mathbb{Z}_0^+ \qquad (16)$$

3 Demonstration of some theorems and the "strong" and "weak" Goldbach's conjectures

3.1 The two fundamental theorems of the Prime Numbers and the Composite Numbers

1. Given that the 22 columns where only composite numbers are formed have a factor mod (2, 3, 5) and these numbers all are primes, all the composite numbers in these 22 columns will have at least one prime number that compose it. In the other 8 columns where primes and composite numbers are formed, the latter have at least one prime that compose it, therefore all the composite numbers must have at least one prime number that compose it. Example the composite number 49 is formed only by the prime number 7, i.e. all composite numbers of the form $N_c = {p_n}^x$ to $n \geq 1$ and $x \geq 2$, where p_n is the nth prime number, comprise only a prime p_n.
2. Primes are infinite, if not, it would be a composite number that does not contain at least one prime, i.e. it would not be a composite number it would be a prime, which verifies that the primes are infinite. Additionally, in each of the 8 columns where the primes are formed, infinite primes are formed according to equation (9) when $n \to \infty$.
   The initial demonstration of the infinitude of primes is done by Euclid (325-265 BC) in "The elements" books VII-IX, [5]:

"*The number of prime numbers is infinite*"

To prove this theorem Euclid assumed that there are a number of finite primes and was able to show that there is another prime apart from those already considered.

Proof:

Suppose that $p_1, p_2, p_3, \ldots., p_n$ are all possible primes. Being q the integer $q = p_1 \cdot p_2 \cdot p_3 \cdots p_n + 1$. Since $q > p_i$, for all $i = 1, 2, 3, \ldots., n$ therefore, q can be prime or composite number. If it is composite number, by the Fundamental Theorem of arithmetic is obtained that q has a prime divisor p, which should be one of the numbers $p_1, p_2, p_3, \ldots., p_n$. On the other hand, it is clear that $p \mid (p_1 \cdot p_2 \cdot p_3 \cdots p_n$. By the property of division p must divide the number $q - p_1 \cdot p_2 \cdot p_3 \cdots p_n = 1$ therefore $p = 1$, which contradicts the primes definition. If q is prime, it is now clear that it could not be contained in $(p_1 \cdot p_2 \cdot p_3 \cdots p_n$ because $q > p_1 \cdot p_2 \cdot p_3 \cdots p_n$.

Thus, Euclid proved that the primes are infinite.

This way of proving the infinitude of the primes made by Euclid saved a direct relationship with the primes of the column $1 + 30n$ of Tables 1 and 2 for $n \geq 1$. By taking into account that 2, 3 and 5 are primes, their multiplication is $2 \cdot 3 \cdot 5 = 30$, and in this case n is the multiplication of all the primes together from the prime number 7 ($n = 7 \cdot 11 \cdot 13 \cdots p_n$), the rest of the primes of columns: [7,11,13,17,19,23,29]+$30n$ for $n \in \mathbb{Z}_0^+$ would be included within this demo to be infinite primes, so there are infinite primes in each of the eight columns where the primes are formed.

3.2 Solutions to the "strong" and "weak" Goldbach's conjectures

In number theory, Goldbach's strong conjecture (1742) [11], is one of the older open problems in mathematic. The conjecture states that:

"*Every even number greater than 2 can be written as the sum of two primes*".

In the form of a mathematical expression, Goldbach's strong conjecture can be expressed by:

$$x = p_n + p_{n+h} \tag{17}$$

Where x is the even number, p_n and p_{n+h} are the nth prime and the $(n + h)$th prime numbers, being $n \geq 1$ and $h \geq 0$.

Assuming that p_n is the largest possible prime number less than or equal to y ($p_n \leq y$), it would be sufficient that the next prime number p_{n+1} above y would be greater than $2p_n - 1$, (where $p_n \leq y < p_{n+1} \Rightarrow y \in Z^+$) for the Goldbach's strong conjecture is not be fulfilled: If $p_n = y$, the even number $2y$ would fulfilled the conjecture, but the even number $2p_n + 2$ does not meet it:

If $p_{n+1} = 2p_n + k, odd\ k \geq 1 \Rightarrow k \in Z^+$would the nearest even number to p_{n+1}, the sum of two primes would be $2p_n + 3$, therefore the pair $2p_n + 2$ would be excluded.

Test:

1. Evidently the conjecture is true for all even number equal to $2p_n$ and for every even number that result of the sum of two odd primes.
2. $2p_n + 2$ would be the sum of three primes $(p_n + p_n + 2)$, taking into account that 2 is a prime number.
3. $2p_n + 2 < 2p_n + k + 3 = p_{n+1} + 3$, therefore it would not be the sum of two primes.

4. According to 2 and 3 the even number $2p_n + 2 \neq the\ sum\ of\ two\ primes$

Q.E.D.[1]

However, Bertrand's postulate demonstrated by Tchebychev [29] states that there is at least one prime between n and $2n$ - 2 for every $n > 3$, therefore the possibility of a prime p_{n+1} greater $2p_n - 1$ is ruled out by the existence of a prime in the interval [n, $2n$-2] for every $n > 3$ being the separation between consecutive primes $p_n - 2 < p_n - 1$. This implies that the conjecture must only be verified in the interval $[n, n - 2\text{n}]$ for each $n > 3$, according to Bertrand's postulate (Figure 7).

An analysis of Equation (16), using this same Bertrand's postulate shows, that there is at least one even number solution in the interval [0, 2y] for $y \geq 3$ for which this interval is divided into two, the intervals [0, y] and [y, 2y].

Making $n = y/2$ would be $2n - 2 = y - 2$, therefore Bertrand's postulate states that in the interval [y/2, y-2], there's always a prime for each $y \geq 6$, or in the interval [y/2, y], for each $y \geq 3$.

This is equivalent of saying that there is always an odd prime in the interval [0, y] , or in the interval [y, 2y], for each $y \geq 3$, where $y \in Z^+$. See Figure 7.

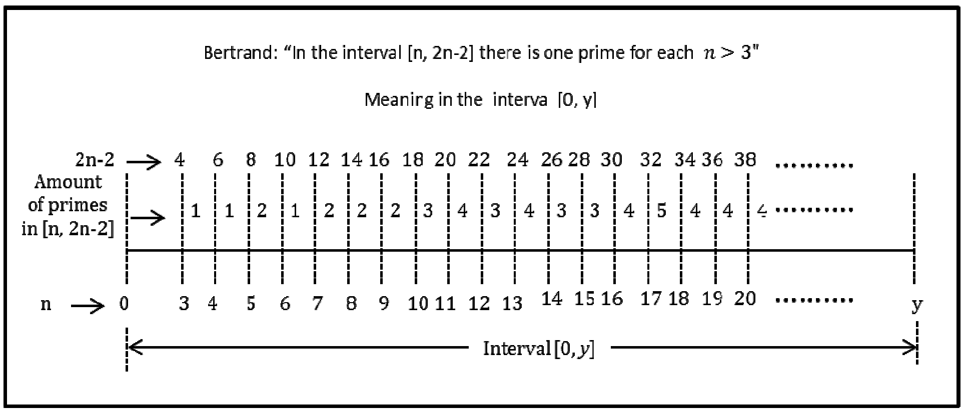

Fig. 7: Meaning of Bertrand's postulate (1845) in the interval [0, y]

From the Equation (17), $p_n \in [0, y]$, and $p_{n+h} \in [y, 2y]$ and assuming that both are odd primes (Figure 8) we conclude:

1. $y - p_n = a$ and $2y - p_{n+h} = b$

2. By adding the previous expressions we would have:

   $3y - (p_n + p_{n+h}) = a + b$ or: $3y - (a + b) = p_n + p_{n+h}$

3. As it was taken p_n and p_{n+h} odd, their sum would be even, therefore, $(a + b) = c$ where c must be even, i.e. $3y - c = x$, and x must be even.

