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Determination of Parameter from Observations Composed of Itself and Errors

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***Abstract* – In the situations where the observations X_1 , X_2 , ………… , X_n are composed of some parameter μ and chance errors ε_i ($i = 1 , 2 , ……….. , n$) i.e. $X_i = \mu + \varepsilon_i$, a method has been developed for determining the true value of the parameter μ. This paper is based on the derivation of this method and on numerical application of the method in the determination of the natural annual maximum temperature and the natural annual minimum temperature at Guwahati.**

Key Words -- **Chance error, determination of parameter, observation, parameter.**

I. INTRODUCTION

Observations or data collected from experiments or survey normally suffer from various errors. Error occurs due to cause/causes which is/are assignable (or intentional). Assignable cause/causes of error are controllable. Even if all the assignable causes of error are controlled or eliminated, observations still do not become free from error; they still suffer from some error which occurs due to some unknown and unintentional (chance) cause which is unavoidable, uncontrollable & immeasurable. Findings obtained by analyzing the observations or data which are free from the assignable errors are also subject to errors due to the presence of chance error in the observations. Determination of parameters, in different situations, based on the observations is also subject to error due to the same reason. There are many situations where observations

X_1 , X_2 , ………… , X_n

are composed of some parameter and chance errors i.e.

$X_i = \mu + \varepsilon_i$, ($i = 1 , 2 , ……….. , n$)

Where (i) μ is the parameter and (ii) ε_i is the chance error associated to X_i.

The existing methods of estimation namely least squares method, maximum likelihood method, minimum variance unbiased method, method of moment and method of minimum chi-square provide

$$\bar{X} = \sum_{i=1}^{n} X_n$$

as estimator of the parameter μ . This estimator suffers from an error

$$\bar{\varepsilon}_i = \sum_{i=1}^{n} \varepsilon_i$$

which may not be zero as in [3], [4], [5], [10], [11], [14] & [16]. In other words, none of these methods can provide the true value of the parameter μ. In the current study, the situation mentioned above has been considered. A method, therefore, has been developed for determining the true value of the parameter μ in such situation. The present paper is based on this development especially on the method of determination of the true value of the parameter and on numerical application of the method in the determination of the natural annual maximum temperature and the natural annual minimum temperature at Guwahati.

II. GAUSSIAN DISCOVERY

In the year 1809, German mathematician *Carl Friedrich Gauss* discovered the most significant probability distribution in the theory of statistics popularly known as normal distribution, the credit for which discovery is also given by some authors to a French mathematician *Abraham De Moivre* who published a paper in 1738 that showed the normal distribution as an approximation to the binomial distribution discovered by *James Bernoulli* in 1713 as in [1], [2], [8], [9], [12], [13], [15], [17] & [18]. The normal probability distribution plays the key role in the theory of statistics as well as in the application of statistics. There are innumerable situations where one can think of applying the theory of normal probability distribution to handle the situations. The probability density function of normal probability distribution discovered by *Gauss* is described by the probability density function

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$$f(x : \mu , \sigma) = \{ \sigma (2\pi) ½\}. exp [- ½ \{(x - \mu)/\sigma\}^2] , \quad (2.1)$$
$$-\infty < x < \infty , \quad -\infty < \mu < \infty , \quad 0 < \sigma < \infty .$$

where (i) X is the associated normal variable,
(ii) μ & σ are the two parameters of the distribution
and (iii) Mean of $X = \mu$ & Standard Deviation of $X = \sigma$.
Note: If $\mu = 0$ & $\sigma = 1$,
the density is standardized and X then becomes a standard normal variable.

