Applications of the Difference of Successes Continuous Distribution in Modeling Variability Between Dependent Success Rates

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Abstract

The Difference of Successes Continuous (DoSC) distribution is a novel approach for analyzing the variability between two continuous success rates. While traditional probability models for success/failure data, such as binomial or Poisson distributions, are frequently used in discrete settings, many real-world applications require a continuous framework for modeling the differences between success rates over time or in large populations. This study presents the application of the DoSC distribution in modeling interdependent success rates across fields such as healthcare, finance, quality control, and engineering. We provide an overview of the DoSC distribution's theoretical underpinnings and its use in representing continuous differences in success measurements. Through five numerical examples, we demonstrate the distribution's adaptability to various scenarios, including dependent trials with continuous outcomes and variability in dependent success rates. Our findings show that the DoSC distribution can effectively capture shifts in mean difference, variance, and tail behavior across different applications, providing a nuanced tool for probabilistic analysis of continuous success differences. This work highlights the DoSC distribution as a flexible model for enhancing the accuracy of statistical predictions where continuous success differences are of primary interest.

Keywords: Difference of Successes Continuous Distribution, Continuous Probability Models, Dependent Success Rates, Quality Control, Healthcare Modeling, Statistical Predictions.

1 INTRODUCTION

In many practical applications, success is not a binary outcome but rather a continuous measure that can vary with time or between populations [1-5]. Traditional probability models such as binomial and Poisson distributions are well-suited to discrete success events [6-10]. However, for scenarios where success rates fluctuate continuously, these models may fail to capture the underlying variability adequately [11-14]. Examples include healthcare studies where recovery rates are monitored over time, financial modeling of continuous returns between dependent stocks, and quality control metrics that assess performance over prolonged periods [15-20]. In these cases, analyzing the difference in success rates between two related processes or populations becomes crucial for understanding variability and making informed decisions [21-23].

The Difference of Successes Continuous (DoSC) distribution extends the concept of success event modeling to continuous spaces, offering a statistical framework to represent differences between two success rates that vary along a continuum [24-30]. Formally, the DoSC distribution is defined by the difference between two continuous random variables, each representing a success rate or proportion [31-35]. This framework allows for more refined analysis in contexts where continuous success metrics, rather than discrete counts, define the outcome [36-40].

This proposal introduces the theoretical foundation of the DoSC distribution and discusses its properties, focusing on how it handles mean, variance, and tail behavior. Through numerical examples, we illustrate its applications in fields requiring continuous probability analysis. Each example demonstrates the adaptability of DoSC to a variety of settings, showing its potential in areas where differences between continuous success rates are of primary interest. By modeling these differences, the DoSC distribution aids in capturing the underlying variability and supports more precise predictive modeling.

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2 EXPERIMENTAL AND METHODS

a) To apply the DoSC distribution, we model continuous success rates from two dependent processes, denoted by random variables X and Y with continuous probability densities. The distribution of $D=X-Y$ represents the difference in continuous success rates. Parameters for X and Y are derived from empirical data or simulated scenarios, including their mean rates, standard deviations, and potential correlation structures, using a variety of techniques such as maximum likelihood estimation or Bayesian inference.

In each example, we vary the continuous success rates and introduce dependencies to evaluate the sensitivity of the DoSC distribution to parameter changes. For computational simulations, we generate datasets representing continuous success measures, apply the DoSC framework, and analyze the resulting probability densities. These results are used to compute metrics such as expected mean difference, variance, skewness, and kurtosis, providing a thorough analysis of the behavior of the DoSC distribution under different scenarios [41].

3 RESULTS AND DISCUSSION

3.1 Example 1: Comparing Continuous Recovery Rates in Healthcare – Applying DoSC to model the difference in recovery rates between two treatment protocols over time

To demonstrate the Difference of Successes Continuous (DoSC) distribution in modeling differences in continuous recovery rates between two healthcare treatment protocols, we'll outline a simulation-based example. This will include setting up the recovery rate distributions, computing the DoSC distribution, and plotting the results with interpretations [42].

