PRELIMINARY DEVELOPMENT AND TEST OF A NEW AUTOMATIC DROWSINESS QUANTIFICATION SYSTEM USING RANGE AND INTENSITY IMAGES OBTAINED FROM A DASHBOARD-MOUNTED NEAR-INFRARED 3D RANGE SENSOR

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Drowsiness is the cause of a variety of accidents, in particular in transportation. It is thus critical to develop systems that can monitor the level of drowsiness of a vehicle operator, such as a driver, automatically and continuously so as to take timely safety measures. One of the least intrusive approaches for this is to use one or more cameras mounted in the vehicle dashboard. We report here on the preliminary development and test of such a system that uses ocular parameters extracted from the images obtained from a dashboard-mounted camera consisting of a 3D range imager, namely the Kinect v2 sensor, which provides near infrared (NIR) intensity images and range images. We use the range images to construct 3D deformable models of the face, and the NIR intensity images to track the face and to analyse the facial expressions, including in darkness.

For our preliminary experiments, we used 16 participants with ages of 22.7 ± 2.2 years (mean $\pm$ SD) and free of drug, alcohol, and sleep disorders. The protocol - approved by the Ethics Committee of our university - led the participants to be in three successive states of increasing sleep deprivation over two days as a result of prolonged waking. For each of theses states, each participant took a 10-minute psychomotor vigilance test (PVT). For each test, we recorded, first the "Karolinska Sleepiness Scale" (KSS) prior to the PVT, and then the following perfectly time-synchronized data: (1) reaction times (RTs) to the PVT visual stimuli, (2) polysomnography (PSG) signals consisting of 5 EEG channels, vertical and horizontal EOG, EMG, and ECG, and (3) the Kinect v2 range and NIR intensity images of the face, with 512x424 pixels and 30 frames per second.

We initialize the tracking of the subject's face with the face detection algorithm of Viola and Jones. We then track the face using 3D deformable models. We focus on the eyes and produce a signal that represents the degree of opening of the eye. We normalize it with an adaptive baseline, take its derivative, and apply experimentally determined thresholds. This leads to the identification of the time periods corresponding to blinks. We then extract ocular parameters such as percentage of closure (PERCLOS), mean blink duration, blink frequency, number of microsleeps, mean closing duration, and mean re-opening duration.

At this early stage of development, we have compared these ocular parameters with 4 drowsiness references: the KSS, the mean RT, the number of lapses (defined as an RT $\geq$ 500 ms), and the "Karolinska Drowsiness Scale" (KDS) that was visually extracted from the PSG for 4 subjects. Results show that blink frequency is weakly correlated with KDS, and uncorrelated with the other 3 references. All of the other ocular parameters are strongly correlated with all 4 references (Pearson's correlation coefficient $\geq$ 0.5). The correlations with the 4 references are found to be the highest for the mean blink duration (mean correlation of 0.64), the number of microsleeps (0.59), the mean re-opening duration (0.57), then the PERCLOS-70 (0.56).

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