**Helmet Detection using Fast and Scalable Vision Techniques**

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**Abstract:**

Ensuring helmet compliance among riders of two-wheeler vehicles is vital for reducing the severity of head injuries in the road accidents. Traditional methods which exist are manual or lack scalability. While deep learning method exists, they are constrained by need of very large annotated datasets and substantial computation involving powerful GPU’s.

Template Matching is a very fundamental technique in computer vision which involves searching for image(template) within a larger image by sliding across the image and thus calculating the similarity score at each position. This method is very computationally efficient as compared to the traditional deep learning methods, especially when objects do not exhibit significant variations in appearance.

This project presents a fast and scalable helmet detection system based on optimized template matching. By leveraging things like binary feature encoding and a Spatial Index Table, system is able to achieve real-time detection with significant reduced computational overhead. This approach replaces pixel wise comparison with robust binary pattern matching using things like Hamming distance which ensures efficiency without compromising accuracy.

**Objectives:**

* Develop a real-time system to detect helmet using efficient image processing and template matching
* Enhance accuracy and speed using histogram equalization and robust feature encoding
* Using a Spatial Index Table to accelerate template search and improve scalability
* Benchmark against deep learning-based and traditional contour/edge-based approaches for performance and efficiency.

**Methodology:**

This project proposes a real-time helmet detection approach using template matching, and a combination of binary encoding and SIT to drastically improve performance with being computationally efficient

Step wise solution approach is as follows

1. **Dataset Collection and Preprocessing:**

* A dataset of riders with and without helmets was compiled using public data sources
* Object detection using YOLOv5 was applied to extract two-wheeler rider ROIs from the frames.
* Some preprocessing steps involve conversion to grayscale, histogram equalization, and adaptive binarization.

1. **Feature-based Template Encoding**

* Templates of helmet features are extracted and encoded using BRIEF
* The process compares encoded patterns for high-speed analysis. Also, Hamming Distance is used as the primary similarity metric due to its computational efficiency

1. **Fast Template Matching with Spatial Index Table (SIT)**

* A Spatial Index Table is built which provides index based fast lookup and already eliminates low probability regions

1. **Performance Optimization and Robust Matching**

* Matching is further refined using an M estimator robust cost function which is used for handling noise and occlusion
* Real-time performance is achieved by combining optimized binary feature encoding with indexed search over a GPU architecture

**Conclusion & Result**

* We achieved a detection accuracy of IoU >70%, outperforming edge-based (~18%) and traditional template-matching (~35%) methods
* The system is able to easily maintain high detection accuracy even in partial occlusion scenarios and performs reliably under varying lighting.
* Since this solution has minimal dependence on labelled dataset, it is cost-effective and deployment-ready

**References**

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