Regis University
ePublications at Regis University

All Regis University Theses

Spring 2010

Improving Optical Character Recognition Accuracy for Cargo Container Identification Numbers

Mark Bayless
Regis University

Regis University
School of Computer & Information Sciences

<u>Certification of Authorship of Thesis/Project</u>

Student Name: Mark Bayless

Student Telephone: 509-582-6326

Student Email: md_bayless@msn.com

Degree Program: MS in Software Engineering

Advisor Name: Daniel Likarish

Date of Submission: March 15, 2010

Title of Submission: Improving Optical Character Recognition Accuracy for Cargo Container Identification Numbers

Certification of Authorship: I hereby certify that I am the author of this document and that any assistance I received in its preparation is fully acknowledged and disclosed in the document. I have also cited all sources from which I obtained data, ideas, or words that are copied directly or paraphrased in the document. Sources are properly credited according to accepted standards for professional publications. I also certify that this paper was prepared by me for the purpose of partial fulfillment of requirements for the MSSE 698 course.

4/15/2010

Student Signature   Date

Revised 1/29/2010

Regis University
School of Computer & Information Sciences

<u>Authorization to Publish Student Work</u>

I, Mark Bayless, the undersigned student in the School of Computer & Information Sciences, hereby authorize Regis University to publish the document described below ("Work"). I acknowledge and understand that the Work will be freely available to all users of the World Wide Web and the Regis University Digital Repository under the condition that it can only be used for legitimate, non-commercial academic research and study. I understand that this restriction on use will be contained in a header note on the Regis University web site but will not be otherwise policed or enforced. I understand and acknowledge that under the Family Educational Rights and Privacy Act I have no obligation to release the Work to any party for any purpose. I am authorizing the release of the Work as a voluntary act without any coercion or restraint. On behalf of myself, my heirs, personal representatives and beneficiaries, I do hereby release Regis University, its officers, employees and agents from any claims, causes, causes of action, law suits, claims for injury, defamation, or other damage to me or my family arising out of or resulting from good faith compliance with the provisions of this authorization. This authorization shall be valid and in force until rescinded in writing.

Title of Document(s) to be published: Improving Optical Character Recognition Accuracy for Cargo Container Identification Numbers

Mark O Bayless ____________________ 4/15/2010 ____________________

Student Signature Date

Check applicable:

<u>XXX</u>____ The Work does <u>not</u> contain private or proprietary information of the associated parties and their attached permission is <u>not</u> required.

_______ The Work contains private or proprietary information of the following parties and their attached permission is required as well: ____

Name of Organization and/or Authorized Personnel

Revised 1/29/2010

IMPROVING OPTICAL CHARACTER RECOGNITION ACCURACY FOR CARGO CONTAINER IDENTIFICATION NUMBERS

A THESIS

SUBMITTED ON 15 OF APRIL, 2010

TO THE DEPARTMENT OF INFORMATION TECHNOLOGY

OF THE SCHOOL OF COMPUTER & INFORMATION SCIENCES

OF REGIS UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF MASTER OF SCIENCE IN SOFTWARE ENGINEERING

BY

Mark O Bayless

Mark Bayless

APPROVALS

Robert Sjodin

Robert Sjodin

Douglas I. Hart

Douglas I. Hart

Richard L. Blumenthal

Richard L. Blumenthal

Running head: IMPROVING OPTICAL CHARACTER RECOGNITION

Improving Optical Character Recognition Accuracy for Cargo Container Identification Numbers

Mark D. Bayless

Regis University

Abstract

Optical character recognition (OCR) software currently being used at radiation portal monitor (RPM) sites to read cargo container identification numbers is expected to produce 90% accuracy when the containers meet ISO Standard 6346: 1995, *Freight containers – Coding, identification, and marking*. One of the RPM seaport sites was reporting low OCR accuracy results, prompting a request to fix the problem. A data analysis conducted at the site determined overall accuracy was only at 68% (69% for nighttime and 62% for daytime) with poor image quality in both day and night conditions being the primary factor in low OCR accuracy. Nighttime image quality was primarily impacted by inadequate lighting. After conducting several tests to find the appropriate lighting, a new lighting configuration was implemented at the site that included using higher wattage light fixtures and placing the light fixtures closer to the target. This improved overall nighttime OCR accuracy from 69% to 87%. Daytime image quality was primarily impacted by the sun. Placing the cameras at different angles and adding cameras to obtain more images of the containers have the potential for improving daytime OCR accuracy. No changes were made at the site to improve daytime OCR.

Acknowledgements

I would like to thank my wife Debbie, daughter Annie, and son Evan for their patience and understanding while working on my graduate degree program. I would also like to thank Doug Reid for all of his assistance with setting up the testing environment, conducting the tests, and collecting data. Finally, I would like to thank Rob Sjodin for his guidance and assistance as my thesis advisor and professor.

Table of Contents

List of Figures

List of Tables

Chapter 1 – Introduction

Radiation portal monitor (RPM) systems are being deployed at land border crossings, international mail facilities, seaports, rail crossings, and international airports across the nation to assist U.S. Customs and Border Protection in preventing unauthorized and potentially hazardous transportation of radioactive materials into the U.S. Some RPM systems are equipped with a camera system known as the visual identification system (VIS) as depicted in Figures 1 and 2. The VIS captures images of vehicles and cargo entering the U.S. and the images along with other vehicle data are stored in a database.

