Synthetic Data Generation for Reliability Engineering:Addressing the Challenge of Limited Sample Size

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Abstract

Reliability engineering depends on sufficient failure data to enable statistically confident predictions of product life. However, practical limitations often restrict accelerated life testing (ALT) to very few samples, producing wide confidence intervals that undermine prediction accuracy. This paper presents a methodology where synthetic failure data is generated using Inverse Transform Sampling (ITS) and Generative Adversarial Networks (GANs), enabling statistically robust life estimation even when only six physical failures are available. The method is applied to ceiling fan blade fatigue testing, where actual failures at 675 and 750 RPM were expanded into 100 synthetic failure times, and reliability was extrapolated to normal operating speed (380 RPM). Results demonstrate that synthetic augmentation reduces uncertainty, ensuring that the standard deviation of predicted time at unreliability is no longer greater than the mean, thus restoring meaningful prediction capability.

Keywords

Reliability engineering, Synthetic data, Accelerated life testing, Inverse transform sampling, Generative adversarial networks.