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AN APPROACH FOR THE IMPLEMENTATION AND OPTIMIZATION OF ALGORITHMS FOR DROWSINESS DETECTION

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ABSTRACT

This study developed a framework for a typical Drowsiness Detection System (DDS) with a view to achieving dynamic computer vision tasks amidsta significant improvement inoptimization and performance. The study used a systematic approach to split involved computational tasks into a number of independent functions handled by parallelprocessors. Furthermore, the ensuing algorithmic functions were prioritized in order to enable sequential processing of data and, also,to specify the appropriate order in which tasks were executed. A suitable set of evaluation criteria and parameters were obtained from the developed frameworkin order to provide a comprehensive assessment of comparable techniques.

Keywords: optimization, sensitivity, computer vision, drowsiness detection.

1. INTRODUCTION

Computer vision is a rapidly growing field devoted towards analyzing, modifying and providing high level understanding of images. Its main objective is to provide computers with human-like perception capabilities so that they can sense and understand the environment, take appropriate actions, and learn from this experience to enhance future performance [1].Due to its wide variety of emerging applications, implementation of computer-based systems in real time is a challenging task, because it needs efficient processing capabilities [2].

Most computer vision tasks are complex because they require a great deal of mathematical computation. This makes its hardware implementation computationally intensive and often requires large memory. The problems associated with CPU-based image processors in real time are high data transfer bandwidth and low sequential data processing rate. Video frames are usually captured from either an analogue or digital camera and transferred to the CPU main memory; hence transfer of frame from one point to another for further processing also imposes data flow constraint on the system. Consequently, a relatively long latency is encountered by the need to wait for the entire frames to be captured before it is processed [3]. Designing parallel algorithms for solving computer vision problems is, therefore, both of theoretical interest and of practical importance [4].

Driver monitoring approach using computer vision has become prominent due to its predictive validity of detecting drowsiness. To analyse driver's drowsiness systems, much research has been done using the non-intrusive method for extracting and analysing facial features, especially the state of the eye. The eye state is assumed to give a good indication of drowsiness level characterized by micro-sleep which is a short period (between 2- 6s) during which the driver rapidly closes the eye and sleep [5]. For instance, [6] developed an improved driver's drowsiness detection system (DDS) for monitoring driver's drowsiness. The eye was detected using motion analysis and subsequently tracked by template matching. The results demonstrated that a low-cost webcam that captures at 30 frames/ sec was used to achieve a blink accuracy of 94.8%, missed blink error of 2.4% and false positive error of 3%. Also an eye tracking accuracy of 72% at a distance of 30cm was obtained. The limitation of this work is as follows: tracking was done with only one eye, which often gets lost due to rapid movements of the head. Once the tracker gets lost, it takes time to get back on line; in extreme cases, the system has to be manually re-initialized.

An embedded system for real-time monitoring of driver's vigilance was developed by [7]. It was tested using different video sequences recorded in real driving conditions with different users (for only those not wearing glasses) during several hours. In each sequence, several fatigue behaviours were detected. The system works robustly at night and for users not wearing glasses, yielding accuracy close to 95%. The performance of the system decreases during daytime, especially in bright days.

A vehicle driver drowsiness warning system using aneural network based image processing technique was developed by [8]. Its subsequent evaluation with confusion matrix produced an overall accuracy of 96.7%. The results indicated that the proposed expert system is effective for increasing safety in driving. Also, [9] presented an automatic drowsy driver monitoring and accident prevention system that is based on monitoring the changes in the eye blink duration. The method detects visual changes in eye locations using the feature of horizontal symmetry of eyes. This method detects eye blinks via a standard webcam in real-time at 110fps for a 320×240 resolution. Experimental results in the JZU Eye-blink database showed that the proposed system detects eye blinks with 94% accuracy with a 1% false positive error.

In general, evaluating the performance of a computer vision algorithm is a complex task [10]. This problem is attributed to the choice of the dataset to be

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used. A quality database must be of sufficient size, and be able to represent the variability of different parameters of interest, such as illumination, pose, expression and identity. This is because the environment and conditions of subjects in the real time implementation of drowsiness detection systems are dynamic and, hence, lots of environmental variables undermine its sensitivity and overall performance. In addition, the existing drowsiness detection systems lack a coherent framework for implementation and evaluation. However, in most of reviewed works, accuracy of the system is the only basis of evaluation. In view of the foregoing, the much needed improvement of these promising systems will be impossible, if these issues were not attended to.

