

Navigator/OOW Fatigue Detection and Alarming System

Kamran Farooq Beigh^a, Tushar Mehta^b, Neeraj Tekwani^c

Anglo Eastern Maritime Academy, Karjat, kamranbeig72@gmail.com

Anglo Eastern Maritime Academy, Karjat, tusharmehta322@gmail.com

Anglo Eastern Maritime Academy, Karjat, tekwanineeraj7@gmail.com

Abstract: This paper is an introduction to our research which aims to develop a navigator/OOW safety assistant system. We proposed an improved strategy and practical system to detect fatigue based on machine vision and OpenCV algorithm. Kinds of face and eye classifiers are well trained by OpenCV algorithm in advance, the proposed strategy firstly detects face efficiently by classifiers of front face and deflected face. Then, candidate region of eye is determined according to geometric distribution of facial organs. Finally, trained classifiers of open eyes and closed eyes are used to detect eyes in the candidate region quickly and accurately. The indexes which consist of PERCLOS and duration of closed-state are extracted in video frames real time. Practical tests demonstrated that the proposed system can detect fatigue with real time and high accuracy. The system assesses the ability of conducting safe navigation and notifies for any dangerous situation.

1. Project Overview

Fatigue “concerns the inability or disinclination to continue an activity, generally because the activity has been going on for too long” example (4 hours watch on bridge). The causes of fatigue can be physical, physiological, or psychological (Lal & Craig, 2001). There is no standard fatigue measurement, because the direct measures are few (Williamson & Chamberlain, 2005). Most measures are of the outcomes of fatigue rather than of fatigue itself. To overcome fatigue, human beings need to sleep. Sleep is essential and inescapable solution for fatigue. In case of fatigue, sleep will overpower any effort to remain awake (NCSDR/NHTSA, 1998). Therefore the best fatigue measurement is drowsiness which is the clearest outcome of fatigue. Detecting drowsiness and taking action to prevent it while navigating is not an easy task. Moreover, detecting fatigue/drowsiness depending on visual information only, adds more restricts on the reliability of the fatigue measurement. This is because it depends mainly on pattern recognition of facial gestures. One of the bottlenecks challenges of object recognition, in general, is finding efficient and discriminative descriptors that are invariant even in difficult illumination.

2. Why do we need this?

Collisions involving sleepy OOW tend to be particularly serious since the sleepy OOW doesn't have a quick enough reaction time, and is too slow to attempt to avoid an accident. Giving OOW early warning that they need to take a break is vital for safe voyage. Following are two case studies reflecting the need of this project;

2.1. Case study 1

Helmsman's Fatigue Held Factor In Louisiana Tug Crash Killing 6

OCT. 6, 1964

WASHINGTON, Oct. 5 (AP) —The Coast Guard said today that the tugboat-bridge-bus accident on Lake Pontchartrain last June that resulted in six deaths was caused by the tugboat helmsman's fainting or falling asleep.

The helmsman was Clifford Miley, mate on the tugboat Rebel Jr.

Although the Coast Guard officer who conducted the investigation said no Federal laws had been violated, the Coast Guard commandant, Admiral E. J. Roland, said the manning of the tugboat had been inadequate and the working hours of the crew unreasonable.

The Rebel Jr. was pushing two steel barges early on the morning of June 16 when it collided with the 24-mile-long structure that spans the lake in Louisiana. It swept away a small section of the bridge, and within seconds a bus carrying eight persons plunged from the bridge into the lake. Two survived.

The Coast Guard said Mr. Miley and the tugboat master, Ned Palmer, had been aboard the vessel almost continuously

Mr. Miley slept on June 15 but was awakened late in the afternoon and worked with Mr. Palmer and a deck hand until after midnight. The others were asleep, with Mr. Miley at the helm, when the collision occurred about 1:20 A.M. Admiral Roland ordered the report turned over to a United States Attorney "for such action as he deems appropriate."

The Rebel Jr. was owned by the Ace Towing Company, Inc., of Gretna, La., and was operated by the Louisiana Materials Company, New Orleans.

2.2. Case study 2

Human error due to fatigue is the prime reason for the collision of two cargo ships near Ennore Port in Chennai in January last, a report of the investigating team of the Directorate General of Shipping said.

