Integrated Camera and Sensor Systems Scan Freight Rail

Improving the performance, efficiency, and safety of the US rail network is a daunting challenge. It takes innovation and creativity to make any progress. But with billions at stake, every single gain can pay off in a big way.

Accounting for 69 percent of U.S. freight rail mileage and 90 percent of employees, America's Class I freight railroads operate in 44 states across the United States and concentrate largely on long-haul intercity traffic. There are seven Class I railroads: BNSF Railway, CN, Canadian Pacific, CSX Transportation, Kansas City Southern, Norfolk Southern, and Union Pacific. Each company is worth billions of dollars and is essential to commerce across the company.

So what do those companies prioritize? Their goals are operational efficiencies, increased situational awareness and the ability to address needs instantaneously. That adds up to one clear mandate: improving network velocity. Trains that are moving, transporting goods, are trains that make money for the company. If trains are undergoing maintenance, break down, or have to slow down, money is lost. So finding ways to improve the reliability of trains improves velocity. But having to check each train can require stopping the train, reducing overall velocity. Increasing the average network velocity by even one mile per hour can add ten million dollars a Class I railroad. Enter Duos Technologies and machine vision.

From Bridges to Pictures

Headquartered in Jacksonville, Florida, Duos Technologies, Inc. specializes in critical infrastructure protection systems. It creates networked intelligence solutions to streamline workflow, improve processes and utilize technology to disentangle those hard to solve quandaries. The company has developed technology solutions for complex, high security sites like railroads, ports, and chemical, industrial and government facilities. They also provide automated, real-time detection and reporting of incidents along with distributive alarm management features.

With combined expertise in instrumentation, control technologies, information technology, and engineering disciplines, Duostech provides customized integrated systems for business and government requirements, with a focus on critical Homeland Security applications.

These advanced systems can provide real-time views of railcars, monitor trains to detect illegal riders, identify missing hatches and open boxcar doors or detect unwanted intrusions on platforms, tracks and within rail yards. Systems are available for remote

drawbridge operation while monitoring the same bridge for piling collisions or for identifying defects on pantographs or undercarriage structural components. The end result: a range of rapid return on investment (ROI) solutions for the railroad industry that enable railroad operators to reduce liability, improve on-time performance and increase rail operations productivity.

Deciding on Machine Vision

Duos Technologies didn't start out in the imaging business. Instead, their work originated with robotics and automation, building remote control bridge systems. After 2001, the government starting looking at critical infrastructure differently. "Everything changed after 9-11," explains Scott Carns, Vice President of Operations & Engineering at Duos Technologies: "Everything went to security."

Duos knew so much about bridges that their rail customers asked them to help secure other critical infrastructure assets that were now being closely analyzed and represented a substantial vulnerability to commerce in the United States.

The first of these new implementations was a test project for the Union Pacific railroad in Texas. Duostech developed what was to become the Train Rider Detection System (trids™), which performed the automated detection of riders hiding in railcar wells, which have been the typical hiding place on trains traveling at speed. This system offered inspection personnel an expedient and efficient method of isolating and identifying anomalies of interest, with much faster and more thorough inspection than the previous all-manual process.

Images of areas of interest are identified automatically by custom Duostech software algorithms and presented to the operator for validation. The system is intentionally set to a high sensitivity to avoid false negatives. A version upgrade has just been completed which expands the detection area to the entire car areas.

Incorporating Machine Vision

Duos knew so much about bridges that their rail customers asked them to help secure other assets and critical infrastructures that were now being closely analyzed and worried about. Monitoring so many different objects led them to video. The company became an early adopter of imaging in the late 90s, and integrated the all-analog NTSC video systems with human-machine interface (HMI) systems.

Today its video-camera-powered imaging systems stitch together HD images to enable foreign object detection. The system operates at speeds up to 15 MPH, which require the trains to slow down as they pass through the inspection portal. For many of the needed applications, this was good.

But good is not always good enough. Duostech knew that by increasing the performance of its imaging system, it could offer its customers greater return on investment. A high

resolution, high-speed intelligent machine vision system would allow its inspection portal to span across security, safety, mechanical and operational applications.

For Duostech, there were pros and cons of the technology, from different compression algorithms to the complexity of managing the speed and sensitivity of more sophisticated cameras. This is especially true when the target is a train travelling at 65+ miles per hour only 18 inches away in an uncontrolled environment.

