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Bridge Safety Monitoring Technology Based on Risk Traceability Mechanism

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Abstract: The role of the environment because the bridge structure is subjected to erosion of harmful substances, vehicles, wind, earthquakes, fatigue, and other human factors, and their continued degradation of the material properties, resulting in the part of the structure to meet the design life far produces varying degrees of injury, this paper analyzes constructed deflection video surveillance systems, including video surveillance system consisting of hardware, design features and recognition module, as well as traceability of risk monitoring database design, wireless remote real-time bridge health monitoring.

Keywords: Deflection Monitoring; Video Monitoring; Risk Traceability

1. Introduction

As the rapid development of bridge construction, the safety and durability of bridge structures are paid closer attention. During the construction and service process of bridges, because of environmental issues, erosion of harmful substances, vehicles, wind, earthquake, fatigue, human factors and degradation of properties of materials, every parts of structures are kind of damaged far before they reach their design ages, furthermore, if those damages are not monitored and repaired on time, the safety of driving vehicles will be impacted and service life will be shorten at least, or sudden damage and collapse will happen at worse.

In order to monitor the safety issues of bridges, a monitor system that includes deflection, inclination, acceleration and stresses was constructed. The hardware parts of the system are series of sensors, they monitor data actively, in other words, data will be collected every short time period (like 1sec) and transferred to the backstage database. Although the system is better at monitoring the safety of bridge structures continuously at every aspects, only time and state of danger of bridges will be known without any reasons or information, as a result, it’ s a disadvantage for engineers to figure out safety risks and analyze the performance evolution of bridge structures. In fact, usually overload vehicles will cause severe deflections of beams, which serve as a main reason of dangerous state for bridge structures. On the other hand, when a relatively large deflection occurs, information of vehicles on bridges need to be traceable simultaneously especially the license tags of suspect overload vehicles, which could serve as additional information of safety monitoring for bridges. Based upon, traceability problem of safety and risk for bridges is put forward.

2. The Risk Traceability Technical System on Basis of Abnormal Triggering of Deflections

As mentioned above, deflections are most related to safety risk. Deflections are collected by deflection sensors actively; as a result, two processes need to be done to obtain information of vehicles under positive deflection: the first process is collecting video information on site simultaneously and continuously, then save photos of vehicles and then recognizes license tags; following is relating video information to deflection data in database to screen suspected vehicles. The technical path is as Figure 1.

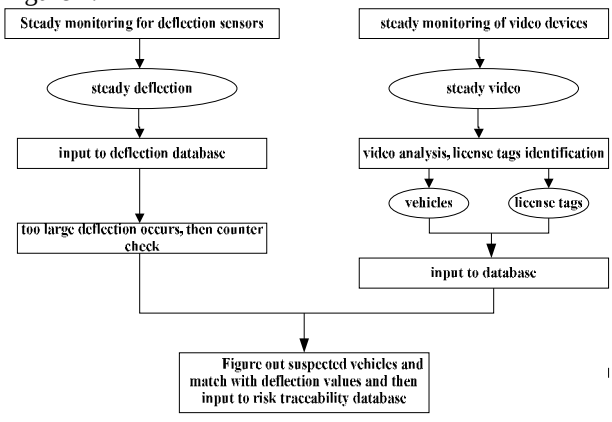

Figure 1. Path of Technology of Risk Traceability

3. The Bridge Safety Monitoring System Design on Basis of Risk Traceability Mechanism

3.1. Construction for Video Monitoring Systems

The main target of video monitoring system is to photograph consistently, recognize and save information of photos of vehicles thus to collect the first data of risk traceability.

2.1.1. The design of hardware components for video monitoring systems

The core of video monitoring system is called High Definition Latch One-body Machine assistance with power supply system, data transmission system and other affiliated devices.

The HD bayonet AIO is most likely a basic product of intelligence transportation integrated with image collection, vehicles screening and capturing, and license tags recognition, which has a performance of high speed information processing. During projects construction, engineers only need set up the machine on the entrance of bridge, then debug and configure to achieve functions above to simplify the project construction and maintenance.

This device has the functions of screening vehicles, capturing strong supplemental light and license tags identification. The image collection module adopts CCD image sensor that supports a working pattern of steady video collection and capturing; in addition, the module of license tags recognition uses the most advanced computer vision technique over the world and it can identify vehicles or vehicles in captured images in high speed in continuous videos in addition with capturing strong supplemental light images, then those images and results of license tags recognition are packed to output to backstage central server simultaneously data backup will be set up via web hard disk.