4. Taking the first even number 6 which is the sum of two odd primes, we have:

5. $3y - c = x = p_n + p_{n+h} \geq 6$:

6. According to 1 and 6 (see Figure 8):
   a. a can only take values between $0 \leq a \leq y$
   b. b can only take values between $y \leq b < 2y$
   c. When $p_n = p_{n+h}$, or when $p_n \wedge p_{n+h}$,then $c = a + b = y$, that is, always $3y - c = 3y - y = 2y = x = p_n + p_{n+h}$.

[1] From latín - Quad Eran Demonstrandum -

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d. The values of p_n and p_{n+h} different from $p_n \wedge p_{n+h}$ are not taken into account, because $c \neq y$, and $p_n + p_{n+h} \neq 3y - c \neq 2y = x$ or we would be taking one prime plus one composite number, which contradicts Goldbach's strong conjecture.

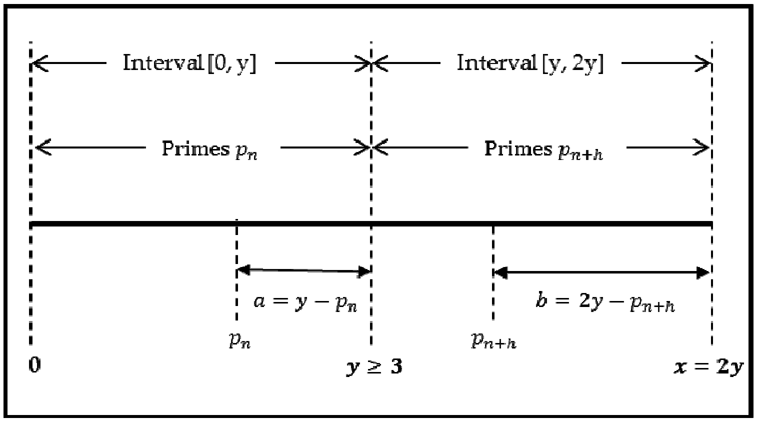

Fig. 8: Primes in the intervals [0, y] and [y, 2y]

7. According to 6 and 7: $x = p_n + p_{n+h}$ for $x \geq 6$ where $x = 2y$ is even number. It is always in the interval [0, 2y] for $y \geq 3$. There will always be an even solution for $x \geq 6$, and all $x = 2y$ with Equation (16), to ensure the existence of a prime at intervals [0, y] and [y, 2y] or two primes in the interval [0, 2y] for each $y \geq 3$ according to Bertrand's postulate. In addition, the even number 4 is included in the equation (16) when $p_n = p_{n+h} = 2$, being the only event that is as the sum of two primes being both even numbers. This is easily checked with Table VIII.

Table VIII. Verification that there is always at least one solution in the interval [0, 2y] to $y \geq 3$ and all $x = 2y$.

y	2y	x=2y	p_n in [0, y]	p_{n+h} in [y, 2y]	a values in [0, y]	b values in [y, 2y]	Total solutions in [0, 2y]
3	6	6	3	3-5	0	3	1
4	8	8	3	5-7	1	3	1
5	10	10	3-5	5-7	0,2	5,3	2
6	12	12	3-5	7-11	1	5	1
7	14	14	3-5-7	7-11-13	0,4	7,3	2
8	16	16	3-5-7	11-13	3,5	5,3	2
9	18	18	3-5-7	11-13-17	2,5	7,4	2
10	20	20	3-5-7	11-13-17-19	7,3	3,7	2
11	22	22	3-5-7-11	11-13-17-19	0,6,8	11,5,3	3
12	24	24	3-5-7-11	13-17-19-23	1,5,7	11,7,5	3
13	26	26	3-5-7-11-13	13-17-19-23	0,10,6	13,3,7	3

From the analysis of Table VIII, it is possible to determine the following:

- The increase of the interval $[0, y]$ and $[y, 2y]$ is always 1 and in the interval $[0, 2y]$ is 2 with respect to the previous interval.
- The increase of x is always $x + 2$ with respect to the previous x, because the previous x already have a solution at the sum of two primes that gives x, therefore in the new x, solutions are considered only where $x = 2y$ and $y = a + b$.
- The value of p_n in the interval $[0, y]$ is either the same of the previous interval $[0, y]$ or it increases because the first $p_{n+h} \leq y$ goes inside the interval $[0, y]$, with the increment of y.
- The value of p_{n+h} in the interval $[y, 2y]$ is either the same of previous interval $[y, 2y]$, or decrease when the first p_{n+h} goes inside the interval [0, y], or augment when appear a new $p_{n+h} < 2y$ inside that interval with the increment of y.

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- The total solutions of $x = 2y = p_n + p_{n+h}$ depends on the number of solutions that give $a + b = y$ in the interval $[0, 2y]$.
- We can see from $x = p_n + p_{n+h} \geq 6$ the even numbers $x + 2$ are also the sum of two primes, being the amount of sums of primes that give such an even number ≥ 1.
- The amount of sums that give an even number, is growing with the increase of y, as grows the amount of $p_n \leq y$ and the amount of $p_{n+h} < 2y$ in the intervals $[0, y]$ and $[y, 2y]$ respectively, i.e. there are more chances to combine p_n with p_{n+h} to find the even number, which will be checked with the pairs of primes counting function $C_{sp}(x)$ that give an even number x.

So far we can conclude that:

1. There must not be one separation between consecutive primes greater than: p_n-2 for Goldbach's strong conjecture to be false. The postulate of Bertrand (1845) confirmed that it is impossible.
2. Transforming Bertrand's postulate demonstrates the existence of a solution with prime numbers such that $x = p_n + p_{n+h}$ in the interval $[0, 2y]$, where $6 \leq x = 2y$ with $y \geq 3$, $y \in Z^+$ confirming that Goldbach's strong conjecture is true.

Q.E.D.

3.2.1 The pairs counter function C_{sp}(x), with both prime components in the interval [0, x] that together give the pair number x

With increase y and x in Equation (16), there must be many p_n and p_{n+h} that together gives the even number $x = 2y$, as it will be demonstrated with the pairs counter function C_{sp}(x), with both primes component in the interval $[0, x = 2y]$, that when add give the even number x.