The aim of this study is to develop ageneralized optimum framework for the implementation of drowsiness detection techniques and, also, to establish adequate parameters and criterion for the needed evaluation.

2. PROPOSED METHOD

2.1 System design

The system consists of a sensor which converts analogue signals into digital form. The sensor acquires the video feed of the driver's face with the aid of a camera as shown in Figure-1. The received video frame in digital form is processed by the machine vision controllerwhose,primary function is to detect and locate the position of the driver's eye. Once this is done, the **decision maker** extracts possible feature (e.g. opening and closing of the human eye). This extracted feature was further analysed by the system in arriving at a logical decision of the driver's alertness state, whether awake, drowsy or asleep.

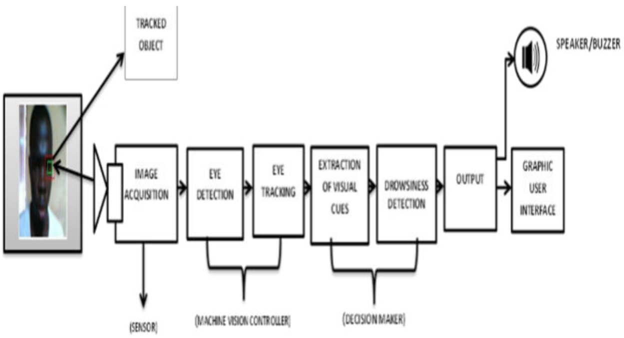

Figure-1. Block diagram showing the design of the system.

This result is forwarded to the output which consists of Graphical User Interface (GUI) and a speaker. The GUI displays the result in two forms: the video preview of the driver's face annotating the actual position of the eye that has been detected and tracked, and the metrics display ofthe lists of evaluation parameters used to evaluate the system. The system is designed to issue an audio warning via the speaker whenever a shortperiodof micro-sleep is detected to alert the driver.

2.2 Overview of generalized framework

The generalized framework is a platform for the integration of the system design in Figure-1to optimize, organize, synchronize and ensure sequential processing of computer vision tasks. It is made up of three basic parts which are the capture module, the processing unit and the display module as shown in Figure-2.The capture module is responsible for acquisition of images either from a live feed of a webcam or a video file. It is converted into a series of frames which are queued for further processing. The processing unit is divided into four modules, namelythe distribution, frame processing, logging and evaluation modules. The distribution module receives video frames from the capture module and decides which of the processors willhandle the task. The frame processing module is responsible for the detection and tracking of the location of the eye. The computer vision algorithms and techniques are implemented in this module.

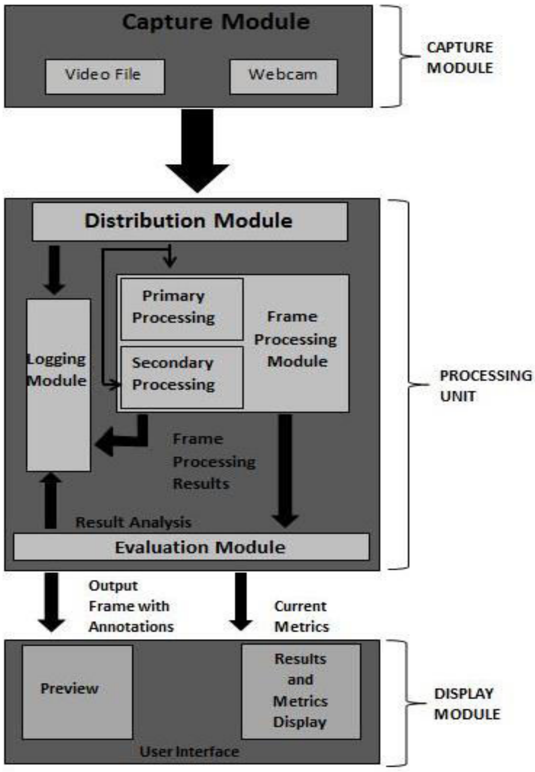

Figure-2. The overview of generalized framework.

The logging module collects input, metrics, processing results events etc. in the course of the session and generates a log file from the collected data at the end of the session. The log file is in a.csv format which is eventually exported to an excel spread sheet to produce graphs or charts for further analysis. The primary function of the evaluation module is to carry out blink and drowsiness detection. The obtained results were further analysed in order to give some assertions, such as the location of the eye, blink status and the alertness level of test subjects.

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The display module is designed to provide a friendly interface that allows users to interact with the system.