The main processing module includes leading collection module of image collection, data processing module (double CPU) and storage module, the structure frame is as Figure 2.

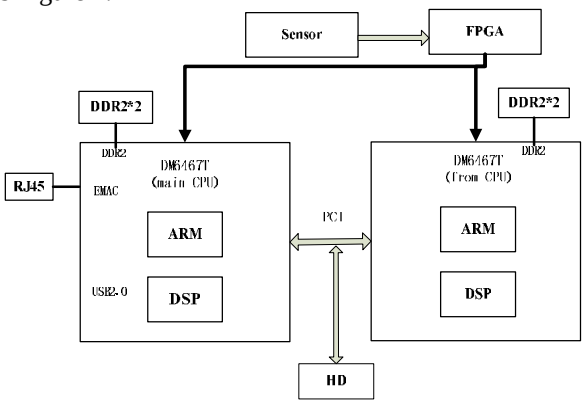

Figure 2. The internal structure of HD bayonet AIO

The vehicles screening and license tags recognition modules of HD bayonet AIO are mainly based on the High Speed Da Vinci Processor (TI DM6467T), equipped with EPROM, RTC and other CMOS chip, built-in with embedded special operating systems, mathematical algorithms library, image algorithms library, TCP/IP protocol stack for capturing and automatic mission recognition and the device provides standard interface for applications of PCs.

The software system has four modules that include image collection, tracing and screening for moving objects, license tags screening and identification and coding output of images, the working flow is as Figure 3.

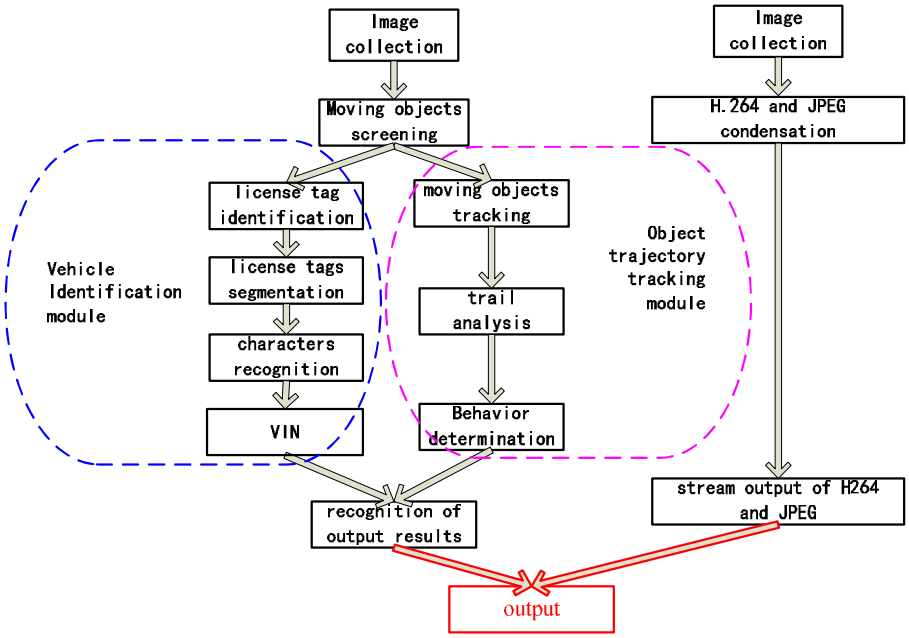

Figure 3. Workflow of HD bayonet AIO

2.1.2. Function design of video monitoring systems

The device includes two functional modules: leading image collection and vehicles screening and license tags identification

1) Main function and characteristic of image collection module

a) Collection mode: supports a working mode of steady video collection as well as under that mode capturing images, in addition, parameters of video collection mode and image capturing mode are independently controlled.

b) Data format: supports two formats: JPEG and H.264 stream media.

c) Output frame rate: under the situation that synchronous signal is input without power grid the frame rate is 15fps, oppositely is 12.5fps.

d) External synchronization: image collection has the function of external synchronization, and when no external synchronization is input, the working pattern is based on frame rate configured internally and vice versa. While under external synchronization, the delay of video mode and capturing mode can configure independently to adjust synchronous phase.

2) Automatic photometric control

The device has the function of automatically photometric control which includes two kinds as below:

a) Automatic gain control AGC: Adjusting according to the brightness of current scene automatically in order to achieve the best effect of images.

b) Automatic white balance AWB: Balancing components of red, green and blue automatically in order to reflect the true color of real scene; In addition, manually white balance is also supported.

