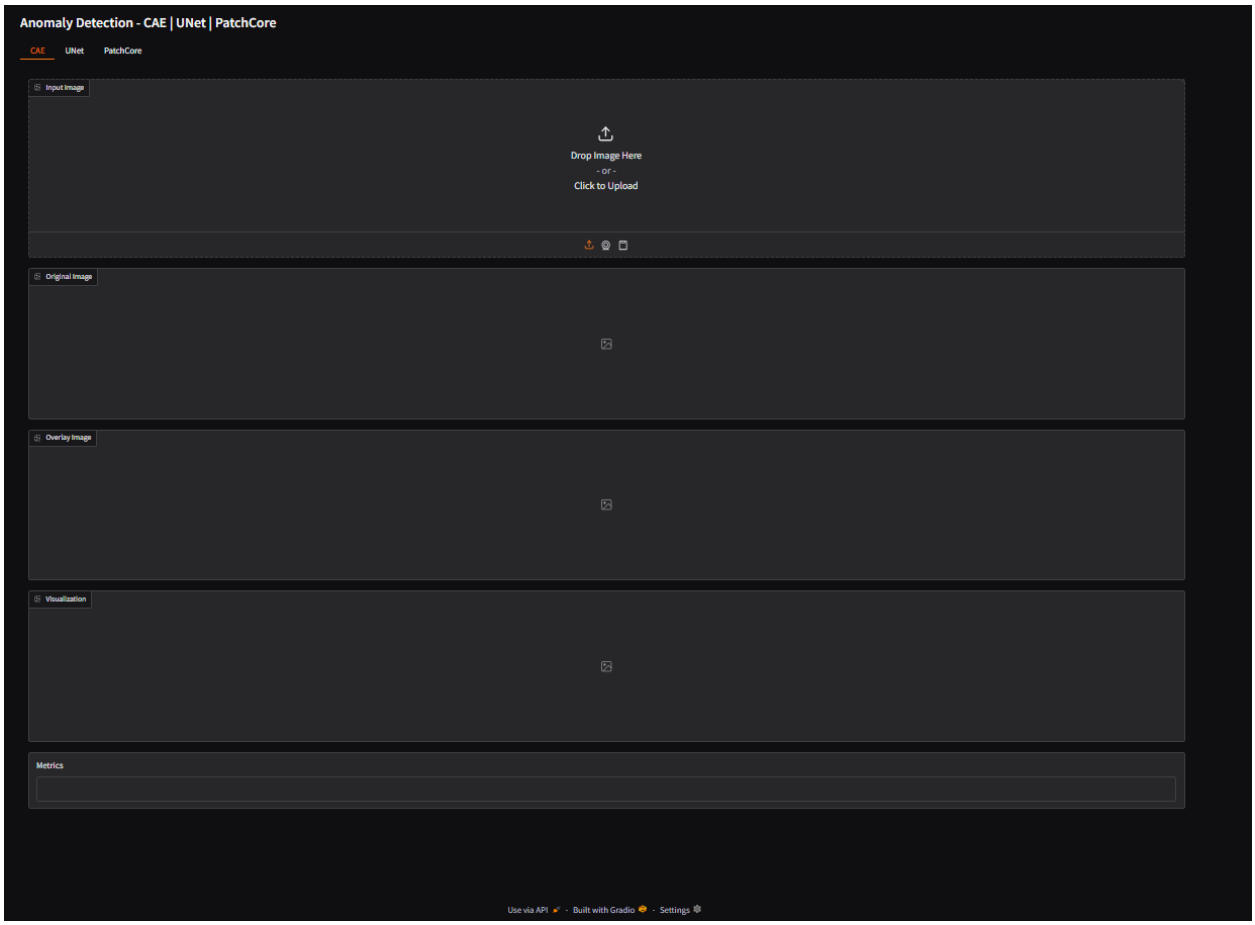
Output



Evaluation Metrics Used

Metric	Definition	Interpretation	Use Case
CAE MSE Score	Mean squared error between input and reconstructed image by CAE.	Low score = image close to normal; high score = possible anomalies causing reconstruction errors.	Detect global anomalies via reconstruction difference.
U-Net Mean Mask	Average pixel-wise predicted anomaly probability from U-Net segmentation output.	Higher value = larger or more extensive anomalous regions detected.	Localize and segment defect regions spatially.
PatchCore Sco	Distance in feature space between image patches and a memory bank of normal patch features.	Higher score = stronger deviation from normal patterns, indicating subtle or localized anomalies.	Detect subtle, feature-level deviations complementing

Metric	Definition	Interpretation	Use Case
re			other methods.

