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Estimating the Parameters of Exponential-Rayleigh Distribution for Progressively Censoring Data with S- Function about COVID-19

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Abstract

The two parameters of Exponential-Rayleigh distribution were estimated using the maximum likelihood estimation method (MLE) for progressively censoring data. To find estimated values for these two scale parameters using real data for COVID-19 which was taken from the Iraqi Ministry of Health and Environment, AL-Karkh General Hospital. Then the Chi-square test was utilized to determine if the sample (data) corresponded with the Exponential-Rayleigh distribution (ER). Employing the nonlinear membership function (s-function) to find fuzzy numbers for these parameters estimators. Then utilizing the ranking function transforms the fuzzy numbers into crisp numbers. Finally, using mean square error (MSE) to compare the outcomes of the survival function before and after fuzzy work. The period of study was (May, June, July, and August). The number of patients who entered the study during the above period was 1058 patients. Six cases have been ruled out including: The number of prisoners was 26. The number of people with negative swabs was 48. The number of patients who exit status was unknown was 29. The number of patients who escaped from the hospital was 2. The number of patients transferred to other hospitals was 35. The number of patients discharged at their responsibility was 133. Then the number of patients who entered the (study) hospital which is the sample size becomes (n=785). The number of patients who died during the period of study was (m=88). The number of patients who survived during the study period was (n-m=697).

Keywords: COVID-19, Exponential-Rayleigh distribution (ERD), Progressively censored data, Ranking function, S-function.

Introduction

In many life testing and reliability studies, the experimenters and researchers may not obtain complete information on failure times for experimental units, the data obtained from experiments are called censoring data [1].

A censored sample is divided into three types: Right-censored sample, left-censored sample, and interval-censored sample. The right-censored sample is also divided into three branches, singly type one censoring sample, singly type two censoring sample, and progressively censoring sample. This paper estimates the parameters under progressively censoring data.

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In 1965 Zadeh L.A discovered the Fuzzy Set Theory [2]. It has been a main field of focus in many ways, many applications related to Fuzzy sets, such as operation research, computer science, logic, statistic, and medicine[3].

In 2013, Hussain I, and Kadhum H. relied on (MLE) method to estimate the unknown parameters of the generalized Rayleigh distribution for singly type one censored sample[4].

In 2016, Makhdoom I, Nasiri P, and Pak A. estimated the parameters of exponential distribution under type two censoring scheme by using the Bayesian estimation method, when the lifetime observations are reported in fuzzy numbers [1].

In 2018, Chaturvedi A, Singh SK, and Singh U. discussed different estimation methods to estimate the unknown parameters for Rayleigh distribution, the methods were (MLE), the Moments method, the Computational approach estimation method, and the Bayes estimation method. After that, using the progressive type two censoring sample. And fuzzy information is used to describe the provided data[5].

In 2020, Abadi QS, and Al-Kanani IH. used the (MLE) method to estimate three parameters of a new mixture distribution consisting of one shape parameter and two scale parameters for type-I censored data and progressively censored data[6,7].

In 2020, Abdullah SN, and Huessian IH. estimated the parameters of Weibull distribution by using the simulation, after that, they utilized the Gaussian function which is the nonlinear membership function, and finally, the ranking function was applied to transform the fuzzy numbers into crisp numbers[3].

In 2021, Heidari KF, Deri E, and Jamkhaneh EB. generalized the estimated methods for real numbers to fuzzy numbers. They estimated the parameters of Rayleigh distribution by using the Bayesian method under type two censoring data under the squared error loss function[8].

In 2021, Mazaal AR, and Karam NS, based on a singly type II censored sample for Weibull Stress-Strength with considering the stress-strength Reliability estimation. Bayesian analysis has been considered to be using loss functions under two prior functions with singly type II censored sample[9].

In 2021, Algari A et al used the Bayesian and non-Bayesian methods to estimate the parameters of the inverse Weibull distribution using the progressively censoring data[10].

