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Some Properties of Quadratic Mean

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ABSTRACT: Due to the importance of quadratic mean, which focuses on the effective magnitude or "strength" of a set of values, in various fields like Physics, Engineering, Signal Processing, Error Analysis, Forestry and many others, attempt has been made on some basic properties of quadratic mean on which this article is based. .

KEYWORDS*:* Quadratic Mean, Basic Properties, Derivation

I. INTRODUCTION

Average [1 , 42] is an entity, that describes a set of many entities, whose measure was first developed by Pythagoras who derived three measures of average namely arithmetic mean [2 , 6 , 48], geometric mean [2 , 6] and harmonic mean [2 , 6 , 47] popularly known as "Pythagorean Means" [3 , 7]. 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 [8 , 3 , 27]. 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 [9 , 11 , 12 , 15]. 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 [14 , 18 – 21].

Each of the measures of average is to carry its own properties of whose some are known. Several studies have already been done on properties of arithmetic mean, geometric mean & harmonic mean [2 , 6 , 34 , 35 , 37 – 39 , 47 , 48]. Arithmetic mean, geometric mean & harmonic mean have been found to be widely in developing most of the statistical measures of characteristics of data like central tendency, dispersion etc. [10 , 16 , 17 , 22 – 26 , 31 , 32] and in developing the statistical concept of expectation [5 , 28 – 30 , 33 , 36 , 44 , 45]. It is to be mentioned that quadratic mean [4 , 40 , 42 , 46], which focuses on the effective magnitude or "strength" of a set of values, is also very important and useful in various fields like

(1) Physics, Engineering & Signal Processing to measure effective magnitude or average value, particularly when dealing with fluctuating quantities,
(2) Statistics for measuring the deviation or variance of a dataset from its mean,
(3) Error Analysis to determine the root mean square error, which is a common metric for evaluating the performance of a model or algorithm,
(4) Forestry to characterize the group of trees in a forest, assigning greater weight to larger trees,

etc. [42 , 43 , 46]. For this reason, it has been thought of for identifying properties satisfied by quadratic mean. Here, attempt has been made on identifying, some basic properties of quadratic mean on which this article is based.

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II. QUADRATIC MEAN

Quadratic mean of a Set of Numbers:

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

$$x_1 , x_2 , \ldots\ldots\ldots , x_N$$

Quadratic mean of them, denoted by $Q(x_1 , x_2 , \ldots\ldots , x_N)$, is defined by

$$Q(x_1 , x_2 , \ldots\ldots , x_N) = \sqrt{\{ \frac{1}{N} (x_1^2 + x_2^2 + \ldots\ldots\ldots + x_N^2)\}} = \sqrt{(\sum_{i=1}^{N} x_N^2)}$$

where the symbol $\sqrt{}$ is used to mean the absolute (positive) square root.

Note (2.1):

Arithmetic mean of $x_1 , x_2 , \ldots\ldots\ldots , x_N$, denoted by $A(x_1 , x_2 , \ldots\ldots , x_N)$, is defined by

$$A(x_1 , x_2 , \ldots\ldots , x_N) = \frac{1}{N} (x_1 + x_2 + \ldots\ldots + x_N)$$

which implies,

$$A(x_1^2 , x_2^2 , \ldots\ldots\ldots , x_N^2) = \frac{1}{N} (x_1^2 + x_2^2 + \ldots\ldots\ldots + x_N^2)$$

i.e. $$\sqrt{\{A(x_1^2 , x_2^2 , \ldots\ldots\ldots , x_N^2)\}} = \sqrt{\{ \frac{1}{N} (x_1^2 + x_2^2 + \ldots\ldots\ldots + x_N^2)\}}$$

Therefore,

$$Q(x_1 , x_2 , \ldots\ldots , x_N) = \sqrt{\{A(x_1^2 , x_2^2 , \ldots\ldots\ldots , x_N^2)\}}$$

Thus, quadratic mean of a set of numbers can also be defined as the absolute square root of arithmetic mean of squares of the numbers.

Quadratic mean of a Variable:

If X is a variable which assumes the values

$$x_1 , x_2 , \ldots\ldots\ldots , x_n$$

then the quadratic mean of X, denoted here by $Q(X)$, can accordingly be defined by

$$Q(X) = \sqrt{\{ \frac{1}{n} (x_1^2 + x_2^2 + \ldots\ldots\ldots + x_n^2)\}} = \sqrt{(\sum_{i=1}^{n} x_i^2)}$$

Note (2.2):

Arithmetic mean of X, denoted here by $A(X)$, can similarly be defined by

$$A(X) = \frac{1}{n} (x_1 + x_2 + \ldots\ldots + x_n)$$

which implies,

$$A(X^2) = \frac{1}{n} (x_1^2 + x_2^2 + \ldots\ldots\ldots + x_n^2)$$

i.e. $$\sqrt{\{A(X^2)\}} = \sqrt{\{ \frac{1}{n} (x_1^2 + x_2^2 + \ldots\ldots\ldots + x_n^2)\}}$$

Therefore,

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$$Q(X) = \sqrt{\{A(X^2)\}}$$

Thus, quadratic mean of a variable can also be defined as the absolute square root of arithmetic mean of its square (i.e. of X^2).

