Intelligent Sensor Based Road Vehicle Driver Assistance:-
Inclusion of Vision Based Drowsiness and Inattention Monitoring

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Abstract: - This paper reports on an extension of earlier work on providing sensor based vehicle driver assistance, covering a number of modes, including imminent collision warnings, panoramic camera views, GPS based navigation advice and back up warnings. Here the use of passive stereovision based head and gaze tracking for drowsiness and inattention monitoring is concentrated on and some early experimental results reported.

1. Introduction

Over the last decade or so a number of researchers have reported very good technical progress on automated driving [1,2,3]. However, risk related legal questions have not been resolved to the extent of permitting widespread use of such systems. In the meanwhile, a practical alternative is to provide a driver with many forms of assistance to reduce accident risk and simultaneously reduce the stress of driving.

There are three levels of assistance that can be identified. The most urgent is that of warning the driver of imminent collision from any direction, but with emphasis on forward obstacles. Less urgent, but nevertheless important, is advice about inattention and erratic and dangerous driving which might be the result of substance abuse, fatigue and/or drowsiness. Many road fatalities are associated with these behaviours. Whilst substance abuse, particularly in relation to driving, is a criminal offence, risk caused by fatigue and/or drowsiness does not carry with it the same societal stigma and many, otherwise responsible, citizens take unnecessary risks in this regard. This level of assistance is the focus of this paper, although it is also planned that aspects of human behaviour related to the above can be linked with imminent collision monitoring in an interesting way to be discussed later.

The third form of assistance relates to finding ways of making driving less stressful by providing camera views all around the vehicle, backing warning sensors and navigation advice with mapping information.

The next section will briefly describe earlier work to provide the context for the main contribution of this paper. Then follows a detailed description of the commercially available head pose/gaze tracking system used for drowsiness and inattention monitoring in
this application. Preliminary results are reported but further experimental outcomes are likely to be available for presentation at the conference. Discussion concerning the linking of inattention monitoring with imminent collision warnings then follows. Conclusions close the paper.

Fig.1. Instrumented 4 x 4 Van

1. The Overall System to Date

Figure 1 shows the Mitsubishi four-wheel drive van, which has been richly instrumented for this project [4]. The vehicle can be used for both on and off-road studies of sensor based driver assistance. Five distinct modes of assistance have previously been provided. Three of these are relatively trivial:

- Ultrasonic proximity based back up warning.
- On the roof video camera that can be panned and tilted to give panoramic views of the areas surrounding.
- Night vision camera for looking forward for country driving at night.

The fourth subsystem deserves a more extensive explanation. A comprehensive commercially available road navigation system (Phillip Carin 520) has been installed to guide the driver along favourable routes to nominated road junction destinations and provides map location information en route. The map data is provided on a CD. The map data can be viewed at a variety of scales so that strategic overviews and local details can be studied. The system combines the information from four sources in an elegant way. Odometry and a gyroscope sensors provide local distance and turn information which is of particular value for continuity of tracking during periods for which the GPS satellite based fix is lost (tunnels, high rise areas, forest roads etc.); otherwise they are used to refine the GPS data. Map data also provides a context for validation of position since the geometry of distance and turns provided by the other sensors can be reconciled with the map data. The systems advises the driver on which turns to make to arrive at a nominated destination efficiently; alternative routes can be provided in contingencies. Voice and graphical advice can be issued. The use of this system, particularly on unfamiliar roads, can take quite a lot of stress out of driving and leave the driver more mentally free to concentrate on safety.

Since the removal of deliberate clock errors a few years ago, GPS stand alone (non-differential) accuracy is in the vicinity of 10 metres r.m.s., which is more than adequate for this application. The system does not provide mapping support for off-road navigation; however GPS fixes are still of value.
The fifth system provides imminent collision information. A laser rangefinder (Erwin Sick) is mounted under the front of the vehicle looking forwards. (See Figure 2) The unit is encased in a steel box with a ‘viewing’ slit to protect it from stones flying up from the road. A downward jet of air can also be turned on to provide an air curtain to ward off water droplets during wet road driving. Rangefinder data consists of up to 360 readings over the 180° forward view in a horizontal scan. Distances up to 50 metres are returned with +/-3cm accuracy. For the scanner used in this project, each scan takes approximately one second to acquire and display using a Silicon Graphics (O2) workstation. Nine polygonal sectors over the forward view can be specified (interactively or recalled from the file) for intrusion warnings. Typically these are used to define close, medium and far spaces to the left, front and right, the warnings consisting of disk shape buttons on the screen which light up. It would be a simple matter to use dispersed audio cues to convey this information more usefully. A typical screen view of a rangefinder scan, polygons and warning buttons is shown in Figure 3. It is planned to combine range data cues with the head pose and eye gaze tracker in the near future; the rationale for this is provided later.

2. Drowsiness, Fatigue and Inattention Monitoring

This aspect of driver assistance is the focus of this paper. A number of approaches can be taken to monitor drowsiness, fatigue and inattention, each with both advantages and shortcomings.

Obviously erratic and road drift behaviour could be tested directly on the vehicle but it is no easy task to discriminate correct driving on a winding road from swerving, lax driving. Detecting only severe cases so as to minimise false alarms may occur too late to avert a catastrophe. Gauging the head, shoulder and upper body pose 'slumping' which may indicate the onset of drowsiness and/or fatigue is also a possibility. In earlier experimentation [4] the author used a Polhemus 6 degree of freedom tracker, developed for virtual reality applications, to indicate when the driver was behaving outside the ordinary, presumed alert, condition. This device uses electromagnetic flux measures to determine the location and pose of a small device (approximately a 1cm cube) relative to the base device.
The wearer of the first (head mounted) is tethered by a cable to operate this device. Even the requirement to wear the sensor on a headband or hat can be regarded as an unacceptable intrusion. Testing smoothed (averaged over 10 seconds) measures of the 6 degrees of freedom for straying beyond a 3 standard deviation tolerance from the means of populations measured during an initial longer period (50 seconds) gave quite a reliable indication of behavioural change, which could partially be attributed to drowsiness and/or fatigue.