A. Area Property of Gaussian distribution

If $X \sim N(\mu , \sigma)$, then
(i) $P(\mu - 1.96\,\sigma < X < \mu - 1.96\,\sigma) = 0.95$, (2.2)
(ii) $P(\mu - 2.58\,\sigma < X < \mu - 2.58\,\sigma) = 0.99$ (2.3)
& (iii) $P(\mu - 3\,\sigma < X < \mu - 3\,\sigma) = 0.9973$. (2.4)
If X is a standard normal variable then
(i) $P(-1.96 < X < 1.96) = 0.95$, (2.5)
(ii) $P(-2.58 < X < 2.58) = 0.99$ (2.6)
& (iii) $P(-3 < X < 3) = 0.9973$. (2.7)

III. DEVELOPMENT OF THE METHOD

Let $X_1 , X_2 , \ldots\ldots\ldots , X_n$ be n observations on some characteristic μ. In this situation, each observation X_i is composed of value of μ and an error ε_i (occurring due to chance). The value of μ is unique. But the observed values on μ are different. The variation among the observations occurs due to two types of causes/errors namely
1. Assignable Cause(s) that is (are) avoidable / controllable
& 2. Chance Cause/Error that is unavoidable / uncontrollable

The values X_i ($i = 1 , 2 , \ldots\ldots\ldots , n$) should be constant if there exists no cause of variation among them over i. However, chance cause of variation exists always. Thus if no assignable cause of variation exists among X_i ($i = 1 , 2 , \ldots\ldots\ldots , n$) , we have

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

Here $\varepsilon_1 , \varepsilon_2 , \ldots\ldots\ldots , \varepsilon_n$ are values of the chance error variable ε associated to $X_1 , X_2 , \ldots\ldots\ldots , X_n$ respectively.
It is to be noted that
(1) $X_1 , X_2 , \ldots\ldots\ldots , X_n$ are known,
(2) $\mu , \varepsilon_1 , \varepsilon_2 , \ldots\ldots\ldots , \varepsilon_n$ are unknown
& (3) the number of linear equations in (3.1) is n with $n + 1$ unknowns implying that the equations are not solvable mathematically.

Reasonable facts /Assumptions regarding ε_i:

(1) $\varepsilon_1 , \varepsilon_2 , \ldots\ldots\ldots , \varepsilon_n$ are unknown values of the variables ε.
(2) The values $\varepsilon_1 , \varepsilon_2 , \ldots\ldots\ldots , \varepsilon_n$ are very small relative to the respective values $X_1 , X_2 , \ldots\ldots\ldots , X_n$.
(3) The variable ε assumes both positive and negative values.
(4) $P(-a - da < \varepsilon < -a) = P(a < \varepsilon < a + da)$ for every real a.
(5) $P(a < \varepsilon < a + da) > P(b < \varepsilon < b + db)$
& $P(-a - da < \varepsilon < -a) < P(-b - db < \varepsilon < -b)$
for every real positive $a < b$.
(6) The facts (3), (4) & (5) together imply that ε obeys the normal probability law.
(7) Sum of all possible values of each ε is 0 (zero) which together with the fact (6) implies that $E(\varepsilon) = 0$.
(8) Standard deviation of ε is unknown and small, say σ_ε.
(9) The facts (6), (7) & (8) together imply that ε obeys the normal probability law with mean (expectation) 0 &standard deviation σ_ε. Thus

$$\varepsilon \sim N(0 , \sigma_\varepsilon) \qquad (3.2)$$

A. The Method

Let the observations be arranged in ascending order of magnitude as

$$X_{(1)} < X_{(2)} < \ldots\ldots\ldots < X_{(n)} \qquad (3.3)$$

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Here, $X_{(1)}$ contains the maximum negative error and $X_{(n)}$ contains the maximum positive error.
Let us construct the averages

$$\bar{X}_{(i)}(1) = \sum_{j=1, j \neq i}^{n} X_{(j)} \qquad (3.4)$$

($i = 1, 2, \ldots, n$).
By the symmetry property of ε_i about zero, some of these averages will lie above μ and others below μ.
Also,

$$\bar{X}_{(1)}(1) > \bar{X}_{(2)}(1) > \ldots > \bar{X}_{(n-1)}(1) > \bar{X}_{(n)}(1) \qquad (3.5)$$