III. SOME BASIC PROPERTIES

Property (3.1):

For real valued variable X,

$$Q(X) > 0$$

Proof:

It follows from the fact that the square of a real number is always positive which implies,

$$x_1^2 + x_2^2 + \ldots\ldots\ldots + x_n^2 > 0$$

i.e. $\sqrt{\{\frac{1}{n}(x_1^2 + x_2^2 + \ldots\ldots\ldots + x_n^2)\}} > 0$

Hence, $Q(X) > 0$

Note (3.1):

By the same logic if

$$x_1 , x_2 , \ldots\ldots\ldots , x_N$$

are N real numbers then

$$Q(x_1 , x_2 , \ldots\ldots\ldots , x_N) > 0$$

Property (3.2): For real valued variable X,

$$Q(\sqrt{X}) = \sqrt{\{A(X)\}}$$

Proof: Definition of quadratic mean implies that

$$Q(X) = \sqrt{\{A(X^2)\}}$$

Replacing X by $\sqrt{X}$, in this equation, this property is obtained.

Note (3.2):

By the same logic if

$$x_1 , x_2 , \ldots\ldots\ldots , x_N$$

are N real numbers then

$$Q(\sqrt{x_1} , \sqrt{x_2} , \ldots\ldots\ldots , \sqrt{x_N}) = \sqrt{\{A(x_1 , x_2 , \ldots\ldots\ldots , x_N)\}}$$

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Property (3.3): For two variables X & Y,

$$\{Q(\sqrt{X+Y})\}^2 = \{Q(\sqrt{X})\}^2 + \{Q(\sqrt{Y})\}^2$$

In general, for k real valued variables are

$$X_1, X_2, \ldots\ldots\ldots, X_k$$

are k real valued variables then

$$\{Q(\sqrt{X_1+X_2+\ldots\ldots\ldots+X_k})\}^2 = \{Q(\sqrt{X_1})\}^2 + \{Q(\sqrt{X_2})\}^2 + \ldots\ldots\ldots + \{Q(\sqrt{X_k})\}^2$$

Proof:

Additive property of arithmetic mean implies that

$$A(X_1 + X_2 + \ldots\ldots\ldots + X_k) = A(X_1) + A(X_2) + \ldots\ldots\ldots + A(X_k)$$

Property (3.2) implies that

$$Q(\sqrt{X_1}) = \sqrt{\{A(X_1)\}}, Q(\sqrt{X_2}) = \sqrt{\{A(X_2)\}}, \ldots\ldots\ldots, Q(\sqrt{X_k}) = \sqrt{\{A(X_k)\}}$$

$$\& \quad Q(\sqrt{X_1+X_2+\ldots\ldots\ldots+X_k}) = \sqrt{\{A(X_1 + X_2 + \ldots\ldots\ldots + X_k)}$$

i.e. $A(X_1) = \{Q(\sqrt{X_1})\}^2$, $A(X_2) = \{Q(\sqrt{X_2})\}^2$, ... , $A(X_k) = \{Q(\sqrt{X_k})\}^2$

& $A(X_1 + X_2 + \ldots\ldots\ldots + X_k) = \{Q(\sqrt{X_1+X_2+\ldots\ldots\ldots+X_k})\}^2$

Hence,

$$\{Q(\sqrt{X_1+X_2+\ldots\ldots\ldots+X_k})\}^2 = \{Q(\sqrt{X_1})\}^2 + \{Q(\sqrt{X_2})\}^2 + \ldots\ldots\ldots + \{Q(\sqrt{X_k})\}^2$$

Note (3.3):

This can be regarded as additive property of quadratic mean.

Property (3.4):

For real valued variable X,

$$A(X) \geq G(X) \geq H(X)$$

where $G(X)$ & $H(X)$ are respectively the geometric mean & the harmonic mean of X.

Proof:

Since square of an expression of real variable is ≥ 0,

$$\{X - A(X)\}^2 \geq 0$$

Accordingly,

$$A\{X - A(X)\}^2 \geq 0$$

From this, it is obtained that

$$A(X^2) \geq \{A(X)\}^2 \quad \text{or} \quad \sqrt{\{A(X^2)\}} \geq A(X)$$

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Hence, $Q(X) \geq A(X)$

It has already been established that arithmetic mean, geometric mean & harmonic mean satisfy the inequality

$$A(X) \geq G(X) \geq H(X)$$

Hence, $$Q(X) \geq A(X) \geq G(X) \geq H(X)$$

Equality holds good if and when X comes down to be a constant.

Note (3.4):

By the same logic if

$$x_1 , x_2 , \ldots\ldots\ldots , x_N$$

are N real numbers, then

$$Q(x_1 , x_2 , \ldots , x_N) \geq A(x_1 , x_2 , \ldots , x_N) \geq G(x_1 , x_2 , \ldots , x_N \, x_N) \geq H(x_1 , x_2 , \ldots , x_N)$$

IV. CONCLUSION

Quadratic mean is a measure of average which measures the absolute magnitude of a set of numbers. Accordingly, quadratic mean of a variable describes the absolute magnitude assumed by the variable.

Some basic properties of quadratic mean have been identified here due to its importance in various fields like Physics, Engineering, Signal Processing, Error Analysis, Forestry and many others. However, more properties of quadratic mean are yet to be identified.

As mentioned above, quadratic mean of a set of numbers (or of a variable) can in other way be defined as the absolute square root of arithmetic mean of squares of the numbers (or of the variable). This definition of quadratic mean may be helpful in identifying its more properties with the help of the properties of Aarithmetic mean which have already been established.

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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

(Dr. Dhritikesh Chakrabarty at the beach near Huwalien City in Taiwan on November 26 of 2017)

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

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 270 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) 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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