Document Title: Image Stabilized Binoculars with Integrated 3D Facial Recognition Imaging Capabilities

Author(s): Gregory Steinthal

Document No.: 249536

Date Received: December 2015

Award Number: 2010-IJ-CX-K001

2400 N. Lincoln Avenue
Altadena, CA 91001
626.296.6292
www.stereovisioninc.com

NATIONAL INSTITUTE OF JUSTICE
June 2013

Attn: Dr. Greene

Re: Award No. 2010-IJ-CX-K001
Final Technical Report

Dear Dr. Greene:

Please find enclosed our final report per Special Condition 14 of our Cooperative Agreement Award No. 20010-IJ-CX-K001

If there are any questions concerning the deliverable, please do not hesitate to call or email to gsteinthal@stereovisioninc.com.

Sincerely,

Gregory Steinthal
Program Manager
Enclosure

2400 N. Lincoln Avenue
Altadena, CA 91001

Image Stabilized Binoculars with Integrated 3D Facial Recognition Imaging Capabilities

June 2013

Final Technical Report

Award No. 2010-IJ-CX-K001

Grant Manager
Dr. Mark Greene
National Institute of Justice
U.S. Department of Justice
810 7th Street NW
Washington, DC 20531

Mark.Greene2@usdoj.gov

Prepared By:

Gregory Steinthal, Program Manager
June 2013

TABLE OF CONTENTS

1.0 PURPOSE OF REPORT

This final report has been submitted in accordance of Special Condition 14 of our Cooperative Agreements.

ABSTRACT

Development of a law enforcement oriented, cost effective, network centric mobile wireless hand held binocular ID system developed to identify non-cooperative persons of interest at ranges of up to 100 meters under uncontrolled lighting and environmental condition integrating surveillance operations with biometrics. These devices are intended to allow law enforcement officers on the street a real-time capability to identify individuals on scene as an added tool to provide public safety and national security. With NIJ support, StereoVision Imaging, Inc. (SVI) has developed this handheld binocular device tethered to a laptop running facial recognition analysis software. The system contains innovative optical and electronic hardware as well as novel algorithms that use two-channel stereoscopic imaging to map the depth of objects in 3D space to automatically isolate individual faces at a given range from the extraneous image data, a process called 3D segmenting. The face images automatically isolated from the background or clutter are then sent to a COTS face matching system to identify the targeted individual from a gallery or database of 2D face images. The 3D segmented image capture has been shown to significantly improve recognition performance over 2D in certain environmental conditions.

1.0 PROJECT SUMMARY

StereoVision Imaging, Inc. (SVI) has been under a cooperative agreement with the Department of Justice (DoJ) to develop proof-of-concept, portable, hand-held 3D binocular-based surveillance device(s) capable of real-time facial recognition since 2009. Proof-of-concept has been accomplished via the construction of a fully functional advanced R&D binocular prototype. The devices provide remote passive (facial) identification of personnel based on a given database of information of wanted individuals or group of individuals at intended ranges of up to 100 meters. These systems support, upon demand, the detection, localization, classification, and identification of a group of individuals while under surveillance via traditional binocular optics. These multi-modal devices allow for 3D viewing

and 3D segmentation of objects (faces) against 2D facial databases for identification.
SVI is working in conjunction with local law enforcement via the Los Angeles Sheriff's Department (LASD) in support of this program and the San Diego Sheriff's Office (SDSO). The Department of Justice (DoJ) may use these devices to allow law enforcement officers on the street a real-time capability to identify individuals on scene as an added tool to provide public safety and national security.

It is the intent that these devices will be integrated with law enforcement systems to support their mobile surveillance mission operations.

This award, in essence, is a continuation of our 2009-IJ-CX-K001 award. The overall goal accomplished of 2009-IJ-CX-K001 award focused on exploratory 3D imaging algorithm research and implementation and the development and demonstration of our first generation R&D prototype to provide proof-of concept. The R&D prototype provided surveillance capabilities and, upon demand, digitized sequence of stereo images of an unknown target. The information was then transmitted to a standalone computer for identification.

The 2009-IJ-CX-K001 award concluded with a technology demonstration with the Los Angeles Sheriff's Department Tactical Training Unit in Monterrey Park, California December 14th, 2010, please see Figure One below. LASD (Commander Bob Osborne) invited members of their Major Crime Division to witness and participate in the product technology demo. The major crime division included team leaders (10-15) of LASD's gang, murder for hire, kidnap for ransom, celebrity stalking, and narcotics mobile surveillance task forces. Invitees represented law enforcement user community.

Also in attendance was Dr. Mark Greene (NIJ PM) and Mr. Rick Chavez (Biometric Consultant to NIJ) as well as middle and upper management of one of SVI's designated subcontractor's, SAFRAN's MorphoTrak formerly known as L-1 Identity Solutions, Inc.

Field demonstration went extremely well with high identification success rate, outdoors, under uncontrolled environmental conditions at ranges up to 100 meters from point of use. A total of twenty two (22) runs were completed. Test runs included individuals enrolled in the database i.e. clients as well as imposters. Results were presented in the have been rolled-up into the Alpha Results documented in the 2009-IJ-CX-K001 final report appendices.

User community was impressed to wow-ed with the technology demo. User community sweet spot regarding range was noted at 50-75 meters.

Further, two (2) fully functional systems were delivered to NIJ's Center of Excellence for test and evaluation with complete documentation including user guides and manuals.

FIG. 2 : Award 2009-IJ-CX-K001 Deliverables

The main thrust of the 2010-IJ-CX-K001 award called out for the design and development of a next generation system allowing end users ease of use and operation over the 2009-IJ-CX-K001 deliverables. The 2009-IJ-CX-K001 demanded a large amount of manual intervention to operate properly. In addition, the 2009-IJ-CX-K001 deliverable, though hand-held, required the use of a tripod for live demonstrations. One goal of the 2010-IJ-CX-K001 award was to develop a truly hand held device and move away from the tripod. In addition it is expected to observe mark improvement in performance over the documented 2009-IJ-CX-K001 results from NIJ's Center of Excellence.

The award also included support of further technology demonstrations to law enforcement community as well as federal agencies. The following technology demonstrations have been performed to date:

Field Demonstrations	Date
NIJ Hosted by LASD	December 2010
Biometric TWG Hosted by NIJ	May 2011
Ft. Belvoir Hosted by NVESD to DoD, DHS and DoJ agencies	June 2011
SOCOM	August 2011
NIJ Center of Excellence , University West Virginia	August 2011
ONR	September 2011
OUSD(I). SPAWAR-ATL, SDSO, SDPD	December 2012

As an outcome of the technology demonstrations, SVI received strong interest from DHS Border Patrol as well as an endorsement from DoD USSOCOM and a sponsorship from DoD SPAWAR-ATL.

The main technical objectives of this contract were:

Task 1: Next Generation Hardware Development

Task 2: Development & Implementation of Imaging Software to support ease of operational use.

Task 3: Technology Integration

Task 4: Hardware Build-Out: Alpha Testing & Field Testing with local law enforcement

2.0 TECHNICAL GOALS AND OBJECTIVES

The following table of specifications were updated per 2010-IJ-K001 award. Performance specification goals had not changed.

Requirement Number	System Parameter Type: (Identification) (Surveillance) (PC) (Database Enrolment)	Item	CATEGORIES: (Mechanical) (Electrical) (Software) (Environmental) (User Interface) (Operational)	Description	Specification Limits		
					Upper Limit	Nominal Limit	Lower Limit
	3DMobileID(TM) SURVEILLANCE AND FACIAL IDENTIFICATION SYSTEM SPECIFICATIONS						
3DMobileID(TM) -001	Identification	Facial Identification Distance	Operational	The system shall identify an object (face) at this distance.	100 m		50 m
3DMobileID(TM) -002	Identification	Identification Response Time	Operational	Time it takes for the end user to request an identification to an identification is generated	15 sec	10 sec	5 sec
3DMobileID(TM) -003	Identification	False Alarm Accept Rate (FAR)	Environmental	The ratio of the number of false acceptances divided by the number of identification attempts.		0.001	
3DMobileID(TM) -004	Identification	False Rejection Rate (FRR)	Environmental	The ratio of the number of false rejections divided by the number of identification attempts.	0.016		0.031
3DMobileID(TM) -005	Identification	False Rejection Rate (FRR)	Environmental		0.13		0.103
3DMobileID(TM) -006	Surveillance	Binocular Magnification	Operational	End user to comfortabley view object with magnification	12x	8x	8x
3DMobileID(TM) -007	Surveillance	Binocular Objective Diameter	Operational			32mm	
3DMobileID(TM) -008	Surveillance	Binocular Exit Pupil	Operational			3mm	
3DMobileID(TM) -009	Surveillance	Binocular Field of View	Operational	74m at 1000m		4.3°	
3DMobileID(TM) -010	Surveillance	User Interface	User Interface	The user interface shall contain the following controls and indicators for operation.		1) BiColor Indicator LED 2) Request for Identification Buttom	
3DMobileID(TM) -011	Surveillance	External Communications (Input & Outputs)	Electrical/Software	Wireless - WUSB	25 m range	3 m	< 1 m
3DMobileID(TM) -012	PC	Facial Recognition Detection Class Visual Indicator	Software	PC tethered to Surveillance Device wirelessly. All detection and classification algorithms will run on the PC. PC displays results.		PC to Identify Object Under Surveillance Upon Demand via User Interface	
3DMobileID(TM) -013	PC	On-board Self Test & Diagnostics	Software	The unit shall contain a self-test and diagnostic function to determine the operational readiness state, and alert the user if a fault condition exists. The unit shall dis-continue processing samples while any fault condition exists and set the appropriate user fault alert.		PC Application Software to Provide Full Power up Self-Test and a periodic continuous self-test of critical functions.	
3DMobileID(TM) -014	PC	Warm up time	Operational	Warm up time		< 2 minutes @ 25 C	
3DMobileID(TM) -015	PC	On-board Raw Data & Event Logging & Data Storage	Software	PC Application Will Store All Revelant Files (Video Clips)		Retrievable via PC USB port	
3DMobileID(TM) -020	Database Enrolment	Database Enrolment Station	Software	Ability to Create & Manage a 2D Facial Databse		ISO 19794-5 Compliant	
3DMobileID(TM) -021	Surveillance	Operating Temperature Range	Operational		40 C		0 C
3DMobileID(TM) -022	CA-160T-029	Fastening	Mechanical	The device shall be tripod mountable			
3DMobileID(TM) -023	Surveillance/PC	Battery Life	Electrical/Software	There is a separate battery power supplies for the stand alone PC and the sureveillance device	4 Hours	2 Hours	1 Hour
3DMobileID(TM) -024	Surveillance/PC	Weight	Mechanical	Weight of the entire system	20 lbs	15 lbs	10 lbs
3DMobileID(TM) -025							
3DMobileID(TM) -026	CA-160T-036	Software and Data File Updates	Software	The unit software and associated data files can be upload/download capable in the field via a commercial standard communication port and protocol.		USB 2.0	

TABLE ONE: Performance Specifications

3.0 RESEARCH EFFORTS

- **Software "bug" issues resolved**

After the 2009-IJ-CX-K001 deliverable, a number of software related issues were identified and resolved that affected performance and needed to be addressed:

Adjusting intensity of color image pair equally via Min/Max

The former method of intensity adjustment for the color image pair involved using a single factor for both images. However, this factor was a static value that did not take into consideration the range of color values in the left nor the right image capture of the binocular system. As a result, there would be instances where the static factor would cause color casting leading to segmentation errors.

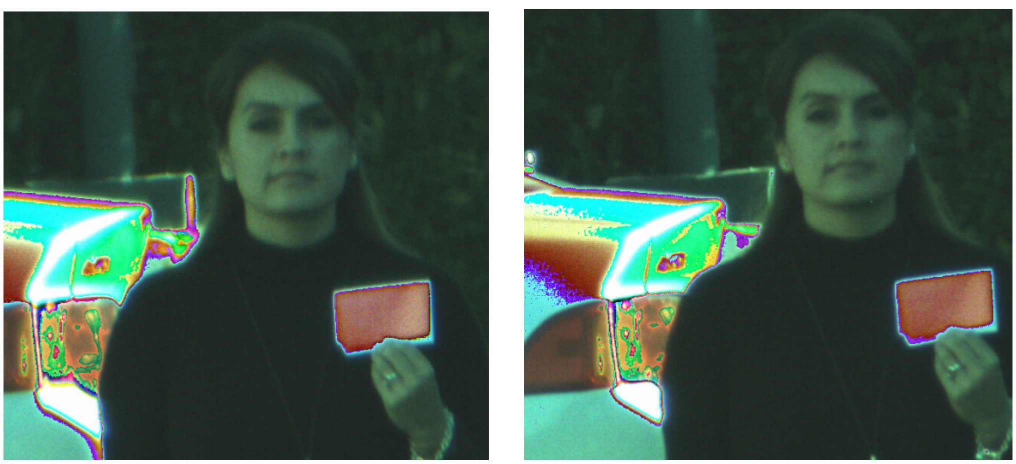


FIG. 3 : Left/Right Image Capture from Binocular Device

As the system is not "officially" color-corrected due to prototype/development stage a method was needed that would perform intensity adjustment without the overflow effect causing modification of the colors. The adjustment would also need to be done so that a pixel on the left image would be adjusted by the same factor as it's correlating pixel on the right image, allowing for proper computation of the SAD.

The solution lies in the proper computation of the factor. By choosing a minimum and maximum value based on all the red, green, and blue component values across both images, a single factor could be computed that will not cause any color casting. This new method was adopted and implemented.

FIG. 4 : Left/Right Image Pair now with a simple min/max color correction

Left/Right Consistency Check

A fix was made to the left-right consistency check logic. Referring to the paper titled *"Calculating Dense Disparity Maps from Color Stereo Images, an Efficient Implementation"*, by Muhlmann, Maier, Hesser, Manner, Section F defines how the right-left disparity map corresponds to the left-right disparity map:

$d_{RL}(x + d_{LR}(x, y), y) = -d_{LR}(x, y)$

Prior to the fix, the logic made the following incorrect assumption:

$d_{RL}(x - d_{LR}(x, y), y) = -d_{LR}(x, y)$

By analyzing the disparity map before the fix (i.e. Figure Five), you'll notice that the bright portions that would normally be assumed to be occluded actually show up as a bright shade of grey in the disparity map. After the fix (Figure Six), you'll notice that pixels within the disparity map that previously showed up as grey are now marked as blue and properly reflect the rejections of the left-right consistency check process.

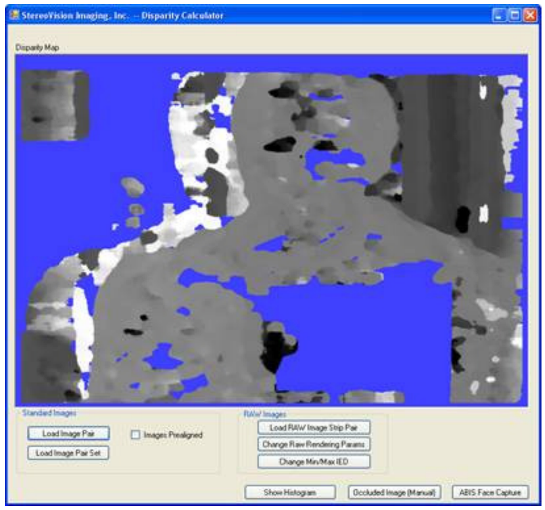


FIG. 5: Left/Right Consistency Check with improper implementation

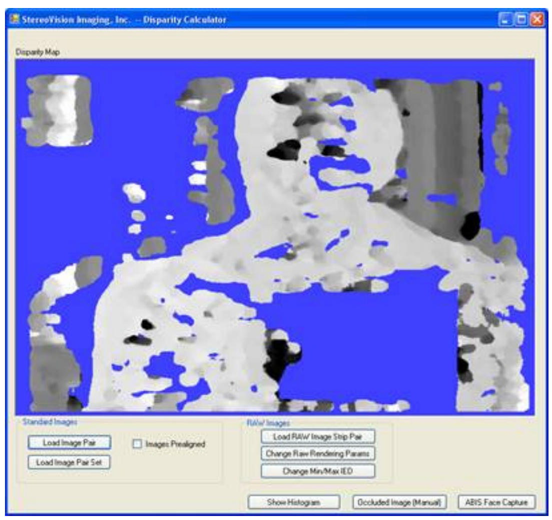


FIG. 6: Left/Right Consistency Check with proper implementation

Correlation Method During Disparity Map Generation

The former method of matching points between the left and right images involved finding the minimum and maximum SADs. While the disparity point is associated with the minimum SAD, in the prior method no attention was given to the SAD computations of the immediate neighboring points (i.e. SAD(d-1) and SAD(d+1)). Rather, determination of uniqueness was based on summing the number of SAD computations that fell below a threshold: minSAD + ((maxSAD – minSAD) * threshold). (Threshold used was set to 0.0005.) If more than 2 SAD computations fell below the threshold, then the disparity at that point was treated as invalid. This ad-hoc method is deprecated in the new code.

After modification to the CUDA code to allow for serialized analysis of SAD values, routes were opened that allowed for processing of SAD data “by the book”. The new method ensures that the minimum SAD found is also less than both SAD(d-1) and SAD(d+1). Also, as per section H of the *“Calculating Dense Disparity Maps from Color Stereo”* Images paper, code to verify the uniqueness of the minimum was added. As such, the 3rd smallest SAD must be higher than the threshold above the minimum SAD. The paper mentions “a threshold of 5% - 20% above the minimum SAD value has been a reasonable choice in our applications”. However, some tests at 5% yielded a disparity map with excessive number of invalid disparities that caused problems during segmentation for this set of data. So, 1% was selected as a suitable margin.

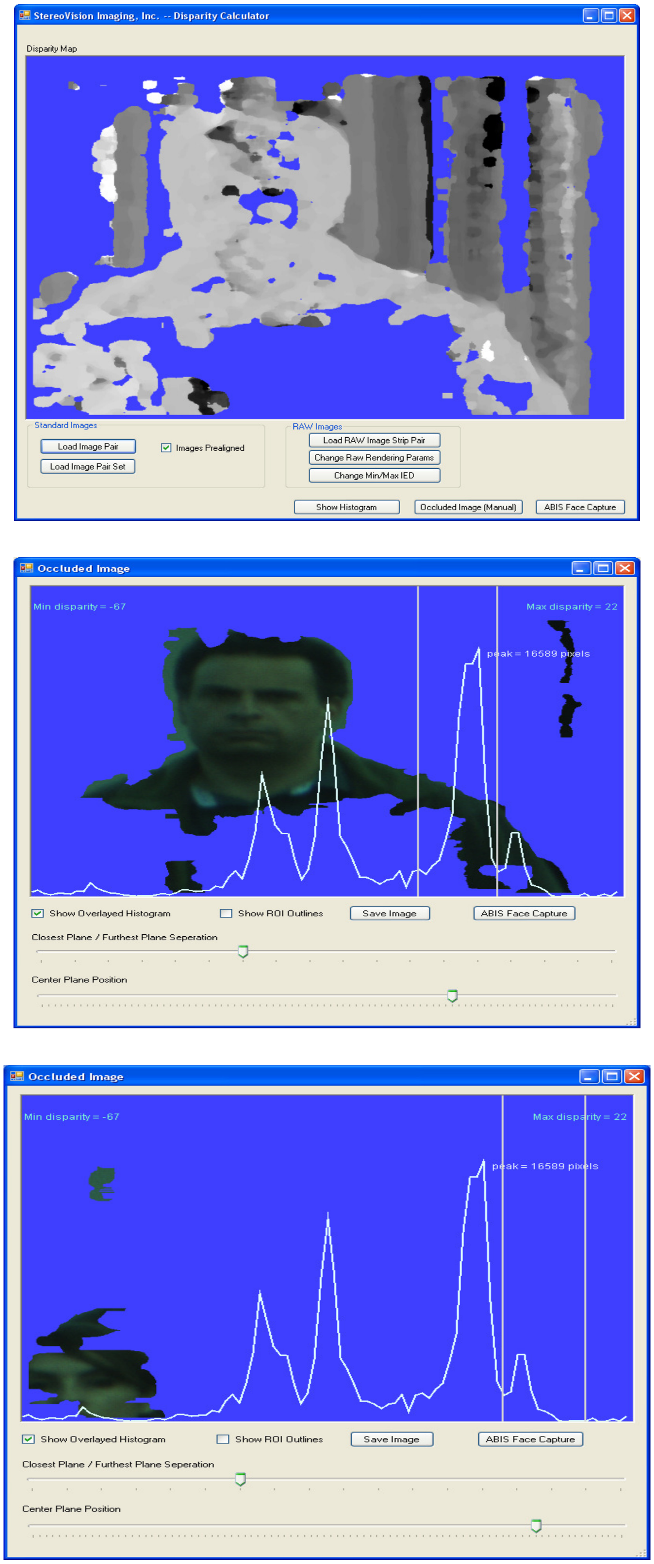


FIG. 7 : Prior Method

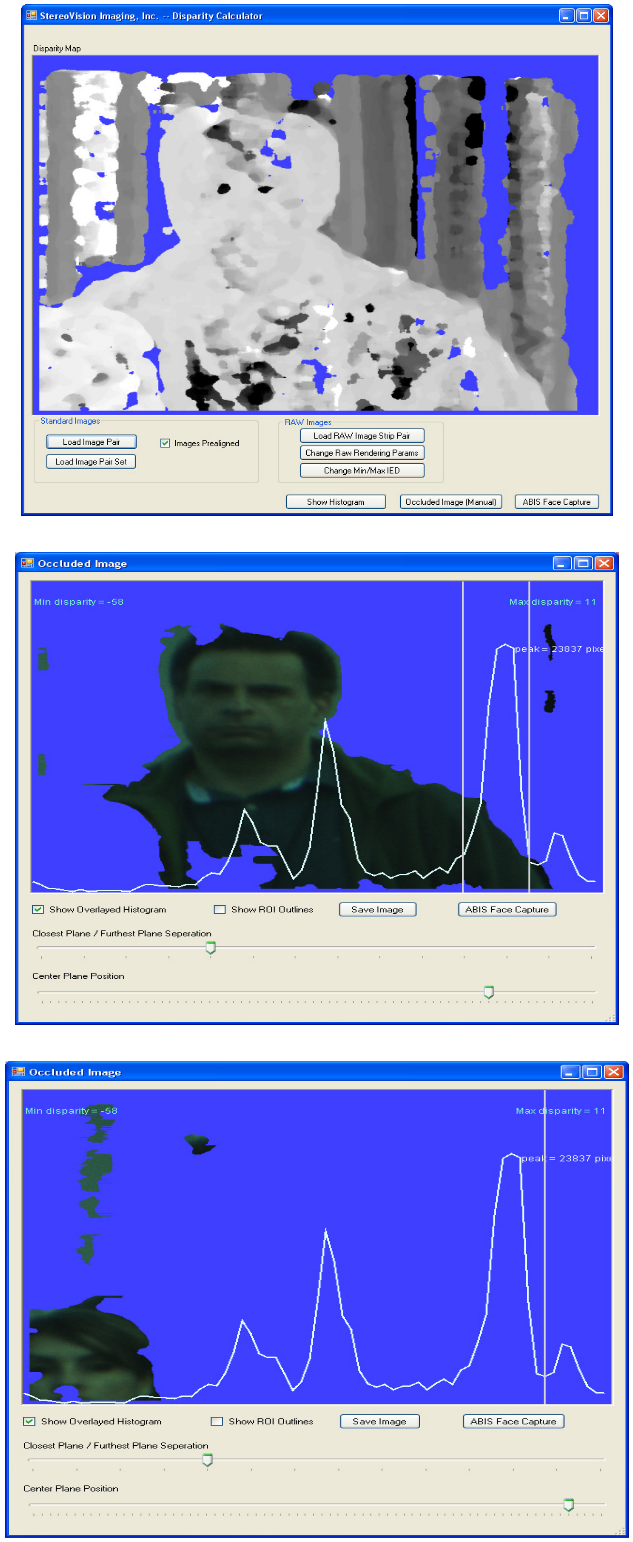
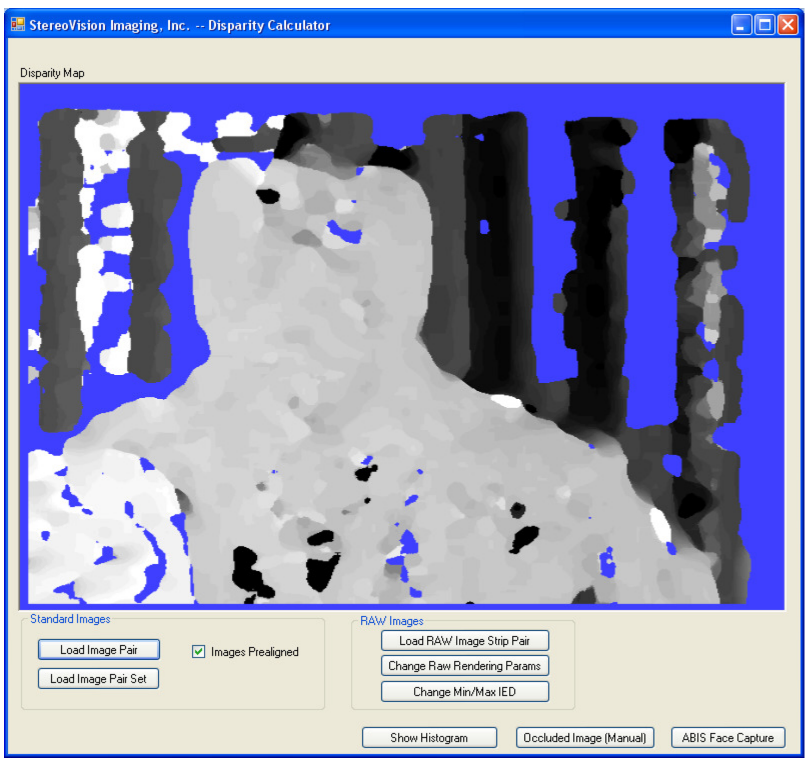


FIG. 8 : Current Method

Please notice that the former method of uniqueness check (minSAD + ((maxSAD – minSAD) * threshold)) improperly masks a large portion of valid disparity map pixels. Whereas, the new method more closely targets the invalid pixels.

Increasing SAD Patch Size

Even with the proper method of checking uniqueness, still some inaccurate disparity computations are made as evidenced by some dark patches in a disparity map as shown in the above disparity map where one would expect to see a lighter shade of grey. By increasing the SAD patch size, a more thorough analysis can be made to determine correlating pixels between the left and right images. The patch size was increased from 7x7 to 17x17. Figure Nine below shows an improvement in the disparity map generation.



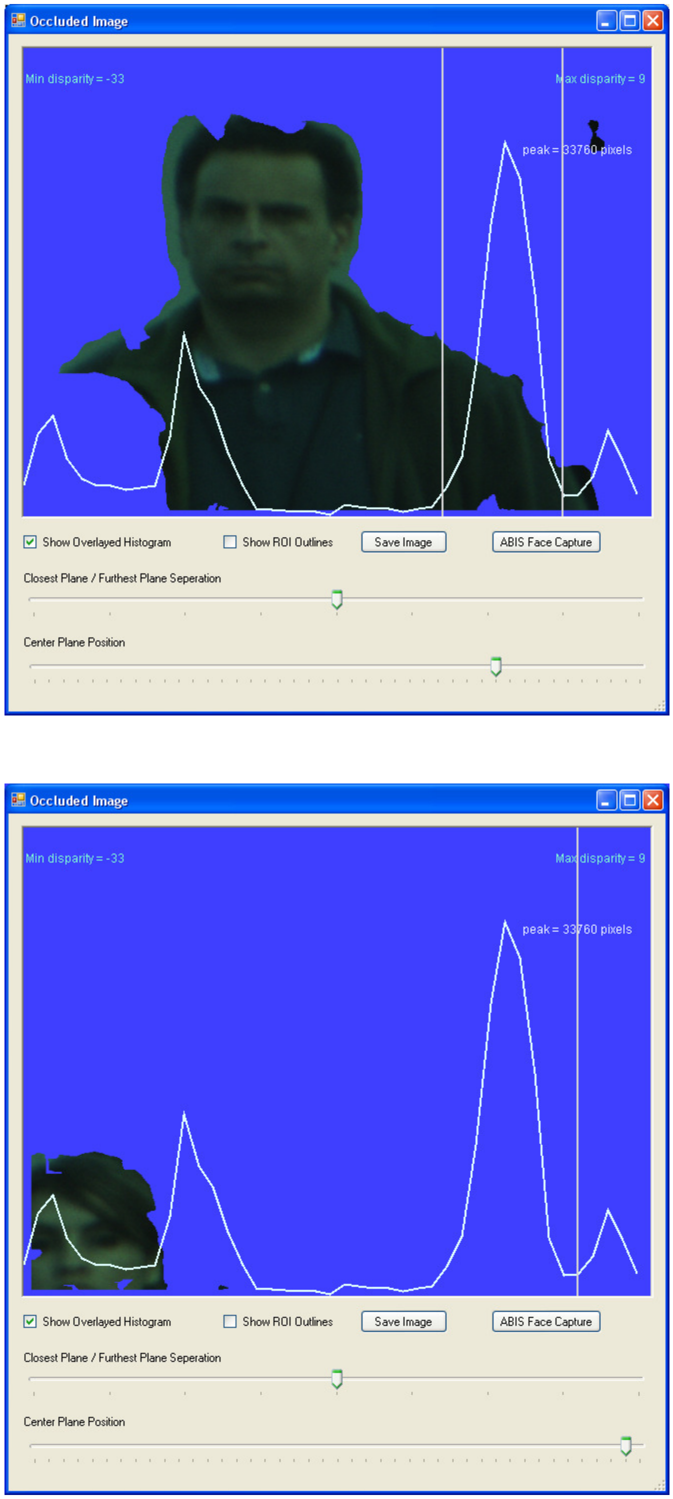


FIG. 9 : Disparity map with increased patch size as compared to Figure Six

Improvements in Peak Detection

The former peak detection algorithm would operate in the following manner:

1. Find the highest peak
2. From that highest peak, progress downward in terms of disparity until either of the following conditions occur
    a. The value at the next step is less than 1/15 of the peak value
3. Upon reaching one of the mentioned conditions, mark the disparity point as AFT.
4. From that highest peak, progress upward in terms of disparity (i.e. forward) until either of the following conditions occur
    a. The value at the next step is less than 1/15 of the peak value
5. Upon reaching one of the mentioned conditions, mark the disparity point as FORE.
6. The range of disparities between AFT and FORE makes up a range considered for use during segmentation as visible.
7. Continue this process at step 2 with the next highest peak.

