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Multiplicative Property of Geometric Mean

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ABSTRACT: Pythagorean classical means play vital roles in finding measures of various characteristics of data namely central tendency, dispersion, correlation regression etc. Various properties of the three Pythagorean means have already been identified which are available in the literature of statistics while more properties of them are yet to be identified. Recently, one property of harmonic mean has been identified which can be termed as its additive property. In this study, one property of geometric mean has been derived which can be termed as its multiplicative property. Derivation of the property has been presented in this article along with numerical example. .

KEYWORDS*:* Geometric Mean, Multiplicative Property, Derivation

I. INTRODUCTION

The concept of average [4 , 49] found to be used in almost everywhere. Measure of average was first developed by the great mathematician Pythagoras [7 , 40 , 42 , 45 , 46 , 51]. He defined three measures of average namely arithmetic mean, geometric mean and harmonic mean which were given the name "Pythagorean Means" [6 , 8 , 9 , 10 , 12 , 15 , 35 , 53] as a mark of honour to him. Later on, a number of definitions / formulations of average had been derived due to necessity of handling different situations. Some of them are quadratic mean or root mean square, square root mean , cubic mean, cube root mean, generalized *p mean* & generalized p^{th} root mean etc. in addition to Arithmetic Mean , Geometric Mean & Harmonic Mean [10 , 15 , 29]. Moreover, one general method had been identified for defining average of a set of values of a variable as well as a generalized method of defining average of a function of a set (or of a list) of values [11, 13 , 14 , 17]. Recently, four formulations of average have been derived from the three Pythagorean means which are Arithmetic-Geometric Mean, Arithmetic-Harmonic Mean, Geometric-Harmonic Mean and Arithmetic-Geometric-Harmonic respectively [16 , 19 , 25 , 29]. Pythagorean classical means, along with the other means derived from these three, play vital roles in finding measures of various characteristics of data namely central tendency, dispersion, correlation regression etc. [1 , 2 , 3 , 18 , 19 – 28 , 30 – 34 , 36 , 37 , 39 , 41 , 43 , 44 , 47 , 48 , 50 , 52 , 54]. Various properties of the three Pythagorean means have already been identified which are available in the literature of statistics [6 , 45] while more properties of them are yet to be identified. Recently, one property of harmonic mean has been identified which can be termed as its additive property [38]. In this study, one property of geometric mean has been derived which can be termed as its multiplicative property. Derivation of the property has been presented in this article along with numerical example.

II. GEOMETRIC MEAN

Let us consider a list of *N* real numbers or values namely

$$a_1 , a_2 , \ldots\ldots , a_N$$

Geometric Mean, denoted by $G(a_1 , a_2 , \ldots\ldots , a_N)$, of them is defined by

$$G(a_1 , a_2 , \ldots\ldots , a_N) = \left(\prod_{i=1}^{N} a_i \right)^{1/N}$$

provided the *N* numbers are strictly positive.

On the other hand, Arithmetic Mean of $a_1 , a_2 , \ldots\ldots , a_N$, denoted by $A(a_1 , a_2 , \ldots\ldots , a_N)$, is defined by

$$A(a_1 , a_2 , \ldots\ldots , a_N) = \frac{1}{n} \sum_{i=1}^{N} a_i$$

Accordingly, if X is a variable which assumes the values

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$$x_1 , x_2 , \dots \dots \dots \dots , x_M$$

then Geometric Mean of X, denoted by $G(X)$, will be

$$G(X) = (\prod_{i=1}^{M} x_i)^{1/M}$$

Similarly,

$$A(X) = \frac{1}{M} \sum_{i=1}^{M} x_i$$

III. MULTIPLICATIVE PROPERTY OF GEOMETRIC MEAN

Let X & Y be two variables such that

X assumes the non-zero values

$$x_1 , x_2 , \dots \dots \dots \dots , x_m$$

and Y assumes the non-zero values

$$y_1 , y_2 , \dots \dots , y_n$$

then

$$G(X) = (\prod_{j=1}^{m} x_i)^{1/m} \quad \& \quad G(Y) = (\prod_{j=1}^{n} y_j)^{1/n}$$

Now the variable XY assumes the nm values

$$x_1 y_1 , x_1 y_2 , \dots \dots \dots \dots , x_1 y_n ,$$

$$x_2 y_1 , x_2 y_2 , \dots \dots \dots \dots , x_2 y_n ,$$

$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$x_m y_1 , x_m y_2 , \dots \dots \dots \dots , x_m y_n ,$$

which are all non-zero.

Accordingly,

$$G(XY) = \left(\prod_{i=1}^{m} \prod_{j=1}^{n} x_i y_j\right)^{1/mn}$$

$$= \{(\prod_{i=1}^{m} x_i)^n (\prod_{j=1}^{n} y_j)^m\}^{1/mn}$$
$$= (\prod_{i=1}^{m} x_i)^{1/m} (\prod_{j=1}^{n} y_j)^{1/n}$$

i.e. $G(XY) = G(X)\ G(Y)$

Now, if X, Y & Z are three discrete random variables such that all assume non-zero values then

$$XYZ = X(YZ)$$

where YZ is a variable.