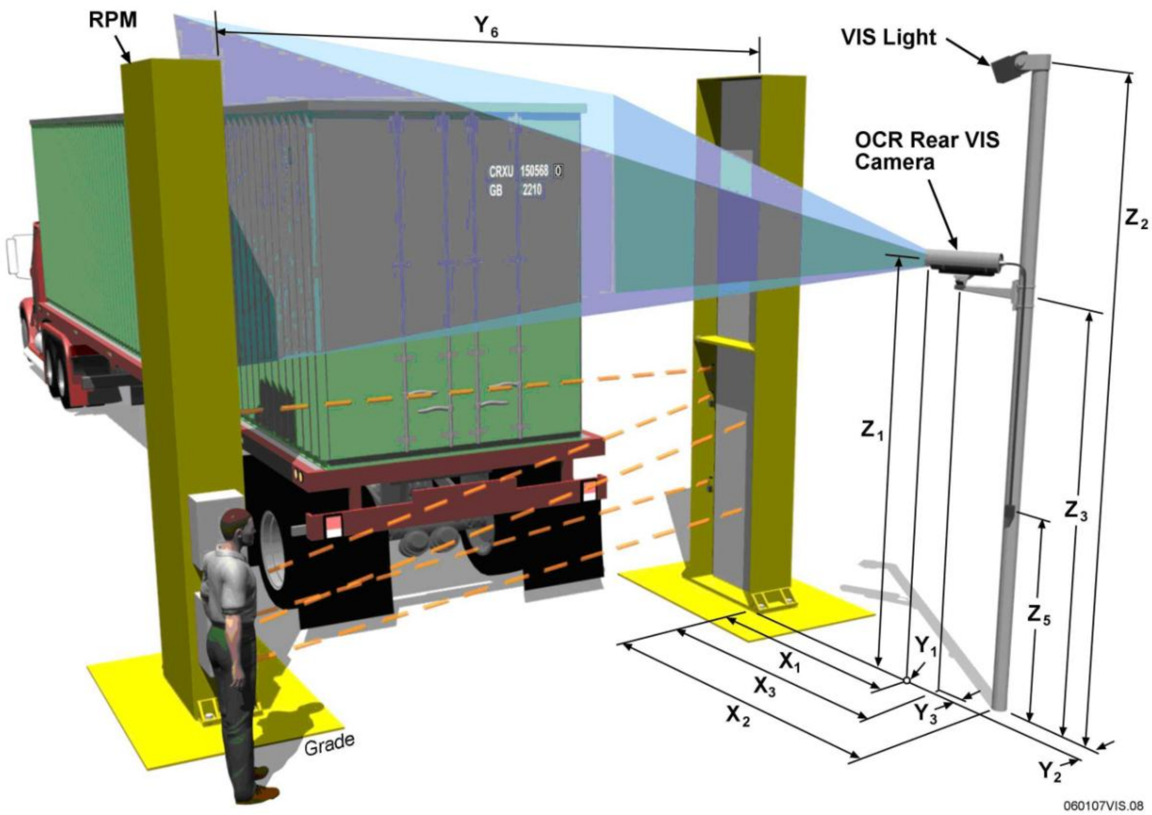

Figure 1: Current Rear Camera Configuration

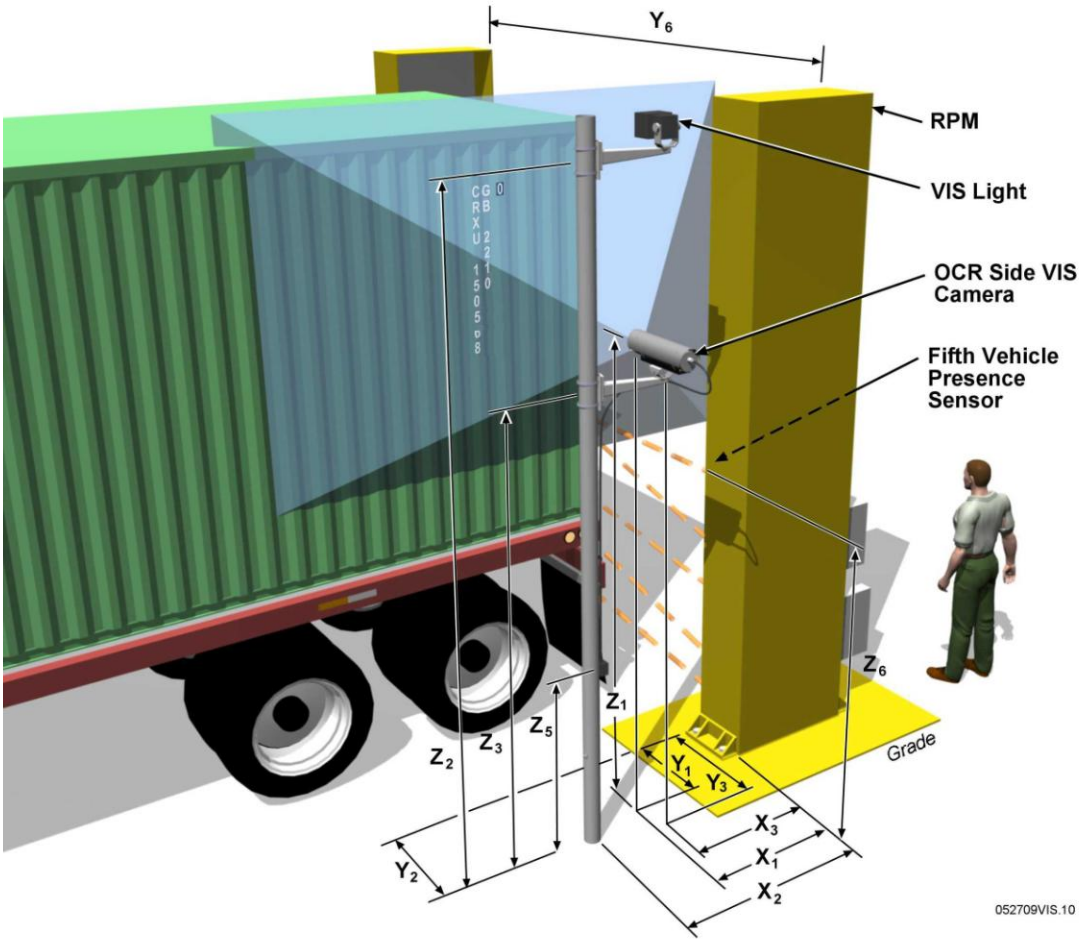

Figure 2: Current Side Camera Configuration

Commercial optical character recognition (OCR) software has been deployed at some RPM sites equipped with a VIS. When digital images of cargo containers are captured, the software reads the images and outputs the 11-character identification number of each container. The software is currently configured to read a single side image and a single rear image of the container. The OCR algorithm uses both images to determine a composite result. The software is capable of generating results at an accuracy rate of 90% for containers that meet ISO Standard 6346: 1995, *Freight containers – Coding, identification, and marking*; however, the software only reaches 90% accuracy when certain conditions exist such as overcast skies during the daytime. Inadequate lighting and non-optimal camera placement are negatively impacting image quality, contributing to low OCR accuracy. The OCR accuracy of radiation portal monitoring systems can be improved by implementing lighting and camera changes that enhance overall image quality.

1.1 Background

In the spring of 2007, one of the RPM seaport sites reported that OCR accuracy was achieving far below the target of 90%. A data analysis of OCR accuracy at the seaport site was conducted, covering a span of seven days. Overall accuracy for both daytime and nighttime images was calculated at 68% as shown in Table 1. Overall daytime accuracy during the same time period indicated that OCR accuracy was only achieving a 62% average, while overall nighttime accuracy was achieving only 69%. OCR accuracy for daytime images only accounted for 16% of the total images analyzed.

Table 1: OCR Accuracy Statistics during Initial Data Analysis

RPM	Containers Scanned	Number Correct	OCR Accuracy
10	779	535	69%
11	1362	913	67%
12	1214	826	68%
Totals:	3355	2274	68%

Having accurate OCR readings is important for a number of reasons. U.S. Customs and Border Protection officers rely on it for an accounting of international cargo containers bound for destinations inside the U.S. For example, if OCR accuracy is only operating at 60% when 500 containers are scanned, this leaves 200 containers that require manual reconciling, causing potential delays in commerce. In addition, correcting a high percentage of OCR records burdens busy officers with additional work. Only a small number of RPM sites currently use the software; therefore, the problems surrounding low OCR accuracy need to be addressed before a wider implementation of the software is required.

1.2 Scope of the Research

A visual observation of the cargo container images concluded that the sun was negatively impacting image quality as shown in Figure 3 and inadequate lighting was negatively impacting nighttime image quality as shown in Figure 4. Because a majority of traffic runs at night and OCR accuracy is poor on the side image (regardless of lighting conditions), the primary focus of the research and testing was to experiment with different lighting combinations to improve rear image quality for nighttime conditions. Limited research and testing was also performed to improve side image quality and poor image quality caused by the sun.

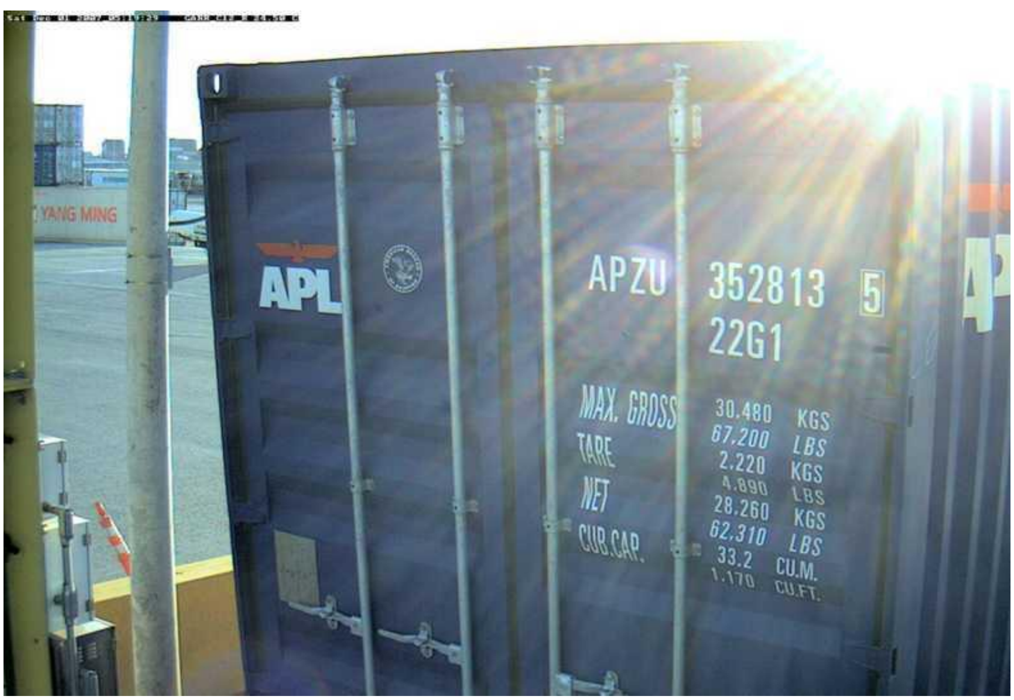

Figure 3: Example of Sun Negatively Impacting Image Quality

Figure 4: Example of Inadequate Lighting Affecting Image Quality

Obtaining good OCR results in various lighting and weather conditions relies heavily on good image quality. Similar to the OCR environment for cargo containers, a more common application of OCR technology is used in reading license plates. Much can be learned in improving cargo container OCR by examining issues surrounding license plate recognition (LPR) systems. Some of the research included examination of LPR systems and how they achieve accurate OCR.