Note that the progression from a histogram peak to AFT and FORE merely involves waiting until a disparity is reached whose value is a fractional amount of the peak. This works for well for several cases. However, in some cases we'd like to separate peaks that may not match the above criteria (i.e. only single condition of 1/15th of the peak value). Take the following example. Note that in Figure 11 and 12, two separable segments may be created to generate two occluded images. Also note that in the histogram (Figure Eleven) the lowest point between the 2 peaks is not very low (< 1/15th), but low enough (< ½) to allow for separation of the two peaks. The former algorithm would generate an occluded image as seen in Figure Thirteen.

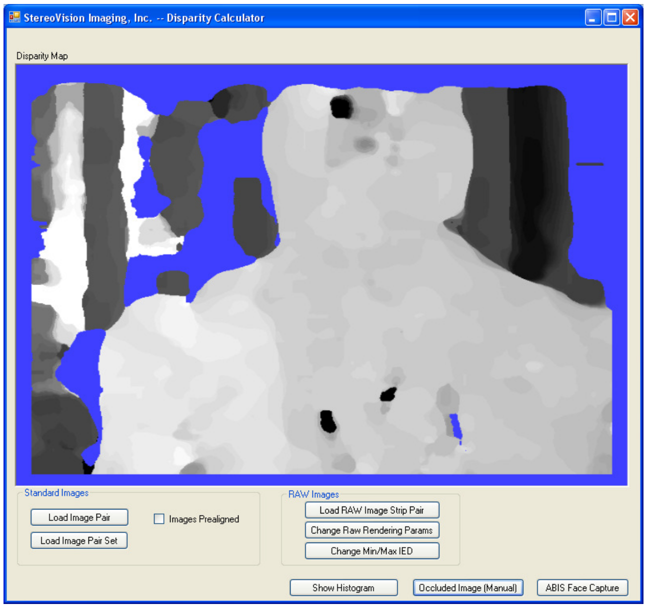

StereoVision Imaging, Inc. -- Disparity Calculator
Disparity Map
Standard Images
Load Image Pair
Images Prealigned
Load Image Pair Set
RAW Images
Load RAW Image Strip Pair
Change Raw Rendering Params
Change Min/Max IED
Show Histogram
Occluded Image (Manual)
ABIS Face Capture

FIG. 10

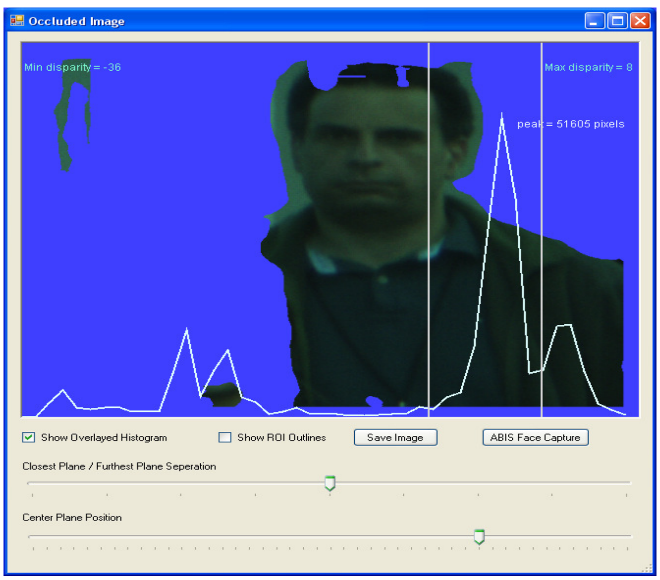

Occluded Image
Min disparity = -36
Max disparity = 8
peak = 51605 pixels
Show Overlayed Histogram
Show ROI Outlines
Save Image
ABIS Face Capture
Closest Plane / Furthest Plane Seperation
Center Plane Position

FIG. 11

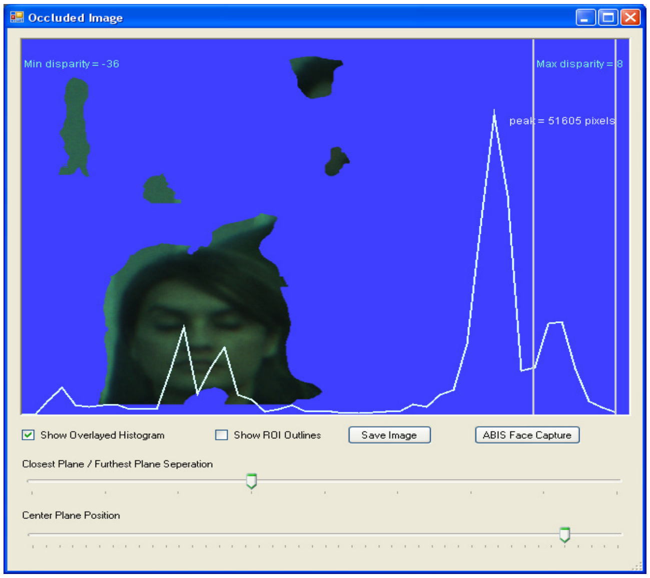


FIG 12

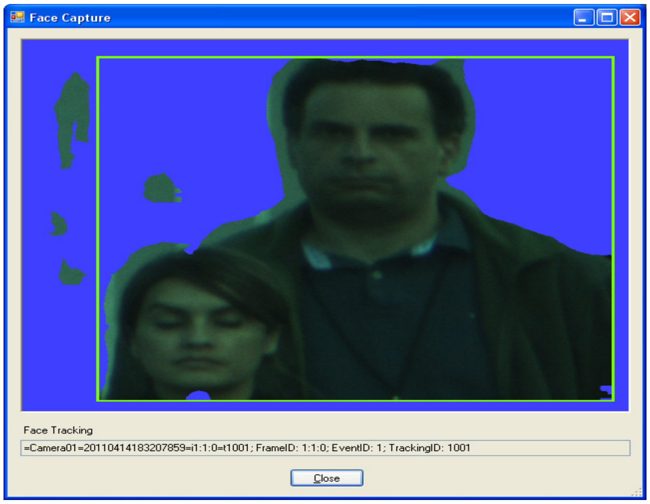


FIG 13

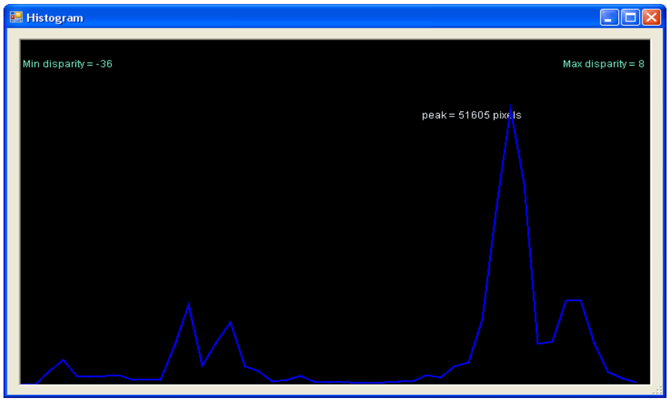


FIG 14

The new algorithm operates in the following manner:

1. Find the highest peak
2. From that highest peak, progress downward in terms of disparity until either of the following conditions occur
    a. The value at the next step is less than 1/15 of the peak value
    b. The value at the next step is greater than the current value and less than ½ of the peak value
3. Upon reaching one of the mentioned conditions, mark the disparity point as AFT.
4. From that highest peak, progress upward in terms of disparity (i.e. forward) until either of the following conditions occur
    a. The value at the next step is less than 1/15 of the peak value
    b. The value at the next step is greater than the current value and less than ½ of the peak value
5. Upon reaching one of the mentioned conditions, mark the disparity point as FORE.
6. The range of disparities between AFT and FORE makes up a range considered for use during segmentation as visible.
7. Continue this process at step 2 with the next highest peak.

Note the addition of steps 2b and 4b. Attention is given to an increase in values when progressing away from the peak towards AFT and FORE. The new algorithm would generate an occluded image as seen in Figure Fifteen. Note that now there's a separation between the two subjects, while prior to the change they were combined into a single range of disparities.

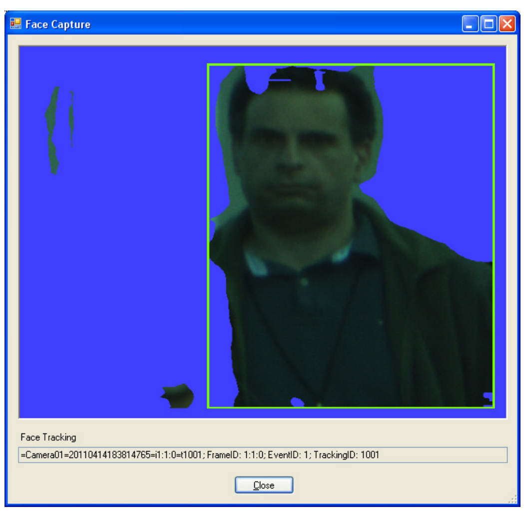


FIG. 15: Image processed with new and improved peak detection algorithm

- **Illumination Compensation Studies**

Please recall from the 2009-IJ-CX-K001 award, our implementation concerning illumination compensation computes local means by convolving an n x n square or a gaussian mask over the captured image. The local mean is computed for each pixel, based on a weighted sum of its neighbors. That is:

- If the mask is 3x3, top hat = equal weight.
- If the mask is gaussian, then the contributions of each neighbor are not equal but weighted by a gaussian function= $c*Exp[-(x^2+y^2)/\sigma^2]$ where x and y are the distances to the neighbor pixel and σ is the STD of the gaussian i.e. the steepness of the drop-off from center.

A sigmoidal function is then used to increase the dynamic range based on the local mean.

The adjusted value of each pixel is given by:

$$\text{Enhanced } Y' = \left(\left(2/(1+ \text{Exp}(-2*Y/Ymean))\right)-1\right)*1023 \qquad (1)$$

Where 1023 is the total 10-bit (2^{10}) dynamic range captured from our 10MP CMOS photoarray.

And where what we describe as Ymean is also a function of a value, ***k***, a bias pixel intensity value.

$$Ymean = (255-k)\left[\frac{Ymean}{255}\right] + k$$

Thus the function is derived to enhance the dark part of the image while preserving the light part of the image providing for uniform illumination across the face.

Again as presented in our 2010-IJ-CX-K001 award, Figure Sixteen below is an example of an image captured before / after dynamic range compression. Although this image is considered over compensated one can note how effectiveness of this “shadow” technology. Note the original image: face half shade / half illuminated by the sun was captured at 75 meters. Enhanced image exhibits a more uniform illumination across the entire face yet retains facial features. Simply increasing brightness level of original image would still result in a non-uniform facial image.

FIG. 16 Dynamic range compression: (a) original image; (b) luminance enhanced image processed via dynamic range compression.

As it turns out the bias intensity value, *k,* as described above in expression (1) is dependent on the image statistics of the original image captured. That is, the mean intensity of the original image is dependent on the image itself and the exposure setting and thus, it is theorized, the bias intensity value should be dependent and thus adjusted **automatically** based upon the original image statistics.

We used the following parameters as a starting point to empirically investigate the relationship between *k,* and the global mean intensity value of the image and the identification scores in the hopes of determining a correlation among these parameters and then to validate the model against a number of different test scenario:

• Hence vary k from 0-1023 and assess scores.
• Input image is maxmin processed.
• Dynamic range compression uses a 7x7 mask with a gaussian kernel sigma value of 7

As an example of the data and data reduction. The bias intensity value, k, is varied over the 10-bit dynamic range of the input captured in steps of 25 and dynamic range compression applied at each step and then used as a 2D only input to face recognition image to obtain an identification score:

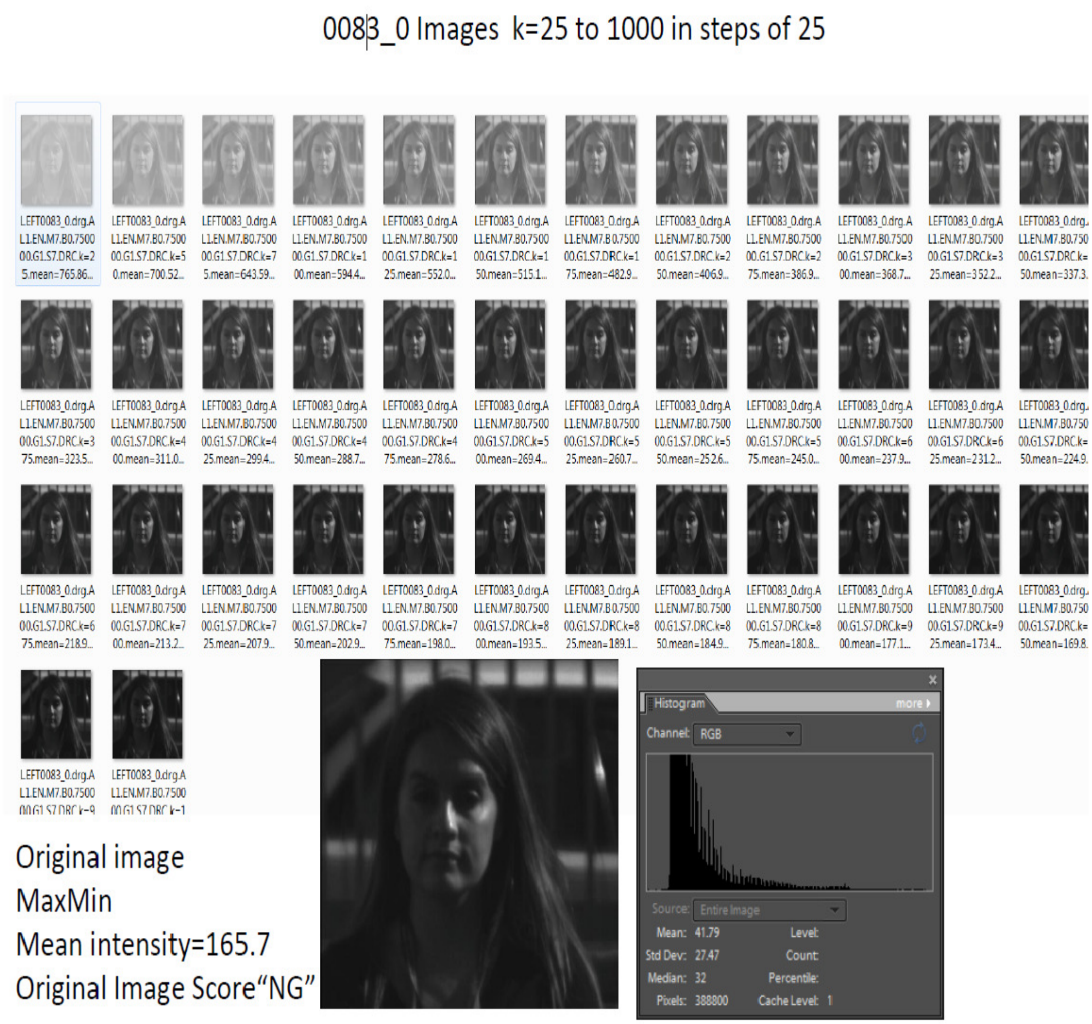


FIG 17. Example of varying k-value and logging image statistics and ID scores. Please note original captured image is 'NG' or no good meaning no identification score due to poor image quality.

The following figure illustrates the results of Figure Eighteen. The green trace is the difference between the Rank1 and Rank2 scores

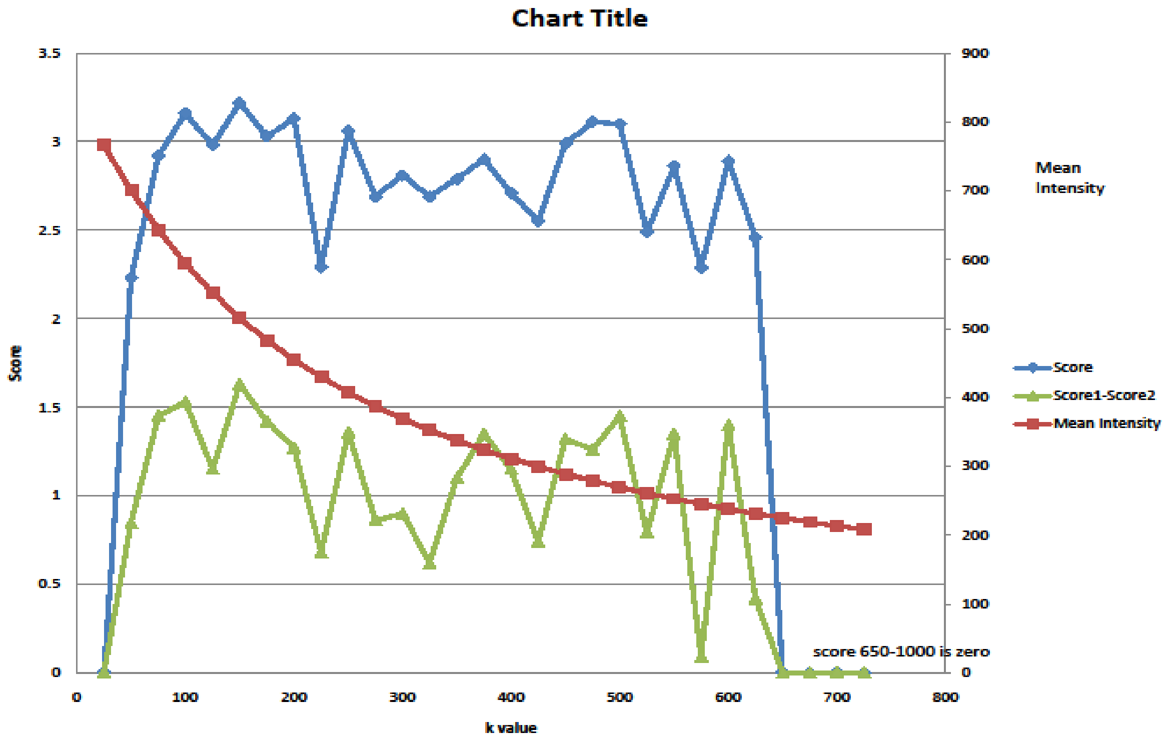


FIG. 18 : Example of data reduction of Figure One plotting identification scores as a function of k-value.

In summary, good scores between 150 and 500 were observed and as noted the original image was rejected due to poor quality. Initially after multiple data runs that 'k' could be determined between 1.1 and 3.0 * Original Mean Intensity. However, more data of different environmental conditions were processed to validate initial findings:

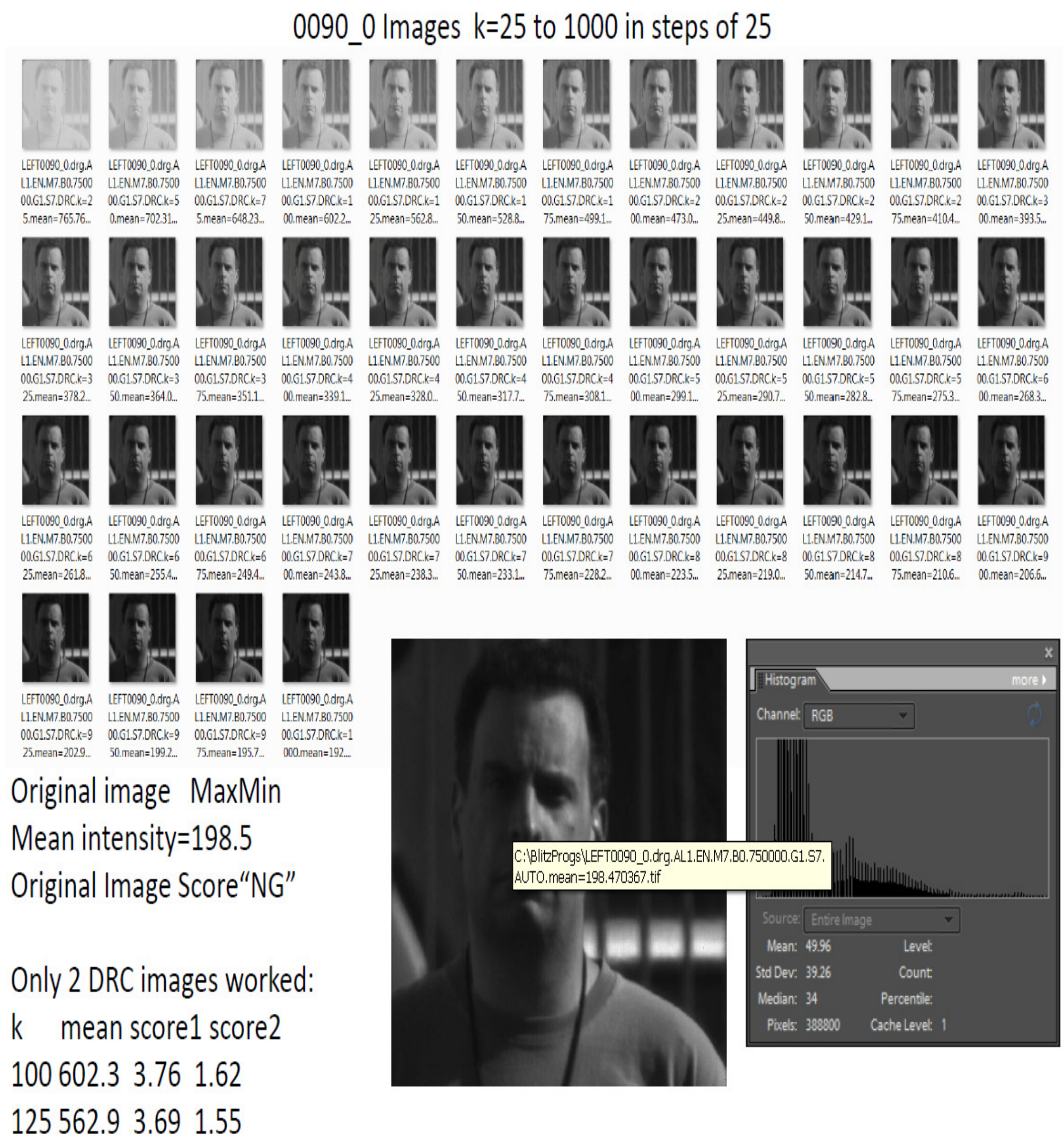


FIG. 19 : Another example of varying the bias intensity value but this time under different environmental condition, face half sunlight / half shade

Almost all strong half lit images images were rejected and to date is definitely the most challenging of all the uncontrolled conditions. For the images that worked so far, it seems that setting k=3*Mean Intensity of the original (MinMax) image would produce good results.

However, unfortunately after looking at many data runs captured under the different environmental conditions **no** consistent relation between scores and k could be derived.

The next set of data was compiled to determine the correlation between the identified score returned as ‘k’ varies with the quality assessment score of the image as returned from the COTS face matcher software.

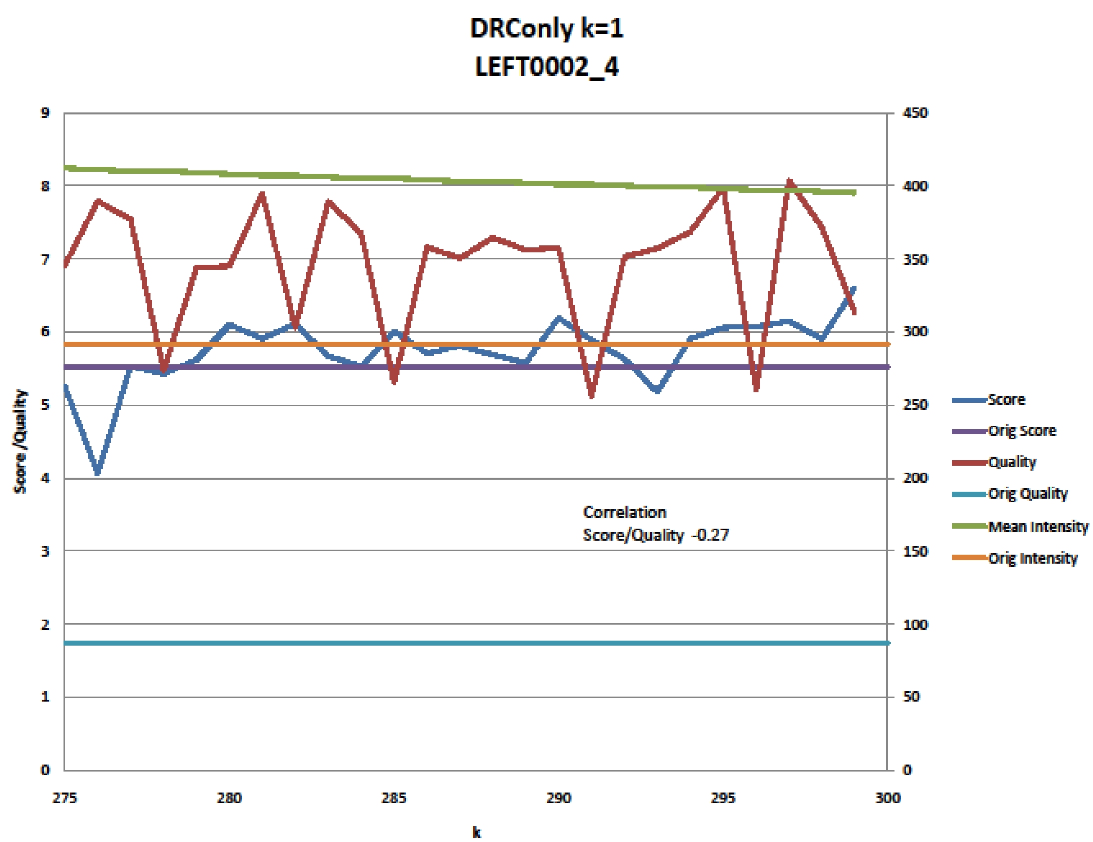


FIG. 20 : Example of ‘k’ versus identification and quality assessment scores

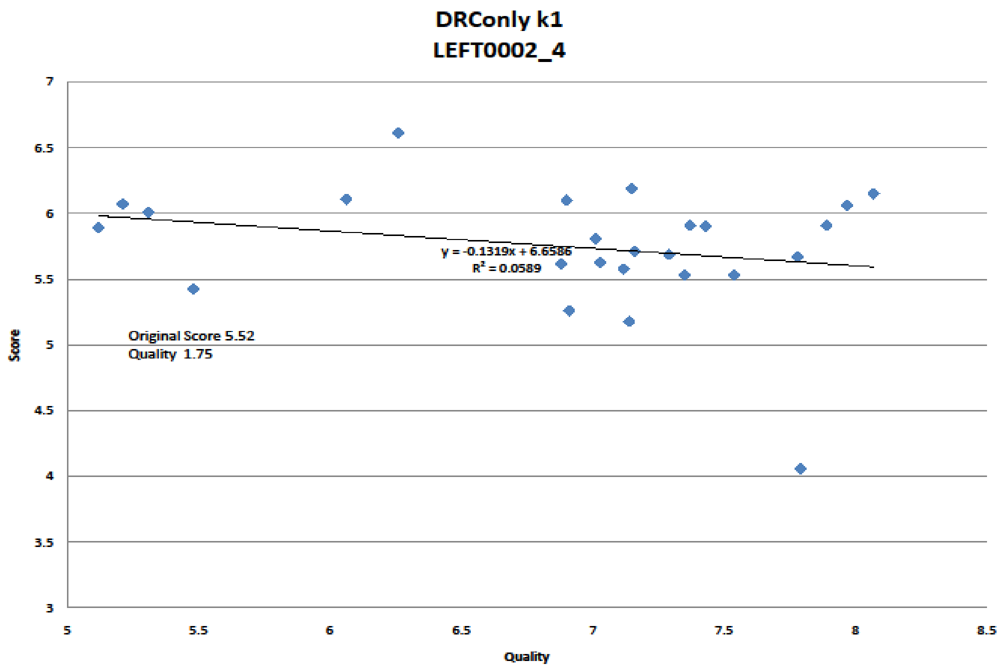


FIG. 21 : Subset of Figure Twenty to determine correlation between identification and quality assessment scores as image quality of the same image changes