In 2022, Yass SB, and Kanani IHA. estimated the parameters of the Modified-Weibull-Extension distribution by using (MLE) method, after utilizing the method of Monte Carlo, they fuzzified the estimation of parameters by a proposed method, then used a new proposed ranking functions to transform the fuzzy parameters to crisp parameters[11].

Exponential Rayleigh Distribution (ERD) [12]

The CDF of ERD is as follows:

$$F(t;\theta,\beta) = 1 - e^{-(\theta t + \frac{\beta}{2}t^2)} \qquad 1$$

- The probability density function is given by:

$$f(t;\theta,\beta) = (\theta + \beta t)e^{-(\theta t + \frac{\beta}{2}t^2)} \qquad t \geq 0\ ;\ \theta,\beta > 0 \qquad 2$$

And zero for otherwise, where θ and β are scale parameters.

- The survival function is obtained by:

$$S(t;\theta,\beta) = e^{-(\theta t + \frac{\beta}{2}t^2)} \qquad t \geq 0\ ;\ \theta,\beta > 0 \qquad 3$$

- The Hazard rate function can be expressed as:

$$h(t;\theta,\beta) = (\theta + \beta t) \qquad t \geq 0\ ;\ \theta,\beta > 0 \qquad 4$$

Progressively Censoring Data [13]

It is one of the most common right-censored types. It is also called randomly censored data or multiply censored data. In this type of censoring, entering times to the study or experiment are different, and survival times occur are also different.

Maximum Likelihood Estimation Method for Progressively Censoring Data

The maximum likelihood estimation method is one of the most popular and widely used classic methods. This method was initially used in 1912 by R.A. Fisher in his first statistical papers. Maximum likelihood describes a technique for estimating the unknown parameters of any distribution[14].

$$L = \frac{n!}{(n-m)!}\prod_{i=1}^{n}\{f[(t_i;\theta,\beta)]^{\delta_i}S[(t_i;\theta,\beta)]^{1-\delta_i}\} \quad 5$$

Let $\frac{n!}{(n-m)!} = k$, then:

$$L = k\prod_{i=1}^{n}\left\{\left[(\theta+\beta t_i)e^{-\left(\theta t_i+\frac{\beta}{2}t_i^2\right)}\right]^{\delta_i}\left[e^{-\left(\theta t_i+\frac{\beta}{2}t_i^2\right)}\right]^{1-\delta_i}\right\} \quad 6$$

Taking the natural logarithm for both sides of the equation:

$$\ln L = \ln k + \sum_{i=1}^{n}\delta_i \ln(\theta+\beta t_i) - \sum_{i=1}^{n}\delta_i\left(\theta t_i + \frac{\beta}{2}t_i^2\right) - \sum_{i=1}^{n}(1-\delta_i)\left(\theta t_i + \frac{\beta}{2}t_i^2\right) \quad 7$$

Deriving Eq.7 partially with respect to θ and β respectively, and setting it equal to zero.

$$\frac{\partial lnl}{\partial\theta} = \sum_{i=1}^{n}\frac{\delta_i}{(\theta+\beta t_i)} - \sum_{i=1}^{n}\delta_i t_i - \sum_{i=1}^{n}(1-\delta_i)t_i = 0 \quad 8$$

$$\frac{\partial lnl}{\partial\beta} = \sum_{i=1}^{n}\frac{\delta_i t_i}{(\theta+\beta t_i)} - \frac{1}{2}\sum_{i=1}^{n}\delta_i t_i^2 - \frac{1}{2}\sum_{i=1}^{n}(1-\delta_i)t_i^2 = 0 \quad 9$$