3) triggering capture

The device has two methods to receive triggering mission and capture images:

a) Software triggering: capturing will be triggered by software

b) Hardware triggering: capturing will be triggered by external devices.

4) Transparent transfer of series of ports:

The device provides a series of ports to finish the transparent transferring process.

5) USB interface:

The device provides an USB interface. That interface is reserved and not to be used.

6) Working state reporting:

The device has instant working state reporting function which includes working state, license identification state, and client connectivity state.

7) Input / Output:

The device provides six IO input ports and three output ports: one power grid synchronous input, four triggering input, one out capturing triggering input, one stroboscopic signal output, two flash lights triggering output.

8) Unchanged user configuration information:

The device utilizes EEPROM to save all information of user configuration in order to continue working after power is off without reconfiguration.

2.1.3. The function of screening and recognition module

1) Vehicles screening

The device adopts a pure video monitoring pattern to screen and recognize video stream images automatically in real time and frame by frame without the assistance of induction coil, which overcomes disadvantages of high budget of construction and difficulty of long term maintenance under traditional vehicle monitoring technique that has external trigger (e.g. induction coil)

2) License tag recognition

The device has function of license tags recognition and supports both standard double layer tags and tags of close range motorcycles. Information provided externally includes: thumbnails of license tags (monitoring images of license tags and dichotomous values), large images of vehicles, VIN number and color of vehicles.

3) Human face identification and capturing

The device can capture all monitoring vehicles, and the system fill light according to special capturing fill-in light, the captured image can recognize the face features of drivers and passengers in front seat clearly without impacting the recognition of license tags.

4) Vehicle colors identification

The device has a color classification function for vehicles in accordance with GA24.8-2005 which classifies ten standard vehicle colors: white, gray, yellow, pink, red, violet, green, blue, brown and black.

5) Determination of vehicle types

The device can determine the type of vehicles and then provides three types of vehicles in additional information: large, medium, small. Furthermore, the detailed dimension in meters of vehicles such as length and wide will be provided to users in order to view or information calling.

6) Speed test via video

The device will test, lock and track moving objects in video stream images, and then describe the moving trail of objects exactly, meter their displacements accurately, calculate the precise velocity of moving vehicles. The accuracy of velocity metering should be in accordance with specific DOTs or other departments.

7) Illegal line passing monitoring

The device will test, lock and track moving objects in video stream images, and judge if vehicles pass the line or have moving violations according to the trail of moving vehicles and user defined lane separating lines or double yellow lines as well as distinguishing, then photograph illegal vehicles as evidences. The output images are advised to use the affiliated tools provided by our company to prevent tampering and authentication.

8) Illegal driving direction monitoring
The device will test, lock and track moving objects in video stream images, and determine if vehicles are driving in right direction according to the moving trail of vehicles. If wrong driving direction is detected, the device will determine that certain vehicles illegal and then photograph as evidence. The output images are advised to use the affiliated tools provided by our company to prevent tampering and authentication.
9) Images overlapping function
The device supports character-overlapping function. After configuring parameters (include device time, section name, and section direction), the device will overlap character information in stream images automatically and in the clear recognition image, the overlapped character information will be available as well as saved video streams.
10) Adaptive parameters control of image collection
The device can determine the brightness of surrounding environment automatically in order to achieve the best effect of recognition and monitoring under whatever brightness such as daytime, cloudy and nighttime.
11) Information filtering
The device provides filter function for license tags recognition information, and users can define the information types of output results based on own needs in order to filter any unconcerned information. In addition, users can change the filter conditions any time without impacting the state of running device.
12) Supervisory computer
The device supports three types of connections:
a) Results-recognition data linking, the device provides two data links.
b) Command links, the device provides one command link. After the connection between server and device is built, the server will send a mission request and the device will respond correspondently to command received. Command links are short links and after execution the connection will disconnect instantly.
c) Video stream links, the device provides one H.264 stream and two JPEG image stream links.