Image:1-CAE

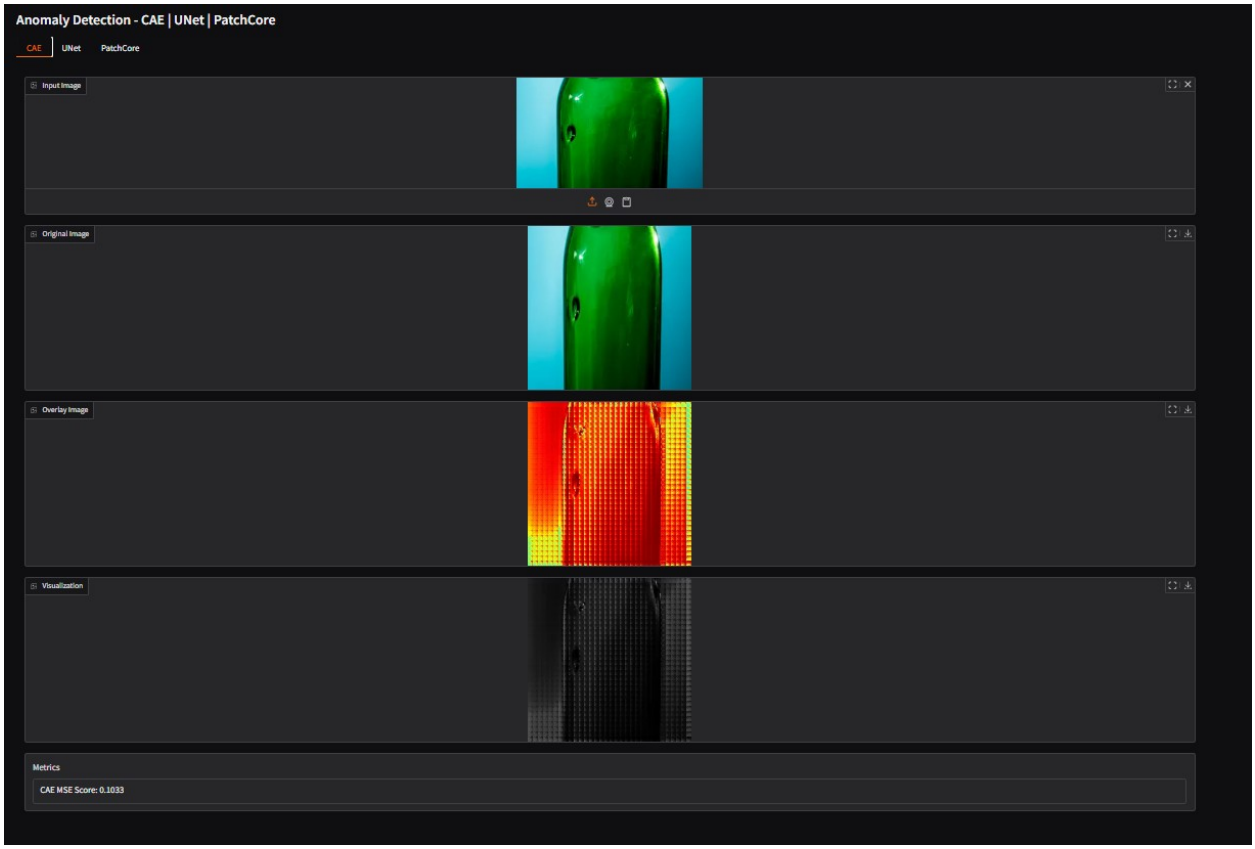


Image:1- U-Net

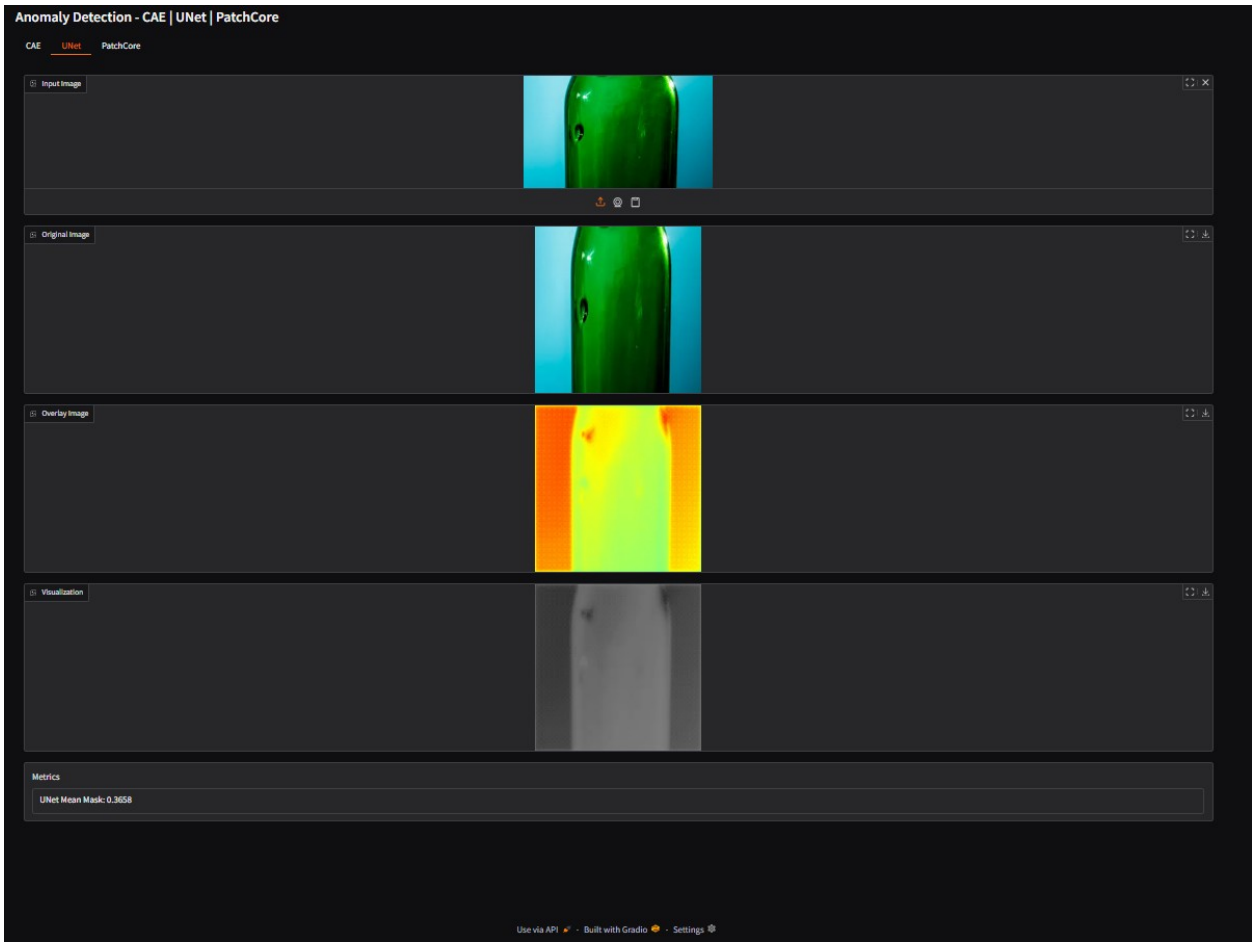

Anomaly Detection - CAE | UNet | PatchCore
CAE
UNet
PatchCore
Input Image
Original Image
Overlay Image
Visualization
Metrics
UNet Mean Mask: 0.3658
Use via API
Built with Gradio
Settings

Image:1-PatchCore

###Interpretations

- **CAE MSE Score: 0.1033** – The **mean squared error** between the input and CAE reconstruction is relatively low. Since CAE learns to reconstruct normal patterns, a small score suggests that the image is **closer to normal**, but not perfectly normal — there may be mild anomalies.
- **UNet Mean Mask: 0.3658** – This is the **average predicted anomaly probability** across all pixels. Around **36% anomaly confidence** means U-Net detects notable defect regions but not the entire image — likely **localized defects** rather than full-image damage.
- **PatchCore Score: 0.4312** – PatchCore measures **feature-space distance** from the normal memory bank. A score of ~0.43 is **moderate**, suggesting the image has feature-level deviations from normal data but not extreme outliers.

Model	Metric Value	Sensitivity in this case	Interpretation
CAE	0.1033 (MSE)	**Low–Moderate**	Reconstruction error is small, meaning most of the image matches learned normal patterns. Only slight deviations are detected.

Model	Metric Value	Sensitivity in this case	Interpretation
UNet	0.3658 (Mean Mask)	**Moderate**	Predicts ~36% of pixels as anomalous, likely marking localized defect regions rather than the full image.
PatchCore	0.4312 (Score)	**Moderate–High**	Feature-space distance is significant, showing that patch-level features differ notably from normal samples.