Being that x even, there are $\frac{x}{4}$ forms to express it as the sum of two odd numbers and $\frac{x}{4}$ forms to express it as the sum of two even numbers, where these numbers are symmetrical with respect $\frac{x}{2} = y$. For example the number 20 can be expressed by (20=19+1=17+3=15+5=13+7=11+9 total of five forms combining odd numbers) or (20=18+2=16+4=14+6=12+8=10+10 total of five forms combining even numbers).

Being that $a \wedge a\bullet$ odd natural numbers, symmetric with respect to $\frac{x}{2}$, where x is the even number, there is no relationship of cause-effect between the odd numbers a and $a\bullet$ (symmetric with respect to $\frac{x}{2}$), in the form of combining two odd numbers to get x and taking into account that:

1. Both numbers can be composite
2. Both can be primes
3. The first composite and the second prime,
4. The first prime and second composite.

Complying with the logic, each of the above four possibilities has equal validity, and there is no a cause-effect relationship among them.

The prime numbers tend to be the same on both sides of $\frac{x}{2}$ in the interval $[0, x]$ (Giraldo-Ospina (1995), Annex A),Chen, 1975 [39].

The amount of odd natural numbers both composites and primes grow with x, on both sides of $\frac{x}{2}$ in the interval $[0, x = 2y]$, then the amount of sums of odd numbers to give x also grows.

It is known that prime theorem states that the number of primes less than x for large x is:

$$\Pi(x) \cong \frac{x}{\ln x}$$

And to $\frac{x}{2}$ would be:

$$\Pi\left(\frac{x}{2}\right) \cong \frac{x}{2\,ln\frac{x}{2}}$$

And the amount of prime numbers between $\frac{x}{2}$ and x would be:

$$\Pi(x-\tfrac{x}{2}) = \Pi(x) - \Pi(\tfrac{x}{2}) \cong \frac{x}{ln\,x} - \frac{x}{2ln\frac{x}{2}}$$

Each of the primes between $\frac{x}{2}$ and x has an odd pair that can be prime or not between odd numbers $\leq \frac{x}{2}$ that meets when is added to get the x number, see Figure 9. If we take all odd numbers $\leq \frac{x}{2}$, the amount of sums would be simply the number of primes between $\frac{x}{2}$ and x, but if it is taking only the proportion of primes$\leq x/2$, because the amount of odd numbers contained in $\frac{x}{2}$ is $\frac{x}{4}$. The proportion of primes in that strip would be:

$$\Pi(x/2)/(x/4) \cong \frac{\frac{x/2}{\ln(x/2)}}{x/4} \cong \frac{2}{ln\,(x/2)}$$

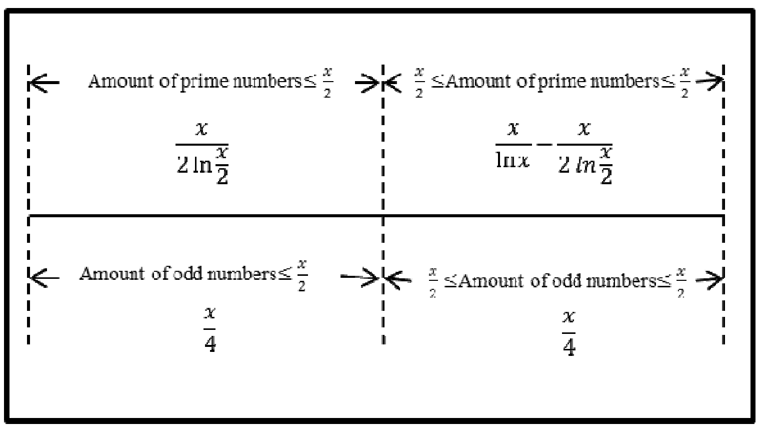

Fig. 9: Graphical representation of the number of primes less or equal to *x*/2 and the number of primes between *x*/2 and *x*.

As the number of prime numbers that are between *x/2* and *x* is known, we can also know how many symmetrical pairs of primes ($C_{sp}(x)$) that could be made between them and the proportion of primes less or equal to *x/2*, which could be the sum of two primes to get x:

$$\boldsymbol{C_{sp}(x)} = \left(\frac{x}{ln\,x} - \frac{x}{2ln\frac{x}{2}}\right)\left(\frac{2}{ln\,(x/2)}\right) \text{ for } x \geq 6^{2} \quad (18)$$

This equation gives an estimate number of symmetrical pairs of primes to find *x* as the sum of two primes, which has been tested in Table IX. It is important to note that if $\frac{x}{2}$ is prime, that prime, has to be considered for the primes less or equal to $\frac{x}{2}$, and for the primes between $\frac{x}{2}$ and x, because we have the even number *x* equal to the sum of two primes $\frac{x}{2}+\frac{x}{2}=x$. For example, the even number 10 has $\frac{x}{2}=\frac{10}{2}=5$ which is prime, there exists two odd primes less or equal to 5 and 2 odd primes between 5 and 10 and the real $C_{sp}(x)$ and the calculated $C_{sp}(x=10)$ is 2.

Table IX. Comparison of possibilities that an even x is equal to the sum of two odd primes (real C_{sp}(x) and calculated C_{sp}(x)).

[2] It is taken to x≥6 because considering pairs of primes are odd, although 4=2+2 is also the sum of two primes, in this case such primes are equal and 2 is the only even prime.

x	*Odd primes<x*	*Odd primes≤x/2*	*x>primes≥x/2*	*Real C(x)*	*Calculated* $C_{sp}(x)$
10	3	2	2	2	2
20	7	4	4	2	3
30	9	5	4	3	3
40	11	7	4	3	3
80	21	11	10	4	5
100	24	14	10	6	5
200	45	24	21	8	9
400	77	45	32	14	12
800	139	77	62	21	21
1,000	167	94	73	28	23
2,000	302	167	135	37	39
4,000	549	302	247	65	65
10,000	1,228	668	560	127	131

Figure 10 shows the behavior (for the data taken from table IX).

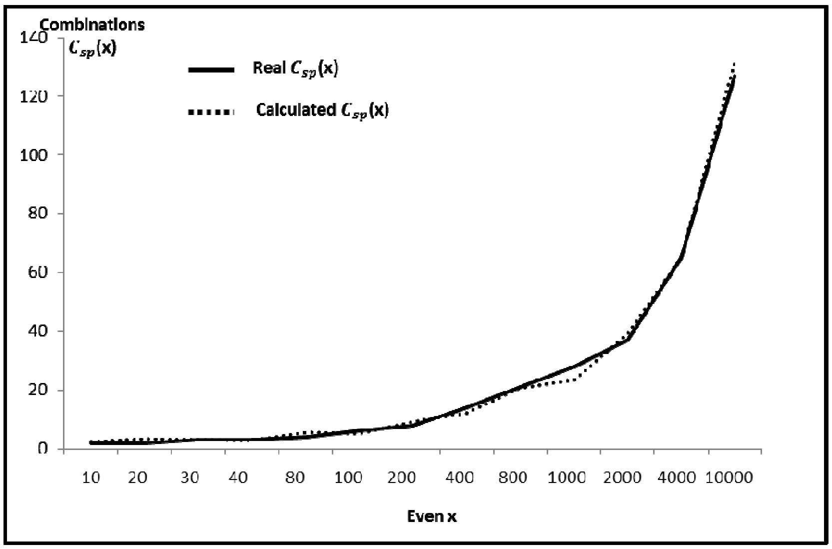

Fig. 10: Comparison of real $C_{sp}(x)$ with $C_{sp}(x)$ form data in Table IX.

