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CONSTRUCTING CONFIDENCE INTERVALS FOR DIFFERENT TEST PROCEDURES FROM RIGHT FAILURE CENSORED NORMAL DATA

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ABSTRACT

We propose some small sample tests from a failure censored normal sample and compare the relative performances of the tests. The small sample tests analogous to one sample student t-test for testing the mean from a failure right censored normal sample. Since censoring greatly complicates the distribution theory, the exact sampling distributions of the tests are not tractable mathematically. Therefore, we simulate the sampling distribution the sampling distributions for each of the tests using some random samples with different sizes generated from normal. In order to compare the relative performance of the tests, the powers of the tests are compared by Monte Carlo simulation. Based on the conclusion of the simulated results, we testable the critical values for only recommended tests at the selected levels of significance or various sample sizes. The critical values can be used for testing the null hypothesis as well as for constructing (1-α) confidence interval for the parameter μ based on failured right censored normal sample. In this article, presenting hypothetical example on constructing of confidence intervals for some proposed tests.

KEYWORD
Censored normal data.

INTRODUCTION

In case of failure censored normal data the exact sampling distribution of the one sample student t-statistic to test $H_0: \mu = \mu_0$ (σ unknown) is not tractable because the individual observations of the censored sample are no longer independently identically distributed (i.i.d) so, the observation are not i.i.d in any censored sample, the sampling distributions of the estimations of the parameters are not tractable mathematically. Consequently there is no suitable test is available to carry out $H_0: \mu = \mu_0$ from failure right censored normal data. Through there are some tests based on asymptotic theory methods available but their performance is not known in samples.

Hence we propose some small sample tests analogous to one sample student t- statistic to carry out $H_0: \mu = \mu_0$ against various alternative hypotheses from failure right censored normal data. We construct the sampling distributions using Monte Carlo simulation. From constructed simulated sampling distribution of the tests to be tested the critical values 1%, 5% and 10% level of significance. We obtained some important characters of the simulated sampling distributions of the proposed tests.

Suppose we have generated 10,000 random samples each of size n (10, 15, and 20) from the standard normal population with random number generator called RAND NORM using MINITAB package. Each sample is then sorted in the ascending order and censored r = 1,2,…………,4n/10 observations on the right side of the sample called failure right censored sample. Based on this sample the proposed test statistics are computed. For given 'n' and 'r', corresponding to each test statistic we get 10.000 values because there 10,000 samples. These values are then sorted in ascending order to give a simulated sampling distribution of the corresponding test statistic at specified values of 'n' and 'r'. .in order to study the behavior of the simulated sampling distributions of the tests. From the simulate sampling distributions of the proposed tests the critical values are constructed at 1%, 5% and 10% levels of significance in left-tail, right-tail and two-tail cases . The critical (percentile) value at α level of significance may be obtained in left-tail (Right-tail) cases by finding 100000 α /100th (10000(1- α)/100th) value from the simulated sampling distribution of the test statistic. Similarly, the pair of critical values in two-tail case may be obtained by finding the pair or points given by 10000(α /2)/100th value and 10000(1- α /2)/100th value on the simulated sampling distribution of the statistic. With that critical values we can construct 1- α confidence intervals for some specified test statistics censored T (T^*), T_{BLUE} and T_{MLE} .

METHODS OF SOME PROPOSED TESTS

1. STUDENT – t APPLIED TO FAILURE RIGHT CENSORED DATA

Suppose $\overline{X}$ and S^{*2} are the sample mean and sample variance are obtained from right censored sample, student – t statistic applied to the sample $X_1, X_2, \ldots, X_{n-r}$ is denoted by

T^* and is given by $T^* = \sqrt{n-r}\,(\overline{x^*} - \mu_0) / S^*$ ……………………………..(i)

$$\overline{X^*} = \frac{1}{n-r}\sum_{i=1}^{n-r} X_i \quad \text{and} \quad S^{*2} = \frac{1}{n-r-1}\sum_{i=1}^{n-r}(X_i - \overline{X})^2$$

It may be noted that the form of the distributing T^* doesn't as the observations are not independently identically distributed.

