2024.10.04

세종대학교
SEJONG UNIVERSITY

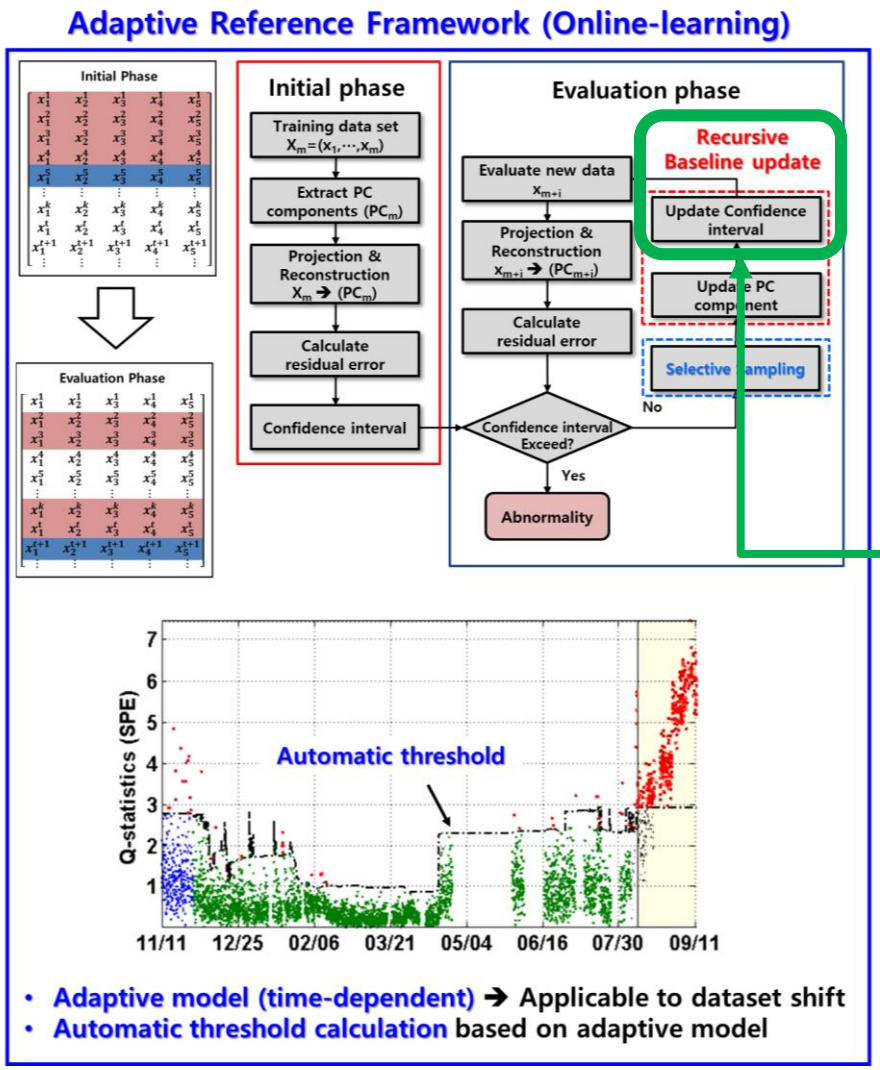
[시설물 알고리즘] 외부환경 변화 적응형 실시간 이상상태 탐지 자동화

Prof. Jin, Seung-Seop

Sejong University
Dept. of Civil Eng.

진행 사항(1/4): 임계치 자동산출기법 검증

↘ 외부환경 변화 적응형 이상상태 탐지 자동화 알고리즘 흐름도



개발방법 방향성 도출
(7월 말 완료)

실시간 이상탐지
소스코드 구축 완료-데이터 중심학습 제외
(8월 말 완료)

데이터 중심학습 기반
임계치 자동산출 기법 소스코드 개발 완료
(9월 말 완료)

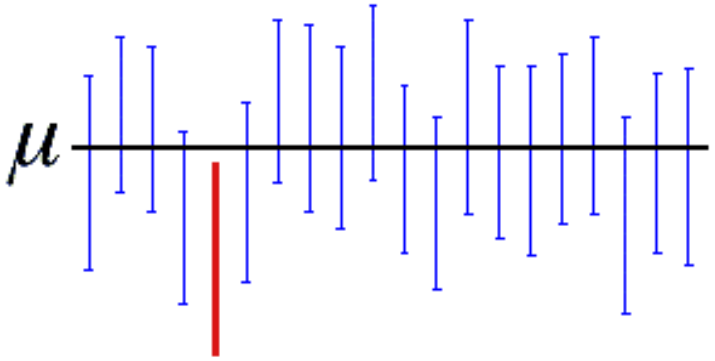
데이터 중심학습 기반
임계치 자동산출 기법 검증 및
소스코드 통합
(10월 초 완료 예정)

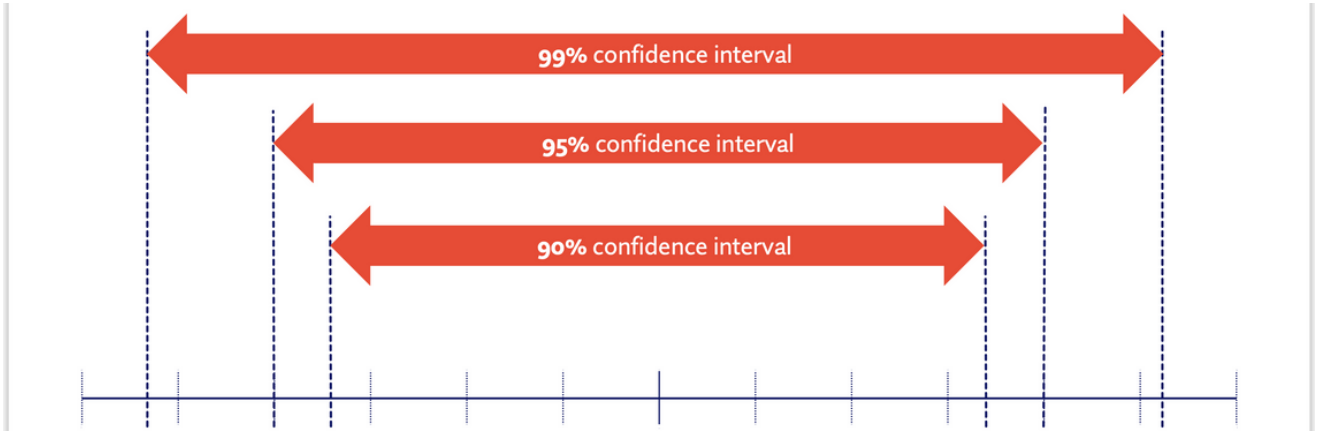
세종대 자체 구축 데이터 기반
성능 평가 및 고도화
(10월 중순 완료 예정)

이노온-건설연 검증 시나리오 별
성능평가 및 고도화
(10월 말 예정)

진행 사항(2/4): 임계치 자동산출기법 검증

A 95% confidence interval indicates that 19 out of 20 samples (95%) from the same population will produce confidence intervals that contain the value





진행 사항(3/4): 임계치 자동산출기법 검증

↘ 기존 임계치 산정 방식 ➔ Q-statistics with Normality assumption

1. Q-Statistic

Q- residual indicates how well each sample conforms to the PCA model.

- It is a measure of the difference, or residual between a sample and its projection into the principal components retained in the model.

$$Q(X, P_{1:r}) = X(I - P_{1:r}P_{1:r}^T)X^T = \|X - \hat{X}\|^2$$

where $\hat{X} = P_{1:r}X$

- X: Normalized X
- P: Principal component (PC) vectors
- r: # of retained PCs

Compute threshold of Q-Statistics

$$Q_{alpha} = \frac{\theta_2}{2\theta_1}\chi_\alpha^2(h)$$

where

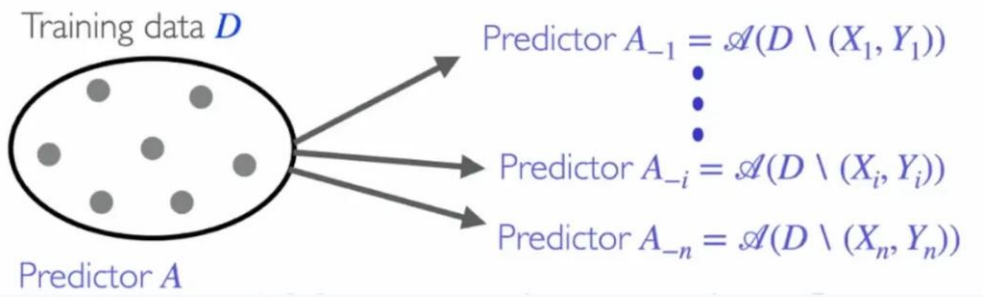
- θ_1: sample mean
- θ_2: sample variance
- $\chi_\alpha^2(h)$: chi-squared distribution with h degree of freedom and the significance level α
- $h = \frac{2\theta_1^2}{\theta_2}$