The mishap occurred at 4 a.m. on January 28, when MT BW Maple with a flag of Isle of Man was leaving the port after emptying Liquefied Petroleum Gas and MT Dawn Kanchipuram, loaded with petroleum oil lubricant was on its way to berth at the port.

Human factor due to fatigue appeared to be the prime reason for the collision, for the mishap, it said.

“Fatigue is apparent on the team of BW Maple, since the vessel had an inspection the previous day [of the incident] and the ship’s master and his team rest hours were near violation,” the report submitted recently said.

The Master of BW Maple was also “psychologically stressed” and that adversely affected his decision-making ability, it said.

“On verification it was revealed that he had received a discouraging mail from the managers on the vessel’s performance in an audit, that was held in the same port and was not in good frame of mind,” it added.

Suggesting regulation of the rest hours of the pilots and other port officials following the mishap, the findings said the draft Indian Maritime Pilots Regulations, which have been drawn by the National Shipping Board’s committee may be “ratified and implemented.”

The master of BW Maple did not alert the master or duty officer about the presence of another vessel which was just right ahead in close range, leading to human error and the mishap, it said.

The report also recommended that one of the lapses in the probe of the incident was the “incorrect assessment of the quantity of oil spill” and said more methods and equipment may be identified and deployed for assessment of extent of spillage.

According to the report, that the final quantity of oil spill following the collision of the two ships was estimated to be 251.46 tonnes.

3. Technical and design challenges

The complex interaction of the major physiological factors responsible for sleepiness – circadian rhythms and the homeostatic drive for sleep – pose formidable technical challenges to the design and development of fatigue detection systems. The technology must be robust and capable of high accuracies in diverse operational environments with constantly changing conditions and varying customer needs.

To meet the requirements of efficiency and functionality the technology should comply with the following guidelines:

- It should measure what it is operationally and conceptually intended to measure and be consistent in these measurements over time. Thus, a device designed to measure eye blinks (operationally) and alertness (conceptually) should measure these all the time for all OOWs.
- The software technology used in the device should be optimized for sensitivity and specificity. False negatives should be minimized through accurate and reliable detection of reduced alertness levels. False positives should be minimized through accurate and reliable identification of safe navigation and operator vigilance.
- The device should be robust, reliable and capable of continuous operation over extended periods, such as a shift. Maintenance and replacement cost should not be excessive.
- Be capable of real time monitoring of navigator or operator behavior.
- The device should be capable of accurately operating under various operational conditions during the day, at night and under illuminated conditions. Accuracy should not be compromised by conditions in different climatic conditions, such as humidity, temperature, vibration, noise, etc.
- Audible warning signals should not startle the operator and should be adjustable over a reasonable range. The signals should be distinct and audible under operating conditions to not be confused with other alarms and signals.