2. TEST BASED ON BLUEs

If μ^* and σ* are the BLUEs of μ and σ respectively obtained from the failure right censored sample using the BLUE coefficients in Sarhan and Greenberg (1962), then test statistic based on BLUEs. Which is analogous to student t-statistic denoted by T_{BLUE} and is given by A. Dattatrearao V.L.Narasimham in 1989.

$T_{BLUE} = \sqrt{n-r}\,(\mu^* - \mu_0) / \sigma^*$……………………….(ii)

3. TEST BASED ON MLEs

If $\hat{\mu}$ and $\hat{\sigma}^2$ are the maximum likelihood estimates (MLES) of μ and σ^2 computed from $X_1, X_2, \ldots, X_{n-r}$ then the statistic, based on MLEs for testing H_0: $\mu = \mu_0$, denoted by T_{MLE} and is given by

$T_{MLE} = \sqrt{n-r}\,(\hat{\mu} - \mu_0)/\hat{\sigma}$ ....(iii)

Here $\hat{\mu}$ and $\hat{\sigma}$ will be calculated using the method suggested by Cohen (1961) and the method is as follows:

Suppose that $S^{*2} = \frac{1}{n-r}\sum_{i=1}^{n-r}(X_i - \overline{X}^*)^2$ = (n – r-1) $S^{*2}/(n-r)$,

h = $\frac{r}{n}$ and $\hat{r} = S^{*2}/(\overline{X}^* - X_{n-r})^2$, then $\hat{\mu} = (\overline{X}^* - X_{n-r})$,

and $\hat{\sigma}^2 = S^{*2} + \hat{\lambda}(\overline{X}^* - X_{n-r})^2$, where $\hat{\lambda}$ is an auxiliary function and depends on two variables h and $\hat{r}$. The values of the auxiliary estimation function λ (h, $\hat{r}$) for singly censored sample from a normal population are tabulated in Cohen (1961) are reproduced in David (1981, PP.142-143) for h =.01(.01).1(.05).9 and $\hat{r}$ =0(.05)1.

USE OF CRITICAL VALUES

The critical and percentile values (percentile values for two tail case given in *Table.1*) can be used for testing H_0: $\mu = \mu_0$ as well as for constructing 1-α confidence interval for the parameter μ based on a given failure right censored normal sample.

FOR TESTING

The test statistics can be tested against alternative hypothesis may be one-tail case

(i.e. H_1:$\mu < \mu_0$ or H_1: $\mu > \mu_0$)or two tail case (i.e. H_1:$\mu \neq \mu_0$). After calculating the test statistic value based on the given censored sample using the test T^*/ T_{BLUE}/ T_{MLE} we reject the null hypothesis H_0: $\mu = \mu_0$ (at given level of significance α = 1% or 5% or 10%) against H_1:$\mu < \mu_0$ (left-tail)or H_1: $\mu > \mu_0$ (Right-tail) or i.e. H_1:$\mu \neq \mu_0$ (two tail case) for a specified values of *n* and *r*.

<u>For construction of 1-α confidence intervals</u>

The critical values can be used for constructing 1-α confidence interval for μ just similar as in testing in the left-tail, right-tail case and two-tail cases. In constructing one side confidence interval, the right limit of the interval is μ_0 in the left-tail case while the left limit of the interval is μ_0 in the right-tail case.

<u>Construction of left-sided 1-α confidence Interval based on T^*-statistic</u>

As we know that in the left-tail case T^* is the better test than the remaining tests under study, we given below the left-side confidence interval for μ based on T^* under alternative hypothesis is H_1:$\mu < \mu_0$.

$[\overline{X} - T^*(\alpha; n, r)\, S^*/\sqrt{n-r}, \mu_0]$

where $T^*(\alpha; n, r)$ denotes the critical value corresponding to T^* test at α l. o. s. for the given 'n' and 'r' values.

<u>Construction of left-sided 1-α confidence Interval based on T_{BLUE} and T_{MLE}</u>

As we know that in the right-tail case T_{BLUE} or T_{MLE} are better tests than the remaining tests under study, we give below the right side confidence intervals for μ based on T_{BLUE} or T_{MLE} statistics respectively under alternative hypothesis is H_1:$\mu > \mu_0$.