Here it is important to highlight the factor:

$$0.956 < \frac{p(x)}{x/\ln x} < 1.045$$

Shown by Sylvester (1881) [38], this is the approximate error in the calculation of $\Pi(x) \cong x/\ln x$, therefore the function c(x) also has a deviation in the calculation of the accuracy of the number of combinations since it simply applies $\Pi(x) = x/\ln x$. In some cases calculated $C_{sp}(x)$ is smaller, equals or greater than the real $C_{sp}(x)$, taking into account the deviation shown in [38].

The limits of the equation (17) then would be:

$$0.956^2 \leq \frac{calculated\ C_{sp}(x)}{real\ C_{sp}(x)} \leq 1.045^2, \text{ or:}$$

$$0.913936 \leq \frac{calculated\ C_{sp}(x)}{real\ C(x)} \leq 1.099025 \qquad (19)$$

The resulting graph of Equation (19) is shown in Figure 11.

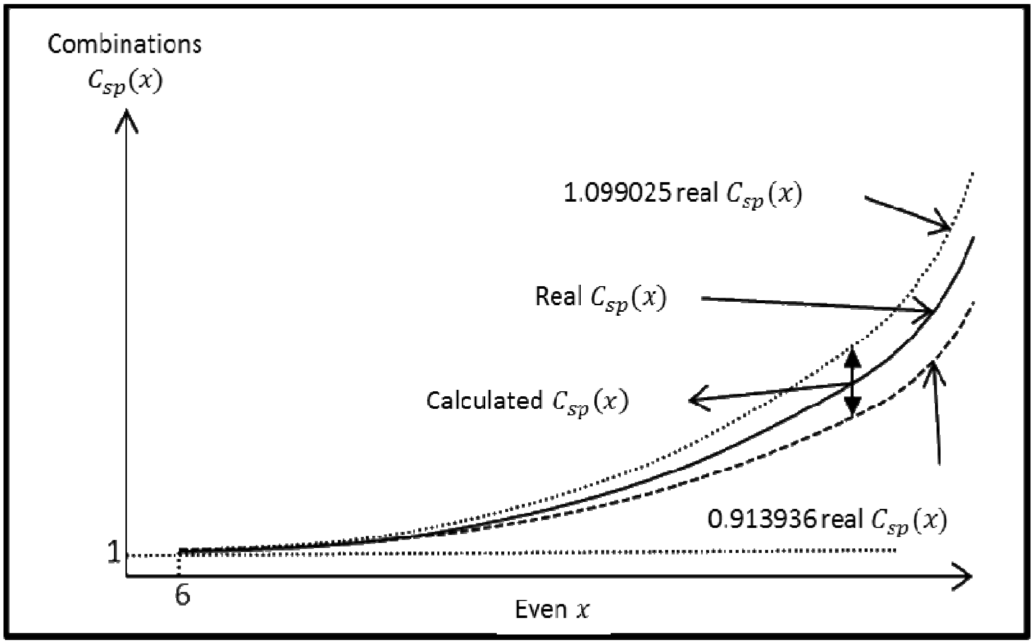

Fig. 11: Graphical representation of the equations (19).

The function C_{sp}(x) is an increasing function, therefore the possibilities of pairs of two primes to give an even number are greater with the increase of x:

$$\lim_{x\to\infty} C_{sp}(x) = \lim_{x\to\infty}\left(\frac{x}{ln\,x} - \frac{x}{2ln\,\frac{x}{2}}\right)\left(\frac{2}{ln\,\left(\frac{x}{2}\right)}\right) = \lim_{x\to\infty}\left(\frac{2x}{(ln\,x)(\ln\frac{1}{2} + \ln x)} - \frac{x}{(\ln\frac{1}{2} + \ln x)}^2\right)$$

$$\lim_{x\to\infty} C_{sp}(x) = \lim_{x\to\infty}\frac{x}{(\ln x)^2} = \infty$$ (eliminating $\ln\frac{1}{2}$ that is very small when $x\to\infty$).

Also, C_{sp}(x) is a continuous and divergent function, because it does not have limits.

Another interesting aspect is that upon analyzing of the primes in the intervals $[0,\frac{x}{2}]$ and $[\frac{x}{2},x]$, it is no more than the application of Bertrand's postulate (1845), as shown in Table X, where the amount of primes at such intervals and the amount of primes are compared, i.e. the symmetrical pairs of primes counting function is a direct application of this postulate.

Table X. Comparison of real possibilities that an even x is equal to the sum of two odd primes using Bertrand's postulate (1845) [29].

x	**Odd primes<x**	**Odd primes Bertrand [x/2, *x*-2]**	***x>odd* primes≥x/2**	***Real Csp (x)***
10	3	2	2	2
20	7	3	4	2
30	9	3	4	3
40	11	4	4	3
80	21	9	10	4
100	24	10	10	6
200	45	20	21	8
400	77	32	32	14
800	139	62	62	21
1,000	167	73	73	28

x	Odd primes<x	Odd primes Bertrand [x/2, x-2]	x>*odd* primes≥x/2	*Real* Csp (x)
2,000	302	134	135	37
4,000	549	247	247	65
10,000	1,228	560	560	127

The difference of a prime in some cases between Bertrand's postulate (1845) [29] and the number of primes between x and $\frac{x}{2}$, does not affect the calculation of C_{sp}(x), because the existence of a prime $p_{n+h} = x - 1$, this is not a solution for an even x as a sum of two primes in this interval since 1 is not a prime.

Annex "B" shows the table for the calculation of real C_{sp}(x).

In this way the concrete form of this conjecture is checked.

Once Goldbach's strong conjecture is demonstrated, Goldbach's weak conjecture: "*Every odd number greater than 7 can be expressed as the sum of three odd primes*." would also be demonstrated.

It is logical that the "weak conjecture" is demonstrated, since every even number plus 3 is odd and any even number can be represented by two primes, therefore adding 3 which is prime and odd, would be an odd number expressed as the sum of three primes. These conjectures may then have the status of theorem.

3.2.2 Another solution of "strong" Goldbach's conjecture using the equation of primes form (11).

Goldbach's "strong" conjecture (1742)[9], "*every even number greater than 2 can be written as the sum of two primes*" and Goldbach's weak" conjecture: "*all odd numbers greater than 7 can be expressed as the sum of three odd primes*", can also be solved as follow:

Given that all even numbers N_e can be written as:

$$N_e=[0,2,4,6,8,10,12,14,16,18,20,22,24,26,28]+30n \text{ where } n \in \mathbb{Z}_0^+ \quad (20)$$

They have a solution as the sum of two primes, with primes in rows that when added are $30n$.

