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Model Describing Central Tendency of Data

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ABSTRACT: In statistics, the three Pythagorean means are widely used as measures of central tendency of data [4 , 5 , 14 , 38 , 72]. In addition to these three measures of central tendency of data, attempt has been continuing on establishing AGM, AHM, GHM & AGHM as more measures of central tendency of data [61 , 62 , 63, 64 , 65]. Since the measure of central tendency is not unique, there is necessity of examining quality of the measures. In order to assess the quality, attempt has here been made on searching for the mathematical model and some vital properties to be satisfied by a measure of central tendency of data.

KEYWORDS: Data, Central Tendency, Measure, Mathematical Model, Property

I. INTRODUCTION

Several research had already been done on developing definitions / formulations of average [1 , 2], a basic concept used in developing most of the measures used in analysis of data. Pythagoras [3], the pioneer of researchers in this area, constructed three definitions / formulations of average namely Arithmetic Mean, Geometric Mean & Harmonic Mean which are called Pythagorean means [4 , 5 , 14 , 18]. A lot of definitions / formulations have already been developed among which some are arithmetic mean. geometric mean, harmonic mean, quadratic mean, cubic mean, square root mean, cube root mean, general *p* mean and many others [6 , 7 , 8 , 9 , 10 , 11 , 12 , 13 , 14 , 15 , 16 , 17, 18 , 19]. Kolmogorov [20] formulated one generalized definition of average namely Generalized *f* - Mean. [7 , 8]. It has been shown that the definitions/formulations of the existing means and also of some new means can be derived from this Generalized *f* - Mean [9 , 10]. In an study, Chakrabarty formulated one generalized definition of average namely Generalized f_H – Mean [11]. In another study, Chakrabarty formulated another generalized definition of average namely Generalized f_G – Mean [12 , 13] and developed one general method of defining average [15, 16 , 17] as well as the different formulations of average from the first principles [19].

In many real situations, observed numerical data

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

are found to be composed of a single parameter μ and corresponding chance / random errors

$$\varepsilon_1 , \varepsilon_2 , \ldots\ldots\ldots , \varepsilon_N$$

i.e. the observations can be expressed as

$$x_i = \mu + \varepsilon_i \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots , N) \qquad (1.1)$$

[21 , 22 , 23 , 24 , 25 , 26 , 27, 28 , 29].

The existing methods of estimation of the parameter μ namely least squares method, maximum likelihood method, minimum variance unbiased method, method of moment and method of minimum chi-square, [31 – 52] cannot provide appropriate value of the parameter μ [21 , 22 , 23]. In some recent studies, some methods have been developed for determining the value of parameter from observed data containing the parameter itself and random error [21 ,22 , 23 , 24 , 25 , 26, 27 , 28 , 29 , 30 , 53 ,54 , 55 , 56, 57 , 58 , 59 , 60]. The methods, developed in this studies, for determining the appropriate value of the parameter from observed data containing the parameter itself and random error involve huge computational tasks. Moreover, a finite set of observed data may not yield the appropriate value of the parameter in many situations while the number of observations required in the methods may be too large for obtaining the appropriate value of the parameter. However, the appropriate value of the parameter is not perfectly attainable in practical situation. What one can expect is to obtain that value which is more and more close to the appropriate value of the parameter. In order to obtain such value of parameter, four methods have already been developed which involves lesser computational tasks than those involved in the earlier methods as well as which can be applicable in the case of finite set of data [61 , 62 , 63 , 64]. The methods developed are based on the concepts of Arithmetic-Geometric Mean (abbreviated as *AGM*) [61 , 62, 66 , 67], Arithmetic-Harmonic Mean (abbreviated as *AHM*) [63], Geometric-Harmonic Mean (abbreviated as *GHM*) [64] and Arithmetic-Geometric-Harmonic Mean (abbreviated as *AGHM*) [65] respectively. In another study, these four formulations have been shown as four measures of average [71].

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In statistics, the three Pythagorean means are widely used as measures of central tendency of data [4 , 5 , 14 , 38 , 72]. In addition to these three measures of central tendency of data, attempt has been continuing on establishing AGM, AHM, GHM & AGHM as more measures of central tendency of data [61 , 62 , 63, 64 , 65]. Since the measure of central tendency is not unique, there is necessity of examining quality of the measures. In order to assess the quality, attempt has here been made on searching for the mathematical model and some vital properties to be satisfied by a measure of central tendency of data.

II. CENTRALTENDENCY OF DATA – ITS MEANING

Occasionally authors use central tendency to denote "the **tendency of quantitative data to cluster around some central value**." The central tendency of a distribution is typically contrasted with its dispersion or variability; dispersion and central tendency are the often characterized properties of distributions.