$[\mu_0, \mu^* - T_{BLUE}(\alpha; n, r)\, \sigma^*/\sqrt{n-r}]$

$[\mu_0, \hat{\mu} - T_{MLE}(\alpha; n, r)\, \hat{\sigma}/\sqrt{n-r-1}]$

where $T_{BLUE}(\alpha; n, r)$, $T_{MLE}(\alpha; n, r)$ are the critical values corresponding to T_{BLUE} and T_{MLE} statistics respectively at α l. o. s. for the given n and r values.

<u>Construction of two-sided 1-α confidence Interval based on T_{BLUE} and T_{MLE}</u>

We give below the two-side confidence intervals for μ based on T_{BLUE} and T_{MLE} under alternative is H_1:$\mu \neq \mu_0$.

$[\mu^* - T^U_{BLUE}(\alpha; n, r)\, \sigma^*/\sqrt{n-r}, \mu^* - T^L_{BLUE}(\alpha; n, r)\, \sigma^*/\sqrt{n-r}]$

$[\hat{\mu} - T^U_{MLE}(\alpha; n, r)\, \hat{\sigma}/\sqrt{n-r-1}, \hat{\mu} - T^L_{MLE}(\alpha; n, r)\, \hat{\sigma}/\sqrt{n-r-1}]$

Where $T^L_{BLUE}(\alpha; n, r)$ [$T^U_{MLE}(\alpha; n, r)$] and $T^U_{BLUE}(\alpha; n, r)$ [$T^U_{MLE}(\alpha; n, r)$] denotes the lower and upper critical values respectively and can be obtained for *Table.1* corresponding to T_{BLUE} [T_{MLE}] statistic at α l. o. s. for the given n and r values.

EXAMPLE

The Hypothetical example gives the days on which the first 7 of a sample of 10 generators are defective after being overhauled. The times of defects were 41, 44, 46, 54, 55, 58, 60 days after overhauled. Assuming lognormal distributions of the survived time (non-defective time) we take the likelihood of μ and σ are given by (Schneider, 1986, p.69)

$\hat{\mu}$ =1.742 and $\hat{\sigma}$ =0.07943

In this example as we have neither priori knowledge about population nor the data is a complete sample (to compare conclusions obtained is censored sample with those obtained using t– test in complete sample). So this example is not used for testing and used for the construction of confidence intervals using the tests T^*, T_{BLUE} and T_{MLE}.

Here n = 10 and r = 3 . Now, the lower and upper critical values for T_{MLE} from *Table 1* at α =0.05 level of significance are

$T^L_{MLE}(\alpha; n, r)$=-3.006, $T^U_{MLE}(\alpha; n, r)$ = 1.986

using the Formula (iii), the 95% confidence interval based on T_{MLE} is [1.678 , 1.840]

Similarly, the BLUEs of μ and σ are μ^* = 1.7459 , and σ^* =0.0915

The lower and upper critical values from *Table 1* for T_{BLUE} at α =0.05 level of significance are

$T^L_{BLUE}(\alpha; n, r)$ -2.006, $T^U_{BLUE}(\alpha; n, r)$ = 1. 848

Formula (ii), the 95% confidence interval based on T_{BLUE} is [1.678 , 1.840]

From the above confidence intervals, we may observe that the confidence intervals based on T_{BLUE} is closer than that based on T_{MLE}, which indicate that T_{BLUE} test is better than T_{MLE}.

Also, the 95% confidence intervals based on T^* is [1.682 , 1.841] and still T_{BLUE} has closer interval than T^*. Hence, T_{BLUE} is better test than T^*.

CONCLUSIONS

From the above example, we may conclude that the test based on BLUEs(T_{BLUE}) can be used for testing and constructing confidence intervals for mean (μ) in failure right censored samples from normal population in two-tail case.

Hence, we conclude that theory has been proved that the BLUEs (T_{BLUE}) perform better than other test procedures.