Summary:

- **Most sensitive here:** PatchCore (higher anomaly score relative to others)
- **Least sensitive here:** CAE (low reconstruction error)
- **Balanced detection:** UNet (clear localized anomalies without over-flagging the whole image)

This suggests the defect might be **feature-visible and spatially localized**, which PatchCore and UNet detect more strongly than CAE.

Image:2-CAE

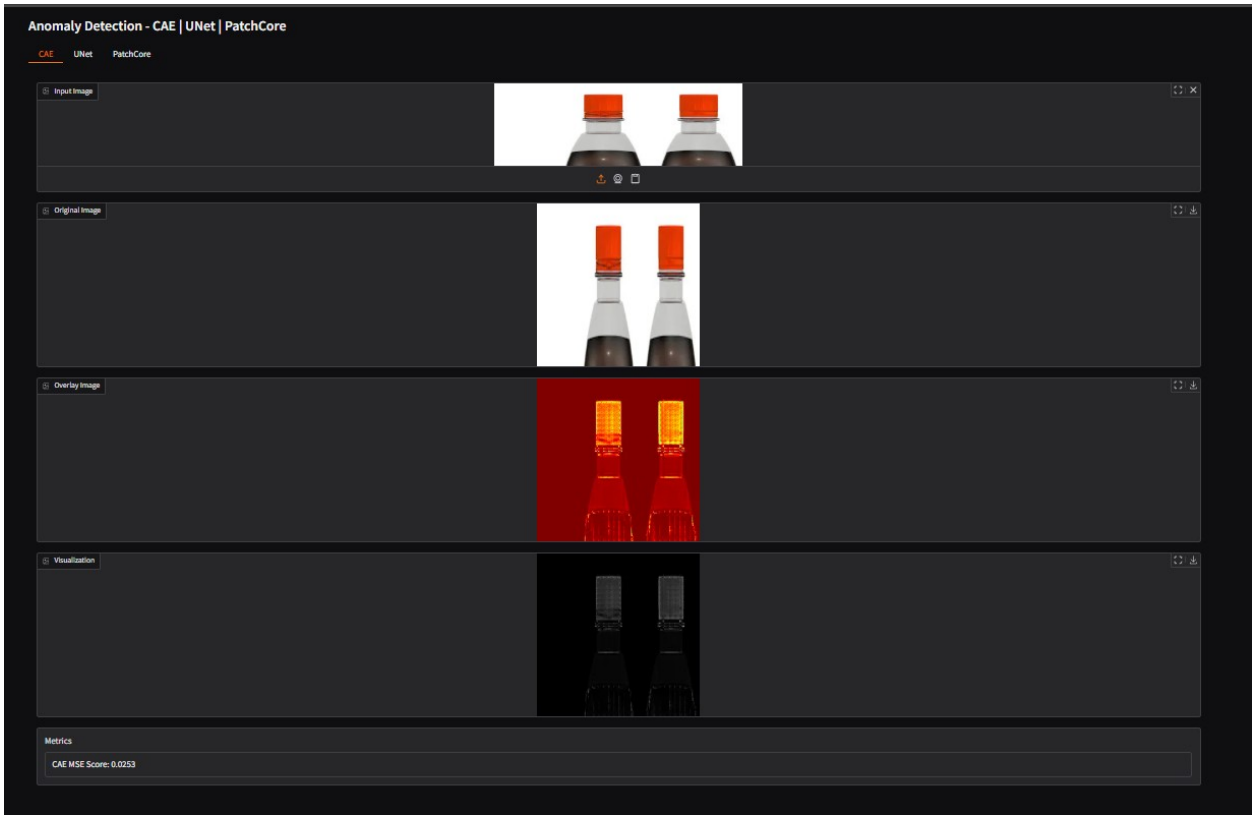


Image:2-UNet

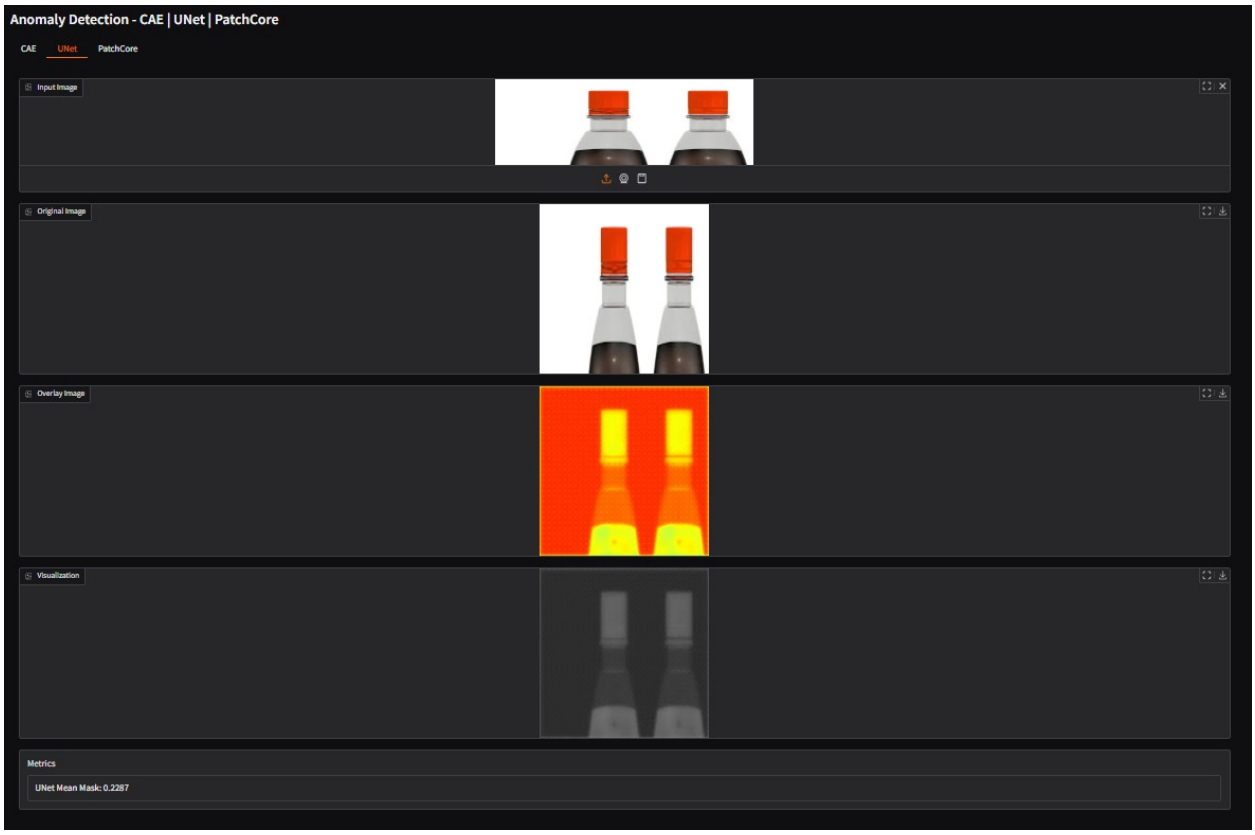
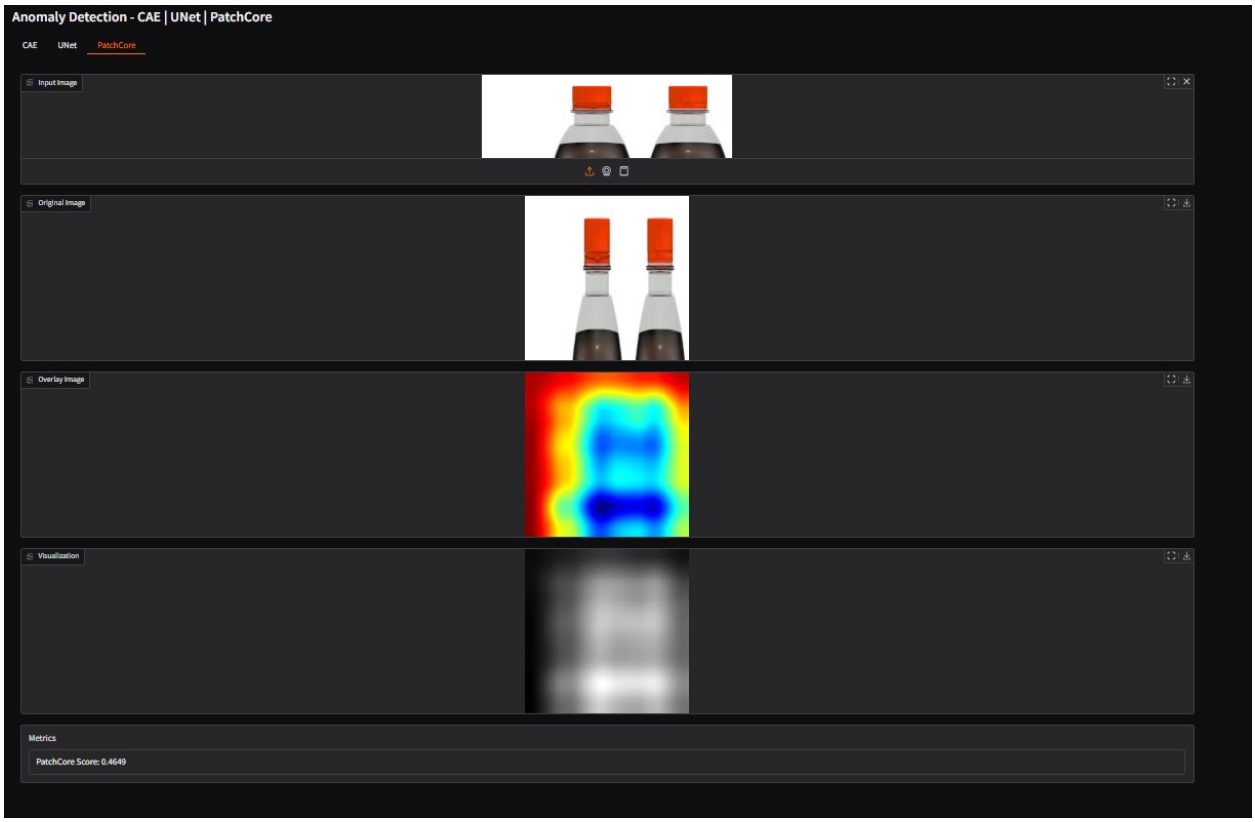