Hence,

$$\bar{X}_{(n)}(1) < \mu < \bar{X}_{(1)}(1) \qquad (3.6)$$

These inequalities can be used to determine the true value of μ.
Now, let us exclude the two extreme values namely $X_{(1)}$ and $X_{(n)}$ and construct

$$\bar{X}_{(i)}(2) = \sum_{j=2, j \neq i}^{n-1} X_{(j)} \qquad (3.7)$$

$$(i = 2, \ldots, n-1)$$

Then, we can obtain that

$$\bar{X}_{(2)}(2) > \bar{X}_{(3)}(2) > \ldots > \bar{X}_{(n-2)}(2) > X_{(n-1)}(2) \qquad (3.8)$$

Hence,

$$\bar{X}_{(n-1)}(2) < \mu < \bar{X}_{(2)}(2) \qquad (3.9)$$

These inequalities can be used to determine the true value of μ.
One can exclude the four extreme values namely $X_{(1)}$, $X_{(2)}$, $X_{(n-1)}$ and $X_{(n)}$ and construct

$$\bar{X}_{(i)}(3) = \sum_{j=3, j \neq i}^{n-2} X_{(j)} \qquad (3.10)$$

$$(i = 3, \ldots, n-2)$$

to obtain

$$\bar{X}_{(2)}(3) > \bar{X}_{(3)}(3) > \ldots > \bar{X}_{(n-2)}(3) > \bar{X}_{(n-1)}(3) \qquad (3.11)$$

so that

$$\bar{X}_{(n-2)}(3) < \mu < \bar{X}_{(3)}(3) \qquad (3.12)$$

One can exclude the six extreme values namely $X_{(1)}$, $X_{(2)}$, $X_{(3)}$, $X_{(n-2)}$, $X_{(n-1)}$ and $X_{(n)}$ and construct

$$\bar{X}_{(i)}(4) = \sum_{j=4, j \neq i}^{n-3} X_{(j)} \qquad (3.13)$$

$$(i = 4, \ldots, n-3)$$

to obtain

$$\bar{X}_{(3)}(4) > \bar{X}_{(4)}(4) > \ldots > \bar{X}_{(n-4)}(4) > \bar{X}_{(n-3)}(4) \qquad (3.14)$$

so that

$$\bar{X}_{(n-3)}(4) < \mu < \bar{X}_{(4)}(4) \qquad (3.15)$$

Some or all of these inequalities can be used to determine the true value of μ.
The process can be continued further if necessary.

IV. ANALYSIS OF ANNUAL EXTRIIMUM OF TEMPERATURE

Temperature at a location attains at a maximum and at a minimum during the calendar year. Let T_1, T_2, ………… , T_n be the observed values of the maximum temperature occurred at a location during the calendar years 1 , 2 , 3 , ……….. , n respectively. The annual maximum of temperature at a location is to remain the same provided there is no cause(s) influencing upon the change in temperature at the location other than the natural cause. However, it is not free from the influence of chance error which is universal. For this reason, variation occurs among the observations on this parameter over years. Thus if β is the natural annual maximum of temperature (*NAMaxT*) at the location,

$$T_i = \beta + \varepsilon_i \quad , \quad (i = 1, 2, \ldots, n) \qquad (4.1)$$

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where ε_i is the chance error associated to the observation T_i.
Similarly if

$$t_1 , t_2 , \ldots\ldots\ldots , t_n$$

are the observed values of the minimum temperature occurred at a location during the calendar years

$$1 , 2 , 3 , \ldots\ldots\ldots , n$$

respectively and α is the natural annual minimum of temperature (*NAMinT*) at the location,

$$t_i = \alpha + e_i \quad , \quad (i = 1 , 2 , \ldots\ldots\ldots , n) \qquad (4.2)$$

where e_i is the chance error associated to the observation t_i.
Thus, the method discussed above can be suitably applied to determine the values of the two parameters α and β.

A. Determination of Natural Annual Maximum Temperature at Guwahati

Observed values of annual maximum Temperature at Guwahati observed during the period from 1969 to 2010 have been collected from the meteorological department of India as in [6] & [7]. These have been presented in Table - I and arranged in ascending order of magnitude in Table - I. Table – III has been constructed for interval values of the Natural Annual Maximum Temperature **(abbreviated as *NAMaxT*)** at Guwahati applying the inequalities (3.6), (3.9), (3.12) & (3.15).