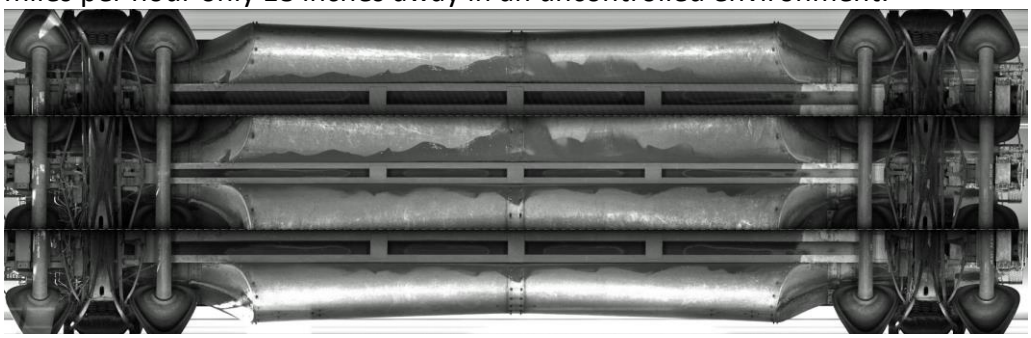

Figure 1: Full Rail Carriage Scan

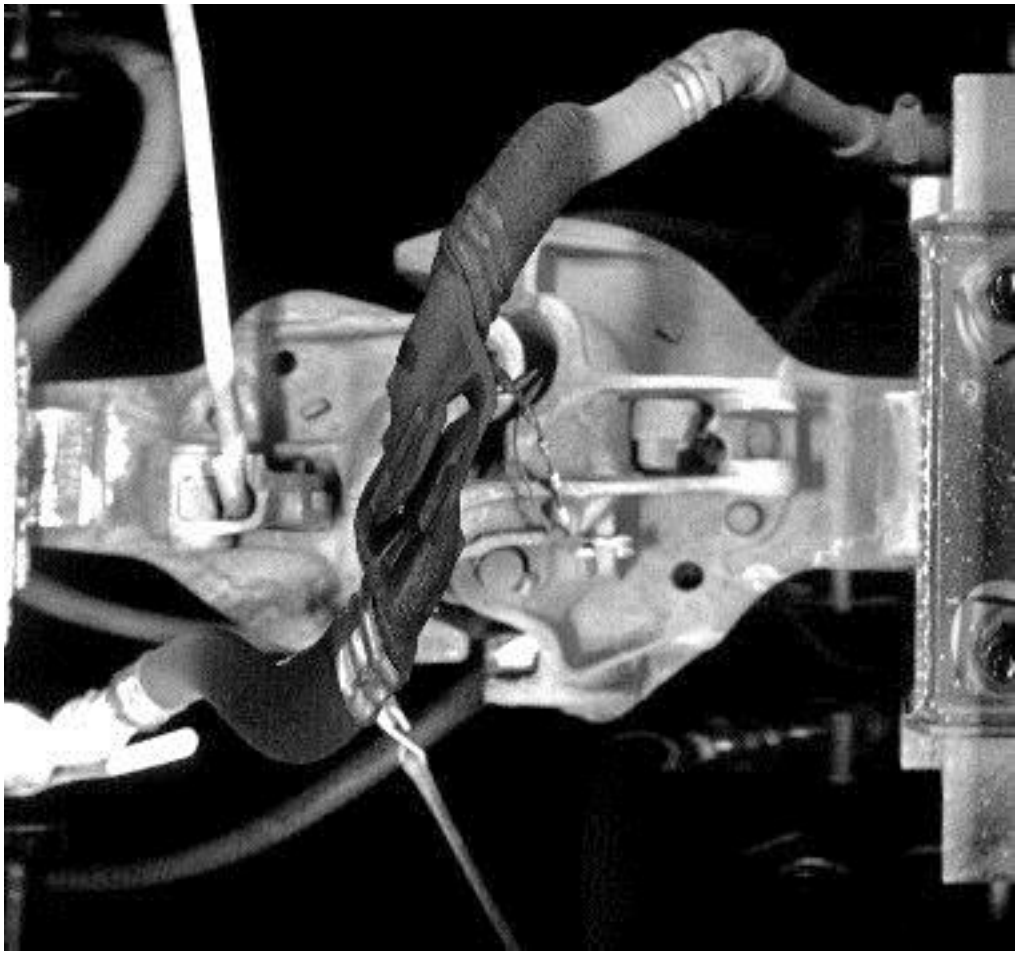

Figure 2: Zoom of Car Coupling on Railcar, Imaged at 45 mph with the xtd Extreme True Definition System, with 2K Teledyne DALSA line scan camera.