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TABLES

TABLE 1: SIMULATED CRITICAL (PERCENTILE) VALUES OF T-blue AND T-mle STATISTICS FOR MEAN FROM A FAILURE RIGHT CENSORED NORMAL SAMPLE IN TWO-TAIL CASE (FOR ALL SAMPLE SIZES BETWEEN 10 AND 20)

		T-blue			T-mle		
		Level of significance			Level of significance		
N	R	1%	5%	10%	1%	5%	10%
10	1	(-3.345, 3.185)	(-2.234, 2.090)	(-1.771, 1.716)	(-3.673, 3.454)	(-2.478, 2.261)	(-1.968, 1.862)
	2	(-3.564, 3.015)	(-2.344, 1.973)	(-1.837, 1.619)	(-3.968, 3.308)	(-2.664, 2.128)	(-2.109, 1.749)
	3	(-4.131, 2.806)	(-2.514, 1.848)	(-1.957, 1.528)	(-4.866, 3.124)	(-3.006, 1.986)	(-2.354, 1.631)
	4	(-5.005, 2.603)	(-2.893, 1.718)	(-2.178, 1.412)	(-6.019, 2.911)	(-3.526, 1.833)	(-2.723, 1.482)
11	1	(-3.239, 2.987)	(-2.207, 2.104)	(-1.763, 1.719)	(-3.514, 3.200)	(-2.407, 2.262)	(-1.936, 1.840)
	2	(-3.427, 2.869)	(-2.272, 1.996)	(-1.784, 1.631)	(-3.801, 3.087)	(-2.534, 2.148)	(-2.009, 1.746)
	3	(-3.651, 2.710)	(-2.375, 1.884)	(-1.852, 1.541)	(-4.184, 2.964)	(-2.757, 2.027)	(-2.154, 1.628)
	4	(-4.492, 2.523)	(-2.681, 1.761)	(-2.000, 1.434)	(-5.202, 2.751)	(-3.193, 1.876)	(-2.422, 1.501)
	5	(-5.167, 2.345)	(-2.970, 1.656)	(-2.221, 1.350)	(-6.251, 2.534)	(-3.655, 1.741)	(-2.800, 1.380)
12	1	(-3.120, 2.960)	(-2.198, 2.125)	(-1.761, 1.720)	(-3.354, 3.167)	(-2.398, 2.262)	(-1.916, 1.834)
	2	(-3.286, 2.821)	(-2.234, 2.030)	(-1.788, 1.643)	(-3.583, 3.026)	(-2.467, 2.160)	(-1.986, 1.740)
	3	(-3.441, 2.664)	(-2.325, 1.928)	(-1.807, 1.565)	(-3.867, 2.869)	(-2.625, 2.054)	(-2.066, 1.644)
	4	(-3.828, 2.518)	(-2.448, 1.813)	(-1.885, 1.478)	(-4.314, 2.708)	(-2.857, 1.918)	(-2.234, 1.536)
	5	(-4.448, 2.347)	(-2.713, 1.703)	(-2.080, 1.396)	(-5.271, 2.531)	(-3.290, 1.778)	(-2.534, 1.432)
13	1	(-3.073, 2.930)	(-2.154, 2.089)	(-1.743, 1.710)	(-3.295, 3.087)	(-2.335, 2.221)	(-1.882, 1.814)
	2	(-3.167, 2.843)	(-2.178, 1.999)	(-1.768, 1.632)	(-3.424, 3.024)	(-2.388, 2.125)	(-1.940, 1.727)