> Note it is based on normality assumption on Q-statistics

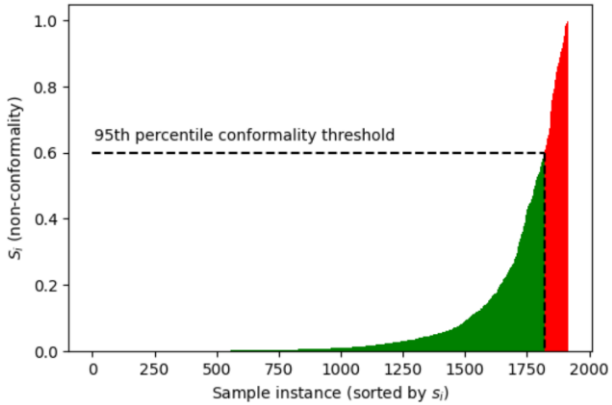
진행 사항(4/4): 임계치 자동산출기법 검증

↘ 데이터 중심학습을 통한 Assumption-free 임계치 자동산정 알고리즘 개발 및 검증 중

- ML의 불확실성 정량화 기법으로 많은 주목을 받고 있는 Conformal prediction 기법 적용
- 임계치 산정을 위한 스코어 산출 방식 정의: **Q-statistics**기반 Leave-one-out error
- 데이터중심 학습을 통한 스코어 산출 기법 도출: Jackknifre+



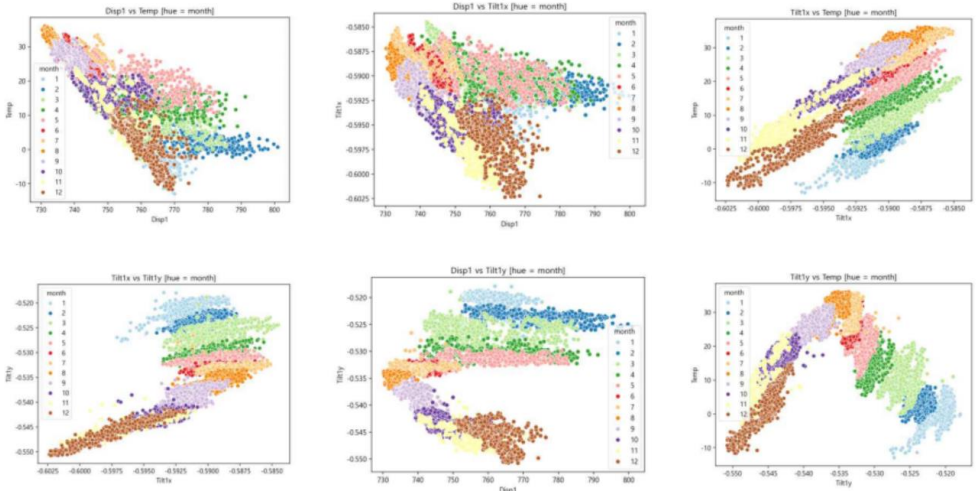
데이터 중심학습을 위한 Jackknife 리샘플링 기법을 통한 LOO error 산출



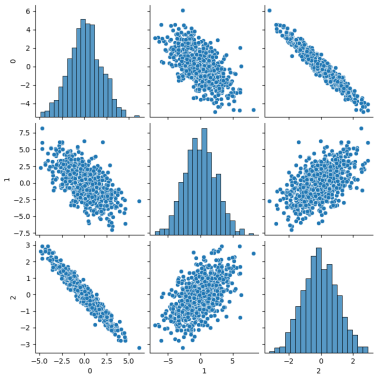
LOO error에 대한 Conformal Prediction 적용 개념도
(데이터 중심 학습을 통한 Assumption-free 임계치 자동산정)

데이터 중심학습 기반 임계치 자동산정기법 검증개요

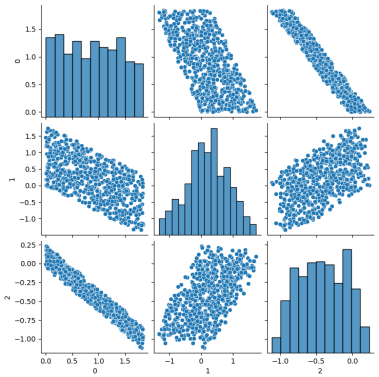
BMS DB 내 실제 정적 데이터
(변위, 경사계, 온도)



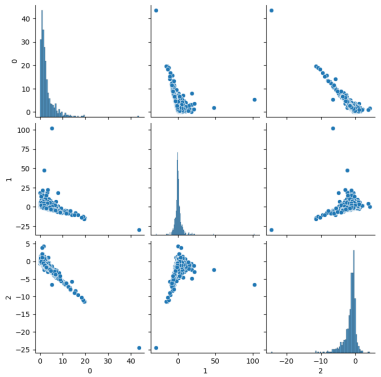
위 산점포의 형상을 토대로 총 4가지 경우에 대한 검증 시나리오를 도출함