FIG. 22 : Another example of correlation observed with identification score and

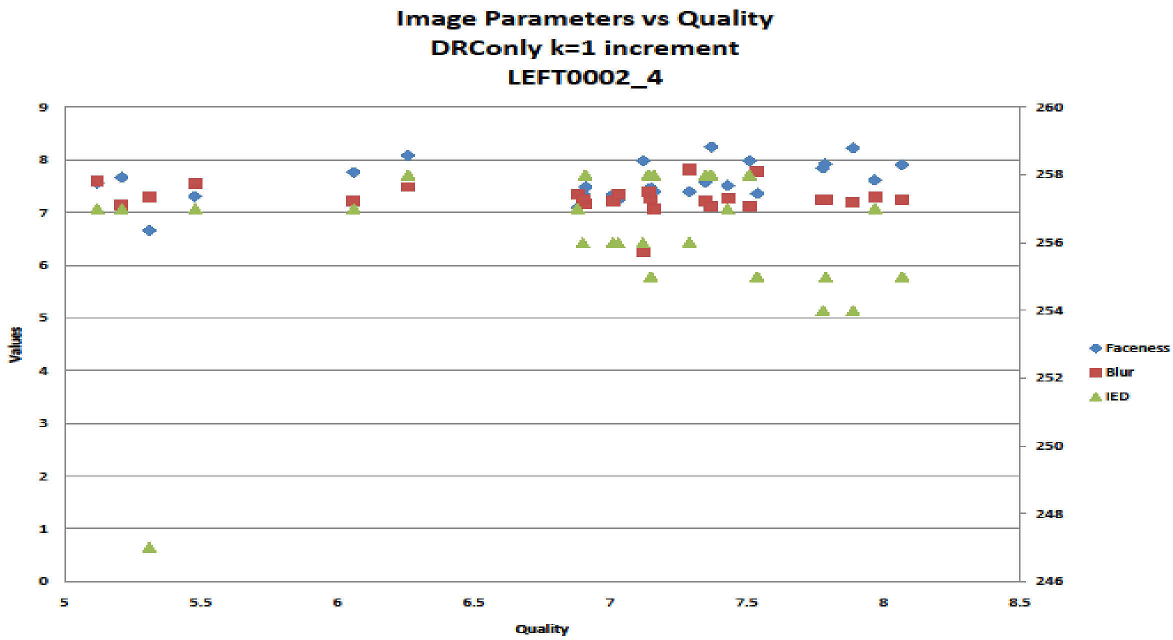
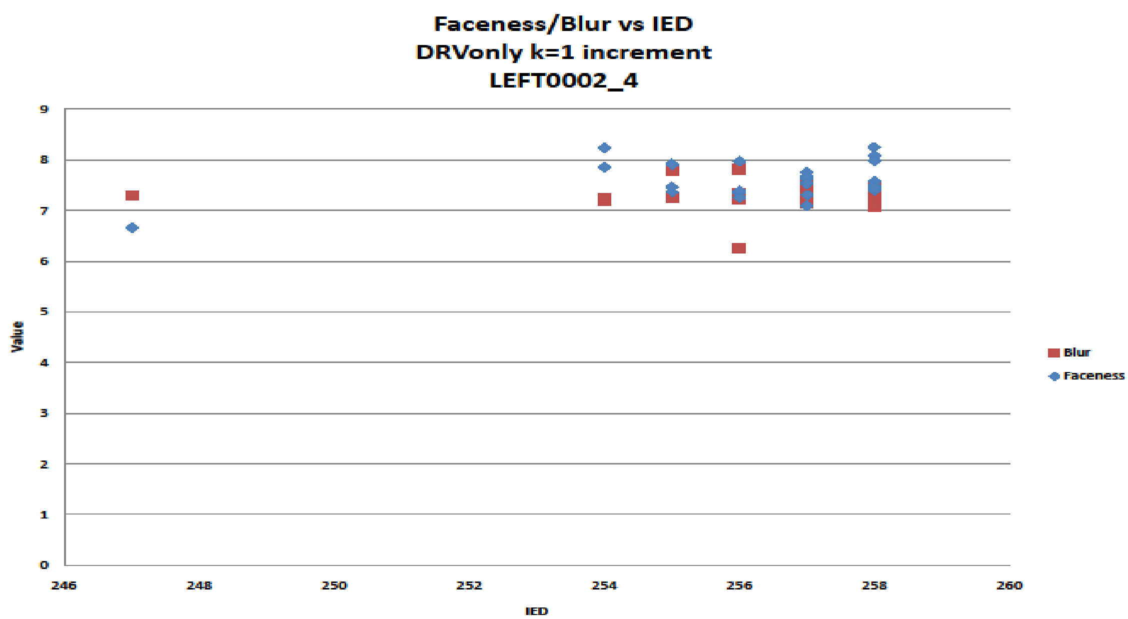
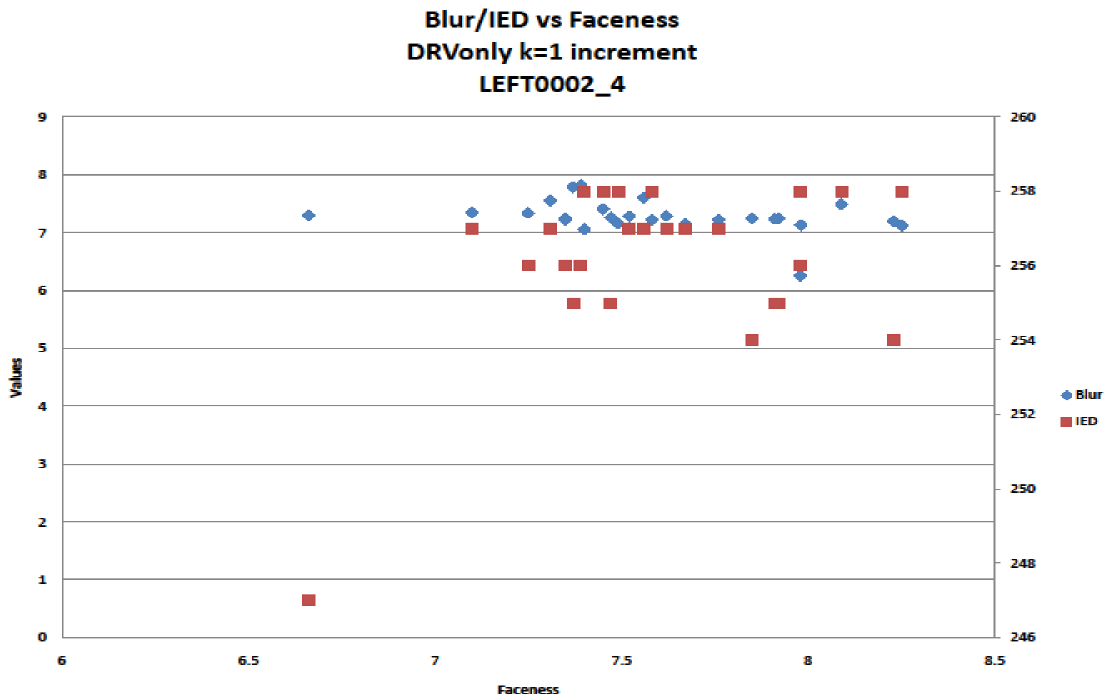
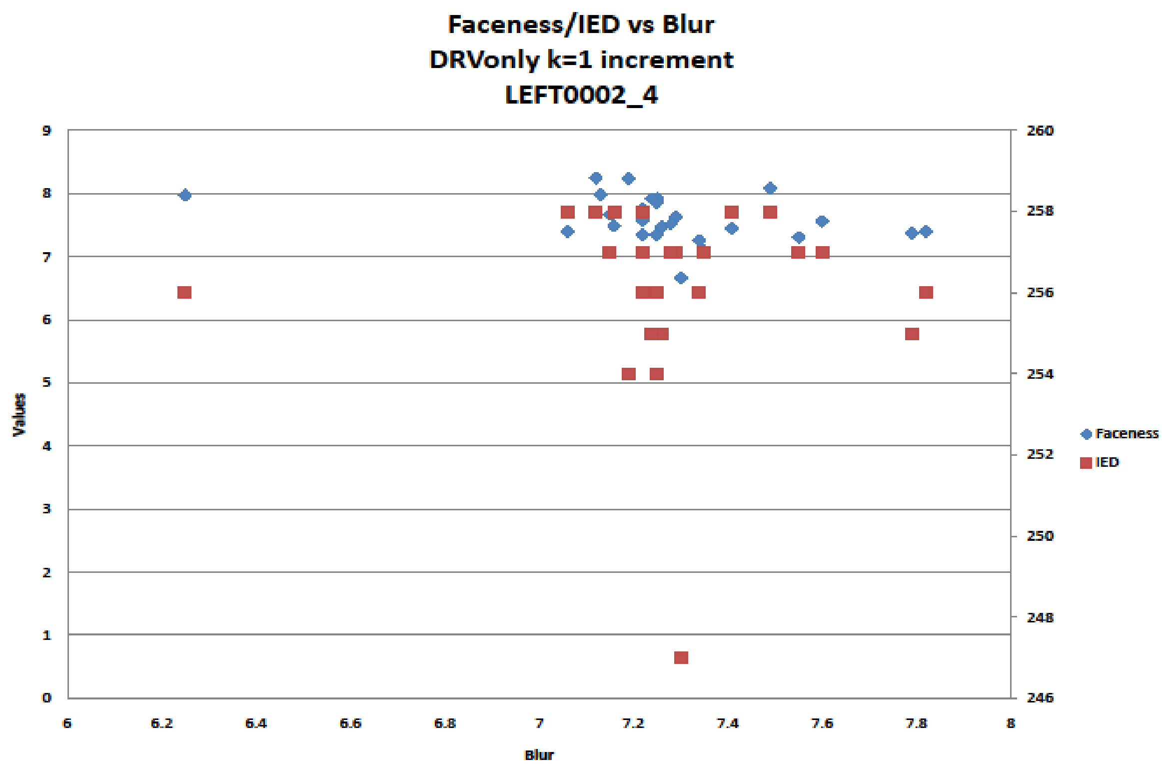


Image Parameters vs Quality
DRConly k=1 increment
LEFT0002_4
Values
Quality
Faceness
Blur
IED



Faceness/Blur vs IED
DRVonly k=1 increment
LEFT0002_4
Value
IED
Blur
Faceness


Blur/IED vs Faceness
DRVonly k=1 increment
LEFT0002_4
Values
Faceness
Blur
IED


Faceness/IED vs Blur
DRVonly k=1 increment
LEFT0002_4
Values
Blur
Faceness
IED

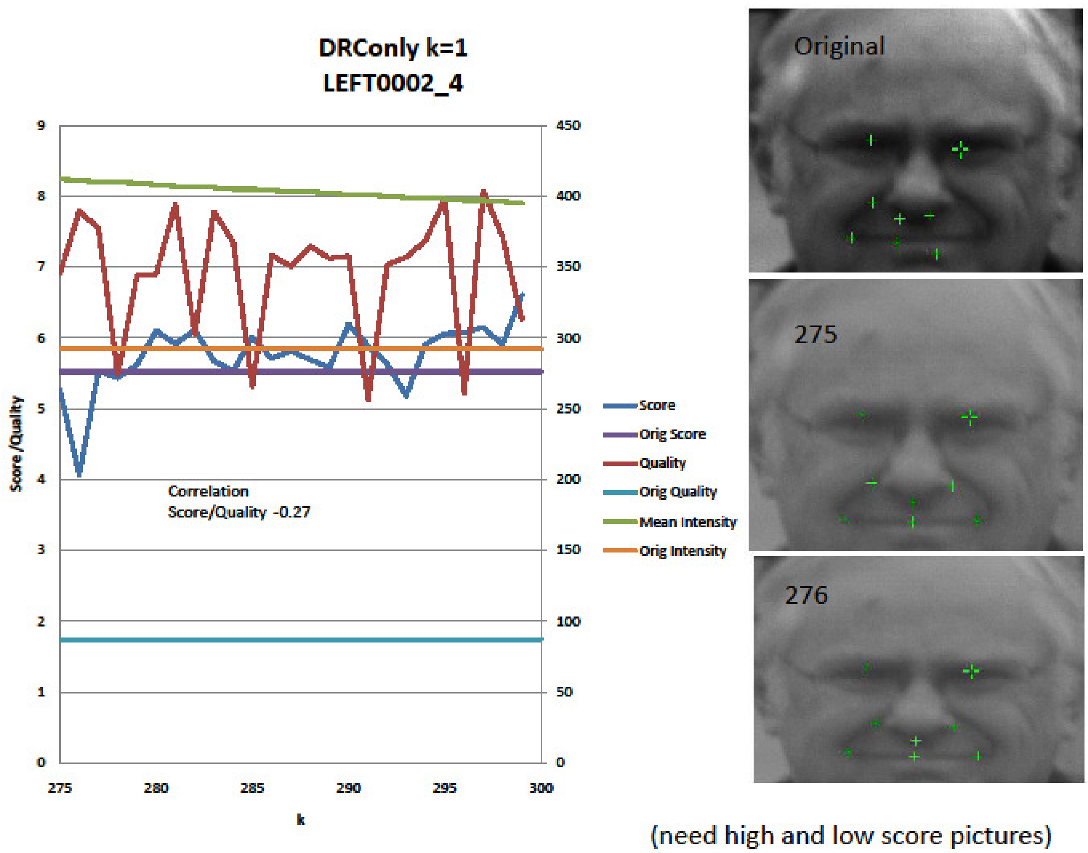
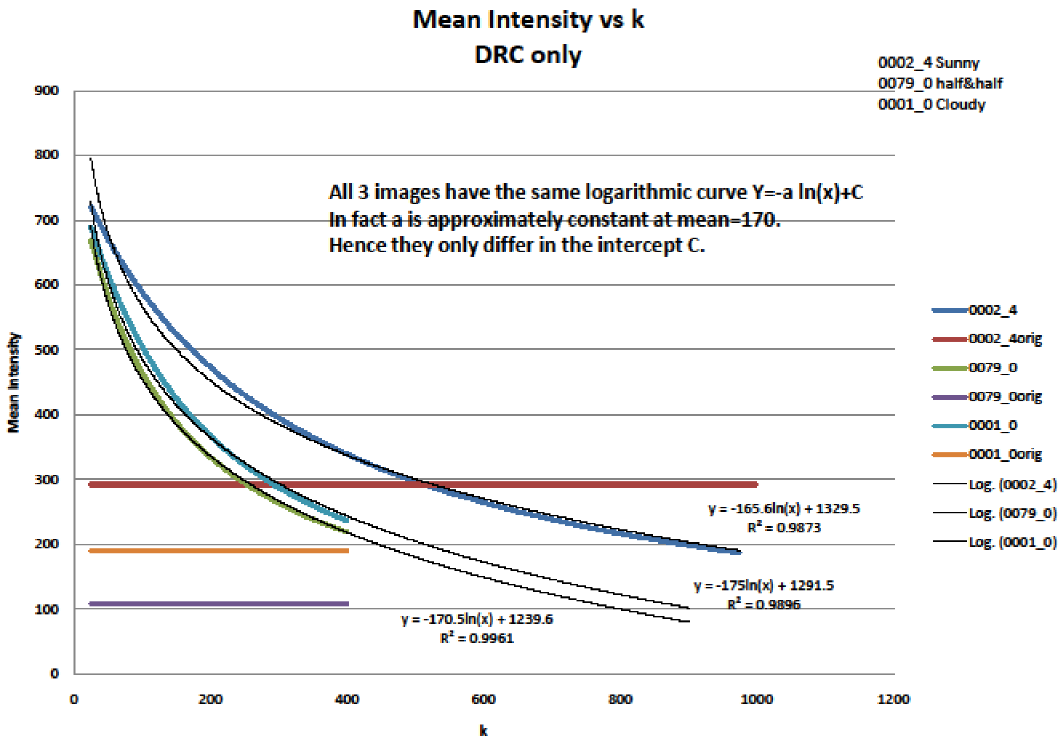
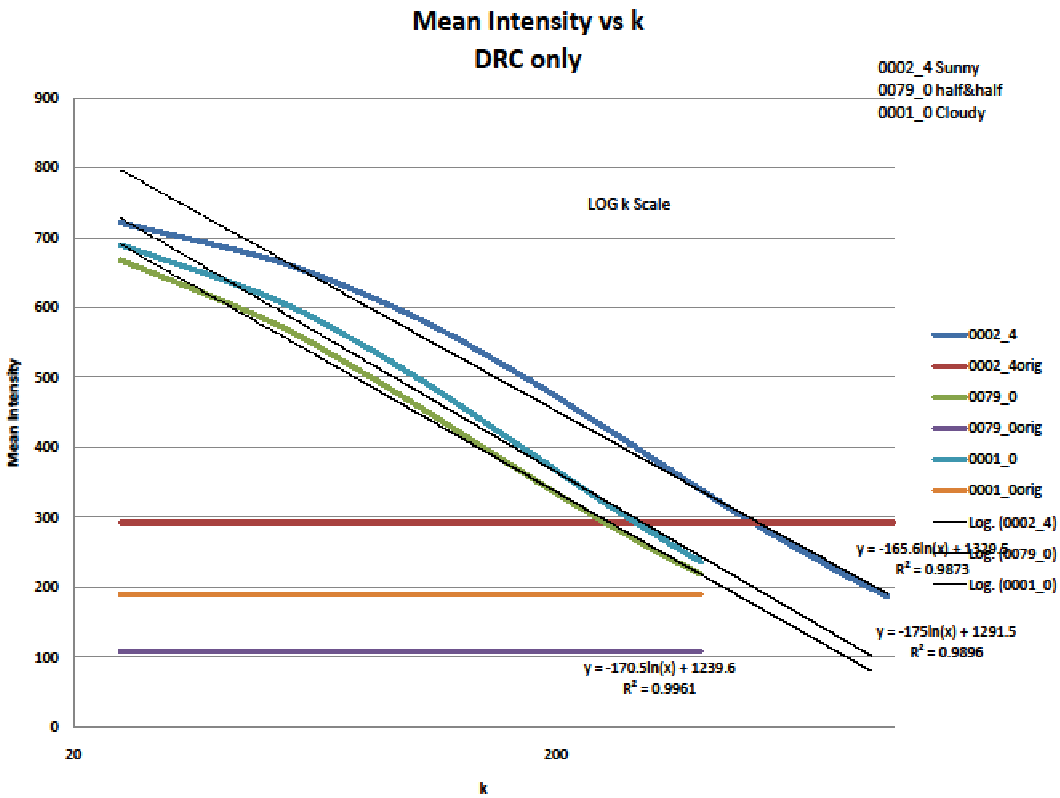


FIG. 23: Another example of correlation observed between the identification score and image quality assessment scores as image quality varies. Please note correlation is negative (not expected). Also please note how the performance of the biometric mark-up improves as the image properties are modified.

In conclusion, after processing many different sets of data, there is a definite unknown understanding between the assessed image quality score factor returned from the COTS face matcher and its identification score as a function of our image enhancements that needs to be properly understood to further optimize our utility as the correlation between these factors has shown to be negative. That is, typically as image quality is determined mathematically to be "better", the identification score drops OR, perhaps, there are some systematic errors in how our data has been processed. Any event, this is an area of continual research.

The following summary curves; however, suggest (given all data has been processed properly) our image enhancements have been proven overall successful and that there is a relationship between our image enhancement techniques utilizing dynamic range compression and identification score in which we can automate on an image capture-to-image capture basis.





This suggests the following algorithm:

1) Start with a fixed value of k say 300
2) Perform DRC and calculate mean intensity.
3) This gives a point on the curve i.e. for Sunny, half & half and cloudy you would get approximately 400,300,275 respectively.
4) Use this point to calculate the value of C = y + 170 * ln(k). This gives 1369, 1269,1244 –pretty close to the actual curves!
5) So now we have a model of the curve.

~~~~~~

6) Lets say we decide from experience that we get good results when the image has a mean intensity of 500 (or a range 300,400,500). i.e. not too bright not too dark.
7) We then calculate the k required to get intensity of 500, i.e. ln(k) = (C-500)/170 , k=exp((C-500)/170)
8) This gives k= 166, 92, 80 for the three images.
9) Then use that value of k.

Please note the above approach has **not** been implemented to date until a better fundamental understanding has been obtained as noted above.
~~~~~~

● Image Stabilization and Super Resolution Studies

Please recall image stabilization is a technology which helps prevent images from becoming blurred. The 2009-IJ-CX-K001 deliverable device is mounted on a tripod for this very reason as image blur can severely degrade image quality. Image stabilization can reduce vibration caused by "camera" shake caused by slow integration times due to the long focal length system we have designed required to capture biometrics at range. In fact, this was the main motivational reasons to investigate moving to the 80/20 BS coatings as discussed below in the Hardware Development section. The 80/20 coatings did effectively increase the speed of the optics thus assisting with the reduction of image blur.

Image stabilization (IS) is divided into optical stabilization (hardware correction) utilizing built-in vertical and horizontal built-in gyroscopic sensors to detect hand-shake and there is digital stabilization (software correction). The digital stabilization (DS) uses image processing techniques to compensate for vibrations.

We explored implementing both methods due to the criticality of our application and the need to obtain the best image quality for 3D segmentation and face recognition and identification.

As is known in literature and in practice, super resolution (SR) is a technique to increase the inherent resolution of the system typically by combining images into a sharper image; however, what is not readily known is the DS and SR actually are very similar and can share some of the first signal processing building blocks if implemented properly. Further some of these early signal processing techniques are currently utilized and implemented for 3D segmentation.

That is SR typically has three (3) main signal processing blocks which are Harris Corner Detection, Feature Matching, and Image Combination. Harris Corner Detector finds the distinct corners to serve as the features of an image. We currently use the Harris Corner Detector for our auto-alignment prior to auto-segmentation. The Feature Matching uses the minimum sum of squared difference error (SAD) to find the corresponding features correctly and then Image Combination reconstructs the sharpest image according to the corresponding features

As hardware modifications are complicated and take a fair amount of time and cost to design in, machine, integrate, electronically support we have initially looked at DS and SR.

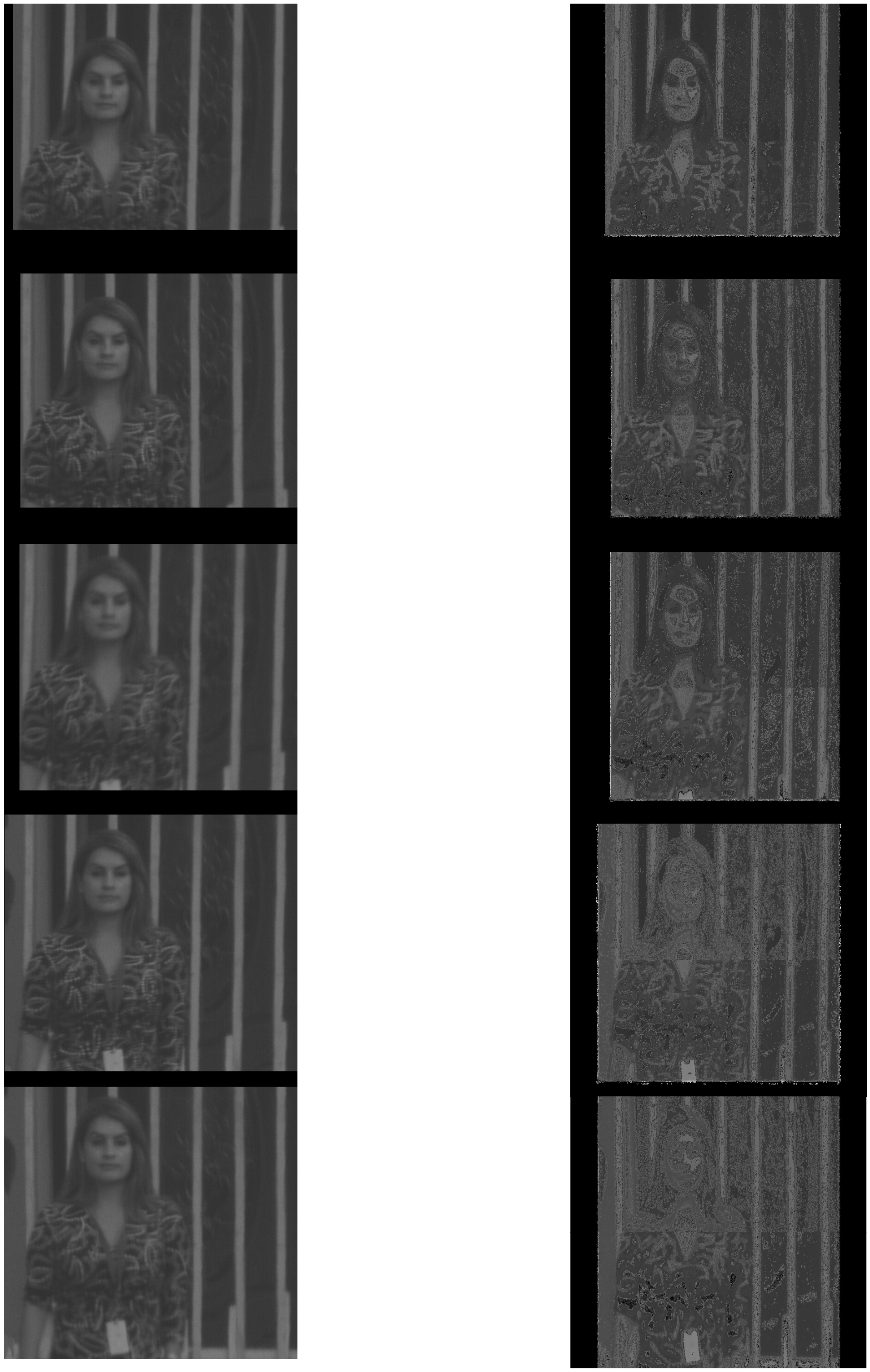


FIG. 24: Left column is a 2D image capture thru the device at 100meters with no tripod under sunny conditions. Right column is after digital image stabilization. Please note (IS) did remove some motion blur.

● Super Resolution

Our main objective is to take the five frame video clip of test subjects captured out on the field of 5 low resolution (LR) images and generate an image with 2x resolution using the super-resolution algorithm

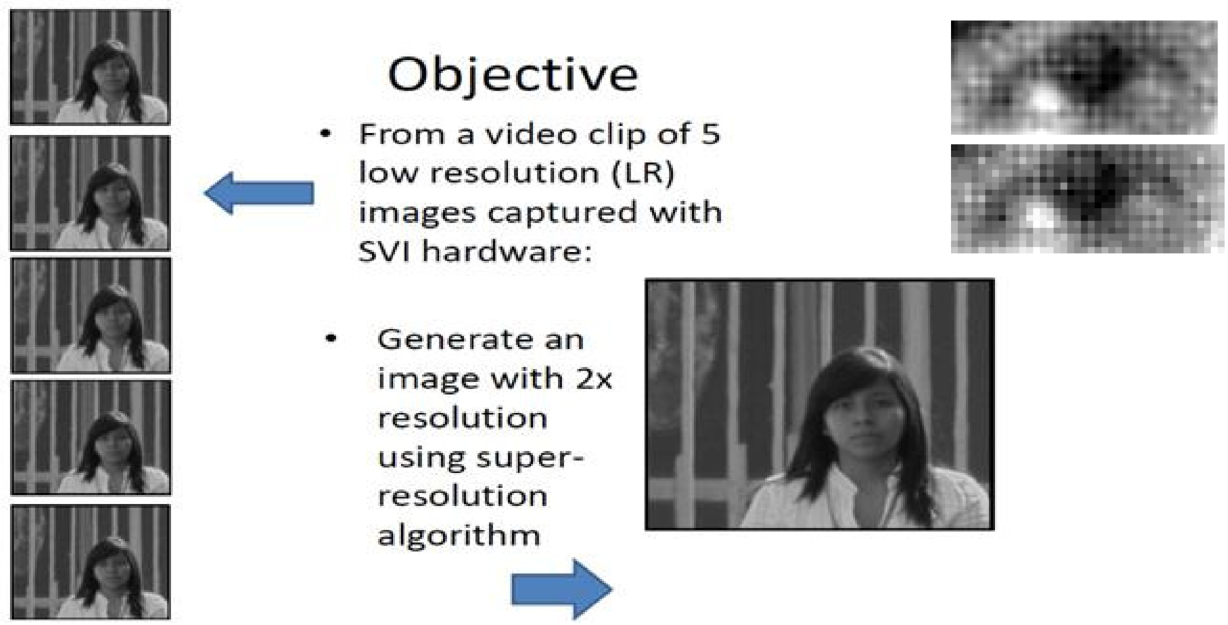


FIG 25: Super Resolution Objective: Take existing five frame video clips of subjects captured outdoor up to 100 meters from point of use and generate a higher resolution image (min. 2x higher resolution). Please note enlarged eye socket image(s) with super resolution (top) and without (bottom).

Algorithm

- Basic algorithm is the iterative method of: M. Irani and S. Peleg, "Super Resolution From Image Sequences", ICPR, 2:115—120, June 1990.
- Bayesian enhancements are also possible: [2] P. Cheeseman, B. Kanefsky, R. Kruft, J. Stutz, and R. Hanson, "Super-Resolved Surface Reconstruction From Multiple Images," NASA Technical Report FIA-94-12, December, 1994.

Two basic steps:

- – Sub-pixel registration of the LR images using one of the images as the “reference” image. Registration is basically image stabilization. They plan is to combine image stabilization with super resolution.
- – Iterative back-projection of the LR images onto the high resolution grid

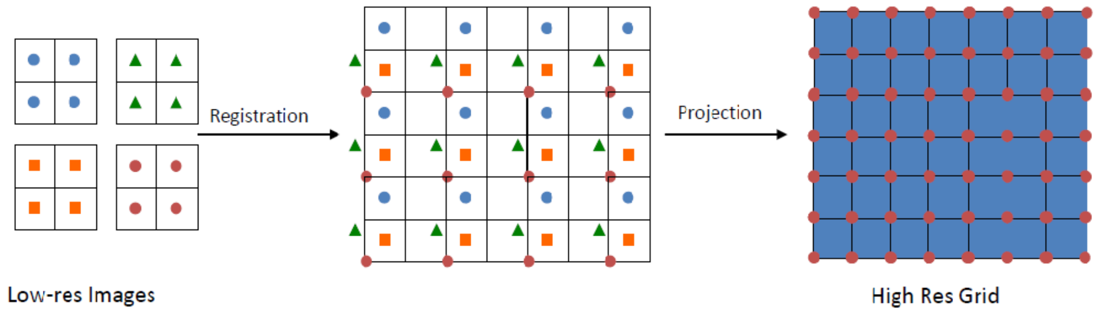


FIG 26: Super Resolution aligns or registers each frame in the video clip. Then determines common features of all frames "projects" the composite image back onto a high resolution plane or grid to create a higher resolution image of any one input image.

Registration (Motion Estimation)

- We assume that there is translational and rotational motion between the reference and the other LR images (Affine Projection).

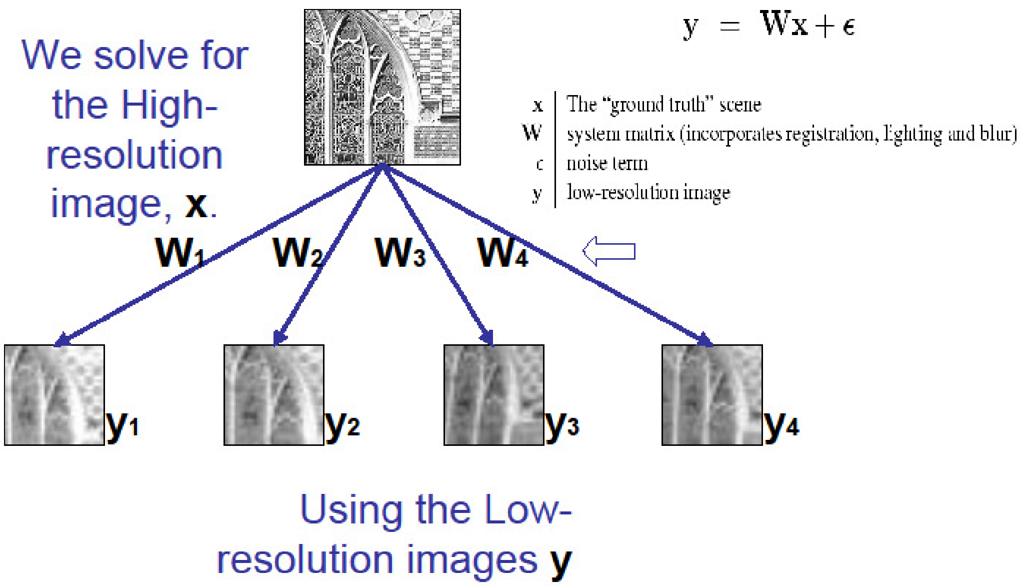
- The affine motion estimation code calculates the affine parameters that warp the nth frame back onto the reference frame. We have adapted the traditional 6 parameter model and reduced it to 4. The motion vectors we use are calculated as follows :

  u = k1*x + k2*y + k3 v = -k2*x + k1*y + k4

  where k3 and k4 describe the translational motion of the image while k1 and k2 describe its rotational motion.