Proof by symmetry of the n rows in Equation (11):

1. For n=0, all the primes that are in that row are taken: [2, 3, 5, 7, 11, 13, 17, 19, 23, 29], from Figure 12, any even number [4,6,8,10,12,14,16,18,20,22,24,26,28,30,32,34,36,38,40,42,44,46,48,50,52,54,56,58], is the sum of two primes $p_a + p_b$.
2. For $n \geq 1$ of equation (11), there are two conditions as the sum of two primes that give an even number $p_a + p_b = N_c$:

$$\left\{\begin{matrix} p_a = [3,5,7,11,13,17,19,23,29] + p_b = ([1,7,11,13,17,19,23,29] + 30b) \\ p_a = ([1,7,11,13,17,19,23,29] + 30a) + p_b = ([1,7,11,13,17,19,23,29] + 30b) \end{matrix}\right\} = [0,2,4,6,8,10,12,14,16,18,20,22,24,26,28] + 30n = N_e = sum\ of\ two\ primes\ (p_a + p_b) \quad (21)$$

To enforce the equation (17) or (21), there are the following cases:

$b = n$:

pa =[3,5,7,11,13,17,19,23,29]+pb =([1,7,11,13,17,19,23,29]+30n=[4,6,8,10,12,14,16,18,20,22,24,26,28]+ 30n= $N_e = sum\ of\ two\ primes\ (p_a + p_b)$

Note: the sum must be: 2<[3,5,7,11,13,17,19,23]+[1,7,11,13,17,19,23]<30, to ensure equality.

$b = n - 1$:

pa =[3,5,7,11,13,17,19,23,29]+pb =([1,7,11,13,17,19,23,29]+30($n-1$))

=[0,2,4,6,8,10,12,16,18,22,28]+$30n = N_e = sum\ of\ two\ primes\ (p_a + p_b)$

Note: the sum must be: 30≤[3,5,7,11,13,17,19,23,29]+[1,7,11,13,17,19,23,29]≤58, to ensure equality.

The same is when $p_a = [1,7,11,13,17,19,23,29] + 30n$ and $p_b = [1,7,11,13,17,19,23,29] + 30n$ for some $n \in \mathbb{Z}^+$

In conclusion, for all $a + b = n$, when [3,5,7,11,13,17,19,23,29]+[1,7,11,13,17,19,23,29]<30 and all $a + b = n - 1$ when [3,5,7,11,13,17,19,23,29]+[1,7,11,13,17,19,23,29]≥30 being a and b rows where there are primes p_a and p_b respectively and $a \le b$, it is possible to have $p_a + p_b = N_e$.

It is important to note: when n increase, more rows a and b will have such given n, where it is possible to obtain $p_a + p_b = N_e$.

Example: for $n = 10$, there are two cases: the first case $a + b = n$ would be the rows [0,10], [1,9], [2,8], [3,7], [4,6] and [5,5], where there are primes that when added can give the even number N_e. For the second case $a + b = n - 1$ would be the rows [0,9], [1,8], [2,7], [3,6], [4,5] where there are primes that when added can give the even number N_e. In addition, as n increases, there are more combinations of rows $a + b = n$ or $a + b = n - 1$ where there are primes $p_a + p_b = N_e$. This is the reason why the combination of primes $p_a + p_b = N_e$ grows, being p_a and p_b primes in the respective rows a and b, such that $p_a + p_b = N_e$. For example, Tables IV and V show there are primes in all rows from row 0 to row 67, therefore in total 67 combinations of rows where there are primes $p_a + p_b$ = [0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28]+30*67.

The above cases are summarized in Figure 12.

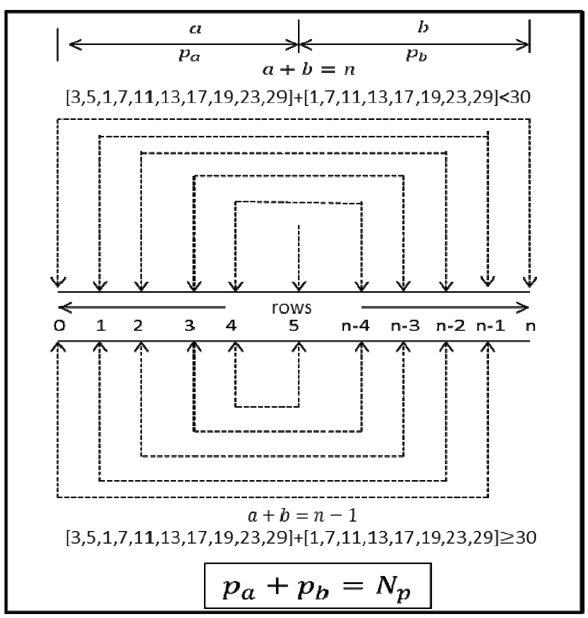

Fig. 12: Symmetry of the rows where there are primes $p_a + p_b = N_e$

Q.E.D.

Also, by symmetry of the columns where primes exist, it is possible to show that an even number N_e =[0,2,4,6,8,10,12,14,16,18,20,22,24,26,28]+$30n$ is equal to the sum of two primes p_1 and p_2, where p_1 is taken from column C_1 and p_2 from column C_2 (Table XI), where the sum of the primes in those columns must give:

$$p_1 + p_2 = [0,2,4,6,8,10,12,14,16,18,20,22,24,26,28] + 30n$$

Table XI Symmetrical columns C_1 and C_2 where are formed the primes p_1 and p_2 such that:

$$p_1 + p_2 = [0,2,4,6,8,10,12,14,16,18,20,22,24,26,28] + 30n.$$

Even number to n≥1	Symmetrical columns C_1 and C_2 where p_1+p_2= even number	Possibilities
30n	[1+29],[7+23],[11+19],[13+17],[29+1],[23+7],[19+11],[17+13]	8
30n+2	[1+1],[3+29],[13+19],[19+13]	between 3 and 2
30n+4	[3+1],[5+29],[11+23],[17,17],[23+11]	between 3.5 and 3
30n+6	[5+1],[7+29],[13+23],[17+19],[29+7],[23+13],[19+17]	between 6.5 and 6
30n+8	[1+7],[19+19],[7+1]	between 3 and 2.5
30n+10	[3+7],[11+29],[17+23],[29+11],[23+17]	between 4.5 and 3.75
30n+12	[5+7],[1+11],[13+29],[11+1],[29+13],[19,23],[23,19]	between 6.5 and 6
30n+14	[3+11],[7+7],[1+13],[13+1]	between 3.25 and 2.75
30n+16	[3+13],[5+11],[17+29],[23+23],[29+17]	between 3.5 and 3
30n+18	[5+13],[7+11],[1+17],[19+29],[11+7],[17+1],[29+19]	between 6.5 and 6
30n+20	[3+17],[1+19],[7+13],[19+1],[13+7]	between 4 and 3.5
30n+22	[3+19],[5+17],[11+11],[23+29],[29+23]	between 3.5 and 3
30n+24	[5+19],[1+23],[7+17],[11+13],[23+1],[17+7],[13+11]	between 6.5 and 5
30n+26	[3+23],[13+13],[7+19],[19+7]	between 3.25 and 2.75
30n+28	[5+23],[11+17],[29+29],[17+11]	between 3.25 and 2.75

The interesting thing about Table XI is that even numbers $30n$ have more possible combinations $C(x)$ with primes $p_1 + p_2 = 30n$ that other even numbers[3]:

$$p_1 + p_2 = [2,4,6,8,10,12,14,16,18,20,22,24,26,28] + 30n$$

The above equation is shown in Table XII and Figure 13, where it is used to study of the amount of symmetrical pairs of primes for even numbers [0,2,8]+$30n$ to $1 \leq n \leq 10$ where the proportion of the amount of symmetrical pairs of primes for each even number, share a relationship similar to the column possibilities of Table XI.