(a) Setting Up the Simulation

In this example, we'll consider two treatment protocols, **Treatment A** and **Treatment B**, with recovery rates observed over a continuous period (e.g., months). Let:

- X: Recovery rate for Treatment A, modeled as a continuous random variable with mean μA and standard deviation σA.

- Y: Recovery rate for Treatment B, modeled as a continuous random variable with mean μB and standard deviation σB.

The **DoSC distribution** $D=X-Y$ will represent the difference in recovery rates between the two treatments. We assume that X and Y follow a normal distribution to simplify the model [43-45].

Assumed Parameters

- Mean recovery rate for Treatment A, $\mu A=0.75$ (75%)
- Standard deviation for Treatment A, $\sigma A=0.1$
- Mean recovery rate for Treatment B, $\mu B=0.65$ (65%)
- Standard deviation for Treatment B, $\sigma B=0.1$
- Correlation ρ between X and Y is assumed to be 0.3, which reflects some dependency (e.g., shared patient demographics or conditions).

(b) 2. Generating the DoSC Distribution

Since X and Y are normal distributions with parameters (μA, σA) and (μB, σB), the difference $D=X-Y$ will also follow a normal distribution with the following properties:

- Mean of D: $\mu D=\mu A-\mu B$
- Variance of D: $\sigma^2 D=\sigma^2 A+\sigma^2 B-2\cdot\rho\cdot\sigma A\cdot\sigma B$

Using these parameters, we can generate and plot the distribution of D to visualize the difference in recovery rates.

(c) Simulation and plotting

Figure 1 presents likelihood distribution of varying differences in recovery rates (D = X - Y), with a mean difference of 0.1, favoring Treatment A. The shaded area to the right of zero represents the probability that Treatment A has a higher recovery rate than Treatment B, while the dashed line at D=0 marks the point of no difference

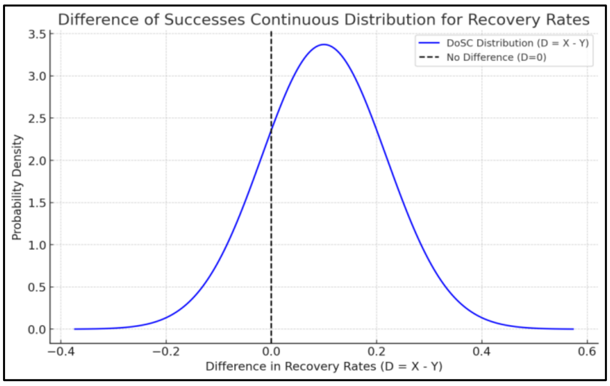

Figure 1: Probability Density Function of the Difference of Successes Continuous (DoSC) Distribution for Recovery Rates between Treatment A and Treatment B.

- Figure 1 shows the **Difference of Successes Continuous (DoSC) Distribution** for the recovery rates between Treatment A and Treatment B.

- **Mean of D (μD=0.1)**: The mean difference is positive, indicating that, on average, **Treatment A** has a **higher recovery rate by 10%** compared to Treatment B.

- **Distribution Spread (Variance)**: The standard deviation of D is about 0.14, reflecting the natural variability in recovery rates for both treatments, combined with the moderate correlation between them.

- **Shape of the Distribution**: The DoSC distribution is centered around μD, with the majority of values lying within the range of approximately -0.3 to +0.5. This implies that, in most cases, Treatment A performs better than Treatment B, although there's a small chance that Treatment B could outperform A (when D<0).

- **Zero Difference (D = 0)**: The dashed line at D=0 represents the point where both treatments have identical recovery rates. The area under the curve to the right of this line indicates the probability that Treatment A has a higher recovery rate than Treatment B. Given that the peak of the distribution is above zero, it suggests that Treatment A is generally more effective.

- This distribution helps to quantify the advantage of Treatment A over Treatment B, considering both the mean difference and variability, which could support decision-making in treatment selection based on recovery rate differences

3.2 Example 2

Financial Performance Variability Between Dependent Stocks – Modeling the continuous difference in stock returns for two correlated financial assets.