Chapter 2 – Review of Literature and Research

A key to improving cargo container OCR is researching what works for the more common LPR OCR systems. Characteristics of good image quality for LPR OCR include sharpness of the characters, spatial resolution of the characters, high contrast of the characters, adequate lighting, good positioning, and optimal view angle ("License plate," n.d.). OCR requires good image quality for high accuracy rates and LPR OCR is often challenged by conditions that negatively affect image quality including the following:

1. Poor image resolution that can be caused by low-quality camera equipment or the camera being too far away from the target.
2. Blurry images primarily caused by motion.
3. Low contrast and poor lightening caused by shadowing, overexposure, or reflections.
4. Objects such as dirt on the lettering obscuring part of the target ("Automatic number," n.d.).

For LPR OCR systems, making physical changes to the camera environment is usually the method for improving OCR accuracy rates instead of making software changes ("Automatic number," n.d.). Any physical changes made at an RPM site must fit within the current RPM equipment footprint. It was determined that some physical changes could be made to the RPM environment in an effort to improve image quality.

2.1 Camera Equipment

The IQeye 301 camera produced by IQinVision is the camera currently used at the OCR site experiencing low accuracy rates but has since been discontinued ("IQinVision IQeye301," n.d.). The replacement camera for the IQeye 301 that best matches the functionality needed for the current RPM OCR implementation is the IQeye 711. The IQeye 711 has a smaller image sensor (“IQeye 711,” n.d.) than the IQeye 301 (“IQeye 711,” n.d.). A larger image sensor typically provides less noise, greater range, and more area for gathering light (“Digital camera,” n.d. and “Image sensor,” n.d.); however, the more modern hardware components used inside the IQeye 711 appear to provide better nighttime image quality as shown in Figures 5 and 6.

Figure 5: Sample Image from the IQeye 301 Camera

Figure 6: Sample Image from the IQeye 711 Camera

2.2 Camera Settings

The IQeye cameras come shipped with factory settings that will work for many implementations of a video surveillance system. Because the RPM environment is unique in that it captures images in day and night conditions with trucks carrying various types of containers at speeds between 3 and 15 miles per hour, some of the camera settings require adjustments to accommodate these conditions (a sample script for programming the IQeye 711 and 301 cameras for day and night use in the RPM environment are shown in Appendixes A and B). A focus in the research of the camera settings was to determine if the cameras were set at the correct shutter speed, known as image gain speed for IQeye cameras ("IQeye Reference," 2007), because some images were blurry in nighttime conditions as shown in Figure 7. The shutter speed manages motion and its effect on the images (Peterson, 2004). After examining images and the camera scripts from other RPM OCR sites, it was determined that the optimal nighttime image gain speed is 120. An examination of the camera settings at the site experiencing low OCR accuracy showed that the correct shutter speed was set on the cameras and that the blur around the lettering in Figure 7 was being caused by inadequate lighting.

Figure 7: Example of Blurry Image

Other camera settings that are critical for accurate OCR are appropriate iris, zoom, and focus settings. These settings are not controlled through the camera software or automatically (e.g., auto-zoom) but are adjusted manually on the camera lens by the person setting up the cameras. The cameras often require several lens adjustments if OCR is having problems reading the container numbers. In general, the rear camera should have the iris 85 – 100% open, be zoomed in as close as possible to the container, and properly focused. The side camera is the same except it should be zoomed out enough to view the side container numbers.

2.3 Camera Placement

The OCR algorithm determines a separate OCR result for each side and rear image and then determines a final composite result based on the results from both images. When determining the composite result, the OCR algorithm places more of an emphasis on the rear image results because the side image has some distortion. One reason for the distortion is the corrugations on the side of the container. Another reason is the side camera is placed very close to the target, requiring the use of a wide-angle lens that causes a fish-eye effect on the image as shown in Figure 8. To reduce the fish-eye effect and improve side image quality, the side camera can be placed further away from the target to increase the field of view as shown in Figure 9; thus, potentially improving OCR results on the side image.

Figure 8: Example of Distorted Side Image with Current Side Camera Placement

Figure 9: Example of Side Image When Camera Placed Further Back (Katchalski, 2008)

Cargo containers have up to six locations (one on each side, one on each end, and two on the top) that contain the full 11-character container number (International Organization for Standardization [ISO], 1995). The OCR software is currently only scanning two locations on the container (rear and driver side). A representative from the OCR vendor, J. Kukawka (conference call, October 2008), has stated that the OCR software can accept up to four images from various locations for OCR processing, giving the OCR software a better chance for success. Another representative from the OCR vendor, Y. Hoffman (personal email, July 16, 2009), stated that the best locations for obtaining the container number are the rear and the sides. He also stated that the top of the container can be helpful because it displays the container number in two locations; however, the lettering is sometimes damaged on the top.

Some of the markings on the containers processed by OCR do not meet ISO 6346. The OCR software has a lower percentage of accuracy when reading non-ISO-compliant containers.

As shown in Table 2, the site experiencing low OCR accuracy was only achieving 41% for non-ISO-compliant containers (this includes both day and night images where only 16% of the images are daytime). Figure 10 contains an example of a non-ISO-compliant container where the layout of the container number is contained on two lines (i.e., NYKU is on the top line and 6167530 is on the second line) (ISO, 1995). In the current placement of the rear OCR camera, the camera is placed at a slight angle on the side closest to the container number. One of the potential problems with reading some non-ISO-compliant containers is that a bar on the rear of the container partially obscures or distorts the container characters as shown in Figure 10. This has been observed analyzing the photos and also confirmed as a potential problem by Y. Hoffman (personal email, July 16, 2009). Repositioning the camera so that it is placed overhead and behind the container should help mitigate problems caused by the bar as shown in Figure 11.

Table 2: OCR Accuracy Statistics on Non-ISO-Compliant Containers

RPM	Containers Scanned	Number Correct	OCR Accuracy
10	136	56	41%
11	239	96	40%
12	72	31	43%
Totals:	447	183	41%

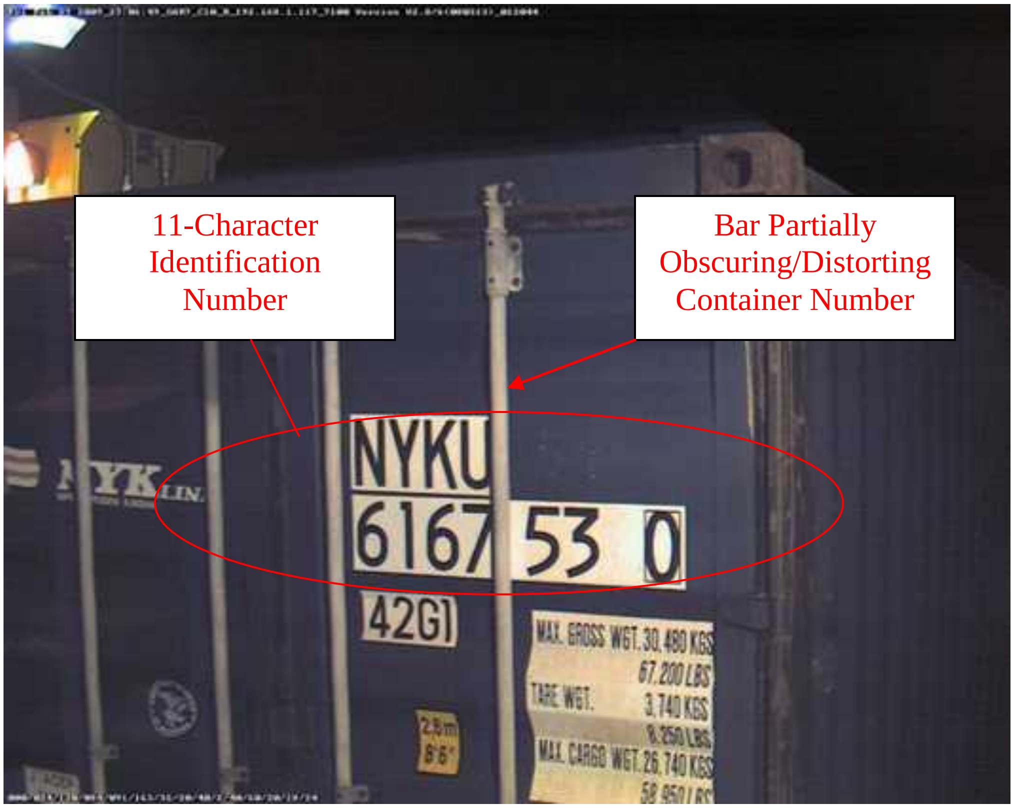

Figure 10: Non-ISO-Compliant Container When Rear Camera at an Angle

Figure 11: Non-ISO-Compliant Container When Rear Camera Not at an Angle (Katchalski, 2008)

2.4 Lighting

The current light fixtures used for illuminating container numbers in the RPM environment are 175-watt metal halides. Metal halide lighting remains the preferred lighting solution for commercial and industrial uses (Harvard University, n.d.) and offers some of the most powerful, efficient lighting for these uses ("Metal halide," n.d.). Infrared lighting (with an infrared camera) is common in LPR systems for illuminating license plates because it works well in both day and night uses ("Automatic number," n.d.). The purpose of acquiring images of truck containers is two-fold – the images help U.S. Customs and Border Protection officers visually identify trucks and their containers by color, license plates, and other physical characteristics and the images are also used for OCR processing. Because infrared lighting affects color and other details of an image, it is not currently a viable solution for the OCR implementation in the RPM environment.