Table – I .Observed values of Annual Maximum Temperature at Guwahati (in Degree Celsius)

Year	Observed value	Year	Observed value	Year	Observed value	Year	Observed value
1969	37.1	1979	38.6	1989	36.7	2002	35.7
1970	36.6	1980	35.1	1990	36.0	2003	37.4
1971	36.0	1981	35.8	1991	37.4	2004	38.0
1972	35.7	1982	36.5	1992	39.4	2005	36.6
1973	39.0	1983	36.7	1993	36.4	2006	38.0
1974	36.1	1984	37.2	1994	37.3	2007	37.3
1975	39.2	1985	36.5	1995	36.3	2008	37.3
1976	39.0	1986	38.4	1996	37.2	2009	38.0
1977	35.3	1987	37.2	2000	37.5	2010	37.2
1978	36.8	1988	36.3	2001	36.7		

Table – II .Observed values of Annual Maximum Temperature at Guwahati in ascending order (in Degree Celsius)

Serial No	Observed value	Serial No	Observed value	Serial No	Observed value	Serial No	Observed value
1	35.1	7	36.3	13	37.1	19	38.4
2	35.3	8	36.4	14	37.2	20	38.6
3	35.7	9	36.5	15	37.3	21	39.0
4	35.8	10	36.6	16	37.4	22	39.2
5	36.0	11	36.7	17	37.5	23	39.4
6	36.1	12	36.8	18	38.0		

Table – III. Interval value of the *NAMaxT* at Guwahati (in Degree Celsius)

Serial No	Based on all distinct observations excluding	Interval value
1	None	(36.9545 , 37.1500)
2	1st & 23rd	(36.9350 , 37.1300)
3	1st, 2nd, 22nd & the 23rd	(36.9111 , 37.0944)
4	1st, 2nd, 3rd, 21st, 22nd & 23rd	(36.8812 , 37.0562)

Values in the third column imply that the value of the *NAMaxT* at Guwahati is 37.0 Degree Celsius.

B. Determination of Natural Annual Minimum Temperature at Guwahati

Observed values of Annual Minimum Temperature at Guwahati observed during the period from 1969 to 2010 have been collected from the meteorological department of India [6] & [7]. These have been presented in Table

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- IV and arranged in ascending order of magnitude in Table - V. Table - VI has been constructed for interval values of the Natural Annual Minimum Temperature **(abbreviated as *NAMinT*)** at Guwahati applying the inequalities (3.6), (3.9), (3.12) & (3.15).

Table – IV. Observed values of Annual Minimum Temperature at Guwahati (in Degree Celsius)

Year	Observed value	Year	Observed value	Year	Observed value	Year	Observed value
1969	5.8	1979	6.2	1989	6.7	2002	8.6
1970	7.2	1980	6.4	1990	8.7	2003	8.0
1971	5.9	1981	7.5	1991	7.4	2004	6.7
1972	8.0	1982	6.2	1992	5.9	2005	8.4
1973	5.0	1983	4.9	1993	7.8	2006	9.6
1974	6.3	1984	6.1	1994	8.8	2007	6.4
1975	7.2	1985	7.8	1995	7.5	2008	9.7
1976	6.6	1986	8.6	1996	9.4	2009	9.8
1977	6.2	1987	7.7	2000	8.5	2010	8.6
1978	7.3	1988	9.2	2001	8.9		

Table – V. Observed values of Annual Minimum Temperature at Guwahati in ascending order (in Degree Celsius)

Serial No	Observed value	Serial No	Observed value	Serial No	Observed value	Serial No	Observed value
1	4.9	8	6.4	15	7.7	22	8.8
2	5.0	9	6.6	16	7.8	23	8.9
3	5.8	10	6.7	17	8.0	24	9.2
4	5.9	11	7.2	18	8.4	25	9.4
5	6.1	12	7.3	19	8.5	26	9.6
6	6.2	13	7.4	20	8.6	27	9.7
7	6.3	14	7.5	21	8.7	28	9.8