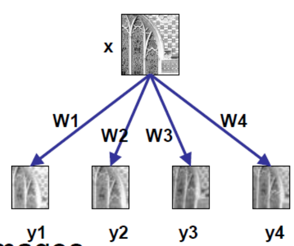
- The values of the parameters are calculated iteratively. We start with a first guess for all parameters (zeros in our case). Decomposing the images in a 3 level pyramid structure, we warp the 2nd image onto the first one, using 3 iterations per level (starting with the coarsest one) Each time the image is warped, we calculate the image spatio-temporal gradients and use them to update the values of the parameters.

Generative Model



Maximum a Posteriori (MAP) Solution

$$\mathcal{F} = \underbrace{\frac{1}{2\sigma^2}\sum_{k=1}^{K}\left\|\mathbf{y}^{(k)} - \mathbf{W}^{(k)}\mathbf{x}\right\|_2^2}_{\text{generative model}} - \underbrace{\log\left(p(\mathbf{x})\right)}_{\text{prior}}$$

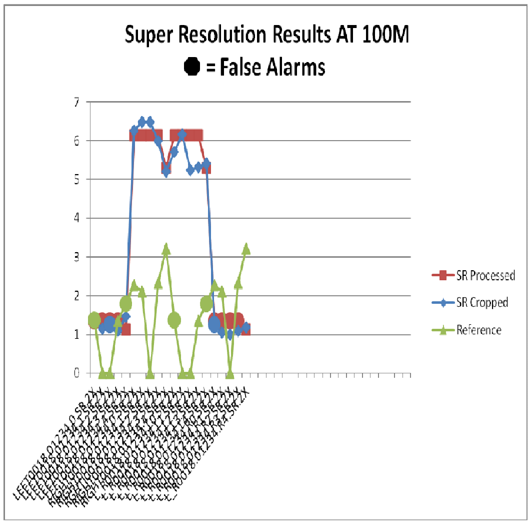


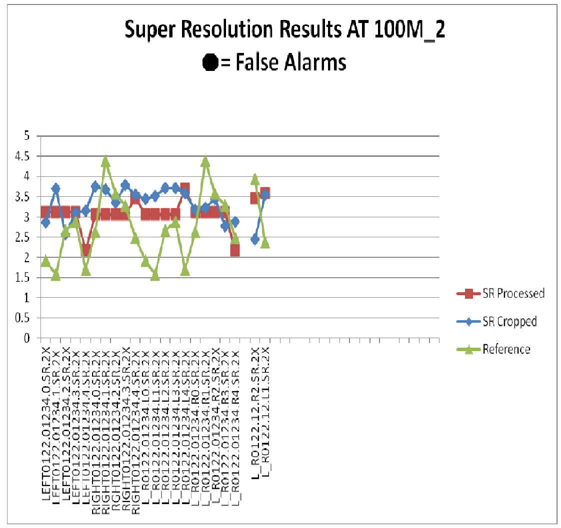
1. Compute registrations from low-res images.
2. Solve for SR image, **x**, using gradient descent.

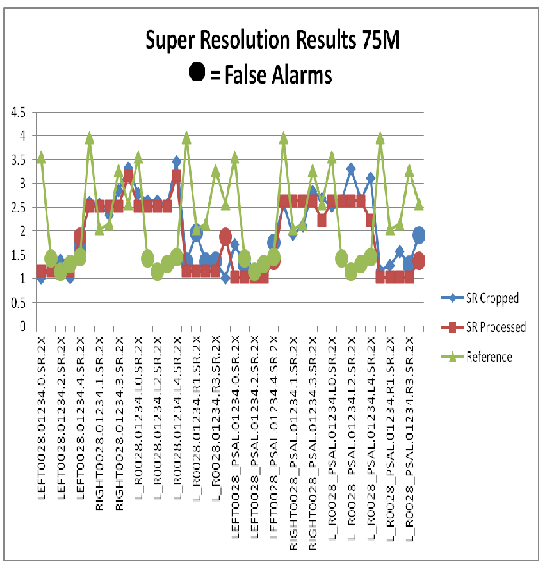
$$\frac{\partial \mathcal{F}}{\partial \mathbf{x}} = -\frac{1}{2\sigma^2}\sum_{k=1}^{K}\mathbf{W}^{(k)T}\left(\mathbf{y}^{(k)} - \mathbf{W}^{(k)}\mathbf{x}\right) - \frac{\partial}{\partial \mathbf{x}}\log\left(p(\mathbf{x})\right)$$

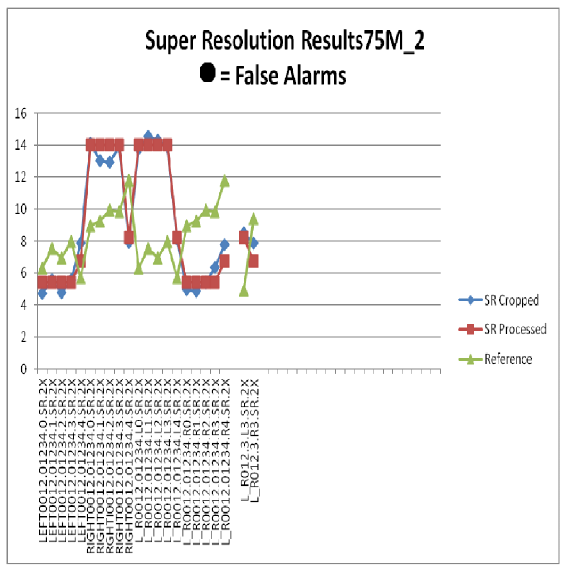
Using the algorithm as described above, we ran a number of test runs with and without super resolution and noted identification results as our sole metric of performance to determine statistically if identification can be improved. All tests to date have been performed on 2D images solely and not on the 2D segmented images. The following Figure Twenty-Seven represents a small sample of data collected to date:

StereoVision Imaging, Inc.
Award No. 2010-IJ-CX-K001


Super Resolution Results AT 100M
⬤ = False Alarms
7
6
5
4
3
2
1
0
SR Processed
SR Cropped
Reference


Super Resolution Results AT 100M_2
⬤= False Alarms
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
SR Processed
SR Cropped
Reference


Super Resolution Results 75M
⬤ = False Alarms
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
SR Cropped
SR Processed
Reference


Super Resolution Results75M_2
⬤= False Alarms
16
14
12
10
8
6
4
2
0
SR Cropped
SR Processed
Reference

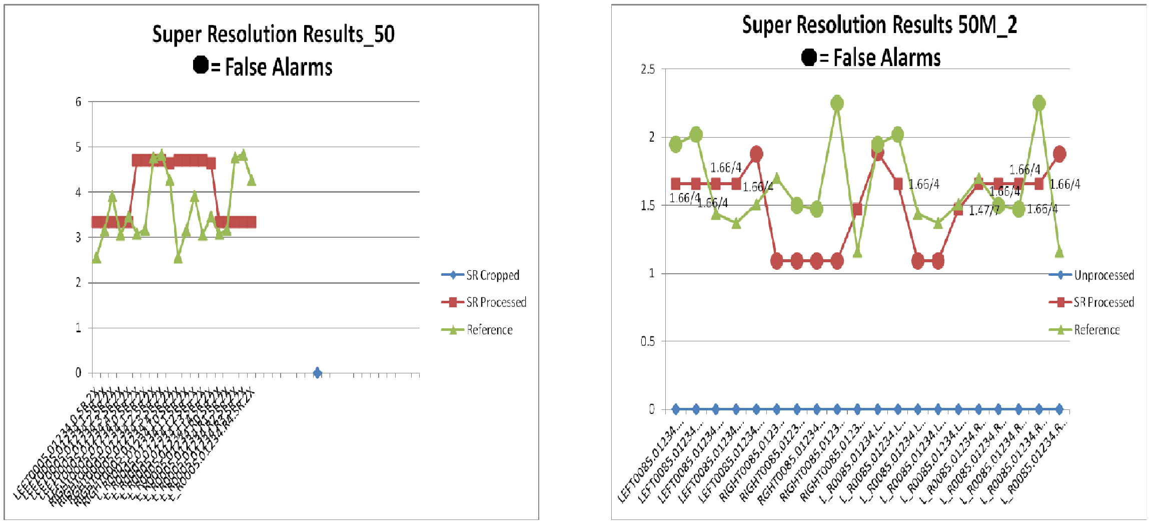


FIG 27: Super Resolution results for two runs at 100m, 75m, and 50m respectively. The green trace represents the ID scores (y-axis) versus the individual image frames of captured images without super resolution. The blue and red traces are results from the data as an output of our super resolution algorithm with the image cropped or as-is (recall the image size is twice the size due to the higher resolution). The cropped image was a manual exercise and image was cropped around the shoulders to top of head).

Super resolution (SR) requires one frame of the five to be used as a reference. The SR results shown in the Figure are multiple SR runs using different frames as the reference and then using the tight channel as well as the second. Please recall we capture ten frames total: five (5) for the left and five (5) for the right.

To date, overall we observed SR improving identification scores sometimes significantly as well as lowering scores for the imposters. And at times where we observed a false alarm, now with SR we have the proper ID. The mean ID scores are typically higher and the standard deviation is typically tighter thus SR also appears to be more consistent. Our next step would be to move to implement SR within our application software.

● Auto Exposure and Auto Focus Algorithm Development

Studies to incorporate auto exposure (AE) and auto focus (AF) were initiated and implemented as part of the 2010-IJ-CX-K001 deliverable. Both algorithms are necessary to fully automate the system as compared to our first generation design in which manual exposure and set focus distances were mandatory for proper operation.

<u>Auto-Exposure</u>

AE can be broken down into two blocks: a statistical and a control block. The Control Block is an implementation issue and well understood. The Statistical Block uses pixel statistics to determine whether the current image captured by the imaging array is too bright, too dark or correctly exposed. The Control Block then acts on the output signals generated by the first module by generating control signals to set the proper gain and integration time for each array in a stable manner.

Matlab code has been developed to import images initially captured off our first generation device as a function of integration time and run our AE algorithm for evaluation and subsequent modifications.

During our initial studies, our “focus” is on the Statistical Block. We implemented a center weighted approach (in Matlab) within our ROI to determine proper exposure for our application.

Performance under controlled testing and various uncontrolled lighting conditions was accomplished.

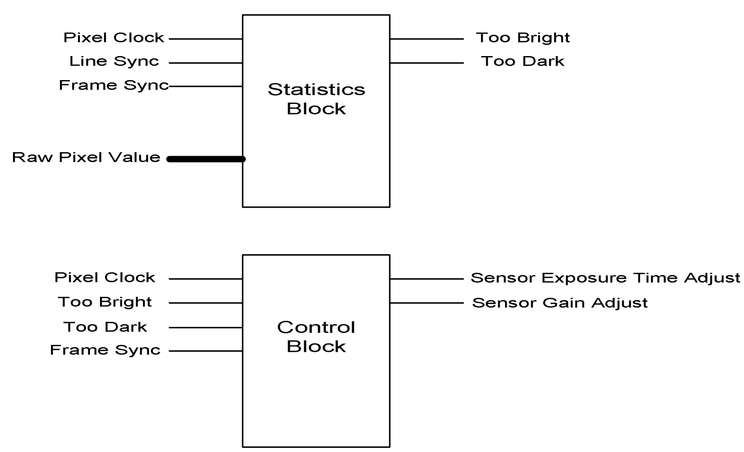


FIG 28: Auto Exposure algorithm can be broken down into a statistical block and a control block. Statistical block determines image statistics. Control block integrates exposure values to the imager properly.

As illustrated in the Figure Twenty-Nine below, image metrics were captured in the red boxes only to perform the operation within a reasonable period of time i.e. in msec’s. The vertical center boxes (3) are weighted higher than the other six (6) boxes The white batch is used as a reference. A large number of images of various scenes had been captured as a function of integration (exposure) time. This data was then fed into our Matlab program.

Our Matlab program simply computed the average intensity values of all the pixels in the red boxes and weights each box accordingly. The white patch was too assure the image was not overexposed.

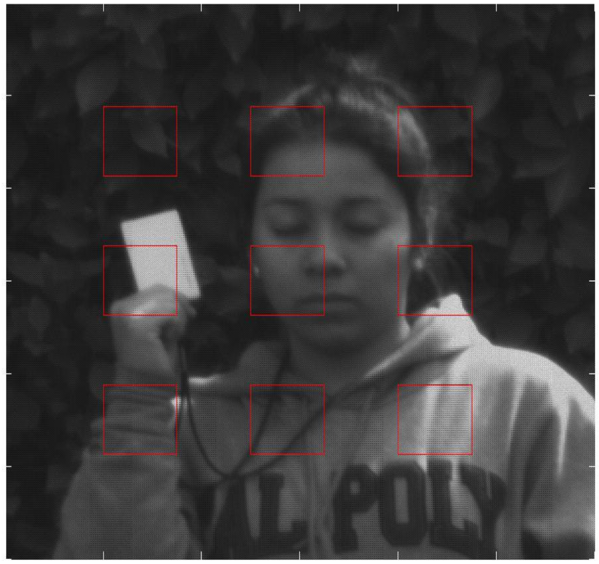


FIG 29: Example of an image capture outdoors. Red boxes indicate regions where image statistics are collected. The middle boxes are weighted higher than the top and bottom rows of boxes.

The following Table are more examples of outdoor test runs of different subjects as a function of exposure settings.

Data is reduced to look at the average intensity of the entire scene as compared to the weighted approach.

The last two columns are comments from visible observations of our Matlab program as well as Aptina's imaging software (imaging array manufacturer) which we use to evaluate the white patch reference as illustrated in Figure Twenty-Nine. Highlighted in red is the best image per run via post analysis.

Testsubject_Run1_75M	130-160	Ideal setting=64ms		
Exposure setting	I avg	I weighted	MatLab Comments	Dev Ware Comments
1ms	11.08	11.03	Too Dark	Too Dark
2ms	12	12.04	Too Dark	Too Dark
4ms	13.96	13.96	Dark	Dark
8ms	18.04	17.78	Dark	Dark
16ms	26.01	25.77	OK	Low
32ms	41.9	42.19	Good	Half Scale
64ms	73.92	74.92	A Little Over Exposed	Full Scale
128ms	128.28	131.16	Over Exposed	Over Exposed
Testsubject_Run2_75M	Lux=100-150	Ideal setting=64ms		
Exposure setting	I avg	I weighted	MatLab Comments	Dev Ware Comments
1ms	11.32	11.32	Too Dark	Too Dark
2ms	12.59	12.09	Too Dark	Too Dark
4ms	15.2	14.39	Too Dark	Too Dark
8ms	20.5	18.7	Dark	Dark
16ms	31.1	27.65	OK	Low
32ms	52.37	45.31	Good	Half Scale
64ms	92.01	79.51	Great	Almost Full Scale
128ms	150.11	133.42	Over Exposed	Over Exposed
Testsubject_Run3_100M	Lux=90-100	Ideal setting=64ms		
Exposure setting	I avg	I weighted	MatLab Comments	Dev Ware Comments
1ms	11.3	10.97	Too Dark	Too Dark
2ms	12.53	11.81	Too Dark	Too Dark
4ms	14.99	13.51	Too Dark	Too Dark
8ms	19.88	16.99	Dark	Dark
16ms	29.71	24.04	OK	Low
32ms	49.76	37.84	OK	Half Scale
64ms	64.25	64.25	Good	Almost Full Scale
128ms	109.7	109.7	Over Exposed	Over Exposed
Testsubject_Run4_100M	Lux=100-110	Ideal setting=64ms		
Exposure setting	I avg	I weighted	MatLab Comments	Dev Ware Comments
1ms	10.88	11.04	Too Dark	Too Dark
2ms	11.64	11.86	Too Dark	Too Dark
4ms	13.17	14.02	Too Dark	Too Dark
8ms	16.46	17.39	Dark	Dark
16ms	22.47	24.88	OK	Low
32ms	35.2	39.55	Good	Half Scale
64ms	57.89	67.05	Great	Full Scale
128ms	96.41	111.62	Over Exposed	Over Exposed

TABLE TWO: Snap shot of a few dozen test runs complied to determine suitable threshold for auto exposure

The goal of the test runs was to determine a suitable threshold from scene to scene that is hard coded. We know this should be close to the 18% grey scale value as cited in literature. Based on empirical data we had observed a value of ’60’ properly exposes most of the images; though note all this data was collected on the first generation platform and then was repeated once the second gen platform was operational.

Implementation was relatively straight forward and included configuration parameters regarding weight of each region and threshold. The control loop was based on interpolation of a second order curve which allowed for auto exposure on each channel to be determined and settle very fast (on order of milliseconds). The initial setting is captured at 1 msec and then interpolated to determine the final exposure.

To deal with localized “hot spots” or high intensity patches that may occur due to direct sunlight hitting small regions of the face only, we increased the video clip from 5 frames to 6 and automatically stepped down the exposure setting every two frames to a full f-stop once proper exposure was determined by the algorithm.

Auto-Focus

Auto-focus is much more complicated than auto exposure. Our approach was to begin with a simple approach and add more complicated techniques as needed based on empirical testing. Figure Thirty below is the typical processing flow:

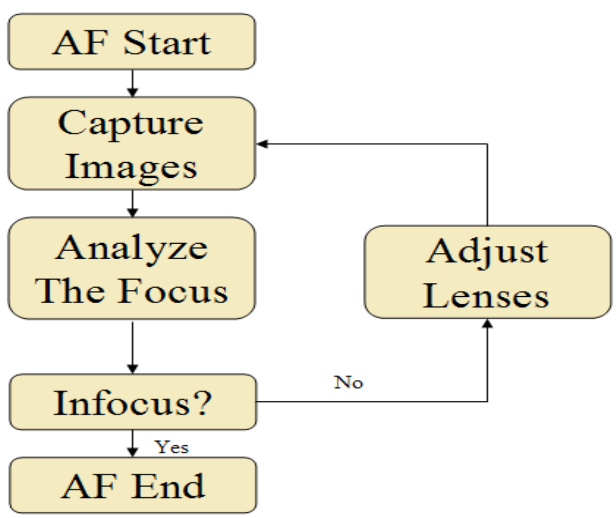


FIG.30. Typical Auto Focus signal processing flow

Auto-focus processing can also be broken down into two block as AE, as depicted in Figure Twenty-Eight. In general, the sharpness of the image is determined utilizing edge detector routines followed by a statistical variance AF score – the statistical block. The score is highest at the best focus (sharpness). The control block then simply goes back and finds the highest peak or score and moves the focusing lens to this determined setting.

Again, utilizing our existing binocular hardware we were able to store a sequence of images as the stepper motor moved at a pre-determined exposure. Another Matlab program was written to accept these images and determine the AF score as a function of several edge detector routines and distance. Each image used the same nine (9) windows as we used with auto-exposure.

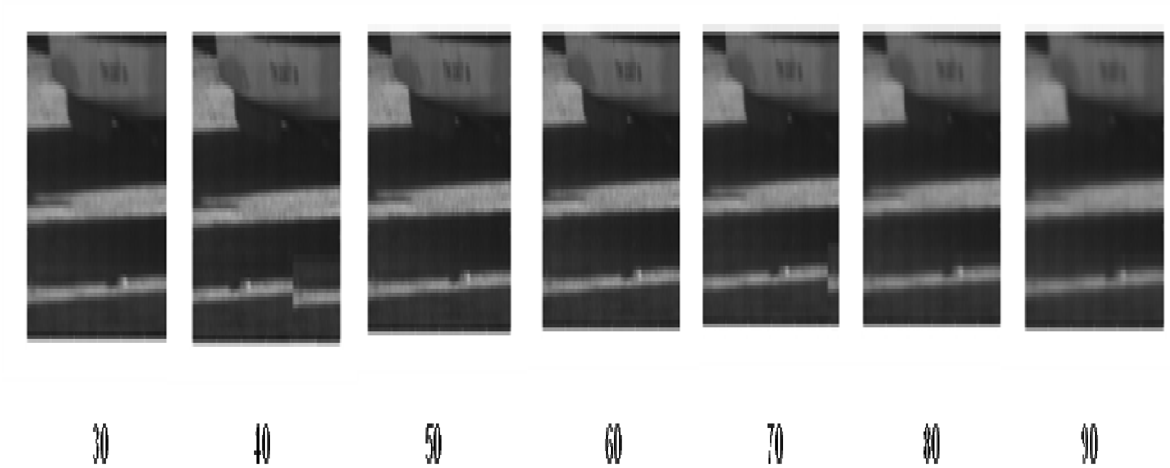


FIG. 31: Images shown above captured at different stepper motor locations. Chart indicates response from each edge detector routine at each location. Note: Proper stepper motor position 60 was the correct image.

A series of 25 indoor / outdoor test runs were completed, compiled and documented. Outdoor test runs were of faces captured at 50, 75 and 100 meters. Of the five (5) edge detector programs used in the study one algorithm, Canny, failed to performed and was removed from subsequent testing.

The Chart below is a summary of ALL test runs. It is clear the 'Log' algorithm out performs all other algorithms tested.

The Laplacian of Gaussian, so-called 'Log' method finds edges by looking for zero crossings after filtering the grey scale image with a Gaussian filter. We then simply used the square of the standard deviation as the metric to determine a "score". Variance did not seem to work reliably.

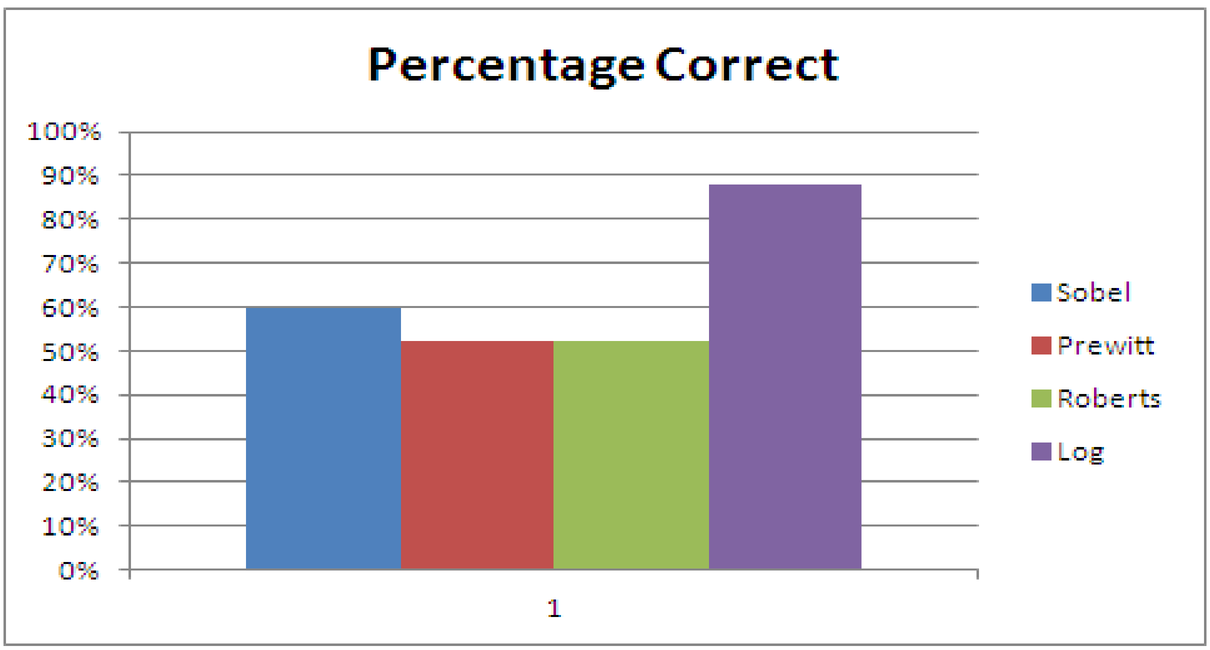


FIG. 32: Summary results of all algorithms studied to determine best approach to move forward to implementation

Implemetation was challenging due to the need to support double precision arithmetic required for the edge detector. We would have to add a FPU IP cores to our FPGA thus we decided to move forward with the Sobel operator due to ease of implementation.

One shortcoming of this approach; however, is that at times the background results are in focus when the foreground was desired and vice-versa due to utilizing windows and movement of the device while capturing. It is recommended to add face detection techniques to resolve this issue but was outside the scope of this award to swtudy and implement.

4.0 HARDWARE DEVELOPMENT

The 2010-IJ-K001 award allowed us to fully automate the system with the notion the system, as a next step, can then be handed-off to law enforcement personnel without the need of SVI personnel present to move towards operational testing.
In particular, we are able to:

- Re-design the binocular and receiver optics to increase the speed of the optics and the integration of discrete auto-focus modules. This allowed for a truly hand-held device without the need for a tripod.

- Move away from a color imager to a highly sensitive monochrome sensor further improving image quality (no need for de-Bayer interpolation algorithms, color processing and then conversion to luminance) and improving 3D disparity resolution by a factor of 3 (due to past RGB pixel spacing).

- Configure and develop firmware to design onto a new COTS Spartan 6 FPGA electronic hardware platform to support the revised optical system design.

• Investigate Increase SNR

As mentioned earlier as a precursor, two (2) devices (8x binoculars with integrated stereoscopic imaging system) were built-out with different anti-reflective properties as compared to past contract efforts. Past efforts resulted in a 50/50 transmissive/reflective coating on the cube beam splitter which splits the incoming light beam to the eye & to the imaging array.

This ratio had been changed to 80/20 to allow more light to the imaging array. The human eye has ~10^8:1 dynamic range from dark vision to fully lit conditions in the visible range and more light is required to increase the speed of the optics and allow for more stable captured images resulting in improved image quality.

The devices were thoroughly characterized re: SNR and image quality.

From which there was over a 2x increase in light (please see Table One), that effectively overall increased the signal-to-noise by a factor of 2 and thus allowing for faster optics and a more stable image capture due to shorter integration times for proper “exposure” required under identical times as compared to the previous 50/50 coating.

However further evaluation of the hardware revealed serious image quality issues regarding focusing that were unpredictable at the onset. Issues concerned were the inability to “match” focusing characteristics between one channel of the binocular and the second channel such that one channel was continuously better focus over the 50-100 meter range as compared to the other. And second, the focus point at 50 meters versus 100 meters exceeded the focusing range of the system.

We discovered that the beam splitting prisms have an angle dependence. This means the transmission characteristics of the anti-reflective coating shift by the ray angle when it hits the beam splitting surface. These characteristics can be improved by re-designing the beam splitting coating; however, we used this information as a pre-cursor to a complete re-design and then decided to maintain the 50/50 ratio till a later time.

Environmental Conditions	50/50 Device Manual Exposure Settings	Integration Time [msec]		80/20 Device Manual Exposure Settings	Integration Time [msec]
Sunny	5	6		2	2
	6	8		3	3
Partly Sunny	7	12		4	4
	8	16		5	6
Cloudy	9	24		6	8
	10	32		7	12
Shade	11	48		8	16

TABLE THREE: Integration (exposure time) differences between the 50/50 original beam splitter coating and the newer 80/20

• COTS Monochrome Sensor Identified, Tested and Evaluated

Through primarily “internet research” and internally derived system design guidelines, SVI identified a COTS monochrome sensor from Aptina (www.aptina.com) that “on paper” appeared to be well suited for integration into our application, Part # MT9P031

The imaging array and associated development kit was procured, tested and evaluated and then an apple-to-apple comparison to the color array that was currently utilized was documented.

Table Two below highlights the key imaging properties between the 10MP color imaging array used today and the identified 5MP monochrome array.

The key motivation to move to the monochrome array is its higher sensitivity and higher expected overall performance for facial recognition. The color imager required a de-Bayer algorithm, color correction and then conversion to luminance to “feed” into any COTS 2D Face Matcher. The de-Bayer algorithm, color correction and conversion to luminance, which adds error, can now all be discarded. In addition, our disparity resolution improves close to a factor of 3 due to the elimination RGB spacing; thus the corresponding pixel we search for regarding disparity is adjacent to each other and not spaced 3 pixels away.

The reduction in resolution (10MP vs. 5MP) is compensated for by moving to a longer focal length system.

The main take away from Table One is indicated in red. These are the measured integration times, in msec, required to achieve the proper exposure on the face as a function of the environment. Ideally we need the integration time to be ~1msec in low light (shade) conditions. At 1msec, image stabilization and motion blur issues are drastically reduced and practically eliminated. This ideal integration time is one the key drivers to move to the monochrome sensor. As indicated there is a need to increase the amount of light captured by a factor of 47 to achieve this goal with the existing design. Moving to the proposed new design we would need almost 60x more light due to the increase in the focal length needed to achieve ~50 pixels between the eyes at 100 meters from point of use.

Paramater	Current Design	Proposed New Design
Imaging Array		
Optical Format	1/2.3-inch	1/2.5-inch
Active Imager Size	6.440(H)x4.616(V)mm	5.70mm(H) x 4.28mm(V)
Active Pixels	3856(H)x2764(V)	2,592H x 1,944V
Pixel Size	1.67 µm	2.2µm
Color Filter Array	RGB Bayer pattern	Monochrome
Shutter Type	Rolling	Global and Rolling
ADC Resolution	12-bit (using only 10-bit)	12-bit
Responsivity	0.31V/lux-sec (550nm)	1.4 V/lux-sec
Dynamic Range	65.2dB	70.1dB
SNRmax	34dB	38.1dB
Optical System (100m)		
Focal Length [mm]	130	160
35mm Equilivant	741	960
Aperature [mm]	23	40
F#	5.65	4.00
Beam Splitter	50/50	
Performance		
Disparity Resolution at 100m	4.85	1.62
Ideal Shutter Speed [msec]	1.35	1.04
Shutter Speed in Shade [msec]	**64**	64
Shutter Speed in Sun [msec]	**6**	6
Needed Shade Improvement [x]	47	61
Needed Sun Improvement [x]	4	6

TABLE FOUR : 10MP versus 5MP imaging array properties

The following test and evaluation results indicate that this key design goal is achievable with the proper combination of system dynamics:

Our first step involved setting up controlled experimentation using a light box (sunlight color temperature) and evaluating the imaging array resolution under different conditions, required integration times and performing signal to noise (SNR) measurements using a COTS 6mm focal length lens.

Within the light box, we placed a Norman Koren test chart (line pair chart) at www.NormanKoren.com, used Aptina's development kit to capture imagery for analysis. Also within the light box we placed our MacBeth Chart and used the white patch to accurately adjust the integration time to obtain the same level of intensity from one experiment to the next, these integration times were recorded in Table Two below.