2.2. Risk Traceability Database and Backstage Software

2.2.1. The design of risk traceability database

Based on deflection sensors and other sensors on bridges, the overload vehicles that exceed the threshold will be captured synchronously. Additionally, the capturing function can utilize two modes of positive synchronization and negative synchronization, and the database designed by system correspondently will save the data information of risk traceability in coordination with matched deflections.
1) Active synchronization method
The video synchronization system applies a specific sampling frequency of 30s and it will actively search and match every that time period to locate any matched data. The deflection early-warning database called alarm form is provided by the bridge dynamic monitoring system, and the form is used to retrieve the time value and search the local video database, and photos before and after 15s of the time value will be transferred to designated server and updated the url and v num to assist the bridge dynamic monitoring system to access and exhibit.
2) Passive synchronization method
Time period is designated by on scene monitoring, which is called a passive method, and photos are searched, sent, and transferred to distal server, which is provided by web service. The video synchronization system provides a data server via an unchanged IP address on public network as well as database field introduction and structure figures, based upon, the bridge dynamic monitoring system takes a responsibility of integration of subsequent sensor data. The bridge dynamic monitoring system provides storage process on basis of different types of data structures, and the video synchronization process accesses storage process and stores data simultaneously.

2.2.2. The design and development of software functions

1) Trend analysis
The software is expected to conclude a long term relationship between changes of bridge deflections and situations of moving overload vehicles according to a long time period accumulation of risk traceability data information through Kadir Coordinate, which, time is on abscissa and risk parameters are on ordinate, as a result, a trend map of parameters-time will be drawn, respectively. According to this trend map, changing conditions of structures can be known and, to some extent, it's an advantage to forecast the possibility of happening danger of structures.
The trend analysis can only be based on a long term and massive data and comprehends the changing conditions of structures to estimate the trend of structure health development according to mathematical statistics, data fitting and other methods. Generally, statistical parameters include extremum, mean value, variance, probability density and number of stress loops as well as frequency of structures and other changes of integrity parameters.
However, if significant changes occur among above parameters throughout time comparing with theoretical and experience values, a detailed analysis needs to be executed to figure out the essence of specific problems. Furthermore, possible development situation of structures can be estimated on basis of massive data to prevent and repair before too late.
2) Risk traceability
During the long term evolution process of safety performance of bridge structures a relative deterioration of the

stage can be analyzed and responsible vehicles that caused extreme positive deflection, shorter service life of bridges can be located quickly. Though a direct accountability is not needed for those vehicles, for the long term evolution process of bridges, a desirable explanation is available. Besides, when severe accidents happen suddenly, in some special conditions, the traceable data information is first hand document and comparably precious.

2.2.3. Software development and application

The software is developed via webpage form and embedded to the backstage of the whole bridge monitoring system. The front page (Figure 4) shows the newest data value information that includes temperature, humidity, traffic flow, wind information and others.

Three icons occur at the upper right corner of the main interface of system, clicking those icons can view the early warning information, change password and close, as Figure 5.

Click to the early warning icon, a pop-up interface is shown (figure 6), corresponding deflection value, time, video information, license tags and others are accessible.

If users are willing to save the data to local, they can click as figure above on upper right corner. Two formats that includes excel type and CSV type are available. Click the Excel image on upper right corner will lead users to download and save data to Excel documents. The pop-up interface for choosing the saving location is as follow (Figure 7):

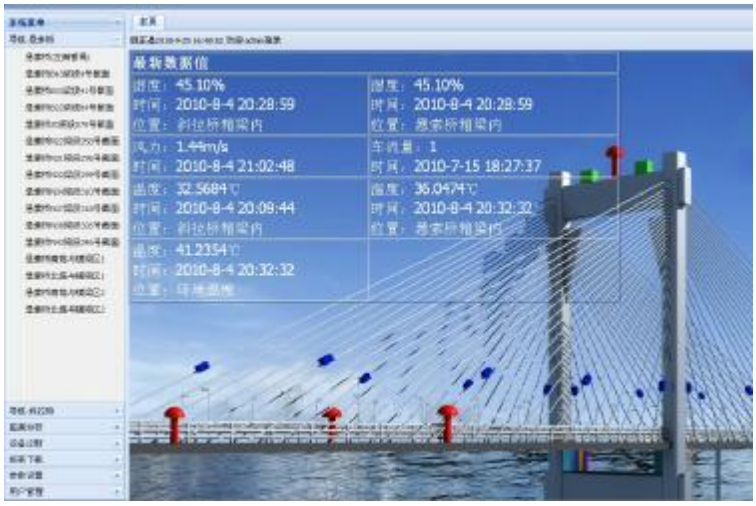

Figure 4. Home page of the software

Figure 5. System management function key

Figure 6. The warning information

Figure 7. The data saving

Conclusion

Based on rigorous analysis, the deflection video monitoring system is constructed, which includes the hardware formation, functions, the design of recognition module, and the designs of risk traceability monitoring database and backstage software, and a wireless and real time monitoring for bridge health is achieved. The achievements mentioned in the paper have a profound and lasting significance for the development of health monitoring of bridge structures and safety estimation.

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