2.5 Optical Character Recognition Software

The software does not currently allow any adjustments to settings other than basic configuration settings that define image orientation/size and database connection parameters. It currently runs as a Windows service and pulls images from a Microsoft® SQL Server® database for processing. J. Kukawka (conference call, October 2008) has stated that revisions can be made to the software that allow certain settings to be controlled by the user; however, it is not known whether enabling additional settings could help improve OCR in the RPM environment. The software vendor can also modify the software to accept up to four images for OCR processing, but it would require the vendor to write custom code and release a new version of the software. Techniques to enhance image quality are also possible through commercial software such as Adobe® PhotoShop®; however, OCR results are needed in real-time and additional fine-tuning of images through software would not be timely.

Chapter 3 – Methodology

3.1 Hardware and Software Testing Environment

The testing was conducted at the RPM integration laboratory located at a U.S. government facility in the Pacific Northwest. The hardware used for testing included an operating RPM with the appropriate camera configuration (see Figures 1 and 2), mobile RPM, two supervisor computers (i.e., personal computers running Microsoft® Windows® XP Professional), light meter, two IQeye 301 cameras, two IQEye 711 cameras, two IQeye Sentinel™ IQ811 cameras, IQeye 752 camera, IQeye V8 varifocal lens, Tamron® 4-12 varifocal lens, two COHU all-weather enclosures with sunshields, Floodzilla™ 175-watt metal halide (model FZH175QT) light fixture, Lumark® 250-watt metal halide light fixture, RAB Floodzilla™ 250-watt metal halide (model FZH250QT) light fixture, two Floodzilla™ 400-watt metal halide (model FZH400QT) light fixtures, two Magnafire 3000® halogen 350-watt light fixtures, five Pelco® pole mount adapters (model PA100), and five Pelco® pole mount arms (model EM22). The software used for testing included the RPM software, FTP software, Microsoft® SQL Server® 2005 Workgroup Edition, and Hi-Tech Solutions Ltd. (HTS) SeePortalDB Version 2.6.2 OCR software. Other resources used in the testing included two researchers, two electricians, cargo container, semi truck, and truck driver.

3.2 Camera Configuration

The internal camera settings were configured to best capture images for variable conditions including day, night, weather, lighting, and motion (see Appendix A and B for the settings used for the IQeye 301 and IQeye 711 cameras). The side cameras were equipped with the Tamron 4-12 varifocal lens and rear cameras with the IQeye V8 lens (images produced from the side camera were not a primary focus of the testing).

3.3 Lighting Configuration

The light fixtures currently used for a standard RPM camera system are 175-watt metal halides. Because the current lighting appears to be insufficient for producing OCR-quality images, various lighting configurations were tested including using lights with different wattages and brands, increasing the number of lights used simultaneously, and placing the light fixtures closer to the target. The placement of the lights and related components are shown in Figures 12 and 13. The lights were controlled by four switches that allowed for the use of any combination of lights. Electricians installed different types of light fixtures throughout the testing.

Figure 12: Light Fixture Placement for Rear Image Testing

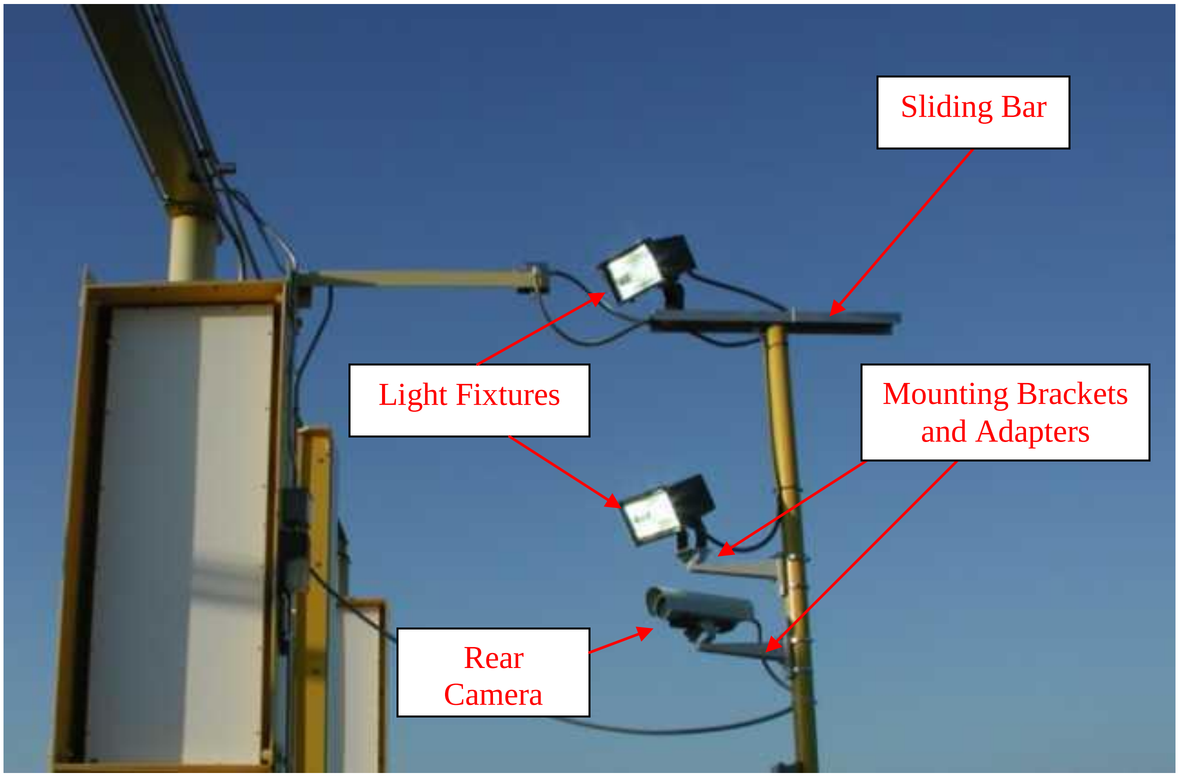

Figure 13: Rear Lighting and Camera Components

3.4 Testing Approach

The approach was to start by testing low-wattage light fixtures and gradually working up to high-wattage fixtures. Testing was conducted over several weeks which allowed electricians time to remove and install the various light fixtures. Several image samples were obtained from the various lighting configurations. A truck driver was scheduled for much of the testing to drive the container through the portal at various speeds. In addition, a light meter was used to take stationary lumen readings from the rear of the container at the numbered target areas shown in Figure 14 at the dimensions defined in Table 3. The lumen readings were documented for each lighting configuration.