We ran the captured images through a software routine called Image J (www.NormanKoren.com) which let us evaluate the image resolution. We then used a code called sfrcalc, again at www.NormanKoren.com, and imported into MATLAB. In MATLAB we were able to create the following MTF charts as a function of F# (see Figures Thirty-Three – Four):

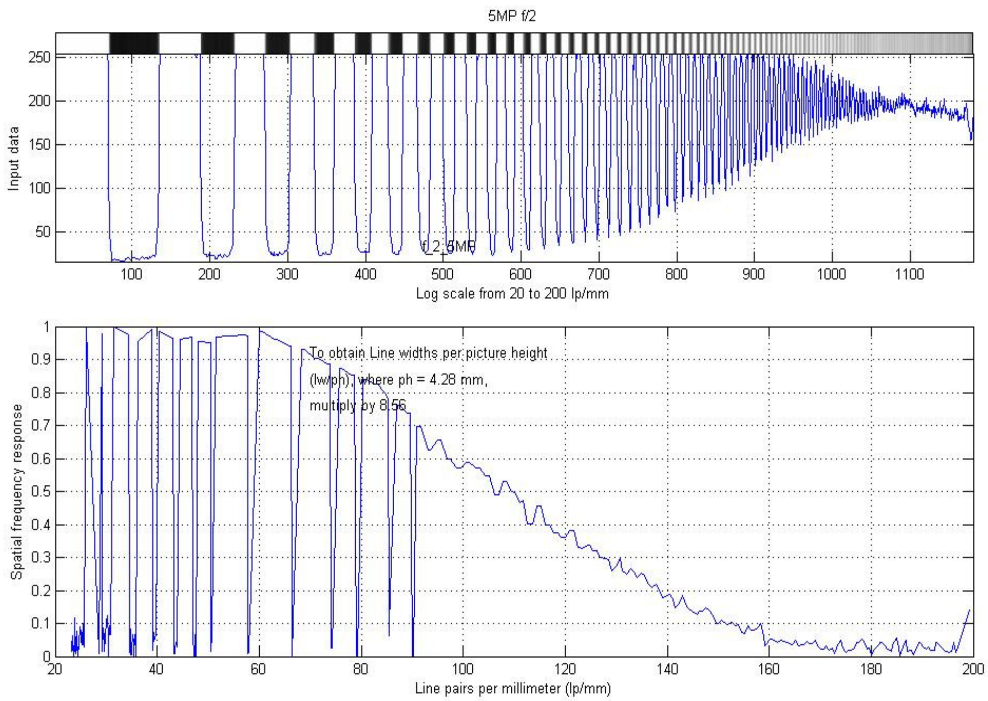


FIG 33: 5MP Monochrom Sensor f/2 MTF response

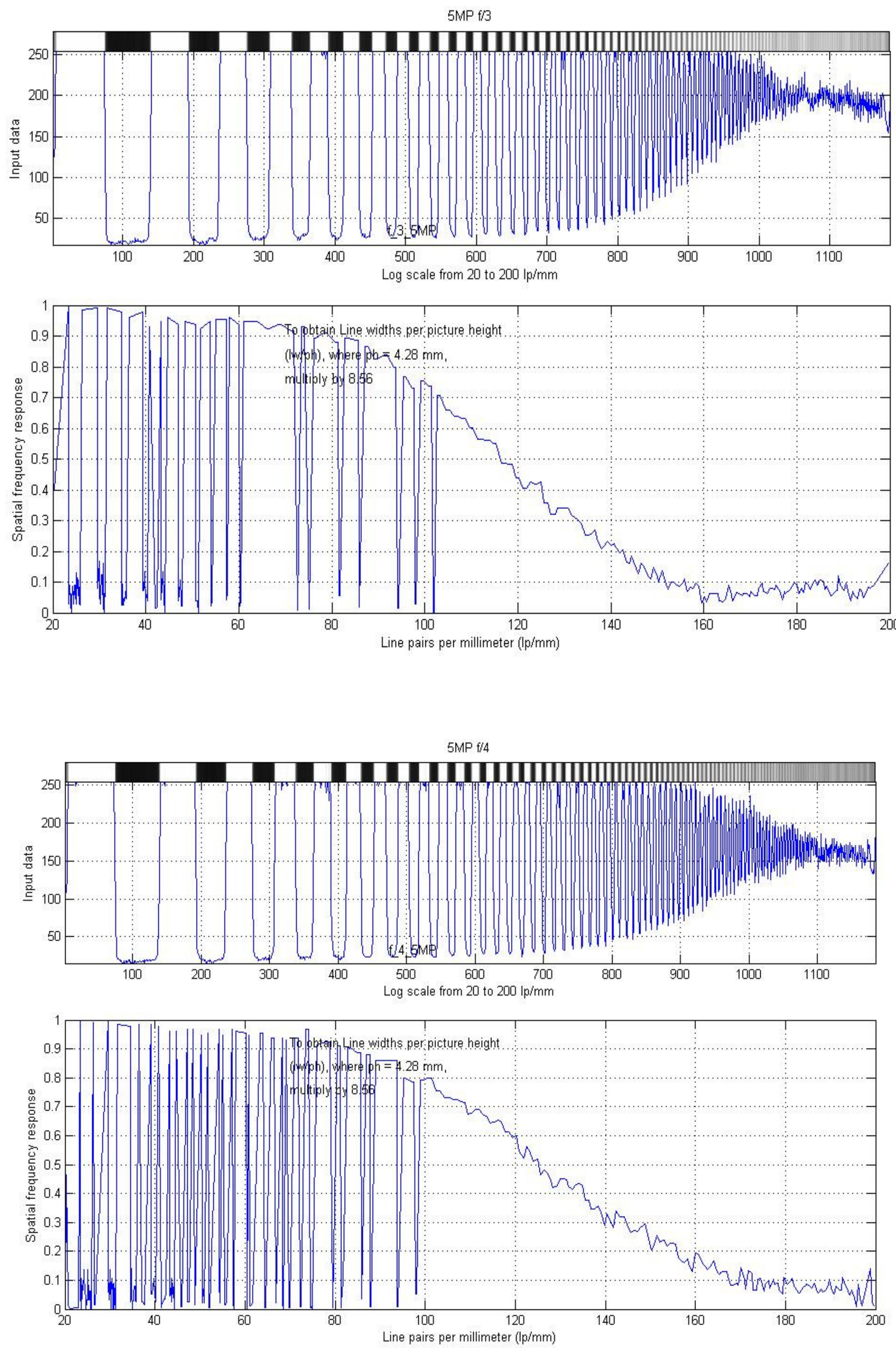


FIG 34: 5MP Monochrom Sensor f/3 and f/4 MTF response

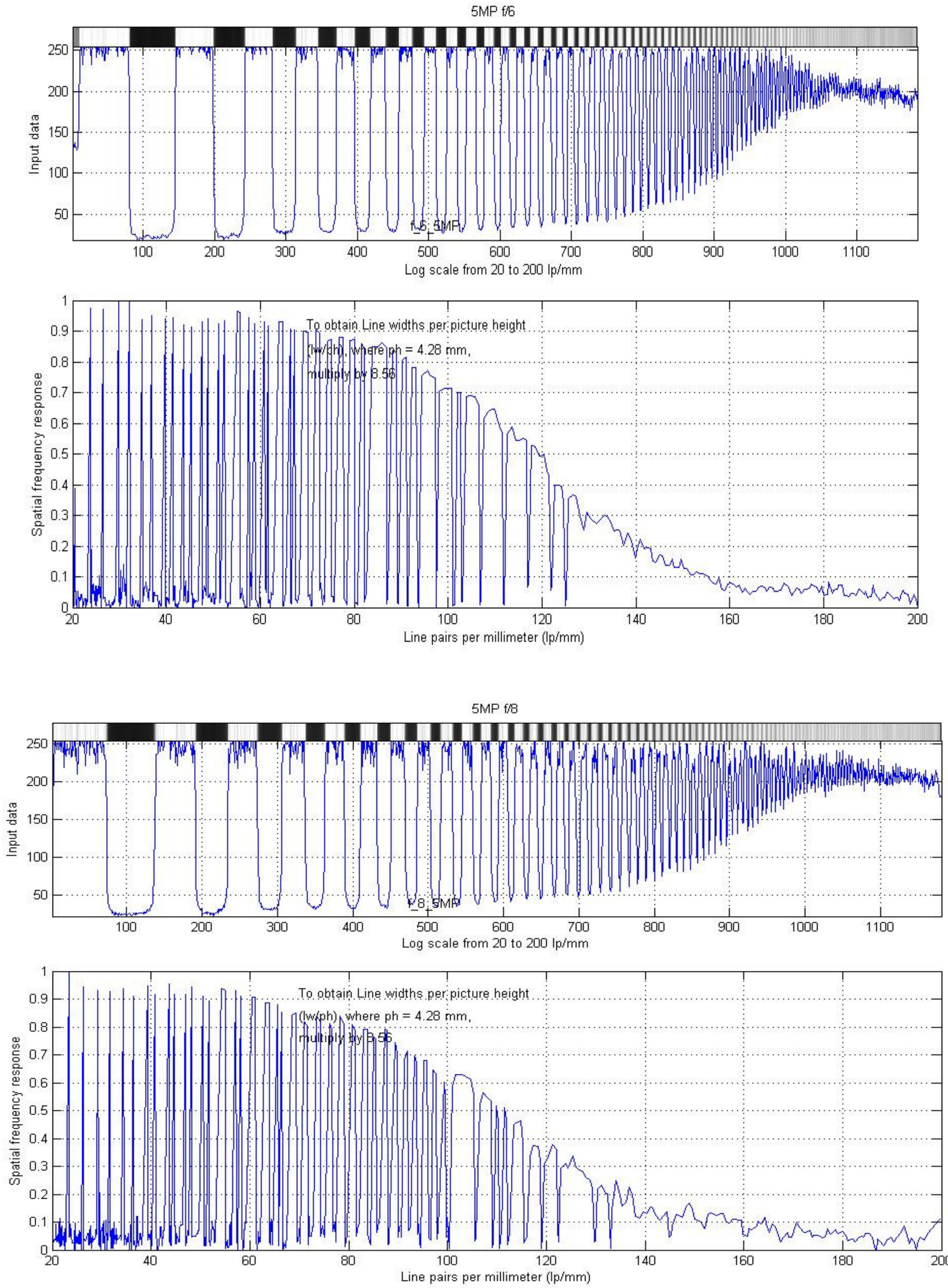


FIG 35: 5MP Monochrom Sensor f/6 and f/8 MTF response

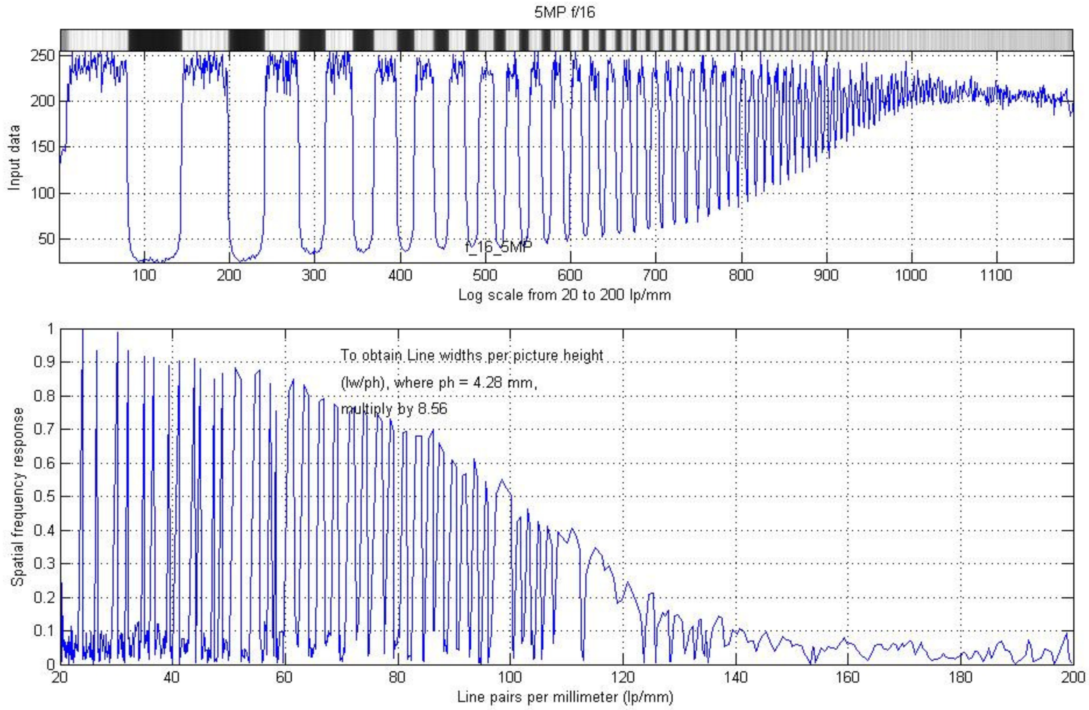


FIG 36: 5MP Monochrom Sensor f/16 MTF response

Please recall the 50% MTF point is a key point to discern a degree of sharpness from one test run to the next. The 10% point typically gives one a sense of the system resolution.

F Number	50% MTF	10% MTF	Exposure [msec]
2	110	150	6.2
3	118	150	10.5
4	125	170	22
6	120	155	45
8	100	145	100
16	90	125	250

TABLE FIVE: 5MP MTF Chart Summary as a Function of F#

From these test runs it was clear that the imager sweet spot is a f/4 – f/6 system. **F/4 would be prefered due to the larger aperature required.**

Test runs above were also ran with the existing 10MP imager with the identical optics but with a needed IR cut-off filter with the following results posted in Table 3 below. Note the increase in exposure time required for this imager at each f-stop. The 5MP imager is over **7x** more sensitive to light and the images obtained are not as sharp (50% point). The resolution (at 10%) appears better as it should since we are comparing a 5MP to a 10MP array but in actuallity the imager exhibits more noise and was difficult to extract the information posted accurately, see Figure Five as an example.

F Number	50% MTF	10% MTF	Exposure[msec]
2	90	170	56
3	90	180	104
4	85	190	204
6	90	160	430
8	82	135	900
16	75	120	2000

TABLE SIX: 10MP MTF Chart Summary as a Function of F#. Please note the exposure or integration time required at each f-stop.

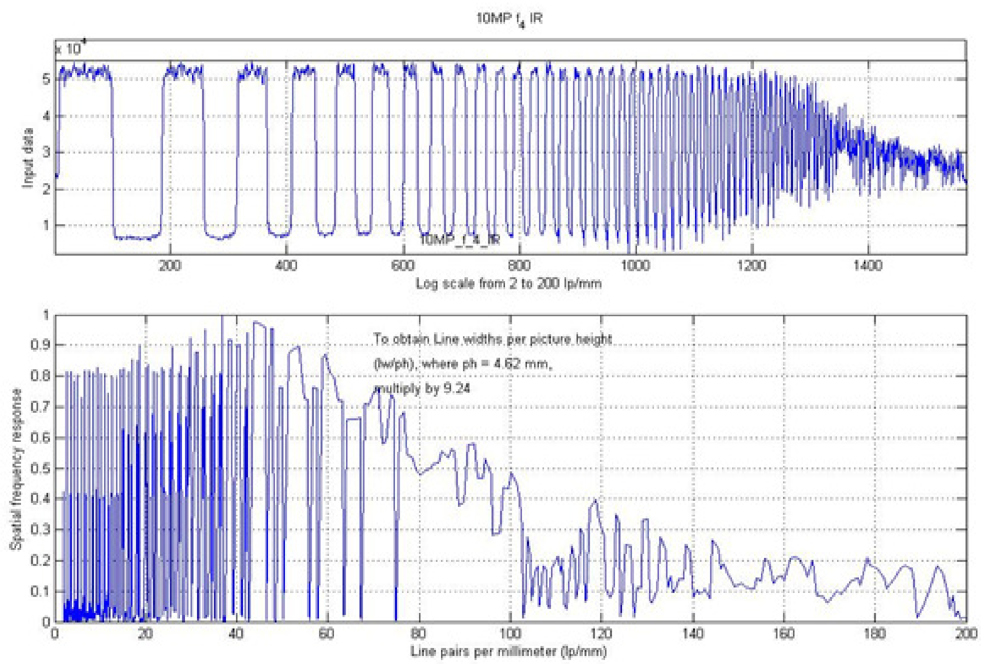


FIG. 37: 10MP MTF curve at f/4. Note curve is 'noisy' and does not exhibit a smooth decreasing exponential type property due most likely to its smaller pixel size.

In summary, based on data captured and analyzed as shown above, a 5MP monochrome system realized in a f/4 system with a 160mm focal length would be highly desirable.

As a follow-up to Table Four we believe we would be able to capture enough light with this system. Table Seven below lists the expected improvements given the same number of optical components in the path. Though we have not factored in the 20mm increase in focal length the approximation below is close enough. Empirically we have seen adequate image quality with gains up to 3. Gain could automatically be set as part of our auto-exposure algorithm in low light conditions easily reaching our goal (60x).

Light Improvement Options	Factor
Inherent (New Imager)	7.36
Change Aperature	3.0
Beamslpitter Ratio	1
IR Filter Characteristics	1.25
Add Gain	1
Improved Xmission Glass	1
Mirror Reflectivity	1
Total Projected Improvement [x]	**27.83**

TABLE SEVEN: Projected improvements with a 5MP f/4 system over the current 10 MP f/5.65 system. Note with monochrome sensor no need to add an IR cut-off filter. Lower f/# means larger aperture allowing 3x more light to pass.

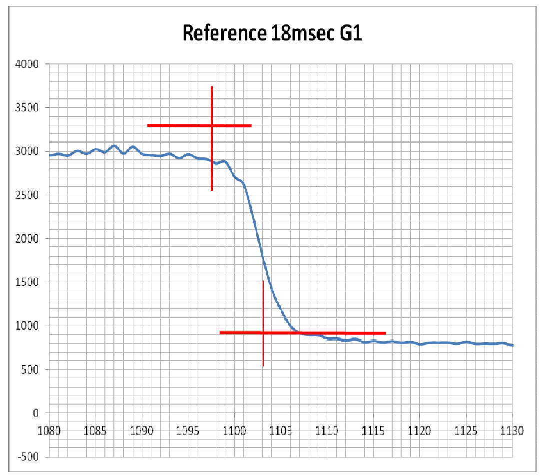
The key question was then can we modify our existing optical bench or must we completely re-design to realize the proposed system?

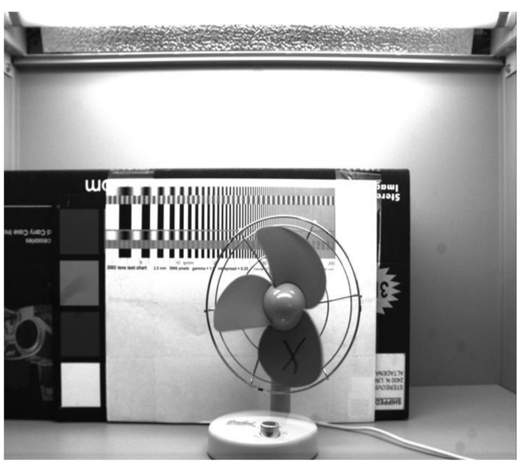
Preliminary Motion Blur Studies

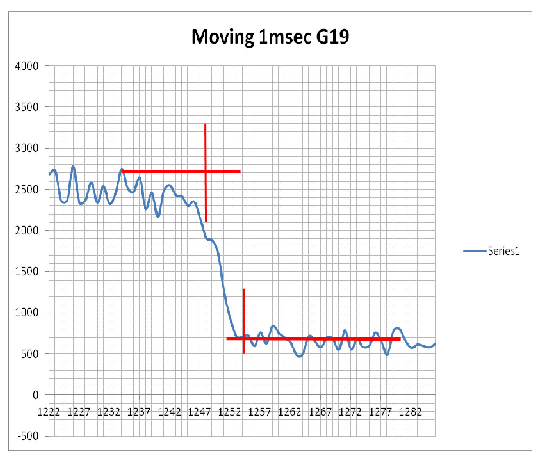
We investigated the notion of identification of moving subjects at a walking pace versus stationary identification as is today's technology capability. A typical individual walks at a rate of 1.5m / sec. If again the integration or exposure time can be minimized to "freeze" motion then this may be possible in conjunction with a global shutter mode.

To verify likelihood we ran number of controlled experiments with DC fan and calculated the proper fan speed to simulate the walk rate. Once we again we used our light box and the MacBeth chart white patch to set the proper gain required for sunlight conditions.

The fan in the “off” state was used as the reference and we used the edge of fan blade as our determining factor by calculating the slope of the edge as the integration time increases:







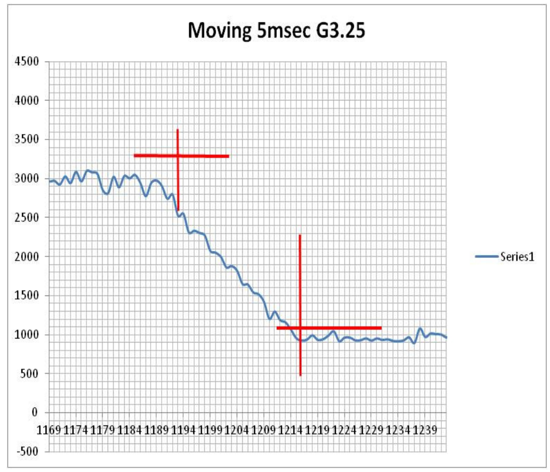


FIG. 38: Examples of our motion blur study ranging from stationary fan captured at proper integration time under these conditions to fan rotating at 4.4 RPM (~1.5m /sec) as integration time increased from 1msec to 5msec. Chart depicts slope of blade.

In summary the following table has been generated. Preliminarily if the integration time is less than 1msec we may be able to capture a subject walking for identification, this looks very promising, please see Table Five.

Please note, the monochrome imager we have identified operates in two different operating modes: rolling shutter and global reset. All data captured today was using the rolling shutter. The rolling shutter “exposes” light on a row to row basis and thus the last row is exposed at a slightly later time than the first row of the array. This lends itself to distorting moving targets as can be seen in the above fan captured images. Note how the fan blade appears elongated. Global reset mode should alleviate some of these issues however an imager that supports true global shutter mode would be more ideal.

Exposure(msec)	Gain	△ Y	90%	10%	△ X	Slope
Ref(18)	1	2100	2690	1010	6	0.004
.5	37	1800	2620	1180	4	0.003
1	19	1800	2220	780	6	0.004
1.5	12	1700	2530	1170	9	0.007
2	8	1300	1865	785	15	0.014
5	3.25	1950	2705	1145	20.5	0.013

TABLE EIGHT: Motion blur study summary chart. Fan was not rotating to record reference data. After which the fan was rotating at 4.5 RPM.

● FPGA Electronics and Signal Processing Development Efforts

To support the proposed optical bench, there is a need to have the proper electronic support. To facilitate this effort, we have identified a COTS FPGA Spartan 6 platform from Opal Kelly (www.opalkelly.com). This platform was customized for our project by designing an expansion board with all the needed electronics and mechanical requirements.

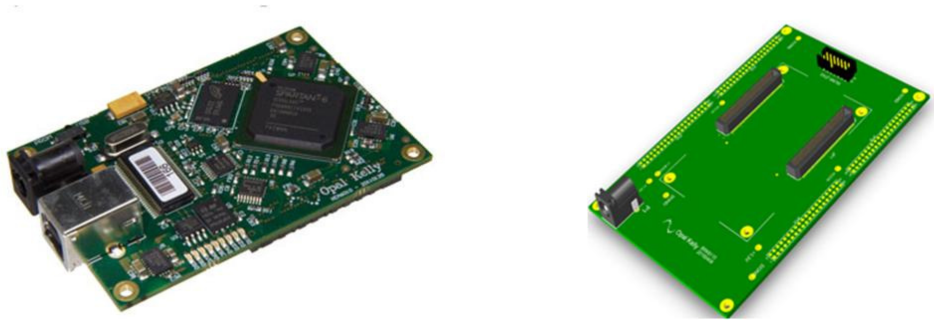


FIG 39: Left hand side, Opal Kelly's Spartan 6 FPGA platform. Right hand side is an example of an expansion board that can connect to the FPGA platform with customized electronics. The board is approximately the size of a credit card.

The following electronic block diagram illustrates the configuration:

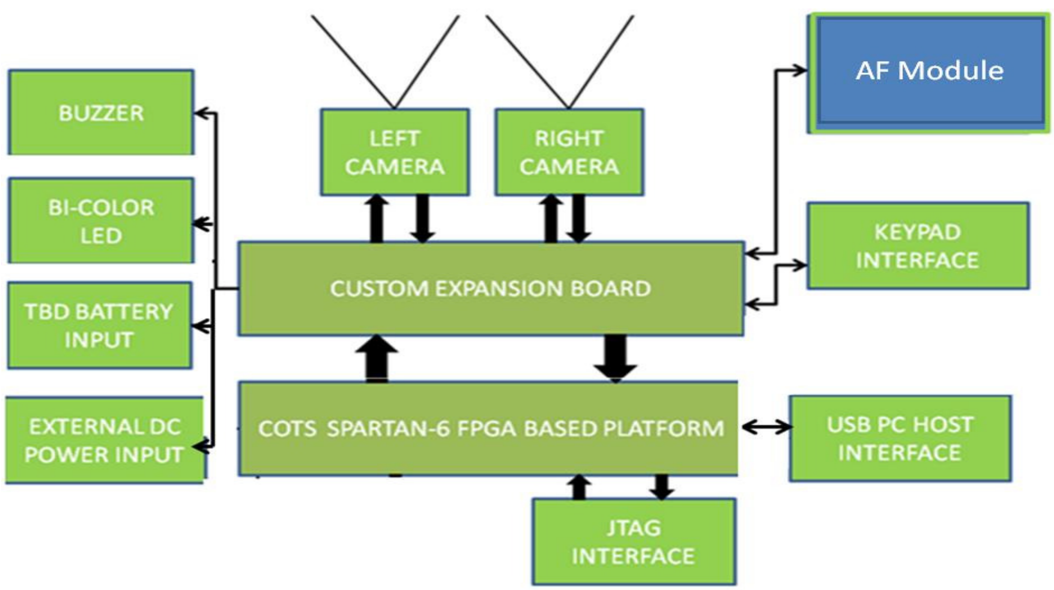


FIG 40: Electronic Block Diagram. A customized expansion board was designed to interface to the COTS FPGA Spartan 6 based platform.

Within the Spartan 6 we have realized two video pipelines to support the monochrome imager. Further we have installed the MicroBlaze soft core into our design. Firmware was developed to control the imager and then to pass the data to the high speed pipelines and out the USB.

In addition, as shown in blue in Figure Forty, we identified discrete auto focus mechanisms to integrate into our optical design. Past design efforts included a stepper motor that drives a single lens to both imagers; however, due to the imager and mechanical mounting tolerances it is very difficult to impossible to obtain a tight focus on both imagers using only one lens and thus we opted to go with manual focus settings. The identified auto focus modules were designed to be directly mounted onto our camera (daughter) boards.

Electronically, we constructed dual video pipelines and performed electronic simulations successfully and have our firmware protocol documented. We also developed a stereo camera breadboard initially to assist in the software development efforts as the optical bench took several months to machine. The breadboard allowed us to test our software using small COTS 6mm lens with the 5MP monochrome imager.

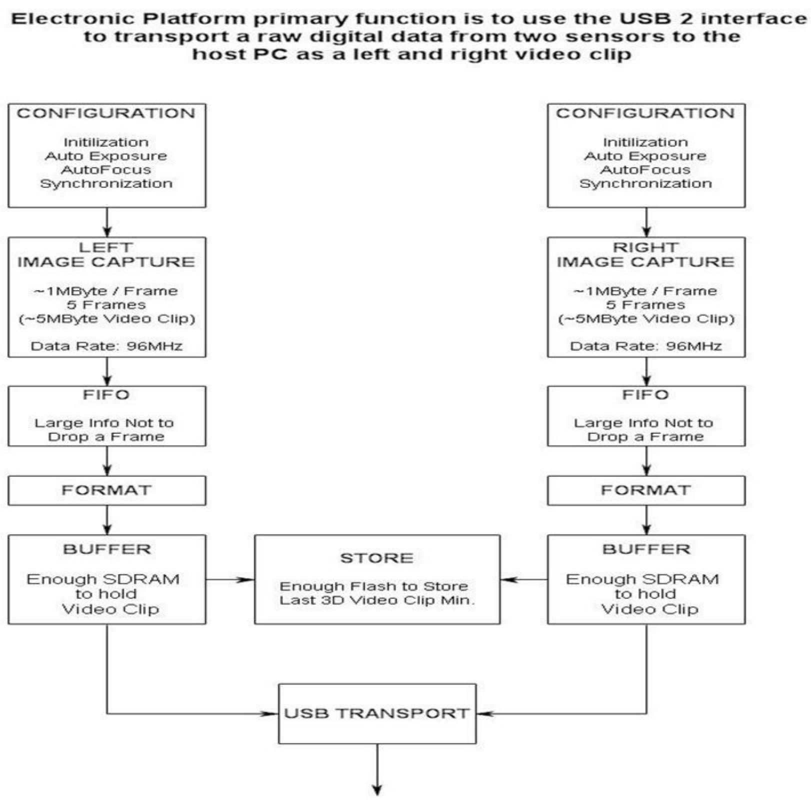


FIG 41: Spartan 6 FGPA Configuration. Development of a high spend dual video pipeline. All configuration code realized as firmware in a MicroBlaze soft core.

FIG 42: Spartan 6 FGPA Configuration. Development of a high spend dual video pipeline. All configuration code will be realized as firmware in a MicroBlaze soft core.

