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A Real Time Vessel Air Gap Monitoring System

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Abstract. A vessel air gap monitoring system for use on shipping lanes, and harbours to protect bridges and other structures is reported. The system utilizes two video cameras to monitor a transect of the waterway downstream from a bridge and image processing to automatically detect vessels and measure the highest point of the superstructure. The system has been successfully trialed on the Loop 602 bridge across the Houston Ship Channel.

1. Introduction
In many waterways and harbours around the world it is common place for vessels to have to pass under bridges and other structures such as power lines that span the waterway. In a number of situations there is very limited clearance for the vessels to pass under the bridges. The trend for increasing vessel size and traffic means that there is an growing risk of vessels colliding with bridges. In tidal waterways the tide variations cause additional problems in assessing whether a vessel may safely pass under a bridge. The known bridge height along with information on nautical charts relating to the highest astronomical tide, are traditionally used in combination with the estimated air draft of a vessel to assess whether it may safely navigate under a bridge. The air draft is the distance from the water line to the highest point on the vessel; typically the highest point will be part of the superstructure such as masts, aerials and cranes. This approach suffers from two principle drawbacks, firstly the actual height of the tide may vary from the astronomically predicted level and secondly inaccuracies in methods of estimating the air draft. Estimating the air draft is not straightforward, as the weight of cargo, fuel load and ballast in a vessel will alter the air draft. These uncertainties have led to a significant number of expensive and dangerous vessel collisions with bridges in waterways across the world. For example the Loop 602, also known as the Sidney Sherman Bridge, in Houston, Texas, which carries the Interstate 610 road over the Houston Ship Channel, has had a number of such ship collisions in recent years. In one instance the crane aboard a vessel punched a truck-sized hole completely through the northbound lanes of the bridge. This incident closed both the freeway and the waterway. These collisions not only cause transport disruption but are expensive. Damage of more than $600,000 to the Loop 602 bridge caused by a vessel collision in December 2000 and a second six months later costing $800,000, illustrates the economic impact of such vessel-bridge collisions. There are thus significant safety and economic gains, both by increased commerce and the avoidance of...
collisions, to be realized by having systems that can rapidly and accurately determine the height of the topmost point of a ship’s superstructure relative to the land and hence the air gap for a given bridge.

Radar and microwave approaches to providing effective bridge air gap monitors have been developed (1,2), however these systems generally require to be fixed on the bridge and thus are of limited use in providing accurate advance warning that a given vessel will not safely pass under the bridge. There are a number of eye-safe laser systems in which scanning laser ranger systems have been used in height measurement as well as bridge and tunnel clearance warning applications. However such systems are not effective over the long ranges required for waterways (3). Although it would be possible to extend the range of such systems by employing higher power lasers, the associated health and safety issues make such an approach impractical. The large number of personnel typically found on vessels and around harbours etc makes it more desirable to employ passive sensing systems for the measurement of vessel heights. Optical ranging and photogrammetry techniques that have been widely applied in civil engineering offer a route to such passive dimensional measurements (4,5). These techniques utilise simple triangulation techniques and when combined with video and imaging systems may be readily automated.

![Figure 1: The Vessel Air Gap Monitoring System](image)

2. The Vessel Air Gap Monitoring System

The vessel air gap monitoring system reported here is a passive optical system designed to monitor shipping lanes, harbours and floating production facilities, and issue an early warning to monitoring stations when ships and crane-booms etc exceed predetermined heights. As shown in figure 1 the system comprises a camera system made up of two high performance video cameras positioned one above the other in a parallel configuration, with a vertical spacing of typically 1m. The camera system is mounted at a known height on a structure as close to the waterway as possible and with a clear view of a transect of the navigation channel. The video signals from the cameras are input to a computer housed in an on-site control unit and processed using custom video-imaging and processing software. The system utilises stereophotogrammetry to measure the height of the vessels. This is achieved by having the software simultaneously capture images from both cameras of a new vessel entering the
field of view. The software then identifies the camera pixels that correspond to the common highest point of the vessel in both images and the measured pixel disparity is used to derive the actual height of the uppermost point of the vessel. The system has a measurement log which records video images and heights of vessels. The system control unit also contains a communications system, which can be configured to suit the local communications infrastructure, for example land lines or wireless systems. The communications system is used to transmit alarms to the monitoring station, which may for example be located in the local harbour master or coast guard facilities. The system is designed to have a measurement range of 700ft and be able to detect and measure superstructure components as small as 4inches, such as radar reflectors at the top of masts. The system has an operating temperature range of –10 to +50°C.

