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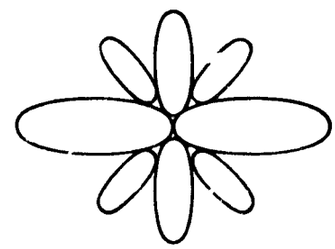
EXACT INTERVALS AND TESTS FOR MEDIAN WHEN ONE "SAMPLE" VALUE POSSIBLY AN OUTLIER

by

John E. Walsh

Technical Report No. 87
Department of Statistics ONR Contract



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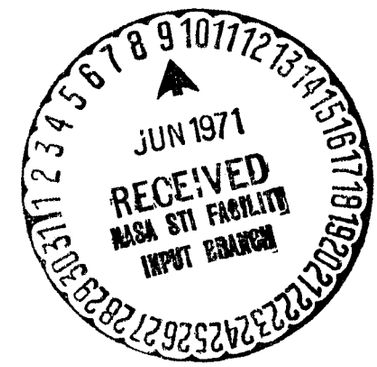

N71-26090

CR-118570

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December 18, 1970

Research sponsored by the Office of Naval Research
Contract N00014-68-A-0015
Project NR 042-260

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DEPARTMENT OF STATISTICS
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EXACT INTERVALS AND TESTS FOR MEDIAN WHEN ONE "SAMPLE" VALUE POSSIBLY AN OUTLIER

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ABSTRACT

Available are n observations (continuous data) that are believed to be a random sample. Desired are confidence intervals and significance tests for the population median. However, there is the possibility that either the largest or the smallest observation is an outlier. That is, the population yielding this observation differs from the population yielding the other n - 1 observations. If this happens, intervals and tests are desired for the median of the population yielding the n - 1 observations. Some analysis difficulties would be avoided if intervals and tests could be developed that simultaneously are applicable for all three of these situations. More specifically, a confidence coefficient, or significance level, has the same value for all three situations. It is found that two-sided intervals and tests based on two symmetrically located order statistics (not the largest and smallest) have this property. Also, some extensions are considered wherein each observation can be from a different population.

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* Research partially supported by Mobil Research and Development Corporation and by NASA Grant NGR 44-007-028. Also associated with ONR Contract N00014-68-A-0515.

INTRODUCTION AND DISCUSSION

The data are n independent observations that are continuous data and are believed to be a random sample. The order statistics of these observations are

$$x(1) < x(2) < \ldots < x(n).$$

Confidence intervals and significance tests are desired for the median θ (not necessarily unique) of the population sampled. However, the experimental situation is such that either x(1) or x(n) might possibly be an outlier. That is, the population yielding the observation that is x(1), or the observation x(n), and the population providing the other n - 1 observations do not have a common median. If this outlier situation should happen to exist, intervals and tests are desired for the median θ of the population yielding the n - 1 other observations. Incidentally, recognition of this outlier possibility could arise in any manner (examination of the observations, past experience with data from this source, the desire to be careful, etc.).

When x(1) is an outlier, x(2), ... , x(n) constitute a random sample of size n - 1. In this sample, x(2) is the smallest value, x(3) is the next to smallest value, etc. Likewise, x(1), ... , x(n - 1) provide a random sample of size n - 1 when x(n) is an outlier. In this sample, x(n - 1) is the largest value, x(n - 2) is the next to largest value, etc.

One approach to this investigation problem is to first develop a method for deciding which of the three situations (random sample, x(1) an outlier, x(n) an outlier) exists. Then, intervals and tests for θ

would be developed for that situation. Unfortunately, meaningful rejection of an outlier when virtually nothing is known about properties of the population sampled is a formidable problem. Even if a satisfactory procedure were available, the decision reached might be incorrect.