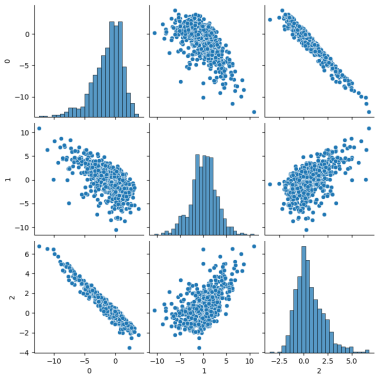
normal



uniform



Log-normal



Gumbel-L

데이터 중심학습 기반 임계치 자동산정기법 검증결과 #1 (1/3)

```
num_samples, residaul_type = 700, 'normal'
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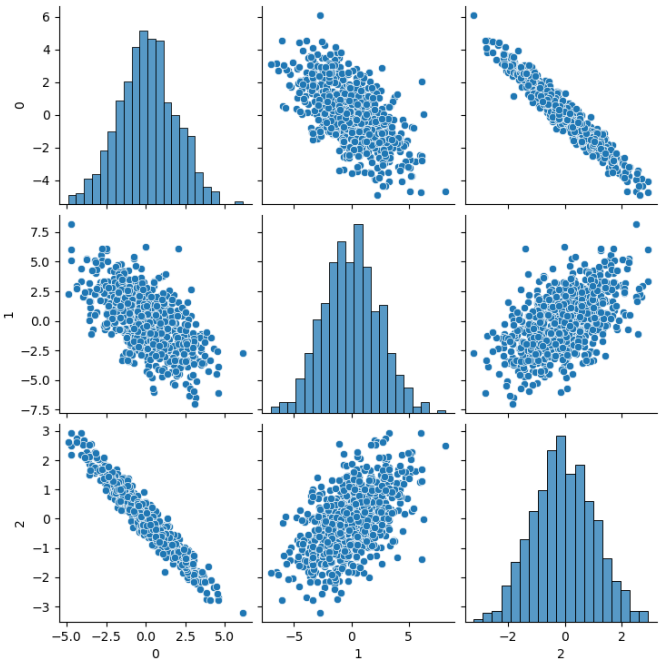
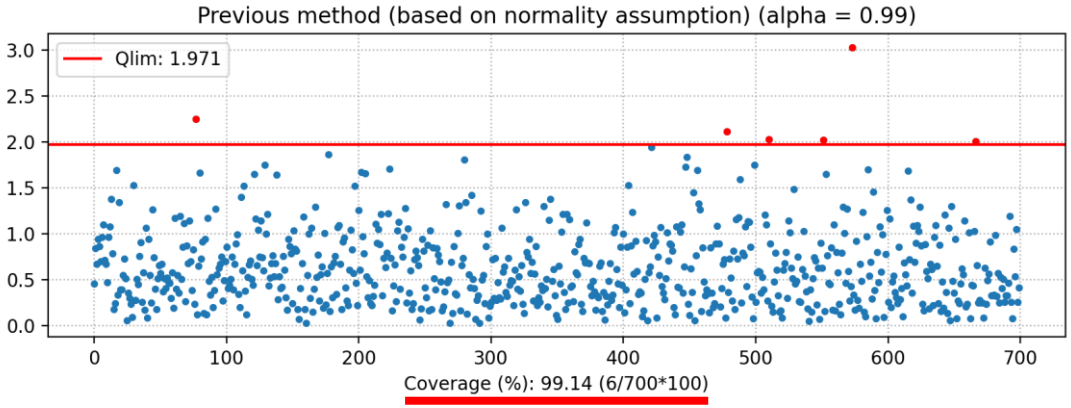
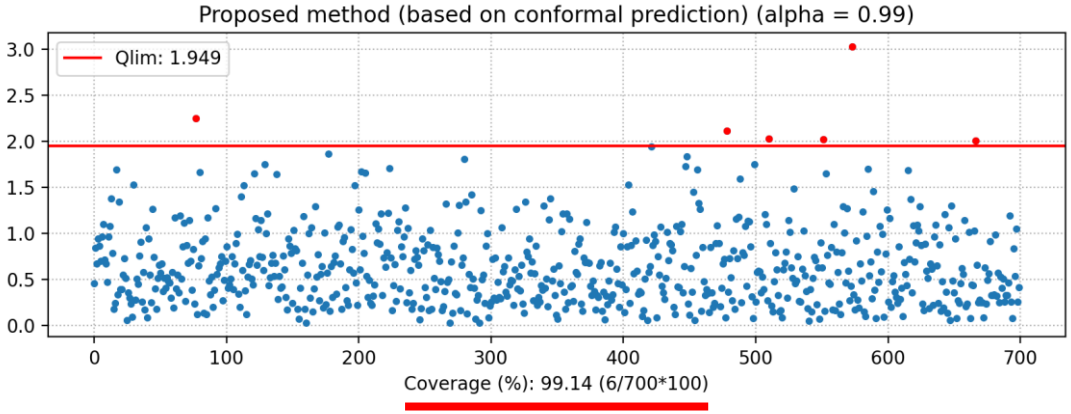
Alpha = 0.99



Normal distribution

Q-statistics for calculating threshold after PCA





데이터 중심학습 기반 임계치 자동산정기법 검증결과 #1 (2/3)

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num_samples, residaul_type = 700, 'normal'
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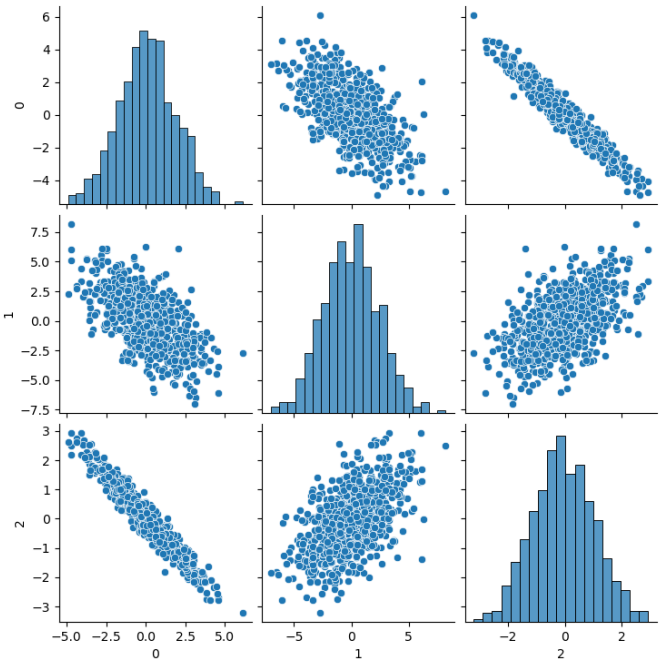
