A NEW VISIBILITY PRE-WARNING SYSTEM FOR THE EXPRESSWAY

L Lin1, Q Hong1, G Li1, X B Han1, Steven C-Y Lu1 and R Ding2

1 Inspiring Technology Research Laboratory, Tianjin University, Tianjin, 300072
CHINA

2 Tianjin University of Technology and Education, Tianjin 300222, CHINA

E-mail: linling815@vip.sina.com

Abstract. One of the most important factors that contribute to traffic accidents on the expressway is the low visibility, which may be caused by local or regional weather status such as agglomerate fog, rain, snow and sandstorm. A pre-warning system would be great help to prevent traffic accidents due to low visibility. Considering some problems of the existing system, such as the limited monitoring area and expensive cost, etc., a new kind of visibility pre-warning system is presented in this paper. The pre-warning system is made up of measuring nodes and communications bus. At the measuring node there is a long-distance photoelectric sensor, which is placed by means of cascade at the middle isolation strip along the expressway. Using the long-distance sensors makes it possible to monitor the visibility status of the whole expressway. CAN bus is used in this system as the communication bus to transmit information about visibility along the expressway. In virtue of the advantages of the CAN bus, a long distance network is constructed to meet the needs of the system, such as real time, reliability and low cost. With this new visibility pre-warning system, the visibility status of the whole expressway can be monitored in time and all day. In this paper, the architectural structure of the system is introduced, and also the detailed designs of the measuring node and hardware connection of the CAN bus communications is described.

1. Introduction

In the past several decades, expressways have made considerable progress in many countries of the world, and have made an enormous contribution to the development of the national economy. Until now, in China, for example, the nationwide expressway general mileage has made a breakthrough of 30000 kilometers, the second longest of the world [1]. However, along with all the advantages and convenience of expressways is the sharply rising rate of traffic accident occurrence. Because of the high speed and large flow of vehicles, accidents maybe occur when the visibility is low, especially when agglomerate fog or sandstorms appear suddenly. In other words, one of the most important factors that contribute to traffic accidents on the expressway is low visibility, which may be regional or emergent. Consequently, it is very important to monitor the visibility status of the whole expressway in a real time, round-the-clock way.

The main existing visibility meters, such as FD12 (Vaisala Corp. Finland), CATON06113 (Belfort Corp. America), FSM [2] (Impulsphysik Corp. Germany) and PEP9012(PEP Corp. Canada) are all scattering-type visibility meters. And some existing systems, such as CJA-1 visibility meter which is
developed by the Luoyang Zhuohang Corporation and the Atmospheric Physics Research Institute of Chinese Academy of Sciences cooperatively, Jiesi expressway intelligent monitor system, ASM-IV automatic meteorological monitoring system of expressway, and Hengyu visibility pre-warning system. The meters adopted in the above-mentioned pre-warning system as visibility status monitor instruments are also all scattering-type visibility meter. As a pre-warning system, there are some problems if scattering-type visibility meters are adopted. First of all, in using scattering-type visibility meters, the air simple space is limited [3], so it is hard to monitor the whole expressway, and cannot find agglomerate fog and sandstorms which are stochastic and instantaneous. Second, the existing system has a lot of information that needs transmitting, and obviously, it will be too expensive to use fiber as the communication bus, and too slow to use an RS485 bus, in other words, it cannot satisfy the cost and real-time performance at the same time.

Considering the problems and conflicts mentioned above, a new kind of visibility pre-warning system is presented in this paper. Take one node for example, we adopt a new pattern long-distance photoelectric sensor to detect the visibility signal, and then the faint optical signal was drawn out by the phase lock-in detecting circuit. Subsequently, we dispose the output signal of the phase lock-in detecting circuit by a single chip, and then send the detected result to the management node and the other nodes by CAN bus. According to the detected result, at the same time, the single chip makes a corresponding control operation to the visibility state at this node. According to the above system design, our visibility pre-warning system has the following advantages. First, only the visibility information, which is closely related to traffic accidents, is transmitted, so we have the reduced systematic structure, and improved systematic efficiency. Second, we adopt the new-type long-distance visibility sensor to realize the purpose to cover the whole length of the expressway. Third, adopting the phase lock-in detecting circuit to deal with the faint optical signal, has improved the systematic precision and stability [4], and we have realized the accurate pre-warning of the visibility state. Using CAN bus as communications bus, we have guaranteed the real-time processing and control of the signal [5] at lower costs. Thanks to the low consumption design of the whole system, we can offer the advantage for all-weather work of the system. Therefore, we have realized the aim to monitor visibility signal of the whole expressway with the simple, steady, effective and practical system all-weather and in real-time.