Now, putting $\frac{\partial lnl}{\partial\theta}$ as a function $f(\theta)$ and $\frac{\partial lnl}{\partial\beta}$ as a function $f(\beta)$

$$f(\theta_k) = \sum_{i=1}^{n}\frac{\delta_i}{(\theta+\beta t_i)} - \sum_{i=1}^{n}\delta_i t_i - \sum_{i=1}^{n}(1-\delta_i)t_i \quad 10$$

$$f(\beta_k) = \sum_{i=1}^{n}\frac{\delta_i t_i}{(\theta+\beta t_i)} - \frac{1}{2}\sum_{i=1}^{n}\delta_i t_i^2 - \frac{1}{2}\sum_{i=1}^{n}(1-\delta_i)t_i^2 \quad 11$$

where $\delta_i = \begin{cases} 1 & \text{if the patients die} \\ 0 & \text{if the ith patients alive} \end{cases}$

Noting that Eq.10 and Eq.11 are difficult to solve, then employing them by an iterative method such as the Newton-Raphson procedure [15] to find the value of $\hat{\theta}$ and $\hat{\beta}$ as follows:

$$\theta_{k+1} = \theta_k - \frac{f(\theta_k)}{\acute{f}(\theta_k)} \quad 12$$

Where $\acute{f}(\theta_k) = -\sum_{i=1}^{n}\frac{\delta_i}{(\theta+\beta t_i)^2}$ 13

And $\beta_{k+1} = \beta_k - \frac{f(\beta_k)}{\acute{f}(\beta_k)}$ 14

Where $\acute{f}(\beta_k) = -\sum_{i=1}^{n}\frac{\delta_i t_i^2}{(\theta+\beta t_i)^2}$ 15

The error term denoted by ϵ, which is a very small and assumed value, is the value for the difference between the new values of θ and β in the new iterative with the previous values of θ and β in the past iterative.

The error term is formulated as:

$$\epsilon_{k+1}(\theta) = \theta_{k+1} - \theta_k$$

$$\epsilon_{k+1}(\beta) = \beta_{k+1} - \beta_k$$

Where θ_k and β_k are initial values that are assumed.

Fuzzy Set Theory

This section includes some definitions of fuzzy set theory and the method used to find the fuzzy numbers.

Membership function [1]

Let Z be a universal set (nonempty set), a fuzzy set $\widetilde{A}$ in Z can be expressed as $\mu_{\widetilde{A}}: Z \to [0,1]$ is said to be a membership function of $\widetilde{A}$ in Z. where $\widetilde{A} = \{(z, \mu_{(\widetilde{A})}(z))\,; z \in Z\}$

The Support of $\widetilde{A}$ [16]

The support of $\widetilde{A}$ is the crisp set $\forall z \in Z$, $\mu_{(\widetilde{A})}(z) > 0$, i.e $\mathrm{Supp}(\widetilde{A}) = \{\forall z \in Z: \mu_{(\widetilde{A})}(z) > 0\}$

α −cut set (α −Level set) [16]

The crisp set of elements belongs to $\widetilde{A}$ at least to the degree α is called the α − Level set, where $\alpha \in [0,1]$

$$A_\alpha = \{\forall z \in Z: \mu_{(\widetilde{A})}(z) \geq \alpha\}$$

$A'_\alpha = \{\forall z \in Z: \mu_{(\widetilde{A})}(z) > \alpha\}$ is said to a be strong α −Level set.

Normal Set [1]

Let Z be the universal set and let $\widetilde{A}$ be a fuzzy subset of set Z, $\widetilde{A}$ is said to be normal set if and only if $\sup_{z\in Z} \mu_{(\widetilde{A})}(z) = 1$.

Convex Fuzzy Set [1]

Let Z be the universal set and let $\widetilde{A}$ be fuzzy subset of set Z, $\widetilde{A}$ is said to be convex set if and only if $\mu_{(\widetilde{A})}(\lambda z + (1-\lambda)w) \geq \min\{ \mu_{(\widetilde{A})}(z) + \mu_{(\widetilde{A})}(w)\} = 1\ \forall z, w \in Z$ and $\forall \lambda \in [0,1]$

Fuzzy Number

A fuzzy set $\widetilde{K}$ is said to be fuzzy number if and only if $\widetilde{K}$ is normal set and convex set on universal set Z.

