

THE ANALYTIC PROPERTY FOR RIEMANN ZETA FUNCTION

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ABSTRACT. This article discusses the analytic property of Riemann zeta function. The popular opinion is denied.

1. INTRODUCTION

$\zeta(s)$ is originally

$$\zeta^*(s) = \sum_{n=1}^{\infty} n^{-s}, \Re(s) > 1$$

It is continued by Riemann as:

$$(1.1) \quad (1 - e^{i2\pi(s-1)})\Gamma(s)\zeta(s) = \int_{C=C_1+C_2+C_3} t^{s-1}/(e^t - 1)dt$$

$$C_1 = (-\infty, r]e^{2i\pi}, C_2 = re^{i\theta}, \theta = (2\pi, \pi], C_3 = (r, \infty), 0 < r < 2\pi$$

Most of people think this function is analytic except $s = 1$ [1]. There is still another series for $\zeta(s)$ that 's called the second definition in this article.

$$(1.2) \quad \zeta^*(s) = \frac{1}{1 - 2^{1-s}} \sum_{n=1}^{\infty} (-1)^{n+1} n^{-s}, \Re(s) > 0$$

This is a continuation of the original $\zeta(s)$. Someone deduced that

$$(1.3) \quad (1 - e^{i2\pi(s-1)})\Gamma(s)\zeta(s) = \frac{1}{1 - 2^{1-s}} \int_C t^{s-1}/(e^t + 1)dt$$

This expression is identical to Riemann's definition. In this article the analytic property is discussed.

2. DISCUSSION

Theorem 2.1. *The second definition of $\zeta(s)$ has divergent derivative near $s = 0$.*

Proof.

$$F(s) := \sum_{n=5}^{\infty} (-1)^{n+1} n^{-s}, \Re(s) > 0$$

Set $s \in (0, 0.1)$.

$$-F'(s) = \sum_{n=5}^{\infty} (-1)^{n+1} \ln(n) n^{-s}$$

Date: June 4, 2010.

2000 Mathematics Subject Classification. Primary 11M06, Secondary 30B10 30B40.

Key words and phrases. Riemann zeta function, analytic continuation, Cauchy integral formula.

$$\begin{aligned}
&= \sum_{n=5,2|n+1}^{\infty} \ln(n)(sn^{-s-1} - n^{-s-2}s(s+1))\theta, 0 < \theta < 1 \\
&> \frac{1}{2} \int_{n=5}^{\infty} \ln(n)n^{-s-1}sdn - \sum_{n=5,2|n+1}^{\infty} \ln(n)n^{-s-2}s(s+1)\theta \\
&= \frac{1}{2} \int_5^{\infty} s \ln(x)x^{-s-1}dx - C_s, |C_s| < C \\
&> \frac{1}{2} \int_{\ln(5)}^{\infty} sxe^{-sx}dx - C_s \\
&> \frac{1}{2} \int_{\ln(5)}^{\infty} \frac{sxe^{-sx}d(sx)}{s} - C_s
\end{aligned}$$

It's easy to find when $s \rightarrow 0$ this term approaches to infinity. \square

There is coming up sharp controversy, as is commonly known the $\zeta(s)$ hasn't infinity derivative in near $s = 0$. But in this article the opinion inclines to find the fault of the Riemann's definition.

The first probe is on that the proposition for analytic function $f(x)$, the similarity of the middle value theorem, like

$$\exists z' \forall z (f(z) - f(0) = f'(z')z), |z'| \leq |z|, |z| < r$$

is invalid. Here is a counterexample

$$f(x) = (1+x)^a, a \in \mathbf{R}$$

If a is great it can be found a little $x_1, r : |x_1| < r$

$$\ln(f(x_1)) - \ln(f(\bar{x}_1)) = 2\pi i, f(x_1) = f(\bar{x}_1)$$

but the derivative zero is at

$$a(1+x)^{a-1} = 0$$

It's impossible on $|x| \leq 3r$.

The second probe is on the definition of integration of real function $f(x, y)$ on curve C .

Theorem 2.2. $l \in [0, c]$ is any continuous finite parametrization of piecewise smooth curve $C(l)$. l is divided into the collection of Δl . If the integration of the real $f(x, y)$ on $C(l)$ is defined as the limit of the sum of $f(x, y)\Delta C$ or $f(x, y)|\Delta C|$ when $\Delta l \rightarrow 0$. then this limit exists if $f(x, y)$ is continuous uniformly in a neighboring set of C .

This is nothing special.

The third probe is on Cauchy Integral Formula that said derivable function is analytic. Integrations about the complex derivable function $f(x)$ in the considered domain is thought meeting

$$\begin{aligned}
f(x) &= \frac{1}{2\pi i} \oint_{C'} \frac{f(z)}{z-x} dz \\
f^{(n)}(x) &= \frac{n!}{2\pi i} \oint_{C'} \frac{f(z)}{(z-x)^{n+1}} dz \\
C' &= re^{i\theta} - x, 0 \leq \theta < 2\pi
\end{aligned}$$

Its famous proof of Cauchy's [2] is incorrect.

