**Title :- "Real-Time Seat Belt Detection Using Fast Template Matching with Inverted Location Index and HOG-Based Binary Encoding"**

**Objectives:-**

1. Create a real-time seat belt detection system based on template matching.
2. Improve the efficiency and accuracy of seat belt detection with histogram-based transformations and robust similarity measures.
3. Employ Inverted Location Index (ILI) to enhance template matching speed.
4. Compare with conventional edge-based and learning-based approaches.

**Methodology:-**

Ensuring seat belt usage is critical for road safety, as wearing a seat belt significantly reduces the risk of fatal injuries in traffic accidents. Current enforcement methods rely heavily on manual monitoring, which is labour-intensive and inefficient. We have investigated seat belt detection employing Genetic Algorithm (GA)-based template matching with enhanced detection performance compared to classical edge-based methods. Nevertheless, GA-based techniques are computationally intensive and call for heavy optimization.

This project extends their work by incorporating rapid and high-speed template matching methods that take advantage of **Inverted Location Index (ILI) and HOG-based binary coding** to enhance speed and robustness, lowering computational complexity while retaining high detection accuracy. Existing enforcement approaches are mostly based on manual supervision, which is inefficient and time-consuming. This project will create an automated seat belt detection system based on template matching with improved search strategies to enable the detection process to be quick, robust, and scalable.

**Key findings:-**

* The new method has **higher detection accuracy (IoU ~50%)** than edge-based techniques (~16.5%) at low computational expense.
* The **ILI-based optimization** has much fewer search iterations than brute-force template matching.
* This method does **not need large amounts of training data** like learning-based approaches, so it is **scalable and efficient** for real-world use.

Step wise solution approach-

**1. Dataset Collection and Preprocessing**

* The dataset consists of images taken from car dashboards centered on the driver's seat belt area.
* The YOLOv3 model is employed for preliminary car detection and localization of the driver's region of interest (ROI).
* Preprocessing involves conversion to grayscale, histogram equalization, and adaptive thresholding for improving contrast between seat belts and attire.

**2. Template Matching using Fast Binary Encoding**

* The method converts the image and template into binary codes based on **Histograms of Oriented Gradients (HOG)**.
* The system does not use conventional pixel-wise intensity matching but encodes a pixel neighborhood into a binary code through **projection and quantization**.
* **Hamming distance** is utilized for similarity computation, thus the method is very efficient.

**3. Robust Similarity Measure and Inverted Location Index (ILI)**

* Rather than traditional **Lp-distance or NCC similarity**, the method utilizes a **robust similarity measure** that eliminates outliers.
* **ILI structure** is employed for fast similarity computation by treating pixel locations according to their values instead of their spatial locations.

**4. Optimization and Speed Improvements**

* The approach utilizes **bounded M-estimators** for enhanced robustness against occlusions and noise.
* The **binary encoding using HOG** reduces the computational burden when compared to conventional methods.
* The **ILI-based method** provides efficient template matching that is scalable and rapid without needing exhaustive search iterations.

**5. Performance Measures**

* **Intersection over Union (IoU)** metric evaluates the accuracy of seat belts detected.
* Time taken to process per frame is measured to assess **real-time viability**.
* Edge-based approaches (**Canny Edge + Hough Transform**) and learning-based techniques (**CNN, Adaboost**) are compared.

**Reference:**

[1] Seat belt detection using Genetic Algorithm-Based Template Matching *Junaya Sato, Takuya Akashi (Manuscript received July 10,2023 and published date: Oct 20,2023*

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