Table – VI. Interval value of the *NAMinT* at Guwahati (in Degree Celsius)

Serial No	Based on all distinct observations excluding observation(s)	Interval value
1	None	(7.5037 , 7.6851)
2	1^{st} & 28^{th}	(7,5200 , 7.7080)
3	1^{st}, 2^{nd}, 27^{th} & the 28^{th}	(7.5391 , 7.7043)
4	1^{st}, 2^{nd}, 3^{rd}, 26^{th}, 27^{th} & 28^{th}	(7.5333 , 7.7000)

Values in the third column imply that the value of the *NAMinT* at Guwahati is 7.6 Degree Celsius.

V. DISCUSSION

1. The method developed here can be summarized as follows:

(i) Arrange the distinct observed values in ascending or descending order of Magnitude.

(ii) Corresponding to each observed value, compute the mean of the distinct observed all the distinct values excluding the former.

(iii) Observe the movements of the means from the highest as well as from the lowest ones and determine the value of the parameter

(iv) The value of the parameter can also be determined from the interval formed by the highest mean and the lowest mean.

(v) Confirm the correctness, of the result obtained, by repeating the process based on the observed values excluding the extreme two observed values, the extreme four observed values, the extreme six observed values,

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etc. respectively as required .

2. The existing statistical methods of estimation yield estimates which are not free from error. However, the method developed here yield the estimate which is free from error (i.e. exactly equal to the true value of the parameter).

3. It may be possible to apply this method in the determination of the true values of the parameters associated to the polynomial curves and to some other types of curves. However, it is yet to be investigated.

4. The estimated value computed by the existing methods of estimation varies if some observations are excluded and / or if some new observations are included. However, the value computed by the method developed here remains the same under this situation. Following findings (in Table - VII, Table - VIII, Table - IX & Table - X are some examples:

Table – VII. Maximum Likelihood / Minimum Variance Unbiased / Least Squares / Method of Moments / Minimum Chi Square Estimate of the *NAMaxT* at Guwahati if only one observation is excluded (in Degree Celsius)

Serial No	Excluded observation	Estimated value	Serial No	Excluded observation	Estimated value	Serial No	Excluded observation	Estimated value
1	37.1	37.0591	9	36.8	37.0727	17	36.3	37.0955
2	36.6	37.0818	10	38.6	36.9909	18	37.4	37.0455
3	36.0	37.1000	11	35.1	37.1500	19	39.4	36.9545
4	35.7	37.1200	12	35.8	37.1100	20	36.4	37.0909
5	39.0	36.9727	13	36.5	37.0864	21	37.5	37.0409
6	36.1	37.1045	14	36.7	37.0772	22	37.3	37.0500
7	39.2	36.9636	15	37.2	37.0545	23	38.0	37.0182
8	35.3	37.1400	16	38.4	37.0000			

However, in each of these situations, the value of the *NAMaxT* at Guwahati by the method developed here has been found to be 37.0 Degree Celsius.

Table – VIII. Maximum Likelihood / Minimum Variance Unbiased / Least Squares / Method of Moments / Minimum Chi Square Estimate of the *NAMinT* at Guwahati if only one observation is excluded (in Degree Celsius)

Serial No	Excluded observation	Estimated value	Serial No	Excluded observation	Estimated value	Serial No	Excluded observation	Estimated value
1	5.8	7.65185	11	7.5	7.58888	21	8.8	7.54074
2	7.2	7.60000	12	4.9	7.68518	22	9.4	7.51851
3	5.9	7.64814	13	6.1	7.64074	23	8.5	7.55185
4	8.0	7.57037	14	7.8	7.57777	24	8.9	7.53703
5	5.0	7.68148	15	8.6	7.54814	25	8.4	7.55555
6	6.3	7.63333	16	7.7	7.58148	26	9.6	7.51111
7	6.6	7.62222	17	9.2	7.52592	27	9.7	7,50740
8	6.2	7.63703	18	6.7	7.61851	28	9.8	7.50370
9	7.3	7.59629	19	8.7	7.54444			
10	6.4	7.62962	20	7.4	7.59259			

However, in each of these situations, the value of the *NAMinT* at Guwahati by the method developed here has been found to be 7.6 Degree Celsius.