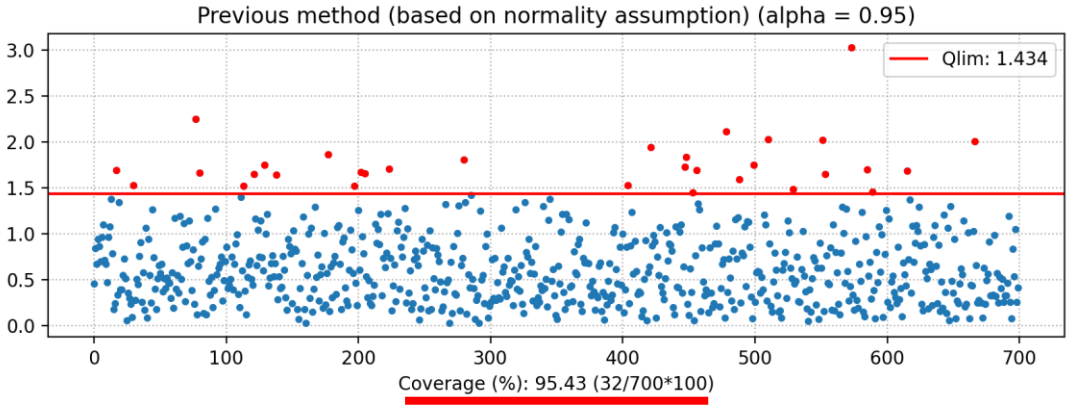
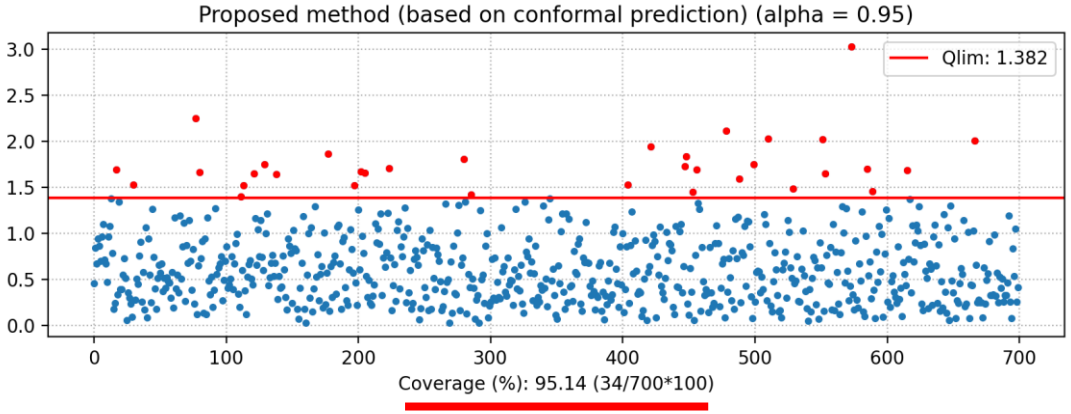
Alpha = 0.95



Normal distribution

Q-statistics for calculating threshold after PCA

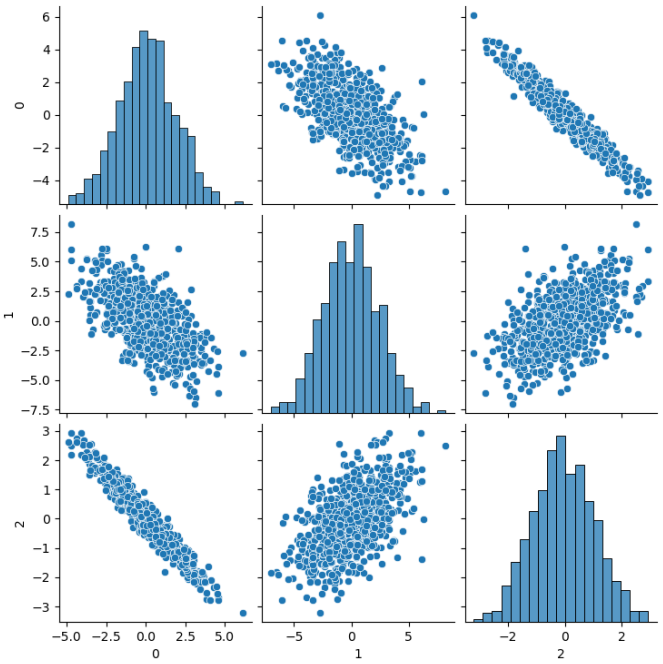




데이터 중심학습 기반 임계치 자동산정기법 검증결과 #1 (3/3)

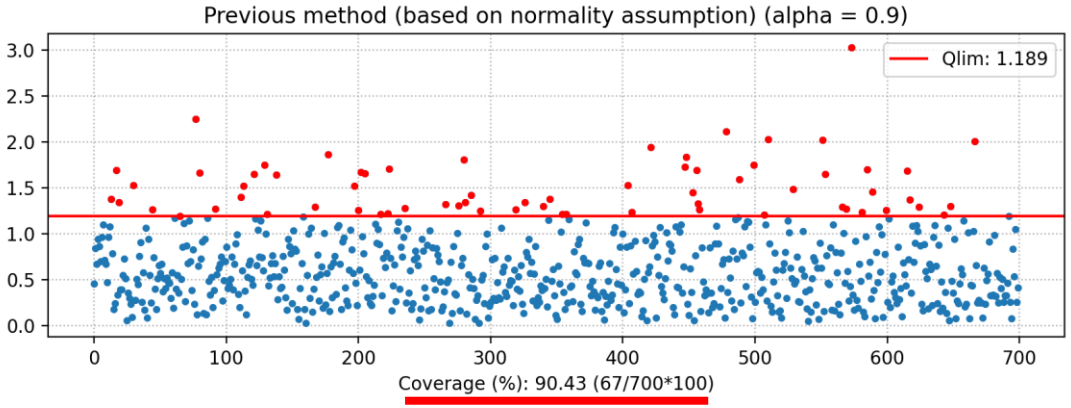
```
num_samples, residaul_type = 700, 'normal'
```

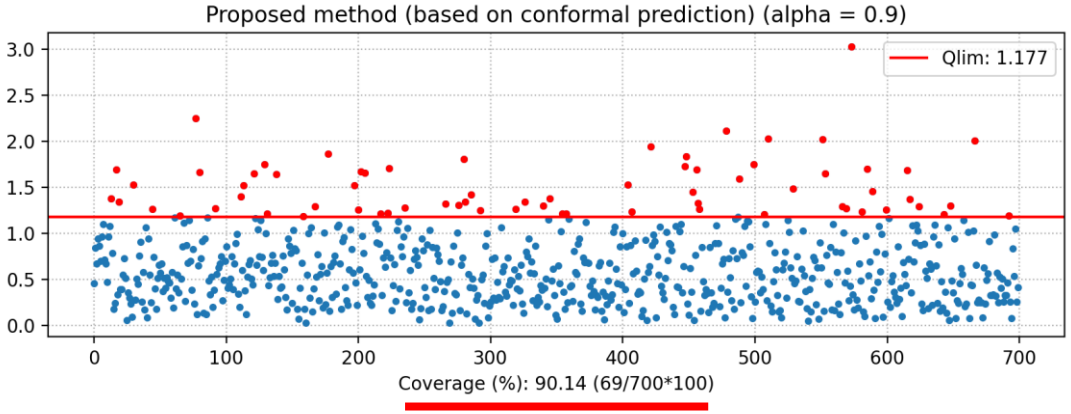
Alpha = 0.90



Normal distribution

Q-statistics for calculating threshold after PCA

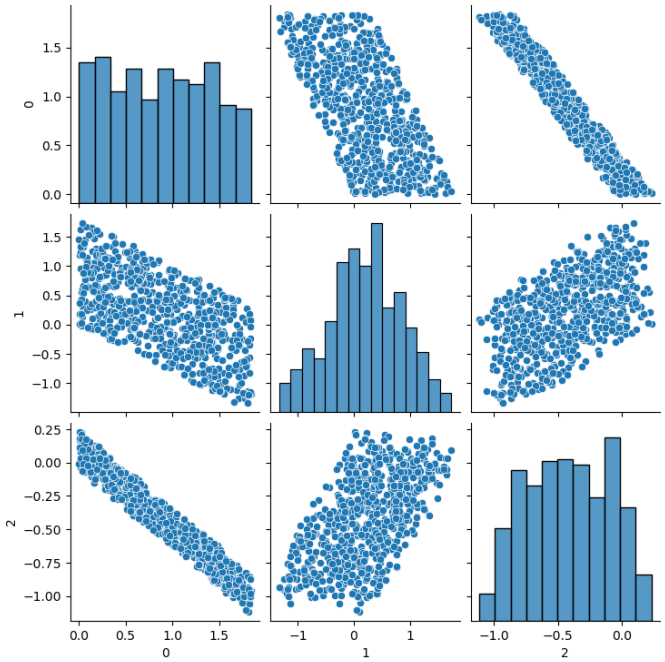




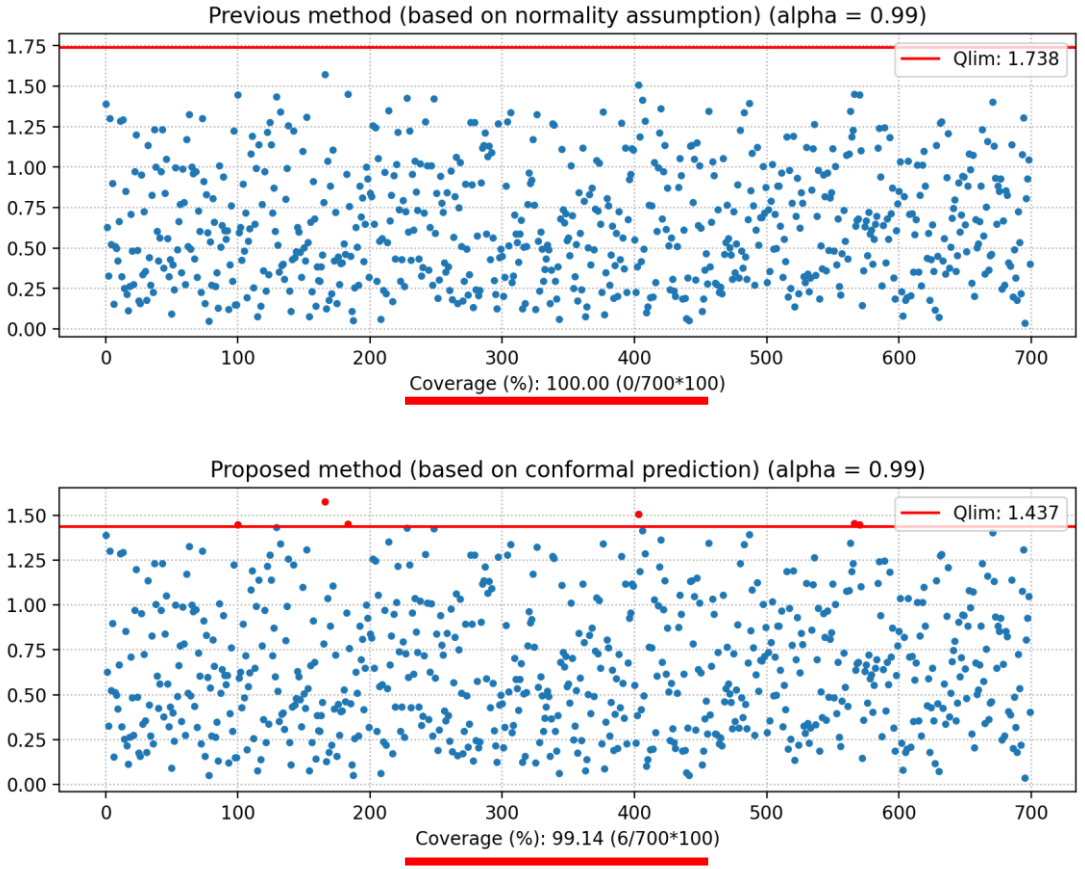
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #2 (1/3)