We developed an architecture utilizing Spartan 6's AXI interconnect bus to connect required system "modules" to allow for high speed communication. The key modules we need to build identified to date are:

1) MicroBlaze softcore
2) I2C Module
3) Video Pipeline
4) SDRAM
5) USB
6) SPI Interface to support FLASH and AutoFocus

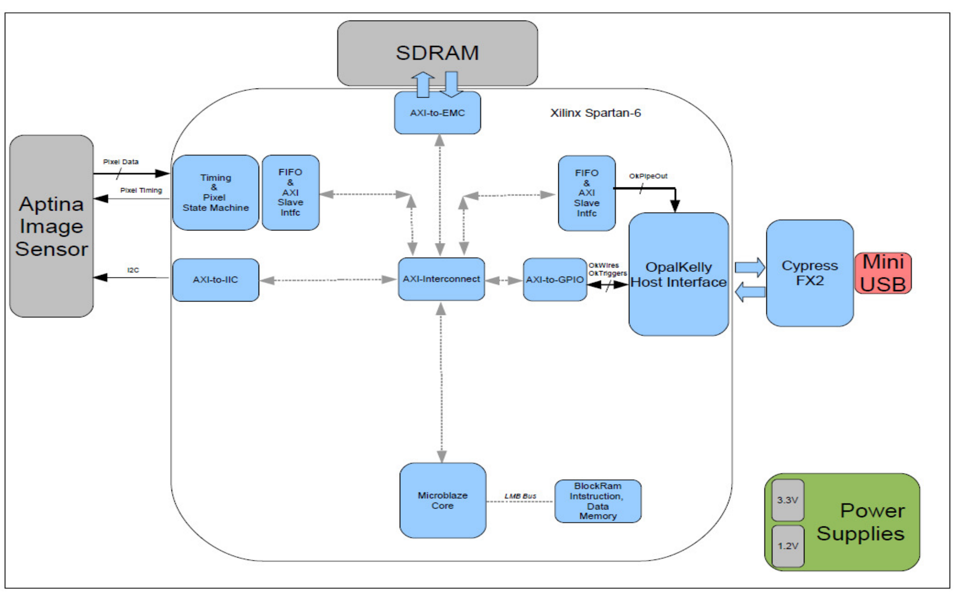


FIG. 9: Single channel FPGA (Spartan 6) electronic architecture.

A stereo “bread board” was developed to support software development during the construction of the hand-held device. The breadboard, see Figure Forty-Three below, utilized COTS optics as well as the identified imager. This platform had proven to be invaluable as a means to run and debug code.

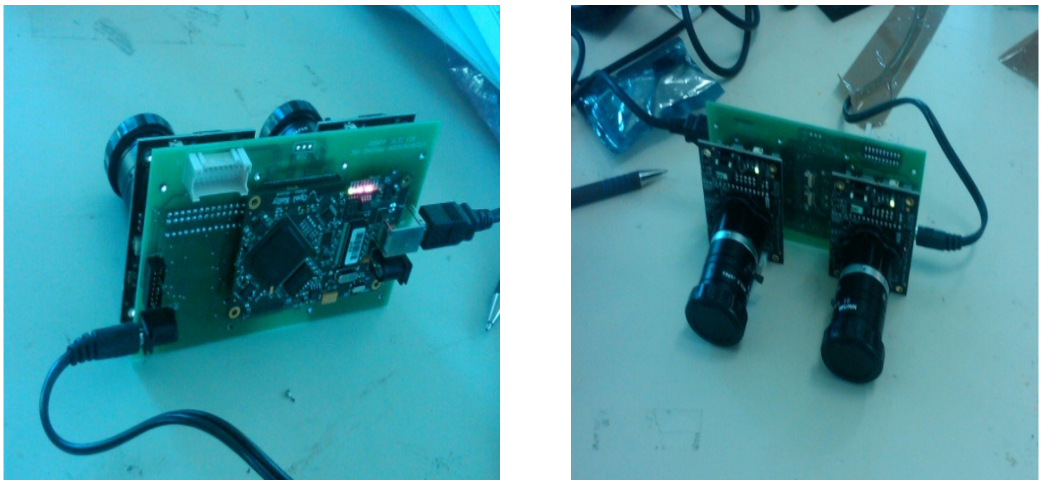


FIG 43: Digital images (Back and Front) of a stereo breadboard developed to test, debug and validate HDL and firmware.

● Optical System Design

Goal: design a hand-held high definition, diffraction limited, optical system that could capture the best image quality possible incorporating monochrome imagers previously identified with discrete, independent auto-focus mechanisms ultimately improving performance over first generation design with ease of use.

Based on past results noted above we determined a f/4 design to be ideal given all other design considerations. From which, we went down a path of initially designing a “theoretical” system. Several design iterations followed were developed and evaluated before we had consensus moving forward with our final design based on a myriad of trade-off issues.

<u>Initial Design</u>

- Binocular is dual mode, shared aperture design
  - Receiver (RX) + standard binocular (BX)
  - Object 75 – 200 meters from Point of Use

- Rx (Receiver/Imager) channel
  - EFL = 160mm, F/4
  - Use Aptina CMOS array with 2.2mm pitch – 2592(H)x1944(V) pixels
  - Use AutoFocus Module on each Channel to mount focusing lens
  - Linear field of view at 100 meters is ~ 3.5 meters (angular field of view 2.04 degrees)

- Bx (Binocular/Human Eye) channel
  - 8x angular magnification
  - Use porro prism sets
  - FOV can be much wider than Rx channel (greater than 2x)
  - Focus to eye via eyepieces only

- Key Question: Can the Rx optical design be packaged (7"x5"x3") in a hand held device along with the BX optics?

To take full advantage of small pixel subtense, Rx (receiver) optics must support reasonably high MTF out to the pixel nyquist frequency of 227 cycles/mm

- The optical system cutoff frequency is 1/(lFNO) = 455 cycles/mm

- This suggests near diffraction limited imagery for the Rx optics contrasting sharply with the imagery required for the Bx (binocular) optics

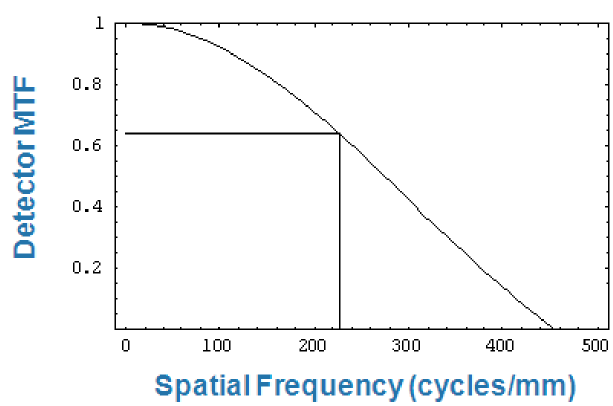


FIG 45: Design goal, to achieve a near-diffraction limited response. Bx system requirements are relaxed as the human eye is much more "forgiving" than a digital imager.

The following performance curves were generated based upon our initial design. The "focus" was first on the Rx optics as this is the most critical. The strategy being to first design an optimized theoretical model using Zemax (an optical system design non-sequential ray tracing software package) and then review the design with our manufacturing partner, Kamakura.

The first performance chart below clearly indicates we are able to achieve a near-diffraction limited design. This is key in obtaining the sharpest image possible from the system. Material selection of each optical component was first attempted via known glass catalogs. Custom optics were only added, if needed.

The performance chart is broken down into four quadrants. The first quadrant illustrates the optical layout. The second quadrant on the right our the transverse ray plots (indicates how well the system is corrected for aberrations). The third quadrant (key) is the MTF plot with several traces added: The ideal diffraction limited trace added as a reference (black) and three traces to cover the optical spectrum i.e. Red, Green, Blue. This gives us an ideal of how well the system corrects for color. The forth quadrant is the focal shift in [um] of the system performance at the imaging plane as a function of wavelength.

Once the Rx optics were optimized we then introduced the beam splitter which is necessary to split the light beam to the eye for surveillance viewing. Unfortunately this did degrade the Rx performance as shown below (see MTF plot). A number of different approaches were investigated. As an example we had to re-optimized designs with actual porro prisms and then add field lens in Bx to shorten Bx path length. The second chart performance below was the best we could obtain.

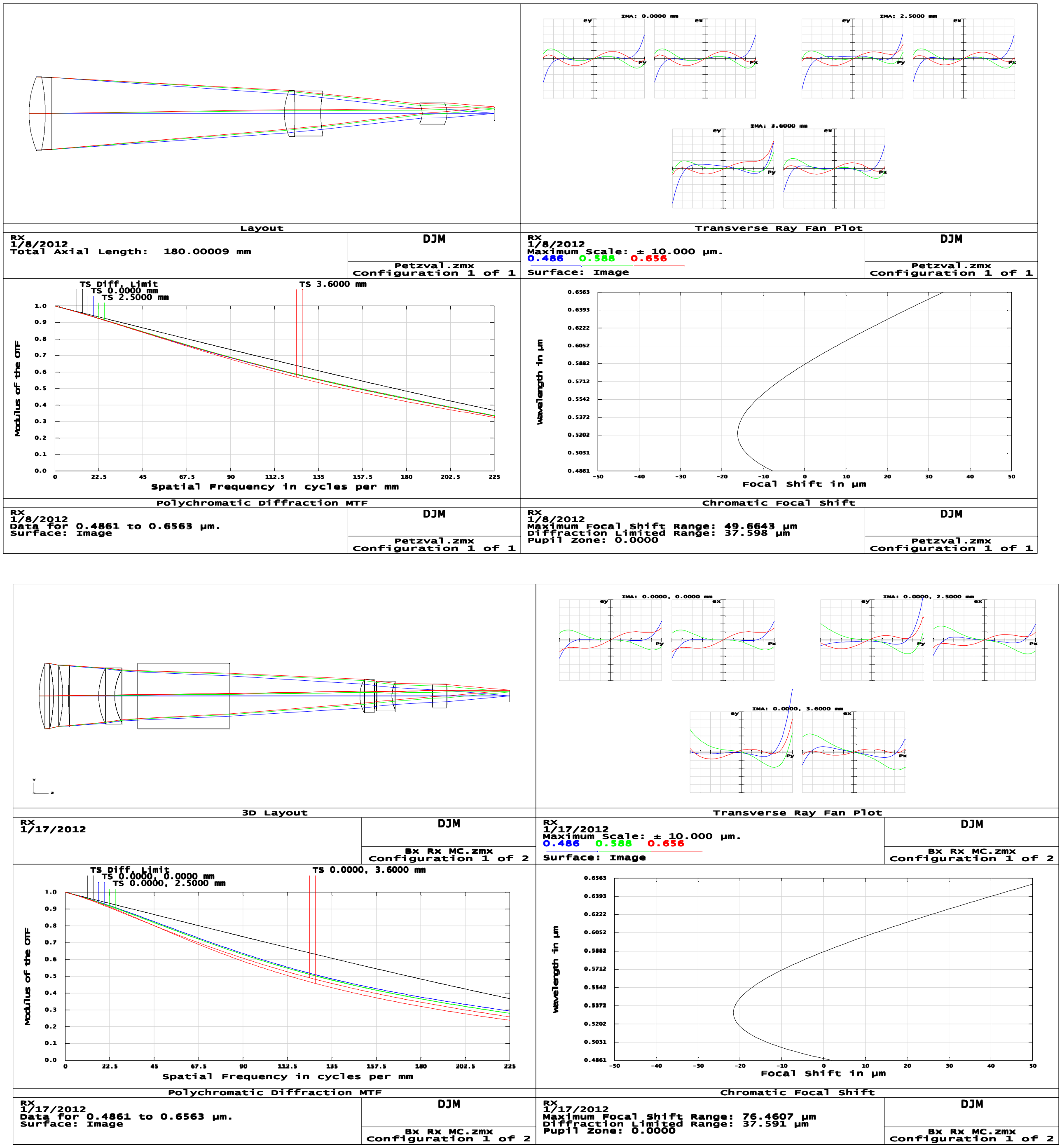
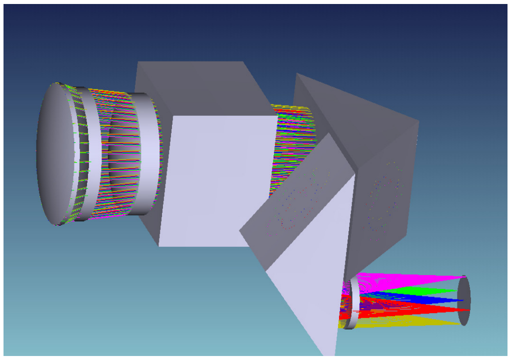


FIG. 46: Example of Rx performance curves of a number of different designs entertained during the initial design phase. The lower left hand corner is the MTF curve. Initial design included a Petzval Lens with Field Flattener. To reduce total track (physical length) to 160mm . But then the design had to be "split" between the two doublets and use the first doublet for the binocular (Bx) system (bottom chart).

Figure Forty-Seven below is a graphical representation of the optical layout as shown in the first quadrant of the performance chart above.



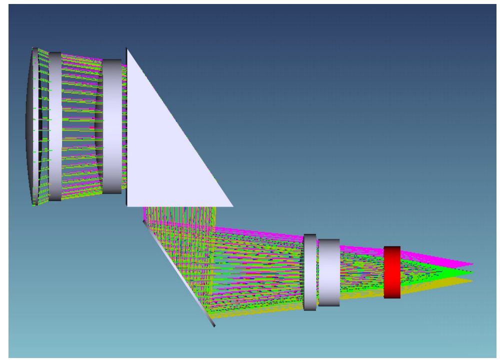


FIG. 47: First image is of the Rx system followed by the Bx.

Preliminary Design I

Early January 2012, we held a design review with Kamakura, our designated manufacturing subcontractor. Kamakura brings to the table the “practicality” of realizing the designing from the manufacturing standpoint.

Our obvious first inclination was addressing the ability of modifying our existing 2009-IJ-CX-K001 deliverable to accommodate this “next generation” design.

The action item was to see if we could remove the beam splitter (located near the objective lens as shown in Figure Forty-Seven above) and couple the light off one of the prism faces. This, in theory, would have two affects: practically the beam splitter being located towards the front of device and due to its size/weight would shift the center of gravity i.e. make the device top-heavy and second performance may be better if the light is split “downstream” versus “upstream” due to ray convergence.

From which, via input from our manufacturer, will were able to theoretically obtain performance we desire in a hand-held format, i.e. f/4 system with f_l =160mm.

Further this design iteration took into account the incorporation of the identified discrete auto-focus mechanisms.

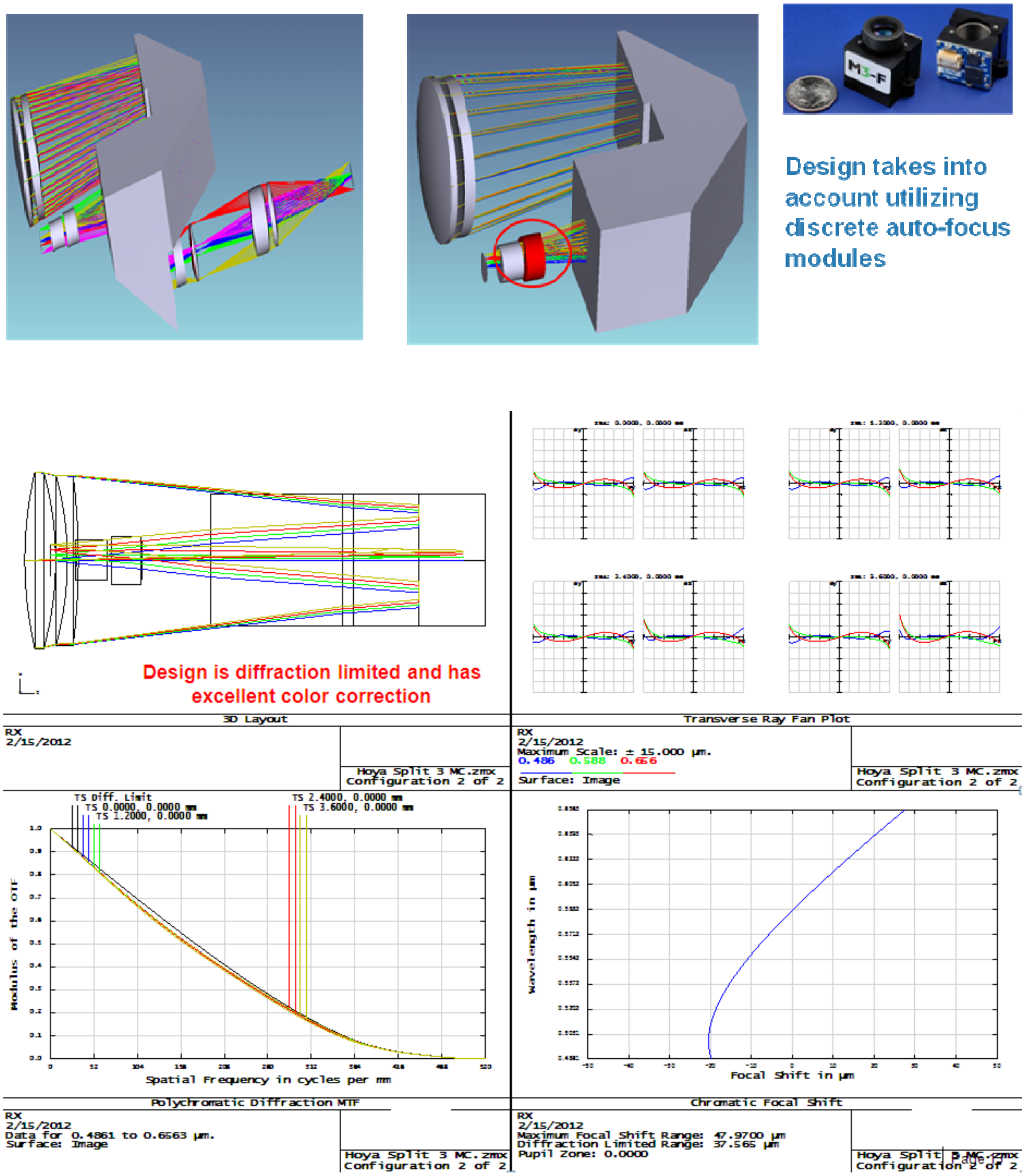


FIG. 48: Second iteration design. Removed beam splitter from initial design to coupling light from one of the prism faces. Performance improved as noted in the MTF chart.

This design was again reviewed with Kamakura but this design too was not practical to move forward though due to other reasons:

1) Due to estimated opto-mechanics required to support the optics called out in our design the overall package size increased from 133x192x65 to 150x200x100 mm

2) Our custom prism design is driving the packaging issues regarding size and weight making the design impractical.

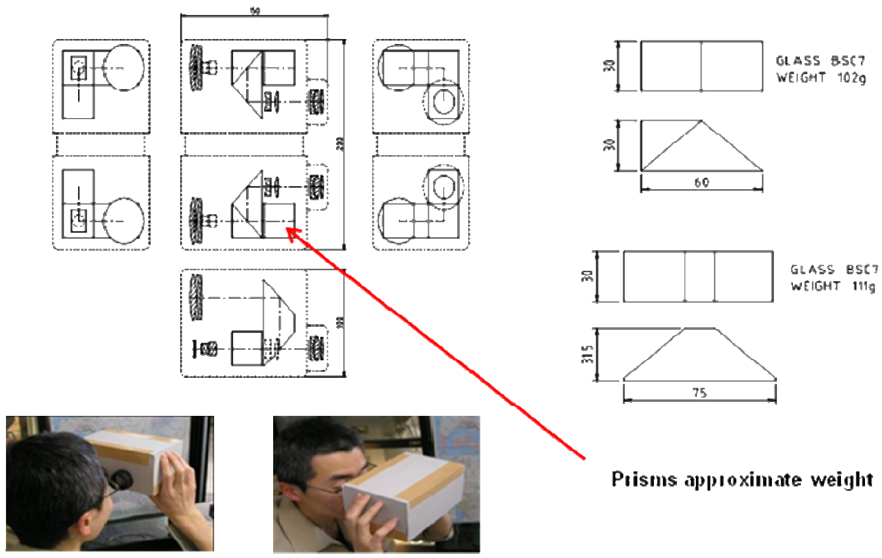


FIG. 49: Second iteration design review from manufacturer. The custom optics required on the beam splitter is impractical to build out due to size/weight and complexity. Figure above includes a mock-up of the overall size of the device.

Thus, the next design iteration goal was to investigate reducing the physical size of the optical system. After several attempts we decided to reduce the f#. Based on past results discussed above, the performance "sweet spot" is f/4-f/6. F/4 is desirable due to fast optics and higher SNR. f/5 performance would be acceptable; however, there is a 2x loss in signal strength. We believe this also is acceptable but in very low light situations we will have to increase analog gain for proper image capture. Increasing analog gain though introduces noise into the system.

Preliminary Design II

Moving from a f/4 to a f/5 system design significantly reduced size of custom prism / beam splitter by removing excess glass. Slower optics allowed for tighter beam.

Physically the two designs are shown below in Figure Fifty. Note these illustrations compare a single receiver (imager) channel only side-by-side. Nearly a 2x reduction in overall area.

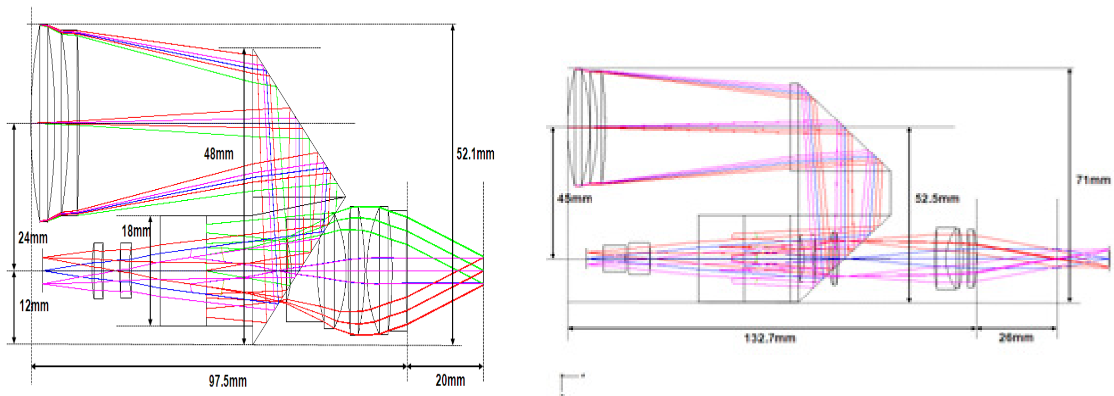


FIG. 50: Latest f/4 design on left, after several iterations, moved to f/5 system as shown on the right due primarily to size/weight of required custom optics. Performance curves as re similar.

After yet another design review, as it turns out, now cost and time to build out the design as shown in Figure Fifty above was a major barrier.

The reduction in size "exercise"; however, as it turns out, did bring out the notion that our first generation design delivered to NIJ could now by modified. Although not as elegant from an optical system layout standpoint and respective packaging, performance would be superior, cost to build out would be much more reasonable and time to delivery more acceptable.

<u>Final Design</u>

The final f/5 design incorporated the new monochrome imager as well as the auto-focus modules and allowed us to utilize our existing chassis to support all optics versus machining a new chassis. There are three (3) new optical elements per channel. Two (2) of the lens elements are custom to accommodate the focusing mechanism. Figure Fifty-One below illustrates the side and top views of the final system architecture. This next generation device looks very similar to the first generation. The display was removed as deemed an unnecessary development effort to support.

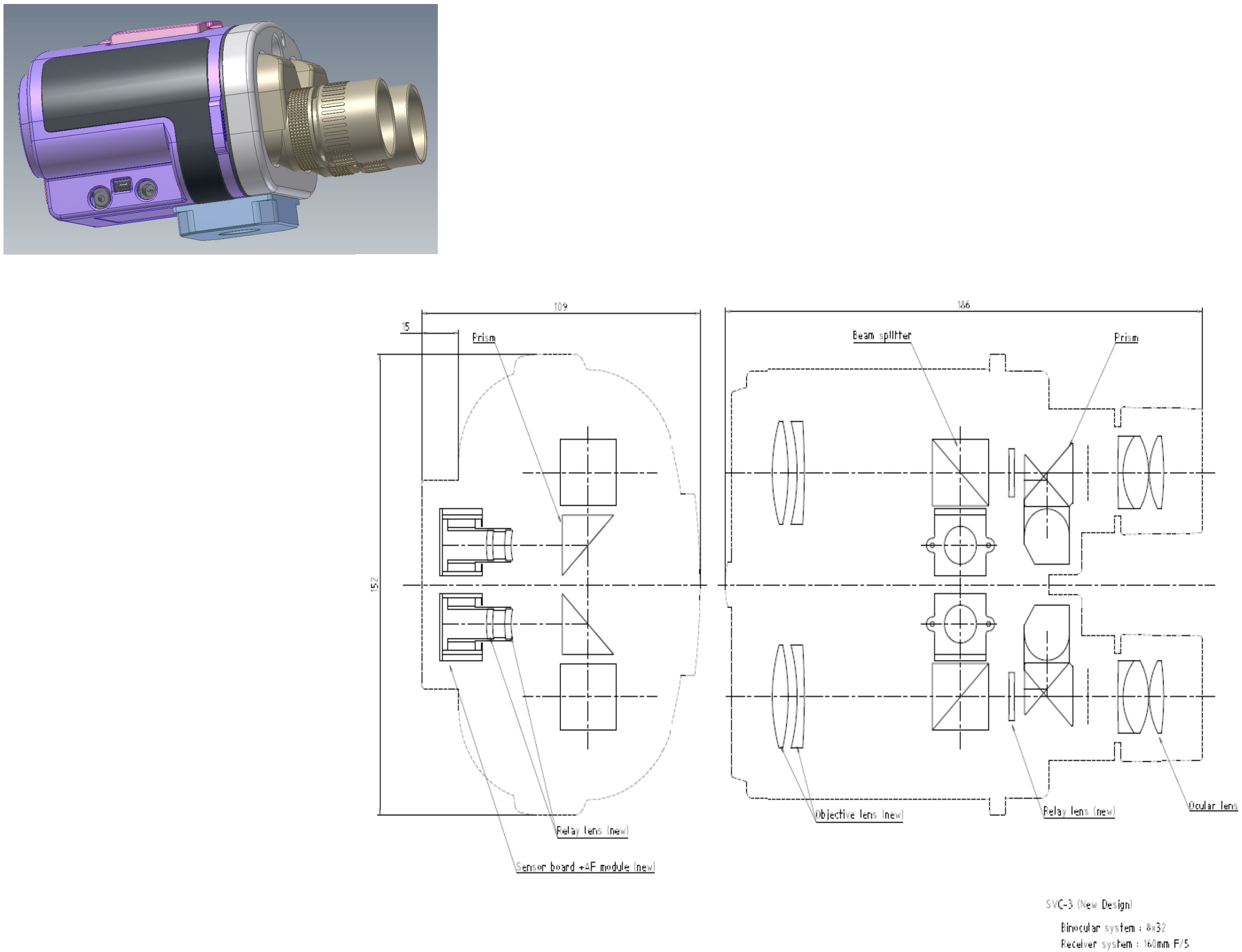


FIG. 51: Optical system lay out of our final f/5 design. The objective lens as well as the focusing relay lens are "new" as compared to our first generation design. The picture above is a conceptual illustration of the final design out package.

Figure Fifty-Two below are side-by-side theoretical performance plots:

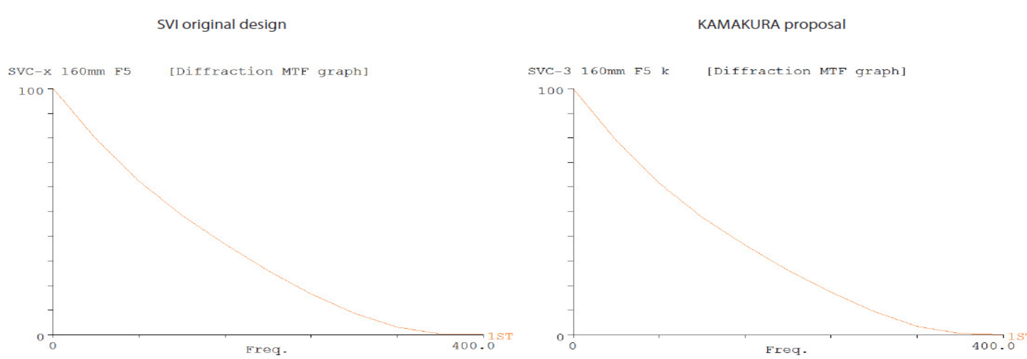


FIG. 52: Side-to-side optical system performance curve of our proposed preliminary design II versus the final design, both as described above.

● System Development

The following Figure show the final completed circuit board with WUSB dongle and circuit board installed in the unpackaged device.

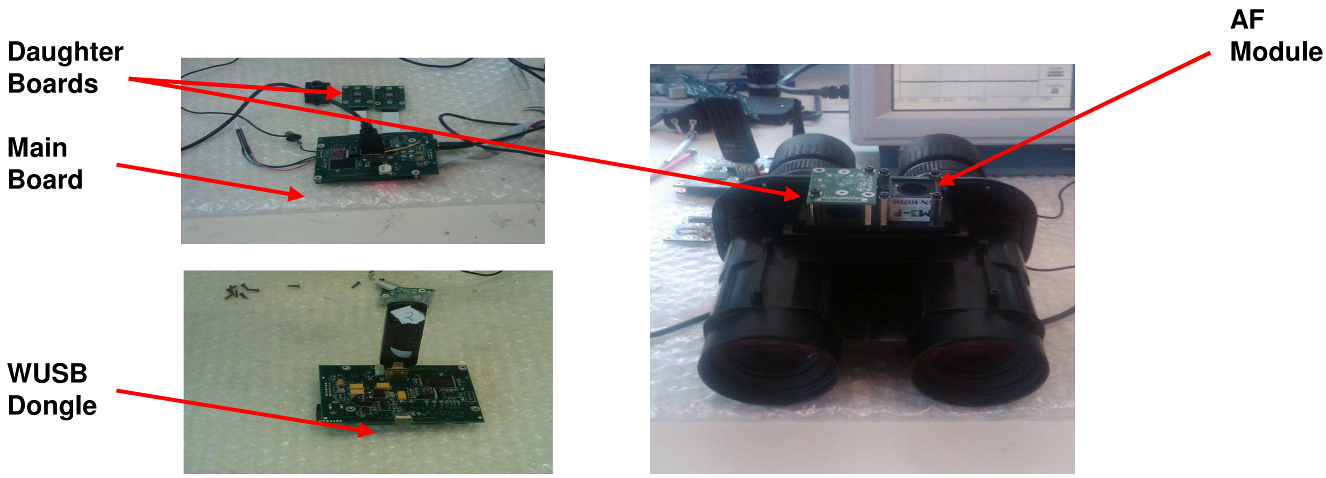


FIG. 53: Final hardware circuit design illustrating left/right daughter boards supporting 5MP monochrome imager as well as WUSB dongle. Second generation binocular platform (unpackaged) also shown with auto-focus module and daughter board mounted.