Accordingly,

$$G(XYZ) = G(X)\ G(YZ)$$

i.e. $G(XYZ) = G(X)\ G(Y)\ G(Z)$

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By the application the mathematical induction, one can obtain that if

$$X_1 , X_2 , \ldots\ldots\ldots\ldots , X_p$$

are p discrete random variables such that all assume non-zero values then

$$G(X_1X_2 \ldots\ldots\ldots\ldots X_p) = G(X_1)\, G(X_2) \ldots\ldots\ldots\ldots G(X_p)$$

Thus the following ***theorem***, interpretable as multiplicative property of geometric mean, has been obtained:

***Theorem* (2.1):**

The geometric mean of the ***product*** *of a number of* ***variable****s is equal to the* ***product*** *of their individual geometric means*

i.e. if

$$X_1 , X_2 , \ldots\ldots\ldots\ldots , X_p$$

are p variables such that all assume non-zero values then

$$G(X_1X_2 \ldots\ldots\ldots\ldots X_p) = G(X_1)\, G(X_2) \ldots\ldots\ldots\ldots G(X_p)$$

IV. NUMERICAL EXAMPLE

Let us define three variables X, Y & Z are as follows:

X = even integer in [1 , 10] ,

Y = odd integer in [1 , 10]

& Z = odd prime integer in [1 , 10] .

Then X assumes the 5 values

2 , 4 , 6 , 8 , 10

such that $G(X)$ = 5.210342169394703784651533847857 2

Similarly, Y assumes the 5 values

1 , 3 , 5 , 7 , 9

such that $G(Y)$ = 3.936283427035351626745901935248 4

Also, Z assumes the 4 values

1 , 3 , 5 , 7

such that $G(Z)$ = 3.201085872943679463768304018522

Now, XY assumes the 25 values

2 , 4 , 6 , 8 , 10

1 , 3 , 5 , 7 , 9

1 , 3 , 5 , 7

2 , 4 , 6 , 8 , 10 , 6 , 12 , 18 , 24 , 30 , 10 , 20 , 30 , 40 , 50 , 14 , 28 , 42 , 56 , 70 , 18, 36 , 54 , 72 , 90

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such that $G(XY)$ = 20.509383530571793200688884177484

Similarly, YZ assumes the 20 values

1 , 3 , 5 , 7 , 9 , 3 , 9 , 15 , 21 , 27 , 5 , 15 , 25 , 35 , 45 , 7 , 21 , 35 , 49 , 63

such that $G(YZ)$ = 12.600381270185196770593306698998

Also, ZX assumes the 20 values

2 , 4 , 6 , 8 , 10 , 6 , 12 , 18 , 24 , 30 , 10 , 20 , 30 , 40 , 50 , 14 , 28 , 42 , 56 , 70

such that $G(ZX)$ = 16.678752711652109981136731372 67

Moreover, XYZ assumes the 100 values

2 , 4 , 6 , 8 , 10 , 6 , 12 , 18 , 24 , 30 , 10 , 20 , 30 , 40 , 50 , 14 , 28 , 42 , 56 , 70 ,
18, 36 , 54 , 72 , 90 , 6, 12 , 18 , 24 , 30 , 18 , 36 , 54 , 72 , 90 , 30 , 60 , 90, 120 , 150 ,
42 , 84 , 126 , 168 , 210 , 54 , 108 , 162 , 216 , 270 , 10 , 20 , 30 , 40 , 50 , 30 , 60 , 90 , 120 , 150 ,
50 , 100 , 150 , 200 , 250 , 70 , 140 , 210, 280 , 350 , 90 , 180 , 270 , 360 , 450 , 14 , 28 , 42 , 56 , 70 ,
42 , 84 , 126 , 168 , 210 , 70 , 140 , 210 , 280 , 350 , 98 , 196 , 294 , 392 , 490 , 126 , 252 , 378 , 504 , 630

such that $G(XYZ)$ = 10.246950765959598383221038680 52

Note that

$G(X)\ G(Y)$ = 5.21034216939470378465153384785 72 × 3.936283427035351626745901935248 4
= 20.509383530571793200688884177484
= $G(XY)$,

$G(Y)\ G(Z)$ = 3.936283427035351626745901935248 4 × 3.201085872943679463768304018522
= 12.600381270185196770593306698998
= $G(YZ)$,

$G(Z)\ G(X)$ = 3.201085872943679463768304018522 × 5.21034216939470378465153384785 72
= 16.678752711652109981136731372 67
= $G(ZX)$

& $G(X)\ G(Y)\ G(Z)$ = 5.21034216939470378465153384785 72 × 3.9362834270 353516267459019352484
× 3.201085872943679463768304018522
= 10.246950765959598383221038680 52
= $G(XYZ)$

V. DISCUSSION AND CONCLUSION

It is an established property of arithmetic mean that the arithmetic mean of the sum of a number of variables is the sum their individual arithmetic means. Geometric mean satisfies similar property with respect to the operation of multiplication.

