Automated Quality Control of Facade Elements

Tim - Fasada na Oko

1 Intro

KFK (Krov, Fasada, Konstrukcija) is a European leader in aluminum and glass facade systems. Each facade element must pass a quality control (QC) step before installation. Today, this process is manual: a worker visually inspects each element and compares it against specifications. This approach is slow, error-prone, and expensive—missed defects are often discovered only on-site, where repair or replacement costs are extremely high.

This project was developed during **NeoData Hackathon 2025**, organized by **Comminus**, with the goal of exploring an automated, scalable computer vision solution for defect detection on facade elements.

2 Approach / Solution

2.1 Dataset Exploration

We started by thoroughly exploring the provided dataset and available 3D models of facade elements. The first step was manual inspection of images to understand:

- Typical appearance of correct (positive) elements
- Common defect patterns in defective (negative) elements
- Variability in lighting, viewpoints, and background clutter

This step was crucial since the dataset contained **no predefined defect annotations**.

2.2 Early Experiments and Key Insight

We initially explored **SAM3** (Segment Anything Model v3) to directly localize defects. While SAM3 showed promising qualitative results, its performance was inconsistent without additional structural context.

> **Defect detection is significantly easier if the facade element type is known first.**

The dataset contains **three distinct facade element types**, each with different geometry and defect characteristics.

2.3 Macro Idea (Final System Design)

We defined the following high-level pipeline:

1. **Detect and classify the facade element** in the image
2. **Apply a specialized defect-detection strategy** tailored to that specific facade element type

This allowed us to trade a single, generic defect detector for **multiple precise, domain-specific methods**.

2.4 Dataset Limitations and Synthetic Data Exploration

The main challenge was the **small size of the real dataset**. We explored generating a synthetic dataset using the provided **3D models** by rendering realistic images with controlled defects. Although conceptually strong, this approach proved too time-consuming to implement robustly within the 24-hour hackathon.

As a practical compromise, we:

- Applied image rotations and simple augmentations
- Balanced classes to stabilize training

2.5 Facade Element Detection (YOLO)

We trained a **YOLO-based object detection model** to classify the facade element type.

- Primary metric: **accuracy**
- Rationale: downstream defect detection depends entirely on correct element classification

This model acts as the entry point to the pipeline.

2.6 Defect Detection (SAM3 + Heuristics)

After classification, we applied **element-specific defect detection strategies**, combining:

- Carefully designed **SAM3 prompts**
- Geometry- and context-aware post-processing

Here, **precision** was the dominant metric: false positives are costly in QC and directly penalized in evaluation.

2.7 Explored but Dropped: 3D–2D Alignment

We also investigated aligning the ideal **3D model** with the **2D image** to detect deviations as defects. While promising for long-term industrial deployment, accurate 3D–2D alignment exceeded the scope of a 24-hour hackathon and was therefore dropped.

2.8 Productization

To make the solution usable, we implemented a **simple Streamlit UI** that:

- Accepts a single image or a batch of images
- Runs the full pipeline
- Generates a clear QC report per image

2.9 Why Now?

KFK is actively expanding its **Data Science and automation efforts**. This solution demonstrates a scalable path toward:

- Reducing manual QC costs
- Improving consistency and reliability
- Laying foundations for future data-driven quality assurance systems

The approach is modular and can evolve with more data and tighter integration of 3D models.

2.10 Product Demo

The final solution is wrapped in a lightweight **Streamlit application** designed for fast and intuitive QC inspection.

The app supports:

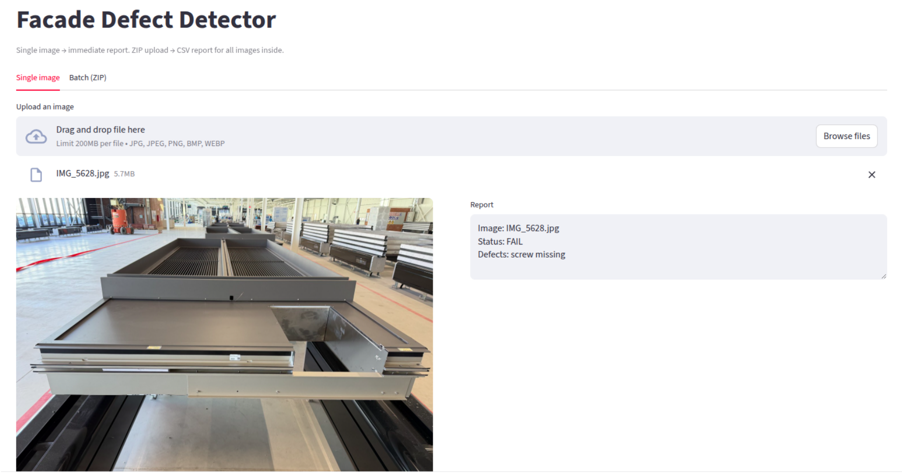
- **Single-image analysis** — upload one image and receive an immediate QC decision and defect report
- **Batch analysis** — upload a `.zip` archive of images and automatically generate a consolidated report for all elements