Anomaly Detection - CAE | UNet | PatchCore
CAE
UNet
PatchCore
Input Image
Original Image
Overlay Image
Visualization
Metrics
UNet Mean Mask: 0.2287

Image:2-PatchCore



Interpretations

- **CAE MSE Score: 0.0253** – The mean squared error between the input and the CAE's reconstructed image is quite low. This indicates the CAE model finds the image to be very close to normal patterns it has learned, with minimal anomalies detected.
- **UNet Mean Mask: 0.2287** – This value represents the average predicted anomaly probability over all pixels. About 23% anomaly confidence means the U-Net detects some defect areas, but these anomalies are likely small or localized rather than widespread.
- **PatchCore Score: 0.4649** – PatchCore's anomaly score measures how far the image's features deviate from the normal feature memory bank. A score near 0.46 is moderate, suggesting a noticeable but not extreme anomaly presence in feature space.

Model	Metric Value	Sensitivity Level	Interpretation
CAE	0.0253 (MSE)	**Low**	Reconstruction error is very small, indicating the image mostly matches normal patterns with almost no anomalies detected.
UNet	0.2287 (Mean	**Low–Mode**	Predicts ~23% of pixels as anomalous, indicating some localized

Model	Metric Value	Sensitivity Level	Interpretation
	Mask)	**rate**	defect regions but mostly normal areas.
PatchCore	0.4649 (Score)	**Moderate**	The feature space distance shows moderate deviation from normal samples, implying the presence of noticeable but not severe anomalies.

Summary:

- **Most sensitive:** PatchCore (moderate anomaly score, best at detecting subtle feature deviations)
- **Least sensitive:** CAE (very low reconstruction error, so minimal anomaly detected)
- **Balanced detection:** U-Net (detects localized anomaly regions with moderate confidence)

This pattern suggests the anomaly in the image is subtle and spatially limited — PatchCore captures feature-level deviations, U-Net highlights specific regions, while CAE finds the image mostly normal.