In statistics, a **central tendency** (or **measure of central tendency**) is a central or typical value for a probability distribution [74]. It may also be called a **center** or **location** of the distribution. Colloquially, measures of central tendency are often called *averages*. The term *central tendency* dates from the late 1920s [73].

Measure of Central Tendency

A measure of central tendency is a single value that attempts to describe a set of data by identifying the central position within that set of data. As such, measures of central tendency are sometimes called measures of central location. They are also classed as summary statistics. The mean (often called the average) is most likely the measure of central tendency which is most popular, but there are others also.

The following are the existing measures of central tendency of data. Some of the are mathematical measures and the others are positional measures in nature:

Arithmetic mean or simply, mean**:** the sum of all measurements divided by the number of observations in the data set.
Median: the middle value that separates the higher half from the lower half of the data set. The median and the mode are the only measures of central tendency that can be used for ordinal data, in which values are ranked relative to each other but are not measured absolutely.
Mode: the most frequent value in the data set. This is the only central tendency measure that can be used with nominal data, which have purely qualitative category assignments.
Geometric mean: the *n*th root of the product of the data values, where there are *n* of these. This measure is valid only for data that are measured absolutely on a strictly positive scale.
Harmonic mean: the reciprocal of the arithmetic mean of the reciprocals of the data values. This measure too is valid only for data that are measured absolutely on a strictly positive scale.
Weighted arithmetic mean: an arithmetic mean that incorporates weighting to certain data elements.
Truncated mean or trimmed mean: the arithmetic mean of data values after a certain number or proportion of the highest and lowest data values have been discarded.
Interquartile mean: a truncated mean based on data within the interquartile range.
Midrange: the arithmetic mean of the maximum and minimum values of a data set.
Midhinge: the arithmetic mean of the first and third quartiles.
Trimean: the weighted arithmetic mean of the median and two quartiles.
Winsorized mean: an arithmetic mean in which extreme values are replaced by values closer to the median.
Geometric median: that minimizes the sum of distances to the data points.
Quadratic mean (often known as the root mean square): useful in engineering, but not often used in statistics. This is because it is not a good indicator of the center of the distribution when the distribution includes negative values.
Simplicial depth: the probability that a randomly chosen simplex with vertices from the given distribution will contain the given center
Tukey median: a point with the property that every half-space containing it also contains many sample points.

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Vol. 8, Issue 9 , September 2021

III. CENTRAL TENDENCY AND SOME MATHEMATICAL MODELS

Let

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

be N observed values (i.e. numerical data) on a variable X and μ the central tendency of them.
Let us suppose that these N numbers (or values or observations) are strictly positive and all of which are not identical.

Model-1

If μ is the measure of central tendency of these N values then some of these values will be greater than μ and the others will be less than μ occurring at random.
Hence, these N values can be described by or expressed as

$$x_i = \mu + \varepsilon_i \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots\ , N) \qquad (3.1)$$

where

$$\varepsilon_1 , \varepsilon_2 , \ \ldots\ldots\ldots , \varepsilon_N$$

are the random errors, which assume positive and negative values in random order, associated to

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

respectively.
This is termed here as the first mathematical model **(Model-1)** satisfied by the measure of central tendency of data.

Model-3

Since μ is the measure of central tendency of these N values then some of these values will be greater than μ and the others will be less than μ occurring at random.
Also since the N values are strictly positive, these can also be described by

$$x_i = \mu \ \varepsilon_i^{//} \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots\ , N) \qquad (3.2)$$

where

$$\varepsilon_1^{//} , \varepsilon_2^{//} , \ldots\ldots\ldots\ldots\ , \varepsilon_N^{//}$$

are the random errors, which assume values in $(0 , 1)$ and in $(1 , \infty)$ in random order, associated to

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

respectively.
This is termed here as the second mathematical model **(Model-2)** satisfied by the measure of central tendency of data.

Model-3

Since the N observations has μ as measure of their central tendency, the reciprocals

$$x_1^{-1} , x_2^{-1} , \ \ldots\ldots\ldots\ldots\ , x_N^{-1}$$

will have μ^{-1} as measure of their central tendency.
Accordingly, some of these N reciprocals will be greater than μ^{-1} and the others will be less than μ^{-1} occurring at random i.e. the reciprocals are composed of μ^{-1} and random errors different from the respective random errors

$$\varepsilon_1 , \varepsilon_2 , \ \ldots\ldots\ldots , \varepsilon_N$$

provided $x_1 \ , \ x_2 \ , \ \ldots\ldots\ldots\ldots\ , x_N$ are all different from zero.
Hence, the reciprocals can be described by

$$x_i^{-1} = \mu^{-1} + \varepsilon_i^{/} \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots\ , N) \qquad (3.3)$$

where

$$\varepsilon_1^{/} , \varepsilon_2^{/} , \ldots\ldots\ldots\ , \varepsilon_N^{/}$$

are the random errors, which assume positive and negative values in random order, associated to are the random errors associated to

$$x_1^{-1} , x_2^{-1} , \ \ldots\ldots\ldots\ldots\ , x_N^{-1}$$

respectively.
This is termed here as the third mathematical model **(Model-3)** satisfied by the measure of central tendency of data.