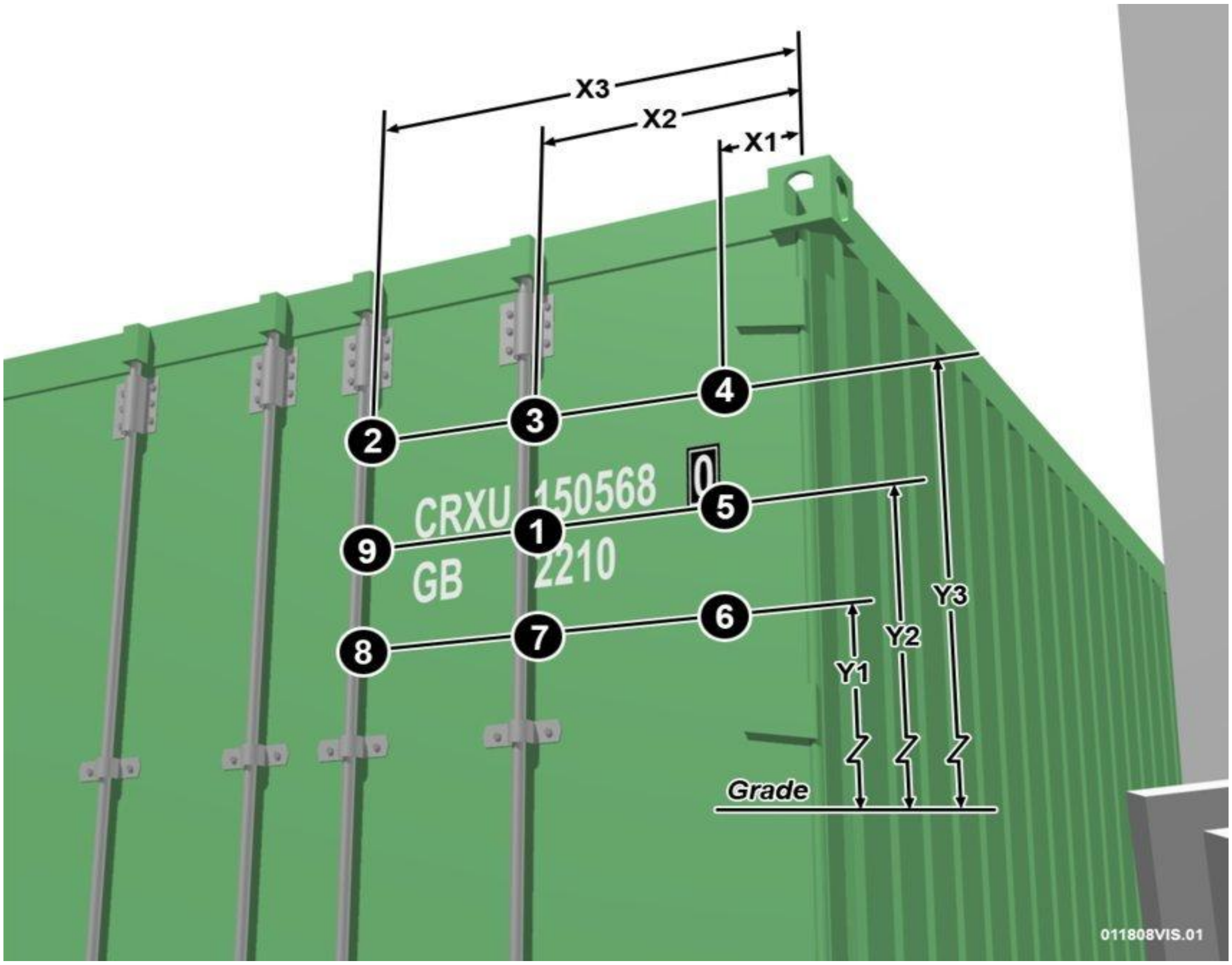

Figure 14: Target Areas for Light Meter Readings

Table 3: Dimensions for Lumen Reading Target Areas

Dimension	Inches
X1	4.5
X2	20.5
X3	35
Y1	127
Y2	133
Y3	139

Chapter 4 – Project Analysis and Results

In early 2008, research staff began experimenting with different lighting combinations at the RPM integration laboratory. Because a majority of RPM OCR traffic runs during nighttime, the primary goal was to find the optimal lighting configuration for improving image quality that would ultimately increase nighttime OCR accuracy. Configurations 1 through 7 outlined below show image samples using the IQeye 301. Configuration 8 shows a sample using the IQeye Sentinel™ IQ811 camera which is based on the same design as the IQeye 700 series (e.g., IQeye 711) cameras ("IQeye Sentinel," n.d.).

4.1 Metal Halide Light Fixtures

4.1.1 Configuration 1

Configuration 1 was designed to examine image quality using a 250-watt metal halide light fixture at the top of the passenger side VIS pole, located 15 feet from the ground (this is the same location of the light fixture at all current RPM OCR sites). The image quality is shown in Figure 15 and the light meter readings are shown in Table 4 (using the numbered target areas shown in Figure 14).

Figure 15: Sample Image from Configuration 1

Table 4: Light Meter Readings for Configuration 1

Target Area	Lux
1	153
2	165
3	170
4	179
5	162
6	154
7	144
8	130
9	140

4.1.2 Configuration 2

Configuration 2 was designed to examine image quality using a 400-watt metal halide light fixture at the top of the passenger side VIS pole, located 15 feet from the ground (this is the same location of the light fixture at all current RPM OCR sites). The image quality is shown in Figure 16 and the light meter readings are shown in Table 5 (using the numbered target areas shown in Figure 14).

Figure 16: Sample Image from Configuration 2

Table 5: Light Meter Readings for Configuration 2

Target Area	Lux
1	415
2	372
3	436
4	517
5	488
6	468
7	400
8	338
9	361

4.1.3 Configuration 3

Configuration 3 was designed to examine image quality using three light fixtures placed at different locations. A 250-watt metal halide light fixture was placed on the rear passenger VIS pole mounted on a Pelco® arm 11 feet from the ground. Another 250-watt metal halide light fixture was placed on the top of the rear passenger VIS pole, located 15 feet from the ground. A third metal halide light fixture (175 watts) was installed on the rear driver VIS pole on the top, located 15 feet from the ground. The image quality is shown in Figure 17 and the light meter readings are shown in Table 6 (using the numbered target areas shown in Figure 14).

Figure 17: Sample Image from Configuration 3

Table 6: Light Meter Readings for Configuration 3

Target Area	Lux
1	486
2	463
3	511
4	567
5	537
6	516
7	482
8	405
9	421

4.1.4 Configuration 4

Configuration 4 was designed to examine image quality using two light fixtures placed at different locations. A 400-watt metal halide light fixture was placed on the rear passenger VIS pole mounted on a Pelco® arm 11 feet from the ground. Another 400-watt metal halide light fixture was placed on the top of the rear passenger VIS pole, located 15 feet from the ground. The image quality is shown in Figure 18. Light meter readings were not available for this test.

Figure 18: Sample Image from Configuration 4

4.1.5 Configuration 5

Configuration 5 was designed to examine image quality using a 250-watt metal halide light fixture placed on the rear passenger VIS pole, located 15 feet from the ground and moved forward two feet on a sliding bar (refer to Figure 13). The image quality is shown in Figure 19 and the light meter readings are shown in Table 7 (using the numbered target areas shown in Figure 14).

Figure 19: Sample Image from Configuration 5

Table 7: Light Meter Readings for Configuration 5

Target Area	Lux
1	180
2	189
3	205
4	220
5	205
6	192
7	176
8	147
9	156

4.1.6 Configuration 6

Configuration 6 was designed to examine image quality using a 250-watt metal halide light fixture placed on the rear passenger VIS pole mounted on a Pelco® arm 11 feet from the ground. This brought the light closer by providing a more direct angle of the light beam (i.e., straight across from the target), as opposed to when the light is at the top of the pole where the light beam points downward toward the target. In addition, placing the light on a Pelco® arm brings the light fixture forward approximately one foot. The image quality is shown in Figure 20 and the light meter readings are shown in Table 8 (using the numbered target areas shown in Figure 14).

Figure 20: Sample Image from Configuration 6

Table 8: Light Meter Readings for Configuration 6

Target Area	Lux
1	312
2	263
3	319
4	371
5	358
6	347
7	307
8	257
9	264

4.1.7 Configuration 7

Configuration 7 was designed to examine image quality using a 400-watt metal halide light fixture placed on the rear passenger VIS pole mounted on a Pelco® arm 11 feet from the ground. This brought the light closer by providing a more direct angle of the light beam (i.e., straight across from the target), as opposed to when the light is at the top of the pole where the light beam points downward toward the target. In addition, placing the light on a Pelco® arm brings the light fixture forward approximately one foot. The image quality is shown in Figure 21 and the light meter readings are shown in Table 9 (using the numbered target areas shown in Figure 14).

Figure 21: Sample Image from Configuration 7

Table 9: Light Meter Readings for Configuration 7

Target Area	Lux
1	415
2	372
3	436
4	517
5	488
6	468
7	400
8	338
9	361

4.2 Other Light Fixtures

4.2.1 Configuration 8

Configuration 8 was designed to examine image quality using a Magnafire 3000® halogen 350-watt light fixture mounted on the roof of the mobile RPM as shown in Figure 22. The image quality is shown in Figure 23 and the light meter readings are shown in Table 10 (using the numbered target areas shown in Figure 14).

Figure 22: Location of Light Fixtures Mounted on Roof of the Mobile RPM

Figure 23: Sample Image from Configuration 8

Table 10: Light Meter Readings for Configuration 8

Target Area	Lux
1	669
2	530
3	641
4	721
5	799
6	847
7	707
8	608
9	574

4.2.2 Configuration 9

Configuration 9 consisted of an infrared light and IQeye 752 infrared-capable camera. Before the testing of this configuration was completed, a decision was made to implement one of the other configurations. No data from this testing was obtained.