4. How does the system work?

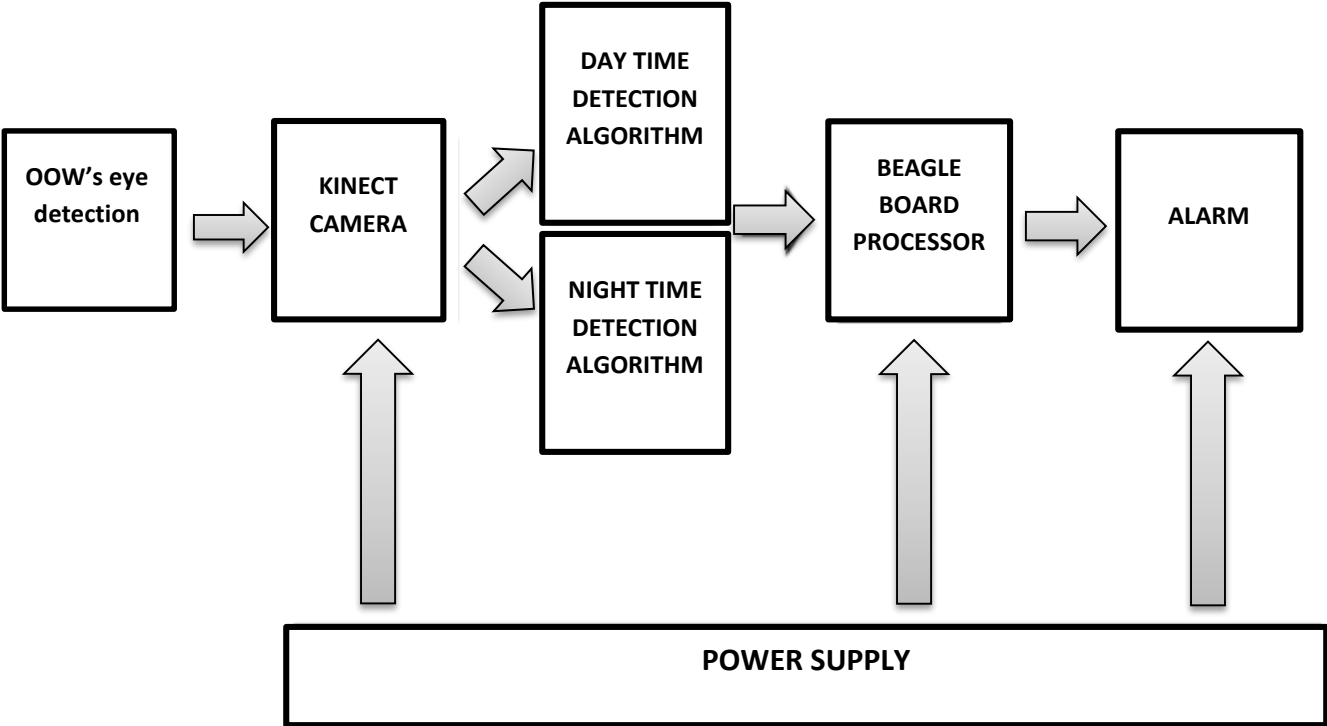
It monitors navigator's behavior closely, noting any erratic eye movements, so that it can judge the moment when OOW start to feel sleepy and need to stop and take a break. It continuously evaluates OOW eye movement, and works out when it may be time to take a break.

There will be a Kinect camera that constantly takes image of OOW, a beagle board that implement image processing algorithm, and a feedback circuit that could generate alarm and a power supply system.

4.1.Features:

1. Daytime eye detection using RGB mode of Kinect.
2. Night time detection using IR mode of Kinect.
3. Eyelid distance tracking to detect the sleepiness.
4. Real time image processing more than 1 frame/second
5. Start of general alarm on ship.
6. Sleepiness detection is efficient and alarms will be generated.
7. Enhanced algorithm to ensure the darkness detection ability.

Block diagram



5. Block Description

5.1.Kinect Camera

The KinectCamera (Microsoft Kinect Xbox360) is used in monitoring/helmsmen capturing there pictures, facial expressions The images are then sent to the Beagle board for processing. The camera will be placed near the helm and on different positions on bridge which will be ship specific. Three modes are available for the Kinect: the RGB mode, IR mode, and Depth mode. Only the RGB and IR mode is required in this project.

For navigator the camera will be rotating and the Kinect will keep the track of the OOW Motion-sensing technology as implemented in Kinect currently requires a sizable area for use (0.8m minimum to 3.5m maximum user distance).

5.2.Detection Algorithm

The coding and algorithm part will be built using OpenCV. The algorithm includes two parts: daytime detection and night detection. For daytime detection, the RGB mode is used; while for night detection, the IR mode is used instead. If IR mode fails to work, however, histogram equalization method will be used for night detection. The histogram equalization is a method to greatly expand the color range of the image. In this case, we need a light that will slightly illuminate the helmsman. The sleepiness is determined based on the change of helmsman's eyelid distance or the black of eyes or by the change sequence. For both daytime and night, the helmsman's initial eyelid distance will be recorded as long as they get on the helm. The record will be removed after person leaves. During the watch, the camera will take 2 or 3 frames per second. Then the eyelid distance will be analyzed: if the distance remains small for several frame, the navigator will be treated as fell sleepy. Same will be done with the officer on watch, for him the action detecting kinect camera will be used so that OOW's mobility is not restricted.

5.3.Main Processing Unit: BeagleBoard

The Beagle Board would operate as the controller for all other components. First, it will send and collect information from the Kinect. Then it would perform algorithms to determine the status of the helmsman by comparing the incoming data with the normal graph.

5.4.Power Supply/Control Unit

System runs on a simple 12-24v power supply which will be connected to our ship power supply.