	3	(-3.275, 2.706)	(-2.251, 1.902)	(-1.773, 1.564)	(-3.663, 2.887)	(-2.526, 2.021)	(-1.984, 1.640)
	4	(-3.484, 2.557)	(-2.382, 1.809)	(-1.870, 1.489)	(-3.977, 2.742)	(-2.703, 1.911)	(-2.152, 1.551)
	5	(-3.958, 2.409)	(-2.484, 1.698)	(-1.959, 1.406)	(-4.550, 2.568)	(-2.912, 1.773)	(-2.326, 1.441)
14	1	(-2.988, 2.984)	(-2.096, 2.084)	(-1.751, 1.714)	(-3.182, 3.185)	(-2.242, 2.207)	(-1.878, 1.807)
	2	(-5.381, 4.676)	(-3.855, 3.248)	(-3.192, 2.634)	(-3.380, 3.079)	(-2.329, 2.119)	(-1.897, 1.737)
	3	(-3.166, 2.779)	(-2.168, 1.923)	(-1.746, 1.574)	(-3.495, 2.935)	(-2.408, 2.027)	(-1.929, 1.651)
	4	(-3.366, 2.646)	(-2.270, 1.836)	(-1.757, 1.503)	(-3.709, 2.790)	(-2.551, 1.927)	(-2.008, 1.563)
	5	(-3.554, 2.504)	(-2.405, 1.755)	(-1.850, 1.441)	(-4.041, 2.645)	(-2.773, 1.833)	(-2.146, 1.477)
15	1	(-2.911, 3.006)	(-2.106, 2.074)	(-1.722, 1.709)	(-3.088, 3.185)	(-2.247, 2.179)	(-1.838, 1.794)
	2	(-2.832, 2.916)	(-2.101, 1.999)	(-1.689, 1.640)	(-3.018, 3.087)	(-2.283, 2.102)	(-1.834, 1.728)
	3	(-2.966, 2.821)	(-2.146, 1.915)	(-1.716, 1.586)	(-3.235, 2.976)	(-2.350, 2.008)	(-1.880, 1.654)
	4	(-3.241, 2.707)	(-2.173, 1.828)	(-1.756, 1.524)	(-3.576, 2.868)	(-2.433, 1.915)	(-1.968, 1.573)
	5	(-3.403, 2.5830	(-2.267, 1.757)	(-1.800, 1.450)	(-3.758, 2.72)	(-2.568, 1.826)	(-2.053, 1.490)
	6	(-3.542, 2.428)	(-2.412, 1.667)	(-1.907, 1.401)	(-4.045, 2.574)	(-2.787, 1.711)	(-2.254, 1.414)
16	1	(-2.894, 2.762)	(-2.115, 2.029)	(-1.720, 1.685)	(-3.064, 2.918)	(-2.242, 2.119)	(-1.829, 1.766)
	2	(-2.930, 2.652)	(-2.108, 1.954)	(-1.721, 1.632)	(-3.110, 2.807)	(-2.269, 2.043)	(-1.855, 1.705)
	3	(-2.932, 2.559)	(-2.094, 1.891)	(-1.713, 1.568)	(-3.200, 2.697)	(-2.284, 1.971)	(-1.860, 1.628)
	4	(-3.967, 1.639)	(-2.462, 1.288)	(-1.853, 1.091)	(-3.370, 2.578)	(-2.427, 1.879)	(-1.944, 1.548)
	5	(-3.322, 2.351)	(-2.197, 1.726)	(-1.762, 1.444)	(-3.700, 2.481)	(-2.475, 1.787)	(-1.989, 1.481)
	6	(-3.446, 2.240)	(-2.373, 1.666)	(-1.823, 1.385)	(-3.843, 2.357)	(-2.705, 1.705)	(-2.108, 1.405)