Image:3-CAE

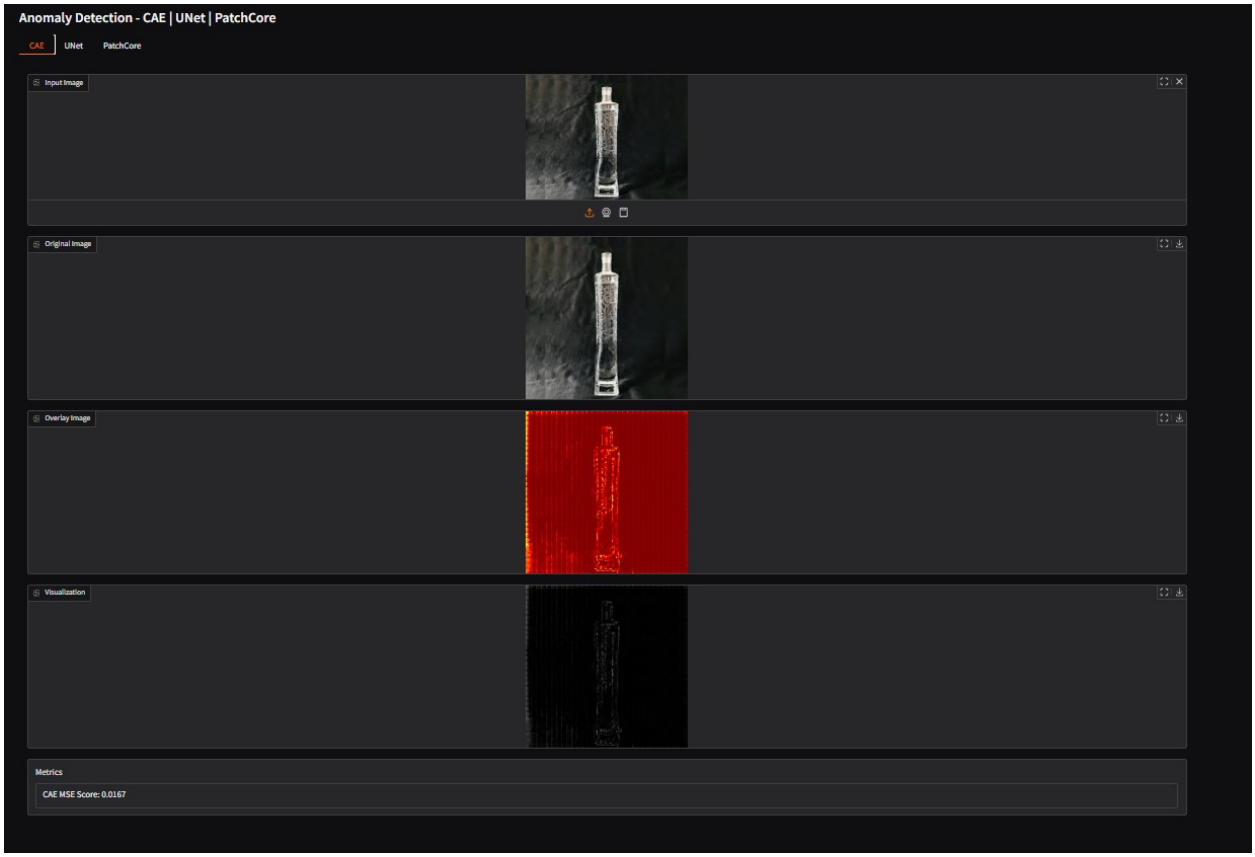
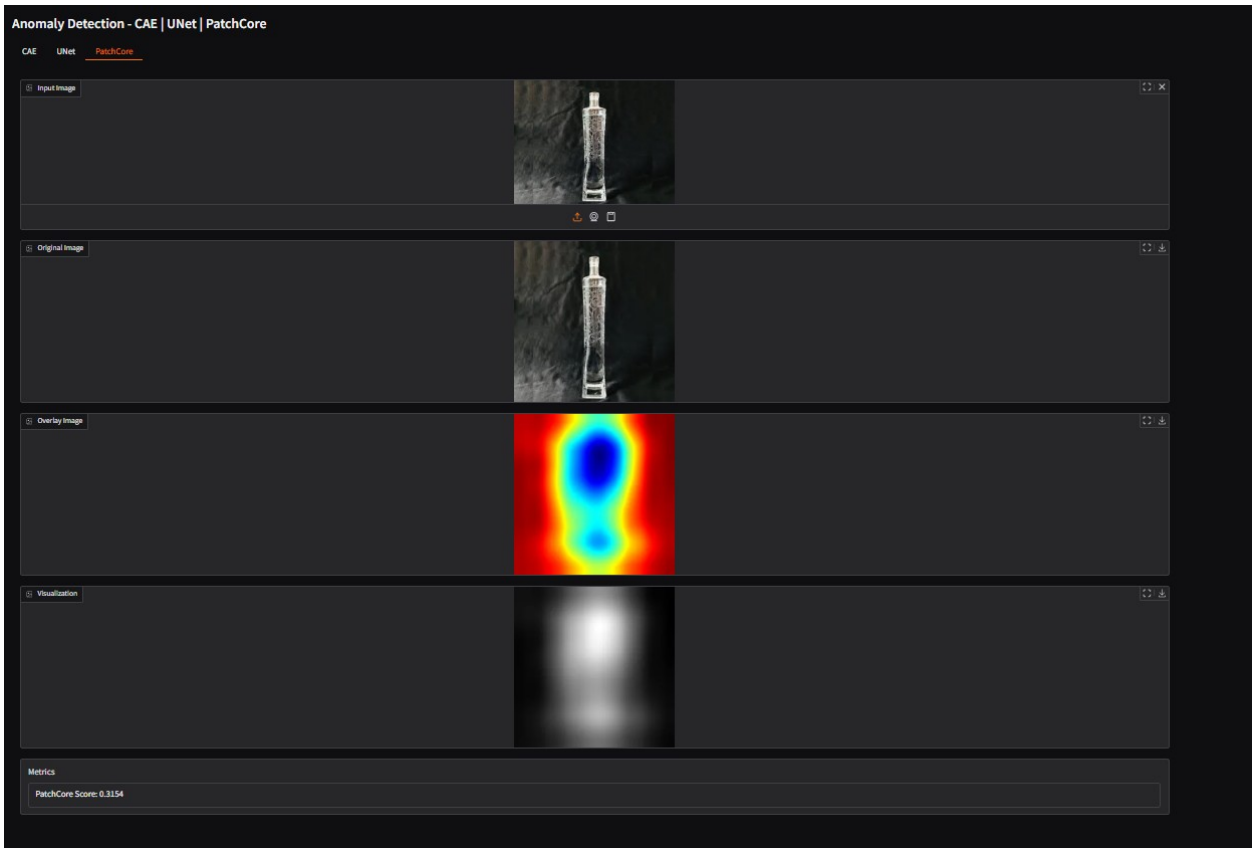