```
num_samples, residaul_type = 700, 'uniform'
```

Alpha = 0.99



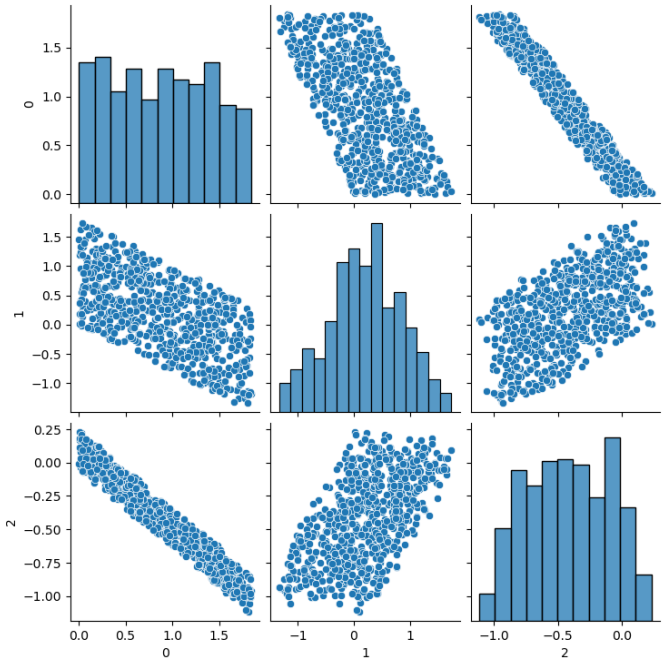
Q-statistics for calculating threshold after PCA



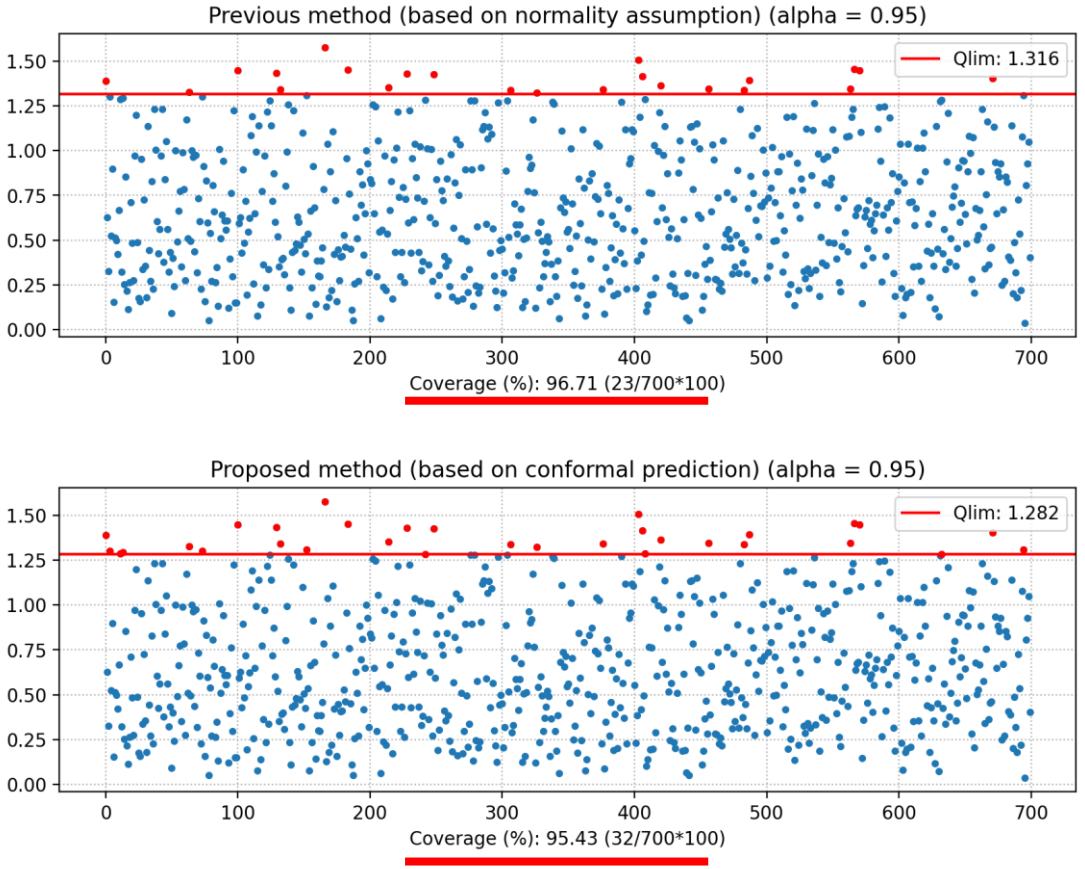
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #2 (2/3)