S-function

In this paper, utilizing an unpopular function it has a second-degree polynomial constructed as the S-function, S: R→ [0, 1] is given by:

$$S(x; a, b, c) = \begin{cases} 0 & x \leq a \\ 2\left(\frac{x-a}{c-a}\right)^2 & a < x \leq b \\ 1 - 2\left(\frac{x-a}{c-a}\right)^2 & b < x < c \\ 1 & x \geq c \end{cases},$$

With $b = \frac{a+c}{2}$

Finding Fuzzy Numbers $[\mathbf{a}, \mathbf{b}, \mathbf{c}]$

Suppose that Δ= 0.002, substitute it in case1 and case2 to find the fuzzy numbers.

Case 1:

Consider $a_1 = \hat{\theta} - \Delta$, $b_1 = \hat{\theta}$, $c_1 = \hat{\theta} + \Delta$, then

$a_1 = \hat{\theta} - 0.002$, $b_1 = \hat{\theta}$, $c_1 = \hat{\theta} + 0.002$

Case 2:

Consider $a_2 = \hat{\beta} - \Delta$, $b_2 = \hat{\beta}$, $c_2 = \hat{\beta} + \Delta$, then

$a_2 = \hat{\beta} - 0.002$, $b_2 = \hat{\beta}$, $c_2 = \hat{\beta} + 0.002$

Ranking Function [3]

In 1976, Jain proposed the ranking function, in 1981 Yager proposed four indices, that might be employed for the aim of ordering fuzzy quantities in [0,1].

A fuzzy number ranking function is a mapping from fuzzy numbers into real numbers.

Algorithm of Ranking Function

In this section, using the nonlinear ranking function (s-function) to transform the fuzzy number into a crisp number, then the ranking function becomes as follows:

Let $\alpha = 2\left(\frac{x-a}{c-a}\right)^2$

Taking root for both sides yields:

$$\sqrt{\frac{\alpha}{2}} = \frac{x-a}{c-a}$$

$$x = a + (c-a)\sqrt{\frac{\alpha}{2}}$$

$$\widetilde{A}^{l}_{(\alpha)} = a + (c-a)\sqrt{\frac{\alpha}{2}} \qquad 16$$

Let $\alpha = 1 - 2\left(\frac{x-a}{c-a}\right)^2$

Taking root for both sides yields:

$$\sqrt{\frac{1-\alpha}{2}} = \frac{x-a}{c-a}$$

$$x = a + (c-a)\sqrt{\frac{1-\alpha}{2}}$$

$$\widetilde{A}^{u}_{(\alpha)} = a + (c-a)\sqrt{\frac{1-\alpha}{2}} \qquad 17$$

Where $\widetilde{A}^{l}_{(\alpha)}$ is bounded left continuous increasing function over $[0, \lambda]$

And $\widetilde{A}^{u}_{(\alpha)}$ is bounded left continuous decreasing function over $[0, \lambda]$

Then the presented for arbitrary fuzzy numbers can be written as an ordered pair of functions $[\widetilde{A}^{l}_{(\alpha)}, \widetilde{A}^{u}_{(\alpha)}]$

$$R(\widetilde{A}) = \frac{1}{2}\int_0^{\lambda}(\widetilde{A}^{l}_{(\alpha)} + \widetilde{A}^{u}_{(\alpha)})d\alpha \qquad 18$$

Where $\lambda \in [0,1]$

$$R(\widetilde{A}) = \frac{1}{2}\int_0^{\lambda}(2a + (c-a)\sqrt{\frac{\alpha}{2}} + (c-a)\sqrt{\frac{1-\alpha}{2}})d\alpha$$

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$$R(\widetilde{A}) = \int_0^{\lambda} a\,d\alpha + \frac{c-a}{2\sqrt{2}}\int_0^{\lambda}\sqrt{\alpha}\,d\alpha + \frac{c-a}{2\sqrt{2}}\int_0^{\lambda}\sqrt{1-\alpha}\,d\alpha$$

