AI-based cost estimation from HVAC symbols

Overview:

Architectural plans for large-scale construction projects often include intricate HVAC (Heating, Ventilation, and Air Conditioning) layouts. These plans contain numerous symbols representing different HVAC components, and manually analyzing them to estimate material costs is a time-consuming and error-prone process. Traditionally, a team of professionals would manually review these plans, identify the symbols, and calculate the total cost of components, making the process inefficient and prone to oversight.

To address these challenges, we developed an AI-driven solution that automates the detection of HVAC symbols in architectural plans. By leveraging deep learning models trained specifically for architectural schematics, our system identifies different classes of symbols and provides an accurate cost estimate based on predefined pricing. This significantly reduces the time required for cost estimation and minimizes human errors, leading to greater efficiency and accuracy in project planning.

Client details:

Name: Confidential **|** **Industry:** Construction, Software **|** **Location**: US

Technologies:

YOLOv8, SAHI, Python, FastAPI, AWS S3, AWS EC2

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Project Description:

The project was structured into two primary phases:

1. Model Training and Symbol Detection

The AI model was trained to recognize and classify HVAC symbols using a dataset of annotated architectural plans. The training phase included:

- Data Collection & Annotation: Architectural plans were collected and annotated to create a comprehensive dataset.
- Model Selection & Training: YOLOv8, along with SAHI was used to detect small and overlapping symbols with high accuracy.
- Preprocessing Techniques: Image augmentation and normalization were applied to improve detection performance.
- Testing & Optimization: The model was fine-tuned to minimize false positives and maximize recall.

2. Automated Cost Estimation

Once the model detects symbols, the system calculates the total estimated cost based on:

- Component Classification: Each detected symbol is mapped to a corresponding HVAC component.
- Predefined Pricing Database: The cost of each component is retrieved from an internal database.
- Summation & Reporting: The system generates a detailed cost estimate and report for project managers.

3. FastAPI Server for Model Hosting

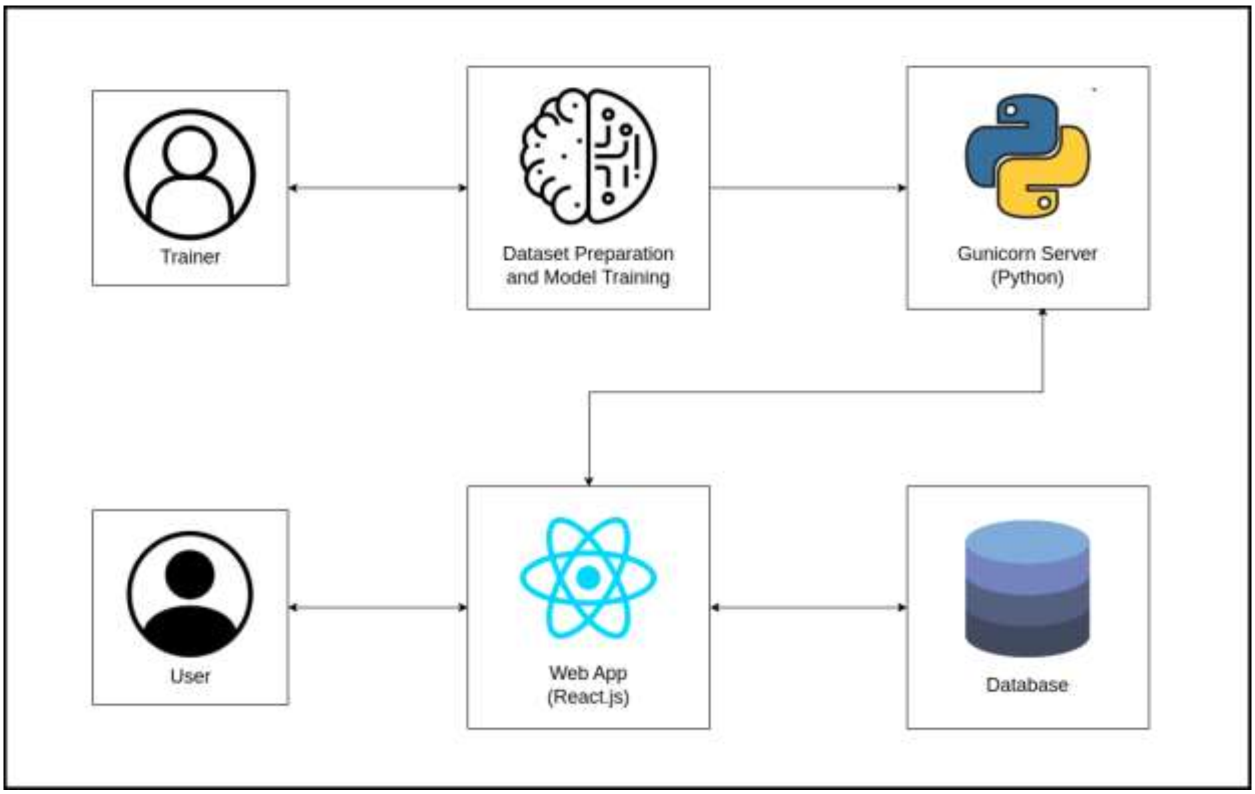
To provide real-time inference and cost estimation via APIs, a FastAPI server was developed. The server:

- Hosts the trained AI model, allowing clients to send HVAC plans as images and receive symbol detection results.

