Utilizing Machine Vision to Enhance Unattended Liquid Handling through Automatic Error Detection and Mitigation

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Current State of Lab Automation

While automated solid phase extraction (SPE) systems aim to free up personnel time, they are designed to perform a very specific and repeatable set of tasks. Nuances arising from challenging field samples, operator error and machine wear can lead to unexpected disruptions. **Without real-time equipment monitoring, labs may only detect issues after failed runs or sample loss, leading to costly rework.**

REACTIVE

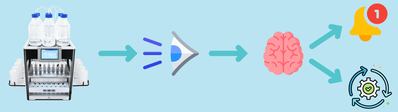
PROACTIVE

PREDICTIVE

LabSentry AI

This presentation explores how the LabSentry AI machine vision system can enhance the reliability of unattended liquid handling by enabling real-time error detection and mitigation. Using deep learning, the system is trained to monitor critical liquid handling components, recognize common operational patterns and identify anomalies similarly to the human eye. **LabSentry AI actively integrates with equipment software to apply corrective actions to maximize productivity.**

LabSentry AI



PromoChrom Pilot

To augment LabSentry AI, the PromoChrom Pilot webapp brings lab monitoring and control directly to the user's fingertips. Users can customize how they handle error detection — from alerts and pausing runs to automatic corrections. The main dashboard shows key metrics like uptime, extraction counts, and live system status. By analyzing fleet performance and trends over time, labs can plan ahead, predict maintenance needs, and prevent unplanned downtime — ensuring that equipment is always running at peak capacity.

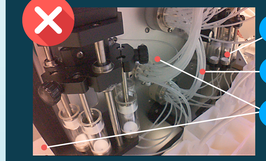
PromoChrom Pilot

Determining What to Monitor

Machine vision, like the human eye, can detect far more subtle cues than any single sensor or sensor array alone. Deciding where to implement machine vision — in other words, where to position the cameras — is critical. On PromoChrom's SPE-03 automated SPE system, the **syringe pumps are responsible for 95% of an extraction method** - accurately transferring liquids between solvents, samples, and cartridges. This makes the syringe pumps a powerful indicator for potential anomalies, such as clogging, solvent depletion, or insufficient sample loading. **By focusing machine vision on the syringe pumps, we achieve a straightforward yet highly effective way to detect most common errors in real-time.**

Camera Positioning

Determining optimal camera positioning is required prior to training the object detection model. The initial approach was to preserve the existing SPE-03 design while adding one camera on each side to view both syringe pumps. As shown in the left camera feed below, each camera would detect 3 syringes on the closer pump and 2 syringes on the further pump. Challenges with this approach are labeled as shown.



1. Limited focus on the far syringes
2. Risk of obstruction from valve tubing
3. Subjectivity to lighting conditions around system

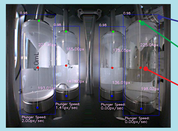
To address the above challenges, the cameras were integrated into the pumps to be looking directly at the pump syringes. This ensured a fixed view and consistent lighting. Lab surroundings are also obscured with this configuration, which prevents any privacy concerns.

Integrated Camera

Fixed Camera View

Object Detection

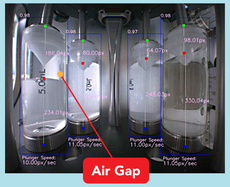
A computer vision model was then trained to detect the pump syringe, plunger, and liquid level. To improve its versatility, the training dataset was augmented with variations in lighting conditions and sample colors. The trained model achieved a mAP50 score of over 99%, indicating highly accurate object detection.



Detection: Unexpected Air Gap

Unexpected air gap during pumping can be due to sample line clogging, leakage or solvent depletion. While operator attentiveness and passive technologies such as PromoChrom's inline filters and anti-clogging tips help minimize this risk, actively monitoring the sample intake allows the system to detect and address rare edge cases that might otherwise go unnoticed.

Symptom: Low liquid level in syringe pump(s) during liquid handling



User Options

1. De-clog sample line and try again
2. Decrease draw speed and try again
3. Automatically run one of the above
4. Pause or abort run

Detection: Early Completion of Sample Loading

To accommodate sample variations, SPE-03 users typically program the loading volume based on the maximum capacity of the sample bottles. As a result, the system may continue loading even after all eight samples are fully processed. By detecting when sample loading is complete, the system can automatically advance to the next step, saving valuable time.

Symptom: Syringe pumps are empty near the end of sample loading

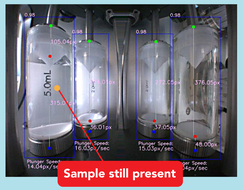
User Options

1. Skip to the next step
2. Pause or abort run

Detection: Incomplete Sample Loading

When client samples vary in volume or if excessive clogging happens, samples may not be fully loaded by the set loading volume in the method. This can be reliably addressed by ensuring the pump strokes are empty towards the end of the sample loading step and appending extra strokes in real time if needed.

Symptom: Liquid level present in syringe pump(s) during final sample loading stroke



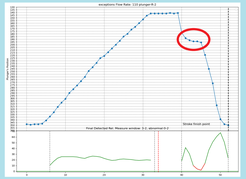
User Options

1. Append extra pump strokes until empty. Can pause and notify after set number of tries.
2. Pause or abort run

Detection: Pump Stalling

Severe cartridge/line clogging or gradual wear and tear can cause syringe pumps to stall during operation. Detecting this in real time enables recovery during extractions and supports proactive maintenance rather than reactive fixes.

Symptom: Pump plunger not pushing at programmed speed



User Options

1. Disable stuck pump and continue
2. Decrease push flow rate and retry
3. Automatically run one of the above
4. Pause or abort run

Conclusion

By progressing from basic automation to intelligent machine vision monitoring and fleet-wide oversight, laboratories can transform how they handle complex extractions. With LabSentry AI, **the AI ("eye") that never blinks** continuously detects run anomalies and takes corrective actions to keep workflows on track. Combined with PromoChrom Pilot's centralized monitoring and data-driven fleet management, labs gain the vision, control, and foresight to operate more smoothly today and plan more effectively for tomorrow.