4.3 Final Results

An examination of the sample images and light meter readings in the configurations outlined above clearly showed that image quality gradually improved as lux readings on the container increased. The results of the tests were submitted to the management team to help in determining the new lighting configuration to be implemented at the seaport site experiencing low OCR accuracy. A decision was made to remove the 175-watt light fixture from the top of the passenger side VIS pole (as shown in Figure 1) and implement Configuration 7 as discussed above and depicted in Figure 24.

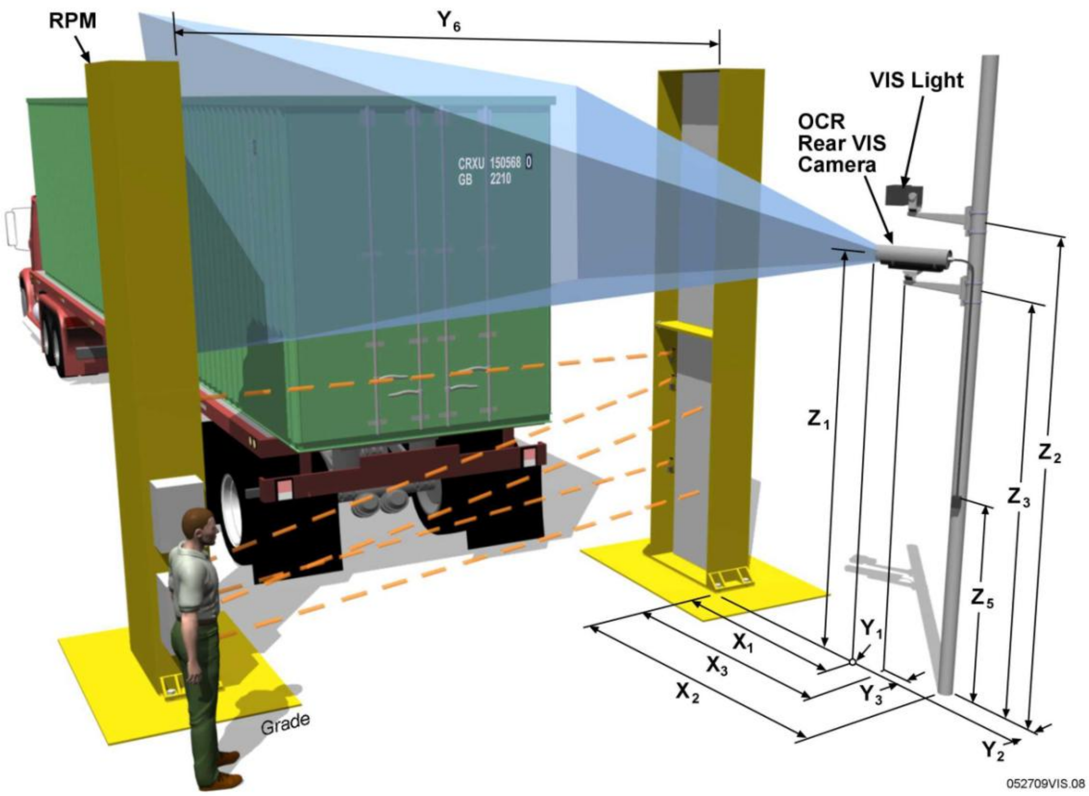

Figure 24: Recommended Lighting Configuration

The lighting changes were implemented in the latter part of 2008 at the seaport site experiencing low OCR accuracy. Immediately after the lighting configuration was implemented, a data analysis was conducted over a period of three days. The analysis revealed a significant improvement in nighttime image quality as shown in Figures 25 and 26. In addition, nighttime OCR accuracy improved from 69% to 87% as shown in Table 11. Accuracy percentages were calculated by running database queries that compared the original OCR results with the final or reconciled OCR results. Using customized software, U.S. Customs and Border Protection officers as part of their daily tasks manually updated incorrect OCR reads to assist in producing the final OCR results.

Figure 25: Sample Image before Implementing New Lighting Configuration

Figure 26: Sample Image after Implementing New Lighting Configuration

Table 11: OCR Accuracy Statistics after Implementing New Lighting Configuration

RPM	Containers Scanned	Number Correct	OCR Accuracy
10	100	81	81%
11	215	190	88%
12	139	125	90%
Totals:	454	396	87%

Chapter 5 – Conclusions

Increasing the number of light fixtures, increasing the wattage of light fixtures, and placing the light fixtures closer to the target all had a positive impact on image quality. The final configuration chosen to implement at the seaport site experiencing low OCR accuracy provided the most impact for the least amount of effort and resources. By implementing the rear lighting changes, nighttime OCR accuracy increased from 69% to 87% and actually achieved 90% when ruling out containers that have non-ISO-compliant rear markings. Other changes can be made to further improve nighttime OCR and potentially improve daytime OCR and these changes are outlined in the recommendations below.

5.1 Recommendations

Since the start of researching the OCR accuracy problem, other RPM sites have reported problems with low OCR accuracy. A data analysis of these sites indicated the same image quality problems such as sunlight washing out images and insufficient lighting at nighttime. At a minimum, the lighting changes implemented at the seaport site experiencing low OCR accuracy should be applied to all RPM sites using OCR. Described below are other changes that could be implemented to potentially improve OCR accuracy for day and night conditions.

5.1.1 Camera Equipment

The IQeye 301 cameras should be replaced with IQeye 711 cameras. The more modern hardware components used inside the IQeye 711 provide better nighttime image quality as shown previously in Figures 5 and 6. In addition, equipping the cameras with electronic pan, tilt, and zoom (PTZ) capabilities will significantly improve the ability to fine-tune image quality for OCR. Though electronic PTZ capabilities are not currently an option from IQinVision for the

711 camera, these cameras can be equipped with PTZ capabilities through a third party as stated from a representative from J-Systems, Inc., R. Johanson (personal email, May 27, 2008).

5.1.2 Camera Placement

5.1.2.1 Side camera.

As stated previously, side OCR accuracy is poor because of image distortion. Table 11 shows a very low accuracy rate of 17% for side images at the seaport site experiencing low OCR accuracy. With the low accuracy, the side image does very little to help OCR achieve optimal results. Because of the narrow portal that trucks must pass through, the side camera obtains images at very close range requiring the use of a wide-angle lens. To reduce the image distortion (i.e., fish-eye effect) caused by using the wide-angle lens, the side camera should be placed at or near the top of the side VIS pole pointing downward. This moves the camera further away from the target, increasing the field of view of the container. In addition to moving the side camera to the top of the pole, the side camera lens should then be replaced with either the same varifocal lens that is used for the rear camera or an electronic lens with PTZ capabilities as discussed above. A better option for camera placement is keeping the camera at the current height and moving it back several feet; however, the current RPM equipment footprint will not allow the camera to be moved further back.

Table 12: OCR Accuracy Statistics of Side Image Only

RPM	Containers Scanned	Number Correct	OCR Accuracy
10	100	21	21%
11	215	13	6%
12	139	45	32%
Totals:	454	79	17%

5.1.2.2 Rear camera.

The lighting upgrade improved nighttime OCR accuracy for non-ISO-compliant containers from 41% to 69% as shown in Table 13 but the accuracy was still lower than the overall 87%. Repositioning the rear camera so that it is placed directly behind the container and raised higher (see image sample shown previously in Figure 11) should help mitigate problems caused by the bar partially obscuring the container number on non-ISO-compliant containers. Another added benefit by placing the camera in this position is that it will help prevent the sun from shining into the camera because the camera is pointing at a downward angle. To place a camera in this position, a modification to the RPM VIS design would be needed such as adding an extension to the existing rear VIS pole that extends over the portal.

Table 13: OCR Accuracy Statistics of Non-ISO-Compliant Containers after Changes

RPM	Containers Scanned	Number Correct	OCR Accuracy
10	19	9	47%
11	46	36	78%
12	3	2	67%
Totals:	68	47	69%

5.1.2.3 Additional camera(s).

As stated by the OCR vendor, adding more cameras can help improve OCR accuracy. Having additional cameras helps in a number of ways. First, it provides more data for the OCR engine to use in calculating the final OCR results. Second, it provides additional views of the container where, for example, if one camera is malfunctioning or the sun washes out an image other cameras are available to assist in OCR processing. Third, it can assist with containers that have a non-ISO-compliant marking on the rear of the container by providing an image or images of an ISO-compliant marking from another location on the container. Updating the current system to use more cameras would require a software change by the OCR vendor. Figure 27 shows a sample image of a container number where the camera was placed overhead pointing directly down on top of the container. An observation of images taken throughout the day from this camera position showed that the sun has less negative affects on image quality compared to other camera positions.