[3] The column of possibilities of Table XI shows a range of possibilities. This range varies taking into account:
1. The amount of combinations between columns where there are always primes
2. When combined with any column and where there are only the primes 3 and or 5.

Table XII. Amount of symmetrical pairs of Prime C (x) that together give even numbers $[0.2.8] + 30n$ to $1 \leq n \leq 10$

Amount of symmetrical pairs of primes C(x) equal to an even number x						
Rows	C(x) to x=30n		C(x) to x=30n+2		C(x) to x=30n+8	
n	x	C(x)	x	C(x)	x	C(x)
1	30	3	32	2	38	2
2	60	6	62	3	68	2
3	90	9	92	4	98	3
4	120	12	122	4	128	3
5	150	12	152	4	158	5
6	180	14	182	6	188	5
7	210	19	212	6	218	7
8	240	18	242	8	248	6
9	270	19	272	7	278	7
10	300	21	302	9	308	8

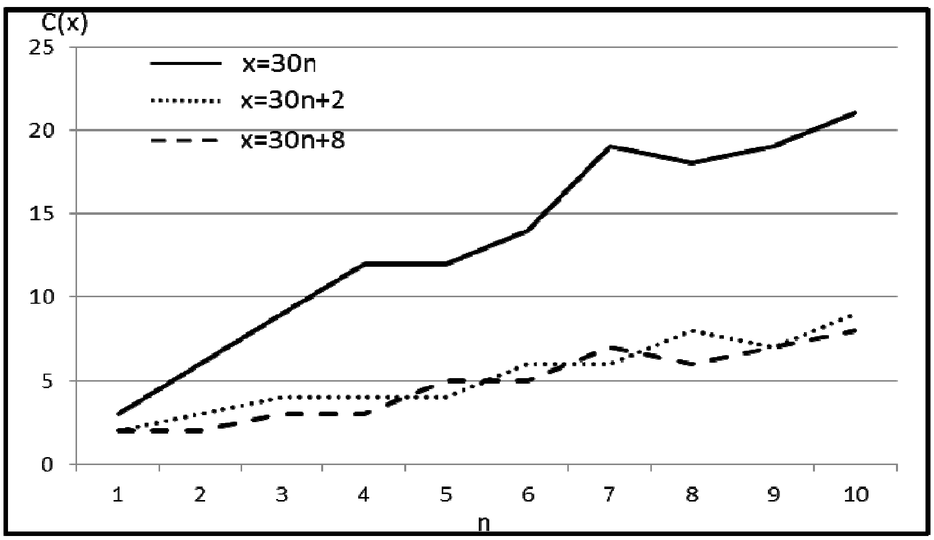

Fig. 13: Graph of amount of symmetrical pairs of Prime C (x) that together give even numbers $x = [0,2,8] + 30n$ for $1 \leq n \leq 10$. Data from Table XII.

Using a computer program where an algorithm was designed to calculate primes using the equation (11), can be studied the various possibilities for Table XI, which are grouped into well-defined four stripes for even numbers equal to the sum of two primes, as shown in Figure 14:

1. The Strip to $x = 30n$, (possibilities 8, in blue)
2. The Strip to $x = [6,12,18,24] + 30n$, (possibilities between 6.5 and 6, in purple)
3. The Strip to $x = [10,20] + 30n$, (possibilities between 4.5 and 3.5, in orange)
4. Overlapping stripes: the Strip to $x = [2,8] + 30n$, (possibilities between 3 and 2, in red), the strip to $x = [4,16,22] + 30n$, (possibilities between 3.5 and 3, in green) and the strip to $x = [14,26,28] + 30n$, (possibilities between 3.25 and 2.75, in yellow).

World Open Journal of Advanced Mathematics
Vol. 2, No. 1, April 2014, PP: 01 - 32
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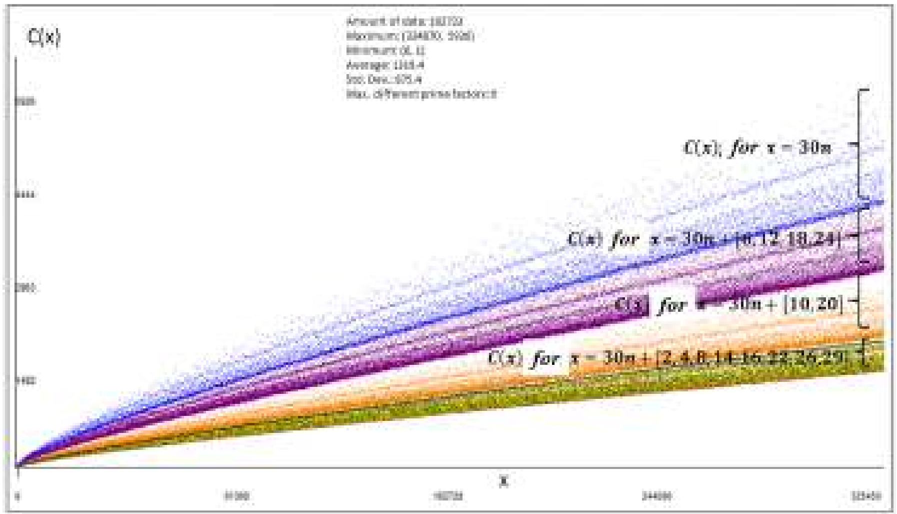

Fig. 14: Stripes of C (x) according to possibilities of combination of Table XI for even x in the form: $30n, [6,12,18,24] + 30n, [10,20] + 30n, and\ [2,4,8,14,16,22,26,28] + 30n$

Also, through this computer program, it is possible to perform all analyses and checks the amount of symmetrical primes $C(x)$ that together give an even number x. For example it was found in the case of $x = 30n$, there are several peak values when $n = 7k$ for $k \geq 1$. The mathematical reasoning is that the prime number 7 is the lowest prime that is repeated twice to obtain $30n$ (see Table XI), therefore in rows $n = 7k$ correspond to the greater amount of symmetrical primes that together give the even number $x = 30 * 7k$ for $k \geq 1$. The following graph shows the above.