2. Architectural structure of the system
The visibility pre-warning system is placed at the middle isolation strip along the expressway by means of cascade, thus, it can monitor both directions as the vehicles come and go. And the eradiating installations and the receiving installations are placed separately, just as shown in the figure 1, the system begins with the first eradiating installation, and is followed by the next node which is made up by the first receiving installation and the second eradiating installation, and so on. The last eradiating installation and the receiving installation formed a single sub-system for the pre-warning of visibility, the whole sub-system, as a node, is controlled by a single chip, just as shown in the figure 2. There are several hectometers or several kilometers apart between two nodes, and the nodes can communicate with each other by the CAN bus. In this way, we can cover the whole expressway with the monitoring system.
3. The design of the measuring nodes

The outline of the measuring node is shown in Figure 2. Because of the scattering, reflectivity and absorbency of the air, the emitting light intensity is weakened. Comparing the ratio of the receiving light intensity and the emitting light intensity with the established warning threshold value, then the single chip can send the visibility information through CAN bus according to the compared result, and give out alarm light and sound to caution the drivers once the visibility is lower than the preset level. While measuring the state signal of visibility, the measuring system must finish the temperature control and pollution detection of the lens. The reason is that, first, temperature control must guarantee all emitting devices and receiving devices work under constant temperature in order to realize light power output and input of all optical devices work steadily. Second, temperature control must prevent the difference in the temperature between the lens and the environment from rising too much, if not, there will be much steam condensed on the lens, and this will influence the passing of the optical signal, and produce an extra error. In the mean time, due to all the nodes being exposed to the environment, dust is deposited on the surface of the lens, and following dust are is pollution of the lens and consequent errors of the system. So, in our system, we use lens pollution self-checked installation to detect the pollution parameter, and then send out the indicated signal to the measuring system.

3.1. Visibility signal detection

In the measuring system, the main task is to measure the state signal of visibility. Because the pre-warning system warn of the visibility state only, it needn’t detect the absolute value of visibility, and based on the Koschmiedier Law, given a fixed threshold value of the vision contrast, the visibility is inverse proportion to the extinction coefficient of the air. So we can monitor the state of the visibility on the expressway indirectly through monitoring the extinction coefficient of the air. We measure the
extinction coefficient of the air by the long-distance transmission method, that is, because of the scattering, reflectivity and absorbency of the air, the emitting light intensity is weakened. Comparing the ratio of the receiving light intensity and the emitting light intensity with the established warning threshold value, then the single chip can send the visibility information through CAN bus according to the compared result, and give out alarm light and sound to caution the drivers once the visibility is lower than the preset level.

The infrared semiconductor laser diode, which is driven by the driving signal at a scheduled frequency, radiated a modulated laser signal with the carrier wave at the same frequency. As shown in the figure 2, the beam of the laser signal is extended by the extender lens of the optical extending system. And then, because of the scattering, reflectivity and absorbency of the air, the beam of the modulation laser signal is weakened when it receives receiving installation, and at the receiving installation, the beam is filtered by the optical filter, assembled by the collecting mirror, and then converted into the electrical signal by the silicon photoelectric cell. Thus, we can get the electrical signal about the state of the visibility. The concrete light path is shown in figure 3.

After the conversion, the electrical signal, which is converted by the silicon photoelectric cell, is inputted into the band-pass filter to eliminate the dark-current and the high frequency interference [6]. It is then amplified by the inverted amplifier, after that, the amplified signal is sent to the single chip, demodulated by the Phase Lock-in demodulated circuit with the demodulation signals, so we can get the amplitude information of the modulated laser signal after being weakened. Now we must explain why we use phase lock-in circuit to process the signal. In our system, we want to monitor the whole expressway with low cost, the detecting nodes must be the less the better, so the distance between two nodes must be several hectometers or several kilometers away. Thus the signal received by the silicon photoelectric cell must be very faint. As we all known that the fainter the signal is, the greater be influenced by ambient noise such as visible light, lamplight, thunder and lightning, temperature and so on. Generally, the ambient noises mentioned above are all low frequency or direct current signal. So if the laser diode is driven by the low frequency or direct current electrical signal, the useful optical signal and the useless interfering signal are superimposed and influence each other. Then it is very hard to get the useful signal from the mixed signal. To resolve that problem, based on the amplitude modulated principle and the phase lock-in detect principle, first, we drive the laser diode with a scheduled frequency electrical signal, the laser signal is modulated at the same frequency. In this case, though the laser signal is also influenced by ambient noises during the transmission, because the useful optical signal is greatly different from frequency of the useless interfering signal, the useless interfering signal can be removed by the filter circuit. Because of the high signal-to-noise ratio of the phase lock-in detecting circuit, the circuit can draw the very faint signal in the noise out. Thus, this method has raised the resolution ratio of the measuring system greatly [7]. So the faint optical signal measure circuit that based on phase lock-in demodulation has very high precision [4].

3.2. Temperature control
In the measuring nodes, both the eradiating installation and the receiving installation are optical devices, we know that the optical devices must work under a constant temperature to guarantee their optic power. Because the system works outside, the difference in temperature changes greatly, thus on one hand, if the temperature of the environment is too high, or too low, or the temperature of the optical devices is too high after long time working, the optical devices will work abnormally because of optic power drifting. On the other hand, if the temperature inside the optic lens is different from the environment temperature, there will be vapor condensation on the lens [8]. There will be precision error during the measuring process because of the refracting and scattering that is caused by the vapor. In summation, we must control the temperature of the measuring nodes.