A more attractive approach would be to develop intervals and tests that apply simultaneously to all three situations. That is, a confidence interval has the same confidence coefficient for the three situations. Also, a test has the same significance level for all three situations. Fortunately, intervals and tests with this property can be developed. In fact, the well-known equal-tail sign tests, and the corresponding two-sided confidence intervals, are shown to have this property (when x(1) and x(n) are not used). For convenience of presentation, only the confidence intervals are explicitly considered. However, the property for the corresponding tests follows in a direct fashion, since the tests can be obtained from the intervals.

If the n observations were truly a random sample, the well-known confidence intervals defined by

$$P[x(i) \le \theta \le x(n+1-i)] = 1 - (\tfrac{1}{2})^{n-1} \sum_{j=0}^{i-1} \binom{n}{j} \qquad (1)$$

are applicable. These are the confidence intervals considered (for $2 \le i < n/2$). The relationship (1) is found to also hold when x(1) is an outlier and when x(n) is an outlier.

Verification of this property is given in the next section. The final section contains a discussion of some extensions. For example, the results apply when the observations are independent and from

continuous populations that are believed to have a common median θ. Also, results can be obtained for cases where the data are not continucus.

VERIFICATION

Only the situation where $x(1)$ is an outlier receives consideration. A similar method provides verification that (1) holds when $x(n)$ is an outlier.

In general, the value of $P[x(i) \leq \theta \leq x(n + 1 - i)]$ can be expressed as unity minus

$$P[x(i) > \theta] + P[x(n + 1 - i) < \theta].$$

When $x(1)$ is an outlier,

$$P[x(i) > \theta] = (\tfrac{1}{2})^{n-1} \sum_{j=0}^{i-1} \binom{n-1}{j},$$

$$P[x(n + 1 - i) < \theta] = (\tfrac{1}{2})^{n-1} \sum_{j=0}^{i-2} \binom{n-1}{j},$$

and their sum is

$$(\tfrac{1}{2})^{n-1} \sum_{j=0}^{i-1} \left[\binom{n-1}{j} + \binom{n-1}{j-1}\right],$$

where $\binom{n-1}{-1}$ is zero. However, $\binom{n-1}{0} = \binom{n}{0}$ and

$$\binom{n-1}{j} + \binom{n-1}{j-1} = \binom{n}{j}$$

for $1 \leq j < i$. Thus, the value of $P[x(i) \leq \theta \leq x(n + 1 - i)]$ is

$$1 - (\tfrac{1}{2})^{n-1} \sum_{j=0}^{i-1} \binom{n}{j},$$

which is the value of (1). It is to be noticed that $P[x(i) > \theta]$ does not differ much from $P[x(n + 1 - i) < \theta]$ when i is of at least moderate size (ordinarily implies that n is at least moderately large).

EXTENSIONS

The preceding results are stated in the manner commonly used when cosidering the possibility of an outlier. However, the random sample requirements are not necessary. The intervals and tests apply, exactly, under more general conditions. Specifically they are usable when the circumstances are such that the observations are independent and from continuous populations that are believed to have a common median θ (not necessarily unique). However, either $x(1)$ or $x(n)$ might be an outlier, in the sense that the population yielding this observation has a median that is different from the common median θ for the populations yielding the other $n - 1$ observations.

The requirement of continuous populations is unnecessary if ties in observed values are resolved by randomization (all possibilities equally likely). Then, the confidence coefficients and significance levels are still exact. In any case,

$$P[x(i) \leq \theta \leq x(n + 1 - i)] \geq 1 - (\tfrac{1}{2})^{n-1} \sum_{j=1}^{i-1} \binom{n}{j}$$

for all three situations.

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1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
SOUTHERN METHODIST UNIVERSITY	UNCLASSIFIED
	2b. GROUP: UNCLASSIFIED

3. REPORT TITLE

"Exact intervals and tests for median when one 'sample' value possibly an outlier"

4. DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Technical Report

5. AUTHOR(S) (First name, middle initial, last name)

John E. Walsh

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 18, 1970	5	0

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
N00014-68-A-0515	
b. PROJECT NO. NR 042-260	87
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Office of Naval Research

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