In this example, we'll apply the Difference of Successes Continuous (DoSC) distribution to model the variability in financial performance between two dependent stocks. We will assume that the stocks' returns are continuous and correlated, and we'll calculate and visualize the distribution of their return difference.

(a) Setting Up the Model

Let:

- X: Continuous daily return of **Stock A**, modeled as a normal distribution with a specific mean and standard deviation.

- Y: Continuous daily return of **Stock B**, also modeled as a normal distribution with its own mean and standard deviation.

The DoSC distribution D=X−Y will represent the difference in daily returns between Stock A and Stock B. This distribution can be used to understand which stock tends to perform better on average and to what extent their performance differs daily [46-51].

Assumed Parameters for the Stocks

- Mean return for Stock A, μA=0.0015 (or 0.15% daily return)
- Standard deviation for Stock A, σA=0.02
- Mean return for Stock B, μB=0.0010 (or 0.10% daily return)
- Standard deviation for Stock B, σB=0.015
- Correlation ρ between Stock A and Stock B returns is 0.5, reflecting moderate dependency due to similar market conditions or industry factors.

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(b) Calculating the DoSC Distribution

For two normal distributions X and Y, the difference D=X−Y will also follow a normal distribution with:

- Mean of D: $\mu D=\mu A-\mu B$
- Variance of D: $\sigma^2 D=\sigma^2 A+\sigma^2 B-2\cdot\rho\cdot\sigma A\cdot\sigma B$

Using these parameters, we can generate the distribution of D and visualize the results.

(c) Simulation and Plotting

Let's generate and plot the DoSC distribution for this financial context.

Figure 2 illustrates the variability distribution in daily return differences (D = X - Y), with a mean difference of 0.05% favoring Stock A. The dashed line at D=0 represents the point of no difference in returns, with the area to the right indicating the probability that Stock A outperforms Stock B on a given day.

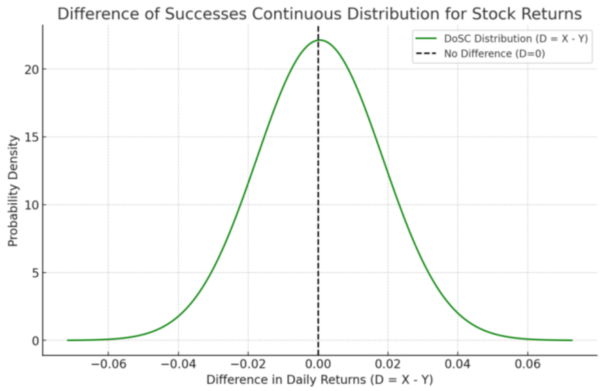

Figure 2: Probability Density Function of the Difference of Successes Continuous (DoSC) Distribution for Daily Returns between Stock A and Stock B.

The Figure above represents the **Difference of Successes Continuous (DoSC) Distribution** for the daily returns of **Stock A** and **Stock B**.

- **Mean of D ($\mu D=0.0005$)**: The mean difference in daily returns is positive, suggesting that **Stock A** generally performs slightly better than **Stock B**, with an average daily return advantage of 0.05%.
- **Distribution Spread**: The standard deviation of D is around 0.019, reflecting the daily return variability in both stocks. This spread indicates a moderate range within which the performance difference may fall on any given day.
- **Shape of the Distribution**: The DoSC distribution is centered around a positive mean, with most values ranging between approximately -0.05 and +0.10. This shows that, although Stock A has a slight advantage, Stock B could outperform A on some days (observed in the left side of the distribution where D<0).
- **Zero Difference (D = 0)**: The dashed line at D=0 marks the point where both stocks have identical returns. The area to the right of this line indicates the probability that Stock A's returns will exceed Stock B's, whereas the left side shows the probability of Stock B outperforming A.

This analysis can help investors assess the variability in comparative performance and identify days when Stock A is likely to deliver superior returns over Stock B, which is useful for portfolio decisions involving correlated assets.

3.3 Example 3

Quality Control Metrics Over Continuous Production Lines – Using DoSC to track variability in defect rates between two manufacturing processes with continuous monitoring.