```
num_samples, residaul_type = 700, 'uniform'
```

Alpha = 0.95



Q-statistics for calculating threshold after PCA



데이터 중심학습 기반 임계치 자동산정기법 검증결과 #2 (3/3)

```
num_samples, residaul_type = 700, 'uniform'
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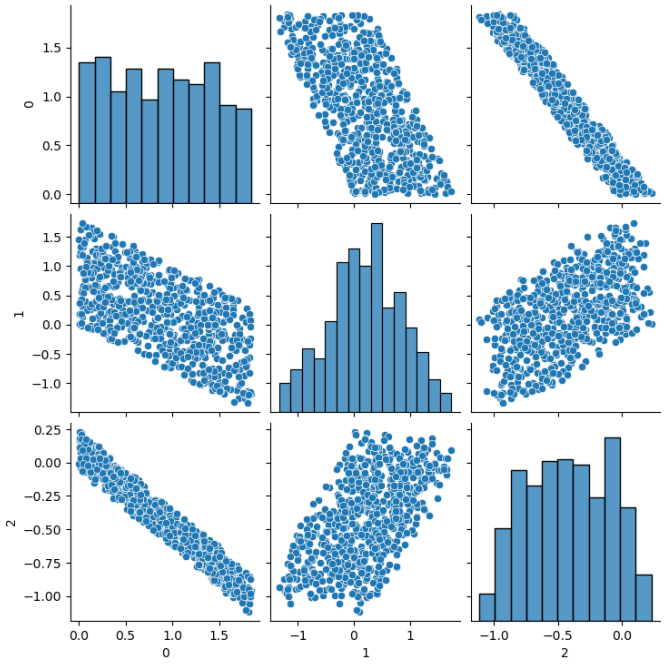
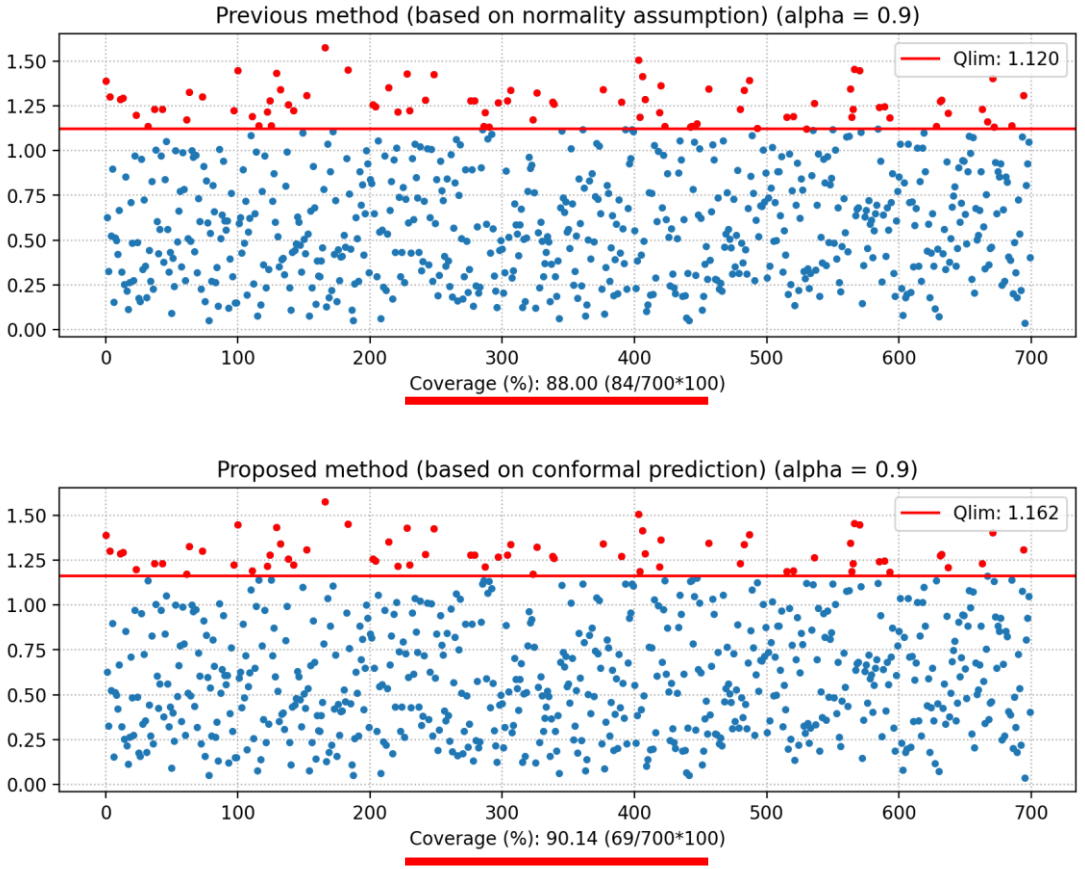
Alpha = 0.90



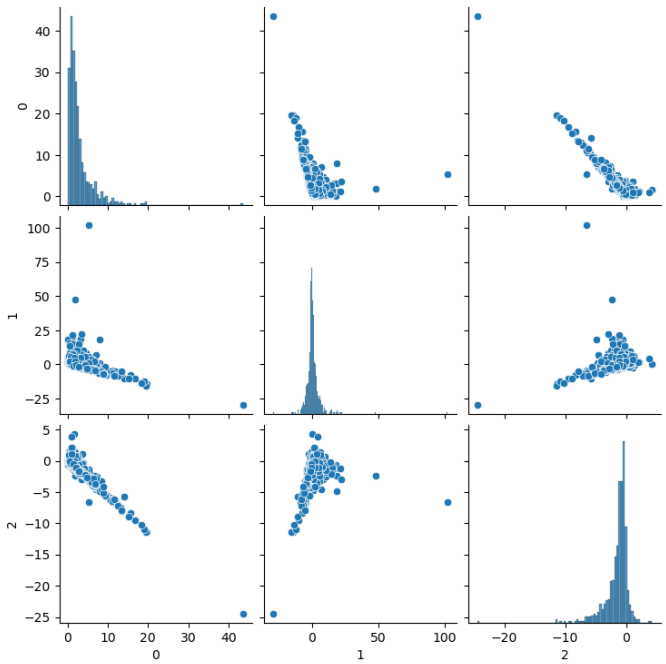
Q-statistics for calculating threshold after PCA



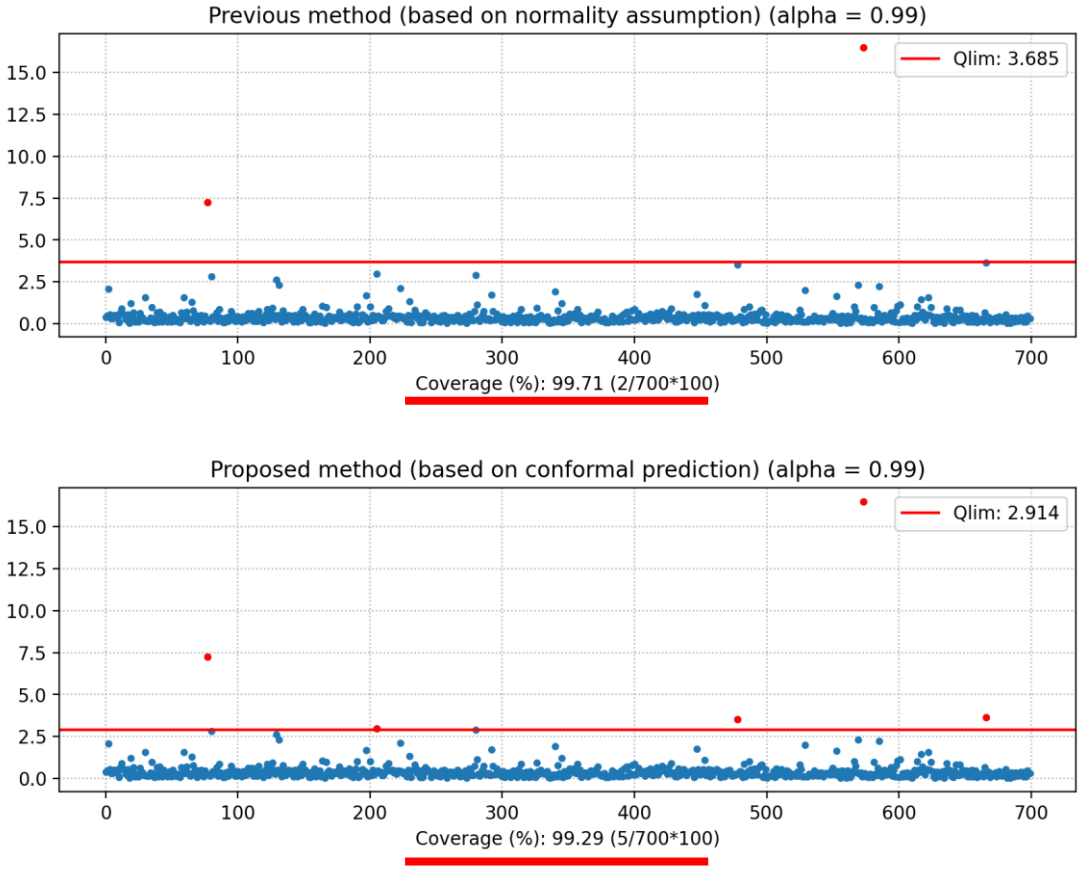
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #3 (1/3)

```
num_samples, residaul_type = 700, 'log_normal'
```