Model-4

Again since μ is the measure of central tendency of these N values and since these values are strictly positive, the squares

$$x_1^{2} , x_2^{2} , \ \ldots\ldots\ldots\ldots\ , x_N^{2}$$

will have μ^2 as measure of their central tendency.

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Hence, the squares can be described by

$$x_i^2 = \mu^2 + \varepsilon_{2i} \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots , N) \qquad (3.4)$$

where

$$\varepsilon_{21} , \varepsilon_{22} , \ldots\ldots\ldots , \varepsilon_{2N}$$

are the random errors, which assume positive and negative values in random order, associated to are the random errors associated to

$$x_1^2 , x_2^2 , \ldots\ldots\ldots\ldots , x_N^2$$

respectively.
This is termed here as the third mathematical model **(Model-4)** satisfied by the measure of central tendency of data.

Model-5
Again since μ is the measure of central tendency of these N values and since these values are strictly positive, the values

$$x_1^p , x_2^p , \ldots\ldots\ldots\ldots , x_N^p$$

will have μ^p as measure of their central tendency.
Hence, the squares can be described by

$$x_i^p = \mu^p + \varepsilon_{pi} \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots , N) \qquad (3.5)$$

where

$$\varepsilon_{p1} , \varepsilon_{p2} , \ldots\ldots\ldots , \varepsilon_{pN}$$

are the random errors, which assume positive and negative values in random order, associated to are the random errors associated to

$$x_1^p , x_2^p , \ldots\ldots\ldots\ldots , x_N^p$$

respectively.
This is termed here as the third mathematical model **(Model-5)** satisfied by the measure of central tendency of data.

IV. SOME PROPERTIES OF MEASURE OFCENTRAL TENDENCY

Here let us use the notation $\mu\ (x_1 , x_2 , \ldots\ldots\ldots\ldots , x_N)$ to denote the measure of central tendency $x_1 , x_2 , \ldots\ldots\ldots\ldots , x_N$ and μ to denote the value of the central tendency of
$x_1 , x_2 , \ldots\ldots\ldots\ldots , x_N$.
the value of the central tendency will also be increased (or decreased) by a.
Let a be a finite real number.
If a is added to (or subtracted from) each of the N values
$x_1 , x_2 , \ldots\ldots\ldots\ldots , x_N$,
then Therefore, the following property of central tendency is obtained:
Property (4.1):
For any finite real number a,

$$\mu\ (x_1 + a , x_2 + a , \ldots\ldots\ldots\ldots , x_N + a) = \mu + a$$

Similarly if each of the N values

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

is multiplied by a non-zero real number c then the value of the central tendency will also be changed by c times.
Thus, the following property of central tendency is obtained:
Property (4.2):
For any non-zero finite real number c,

$$\mu\ (cx_1 , cx_2 , \ldots\ldots\ldots\ldots , cx_N) = c\mu$$

In a similar manner, the following property of the central tendency can be obtained:
Property (4.3):
If $\mu\ (x_1 , x_2 , \ldots\ldots\ldots\ldots , x_N) = \mu$
then

$$\mu\ (x_1^{-1} , x_2^{-1} , \ldots\ldots\ldots\ldots , x_N^{-1}) = \mu^{-1} ,$$
$$\mu\ (x_1^2 , x_2^2 , \ldots\ldots\ldots\ldots , x_N^2) = \mu^2$$
$$\& \ \mu\ (x_1^p , x_2^p , \ldots\ldots\ldots\ldots , x_N^p) = \mu^p , \text{ for finite integer } p$$

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Vol. 8, Issue 9 , September 2021

V. CONCLUSION

The information on

(1) the mathematical model satisfied by the measure of central tendency

and (2) the properties of the measure of central tendency

as described above are expected to carry significance in the field of measures of central tendency of data.

From the mathematical models satisfied by the measure of central tendency, as described above, it may be possible to derive measure(s) of central tendency of data.

The properties of the measure of central tendency may help in examining the quality of the measure(s) of central tendency and to identify/determine the most suitable measure of central tendency of data.

Finally, as per the meaning of research [68 , 69 ,70], it can be concluded that the extraction of the information on central tendency, as described above, can be regarded as research findings carrying fundamental importance and high significance in the theory of measure of central tendency of data.

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