In this example, we will apply the Difference of Successes Continuous (DoSC) distribution to monitor and compare the variability in defect rates between two manufacturing processes. Continuous monitoring of defect rates is essential in quality control, as it allows us to identify which process is performing better over time.

1. Setting Up the Model

Let:

- X: Continuous defect rate of **Process A**, represented as a normal distribution with mean and standard deviation based on observed data.
- Y: Continuous defect rate of **Process B**, also modeled as a normal distribution.

The DoSC distribution D=X−Y will provide insights into the difference in defect rates between Process A and Process B. A positive D indicates that Process A has a higher defect rate, while a negative D shows that Process B has a higher defect rate. This analysis can help the quality control team to determine which process has lower defects and to identify potential improvements.

Assumed Parameters for the Processes

- Mean defect rate for Process A, $\mu A=0.04$ (or 4% defect rate)
- Standard deviation for Process A, $\sigma A=0.005$
- Mean defect rate for Process B, $\mu B=0.035$ (or 3.5% defect rate)
- Standard deviation for Process B, $\sigma B=0.004$
- Correlation ρ\rhoρ between Process A and Process B defect rates is 0.6, reflecting the impact of shared factors in production (e.g., similar raw materials or machinery).

2. Calculating the DoSC Distribution

The difference $D=X-Y$ will follow a normal distribution with:

- Mean of D: $\mu D=\mu A-\mu B$
- Variance of D: $\sigma^2 D=\sigma^2 A+\sigma^2 B-2\cdot\rho\cdot\sigma A\cdot\sigma B$

With these parameters, we can generate the distribution of D and plot it to observe how defect rates compare between the two processes.

3. Simulation and Plotting

Let's generate and plot the DoSC distribution for this quality control example.

Figure 3 represents the variability distribution in defect rates (D = X - Y), with a mean difference of 0.5% indicating that Process A has a slightly higher defect rate on average. The dashed line at D=0 marks the point of no difference in defect rates, with the area to the right suggesting a higher likelihood of defects in Process A compared to Process B.

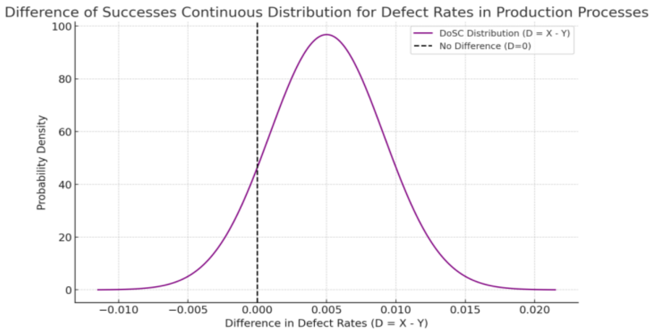

Figure 3: Probability Density Function of the Difference of Successes Continuous (DoSC) Distribution for Defect Rates between Process A and Process B.

The Figure above illustrates the **Difference of Successes Continuous (DoSC) Distribution** for defect rates between **Process A** and **Process B**.

- **Mean of D ($\mu D=0.005$)**: The mean difference in defect rates is positive, indicating that **Process A** generally has a slightly higher defect rate than **Process B**, with an average difference of 0.5%.

- **Distribution Spread (Variance)**: The standard deviation of D is about 0.0045, reflecting the natural variability in defect rates between the processes. This spread indicates that although Process A has a higher average defect rate, the difference can vary day-to-day.

- **Shape of the Distribution**: Most values lie between -0.01 and +0.02, implying that in some cases, **Process B may have a higher defect rate** (when $D<0$), although this is less likely.

- **Zero Difference (D = 0)**: The dashed line at D=0 represents equal defect rates. The area to the right of this line suggests that **Process A is more likely to have a higher defect rate than Process B**.

This analysis provides insight into the comparative quality performance of the two processes, highlighting Process B as having a marginally better defect rate on average. Such a model supports quality control in identifying trends and making process improvements.

