**Seat Belt Detection Using Fast and High-Performance Template Matching**

Objectives:-

* Create a real-time seat belt detection system based on template matching.
* Improve the efficiency and accuracy of seat belt detection with histogram-based transformations and robust similarity measures.
* Employ Inverted Location Index (ILI) to enhance template matching speed.
* 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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