Alpha = 0.99



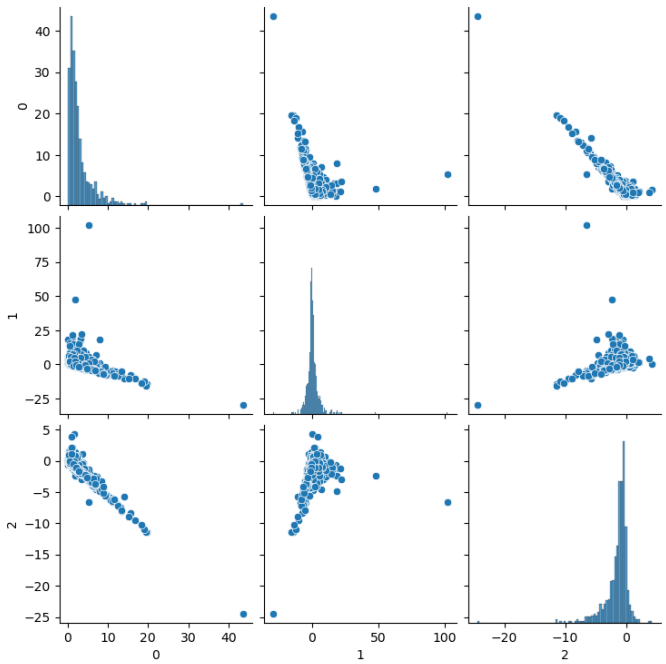
Q-statistics for calculating threshold after PCA



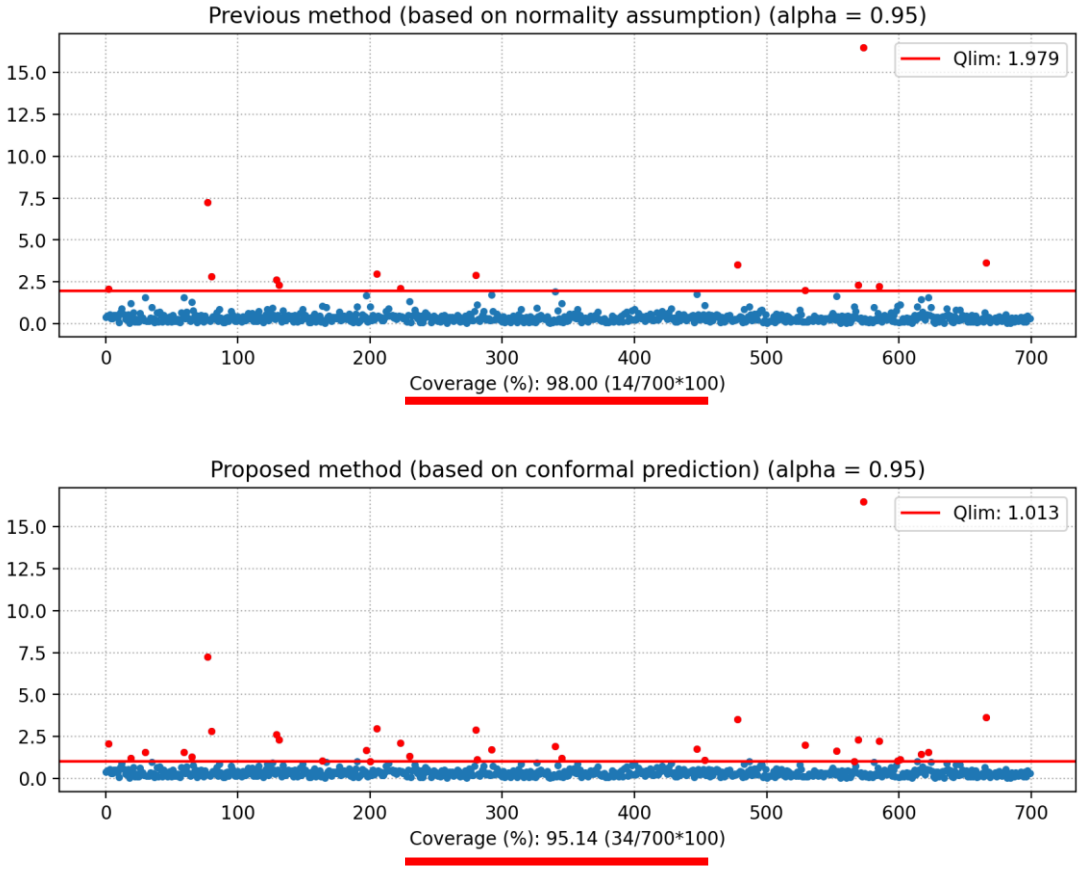
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #3 (2/3)

```
num_samples, residaul_type = 700, 'log_normal'
```

Alpha = 0.95



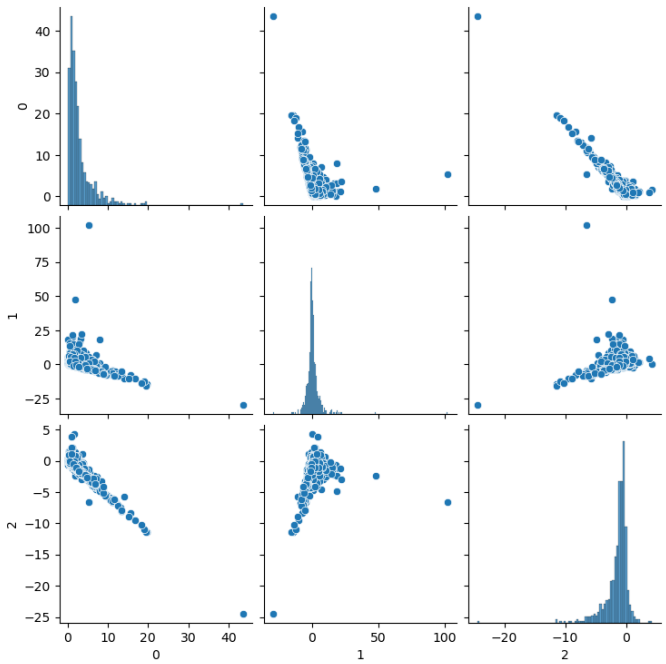
Q-statistics for calculating threshold after PCA



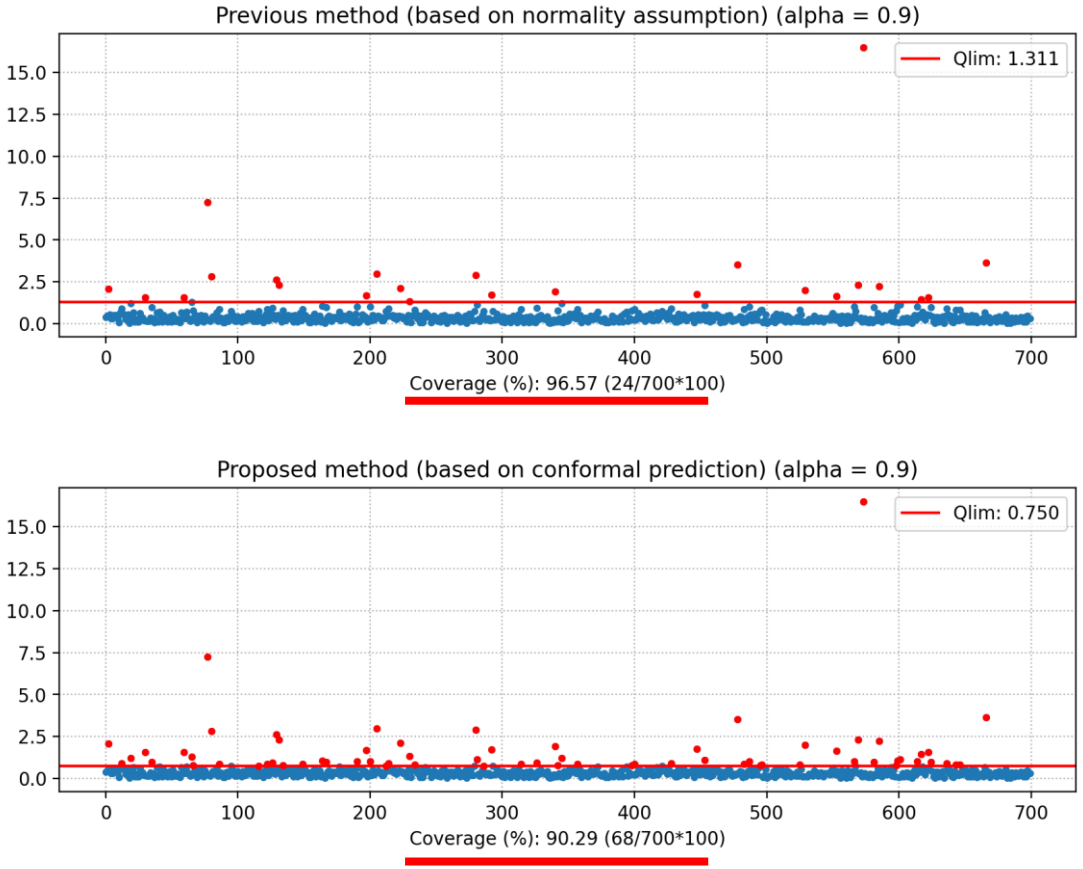
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #3 (3/3)

```
num_samples, residaul_type = 700, 'log_normal'
```