The Vessel Air Gap Monitoring System reported here was developed specifically for vessels on the Houston Ship Channel passing under the loop 602 bridge in Houston, but is applicable to a wide range of other bridges and structures. There are a number of local factors that have to be taken into account in designing the system. The first is the small number of suitable sites along the channel to locate the Air Gap Monitoring system. A suitable site has to be sufficiently up or downstream from the bridge to allow a vessel to be stopped before reaching the bridge, as well as having access to a power supply and being accessible for system maintenance. As illustrated in the figure 2, which shows the view from a system site, the banks of the Houston Ship Channel are heavily built up. From the image in figure 2 it can be seen that there are a large number of buildings and structures in the field of view of the system.

![Figure 2: Typical view of a vessel travelling along the Houston Ship Channel.](image)

**3. Field of View and Threshold Settings**

For effective operation it is important for the air gap monitoring system to have a clear background against which it can detect objects coming into view. As can be seen from the images in figures 2 and 3, taken at typical sites on the Houston Ship Channel, there are many objects within the field of view of the system. As the system works by detecting the highest point visible in the image it is clear in these examples that there are many structures that would give false readings. These include the obvious Tower and Pole which span the complete height of the cameras view, as well as the two chimneys towards the centre of the screen in figure 3a. To overcome this problem the camera view to be monitored can be narrowed down to a selected Region of Interest (ROI) using the software. In normal operation this ROI will be set during installation of the system. However, it is important to
understand that should a permanent structure be erected within this region after the ROI has been set then this will be detected as an alarm. Should this occur then the ROI field will require to be updated.

As shown in figure 3b there are three Region Of Interest lines that can set to define the monitored area, these are the Left and Right ROI Horizontal scan lines and the Vertical ROI scan line. Once set, the software will only scan within the area above the Vertical ROI and between the left and the right Horizontal ROI’s. Once the ROI has been defined, height threshold levels that will generate an alarm when an object exceeding the height threshold is detected can be set. When an alarm is generated the video image of the vessel that triggered the alarm and the measured height of it’s uppermost point are sent to the local monitoring station.

![Figure 3: Region of Interest lines](image)

4. System Trials
The system was trialed as a vessel air gap monitor for the Loop 602 bridge across the Houston Ship Channel. The shipping channel is around 500 feet wide at the bridge, while the bridge is 1,233 feet long, however only 400 feet of the span is high enough for ships to pass beneath it. The air gap monitoring system was installed on top of a transmission tower located 200 feet from the shipping channel. The site was sufficiently far down stream from the bridge and a vessel turning basin to allow time for the Coast Guard to inform the vessel that it cannot pass under the bridge and have it stop at the turning basin. The height threshold for safe navigation was set at 135 feet and height alarms along with the associated vessel images were communicated to the local Houston U.S. Coast Guard facility. The system was successfully run at the trial location for a six month trial period during which it detected a number of vessels with dangerously high superstructure. Figure 5 shows two examples of images of vessels navigating the ship channel at the air gap monitoring system location with the measured heights. In the first image it can be seen that upper most point on the superstructure was measured at 112 feet and hence the vessel was able to safely pass under the bridge. In the second image it can be seen that a crane on the vessel is raised and the measured height is 155 feet. This exceeded the 135 feet threshold and thus generated an alarm. In this instance the Coast Guard was able to advise the ship to lower the crane prior to passing under the bridge.
5. Conclusions

An effective vessel air gap monitoring system designed to monitor shipping lanes, harbours and floating production facilities, and issue an early warning to monitoring stations when ships and crane-booms etc exceed predetermined set heights has been developed. The system utilizes two video cameras positioned one above the other with a vertical spacing of typically 1m, which are mounted close to the waterway with a clear view across the navigation channel. The system has been shown to have an operating range of 700ft and is able to automatically detect vessels and measure the highest point of the superstructure. The system allows threshold height levels to be set for safe navigation under a bridge and transmits alarms along with a video image of the relevant vessel if the threshold level is exceeded. The system has been successfully trialed as a vessel air gap monitor for the Loop 602 bridge across the Houston Ship Channel.

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