Named *xtd Extreme True* Definition Technology, the system uses 2K line scan cameras that generate 224 Megapixel images per railcar. “I could write my name in pencil on the axle of a trainer and be able to read it perfectly clearly.” says Carns. “Once you have clearer view of one object or feature, you move on to what else you can look at,”

The use of a line scan camera (as opposed to an area scan camera) gave an additional level of adaptability. Scanning and identifying trains cars is complicated by the fact that they don’t run with the regularity of a manufacturing line. They stop. They back up, and then go forward again. Without a line scan cameras, system would have had a much tougher time adapted to these kinds of events, with the images becoming bloated, fragmented, or distorted. For this integration, Duostech developed a high precision speed sensor that allowed for synchronized system capture at increased speeds of up to 70 mph.

Taking a Closer Look

Duos Technologies' Rail Inspection Portal (rip™) is the latest technological innovation and deployment for rail security and inspection at border, yards and inspection areas.

Under a Union Pacific (UP)-funded pilot program at the Eagle Pass, TX border crossing, duostech designed and developed a leading edge portal to provide the US Customs and Border Protection (CBP) agency with a tool that would aid customs officers in the inspection of inbound rail cars. The rip™ system uses multiple technologies and sub-systems to remotely scan all railcars passing through the inspection portal, then displays stitched 360-degree views of the entire rail consist.

It uses sensors and analytical algorithms to pre-screen railcars and to automatically detect and report anomalies and standard deviations from established norms. The system features an automated Foreign Object Detection (FOD) algorithm that compares the undercarriage images to reference images taken from the same car during an earlier scan. The uvis images are "matched up" for comparison by using the unique car identification code provided by the AEI tag system.

The detection algorithm looks for "all" differences and circles respective detections for closer inspection by an operator. Detections can be filtered through sensitivity variables. When it came to looking further, a better solution was needed that would adapt to this tougher application. Adapted area cameras were selected for looking up from under the train. That required developers to build new systems and learn the new machine vision industry with its new formats. These systems have now been adopted to secure multiple border crossings throughout Southern United States border crossings.

Utilizing the centraco™ command and control platform as the system interface, the user accesses a variety of features enabling remote inspection, analysis and detection from the safety of remote command centers. Images containing detailed views of areas of concern, determined to be "potentially suspicious", are automatically presented to a

human operator for further inspection. Users conduct a quick review of the pre-screened imagery and decide whether to refer specific areas of interest to field personnel for further (physical) inspection.
The system is not intended to "replace" the human operator; rather it is designed to help streamline the physical inspection process by narrowing the number of inspection targets down to cars with "potential" anomalies. Consequently, the detection sensitivity is intentionally set to err on the safe side so as to avoid false negatives.

The system also resolves the particularly difficult process of inspecting rail car undercarriages by providing high-resolution images for remote evaluation. Embedded between the rails, it captures a dual view of the train at opposing angles in order to maximize the visual information. The images are assembled (stitched) to create a continuous panoramic view of the entire length of the rail car's undercarriage. Images are stored indefinitely depending on the size of the storage drives.

Even though the trains are moving at up to 65 miles per hour, and the camera is just 18 inches from the trains' undercarriages, the line scan cameras Duos employs still get their image: "I could write my name in pencil on the axle of a trainer and be able to read it perfectly clearly."

Getting It from All Sides
The Linear Panorama Generator (LPG) assembles images gathered from cameras on all four sides of the train and stitches all frames to create a continuous 360-degree view of the entire train.

As the train passes, laser sensors scan the top and sides of the train to detect open/missing hatches and open doors. In the event of a potential positive identification, the system saves a series of images and enters the corresponding car information into a database: the approximate geo-spatial location of detection, the target car location in the train's sequence, and the approximate distance from the locomotive and/or the AEI tag data.

Operators can quickly inspect the entire train consist by selecting the side of interest and scrolling through the continuous panorama view. The detections are marked on the Panorama images and presented to the operator who will either acknowledge the suggested detection as valid (green button) or reject the detection as invalid. The operator can expand the event to view car and consist information, additional images, or can enlarge specific areas for a closer view of the detection. The operator can select areas to enlarge, tag, save, or print any image of interest. Panoramas are stored indefinitely and dependent only on the size of the storage drives.