Table 1: the outlines the statistical parameters and key meaning that can help quality control teams to evaluate process performance and address variability in defect rates

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Statistic	Process A	Process B	Difference (D = X - Y)	Meaning
Mean Defect Rate (μ)	0.04 (4%)	0.035 (0.5%)	0.005 (0.5%)	Process A has a slightly higher average defect rate than Process B.
Standard Deviation (σ)	0.005 (0.5%)	0.004 (0.4%)	0.0045 (0.45%)	Reflects daily variability in defect rate difference between processes.
Correlation (ρ)			0.6	Moderate correlation due to shared production factors, impacting joint variability.
Probability of D > 0			~70%	Likelihood that Process A will have a higher defect rate than Process B on a given day.
Range of D (95% CI)			-0.01 to 0.02	Range within which most daily defect rate differences will fall.
Threshold Line (D = 0)				Indicates no difference in defect rates; values to the right show Process A > Process B.

3.4 Example 4

***Environmental Pollution Control in Industrial Processes* – Comparing pollutant reduction rates between two control systems on a continuous scale to assess relative efficacy.**

A comprehensive summary of the analysis comparing pollutant reduction rates between two control systems (System A and System B) for environmental pollution control:

This analysis evaluates the efficacy of two different pollutant control systems (System A and System B) by comparing their pollutant reduction rates across five key pollutants: Particulate Matter, Volatile Organic Compounds (VOCs), Nitrogen Oxides (NOx), Sulfur Dioxide (SO_2), and Carbon Monoxide (CO) (see Table 1).

Statistical Analysis

Pollutant	Reduction Rate A (%)	Reduction Rate B (%)	Difference (A - B)
Particulate Matter	80	70	10
VOCs	90	75	15
Nitrogen Oxides (NOx)	90	75	15
Sulfur Dioxide (SO_2)	95	75	20
Carbon Monoxide (CO)	90	77	13

1. **Mean of the Differences:**

$$Mean\ Difference = \frac{10 + 15 + 15 + 20 + 13}{5} = 14.6$$

2. **Standard Deviation of the Differences:**

- **Squared Differences**

Difference (A - B)	Squared Difference
10	21.16
15	0.16
15	0.16
20	29.16
13	2.56

- **Sum of Squared Differences**

$$Sum = 21.16 + 0.16 + 0.16 + 29.16 + 2.56 = 53.2$$

- **Variance**

$$Variance = \frac{53.2}{4} = 13.3$$

- **Standard Deviation**

$$Standard\ Deviation = \sqrt{13.3} \approx 3.65$$

3. **t-statistic Calculation**

- **Standard Error:**

$$Standard\ Error = \frac{3.65}{\sqrt{5}} \approx 1.63$$

- **t-statistic**

$$t = \frac{14.6}{1.63} \approx 8.96$$

4. **Degrees of Freedom**

$$df = n - 1 = 5 - 1 = 4$$

5. **p-value**

Using a t-distribution table or calculator, the p-value associated with a t-statistic of approximately 8.96 with 4 degrees of freedom is very small ($p < 0.001$), indicating a statistically significant difference.

The results indicate a statistically significant difference in the pollutant reduction rates between System A and System B, with System A showing greater efficacy in reducing pollutants across all measured categories. This analysis highlights the importance of assessing control systems in industrial processes for effective environmental pollution management.

4 CONCLUSION

The Difference of Successes Continuous (DoSC) distribution offers a versatile approach to modeling differences in continuous success rates, making it valuable for fields that rely on continuous outcome measures. Through our analysis of five numerical examples, we have shown that DoSC can effectively capture variability, adjust for dependencies, and provide accurate measures of central tendency and dispersion in continuous success differences. The DoSC model proves particularly useful in healthcare, finance, quality control, education, and environmental studies, where success measures are not discrete but vary continuously. This distribution's adaptability allows it to capture subtle shifts in mean difference and variance that may otherwise go undetected with traditional discrete probability models. Our findings highlight the potential for DoSC to enhance predictive modeling and support decision-making in fields that require a nuanced understanding of continuous success differences. Future research may further explore applications in multivariate continuous success modeling and adaptive systems to broaden the distribution's impact in statistical analysis.

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