6. Alarming system

If the system detects that OOW might be starting to lose concentration , for first line of alert, in accordance with IMO Res. MSC.128(75), sufficient number of visual(flashing lights) and audio indications will get executed.

The visual indications will be visible from all operational positions within the bridge where the OOW (Officer of the Watch) may be stationed to perform his duties.

These positions are made up by, but not limited to, Conning work station, Navigation support work station, steering work station and 2 x docking work stations

The buzzer stops when the officer presses the [RESET] button. The Main Alarm Panel will reset the timer and return to the dormant period, when the alarm is acknowledged by the watch officer if there was repetition of the same situation there will be an alarm in captain's cabin for recommendation to assess the situation and change OOW if required.

7. Schematics and Simulation

The coding and algorithm part will be built using OpenCV on the Ubuntu System. The algorithm should work all the time to detect the sleepiness of the navigator. While daytime detection is accomplished by taking RGB images, nighttime detection is done by taking IR images. If IR mode fails to work, however, histogram equalization method will be used for night detection, which could effectively expand the color contrast of a local area in the image. In this case, we need a LED to slightly brighten the OOW.

8. Histogram Equalization

Histogram Equalization will be used at night detection if IR mode fails. Basically this method increases the global contrast of images, by effectively spreading out the most frequent intensity values. The basic idea of it is to spread the low contrast image pixel values to the entire 0 to 255 color range, according to the frequency of each pixel value in the image.

9. BeagleBoard

Our BeagleBoard will power and communicate with Kinect camera board and openCV to run our algorithms. Then the output will be sent to our alarm system if danger is discovered by the algorithm.

Experiment and Data Analysis

Our system(experimental system) runs on a PC with Intel Core(TM)2 Duo 2.10 GHz CPU and 2 GB RAM, using the third-party library OpenCV to perform system tests in Visual Studio 2008. Racing game was used as driving conditions. Nine subjects took part in the experiment with simulate driving environment. The resolution of these videos is 352×288 pixels and the frame rate is 25 fps. Each frame contains human face.

We recorded ten groups of video streams in this experiment. The videos are divided into two categories. The first category (i.e., 1st–4th groups) shows various facial expressions which occurred in three subjects' simulate driving experiments. There are 1630 frames in each group of videos. These videos are used to test the performance of face detection and eyes detection.

The second category consists of the remaining 6 groups (i.e., 5th–10th). Six subjects were asked to implement driving tasks for long enough time to become fatigued finally. These videos are used to extract fatigue index. In order to collect valid videos for assessment of driver fatigue, subjects are involved in training and experimental sessions. The whole experiment duration for one subject may last two or more days, it depends on his training performance. Before experiment, subjects are asked not to eat chocolate and drink coffee or alcohol. The length of each video is about 70 minutes. There are 105,000 frames in each group of videos. In the first 55 minutes of experiment, subjects are asked to take intensive simulate driving. Many curves and steep slopes are presented in driving conditions. And extra tasks of alert and vigilance (TAV) were exerted in order to ensure subjects concentrating on driving highly during the experiment. In the last 15 minutes, we relieved subjects' stress by declining missions and using a flat road with fewer curves. The monotony of driving induced driver to be fatigued. Obvious features of fatigue for subjects in this simulate driving can be summarized as increased blink times, blinks frequency, and duration of closed-eyes state.

In order to distinguish detection results, the result of front face classifier was marked as a white rectangle and the result of deflected face classifier was marked as a green rectangle. The first row shows the results which were detected by the front face classifier marked with white rectangles. Face was lost because the right deflection angle of face is too large in 3rd frame. The second row shows the results which were detected by deflected face classifiers marked with green rectangles. And in the second row, face was lost by the deflected classifier in the first and fourth frame because the faces were in the state of looking straight ahead. The third row shows the results detected by the two classifiers. Hence, all faces including front and deflected conditions were detected successfully. This method can carry out real-time detection with a high accuracy.