Like arithmetic mean, there may be more properties of geometric mean which are required to be extracted in further research study.

Similarly, harmonic mean is also to carry some properties besides its established properties. Study can be made on extracting these properties also.

It is to be mentioned that the multiplicative property of **geometric mean** has here been derived in the case of a discrete variable. Derivation of this property is to be done in the case of continuous variable.

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AUTHOR'S BIOGRAPHY

Dr. Dhritikesh Chakrabarty passed B.Sc. (with Honours in Statistics) Examination from Darrang College, Gauhati University, in 1981 securing 1st class &1st position. He passed M.Sc. Examination (in Statistics) from the same university in the year 1983 securing 1st class & 1st position and successively passed M.Sc. Examination (in Mathematics) from the same university in 1987 securing 1st class (5th position). He obtained the degree of Ph.D. (in Statistics) in the year 1993 from Gauhati University. Later on, he obtained the degree of Sangeet Visharad (inVocal Music) in the year 2000 from Bhatkhande Sangeet vidyapith securing 1st class, the degree of Sangeet Visharad (in Tabla) from Pracheen Kala Kendra in 2010 securing 2nd class, the degree of Sangeet Pravakar (in Tabla) from Prayag Sangeet Samiti in 2012 securing 1st class, the degree of Sangeet Bhaskar (in Tabla) from Pracheen Kala Kendra in 2014 securing 1st class and Sangeet Pravakar (in Guitar) from Prayag Sangeet Samiti in 2021 securing 1st class. He obtained Jawaharlal Nehru Award for securing 1st position in Degree Examination in the year 1981. He also obtained Academic Gold Medal of Gauhati

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University and Prof. V. D. Thawani Academic Award for securing 1st position in Post Graduate Examination in the year 1983.

(Dr. Dhritikesh Chakrabarty, 2nd from the left, in the International Conference on Electronics and Advances in Science & Technology 2024 held during 08 - 09 November, 2024)

Dr. Dhritikesh Chakrabarty, currently an independent researcher, served Handique Girls' College, Gauhati University, during the period of 34 years from December 09, 1987 to December 31, 2021, as Professor (first Assistant and then Associate) in the Department of Statistics along with Head of the Department for 9 years and also as Vice Principal of the college. He also served the National Institute of Pharmaceutical Education & Research (NIPER) Guwahati, as guest faculty (teacher cum research guide), during the period from May, 2010 to December, 2016. Moreover, he is a Research Guide (Ph.D. Guide) in the Department of Statistics of Gauhati University and also a Research Guide (Ph.D. Guide) in the Department of Statistics of Assam Down Town University. He has been guiding a number of Ph.D. students in the two universities. He acted as Guest Faculty in the Department of Statistics and also in the Department of Physics of Gauhati University. He also acted as Guest Faculty cum Resource Person in the Ph.D. Course work Programme in the Department of Computer Science and also in the Department of Biotechnology of the same University for the last six years.

Dr. Chakrabarty has been working as an independent researcher for the last more than thirty years. He has already been an author of 260 published research items namely research papers, chapter in books / conference proceedings, books etc. He visited U.S.A. in 2007, Canada in 2011, U.K. in 2014 and Taiwan in 2017. He has already completed one post doctoral research project (2002 – 05) and one minor research project (2010 – 11). He is an active life member of the academic cum research organizations namely (1) Assam Science Society (ASS), (2) Assam Statistical Review (ASR), (3) Indian Statistical Association (ISA), (4) Indian Society for Probability & Statistics (ISPS), (5) Forum for Interdisciplinary Mathematics (FIM), (6) Electronics Scientists & Engineers Society (ESES) and (7) International Association of Engineers (IAENG). Moreover, he is a Reviewer/Referee of (1) Journal of Assam Science Society (JASS) & (2)

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Biometrics & Biostatistics International Journal (BBIJ); a member of the executive committee of Electronic Scientists and Engineers Society (ESES); and a Member of the Editorial Board of (1) Journal of Environmental Science, Computer Science and Engineering & Technology (JECET), (2) Journal of Mathematics and System Science (JMSS) & (3) Partners Universal International Research Journal (PUIRJ). Dr. Chakrabarty acted as members (at various capacities) of the organizing committees of a number of conferences/seminars already held.

Dr. Chakrabarty was awarded with the prestigious SAS Eminent Fellow Membership (SEFM) with membership ID No. SAS/SEFM/132/2022 by Scholars Academic and Scientific Society (SAS Society) on March 27, 2022.

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