3.3. Lens pollution self-detected
As mentioned in 3.2, the measuring nodes are working outside, there will be much dust on the optic lens after using some time. So we must design the lens pollution self-detected installation to solve the problem. We design the dust preventor also, so we can reduce the influence of the dust as much as possible.

4. Communications network based on can bus
The Controller Area Network (CAN) is a serial communications protocol which efficiently supports distributed real-time control with a very high level of security. Controller Area Network (CAN) was initially created by German automotive system supplier Robert Bosch in the mid-1980s for automotive applications as a method for enabling robust serial communications. The CAN nodes have the ability to determine fault conditions and transition to different modes based on the severity of problems being encountered. With the release of version 2.0B of the CAN specification, the maximum communication rate was increased to 1Mbit/sec (communication distance less than 40m), the maximum communication distance was increased to 10Km (communication rate at 5kb/s), the maximum communication nodes were increased to 110. A 15-bit Cyclic Redundancy Check make the error of the CAN bus is extremely low, and the dependability is extremely high. With its remarkable characteristic, cheap price, extremely high dependability and flexible structure, CAN bus has already been recognized as one of the most promising buses.

With the aid of the above advantages, we form our visibility pre-warning system with the CAN bus. Thanks to the CAN bus, we get an economic and practical measuring system. The hardware circuit connection of the measuring nodes and the CAN bus was shown in figure 4. There are three parts of the hardware circuit: microcontroller, isolator and CAN driver.

Our selection of microcontroller is microchip’s PIC18LF458 which is integrated CAN controller. The PIC18LF458 is an 8 bit COMS single chip, it adopts a Harvard bus structure, and all the instructions are monocyclic. Those advantages improve the operation speed of the microcontroller. At the same time, the voltage of power supply for the microcontroller can fall as low as 2V, this provides the low consumption performance for the microcontroller. So PIC18LF458 not only meets speed requirement but also meets the time requirement of work round-the-clock. In the CAN bus system,
there must be an isolator between the microcontroller and the CAN driver to improve the anti-interference ability of all the nodes. Our selection of the isolator is ADI’s two-channel digital isolator ADUM1201 which is based on iCoupler technique. It has better performance than the traditional photoelectric isolator. For example, compared with the traditional photoelectric isolator it has dispelled the uncertain transfer rate, non-linear transmission functions, and the influence of temperature and life-span to the device. At the same time, ADUM1201 can work effectively without other drivers or discrete components. And the power consumption of the ADUM1201 is only 1/10 to 1/6 of the traditional photoelectric isolator at the same transfer rate. The two opposite channels of the ADUM1201 provide a very convenient solution of the CAN bus communications and have simplified the hardware structure greatly. Our selection of CAN driver is the microchip’s MCP2551, which is compatible with IOS-11898 standard. The supreme speed of the MCP2551 can reach 1Mbps, and the anti-interference electromagnetic is much better than the 82C250. In order to assure the stability of the system better, the resistances (R2 and R3) are used to limit the current of the bus, and the capacitances (C3 and C4) are used to filter the electromagnetic radiation and prevent high frequency interference. Transient interference is eliminated by the lightningproof diodes [5] (D1and D2).

The 10km communications subnet is formed by the CAN bus and measuring nodes which are connected by the CAN bus, and then all the subnets of the CAN bus are connected by the relay installations to cover the whole expressway.

5. Conclusions
A new kind of expressway visibility pre-warning system is introduced in this paper. Owing to the accurate and effective detection method as well as the simple and practical circuit, the visibility of the whole expressway can be detected in a real time, round the clock way. It is very important for the traffic safety of the expressway and plays an effective role of preventing the vicious traffic accident caused by agglomerate fog or sandstorm. However, there are still some problems to be solved. First of all, it is the pre-warning threshold, so we must get the proper threshold of the visibility status through the spot experimentations. And the second is the collimation of the laser, so we must collimate the laser beam at the middle of a silicon photoelectric cell. Because of the long-distance sensor, it is difficult to collimate the laser beam at the construction spot. So we need to solve the problem by some engineering methods.

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References
[1] Xinhuaten The expressway of China is the second longest of the world
http://news3.xinhuanet.com/photo/2004-10/27/content_2145944.html.
[2] Sun H J 1994 The survey of the visibility measuring meter J.Marine instrument of meteorological hydrology 1 32-40
[3] Wang Q M, Xie L B and Mei P CH 2001 The principle and picketage method of forward scatter measuring of the visibility J.Optical technology 4 10-16
[4] Lin L, Wang X L and Li G 2005 Study on a New Type Lock-in Amplifier Detecting Circuit J.Journal of Tianjin University 36 65-68
[5] Rao Y T 2003 The Principle and Application Technology of The CAN Bus(Beijing:Beihang University Publishing House)
[6] Li G and Lin L 2004 The Measuring and Controlling Circuit (Beijing: Higher Education Press)
[7] Qian J Q, Hui M and Wang D SH 2004 Dual axis small angle measurement installation based on track signal processing J.Optics technology 30 176-178
[8] Chen J Y, Zhang B Q 2002 Temperature Control of Optical Heads in Visibility at Airports J.Measuring and Controlling technology 21 23-25