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$$R(\widetilde{A}) = a\lambda + \frac{c-a}{3\sqrt{2}}\lambda^{\frac{3}{2}} - \frac{c-a}{3\sqrt{2}}(1-\lambda)^{\frac{3}{2}} + \frac{c-a}{3\sqrt{2}}$$

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$$R(\widetilde{A}) = a\lambda + \frac{c-a}{3\sqrt{2}}(1 + \lambda^{\frac{3}{2}}) - \frac{c-a}{3\sqrt{2}}(1-\lambda)^{\frac{3}{2}}$$

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Description of Data

This study is based on a sample and real data taken from the Iraqi Ministry of Health and Environment, AL-Karkh General Hospital. About COVID-19. The duration of the study was the interval 4/5/2020 until 31/8/2020 equivalent to 120 days. The period of study was (May, June, July, and August).

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The number of patients who entered the (study) hospital which is the sample size was (n=785).
The number of patients who died during the period of study was (m=88).
The number of patients who survived during the study period was (n-m=697).
In this study, using Chi-square test which is one of the non-parametric tests, to determine if the sample (data) correspond with the Exponential-Rayleigh distribution (ER).
The null and alternative hypotheses for Chi-square test are:

H_0 : The data are distributed as (ER) distribution.

H_1 : The data are not distributed as (ER) distribution.

The formula of this test is given by:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{O_i}$$

Where:

O_i refers to the observed in class i.

E_i refers to the expected frequency in class i.

k refers to the number of class.

The calculated value (15.32008) is less than the tabulated value (21.67) with the degree of freedom (9) and level of significant (0.01). That means accepting the null hypothesis H_0 and the data distributed as (ER) distribution.

Results and Discussion

Numerical Results

In this section, MATLAB programming (version 2021) was employed to estimate values of the following parameters: $\hat{\theta} = 0.00263$, $\hat{\beta} = 0.0079$ when the initial values are $\theta_0 = 0.003$, $\beta_0 = 0.005$
While arranging the data, noting that many patients died on the same date, and to avoid repetition in the table, the data is written briefly, 15 patients died in one day, 7 patients died two days later, 5 patients died three days later, 9 patients died four days later, 4 patients died five days later, 17 patients died six days later, 5 patients died seven days later, 4 patients died eight days later, 3 patients died nine days later, 2 patients died ten days later, 6 patients died twelve days later, 3 patients died fifteen days later, 4 patients died eighteen days later. The results were evaluate for the probability death density function, survival function, and hazard rate function.

Table 1. The values of $\hat{f}(t)$, $\hat{F}(t)$, $\hat{S}(t)$, and $\hat{h}(t)$ by (MLE) method for progressively censored data.

Life time	$\hat{f}(t)$	$\hat{F}(t)$	$\hat{S}(t)$	$\hat{h}(t)$
1	0.010478	0.006558	0.993442	0.010547
2	0.018101	0.02084	0.97916	0.018486
3	0.025323	0.04251	0.95749	0.06447
4	0.031984	0.071068	0.928932	0.034431
5	0.037948	0.105866	0.894134	0.042441
6	0.043103	0.146133	0.853867	0.05048
7	0.047368	0.191003	0.808997	0.058551
8	0.050691	0.239546	0.760454	0.066658
9	0.053054	0.290802	0.709198	0.074808
10	0.054469	0.343807	0.656193	0.083008
11	0.054976	0.397628	0.602372	0.091266
12	0.054639	0.451386	0.548614	0.099594
13	0.053541	0.504278	0.495722	0.108005
15	0.049469	0.604735	0.395265	0.125154
16	0.046717	0.651208	0.348792	0.13394
17	0.04364	0.694639	0.305361	0.142913
18	0.040346	0.734765	0.265235	0.152116

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Note that the values of $\hat{f}(t)$ increase until $t = 11$, and they decrease when $12 \leq t \leq 18$. The values of $\hat{F}(t)$ increase with the increase in failure times. The values of $\hat{S}(t)$ decrease with the increase of failure times. The values of $\hat{h}(t)$ increase with the increase in failure times. The mean square error for the survival function is 0.041479.

Now, finding the fuzzy numbers as:

Case1

$a_1 = 0.00063, b_1 = 0.00263, c_1 = 0.00463$

Case2

$a_2 = 0.0059, b_2 = 0.0079, c_2 = 0.0099$

From case1, case2 and from Eq.22, substituting $\lambda = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9$, to find the best one utilizing mean square error (MSE). Table 1 represents the values of $\hat{f}(t)$, $\hat{F}(t)$, $\hat{S}(t)$, and $\hat{h}(t)$ when $\lambda = 0.5$.

Table 2. The values of $\hat{f}(t)$, $\hat{F}(t)$, $\hat{S}(t)$, and $\hat{h}(t)$ when $\lambda = 0.5$

Life time	$\hat{f}(t)$	$\hat{F}(t)$	$\hat{S}(t)$	$\hat{h}(t)$
1	0.005095	0.003159	0.996841	0.00511
2	0.008912	0.01017	0.98983	0.00900
3	0.012627	0.02095	0.97905	0.012897
4	0.016196	0.035375	0.964625	0.01679
5	0.019581	0.53281	0.946719	0.020683
6	0.022746	0.074464	0.925536	0.024576
7	0.025659	0.098689	0.901311	0.028469
8	0.028294	0.12569	0.87431	0.032362
9	0.030629	0.155177	0.844823	0.036255
10	0.032647	0.186842	0.813158	0.040148
11	0.034336	0.220361	0.779639	0.044041
12	0.035692	0.255403	0.744597	0.047934
13	0.036713	0.291633	0.708367	0.051827
15	0.037775	0.366332	0.633666	0.05613
16	0.036102	0.383309	0.616691	0.058542
17	0.036045	0.4194039	0.580596	0.062083
18	0.035744	0.455319	0.544682	0.065625

Note that the values of $\hat{f}(t)$ increase until $t = 15$, and they decrease when $16 \leq t \leq 18$. The values of $\hat{F}(t)$ increase with the increase in failure times, the values of $\hat{S}(t)$ decrease with the increase in failure times, and the values of $\hat{h}(t)$ increase with the increase of failure times. The mean square error of the survival function is 0.008312. Table. 2, represents the values of $\hat{f}(t)$, $\hat{F}(t)$, $\hat{S}(t)$, and $\hat{h}(t)$ when $\lambda = 0.9$

Table 3. The values of $\hat{f}(t)$, $\hat{F}(t)$, $\hat{S}(t)$, and $\hat{h}(t)$ when $\lambda = 0.9$

Life time	$\hat{f}(t)$	$\hat{F}(t)$	$\hat{S}(t)$	$\hat{h}(t)$
1	0.009188	0.005711	0.994289	0.009241
2	0.015971	0.018312	0.981688	0.016269
3	0.022422	0.037542	0.962458	0.023297
4	0.028414	0.063004	0.936996	0.030325
5	0.033835	0.09418	0.90582	0.037353
6	0.038591	0.130452	0.869548	0.044381
7	0.042612	0.171118	0.828882	0.051409
8	0.045849	0.215415	0.784585	0.058437
9	0.048277	0.262546	0.737454	0.065465
10	0.049897	0.3117	0.6883	0.072493
11	0.050728	0.362077	0.637923	0.079521
12	0.050812	0.412907	0.587093	0.086549
13	0.050207	0.463471	0.536529	0.093577
15	0.047223	0.561259	0.438741	0.107633
16	0.045015	0.607411	0.392589	0.114661
17	0.042449	0.651169	0.348831	0.121689
18	0.039617	0.69222	0.30778	0.128717

Note that the values of $\hat{f}(t)$ increase until $t = 12$, the probability density function decrease when $13 \leq t \leq 18$. The values of $\hat{F}(t)$ increase with the increase in failure times, the values of $\hat{S}(t)$ decrease with the increase in failure times, and the values of $\hat{h}(t)$ increase with the increase in failure times. The mean square error of the survival function is 0.033236.

Conclusion

The major findings in this paper are as following:

- Before and after fuzzy work, note that there is a direct relationship between the hazard rate function and the failure times, $\hat{h}(t)$ is increasing with the increase in failure times.
- Observing that there is an opposite relationship between the survival function and the failure times, $\hat{S}(t)$ are decreasing with the increase in failure times.
- The fuzzy numbers are better than the crisp numbers by using mean square error (MSE).
- The mean square error for fuzzy numbers is less than the mean square error for traditional numbers when $\lambda \in [0.5,0.9]$.

Author's Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours.
- Ethical Clearance: The project was approved by the local ethical committee in University of Baghdad.

Author's Contribution Statement

I.H. proposed the idea of the research, reviewed, suggested the modifications and gave advice how to write the paper. R. N. calculated the results before and after fuzzy work, wrote the research and performed the programming of the estimated values of the parameters.

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تقدير معلمات توزيع رايلي الأسي للنوع الثالث من البيانات الخاضعة للرقابة مع دالة-s لفايروس كورونا

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الخلاصة

في هذه الدراسة تم تقدير معلمات توزيع رايلي_الأسي للنوع الثالث للبيانات الخاضعة للرقابة و ذلك بأستخدام طريقة الامكان الاعظم. وتم الاعتماد على بيانات حقيقية خاصة بمرضى بفايروس كورونا تم الحصول عليها من وزارة الصحة العراقية/ مستشفى الكرخ العام وتم استخدام اختبار كاي_سكوير لأختبار العينة المستخدمة في الدراسة تتوزع توزيع رايلي_الاسي. وبعد ذلك تم استخدام دالة ضبابية غير خطية لإيجاد القيم الضبابية لقيم المعلمات المقدرة وتم استخدام الدالة الرتيبة الضبابية لتحويل القيم الضبابية الى القيم التقليدية.تمت مقارنة النتائج قبل وبعد استخدام المنطق الضبابي من خلال حساب متوسط مربع الخطأ لكل منهم. هدف البحث هو تقدير معلمات توزيع رايلي-الأسي للنوع الثالث من البيانات الخاضعة للرقابة.بعد ذلك يتم تضبيب المعلمات بأستخدام دالة-s الغير خطية الضبابية لإيجاد القيم الضبابية للمعلمات. بعد ذلك يتم تحويل القيم الضبابية الى قيم تقليدية بأستخدام الدالة الرتيبة الضبابية. نقارن النتائج قبل وبعد استخدام المنطق الضبابي بأستخدام طريقة متوسط مربعات الخطأ. كانت فترة الدراسة (مايو ويونيو ويوليو وأغسطس) وبلغ عدد المرضى الذين دخلوا الدراسة خلال الفترة المذكورة أعلاه 1058 مريض. تم استبعاد ست حالات من بينها: عدد السجناء 26. عدد الأشخاص الذين كانت مسحاتهم سالبة 48. عدد المرضى الذين كانت حالة خروجهم غير معروفة 29. عدد المرضى الذين هربوا من المستشفى كان 2. بلغ عدد المرضى الذين تم نقلهم إلى مستشفيات أخرى 35 مريضًا. وبلغ عدد المرضى الذين تم إخراجهم على مسؤوليتهم 133. ثم أصبح عدد المرضى الذين دخلوا مستشفى (الدراسة) وهو حجم العينة (n=785). بلغ عدد المرضى الذين ماتوا خلال فترة الدراسة (m=88). كان عدد المرضى الذين تشافوا من المرض خلال فترة الدراسة (n-m=697).

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