

Iwuamadi's Primality Test

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Abstract

The formulation of a fast, one-time, and deterministic primality test is the motivation behind this research paper. The main mathematical formulae were researched to achieve the objectives mentioned above. This paper covers theoretical use, while a sister paper would spell the practical applications—theoretical experience is pro rata to practical experience (reality).

Keywords: Iwuamadi, Primality, Testing.

1. Introduction

Iwuamadi's primality test is a one-time, deterministic test with ease in identifying primes. The main formulae are from the triangular array below.

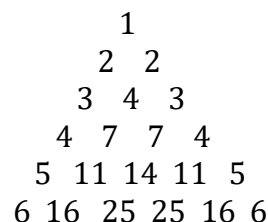
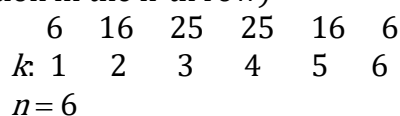


Figure 1

n = row ; k = column (position in the n -th row)



$$T(n, k) = C(n, k-1) + C(n-1, k) \quad (1)$$

$T(n, k)$ = entry

To test whether n is a prime, $n > 2$ and $2 \leq k \leq n-1$ ($n \in \mathbb{Z}^+$, $k \in \mathbb{Z}^+$)

In an n -th row, entries ($k=2$ to $k=n-1$) begin by subtracting 1 from entry $k=2$ followed by adding 1 to entry $k=3$, and alternating others in that order. And if the result of every entry is divisible by the number n , definitely, n is a prime, and if not divisible by number n , n is a composite.

$$R(n, k) = C(n, k-1) + C(n-1, k) - (-1)^k \quad (2)$$

$$R(n, k) = \text{entry} - (-1)^k \quad (3)$$

$R(n, k)$ = result (divided by n)

2. Preliminaries

Lemma 2.1:

$$R(n, k) = C(n, k-1) + C(n-1, k) - (-1)^k \quad (4) \quad (\text{derived from figure 1})$$

1)

Proof

$T(n, k)$ = entry in the triangular array of figure 1

$R(n, k)$ = result by subtraction/addition of 1 from/to $T(n, k)$, (which begins with subtraction and $k=2$)

k = divisor of n

n = tested number (the n -th row)

Figure 2 below shows $R(n, k)$ entries divided by n (of n -th rows) from $k=2$ to $k=n-1$, where n is the tested number for primality, and $n \geq 3$.

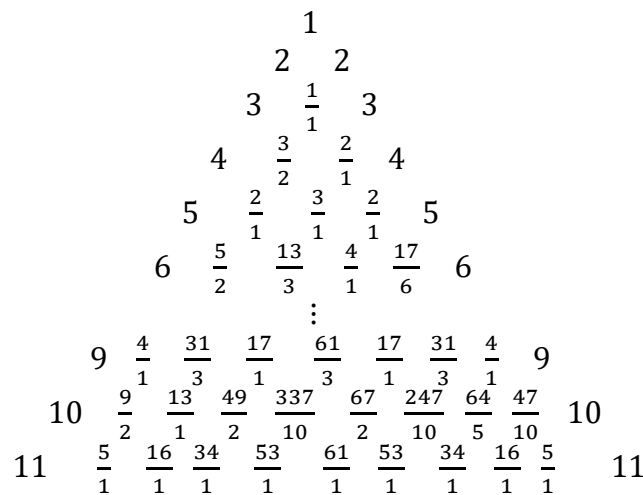


Figure 2

When $n=3$,

for $k=2$ (the only entry when $n=3$),

$$\begin{aligned}\frac{4-1}{n} &= \frac{3}{3} \\ &= \frac{1}{1} \quad (k=2 \text{ is not a factor of } n=3)\end{aligned}$$

$k=2$ is not a factor of $n=3$, and therefore, the denominator 1 is not a multiple of $k=2$.

When $n=4$,

for $k=2$,

$$\begin{aligned}\frac{7-1}{n} &= \frac{6}{4} \\ &= \frac{3}{2}\end{aligned}$$

$k=2$ is a factor of $n=4$, and therefore, the denominator 2 is a factor of $k=2$;

for $k=3$,

$$\begin{aligned}\frac{7+1}{n} &= \frac{8}{4} \\ &= \frac{2}{1}\end{aligned}$$

$k=3$ is not a factor of $n=4$, and therefore, the denominator 1 is not a multiple of $k=3$.