2.3 Framework optimization

The generalized framework in Figure-2 is designed to manage frame distribution and processing, including the speed up and simplification of the computations involved. Parallel processing is used to reduce the computational problems by disintegrating frame processing into appropriate fields/parts. Subsequently, instructions from each part are executed simultaneously on different processors as illustrated in Figure-3.

The distribution module coordinates the activities of the primary and secondary processors in the handling of incoming frames, which is aimed at reducing latency by effectively monitoring the rate at which frames are processed.

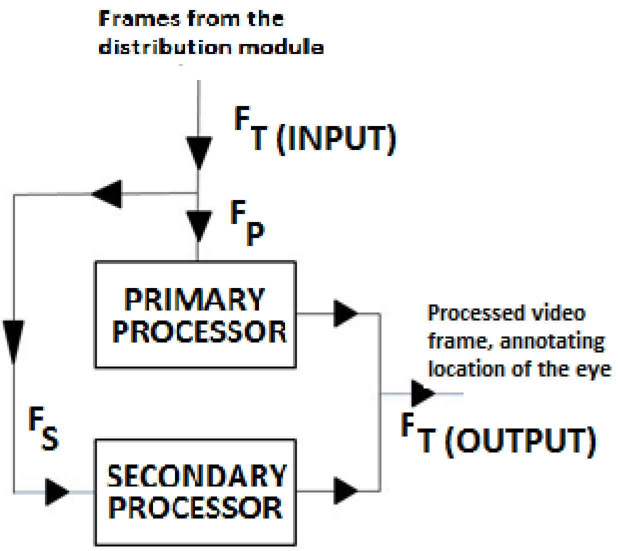

Figure-3. Diagram illustrating framework optimization process

Once the distribution module discovers that the system spends more time working on incoming frames, the remaining frames on the queue will be passed to the secondary processor to enhance faster processing. The system is designed in such a way that the primary processor performs its task synchronously while the secondary processor performs its execution asynchronously to make sure that both processors work at different rates.

The process of optimization is achieved as shown in Figure-4. Blocks A(s) and B(s) performs three specific functions which are the handling of incoming frames, detection and tracking of the two eyes independently with two separate feeds, as well as re- initialization of the algorithm which is handled by B(s). The summer combines the two signals which are forwarded to the output (Y). This makes it difficult for the system to lose track of the two eyes at the same time due to rapid head movements.

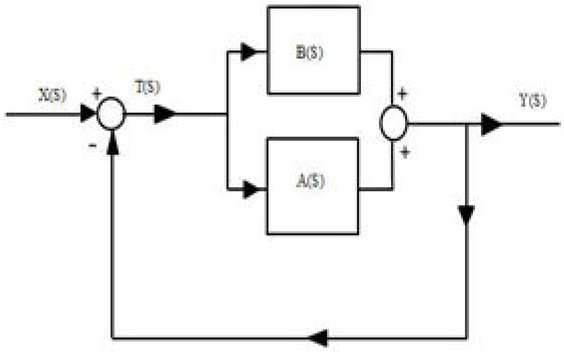

Figure-4. A typical control diagram drowsiness detection system.

The transfer function of the closed loop system is given by:

$$G(s) = \frac{Y(s)}{X(s)} \tag{1}$$

where,

$$Y(s) = A(s) + B(s) \tag{2}$$

$$T(s) = X(s) - Y(s) \tag{3}$$

$$G(s) = \frac{Y(s)}{1 + Y(s)} \tag{4}$$

Where

G(s) = Gain /sensitivity of the system,
X(s) = input,
Y(s) = output
T(s) = tracking error
A(s) and B(s) represent the detection and tracking subsystem.

Based on (2) and (4), the use of parallel processors and/or buffersthererefore optimizes real-time systemssuch that they attainimproved dynamic parameters, including sensitivity, response time, accuracy, computational demand, stability, costs, and reliability of the system. Accuracy is used to determine the level of sensitivity of the system. The established criteria for determining the level of accuracy, denoted byA_l, is shown in Table-1 (a). It is divided into three categories namely high, average and low accuracy with scores of 5, 3 and 1 respectively. Sensitivity is the measure by the degree of consistency of the system in producing accurate results under various conditions. Table-1 (b) shows the sensitivity benchmark table. Sensitivity is the sum of the accuracy aggregate score under various conditions as:

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$$S_l = A_{l1} + A_{l2} + A_{l3} + ...A_{ln} \quad (5)$$

where

S_l is the system's sensitivity, and the accuracy (A) under various conditions are defined, respectively, as

$A_{l1}, A_{l2}, A_{l3}, ...A_{ln}$

Table-1(a). Established criteria for determining Accuracy level of the system.