Image:03-UNet

Image:03-PatchCore



Interpretations

- **CAE MSE Score: 0.0167** – The mean squared error is very low, indicating that the CAE reconstructs the image almost perfectly. This suggests the image largely resembles normal patterns with minimal anomalies.
- **UNet Mean Mask: 0.4168** – The average predicted anomaly probability is about 42%, meaning the U-Net detects a substantial portion of the image as anomalous, likely indicating more pronounced or widespread defect regions.
- **PatchCore Score: 0.3154** – PatchCore's anomaly score is moderate but lower than U-Net's, indicating some deviation in feature space from normal samples but not highly extreme.

Model	Metric Value	Sensitivity Level	Interpretation
CAE	0.0167 (MSE)	**Low**	Reconstruction error is very small, suggesting the image mostly aligns with normal patterns and contains minimal anomalies.
UNet	0.4168 (Mean Mask)	**High**	Predicts ~42% of pixels as anomalous, indicating significant or widespread localized defects in the image.

Model	Metric Value	Sensitivity Level	Interpretation
PatchCore	0.3154 (Score)	**Moderate**	Feature space distance shows moderate anomaly presence, capturing some deviation from normal feature distributions.

Summary:

- **Most sensitive:** U-Net (high anomaly mask, detecting extensive defect areas)
- **Least sensitive:** CAE (very low reconstruction error, minimal anomaly detected)
- **Balanced detection:** PatchCore (moderate anomaly score, indicating some feature-level deviation)

This suggests the anomaly in this image is fairly pronounced and spatially extensive, which U-Net highlights strongly, while PatchCore captures moderate feature differences and CAE sees the image as mostly normal.

Overall Conclusion

This project successfully demonstrates the potential of deep learning models—Convolutional Autoencoder (CAE), U-Net, and PatchCore—in **automated visual defect detection and inspection** for manufacturing quality control using the MVTec Anomaly Detection dataset.

The **exploratory data analysis** revealed diverse defect types and varying anomaly distributions across categories, highlighting the dataset's richness and the challenges in detecting subtle or localized defects. This informed the choice of complementary models combining reconstruction-based, segmentation-based, and feature memory-based approaches.

The **quantitative results** showed:

- **CAE's MSE scores** were generally low for near-normal images, indicating effective reconstruction of normal patterns and the ability to flag deviations via reconstruction error.
- **U-Net's mean anomaly masks** highlighted spatially localized defects with varying sensitivity—higher mask values corresponded to more pronounced or extensive defect regions.
- **PatchCore's anomaly scores** captured feature-level deviations effectively, often providing the highest sensitivity to subtle, spatially limited anomalies that reconstruction methods might miss.

Together, these models provide a **balanced detection system**—CAE excels in identifying global deviations, U-Net localizes defects precisely, and PatchCore detects nuanced feature anomalies. This multi-model approach enhances reliability and robustness in real-time automated inspection scenarios.

By integrating these insights, the project paves the way for deploying scalable, accurate visual defect detection systems that can reduce manual inspection errors, optimize production workflows, and improve product quality—especially benefiting SMEs with limited access to advanced automation.