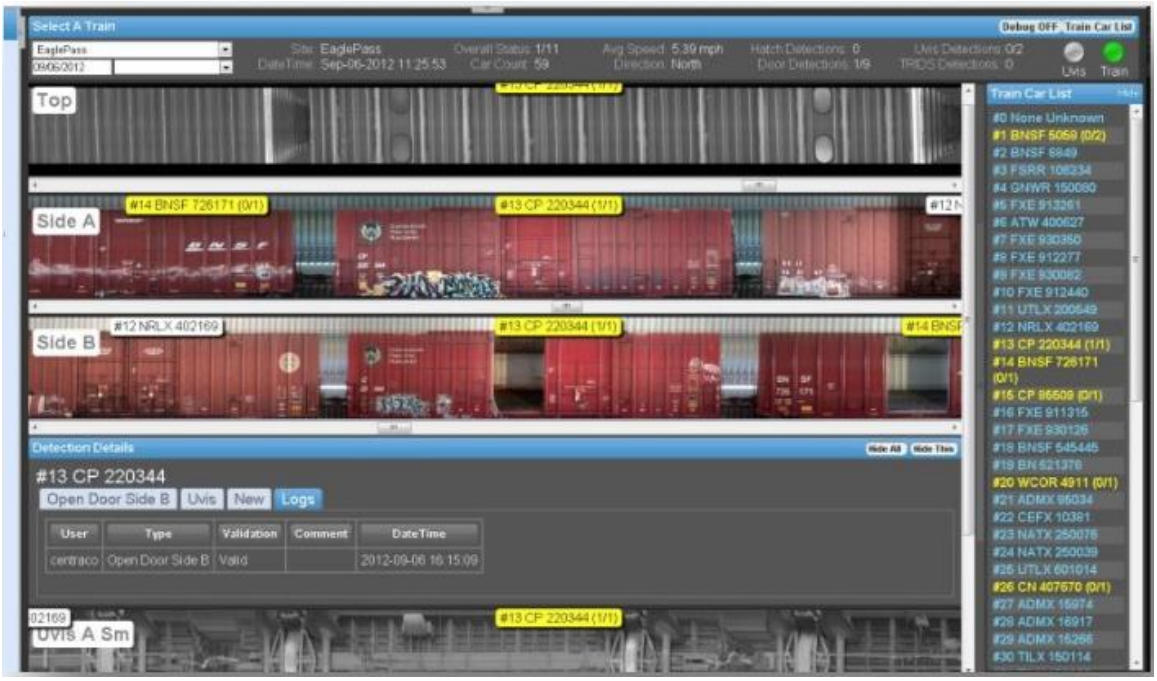

Figure 3: The Linear Panorama Generator (assembles images gathered from cameras on all four sides of the train and stitches all frames to create a continuous 360-degree view of the entire train.

Figure 4: Under-Vehicle Inspection System

This project required Duos to integrate multiple systems: several surveillance systems, including video analytics and radio frequency identification. Together, they created virtual security fence that could detect everything, from moving objects, perimeter breaches, foreign and removed objects, and loiterers along freight-rail tracks.

Increasing Velocity, Accelerating Value

Duos did such a good job on early projects that it continues to lead to new opportunities today. With consistent funding for security projects, the needs of the direct customers come to the fore. What can we do with all these awesome imaging of trains that support the business of the rail transit companies? “The system is in a good place. We have a strong system, and very good images.

With a refined imaging installation, the challenge moves from capturing as much information as possible to analyzing what they get. “If I can see it in a picture, how can software look at that and figure out what it is, at scale? We want to eliminate the human variable.”

Duos is exploring all of the things it can analyze and process based on its high-resolution images, everything from sudden events such as intruders, registration information, foreign objects, or breakages, but also , changes wrought by gradual stresses that take train hardware out of regulatory tolerances.

New Technologies, New Opportunities

“We have to stay on the bleeding edge. We do these ground-up deployments. We always have to stay abreast of the latest stuff,” says Carns.“We go to SPIE Photonics Group conferences to look at camera tech every year. Short-wave infrared (SWIR) imaging is interesting,” says Scott Carns, “With our current cameras, we often use white LED lighting for our inspection systems, which has pros and cons. The crazy variance of depth means that proper exposure is really hard to get. With SWIR, we can look at illuminating with laser light, which is much more even, giving us better coverage even with a lot of depth and light variance.”

Trains will also be going faster soon. “At 65mph, our 2k color line scan cameras can handle it all day. But trains in the US will start going faster soon. The high-speed rail line being built from St. Louis to Chicago will be able to go 120mph. Trains in Asia and Europe already go much faster than that. We’ll want to keep up.”

So while security continues to be an evolving challenge, the overall business benefits of 100% rail inspection across multiple domains will drive investment and innovation.

“The coolest part of my job is that we get to invent things that don’t exist.” With a clear business value, fast-evolving technology, and a long future, the coolest part of Scott Carns’ job is secure.