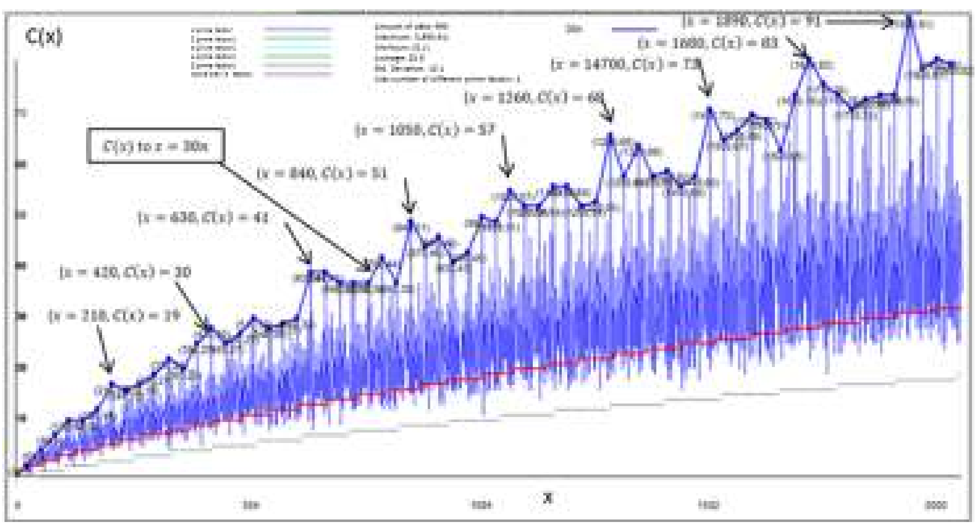

Fig. 15: Peak values $C(x)$ to $x = 30n$, where $n = 7k$ to $k \geq 1$

Conclusion

There is regularity in the formation of the prime numbers not known before, that allows finding and checking whether a given number is prime or not. Additionally, it facilitates the application of the concept of the Sieve of Eratosthenes in an efficient way to get primes and demonstrates that these primes are due to an orderly and general form as given by equation (11) and simplified in the Equation [16] and shown in Tables IV and V, similar to the natural numbers, given in equation (10). The rows of any of the eight columns where the composite numbers are formed, where there are no primes, can be computed or found by the procedure of the reminder manually. Furthermore, in rows $n = n_1 + pk$ to $k \geq 1$ within each column, where p is the corresponding prime in the n_1 cell, primes are not formed.

Two of the fundamental theorems of mathematics are proved: "every composed number is formed at least by one prime number and primes are infinite. The limits established by Tchebychev (1852) and Sylvester (1881) in the $\Pi(x)$ function are checked using the $W(a(x)$ and $W(b(x)$ functions and the oscillatory nature of the density of primes related to $\frac{x}{\ln x}$ and $Li(x)$ functions could be determined.

The "strong" and "weak" Goldbach's Conjecture are demonstrated using Bertrand's postulate by the development of an equation that describes the amount of pairs of primes that together give an even number and by symmetry of rows and columns using the equation that describes how the prime numbers are formed. This is also verified by computer programing.

Acknowledgments

We thank our professors at the Colombian Naval Academy and at the Naval Postgraduate School, Monterey California, USA. We are most indebted to Pedro Ortega-Palencia, at University of Cartagena de Indias for his comments and suggestions in several proofs and to Adolfo Augusto Gordillo-Rengifo, E.E., M.Sc. for his help with the coding process.

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ANNEX A

Double interval theorem

$$\lim_{x\to\infty} \Pi(2x) = 2\Pi(x)$$

Test:

1. $\Pi(2x) = 2x/ln\frac{2x}{c} = 2x/(ln\,2x - ln\,c)$...................................... Prime function.
2. $\Pi(2x) = 2x/(\ln x + \ln 2 - \ln c)$.. According to 1.
3. $\Pi(2x) = (2x/\ln x)/(1 + \ln 2/\ln x - \ln c/\ln x)$......................... According to 2.
4. $\lim_{x\to\infty} \Pi(2x) = (2x/\ln x)/(1 + 0 - 0)$.................................. According to 3.
5. $\lim_{x\to\infty} \Pi(2x) = 2\Pi(x)$ .... According to 4.

Q.E.D.

This means that the number of primes in the interval [x, 2x] tends to the interval [0, x] when x→∞ and, moreover, resolved one of the most famous questions in the set of prime numbers referring to the number of primes between x and 2x and, in general, between x and kx when x→∞ and $k \geq 2 \in Z^+$.

ANNEX B

TABLE: THE SUM OF TWO PRIMES COUPLES EQUAL TO AN EVEN X NUMBER

x	***Primes couples***								***Real $C_{sp}(x)$***
10	7+3	5+5							2
20	17+3	13+7							2
30	23+7	19+11	17+13						3
40	23+17	29+11	37+3						3
80	73+7	67+13	61+19	43+37					4
100	97+3	89+11	83+17	71+29	59+41	53+47			6
200	197+3	193+7	181+19	163+37	157+43	139+61	127+73	103+97	8
400	397+3	389+11	383+17	359+41	353+47	347+53	317+83	311+89	
	293+107	269+131	263+137	251+149	233+167	227+173			14
800	797+3	787+13	769+31	757+43	739+61	733+67	727+73	691+109	
	673+127	661+139	643+157	619+181	607+193	601+199	577+223	571+229	
	523+277	487+313	463+337	433+367	421+379				21
1000	997+3	983+17	977+23	971+29	953+47	947+53	941+59	929+71	
	911+89	887+113	863+137	827+173	821+179	809+191	773+227	761+239	
	743+257	719+281	683+317	653+347	647+353	641+359	617+383	599+401	
	569+431	557+443	521+479	509+491					28
2000	1009+991	1033+967	1063+937	1093+907	1117+883	1123+877	1171+829	1213+787	
	1231+769	1249+751	1291+709	1327+673	1381+619	1399+601	1423+577	1429+571	
	1453+547	1459+541	1543+457	1567+433	1579+421	1621+379	1627+373	1663+337	
	1669+331	1693+307	1723+277	1759+241	1777+223	1789+211	1801+199	1861+139	
	1873+127	1933+67	1987+13	1993+7	1997+3				37