When $n=5$,

for $k=2$

$$\begin{aligned}\frac{11-1}{n} &= \frac{10}{5} \\ &= \frac{2}{1}\end{aligned}$$

$k=2$ is not a factor of $n=5$, and therefore, the denominator 1 is not a multiple of $k=2$;

for $k=3$,

$$\frac{14+1}{n} = \frac{15}{5}$$

$$= \frac{3}{1}$$

$k=3$ is not a factor of $n=5$, and therefore, the denominator 1 is not a multiple of $k=3$; for $k=4$,

$$\frac{11-1}{n} = \frac{10}{5} = \frac{2}{1}$$

$k=4$ is not a factor of $n=5$, and therefore, the denominator 1 is not a multiple of $k=4$.

Observe the trend with $n=6, 9, 10, 11$, you will deduce that when n is a composite, where k is a factor, the denominator is always the multiple of k , and where k is not a factor, the denominator is always a nonmultiple of k , and when n is a prime, the denominators are always 1 (a nonmultiple of k).

Therefore, $R(n, k)$ fits the primality test in the triangular array of figure 1. ■

Lemma 2.2:

$$R(n, \frac{n}{2}) = C(n, \frac{n}{2} - 1) + C(n - 1, \frac{n}{2}) - (-1)^{\frac{n}{2}} \quad (5) \quad (\text{middle entries})$$

when

$$n \text{ is even) } R_{me}(n, k) =$$

$$R(n, \frac{n}{2})$$

Proof

When $k = \frac{n}{2}$, where n is even, means, k is a factor of n , and therefore, the denominator will be a multiple of k . Remember, $2 \leq k \leq n - 1$.

Therefore, $R(n, \frac{n}{2})$ fits the primality test where n always comes as composite. ■

Lemma 2.3:

$$R(n, \frac{n+1}{2}) = C(n, \frac{n+1}{2} - 1) + C(n - 1, \frac{n+1}{2}) - (-1)^{\frac{n+1}{2}} \quad (6) \quad (\text{middle entry when } n \text{ is odd})$$

$$R_{mo}(n, k) = R(n, \frac{n+1}{2})$$

Proof

$$R(n, k) = T(n, k) - (-1)^k$$

Using $T(n, k)$,

$$\begin{aligned} T(n, k) &= C(n, k-1) + C(n-1, k) \\ &= \frac{n!}{(n-k+1)!(k-1)!} + \frac{(n-1)!}{(n-1-k)!k!} \\ &= \frac{n!k!(n-k-1)!(n-1)!(k-1)!(n-k+1)!}{(n-k+1)!(k-1)!(n-k-1)!k!} \\ &= \frac{(n-1)!(k-1)!(n-k-1)!(nk+(n-k+1)(n-k))}{(n-k+1)!(k-1)!(n-k-1)!k!} \\ &= \frac{(n-1)!(nk+n^2-nk-nk+k^2+n-k)}{(n-k+1)!k!} \\ &= \frac{(n-1)!(n^2+k^2-nk+n-k)}{(n-k+1)!k!} \\ &= \frac{(n-1)!(n(n-k+1)+k(k-1))}{(n-k+1)!k!} \end{aligned}$$

When $k = \frac{n+1}{2}$,

$$\begin{aligned} &= \frac{(n-1)!(n^2 - n(k-1) + k(k-1))}{(n-k+1)!k!} \\ &= \frac{(n-1)!(n^2 + (k-1)(k-n))}{(n-k+1)!k!} \\ &= \frac{(n-1)!(n^2 + (\frac{n+1}{2}-1)(\frac{n+1}{2}-n))}{(n-\frac{n+1}{2}+1)!(\frac{n+1}{2})!} \\ &= \frac{(n-1)!(n^2 + (\frac{n-1}{2})(\frac{1-n}{2}))}{(\frac{n+1}{2})!(\frac{n+1}{2})!} \\ &= \frac{(n-1)!(n^2 - (\frac{n-1}{2})^2)}{((\frac{n+1}{2})!)^2} \\ &= \frac{(n-1)!(\frac{n+1}{2})(\frac{3n-1}{2})}{((\frac{n+1}{2})!)^2} \end{aligned}$$

$\frac{3n-1}{2}$ is a multiplier that forms a linear sequence for n .