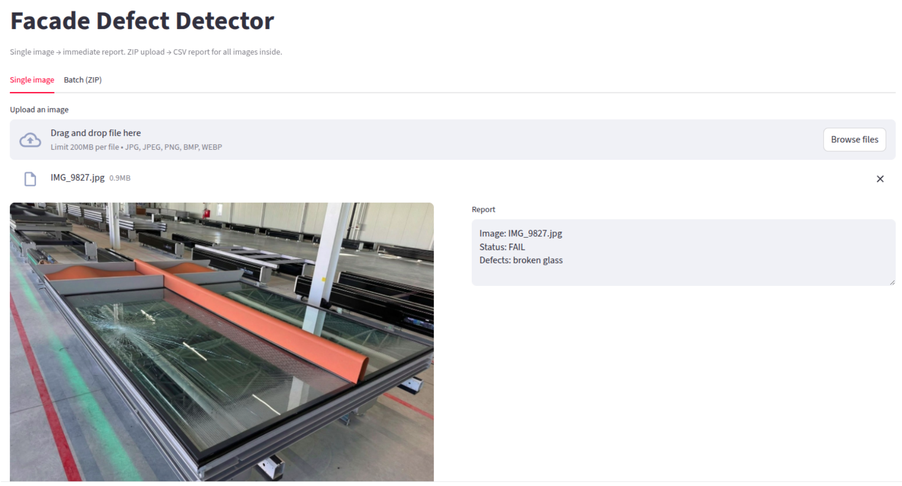
For each image, the application:

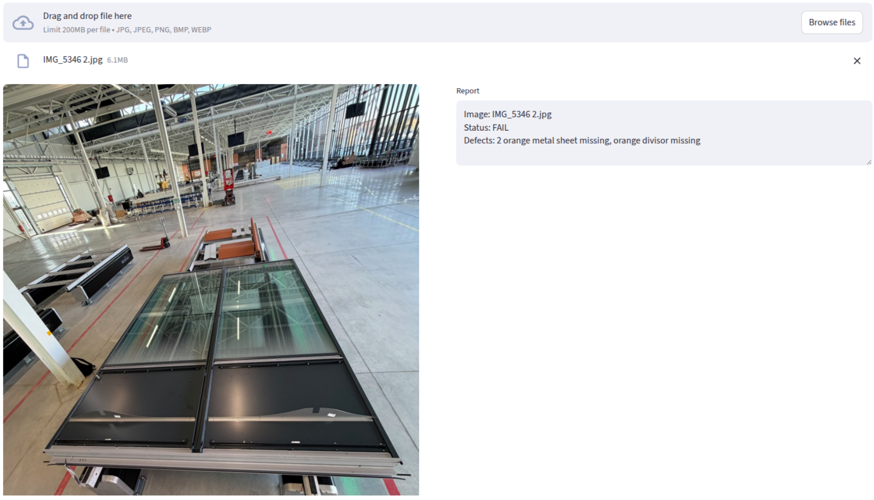
- Predicts the facade element type
- Runs the corresponding defect-detection pipeline
- Generates a structured QC report (PASS / FAIL with detected defects)
- **Visually highlights selected defects** directly on the image for easier interpretation

The demo includes screenshots of example usage for both single-image and batch workflows.

2.11 Demo Screenshots







2.12 Long-Term Vision

Although not fully implemented during the hackathon, **3D-model-based synthetic data generation** remains a highly promising direction. With sufficient time, this approach could enable:

- Large, realistic training datasets
- Controlled simulation of rare defects
- Strong generalization across projects and configurations

2.13 Team

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