Criteria	Degree	Score
$A_l \geq 70$	High accuracy	5
$50 \leq A_l < 70$	Average accuracy	3
$A_l < 50$	Low accuracy	1

Table-1(b). Established criteria for determining sensitivity level of the system.

Criteria	Degree
$S_l \geq 15$	High sensitivity
$10 \leq S_l < 15$	Average sensitivity
$S_l < 10$	Low sensitivity

Stability status is the measure of the degree of variation in RAM and CPU utilization during the program execution. It is determined by calculating the standard deviation of the obtained average value. Hence, the established criteria for determining the stability of the system is such that if:

$$S_s < 10: \textit{system is stable} \quad (6)$$

$$S_s > 10: \textit{system is unstable} \quad (7)$$

where

$S_s = S_{sr}$ and S_{sc} is the stability status for RAM and CPU utilization.

A stable system indicates that the level of fluctuation of the obtained value is low while an unstable system indicates that the level of fluctuation from its obtained value is relatively high. Response time is a measure of the speed of the algorithms in its ability to detect and track the eye; this is given by

$$R_t = D_t + T_t \quad (8)$$

where

D_t = Estimated time of detection (sec)
T_t = Estimated tracking time (sec)

Equations (9) and (10) show the established benchmark for response time, categorized into short response and long response. Short response indicates that the response time is less than 3 seconds. Long response indicates that with a response time greater than 3 seconds the system is very slow. This is based on the postulation in [5], which characterized the duration of micro-sleep.

$$R_t < 3: \textit{short reponse} \quad (9)$$

$$R_t > 3: \textit{long response} \quad (10)$$

Due to the dynamism of the environment in which varying environmental factors such as noise, vibrations, background movements, lighting condition, the use of eye glass undermine the sensitivity, accuracy and response time of the system, it is important to estimate the tendency of system failure with respect to its evaluation under various conditions. This is obtained by calculating the probability of failure which is given by:

$$P_f = \frac{\textit{Number of failed test}}{\textit{Total number of subjects tested}} \quad (11)$$

The criteria for determining the tendency of failure through estimated probability is established as:

$$P_f < 0.05: \textit{low tendency of faliure} \quad (12)$$

$$P_f > 0.05: \textit{high tendency of faliure} \quad (13)$$

It is important to monitor the rate at which each processor handles incoming frames. However, the primary and secondary frame rates are dynamic. This gives the system the ability to decide the rate at which the tasks can be handled conveniently, without trading off its accuracy.The computational ability of the algorithm and the nature of the video being processed are possible factors. Estimation of percentage of primary frame rate denoted as F_P and secondary frame rate denoted as F_S utilization (illustration given in Figure-3) are defined respectively as:

$$F_t = F_P + F_s \quad (14)$$

$$\%F_P = \frac{F_P}{F_t} x 100 \quad (15)$$

$$\%F_S = \frac{F_S}{F_t} x 100 \quad (16)$$

where

F_t = Total frame rate

F_P = Primary frame rate

F_s = Secondary frame rate

However, it is important to carry out an overall assessment to ascertain the level of optimization achieved in the implemented algorithms by checking if the considered factors have met the minimum requirements shown in Table-2. This is characterized by optimization rating denoted by O_R based on the following established criteria:

$$O_R > 70\% : optimized \quad (17)$$

$$O_R < 70\% : not\ optimized \quad (18)$$

Table-2. Minimum requirements for optimization of considered factor.

Minimum requirement for optimization	Considered factors
$S_l > 15$	Sensitivity level
$R_t < 3\ sec$	Response time
$P_f < 0.05$	Tendency of failure
$S_{osr} < 10$	Stability status of RAM
$S_{osc} < 10$	Stability status of CPU

3. CONCLUSION

In order to reduce the problems associated with real time implementation of drowsiness detection systems, a generalized framework has been developed. The framework is made into units and modules, which perform specialized functions such as frame distribution, optimization and evaluation. An appropriate control and communication structure were incorporated so that the various units and processes can be executed concurrently and seamlessly with each other.

In further works, existing computer vision algorithms will be adapted, modified and implemented to work optimally and efficiently for drowsiness detection based on the proposed framework. The proposed design can be used as a blue print in the automobile industry for fabrication of upgradable chips in the implementation of DDS.

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