$\frac{(n-1)!(\frac{n+1}{2})}{((\frac{n+1}{2})!)^2}$ is the coefficient of $\frac{3n-1}{2}$ with distinct character, which differentiates primes from composites. $\frac{(n-1)!(\frac{n+1}{2})}{((\frac{n+1}{2})!)^2}$ separately identifies primes (named Iwuamadi's second primality test) without requiring $\frac{3n-1}{2}$.

$$\frac{(n-1)!(\frac{n+1}{2})}{((\frac{n+1}{2})!)^2} + 2(-1)^{\frac{n+1}{2}} \bmod n = 0 \quad (\text{Iwuamadi's second primality test; } n \text{ is prime, and prime only, otherwise, } n \text{ is composite.})$$

Arrangements and values from $\frac{(n-1)!(\frac{n+1}{2})}{((\frac{n+1}{2})!)^2}$:

For $n = 3$: $\frac{2!}{1!2!} = \frac{2}{2 \times 1}$

For $n = 5$: $\frac{4!}{2!3!} = \frac{3 \times 4}{3 \times 2 \times 1}$

For $n = 7$:
$$\frac{6!}{3!4!} = \frac{4 \times 5 \times 6}{4 \times 3 \times 2 \times 1}$$

For $n = 9$
$$\frac{8!}{4!5!} = \frac{5 \times 6 \times 7 \times 8}{5 \times 4 \times 3 \times 2 \times 1}$$

For $n = 11$
$$\frac{10!}{5!6!} = \frac{6 \times 7 \times 8 \times 9 \times 10}{6 \times 5 \times 4 \times 3 \times 2 \times 1}$$

For $n = 13$
$$\frac{12!}{6!7!} = \frac{7 \times 8 \times 9 \times 10 \times 11 \times 12}{7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1}$$

...

For $n = 25$
$$\frac{24!}{12!13!} = \frac{13 \times 14 \times 15 \times 16 \times 17 \times 18 \times 19 \times 20 \times 21 \times 22 \times 23 \times 24}{13 \times 12 \times 11 \times 10 \times 9 \times 8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1}$$

Apply the dividend-divisor pair to the arrangements above beginning from the far right. It would be observed that when n is a composite, in at least a pair (apart from divisor = 1), divisor of a pair is a factor of its corresponding dividend, and when n is a prime, no pair has a divisor as a factor apart from divisor = 1. Divisibility in dividend-divisor pairs associated with composites makes it impossible for composites to behave as primes in $R\left(n, \frac{n+1}{2}\right)$. ■

3. Main results

$$R\left(n, \frac{n}{2}\right) \equiv \emptyset \pmod{n} \quad (n \text{ is a composite}) \quad (7)$$

When:

$$R\left(n, \frac{n+1}{2}\right) \equiv 0 \pmod{n} \quad (n \text{ is a prime}) \quad (8)$$

$$R\left(n, \frac{n+1}{2}\right) \equiv \emptyset \pmod{n} \quad (n \text{ is a composite}) \quad (9)$$

4. Applications

1. $R\left(n, \frac{n}{2}\right) \pmod{n}$ (one-time trial)

$$R\left(n, \frac{n}{2}\right) \pmod{n} \neq 0 \quad (n \text{ is a composite}) \quad (10)$$

2. $R\left(n, \frac{n+1}{2}\right) \pmod{n}$ (one-time trial)

$$R\left(n, \frac{n+1}{2}\right) \pmod{n} = 0 \quad (n \text{ is a prime}) \quad (11)$$

$$R\left(n, \frac{n+1}{2}\right) \pmod{n} \neq 0 \quad (n \text{ is a composite}) \quad (12)$$

5. Conclusion

Iwuamadi's primality test has been theoretically tested, and awaits its speed (operating time).

Reference

- [1] Mahavira. 850/1912. *Ganita-sara-sangraha of Mahāvīrācārya with English translation and notes* (M. Rangacharya, Translated & Edited). Government Press.



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