Alpha = 0.90



Q-statistics for calculating threshold after PCA



데이터 중심학습 기반 임계치 자동산정기법 검증결과 #4 (1/3)

```
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```
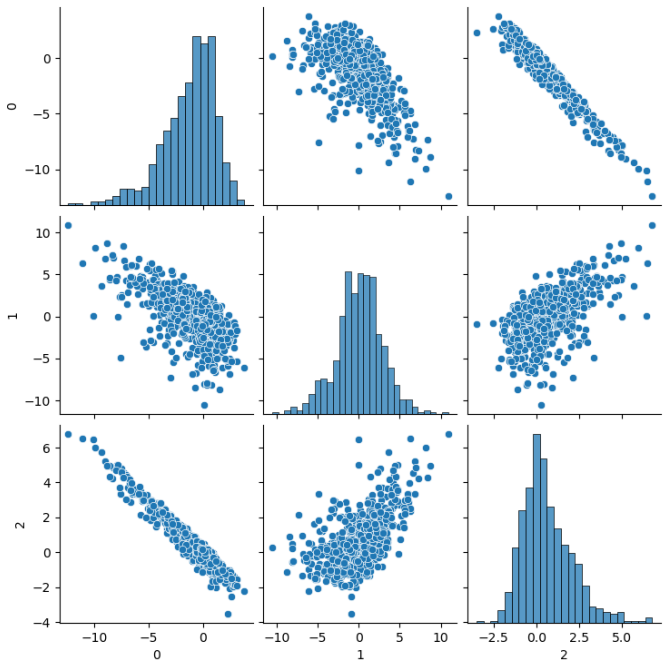
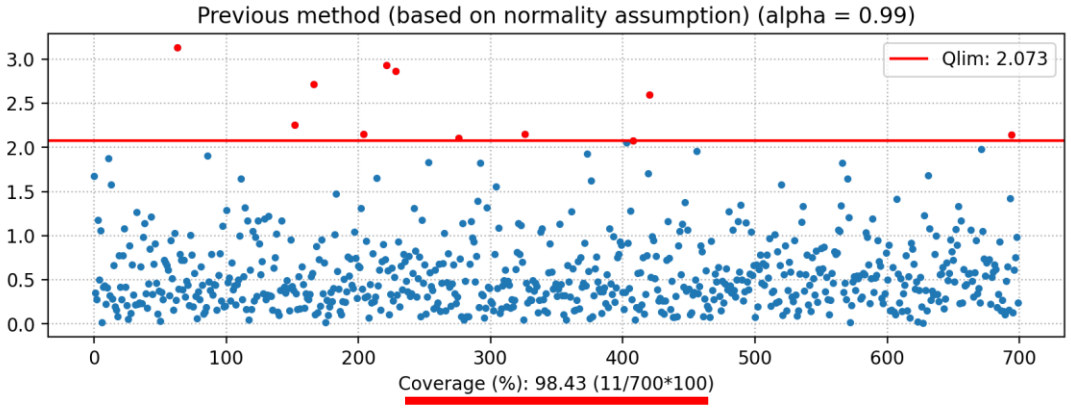
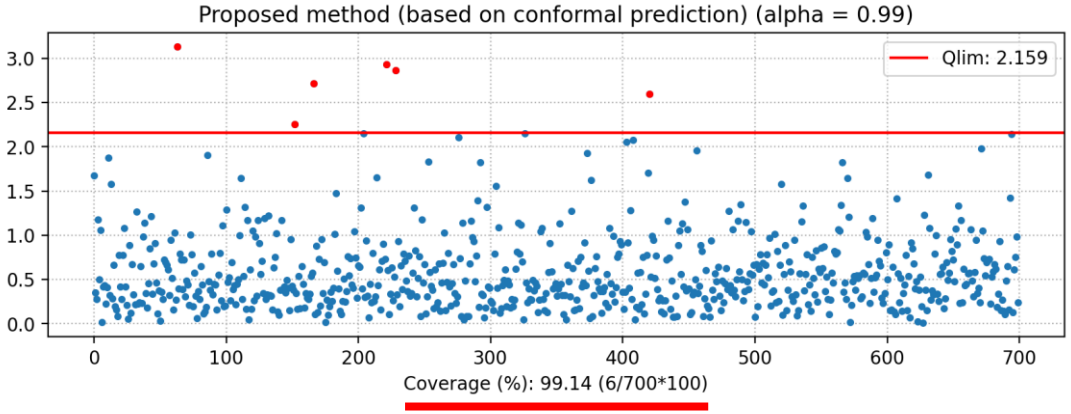

Alpha = 0.99



Q-statistics for calculating threshold after PCA

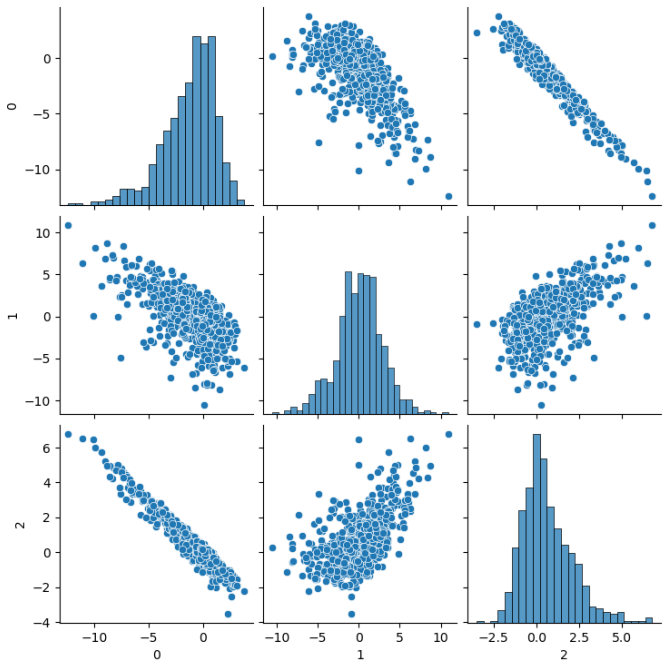




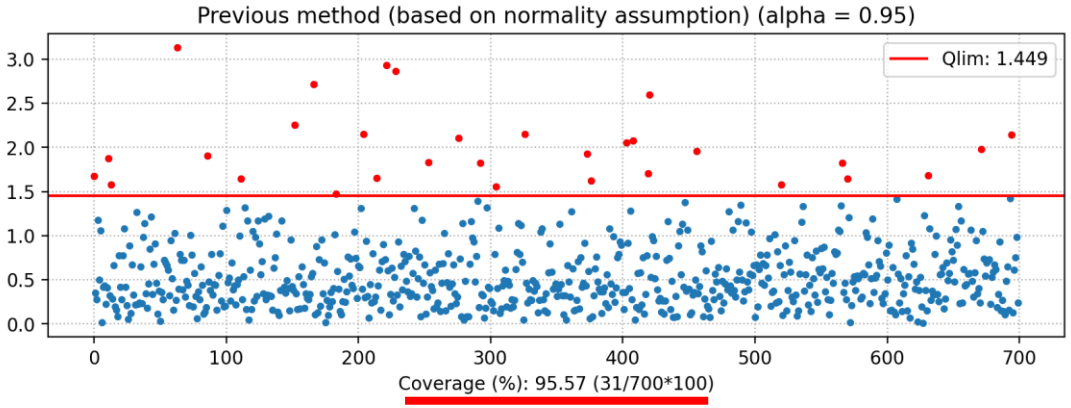
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #4 (2/3)

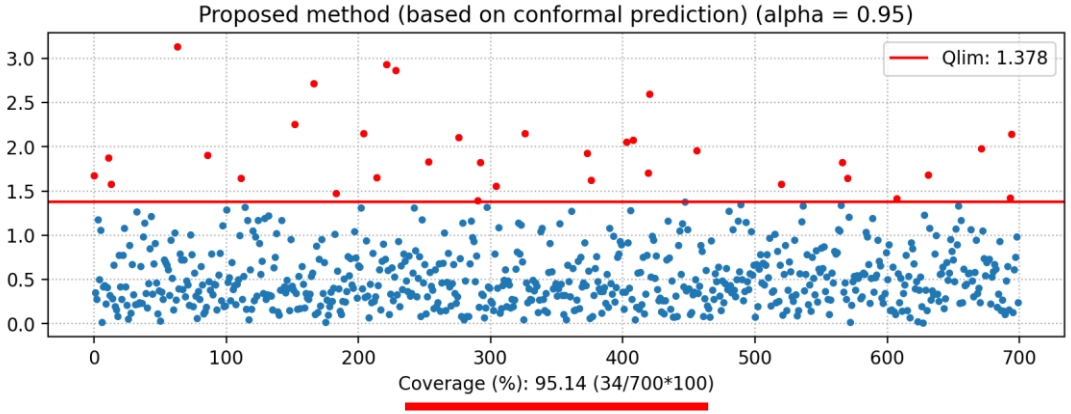
```
num_samples, residaul_type = 700, 'gumble_l'
```

Alpha = 0.95



Q-statistics for calculating threshold after PCA

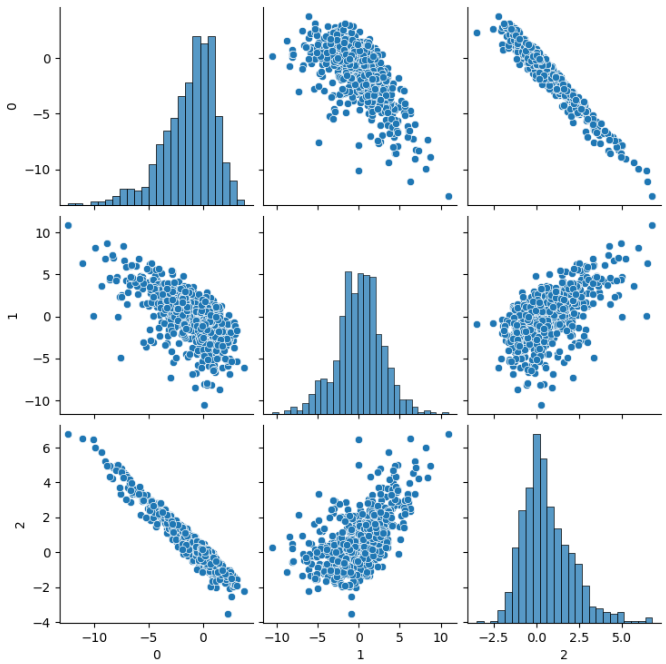




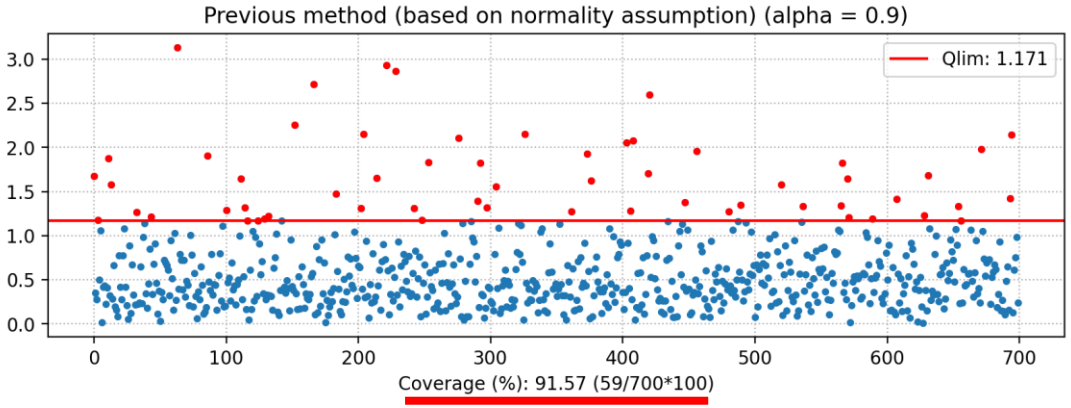
데이터 중심학습 기반 임계치 자동산정기법 검증결과 #4 (3/3)

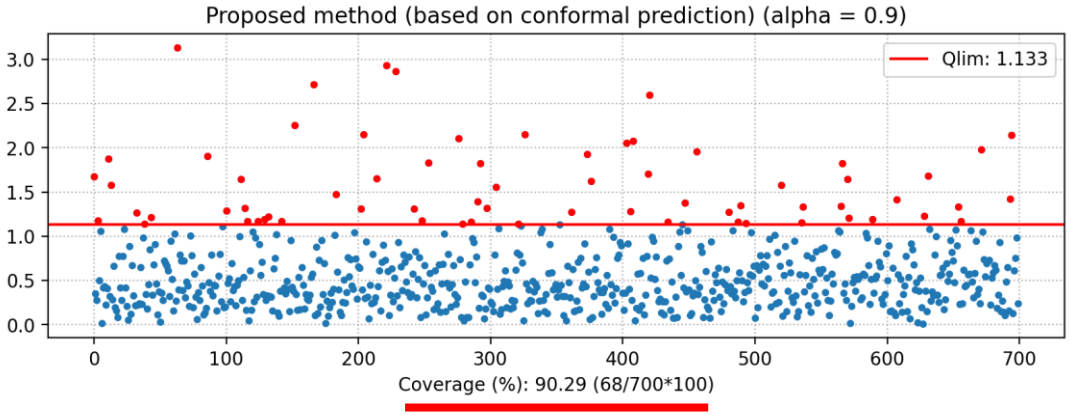
```
num_samples, residaul_type = 700, 'gumble_l'
```

Alpha = 0.90



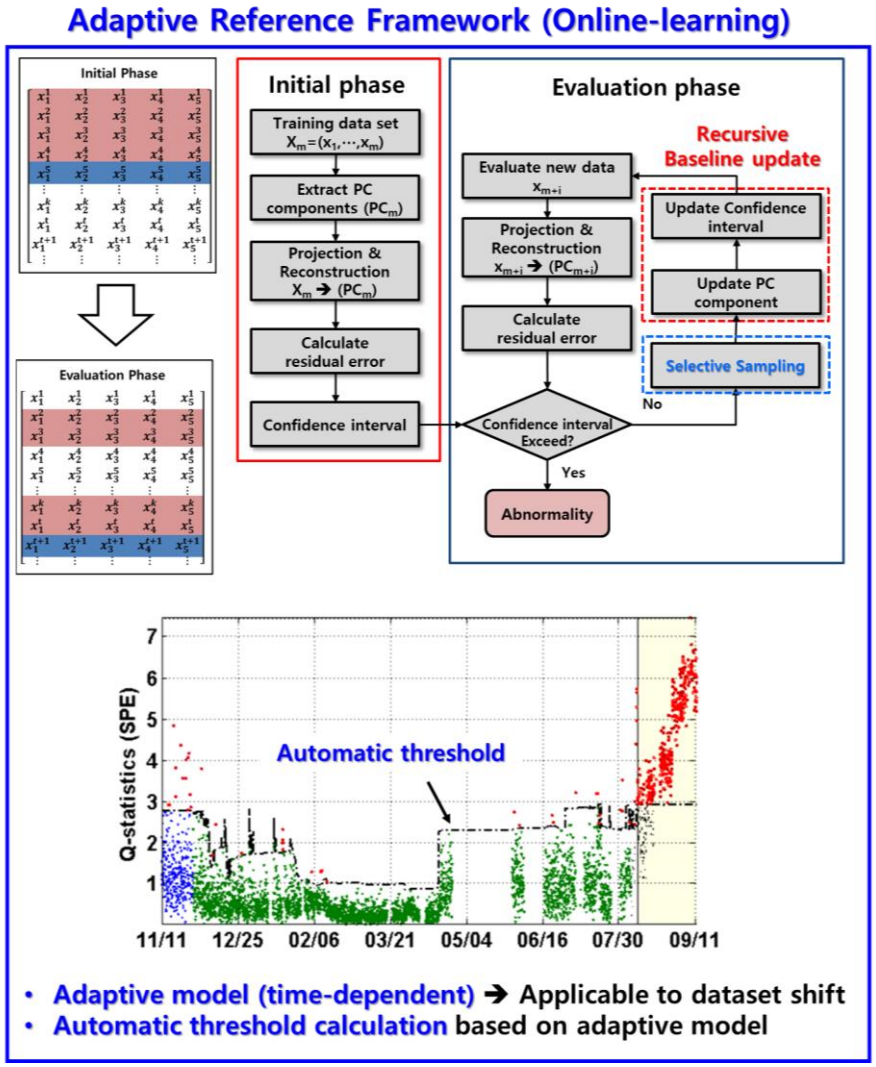
Q-statistics for calculating threshold after PCA





논의사항

↘ 외부환경 변화 적응형 이상상태 탐지 자동화 알고리즘 흐름도



개발방법 방향성 도출
(7월 말 완료)

실시간 이상탐지
소스코드 구축 완료-데이터 중심학습 제외
(8월 말 완료)

데이터 중심학습 기반
임계치 자동산출 기법 소스코드 개발 완료
(9월 말 완료)

데이터 중심학습 기반
임계치 자동산출 기법 검증 및
소스코드 통합
(10월 초 완료 예정)

세종대 자체 구축 데이터 기반
성능 평가 및 고도화
(10월 중순 완료 예정)

이노온-건설연 검증 시나리오 별
성능평가 및 고도화
(10월 말 예정)