Beyond adding video pipelines, debugging AE and AF algorithms and verifying/validating device functionality a new SVI 3D Video Capture PC application was developed. This application was required to transfer the video clips captured from the device to the PC. The device is unable to store video clips on-board currently and most be connected to the PC to transfer data and store to disk. Install and operational details are included in the User Manual attached as Appendix II.

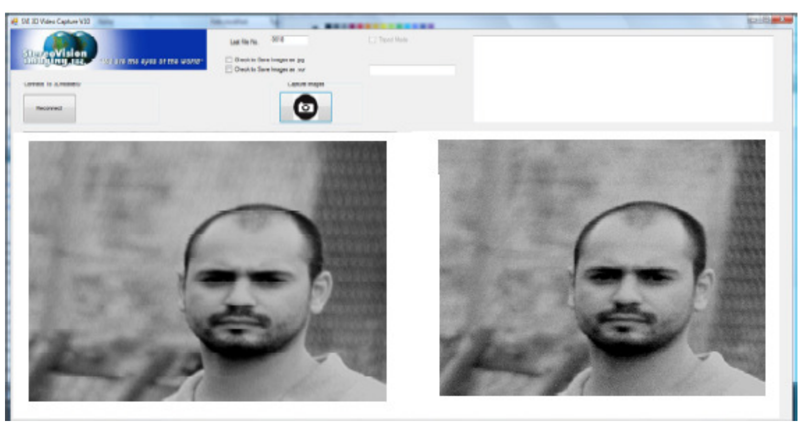


FIG 54: Snap shot of a new 3D Video Capture utility

Also a new client application was developed as a modification of the 2009-IJ-CX-K001 DisparityCalcTest application previously documented (see Appendix II). The modifications included compatibility with the new monochrome imager and subsequent 3D processing as well as new peak identifier technique to improve segmentation by processing foreground objects only. Please recall this application is required to automatically "feed" in enhanced imagery to the COTS face recognition (FR) engine for identification. The interface to the FR engine was not changed and fully documented as well in Appendix II.

The 3D Video Capture utility saves the .vur files transferred from the device to be imported into the DisparityCalcTest application. It can also save an unprocessed .jpeg of the first frame of the video clip.

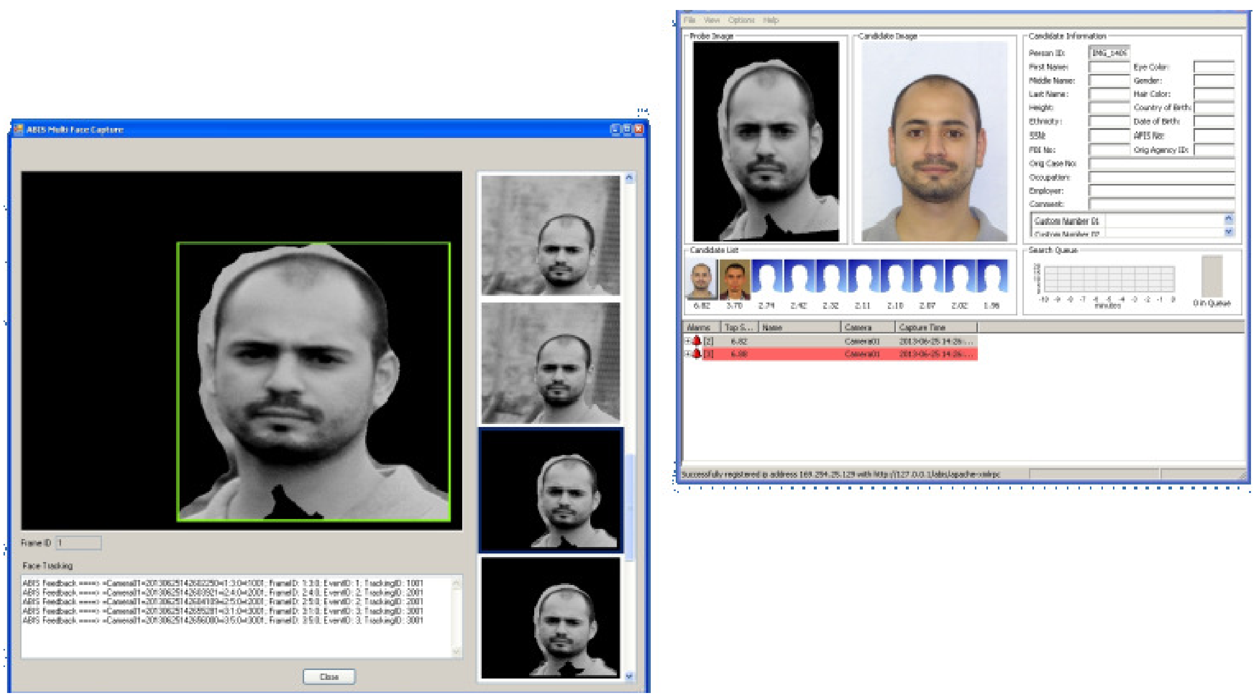


FIG 55: Screen capture of the DisparityCalcTest client application (left image). Application retrieves files stored on PC via the 3D video Capture utility; automatically segments faces from background, photo-metrically enhances 2D segmented faces to provide uniform illumination across the face and sends imagery to face recognition engine for identification (right image)

<u>Operation</u>

The device is by default a pair of 8x 32 binoculars with an integrated stereoscopic imaging system. The first step is to become comfortable viewing thru the optics. If one wears glasses they should be removed. The eyepieces rotate to adjust for your eye spacing and there is a left and right ocular adjustment for focus, adjust accordingly.

A single SHUTTER button, on the packaged device membrane pad is active. All other buttons are not active. The SHUTTER button has been programmed as a two step operation. The button is first depressed to allow for AE and AF to operate as the end user is viewing the test subject. This operation takes approximately 2 seconds and required the end user to hold the device stable. Once completed a “chirp” is sounded.

The end user then positions the face of the unknown subject within the device retical and releases to capture a short 3D video clip. The buzzer chirps again to indicate end of operation (second step is approximately 500msec). The video clip is then transferred wirelessly to the laptop via the 3D Video Capture utility where it is stored within a pre-defined file location.
The DisparityTestCalc application can then retrieve the files stored by the 3D capture Video application for further processing and, if interfaced to the server FR engine, for identification.

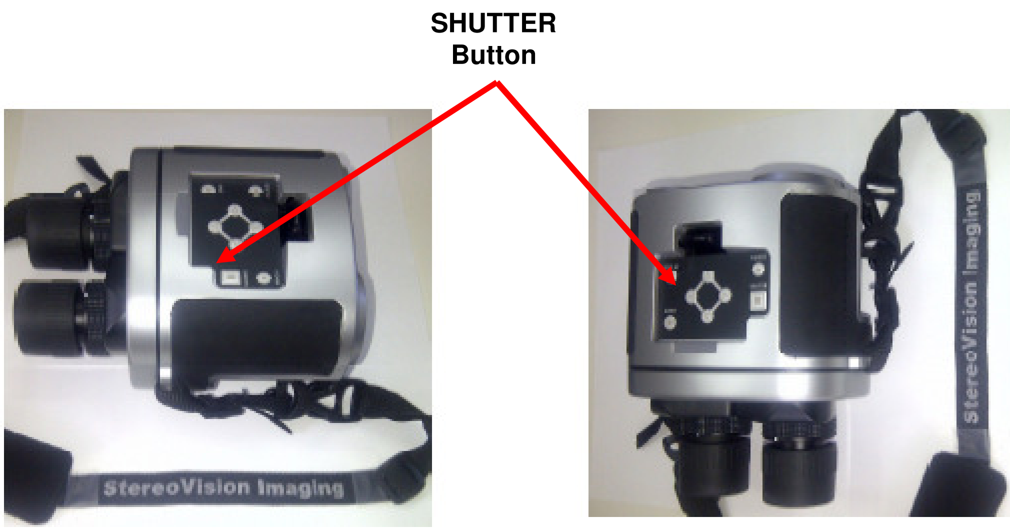


FIG. 56: Only the SHUTTER push button is active as shown above

The following chart indicates the improvement in signal over the first generation efforts primarily due to the new imager and faster optics:

Light Meter Reading [LUX]	2cd Generation Integration Time [msec]	1st Generation Integration Time [msec]	Improvement Factor [X]
59-63 (Shade)	~4	~64	~16
550-650 (Partly Sunny)	~0.6	~11	~18
975-1000 (Sunny)	~0.4	~6	~15

TABLE NINE: **'Old' versus 'New' Light Sensitivity Comparison Chart**

These results were key for image stabilization / hand-held operation and used to generate the curve for auto-exposure.

Empirically a gain of 6 was determined to be the maximum gain possible due to introduction of noise. In hand-held mode, to reduce and practically eliminate image stabilization issues, the device is limited to operating outdoors with a maximum allowed physical integration time of **1 msec** and thus can identify persons of interest in shade to sunny conditions as the virtual integration time is the product of the (physical integration time) x (the gain) = 6 msec max.

If the device is used indoors through glass to ID test subjects outdoors the transmission properties of the glass must be considered. In this case analog gain may be higher than outdoor use and automatically applied depending on the glass properties and outdoor conditions and higher noise will be introduced into the system; thus performance may be degraded.

If there is not enough light present for AE algorithm to work properly the device will beep two times and LED with pulse RED.

If more light is required, an option is to place the device in "tripod" mode via the 3D Video Capture application. In tripod mode, the physical integration time is extended to 8msec and the virtual integration time = 32 msec. Thus should be adequate to operate through glass.

Please note system is **NOT** designed to operate in any other type of lighting beyond sunlight, i.e. incandescent, florescent, LED etc. etc.

5.0 ALPHA TESTING DATA COLLECTION AND ANALYSIS

Preparation of the Watch-List

The following steps were followed in preparation for a field demonstration.

1. IRB Database Creation for watch-list:
    a. Several IRB approved people of different skin tone, facial anatomy and hairstyle were captured. A total of 25 individuals were initially enrolled in the database.
    b. Camera settings for Enrollment (Indoors, under controlled lighting)
        i. Set the aperture to Auto.
        ii. Set ISO to 100.
        iii. Images size large jpeg.
        iv. Focus using Auto focus
        v. Continuous shot mode capturing a few shots quickly.

Probe-List Test Protocol

1. Outdoor Field Testing at 50 - 100m
        vi. Single Individual, 0 +/- 10 degree pose within database

Analysis - Introduction

Image Datasets

Table 4 summarizes the source of our 2D facial database. All enrolled images i.e. the Watch List, were captured indoors under controlled lighting, at a zero degree pose and in color with a Cannon 40D COTS camera.

A total of greater than 500 different subjects were enrolled into our database utilizing our test subjects and the publicly-available subset of the Color FERET dataset to assure validity of our results.

All probe images were captured outdoors under uncontrolled environmental daylight conditions ranging from sunny, partly sunny, partly cloudy, cloudy and shade at ranges of 50 to 100 meters.

Preliminary Performance Analysis

In the following section, we adopted NIJ's Center of Excellence performance reporting format of their prior 2009-IJ-CX-K001 interim evaluation in lieu of traditional ROC curves. This prior evaluation required a fair amount of manual intervention which unfortunately was too cumbersome to follow and thus affected performance results; the 2010-IJ-CX-K001 as noted throughout is expected to provide superior results.

We conducted two runs to characterize the performance of our second generation platform; all runs were taken in the hand-held format with the battery pack clipped onto the end user's belt.

Run 1 consisted of probe images collected within the 50-100 meter range. This run represents the 2D only capability of the binocular system operating in a true "point and shoot" mode where the test subject is located anywhere within our detectable range under various different environmental conditions from shade to sunny conditions.

The 3DMobileID™ device generates both a left and right .vur file of 6 frames each and the face matcher selects the images that are probes for matching to the enrollment gallery. Run 1 consisted of 60 probes and 515 enrolled subjects where the true accept rate was 100% and the false accept rate is 0%; obviously a larger sample will include false alarms but with this limited testing all runs were 100% successful. The similarity scores for the genuine population ranged from a low of 2.12 (at the longer ranges, i.e. 100 m) to a high of 13.41. Please note most of the runs captured were in the 50-70 m range. The graph below represents the frequency of True Matches for each Rank Order on the vertical axis and the True Match Rank Order to Rank 10 on the horizontal axis.

Run Description	**Description**		**Results**	**Score Min.**	**Score Max.**
50 – 100 meter range; hand-held; outdoors and indoors with subjects outdoors; various environmental conditions from shade to full sun.					
	Gallery	Total	515		
		Unique Subjects	515		
	Probe	Total	120		
		Unique Subjects	8		
	Matches				
		True Mat	100	2.12	13.41
		False Mat	0	0.00	0.00
		Total			

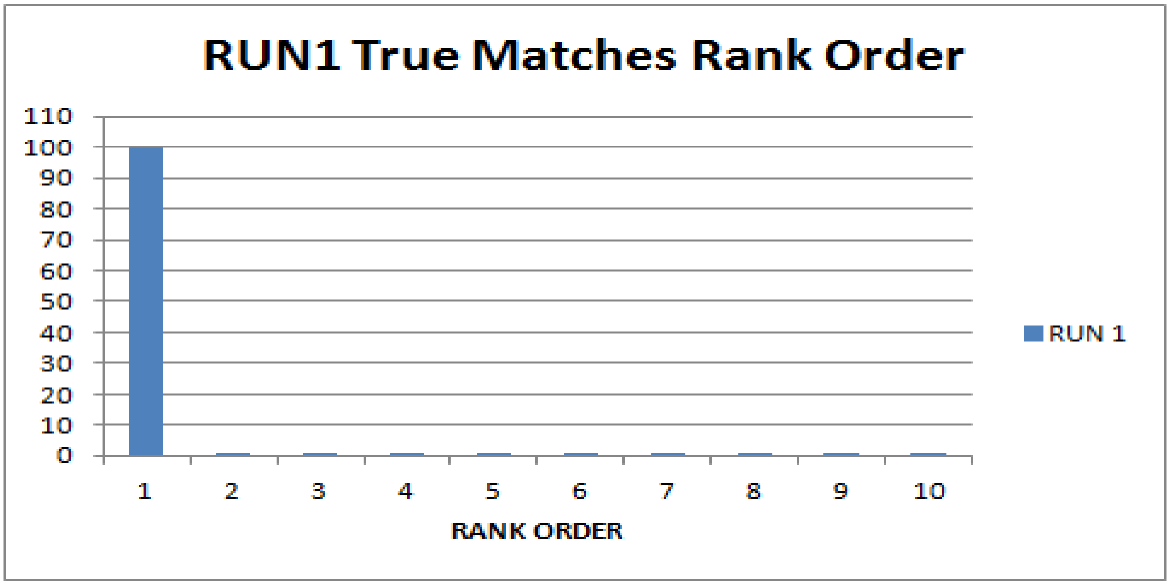


FIG. 57: Run 1 2D Only Results

__Run 2__ consisted of probe images collected within the 50-100 meter range. This run represents the 3D only capability of the binocular system operating in a true “point and shoot” mode where the test subject is located anywhere within our detectable range under various different environmental conditions from shade to sunny conditions.

The purpose of this run was to determine the matching performance of all the 2D segmented images collected by the 3dMobileID™ system. This Run is used to determine the change in performance that is the result of having the disparity calculator combine the left and right images so that the background is removed prior to matching. Run 2 consisted of the same 60 probes and 515 enrolled subjects where the true accept rate again was 100% and the false accept rate is 0%.

Run Description	Description		Results	Score Min.	Score Max.
50 – 100 meter range; hand-held; outdoors and indoors with subjects outdoors; various environmental					
	Gallery	Total	515		
		Unique Subjects	515		
	Probe	Total	60		
		Unique Subjects	8		
	Matches				

conditions from shade to full sun.		True Mat	100	2.65	14.24
		False Mat	0	0.00	0.00
		Total			

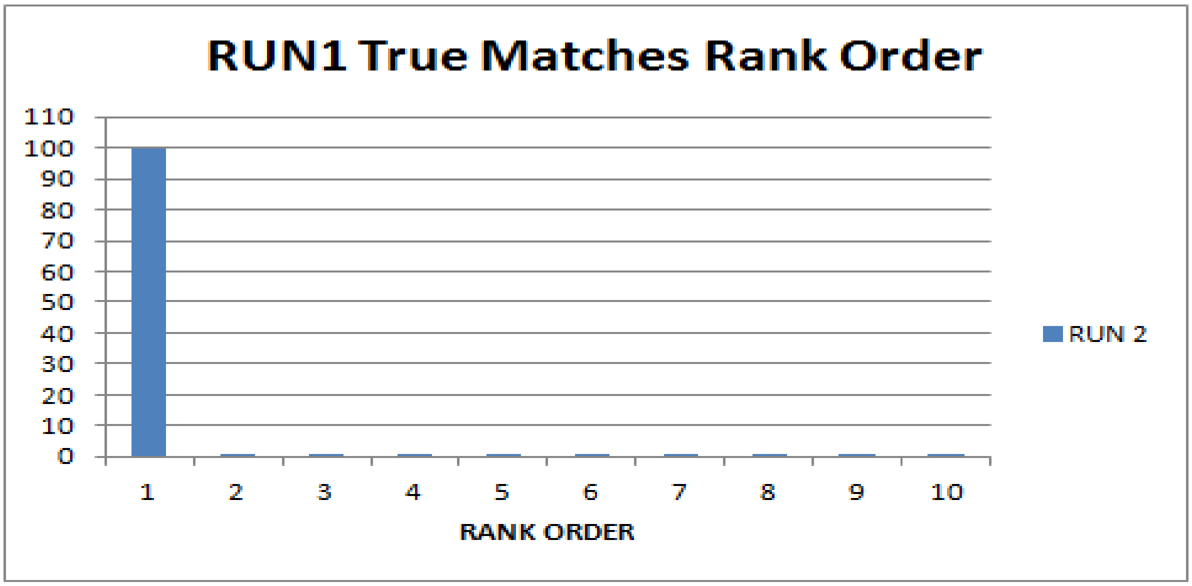


FIG. 58: Run 2 3D Results of the 2D segmented images match performance. Performance of these limited data sets indicate slightly better than Run 1 due to min. and max scores higher.

6.0 SUMMARY & CONCLUSION

The 2009-KX-IJ-K001 award resulted in a successful development of a man-portable 3D face recognition binocular technology and though requiring a fair amount of manual set-up to operate, resulted in an impressive technology demonstration to local law enforcement at ranges up to 100 meters from point of use.

The 2010-KX-IJ-K001 has resulted in the research and development of a fully automated wireless hand-held 3D face recognition binocular system; though, the system is limited to certain daylight conditions, a true hand-held “point and shoot” effort has been realized at ranges up to 100 meters from point of use. Further known development efforts and enhancements are needed to fully realize potential but this award has significantly assisted in developing this next generation platform.

Preliminary results look promising but too little data to quantify true performance; full identification statistical performance evaluation to be conducted and documented by NIJ's Center of Excellence (CoE) and compared to first generation efforts.

The award also concluded with another key performance validation under daylight conditions on the campus of San Diego State University (SDSU) organized in conjunction with SDSU's Center for Commercialization of Advanced Technology last December 13th, 2012 - a first with our second generation wireless system. A briefing to law enforcement officials was presented at SDSU's Gateway Center and the actual demonstration was set-up in the lobby of Gateway Center. The set-up consisted of the battery powered binoculars and end user operating outdoors and connected wirelessly to a laptop inside the lobby running our face recognition software. Test subjects were located across the street approximately 65 meters away. Our latest technology allowed for test subjects to be located anywhere in the 50 -100 meter range versus the set distances required for the first generation design due to the lack of auto-focus. Also no light meter was required due to running auto exposure for the first time.

FIG 59: Actual street layout of the technology demonstration at San Diego State University December 13th, 2012.

The laptop, in turn, was connected to a large 32" monitor in order for everyone in the lobby to easily view the results. All test runs were 100% successful. Below is an example screen capture result from a test run of a law enforcement officer at 65 meters from point of use.

FIG. 60: Actual screen image capture of a recognition test run result as displayed on the monitor. Officer located 60-70 meters from point of use.

Attendees beyond SVI employees and CCAT administration included federal, state and local law enforcement personnel. This included personnel from the Space and Naval Warfare Systems Command (SPAWAR-ATL), Under Secretary for Defense Intelligence (OUSD/I), San Diego Sheriff Office, San Diego Police Department, and SDSU Police. Please see Appendix I Technology Demonstration Invite Flyer as well as the Attendee List.

The technology field demonstration feedback exceeded expectations. Immediate follow-up, post demo, was highly interactive. The feedback from law enforcement personnel present was extremely positive:

- Asked if this technology is needed, the response was “that is a no-brainer”
- The interest: “ we need this technology yesterday”
- Asked regarding the range, “50-100 meters is adequate for most surveillance operations”
- Overall response “when can we get our hands on this technology”
- There were also discussions of system installation and cost.

In conclusion, assuming performance is acceptable as deemed by CoE, it is recommended to further optimize AF algorithm and photometric capabilities as well as add super resolution based on past studies and investigate adding pose-invariant techniques with a goal to hand-off system technology directly to TBD law enforcement agency for BETA (operational) testing.

7.0 DELIVERABLES

Per award agreement, two (2) wireless 3D face recognition binoculars were delivered to NIJ's Center of Excellence, June 2013. In addition, two (2) software applications were installed (SVI's 3D Video Capture Utility and SVI's DisparityCalcTest Application) on the 2009-IJ-CX-K001 laptop notebook computer required to wirelessly transfer the 3D video clips from the device to the notebook computer and to process and enhance the video properly in order to transfer to the pre-installed COTS face recognition engine for identification, respectively.

APPENDIX I

Technology Demonstration Invite Flyer and Attendee List

Wireless Hand-Held Long Range 3D Facial Recognition Technology Demonstration

StereoVision Imaging, Inc. (SVI) has developed a technology which combines facial recognition with a handheld binocular system. It allows law enforcement officers on the street a real-time capability to identify individuals on scene at ranges up to 100 meters from point of use supporting mobile surveillance task force operations.

The demonstration will show the technology outdoors under uncontrolled daylight conditions with individuals enrolled and not enrolled in the facial database. It will employ SVI's current release of real-time facial recognition software.

Funding for the project was provided by the National Institute of Justice and from the Department of Defense via the SDSU Research Foundation Center for Commercialization of Advanced Technology.

Location: SDSU Research Foundation

5250 Campanile San Diego CA 92182

SDSU POC: Bob Welty 619-980-6590

AGENDA

10:00 - 10:20	Introductions and Project Overview
10:20 – 10:30	Enrollment (optional)
10:30 – 11:15	Field Demonstration
11:00 – 11:30	Wrap-up, Questions and Answers

[redacted]

APPENDIX II

DETAILED USER MANUALS

StereoVision Imaging, Inc.

2400 N. Lincoln Avenue
Altadena, CA 91001

Image Stabilized Binoculars with Integrated 3D Facial Recognition Imaging Capabilities

June 2013

User Manuals

Award No. 2010-IJ-CX-K001

Grant Manager
Dr. Mark Greene
National Institute of Justice
U.S. Department of Justice
810 7th Street NW
Washington, DC 20531

Mark.Greene2@usdoj.gov

Prepared By:

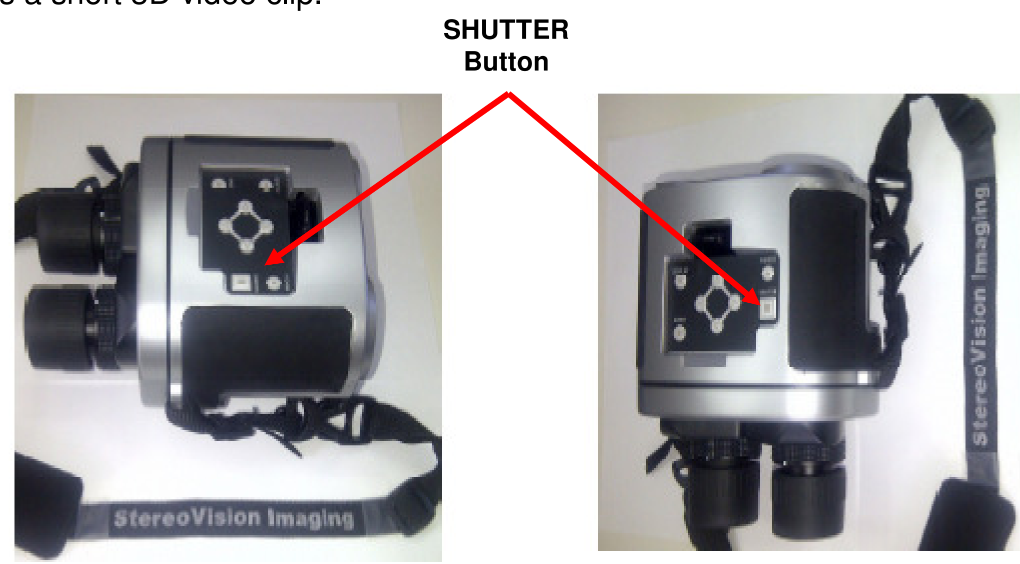
Gregory Steinthal, Program Manager
June 2013

This second generation 3DMobileID™ face recognition binocular system offers 8x angular optical magnification integrated with a 5 MP stereoscopic imaging system designed for 3D capture of persons of interest viewed through the optics and on-demand face recognition, outdoors, at ranges 50 to 100 meters from point of use.

Overview of the System

The patented design allows end user to place a “person-of-interest” within the retical markings for identification. The imaging pixels only corresponding to the retical marking are captured from the internal CMOS photo arrays. Image size: 600 x 600 pixels.

The device was developed for portability and ease of use. The 3D binoculars can be adjusted for individual eyes pacing and manual focus to the eye via the rotating eye pieces and ocular adjustments, respectively. A single press of the shutter button captures a short 3D video clip.



SETTINGS	DESCRIPTION	COMMENTS
External Battery Pack	Please Use Specified 5V Battery Pack to Power device	Future Efforts Will Move Away from External Pack and Run off Internal Supply Batteries
Wireless WUSB Interface to PC	Please Use Specified WUSB Dongles	Range is up to 25 feet, 10 feet is nominal

FIG. 1: Only the SHUTTER push button is active as shown above. Table above reflects other key operational parameters such as external 5V battery pack and WUSB wireless dongle required for proper device operation.

The following sections described the required software required for system operation which consists of:

1) COTS server face recognition (FR) engine, a SAFRAN MorphoTrak product (formerly L1-Identity Solution, Inc.)

2) SVI client 3D segmentation/enhancement software application, DisparityCalcTest – required to import files stored to disk from the 3D Video Capture utility described below, automatically extracts and isolates faces from background clutter, photo-metrically enhances imagery to provide uniform illumination across the face and automatically sends face templates to the COTS FR engine for real time identification against a pre-loaded 2D facial database.

3) SVI 3D Video Capture utility – required to transfer 3D video clips from the device to a remote computer and store files to disk (to be described in the Quick Guide, Appendix III

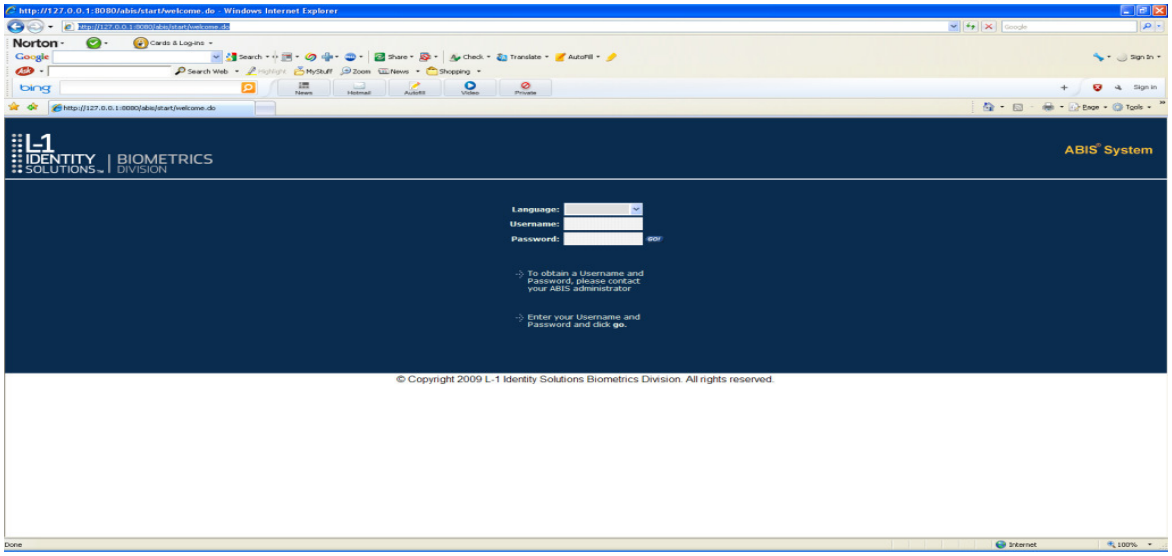
COTS FR Engine Server Software and System Setup

The following will outline launch and configuration of the software components of the server-based FR matching software. Installation is not required since the components have been pre- installed onto the laptop computer.