Figure 27: Sample Image from Overhead Camera

5.1.3 Lighting

The continued use of metal halide light fixtures is recommended because of their efficiency and long bulb life which is between 12,000 to 20,000 hours for pulse start bulbs ("Floodzilla™ Specification," n.d.). Limited testing was conducted at the RPM integration laboratory with infrared lighting and cameras and this combination could be a viable option if images are strictly for OCR processing and not needed for visual identification by U.S. Customs and Border Protection officers. Testing was also conducted with the Magnafire 3000® halogen 350-watt light fixtures with the fixtures providing good illumination on the container; however, the bulb life is only 400 hours ("Magnafire 3000®," n.d.), requiring more frequent maintenance.

5.2 Lessons Learned

The OCR software is not a product that comes ready to use out of the box. It requires several days and possibly weeks fine-tuning camera settings and placements. Significant time must also be spent analyzing OCR data to ensure the camera settings and placements are producing consistent, accurate OCR readings for most day and night conditions. In addition, making the correct manual adjustments to iris, zoom, and focus settings when optimizing cameras for OCR is very cumbersome and time-consuming. To make these adjustments, the cameras have to be taken down from the poles, removed from the all-weather enclosures, adjustments made, sealed back up in the enclosures, placed back on the poles, and retested. This cycle usually needs to be repeated several times before the cameras are fully optimized for OCR. Having a camera system with electronic PTZ capabilities would streamline setup and help produce better image quality.

References

Harvard University. (n.d.). *Metal Halide Lamps*. Retrieved on November 18, 2009, from http://www.uos.harvard.edu/ehs/fire_safety/metal_halide_lamps.pdf

International Organization for Standardization. (1995). *Freight containers – Coding, identification, and marking* (ISO 6346). Geneva, Switzerland.

Katchalski, A. (2008, November 8). *End to End – Automated OCR Solutions*. Retrieved November 13, 2009, from http://x.htsol.com/!_attachments/images/117b.pdf

No Author Given. (2007). *IQeye Reference Manual*. Retrieved on November 13, 2009, from http://www.IQeye.com/IQeye/images/uploads/File/manuals/reference.pdf

No Author Given. (n.d.). Automatic number plate recognition. Retrieved November 12, 2009, from http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

No Author Given. (n.d.). Digital camera sensor sizes. Retrieved on November 13, 2009, from http://www.cambridgeincolour.com/tutorials/digital-camera-sensor-size.htm

No Author Given. (n.d.). Floodzilla™ Specification Sheet. Retrieved on November 19, 2009, from http://www.rabweb.com/common/catalog/install/FZT.pdf

No Author Given. (n.d.). Image sensor format. Retrieved November 12, 2009, from http://en.wikipedia.org/wiki/Image_sensor_format

No Author Given. (n.d.). IQeye 301. Retrieved on November 13, 2009, from http://www.networkcamerareviews.com/networkcameras/IQeye/IQ301NOLENS/camera_details.html

No Author Given. (n.d.). IQeye 711. Retrieved on November 13, 2009, from http://www.networkwebcams.com/product_info.php?products_id=436

No Author Given. (n.d.). IQinVision IQeye301 network camera. Retrieved November 13, 2009, from http://reviews.cnet.com/search-results/iqinvision-IQeye301-network-camera/1707-5-31273421.html

No Author Given. (n.d.). IQeye Sentinel IQ811. Retrieved February 16, 2010, from http://www.a1securitycameras.com/IQinvision-IQ811V8NPSS.html

No Author Given. (n.d.). License plate recognition algorithms and technology. Retrieved on February 22, 2009, from http://www.platerecognition.info/1102.htm

No Author Given. (n.d.). License Plate Recognition - A Tutorial. Retrieved November 16, 2009, from http://www.licenseplaterecognition.com/

No Author Given. (n.d.). Magnafire 3000® Specification Sheet. Retrieved on November 19, 2009, from http://www.havis.com/data/KwRaz/MAGNAFIRE%203000/KR-3x_NPR_9-06.pdf

No Author Given. (n.d.). Metal halide lamp. Retrieved November 18, 2009, from http://en.wikipedia.org/wiki/Metal_halide_lamp

Peterson, B. (2004). *Understanding Exposure*. New York: Watson-Guptill Publications.

Appendix A – Sample IQeye 711 Camera Script

set image compression medium

set image max none

set image window max

set image downsample 1

set image lighting sunlight

set image gain min speed 240

set image gain hmcenter .8

set image gain hmwidth .1

set image nightmode enabled

set image overlay 1 enabled

set image overlay 1 text "$IMGDBG"

set image overlay 2 enabled

set image overlay 2 text "$SD_$ST_$SN_$SV_$SI_$Sh"

set trigger action ftp

set trigger idletime 0

set ftp site trigger host "192.168.1.50"

set ftp site trigger username "camera"

set ftp site trigger password "camera"

set ftp site trigger path "vis/$SN"

set ftp site trigger fspec "$SN_$ST.jpg"

set ip timeserver ipaddress 192.168.1.50

set ip timeserver protocol ntp

set ip timeserver broadcast disabled

set trigger input onopen

set server timezone america/pacific

set server name "TEST_C01_F"

set ip ipaddress 192.168.1.100

set ip subnet mask 255.255.255.0

set image gain thresh day 0.8

set image gain thresh night 0.9

set image gain thresh enabled

save image

config write day

define image compression medium

define image max none

define image window max

define image downsample 1

define image lighting sunlight

define image gain min speed 240

define image gain hmcenter .8

define image gain hmwidth .1

define image nightmode enabled

define image overlay 1 enabled

define image overlay 1 text "$IMGDBG"

define image overlay 2 enabled

```
define image overlay 2 text "$SD_$ST_$SN_$SV_$SI_$Sh"
define trigger action ftp
define trigger idletime 0
define ftp site trigger host "192.168.1.50"
define ftp site trigger username "camera"
define ftp site trigger password "camera"
define ftp site trigger path "vis/$SN"
define ftp site trigger fspec "$SN_$ST.jpg"
define ip timeserver ipaddress 192.168.1.50
define ip timeserver protocol ntp
define ip timeserver broadcast disabled
define trigger input onopen
define server timezone america/pacific
define server name "TEST_C01_F"
define ip ipaddress 192.168.1.100
define ip subnet mask 255.255.255.0
define image gain thresh day 0.8
define image gain thresh night 0.9
define image gain thresh enabled
config write day
set image compression medium
set image max none
set image window max
```

```
set image downsample 1
set image nightmode enabled
set image lighting raw
set image gain min speed 120
set image gain max 50
set image gain hmcenter .3
set image gain hmwidth .4
set image overlay 1 enabled
set image overlay 1 text "$IMGDBG"
set image overlay 2 enabled
set image overlay 2 text "$SD_$ST_$SN_$SV_$SI_$Sh"
set trigger action ftp
set trigger idletime 0
set ftp site trigger host "192.168.1.50"
set ftp site trigger username "camera"
set ftp site trigger password "camera"
set ftp site trigger path "vis/$SN"
set ftp site trigger fspec "$SN_$ST.jpg"
set ip timeserver ipaddress 192.168.1.50
set ip timeserver protocol ntp
set ip timeserver broadcast disabled
set trigger input onopen
set server timezone america/pacific
```

```
set server name "TEST_C01_F"
set ip ipaddress 192.168.1.100
set ip subnet mask 255.255.255.0
set image gain thresh day 0.8
set image gain thresh night 0.9
set image gain thresh enabled
save image
config write night
define image compression medium
define image max none
define image window max
define image downsample 1
define image nightmode enabled
define image lighting raw
define image gain min speed 120
define image gain max 50
define image gain hmcenter .3
define image gain hmwidth .4
define image overlay 1 enabled
define image overlay 1 text "$IMGDBG"
define image overlay 2 enabled
define image overlay 2 text "$SD_$ST_$SN_$SV_$SI_$Sh"
define trigger action ftp
```

define trigger idletime 0

define ftp site trigger host "192.168.1.50"

define ftp site trigger username "camera"

define ftp site trigger password "camera"

define ftp site trigger path "vis/$SN"

define ftp site trigger fspec "$SN_$ST.jpg"

define ip timeserver ipaddress 192.168.1.50

define ip timeserver protocol ntp

define ip timeserver broadcast disabled

define trigger input onopen

define server timezone america/pacific

define server name "TEST_C01_F"