TABLE 1 (CONTINUED)

		T-blue			T-mle		
		Level of significance			Level of significance		
N	R	1%	5%	10%	1%	5%	10%
17	1	(-2.844, 2.747)	(-2.091, 2.030)	(-1.723, 1.682)	(-3.005, 2.878)	(-2.195, 2.123)	(-1.811, 1.754)
	2	(-2.823, 2.659)	(-2.101, 1.973)	(-1.729, 1.624)	(-3.003, 2.786)	(-2.244, 2.053)	(-1.847, 1.690)
	3	(-4.687, 3.195)	(-3.320, 2.401)	(-2.608, 1.993)	(-3.058, 2.687)	(-2.270, 1.978)	(-1.846, 1.625)
	4	(-5.345, 7.537)	(-3.310, 5.924)	(-2.324, 5.267)	(-3.288, 2.589)	(-2.361, 1.902)	(-1.928, 1.562)
	5	(-4.241, 2.595)	(-2.762, 1.967)	(-2.230, 1.642)	(-3.520, 2.468)	(-2.385, 1.827)	(-1.964, 1.503)
	6	(-3.317, 2.280)	(-2.228, 1.701)	(-1.799, 1.424)	(-3.691, 2.379)	(-2.523, 1.736)	(-2.058, 1.445)
18	1	(-2.844, 2.768)	(-2.078, 2.049)	(-1.726, 1.700)	(-2.997, 2.885)	(-2.185, 2.131)	(-1.807, 1.774)
	2	(-2.818, 2.880)	(-2.096, 1.987)	(-1.720, 1.657)	(-3.000, 2.805)	(-2.228, 2.062)	(-1.835, 1.721)
	3	(-2.900, 2.599)	(-2.067, 1.913)	(-1.728, 1.592)	(-3.079, 2.715)	(-2.208, 1.994)	(-1.858, 1.646)
	4	(-2.878, 5.274)	(-2.195, 3.346)	(-1.866, 2.627)	(-3.198, 2.614)	(-2.280, 1.929)	(-1.877, 1.585)
	5	(-3.066, 2.426)	(-2.133, 1.791)	(-1.738, 1.496)	(-3.311, 2.526)	(-2.364, 1.853)	(-1.919, 1.532)
	6	(-3.286, 2.345)	(-2.202, 1.701)	(-1.764, 1.442)	(-3.625, 2.446)	(-2.455, 1.747)	(-1.985, 1.465)
	7	(-3.453, 2.251)	(-2.308, 1.667)	(-1.820, 1.396)	(-3.865, 2.342)	(-2.613, 1.696)	(-2.099, 1.401)
19	1	(-2.820, 2.690)	(-2.075, 2.027)	(-1.725, 1.722)	(-2.970, 2.815)	(-2.176, 2.108)	(-1.812, 1.787)
	2	(-2.742, 2.619)	(-2.100, 1.968)	(-1.740, 1.672)	(-2.907, 2.733)	(-2.219, 2.044)	(-1.841, 1.734)
	3	(-2.845, 2.542)	(-2.082, 1.911)	(-1.722, 1.610)	(-3.028, 2.644)	(-2.222, 1.975)	(-1.835, 1.670)
	4	(-2.936, 2.459)	(-2.084, 1.845)	(-1.734, 1.564)	(-3.124, 2.565)	(-2.248, 1.911)	(-1.869, 1.615)
	5	(-3.004, 2.379)	(-2.135, 1.790)	(-1.729, 1.513)	(-3.244, 2.470)	(-2.313, 1.844)	(-1.902, 1.551)
	6	(-3.162, 2.275)	(-2.152, 1.744)	(-1.742, 1.473)	(-3.444, 2.358)	(-2.398, 1.785)	(-1.942, 1.499)
	7	(-3.265, 2.184)	(-2.206, 1.673)	(-1.795, 1.412)	(-3.618, 2.250)	(-2.508, 1.709)	(-2.040, 1.426)
20	1	(-2.766, 2.724)	(-2.095, 2.054)	(-1.718, 1.730)	(-2.915, 2.832)	(-2.184, 2.139)	(-1.793, 1.792)
	2	(-2.742, 2.642)	(-2.096, 2.000)	(-1.711, 1.675)	(-2.893, 2.755)	(-2.203, 2.064)	(-1.809, 1.734)
	3	(-2.798, 2.569)	(-2.064, 1.946)	(-1.703, 1.627)	(-2.983, 2.683)	(-2.191, 2.013)	(-1.813, 1.677)
	4	(-2.887, 2.496)	(-2.052, 1.878)	(-1.690, 1.584)	(-3.075, 2.598)	(-2.196, 1.942)	(-1.821, 1.630)
	5	(-2.962, 2.421)	(-2.068, 1.843)	(-1.689, 1.526)	(-3.194, 2.529)	(-2.231, 1.899)	(-1.842, 1.564)
	6	(-3.050, 2.331)	(-2.083, 1.790)	(-1.726, 1.490)	(-3.306, 2.412)	(-2.295, 1.834)	(-1.902, 1.516)
	7	(-3.276, 2.256)	(-2.183, 1.725)	(-1.757, 1.434)	(-3.567, 2.340)	(-2.419, 1.754)	(-1.965, 1.447)
	8	(-3.438, 2.179)	(-2.268, 1.672)	(-1.803, 1.378)	(-3.782, 2.241)	(-2.562, 1.689)	(-2.065, 1.375)

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