AI-based cost estimation from HVAC symbols

- Provides RESTful APIs for easy integration with frontend applications and other construction software.
- Handles asynchronous requests efficiently, ensuring scalability for processing multiple large architectural plans concurrently.
- Returns structured JSON responses, including detected symbols and cost estimations, which can be further used for reporting and analysis.

Application Architecture:



Description:

The system is designed for high-performance processing of large architectural plans while ensuring scalability. The architecture includes:

- Frontend: Built with React.js, allowing users to upload architectural plans, view detected symbols, and download cost reports.

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- Backend: Developed using FastAPI, handling image processing, model inference, and database interactions.
- Storage & Retrieval: AWS S3 is used for storing newly uploaded and annotated plans that can be later used for training the existing model for better inference.
- Processing Pipeline: The AI model runs on an AWS EC2 instance with GPU acceleration to handle large-scale image processing efficiently.

Variables impacting performance of the application:

- Image Resolution and File Size: Large and high-resolution architectural plans require extensive processing power and memory, impacting model inference speed.
- Server Load and Concurrency: High concurrent API requests may slow down processing if the server does not have sufficient resources or load balancing mechanisms.
- Model Complexity and Optimization: The choice of AI model, hyperparameter tuning, and optimization techniques directly impact detection accuracy and processing efficiency.

Key Challenges & Solutions

Processing Large-Scale Plans

Challenge: Architectural plans are extremely large, making direct processing difficult.

Solution: Implemented image tiling and slicing techniques to break large images into smaller sections for model inference.

Detecting Small & Overlapping Symbols

Challenge: Many HVAC symbols are small and overlap with other annotations in the plans.

Solution: Used YOLOv8 with higher resolution inputs to improve small object detection accuracy.

Concurrent Handling of Multiple Jobs

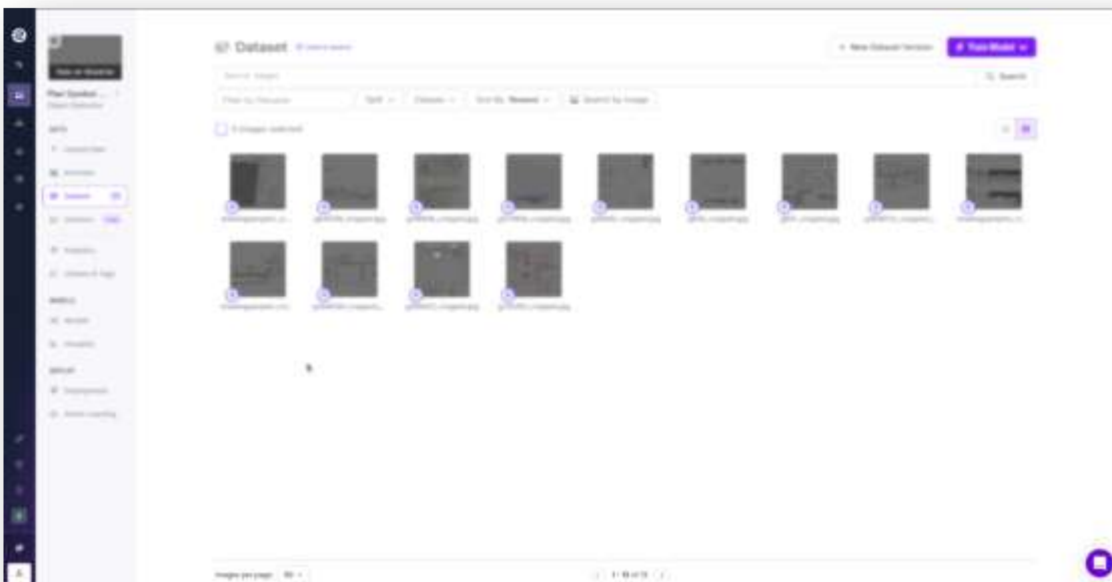
AI-based cost estimation from HVAC symbols

Challenge: Having the server available for receiving multiple jobs containing multiple images while other images are being processed.

Solution: Employed FastAPI's background processing threads with unique IDs for each job that run independently.

Screenshots:

Annotation and Training:



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Inference results from server:

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        521.9125518798828,
        892.9154052734375,
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        25.848859786987305
    ],
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    "category_id": 3,
    "category_name": "Return Diffuser",
    "segmentation": [],
    "iscrowd": 0,
    "area": 665
},
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    "image_id": null,
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        1034.0142211914062,
        26.07220458984375,
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    "segmentation": [],
    "iscrowd": 0,
    "area": 711
},
{
    "image_id": null,
    "bbox": [
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        25.076358032226562,
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    "category_name": "Return Diffuser",
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