Conclusions

This paper provides a practical driving fatigue detection system based on OpenCV algorithm. We proposed a new strategy to detect eye state instead of detecting eye directly. In our detection strategy, we first detect face efficiently using classifiers of both front face and deflected face. Then, candidate region of eye is determined according to geometric distribution of facial organs. Finally, trained classifiers of open eyes and closed eyes are used to detect eyes in the candidate region quickly and accurately. As a result, PERCLOS escalating rate could be calculated and used as the index of fatigue. When the PERCLOS escalating rate increased more than 200%, the OOW could be considered in fatigue state. Moreover, this paper implemented a Fatigue Detection Warning System. The system makes decision of fatigued or not according to PERCLOS and duration of closed-eyes state. Experiments demonstrated that the proposed system has a high accuracy. Meanwhile, the processing speed can reach 30 fps on PC and 14 fps on tablet, which meets the requirement of real time.

Of course, this system could make further improvement on accuracy and speed of detection by using discrete cosine coefficients and covariance feature, respectively. In addition, this paper has dodged the conditions under poor illumination. It should be perfected in the future research.

Acknowledgment

This work was supported by the Anglo Eastern Maritime Academy.

References

1. [^ "Coroner calls for shake-up of laws"](#). The Morning Bulletin. February 24, 2011.
2. [^ "Viewpoint: Perspectives on Modern Mining"](#). Caterpillar Global Mining. 2007.
3. [^](#) Friswell, R.; Williamson, A.M. (2011). "Investigating the relative effects of sleep deprivation and time of day on fatigue and performance". *Accident Analysis & Prevention*. **43** (2011): 690–697. [doi:10.1016/j.aap.2010.10.013](#). [PMID 21376856](#).
4. [^](#) [Jump up to:^a ^b ^c ^d "Facts and Stats"](#). DrowsyDriving.org. Retrieved April 30, 2017.
5. [^](#) "Fatigue Management Plan". NSW Government Department of Industry and Development. 2001.
6. [^](#) Dingus, T.A.; Hardee, H.; Wierwille, W.W (1987). "Development of models for on-board detection of driver impairment". *Accident Analysis & Prevention*. **19** (4): 271–283. [doi:10.1016/0001-4575\(87\)90062-5](#). [PMID 3651201](#).
7. [^](#) [Jump up to:^a ^b](#) Maldonado, C.C.; Schutte, P.C. (2003). "[Factors affecting driver alertness during the operation of haul trucks in the South African mining industry](#)" (PDF). Pretoria: CSIR Mining Technology.
8. [^](#) Barr, L.; Howarth, H.; Popkin, S.; Carroll, R. J. (2005). "A review and evaluation of emerging driver fatigue detection measures and technologies". Washington, DC: US Department of Transportation. [CiteSeerX 10.1.1.508.8409](#).
9. [^](#) [Jump up to:^a ^b ^c ^d ^e ^f "www.smartcaptech.com"](#). www.smartcaptech.com. EdanSafe. 2015. Retrieved April 30, 2017.

10. ^ [Jump up to:](#)^a ^b Federal Highway Administration (1998). "[PERCLOS: A valid psychophysiological measure of alertness as assessed by psychomotor vigilance](#)" (PDF). Washington, DC: US Department of Transportation.
11. ^ Ji, Q.; Lan, P.; Zhu, Z. (2004). "Real-time nonintrusive monitoring and prediction of driver fatigue". *IEEE Transactions on Vehicle Technology*. **55** (3): 1052–1068. doi:[10.1109/TVT.2004.830974](#).
12. ^ Abulkair, M.; Alsahli, A.H.; Alzahrani, F.M; Alzahrani, H.A; Bahran, A.M; Ibrahim, L.F; Taleb, K.M (2015). "Mobile platform detect and alerts system for driver fatigue". *Procedia Computer Science*. **62** (2015): 555–564. doi:[10.1016/j.procs.2015.08.531](#).
13. ^ [Jump up to:](#)^a ^b Taub, E.A. (May 16, 2017). "[Sleepy behind the wheel? Some cars can tell](#)". *New York Times*. Retrieved May 16, 2017.
14. ^ "Fatigue Detection". Volkswagen Australia Official Website New Cars & SUVs. Missing or empty |url= ([help](#))
15. ^ "Volvo Cars introduces new systems for alerting tired and distracted drivers". Volvo Car Corporation. October 22, 2013.
16. ^ Tinoco De Rubira, T. (December 11, 2009). "[Automatic Fatigue Detection System](#)" (PDF). Stanford University.