AI-based colony tracking for early microbial growth detection in environmental monitoring

C. Giardini[1], F. Frangiamore[2], G. Mazza[1], G. Uberti[1], V. Brembati[1]

[1] Copan NewLab – Brescia (Italy)
[2] Imago – Brescia (Italy)

Background

Integrating automation into Microbiological Environmental Monitoring is essential to sustain increasing laboratory workloads. Automated incubators combined with digital imaging and artificial intelligence are now available and provide clear advantages in streamlining microbiological workflows, improving standardization and reducing manual intervention.

Materials and Methods

Materials for this study included both **TSA and SDA agar plates** (55mm and 90mm) from multiple manufacturers. Real environmental monitoring (EM) samples were collected using active and passive **air sampling**, **contact sampling**, swab sampling with **Copan SRK®** followed by filtration, and negative controls (Figure 1).

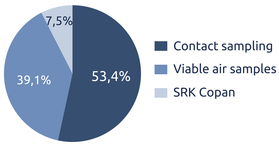

Figure 1. Distribution of Environmental Samples

Analyses were performed using the **Copan PharmaLab™ System**, which acquires images throughout the entire incubation period using multiple cameras and lighting conditions to maximize information extraction. **Object detection models** identify colonies across all views, followed by a cross-view matching process, to filter out false positives by ensuring detections are consistent across different acquisitions. This process is extended temporally through periodic scans during incubation, where a tracking algorithm maintains a **persistent history for each colony** (Figure 2).
This approach preserves information from early or later-obscured colonies, enabling accurate final counts beyond single end-point imaging.

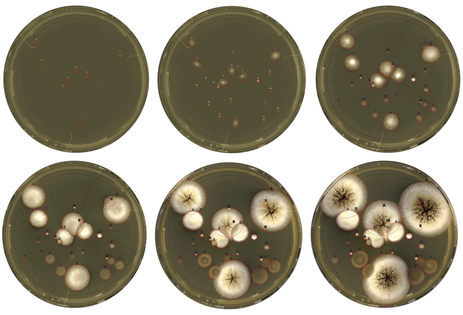

Figure 2. Example of AI colony growth tracking software integrated into PharmaLab™

Results

The AI-integrated software was benchmarked against **two expert microbiologists**. System performance in distinguishing plates with and without microbial growth was evaluated using a confusion matrix, showing perfect agreement between AI and operator classification, with 151 true positives and 115 true negatives, and no false positives or false negatives. These results demonstrate a **100% sensitivity and specificity** in distinguishing plates with and without microbial growth.

Quantitative analysis reveals a high degree of concordance and linearity, evidenced by a **Coefficient of Determination (R^2) of 0.9902**. The regression analysis shows data points tightly clustered along the identity line across the full dynamic range (0–250 CFU), confirming that the model effectively replicates human heuristic logic while successfully mitigating the variance inherent in inter-operator subjectivity (Figure 3).

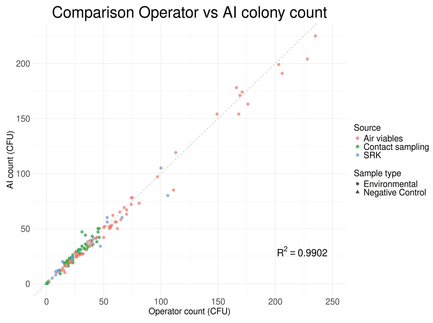

Figure 3. Linearity between operator and AI counts

Residual diagnostics further substantiate the system's precision and systematic accuracy. The **Mean Prediction Error (MPE) of -0.08%** and a **Median of 0.00%** indicate an absence of significant overestimation or underestimation bias, affirming optimal calibration. Analytical agreement is exceptionally high, with **84.6%** and **96.2%** of samples falling within **±10%** and **±20%** error margins, respectively. Furthermore, the residual distribution exhibits a notably leptokurtic profile (Excess Kurtosis: +8.06), signifying that prediction errors are heavily concentrated around the mean with a negligible frequency of outliers. These metrics demonstrate a level of **reproducibility and stability** that meets or exceeds traditional manual benchmark standards for environmental monitoring (Figure 4).

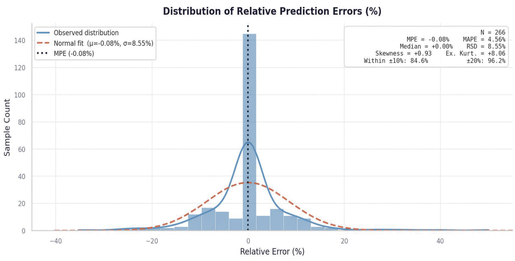

Figure 4. Distribution of Relative Prediction Errors (%)

Conclusions

Time-stamped imaging and AI-based analysis delivers highly **accurate** and **reproducible** microbial colony detection, achieving perfect agreement with expert evaluation. Early-stage **colony tracking** overcomes the limits of single end-point imaging and minimizes operator variability. These results confirm AI as a robust, validated enabler for standardized environmental monitoring.

Copan
innovating together

Copan
innovating together