Table – IX. Maximum Likelihood / Minimum Variance Unbiased / Least Squares / Method of Moments / Minimum Chi Square Estimate of the *NAMaxT* at Guwahati if extreme observations are (in Degree Celsius)

Serial No	Excluded observation	Estimated value (in Degree Celsius)	Serial No	Excluded observation	Estimated value (in Degree Celsius)
1	None	37.06086	6	1^{st}, 27^{th} & 28^{th}	36.93500
2	1^{st}	37.15000	7	1^{st}, 2^{nd}, 27^{th} & 28^{th}	37.02105
3	28^{th}	36.95450	8	1^{st}, 2^{nd}, 3^{rd}, 27^{th} & 28^{th}	37.09440
4	1^{st} & 28^{th}	37.04280	9	1^{st}, 2^{nd}, 26^{th}, 27^{th} & 28^{th}	36.91110
5	1^{st}, 2^{nd} & 28^{th}	37.13000	10	1^{st}, 2^{nd}, 3^{rd}, 26^{th}, 27^{th} & 28^{th}	36.98230

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However, in each of these situations, the value of the *NAMaxT* at Guwahati by the method developed here has been found to be 37.0 Degree Celsius.

Table – X. Maximum Likelihood / Minimum Variance Unbiased / Least Squares / Method of Moments / Minimum Chi Square Estimate of the *NAMinT* at Guwahati if extreme observations are (in Degree Celsius)

Serial No	Excluded observation	Estimated value	Serial No	Excluded observation	Estimated value
1	None	7.58571	6	1st, 27th & 28th	7.52000
2	1st	7.68518	7	1st , 2nd, 27th & 28th	7.62500
3	28th	7.50370	8	1st , 2nd, 3rd, 27th & 28th	7.70434
4	1st & 28th	7.60384	9	1st , 2nd, 26th, 27th & 28th	7.53913
5	1st , 2nd & 28th	7.70800	10	1st , 2nd, 3rd, 26th, 27th & 28th	7.61816

However, in each of these situations, the value of the *NAMinT* at Guwahati by the method developed here has been found to be 7.6 Degree Celsius.

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AUTHOR'S PROFILE

Dr. Dhritikesh Chakrabarty passed B.Sc. (with Honours in Statistics) securing 1st Class (1st Position), M.Sc. in Statistics securing 1st Class (1st Position) and M.Sc. in Mathematics securing 1st Class (5th Position) in the years 1981, 1983 and 1987 respectively all from Gauhati University. He obtained Ph.D. in Statistics from the same university in the year 1993. He also passed Sangeet Visharad in Vocal Music securing 1st Class from Bhatkhande Sangeet Vidyapith, Sangeet Visharad in Tabla securing 2nd Class from Pracheen Kala Kendra and Sangeet Pravakar in Tabla securing 1st Class from Prayag Sangeet Samiti in the years 2000, 2009 and 2011 respectively.

Dr. Chakrabarty, who obtained post doctoral research award (2002–05), has already presented 38 papers in research conferences, published 36 research papers in various journals both of national and international level. He has also attended a number of refresher's courses, seminars, workshops both as participant as well as resource person. Besides conducting research projects and producing M. Phil., he has been guiding a number of Ph. D. students. He acted as chair person in some research conferences and presented invited talks. Dr. Chakrabarty is a life member of each of the five social academic non-government organizations namely (1) Assam Science Society, (2) Assam Statistical Review, (3) Indian Statistical Association, (4) Indian Society for Probability & Statistics, (5) Forum for Interdisciplinary Mathematics and (6) Electronics Scientists and Engineers Society.