The first reason is that the limit of integral contours $r \rightarrow 0$ causes the integrated is not bounded (hence not continuous) uniformly in $0 < r < R$. The second, Cauchy's first integral formula is interpreted as the following in effective

$$\lim_{r \rightarrow 0} \lim_{\Delta x \rightarrow 0} \sum_{\Delta x(\Delta_r, x)} g \Delta \theta = \lim_{\Delta x \rightarrow 0} \lim_{r \rightarrow 0} \sum_{\Delta x(\Delta_r, x)} g \Delta \theta$$

$$x = \Re(z), y = \Im(z), (\Delta x, r) \rightarrow \Delta_r x$$

Suitable and valid connection between $\Delta \theta$ and $(\Delta x, \Delta y)$ has been defined. This implies that the convergence of the integrations for $0 < r < R$ is uniform for $0 < |\Delta x| < c$.

Now it is critical to define the conception of Analytic as expandable to power series. French mathematician J.Dieudonne use this definition consistently in his famous book "Foundations of Modern Analysis".

Definition 2.3. The *wide convergence* of 2-arguments real power series

$$\sum_{n=0, m=0}^{\infty} a_{nm} x^n y^m$$

is the convergence of

$$\sum_{n=0}^{\infty} \sum_{m=0}^{\infty} a_{nm} x^n y^m = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} a_{nm} x^n y^m$$

The *convergent radius* (r_1, r_2) of the series is defined meeting

$$|a_{nm}| < C/(r_1^n r_2^m), C > 0$$

The fourth probe is on two-arguments positive power series' convergence in different sequences. A example is

$$\sum_{m=0, n=0}^{\infty} x^m y^n$$

In one sequence it's

$$\sum_{n=0}^{\infty} \sum_{m=0}^{\infty} x^m y^n = \frac{1}{(1-x)(1-y)}, 0 < x, y < 1$$

After y is substituted by $y/x, y < x$, it's

$$\begin{aligned} & \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} x^m y^n + \sum_{n=1}^{\infty} y^n \frac{1-x^{-n}}{1-x^{-1}} - \sum_{n=1}^{\infty} y^n \\ &= \frac{1}{(1-x)(1-y)} + \frac{y}{(1-1/x)(1-y)} - \frac{y/x}{(1-y/x)(1-1/x)} - \frac{y}{1-y} \\ &= \frac{1-y/x+y^2/x-y^2}{(1-x)(1-y)(1-y/x)} \end{aligned}$$

These two sequences are inequivalent. This evinces that the popular knowledge on absolute convergence and countable set is incomplete.

Definition 2.4. 2-dimensional power series $f(z)$ of real arguments as $\Re(z), \Im(z)$, its convergence is called wide convergence. In the 2-dimensional series, the same degree terms is combined as one term to form an 1-dimensional series, convergence of which is called narrow convergence. Complex smooth and narrowly convergent power series is narrowly analytic, Complex smooth and widely convergent power series is widely analytic.

Maybe somebody had said

Theorem 2.5. *A smooth complex function is analytic if both its real part and its imaginary part have narrowly convergent power series expressions.*

It's obvious that narrowly analytic is equivalent to analytic.

However, after the *analytic function* is defined as power series locally expandable, the Cauchy Integral Formula for *analytic function* is all right, hence the end-points of the biggest analytic convergent radius stops at the non-analytic point.

The analytic property of $\Gamma(s)$ is discussed.

$$\Gamma^{(2k)}(1) > \int_1^\infty \ln^{2k} x e^{-x} dx = - \int_1^\infty \ln^{2k} x d e^{-x} = (2k)! \int_1^\infty e^{-x} / x dx$$

$$\Gamma^{(2k)}(r+1) > \Gamma^{(2k)}(1) - e, r > 0$$

It seems that singularities are everywhere on $\Re(s) > 1$ by the reason of the revised Cauchy integral formula. As a fact the Taylor remainder of n -th order of derivative is

$$(\Delta s)^k \int_0^\infty \ln^{n+k} x s^{-1} e^{-x} dx / k! > C \frac{(\Delta s)^k (n+k)!}{k!}, s > 1, 2|n+k$$

It's not approaching to zero as $k \rightarrow \infty$ if n is great enough.

3. CONCLUSION

The function $\Gamma(s)\zeta(s)$ of Riemann's definition is non-analytic on $s > 1$, hence it can't be continued analytically to the whole complex plane in Riemann's method. However, $(1 - 2^{1-s})\zeta^*(s)$ is analytic on $\Re(s) > 0$.

The classical Cauchy integral formula implies that first order complex derivable function is analytic. Its counterexample can be found through the solution of this second order differential equation

$$\Delta f(x, y) = 0$$

$f(x, y)$ is unnecessary to be smooth, and by Cauchy-Riemann formula, $g(x, y) + if(x, y)$ is obtained as a function derivable complexly. A direct counter-example of Cauchy Integral Formula is the following absurdity

$$\Gamma(s) = 1/(s(s+1)) + F(s)$$

$F(s)$ is classically analytic on $\Re(s) > -2$

$$\Gamma(s+1) = s\Gamma(s)$$

$$\ln(s) = \ln(\Gamma(s+1)) - \ln(\Gamma(s))$$

$$\frac{1}{s} = \frac{\Gamma'(s+1)}{\Gamma(s+1)} - \frac{\Gamma'(s)}{\Gamma(s)}$$

It's integrated circling $s = -1$

$$2 = F(0) + F(-1), \Gamma(2)' - \Gamma'(1) = 2$$

This identity is wrong.

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