define ip ipaddress 192.168.1.100

define ip subnet mask 255.255.255.0

define image gain thresh day 0.8

define image gain thresh night 0.9

define image gain thresh enabled

config write night

init delay 0

Appendix B – Sample IQeye 301 Camera Script

set image compression medium

set image max none

set image window max

set image downsample 1

set image lighting sunlight

set image gain min speed 240

set image gain hmcenter .1

set image gain hmwidth .95

set image nightmode enabled

set image overlay 1 enabled

set image overlay 1 background 0

set image overlay 1 foreground 1

set image overlay 1 text "$IMGDBG"

set image overlay 1 xpos left

set image overlay 1 ypos bottom

set image overlay 1 xoffset 8

set image overlay 1 yoffset 8

set image overlay 2 enabled

set image overlay 2 background 0

set image overlay 2 foreground 1

set image overlay 2 text "$SD_$ST_$SN_$SI_$SV_$Sh"

set image overlay 2 xpos left

set image overlay 2 ypos top

set image overlay 2 xoffset 8

set image overlay 2 yoffset 8

set trigger action ftp

set trigger idletime 0

set ftp site trigger host "192.168.1.50"

set ftp site trigger username "camera"

set ftp site trigger password "camera"

set ftp site trigger path "vis/$SN"

set ftp site trigger fspec "$SN_$ST.jpg"

set ip timeserver ipaddress 192.168.1.50

set ip timeserver protocol ntp

set ip timeserver broadcast disabled

set image flip none

set image sharpen 2.0

set trigger input onclose

set server timezone america/eastern

set server name "SAOT_C01_R"

set ip ipaddress 192.168.1.101

set ip subnet mask 255.255.255.0

set image gain thresh day 0.8

set image gain thresh night 0.9

set image gain thresh enabled

save image

define image compression medium

define image max none

define image window max

define image downsample 1

define image lighting sunlight

define image gain min speed 240

define image gain hmcenter .1

define image gain hmwidth .95

define image nightmode enabled

define image overlay 1 enabled

define image overlay 1 background 0

define image overlay 1 foreground 1

define image overlay 1 text "$IMGDBG"

define image overlay 1 xpos left

define image overlay 1 ypos bottom

define image overlay 1 xoffset 8

define image overlay 1 yoffset 8

define image overlay 2 enabled

define image overlay 2 background 0

define image overlay 2 foreground 1

define image overlay 2 text "$SD_$ST_$SN_$SI_$SV_$Sh"

define image overlay 2 xpos left

define image overlay 2 ypos top

define image overlay 2 xoffset 8

define image overlay 2 yoffset 8

define trigger action ftp

define trigger idletime 0

define ftp site trigger host "192.168.1.50"

define ftp site trigger username "camera"

define ftp site trigger password "camera"

define ftp site trigger path "vis/$SN"

define ftp site trigger fspec "$SN_$ST.jpg"

define ip timeserver ipaddress 192.168.1.50

define ip timeserver protocol ntp

define ip timeserver broadcast disabled

define image flip none

define image sharpen 2.0

define trigger input onclose

define server timezone america/eastern

define server name "SAOT_C01_R"

define ip ipaddress 192.168.1.101

define ip subnet mask 255.255.255.0

define image gain thresh day 0.8

define image gain thresh night 0.9

define image gain thresh enabled

```
config write day
set image compression medium
set image max none
set image window max
set image downsample 1
set image nightmode enabled
set image lighting raw
set image gain min speed 120
set image gain max 50
set image gain hmcenter .2
set image gain hmwidth .4
set image overlay 1 enabled
set image overlay 1 background 0
set image overlay 1 foreground 1
set image overlay 1 text "$IMGDBG"
set image overlay 1 xpos left
set image overlay 1 ypos bottom
set image overlay 1 xoffset 8
set image overlay 1 yoffset 8
set image overlay 2 enabled
set image overlay 2 background 0
set image overlay 2 foreground 1
set image overlay 2 text "$SD_$ST_$SN_$SI_$SV_$Sh"
```

set image overlay 2 xpos left

set image overlay 2 ypos top

set image overlay 2 xoffset 8

set image overlay 2 yoffset 8

set trigger action ftp

set trigger idletime 0

set ftp site trigger host "192.168.1.50"

set ftp site trigger username "camera"

set ftp site trigger password "camera"

set ftp site trigger path "vis/$SN"

set ftp site trigger fspec "$SN_$ST.jpg"

set ip timeserver ipaddress 192.168.1.50

set ip timeserver protocol ntp

set ip timeserver broadcast disabled

set image flip none

set image sharpen 2.0

set trigger input onclose

set server timezone america/eastern

set server name "SAOT_C01_R"

set ip ipaddress 192.168.1.101

set ip subnet mask 255.255.255.0

set image gain thresh day 0.8

set image gain thresh night 0.9

```
set image gain thresh enabled

save image

define image compression medium

define image max none

define image window max

define image downsample 1

define image nightmode enabled

define image lighting raw

define image gain min speed 120

define image gain max 50

define image gain hmcenter .2

define image gain hmwidth .4

define image overlay 1 enabled

define image overlay 1 background 0

define image overlay 1 foreground 1

define image overlay 1 text "$IMGDBG"

define image overlay 1 xpos left

define image overlay 1 ypos bottom

define image overlay 1 xoffset 8

define image overlay 1 yoffset 8

define image overlay 2 enabled

define image overlay 2 background 0

define image overlay 2 foreground 1
```

define image overlay 2 text "$SD_$ST_$SN_$SI_$SV_$Sh"

define image overlay 2 xpos left

define image overlay 2 ypos top

define image overlay 2 xoffset 8

define image overlay 2 yoffset 8

define trigger action ftp

define trigger idletime 0

define ftp site trigger host "192.168.1.50"

define ftp site trigger username "camera"

define ftp site trigger password "camera"

define ftp site trigger path "vis/$SN"

define ftp site trigger fspec "$SN_$ST.jpg"

define ip timeserver ipaddress 192.168.1.50

define ip timeserver protocol ntp

define ip timeserver broadcast disabled

define image flip none

define image sharpen 2.0

define trigger input onclose

define server timezone america/eastern

define server name "SAOT_C01_R"

define ip ipaddress 192.168.1.101

define ip subnet mask 255.255.255.0

define image gain thresh day 0.8

define image gain thresh night 0.9

define image gain thresh enabled

config write night

init delay 0

Glossary

fish-eye effect – The result of a picture taken using a wide-angle lens which causes the picture to look distorted.

license plate recognition (LPR) – An OCR technology that reads license plates.

lumen – A unit of luminous flux equal to the luminous flux emitted in a unit solid angle by a point source of one candle intensity.

lux – A unit of illumination that is equivalent to one lumen per meter.

pan, tilt, and zoom (PTZ) – An electronic mechanism inside a camera that allows auto-adjusting of settings such as zoom.

radiation portal monitor (RPM) – A system that scans for radioactive material.

varifocal lens – A camera lens that allows the focal length and focus to be adjusted to accommodate the view of objects from various distances.

visual identification system (VIS) – A camera system used in the RPM environment that includes camera equipment, software, lighting, mounts, and poles.

REGIS UNIVERSITY

Rueckert-Hartman College for Health Professions
Graduate Programs Final Project/Thesis

Authorization to Publish Student Work on WWW

I, Adam Bergquist, the undersigned student,
Print student name

in the HSA Degree Program hereby authorize Regis University to publish through
Degree Program

a Regis University owned and maintained web server, the document described below ("Work"). I acknowledge and understand that the Work will be freely available to all users of the World Wide Web under the condition that it can only be used for legitimate, non-commercial academic research and study. I understand that this restriction on use will be contained in a header note on the Regis University web site but will not be otherwise policed or enforced. I understand and acknowledge that under the Family Educational Rights and Privacy Act I have no obligation to release the Work to any party for any purpose. I am authorizing the release of the Work as a voluntary act without any coercion or restraint. On behalf of myself, my heirs, personal representatives and beneficiaries, I do hereby release Regis University, its officers, employees and agents from any claims, causes, causes of action, law suits, claims for injury, defamation, or other damage to me or my family arising out of or resulting from good faith compliance with the provisions of this authorization. This authorization shall be valid and in force until rescinded in writing.

Print Title of Document(s) to be published: Evaluation of the Pathways Palliative Care Program at the Denver Hospice

Adam Bergquist — 11/5/2008
Student Signature — *Date*

Complete if applicable:

☐ The Work contains private or proprietary information of the following parties and their attached permission is required as well:

____

☐ I do not authorize Regis University to publish my work

Student Signature — *Date*

Updated 6/20/08