One of the most reliable ways of judging drowsiness and/or fatigue is to take encephalographic signals from probes making electrical contact with the head and to look for changes related to reduced brain activity. However, this approach is severely 'intrusive' and not likely to be accepted by the driving public.

Measuring the frequency and dwell period of eye blink is also considered a reliable way of monitoring drowsiness and/or fatigue. Again, devices attached to eye-ware and other worn objects can provide such information. However, calculating such measures entirely passively using vision, is a practical possibility, which has no intrusive element. If the head location and pose can be measured simultaneously, along with gaze direction, as is afforded by the instrument described in this paper, all the better, as they can, together, indicate drowsiness and/or fatigue as well as inattentive driving.

3. Head Pose/Eye Gaze Tracker
A passive stereovision based head pose/eye gaze tracker [5] (Seeing Machines) has been installed on the dashboard directly in front of the driver's position for normal driving [See Figures 4 and 5]. The system is capable of providing the six degrees of freedom of head pose (three linear, three angular) as well as pitch and yaw eye gaze directions at up to 60 times per second. The head of an individual is tracked once a set of visually distinct 'landmarks' is specified interactively. For this application, for which any requirement of wearing special markers is not really acceptable, natural landmarks, specifically including the corners of the eyes and mouth are used. Stick-on markers can be used for other applications to increase the reliability and accuracy of the system. The head model allows the approximate location of the yes to be determined and, in due course, the centre of each iris within the frame of the relevant eye is determined to provide gaze data. Obviously, gaze and head pose data can be combined to estimate where the user is looking in absolute terms. In addition, blink status can be returned. Blink, gaze direction and head pose data are all used in this specific project.
As mentioned earlier, blink dwell and frequency are strongly correlated with drowsiness and/or fatigue, whilst gaze direction can be monitored for inattentive driving behaviour. Head pose changes can also indicate drowsiness and/or fatigue.

This idea is as follows. During the first few minutes of driving the driver is assumed to be alert and attentive. Normal head pose, gaze and blink data statistics are collected during this initial period. Subsequently, variations of these measures (each averaged over short periods) beyond a specified number of standard deviations (assuming Gaussian probability density distributions) cause warnings to be issued. The first tests are reported below but represent just the beginning of an ongoing research on how to use the collected data to provide reliable warnings without many false alarms (which would cause distrust and subsequence dismissal of the warnings and thus defeat their purpose).

The following preliminary experimentation was carried out. Two distinct types of calculations were implemented on data collected by a Silicon Graphics workstation to which the head and gaze tracking system logged live data on a local area network connection. This is significant in that other aspects of driver assistance, such as imminent collision monitoring, is also carried out on a SG. Thus, combining head/eye tracking data with range data will be easily accomplished. The mean and standard deviations for all 8 variables (three lateral positions of the head, three rotational pose values plus gaze pitch and yaw) were calculated, firstly on base line data collected first over a selectable period (typically 50 seconds) and then repeatedly over shorter periods (typically a few seconds). If the means of the repeatedly collected data (each variable separately) fell outside a specified number of standard deviations of the means of the base line data a warning for that infringement was given.

This worked amazingly well. For drowsiness detection the blink mark space ratio (closed to open) was calculated for the base line data. If the same ratio for the repeatedly collected data fell over a specified times (say 2.0) the base line data ratio (that is, a ratio of ratios was tested) a drowsiness warning was issued. Again this worked with considerable reliability. The author is now convinced that this overall approach to inattention, fatigue or drowsiness monitoring is likely to be very fruitful though further testing and modelling is required. Video sequences of the sytem operating on thr bench will be shown at time of presentation. Testing in a moving vehicle for realistic situations is yet to be carried out.

Combining Inattention Monitoring with Instrument CollisionWarnings
An interesting future development is to relate gaze direction with close obstacles (moving or otherwise) detected by the laser rangefinder system. This idea has to do with gauging whether the driver is likely to be aware of the presence of a close obstacle in danger of being collided with so that he/she can take the appropriate diversionary action. If it can be detected that the driver is in fact looking towards the source of collision danger then the hope of safe passage is relatively high. Whilst general inattention to looking at the road for safe driving is only a mildly urgent situation, not looking at a potential collision object is certainly more urgent. This urgency is somewhat diminished if the driver is aware of the danger. Thus, relating range data, which locates objects which are the targets of imminent collision, with the gaze direct of the driver can provide the reassurance of drive awareness and potential to save the situation. Thus, not only can warnings of potential collision be given but a special urgency of warning can be associated with inappropriate behaviours of the driving during such crises. The practicability of this scheme and its genuine helpfulness or otherwise can only be gauged by experiments which have not yet taken place.

Conclusions

This paper has outlined the components of a system to provide assistance to vehicle drivers in terms of imminent collision warnings, navigations advice, panoramic camera views, night vision and backing proximity sensing. The main focus has been a vision based head pose and gaze tracking to provide warnings of inattention and drowsiness/fatigue. The results to date using this new system are promising but further experimentation is called for. A plan to relate eye gaze to collision warnings has also been touched upon.

References: