Advancements in Automated Plastic Classification

This presentation details the journey of developing a sophisticated software solution for real-time detection and classification of plastics on a conveyor belt. We will explore the iterative process, addressing challenges and evolving methodologies to achieve precise and reliable object identification based on size and color, paving the way for enhanced recycling and material sorting capabilities.

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Initial Approach: Brightness Thresholding

Methodology

Our initial concept leveraged the assumption of a uniformly black conveyor belt, with all target objects being brighter. We transformed RGB camera input to grayscale, applying a brightness threshold of 30 (on a 0-255 scale) to generate a binary mask. Pixels below this threshold were set to white, and the rest to black. This mask was then used to draw contours around potential objects, which were then mapped back to the original image for classification.

Evaluation

This method proved highly accurate in perfectly controlled environments with ideal test objects. Its simplicity offered efficient processing under consistent lighting conditions and for objects with strong, uniform reflectivity. However, its significant limitations in real-world scenarios quickly became apparent.

- **Pros:** Works for ideal test cases, accurate in controlled lighting, effective for bright objects.
- **Cons:** Highly susceptible to lighting noise (bright spots on the conveyor appearing as objects), inconsistent detection due to varying object reflectivity.

Evolving to Median Background Subtraction

Median Background Capture

The camera runs for 60 frames to establish a robust median background representation of the empty conveyor belt. This statistical approach helps average out minor variations in lighting.

Pixel-by-Pixel Differencing

Real-time frames are then subjected to an absolute difference calculation against the established median background. This highlights pixels that have changed, indicating the presence of new objects.

Contour Detection

Areas of significant pixel difference are then processed to identify and draw contours, precisely outlining the objects on the conveyor belt.

Recognizing the limitations of static thresholding, our second iteration focused on dynamic background separation. By calculating the median of the conveyor belt over several frames, we aimed to create a more resilient baseline. Any deviations from this median were considered foreground objects, allowing for more adaptive detection.

Strengths and Weaknesses of Median Background

Reliability in Variable Lighting

This method significantly improved accuracy and reliability, even under changing ambient light conditions, as long as the overall lighting remained stable during operation. It adapted well to minor fluctuations that would have severely impacted the previous approach.

Performance on Fast Conveyors

It proved highly accurate for fast-moving conveyor belts, providing reliable processing for high-throughput sorting. The rapid differencing method was well-suited for dynamic environments.

Challenges with Object Size & Brightness

Very large or bright objects could trigger the camera's autofocus, causing the entire median background to shift and resulting in detection failures. The system struggled to maintain its baseline when the scene changed dramatically.

Conveyor Stitching Issues

The presence of physical seams or stitches in the conveyor belt, which are drastically different from the typical median background, led to false positives, as these areas were incorrectly identified as objects.

Addressing Challenges with Video Separation

1

Solution for Stitching

By recording a complete video cycle of the empty conveyor belt, we could use frame-by-frame background subtraction. This allowed the system to learn the conveyor's entire texture, including stitches, and accurately differentiate them from actual objects.

2

Refined Background Modeling

This approach provides a more nuanced background model, adapting to the non-uniformities of the belt itself. It significantly reduces false positives caused by fixed features of the conveyor.

3

Processing Overheads

Despite solving the stitching issue, this method introduced significant computational overhead. Processing video frame-by-frame backed up the computer, leading to dropped frames and synchronization issues over time.

4

Inherited Limitations

It inherited some of the limitations from the Median Background method, particularly concerning large or extremely bright objects triggering autofocus and disrupting the learned background model.

Future Directions and Project Expansion

Mechanical Integration

The next crucial step involves seamless integration with the mechanical aspects of the sorting system. This includes triggering sorting mechanisms based on detected plastic types and sizes, ensuring a fully automated process.

OpenCV Module Integration

Exploring and integrating advanced modules within OpenCV for dynamic background separation will enhance adaptability to diverse lighting and conveyor conditions. This includes adaptive thresholding and more complex foreground detection algorithms.

Optimized Video Separation

Future work will focus on making the video separation method significantly lighter and less resource-intensive. This involves optimizing algorithms, potentially leveraging GPU acceleration, or exploring event-driven processing to prevent frame drops and system lag.

The project's evolution demands a holistic approach, extending beyond pure software. Integrating with hardware and refining existing algorithms are vital for achieving a robust, scalable, and commercially viable plastic classification system.