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x	***Primes couples***								***Real $C_{sp}(x)$***
4000	3989+11	3947+53	3929+71	3917+83	3911+89	3863+137	3851+149	3833+167	
	3821+179	3803+197	3767+233	3767+233	3761+239	3719+281	3617+383	3581+419	
	3557+443	3589+461	3533+467	3491+509	3413+587	3407+593	3359+641	3347+653	
	3323+677	3299+701	3257+743	3203+797	3191+809	3137+863	3119+881	3089+911	
	3023+977	2999+1031	2939+1061	2909+1091	2903+1097	2897+1103	2837+1163	2819+1181	
	2813+1187	2777+1223	2741+1259	2711+1289	2699+1301	2633+1367	2591+1409	2477+1523	
	2447+1553	2441+1559	2417+1583	2399+1601	2393+1607	2381+1619	2333+1667	2267+1733	
	2213+1783	2153+1847	2129+1871	2111+1889	2099+1901	2087+1913	2069+1931	2027+1973	
	2003+1997								65
10000	9941+59	9929+71	9887+113	9851+149	9833+167	9803+197	9767+233	9749+251	
	9743+257	9719+281	9689+311	9551+449	9539+461	9533+467	9521+479	9497+503	
	9491+509	9479+521	9437+563	9431+569	9413+587	9341+559	9323+677	9281+719	
	9257+743	9239+761	9227+773	9203+797	9173+827	9161+839	9137+863	9059+941	
	9029+971	8969+1031	8951+1049	8849+1151	8837+1163	8819+1181	8807+1193	8783+1217	
	8741+1259	8699+1301	8693+1307	8681+1319	8627+1373	8573+1427	8513+1487	8501+1499	
	8447+1553	8429+1571	8387+1613	8363+1637	8291+1709	8111+1889	8123+1877	8093+1907	
	8087+1913	8069+1931	7937+2063	7919+2081	7901+2099	7793+2207	7757+2243	7727+2273	
	7703+2297	7649+2351	7643+2357	7607+2393	7589+2411	7583+2417	7577+2423	7559+2441	
10000	7541+2459	7523+2477	7457+2543	7451+2549	7307+2693	7247+2753	7211+2789	7121+2879	
	7103+2897	7043+2957	7001+2999	6977+3023	6959+3041	6917+3083	6911+3089	6863+3137	
	6833+3167	6791+3209	6779+3221	6701+3299	6653+3347	6551+3449	6473+3527	6329+3671	
	6323+3677	6299+3701	6221+3779	6203+3797	6197+3803	6089+3911	6053+3947	6011+3989	
	5981+4019	5987+4013	5927+4073	5867+4133	5861+4139	5643+4157	5783+4217	5741+4259	
	5717+4283	5711+4289	5651+4349	5591+4409	5519+4481	5507+4493	5483+4517	5477+4523	
	5417+4583	5351+4649	5309+4691	5297+4703	5279+4721	5081+4919	2309+7691		127

ANNEX C

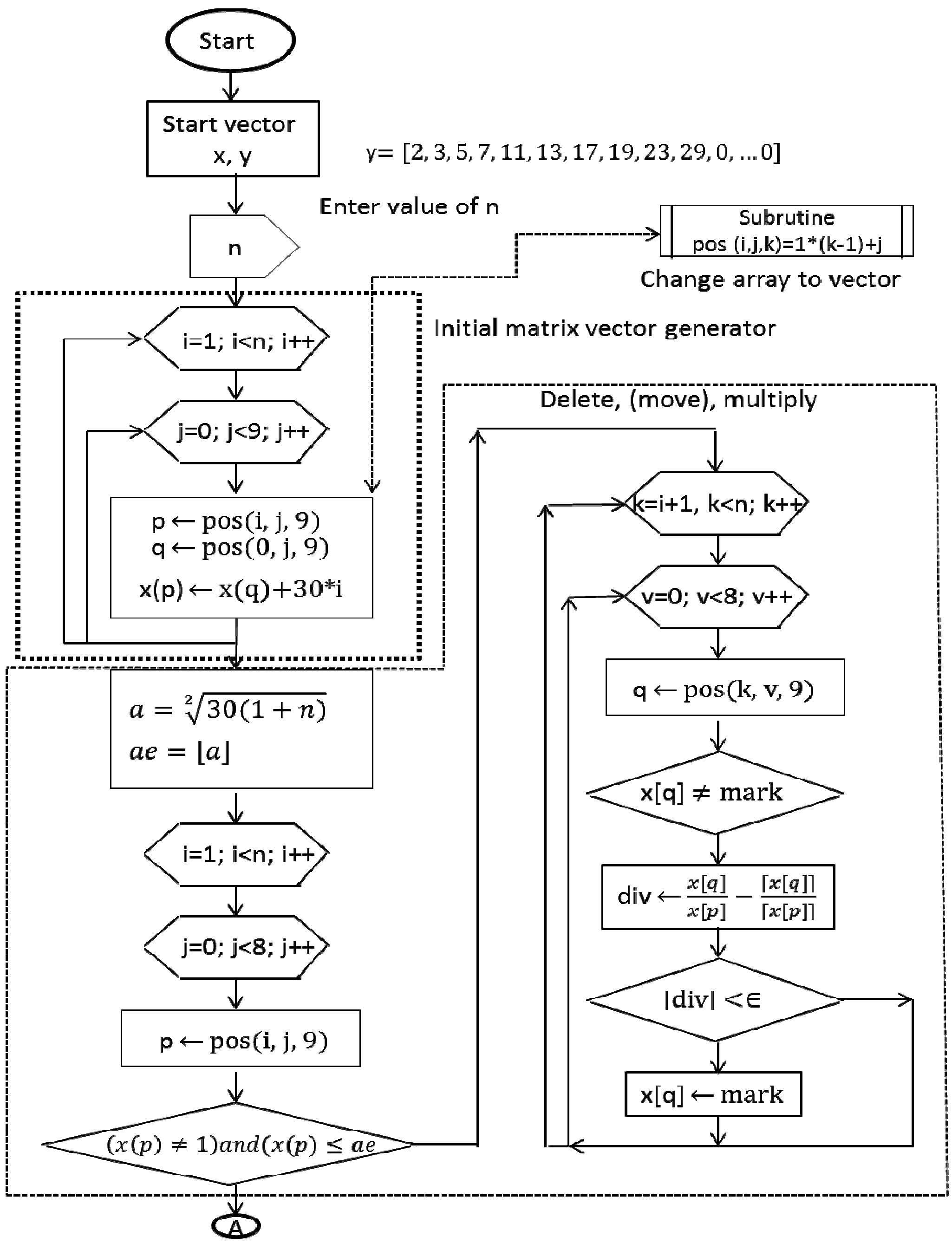
HOW TO DEVELOP A SIMPLE PROGRAM FOR A LISTING OF PRIME NUMBERS IN ANY COMPUTER PROGRAMMING LANGUAGE

1. Set up how many n rows wants to get primes
2. Formulate equation (9) as an array:

   $p_{ni} = [1, 7, 11, 13, 17, 19, 23, 29] + 30n$ to $n = 0$ up to n, and $i = 1$ up to 8
3. To the row $n = 0$ delete 1 because is not prime, i.e. $p_{01} = 0$
4. From row 1 until n remove all the multiples less than $\sqrt[2]{30(1+n)}$ from p_{ni} matrix (remember that 1 was erased in row 0), dividing p_{n1} from $n = 1$ up to n, by all the $p_{km} < \sqrt[2]{30(1+n)}$. Starting from $k = 0, m = 1$ up to $m = 8$, and increasing k if necessary one by one. If the result of this division is an integer, i.e.: $p_{ni} \equiv 0 \pmod{p_{km}}$, then the corresponding $p_{ni} = 0$
5. The result of numbers not eliminated in the p_{ni} matrix, will be primes.
6. Enter the matrix resulting in tabular form, for example in 16 columns, including this table numbers 2, 3, and 5 that are prime and we will have all the primes less than or equal to $29 + 30n$.

ANNEX D

FLOWCHART TO FIND PRIMES IN VISUAL BASIC C++



World Open Journal of Advanced Mathematics
Vol. 2, No. 1, April 2014, PP: 01 - 32
Available online at http://scitecpub.com/Journals.php