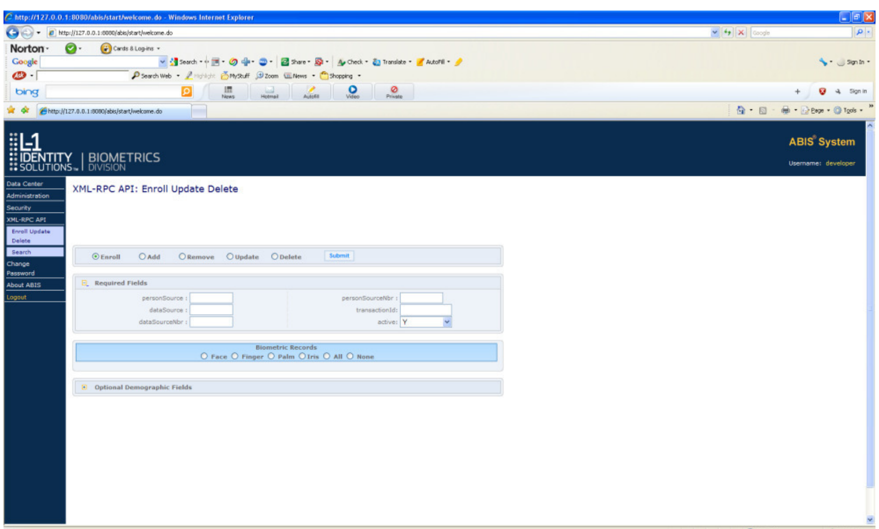
Launching the L-1 ABIS® System

Prior to starting the Gallery Manager, FRT Tracker, and Argus Monitor applications, we'll need to confirm that the ABIS® System search engine core is running. Using Internet Explorer, access the following URL: http://127.0.0.1:8080/abis

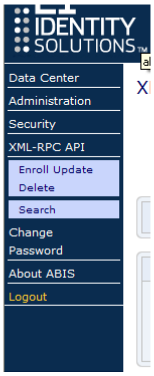
You should see the web page below:



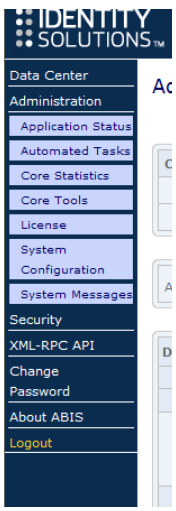
For the **Username** field, enter *developer*. For the **Password** field, enter *password*. Click on **Go!**. You should see something similar to this after clicking on **Go!**:



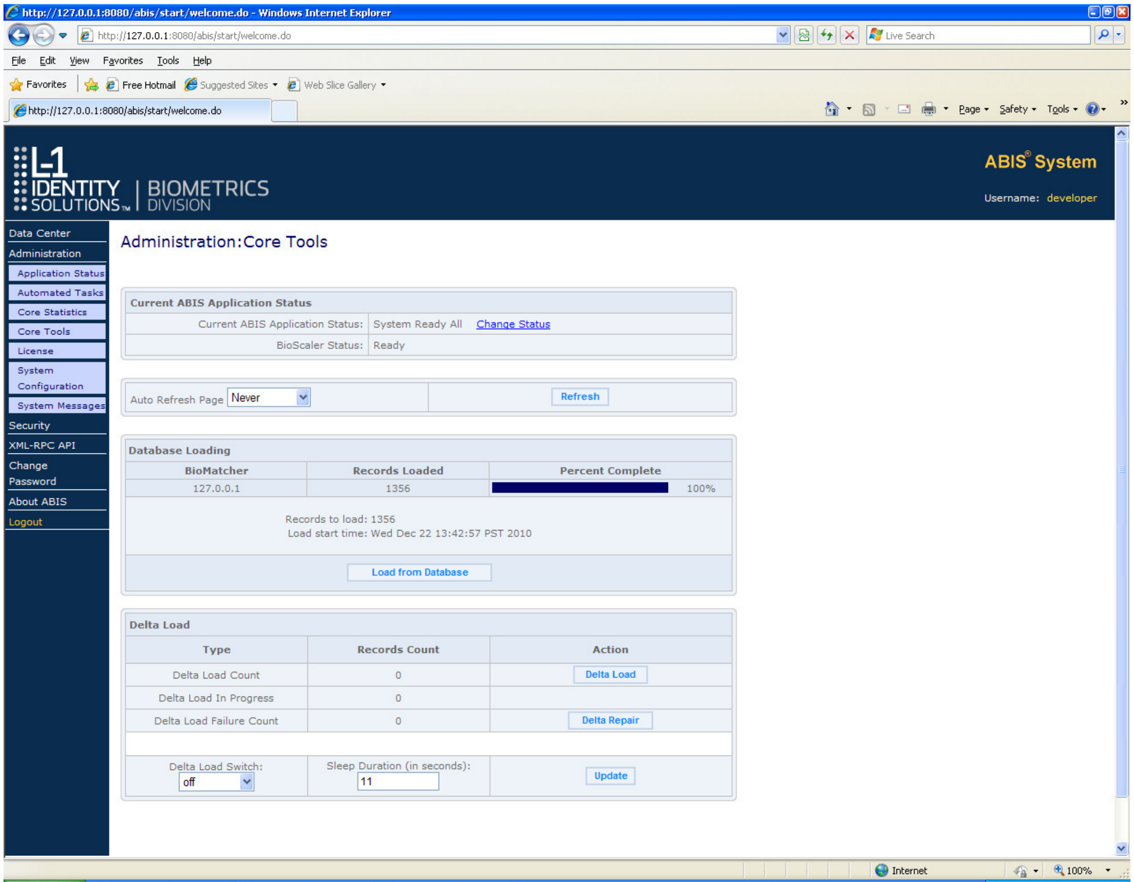
You'll notice a menu on the left side of the page:



Click on **Administration**, and then from this menu:



Click on **Core Tools**:



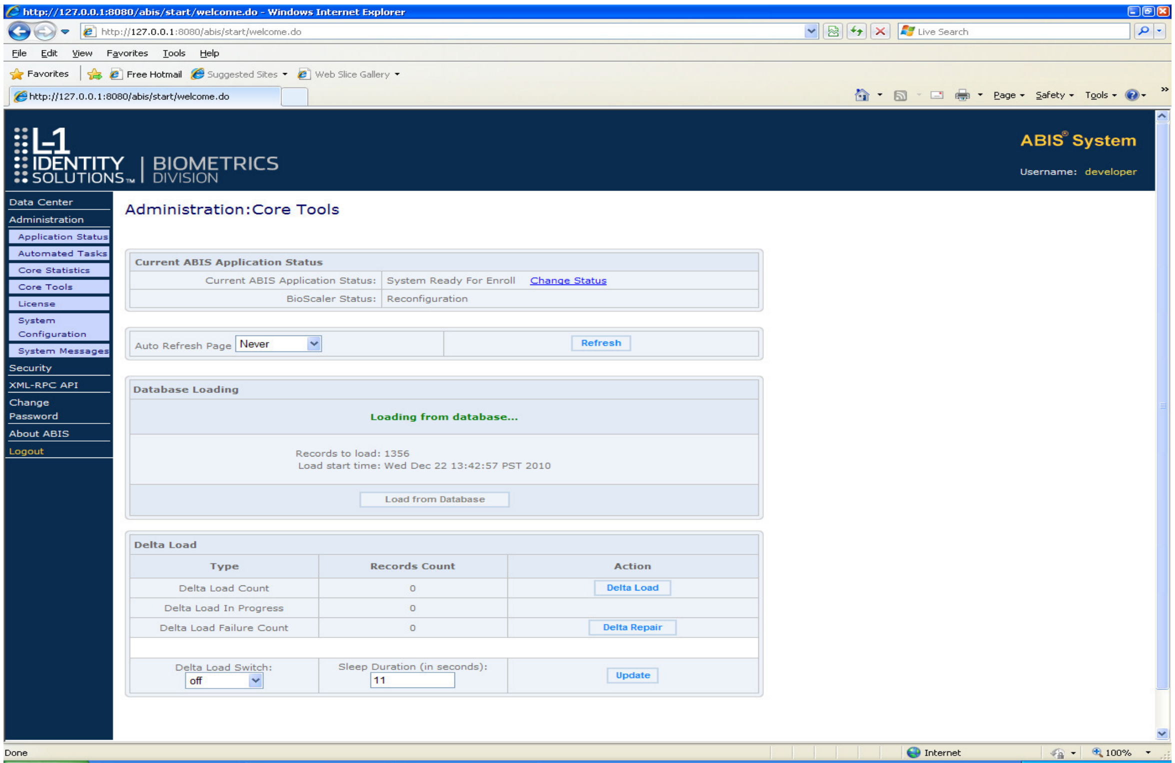
The web page above illustrates a machine with its ABIS® System core in its running state. Two things that confirm it's in this state are:

- **Current ABIS Application Status** shows **System Ready All**
- The progress bar beneath **Percent Complete** shows up as 100%

If the page shows up in this state, then this is a confirmation that the database is fully loaded and the ABIS® System is running. (NOTE: Don't worry about the number of records under **Records Loaded** as this count shown above may or may not be the same as what you see on your machine at the moment. This count is associated with the number of identities enlisted in the database which may change. The important thing is that you see 100% of the records are loaded.) If it's in this state, you may jump to the section titled *Launching Argus Monitor*. If the page does not show up in this state, but rather this state:

It's an indication that the database hasn't been loaded yet. You'll need to click on the **Load from Database** button.

After you’ve clicked on **Load from Database**, you’ll notice the page display **Loading from database…** as a notification that the ABIS System is loading records from the database. You should see the page as displayed below:



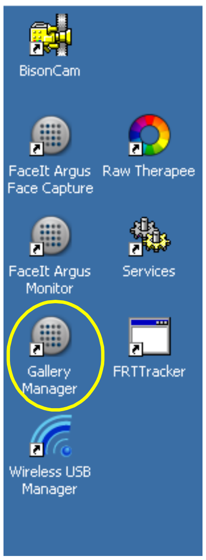
Waiting a minute or two for the database to load may be required. While this page is displayed, you can click on the **Refresh** button to update the display to show what percentage of the database has been loaded so far. Click **Refresh** until it displays a progress bar showing 100% (wait at least 5 seconds between clicks). You should also see **Current ABIS Application Status** show up as **System Ready All**.

At the bottom left of the web page, you should see a drop-down selection box labeled **Delta Load Switch**. Click on this and select the **periodic** option. Then, click on the Update button at the bottom right. Once these conditions have been met, you may continue with the next section.

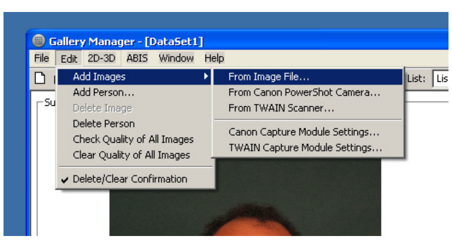
Note: For more detailed information on the ABIS® System, refer to the *080-613-L_ABIS_Search_Engine_6.5.1_Administration_Guide.pdf* document available upon reques

Adding Images to the Database

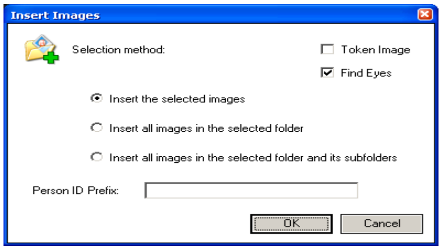
Before attempting to identify subjects from image captures, you'll need to make sure the subjects you're trying to identify are in the ABIS® System database. Here, a series of steps will be presented to outline the process of enrollment for a single person with one image. First, you'll need to have an image file of the person you wish to identify. This is an image captured using a standard digital camera at close range. It should be taken indoors, with the lighting fairly uniform across the face. After acquiring the image, launch GalleryManager by clicking on the shortcut located on the left side of the desktop.



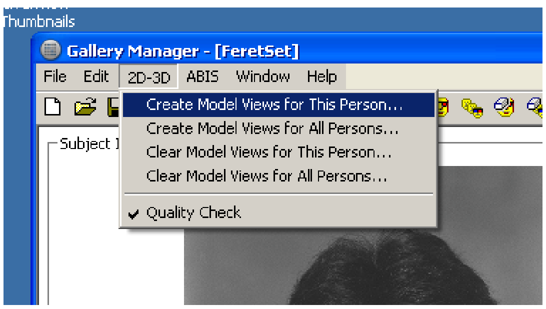
Once the Gallery Manager application window is up, click **Edit** **Add Images** **From Image File…**



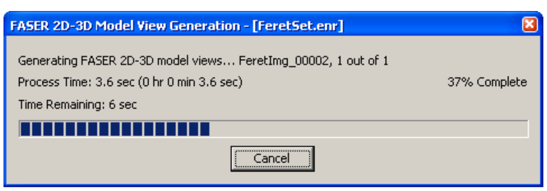
From the following window, make sure **Insert the selected images** is selected and **Find Eyes** is checked. Then click OK.



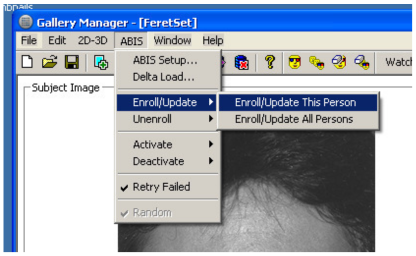
From the list of files displayed, select the single image file associated with the identity, then click Open. Make sure the image just selected shows up in the **Subject Image** sub-window, then click on **2D-3D Create Model Views for This Person**.



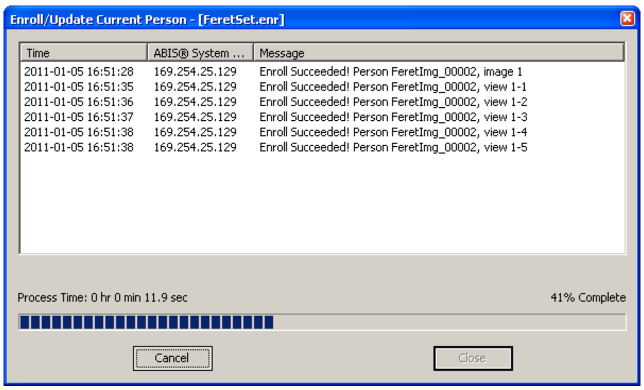
This will generate a set of 3D images associated with the initial image that reflect the face at different positions.



Once the model view generation has completed, click on **ABIS Enroll/Update Enroll/Update This Person**. This will add all the data to the ABIS® System database.



A progress window will show up indicating the enrollment status. Upon completion of the enrollment, click on the Close button.



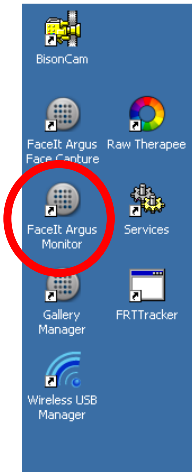
The person just enrolled is now in the database and ready for identification.

Note: For more details on the enrollment process, refer to the *080-637-D_GalleryManager_User_Guide.pdf*

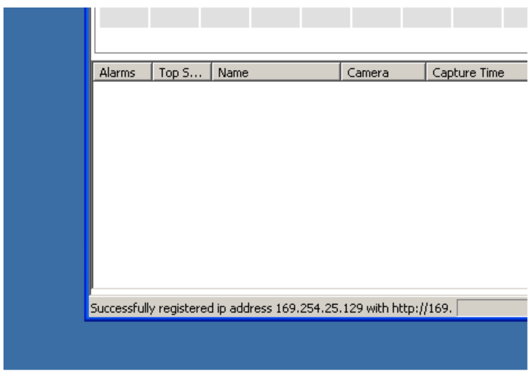
Launching Argus Monitor

The Argus Monitor application is required to show the results of the identification. Once the ABIS® System is up and running, Argus Monitor may be launched. To do this, you can double-click on the Argus Monitor located at the left side of the desktop.

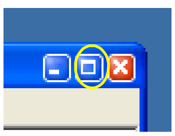
StereoVision Imaging, Inc.
Award No. 2010-IJ-CX-K001



Once launched, the monitor needs to register itself with the ABIS system. This may take 15 to 20 seconds. Once this is done, the status is displayed on the bottom left corner of the application's window:

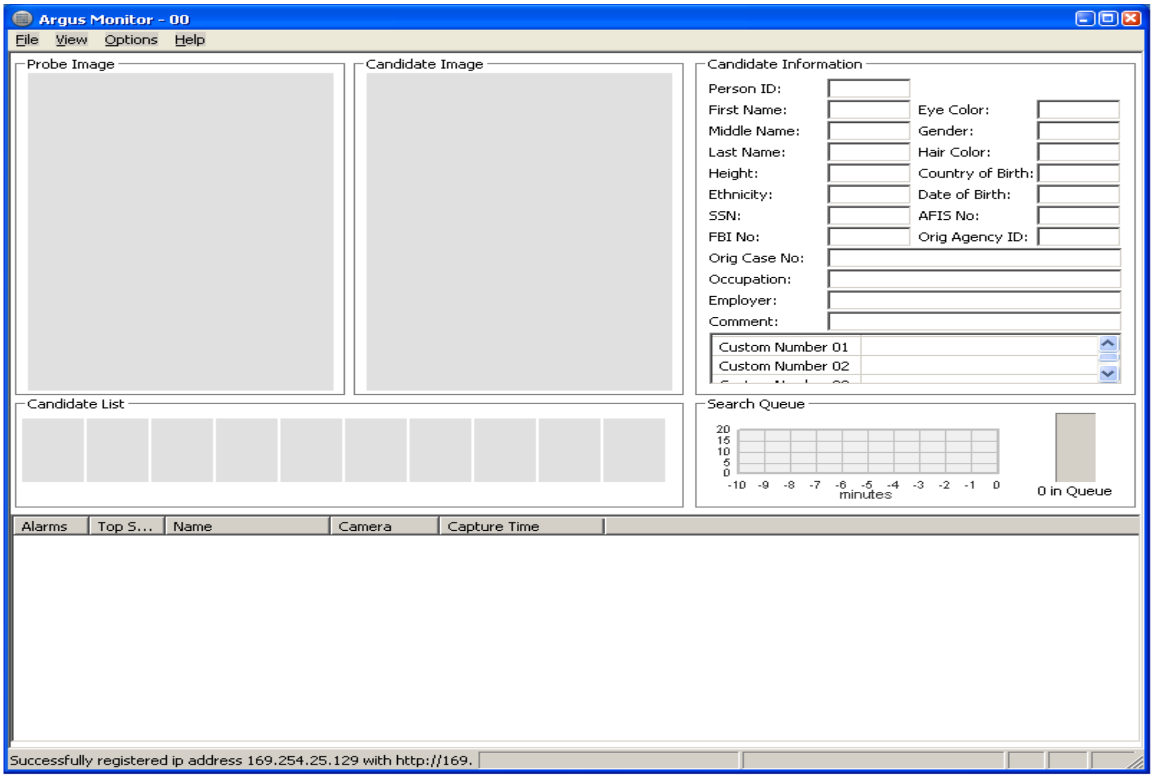


The application starts off with the window at its maximum size. Reducing this to a moderate size would be beneficial since you'll also be running the FRT Tracker application simultaneously. This can be done by clicking the button outlined below located at the top-right of the Monitor application's window:



StereoVision Imaging, Inc.
Award No. 2010-IJ-CX-K001

The image below is of the Monitor application default window:



StereoVision Imaging, Inc. Disparity Calculator Guide

The new Disparity Calculator application generates 2D segmented images from the left/right 2D images, and sends them to ABIS for identification. However, it can also be used as an analysis tool where segmentation properties can be manually changed to note any improvements in performance..

The following flowchart diagram assists in understanding the architecture:

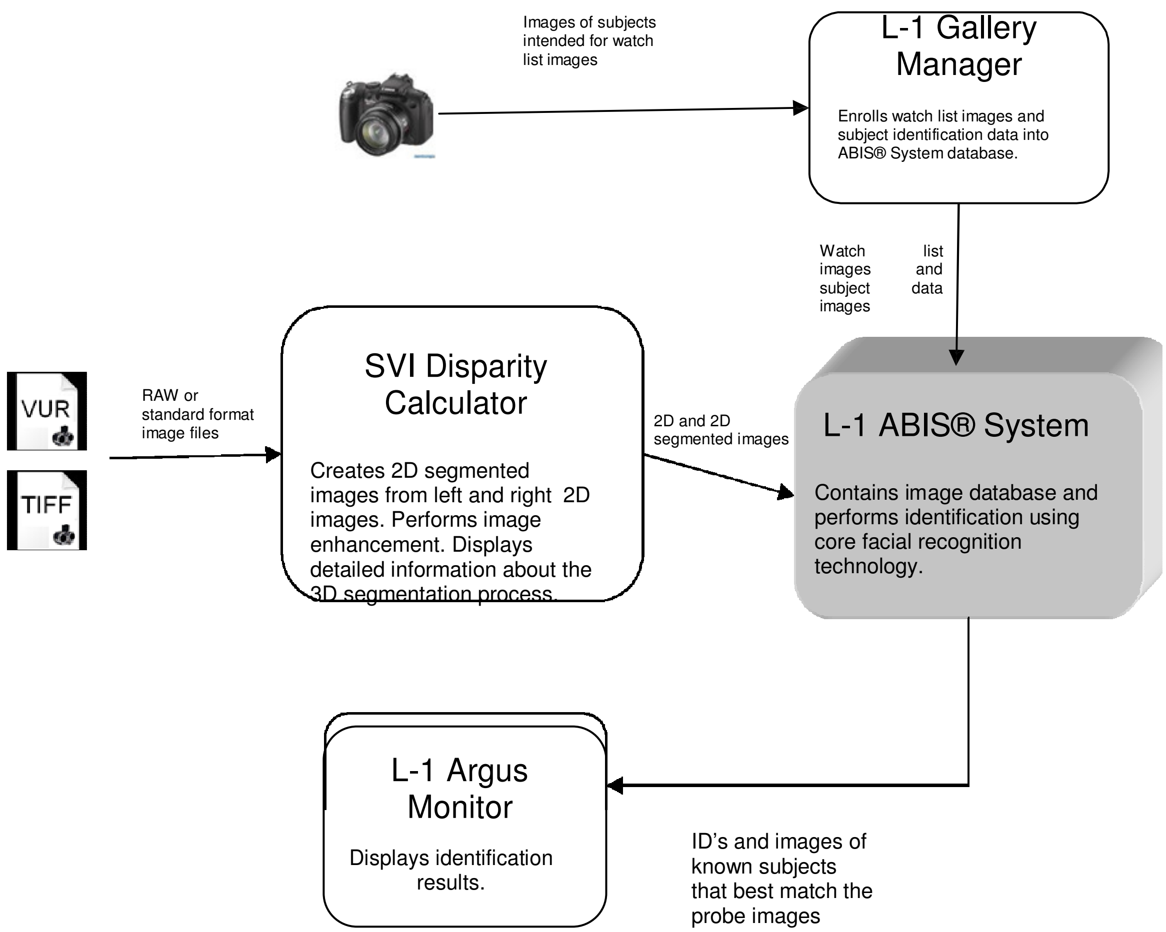
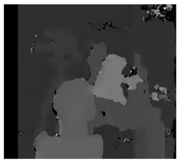


FIG 2: System Architecture.

Launching Disparity Calculator

A shortcut for Disparity Calculator icon exists on the desktop.
Double- click this to launch:



The following main screen will appear:

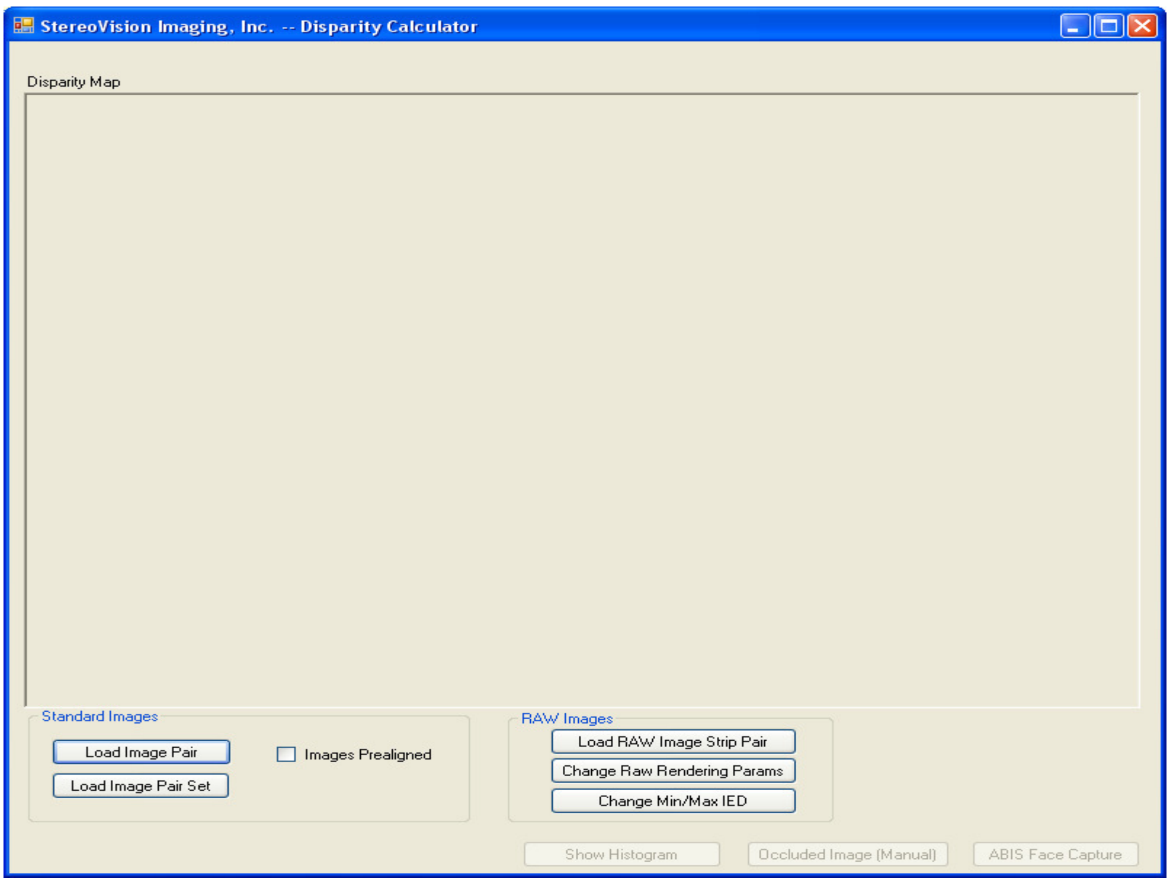


FIG 3: Main DisparityCalcTest screen. Please note the 'Change Raw Rendering Params' and 'Change Min/Max IED' buttons should not be accessed.

Please note the ‘Change Raw Rendering Params’ and the ‘Change Min/Max IED’ button should not be accessed. These contain key configuration parameters that if modified would severely affect identification performance.

Loading RAW image files

Two files are generated from the each test run and saved to the computer as XXXXL.VUR, XXXXR.VUR where XXXX represents a 4 digit number. Each of these files contains a 3D video clip of 6 frames, comprising a sequence spaced approximately 50 milliseconds apart. As these files are raw, the format is proprietary and the files can only be opened using the Disparity Calculator application. (VUR stands for VuCAM RAW)

On the main application window (Figure 3), you’ll notice the button labeled **Load RAW Image Strip Pair**. This allows you to access to the original raw image files. After clicking this, you’ll be requested to select the left and right image files. The files selected should be XXXXL.VUR and XXXXT.VUR where XXXX is the same numeric ID for both files (ex: 0003L.VUR and 0003R.VUR).

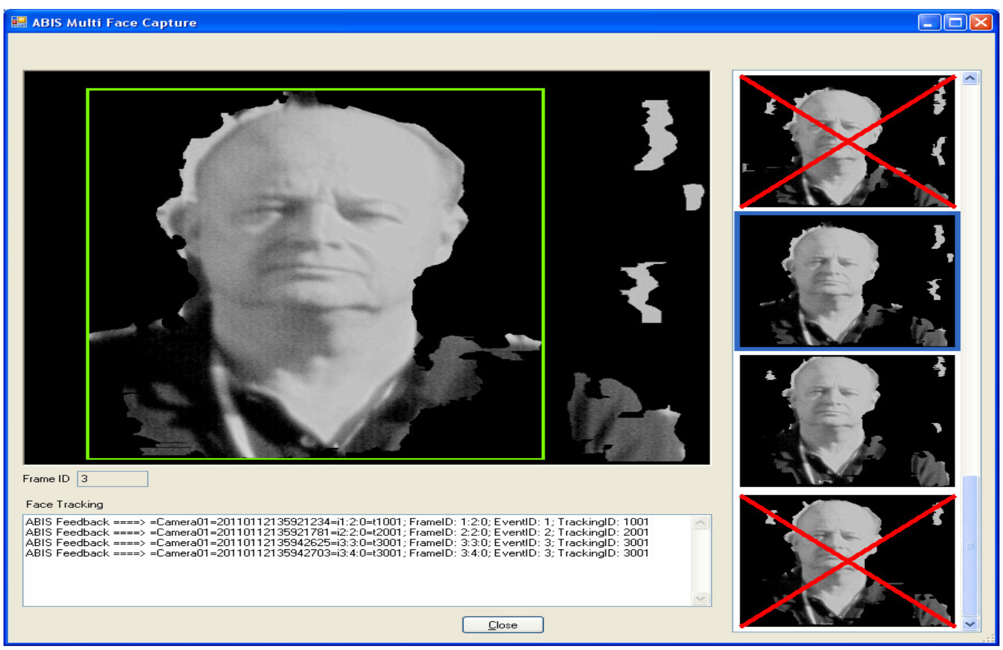
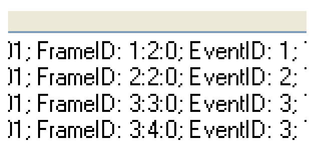


FIG. 4

The images on the right hand side represent the frames taken from the raw image files. You’ll notice as you move the scroll bar that there are a total of 18 images displayed on the right side. At the top of the list, the first 6 frames are those taken from the LEFTXXXX.VUR raw file. Besides some enhancement with respect to lighting, these are just the standard 2D images with no 3D segmented processing added.

The next 6 frames down are the those taken from XXXXR.VUR raw file. The last 6 frames are those that involve the 3D processing of both XXXXL.VUR and XXXXR.VUR. The window displayed above shows these images.

All 18 of these frames are sent to the ABIS System for identification. From each set of 6 frames, ABIS determines which frames are the best to perform identification on. In this case, the best could be 1 or 2 frames from a set of 6. Within the **Face Tracking** section, ABIS sends a response back to the application indicating which frames from each set were selected as the best. The **EventID** identifies the set (3 sets altogether). The **FrameID** identifies a frame within a set. For example: 1:2:0 refers to the 2nd frame of the 1st set. So, for the 3 sets of 5 frames above, ABIS chose the 2nd frame of the 1st set, the 2nd frame of the 2nd set, and the 3rd and 4th frames of the 3rd set to perform identification on.



You'll notice in Figure Four that 2 of the above frames have red X's. This is an indication from ABIS that the frame quality was not high enough to detect the face and is considered bad. **NOTE**: A frame doesn't necessarily have to be "red X-ed" to be excluded from the best.

Also Note: When loading a RAW image strip pair, the individual frames from XXXXL.VUR and XXXXR.VUR are saved as standard .tiff image files. Each frame is saved as a separate file. You should see files with the names XXXXL_0.tiff, XXXXL_1.tiff, XXXXL_2.tiff, XXXXL_3.tiff, XXXXL_4.tiff, and XXXXL_5.tiff, located in the same folder as the RAW files that were loaded. The same naming scheme applies for XXXXR.VUR.

Please ignore the other two files generated with the _color and _occluded tags.

Loading Standard Images

More information related to the 3D segmentation process can be viewed when loading a single pair of frames rather than multiple frames. The Disparity Calculator application allows loading of a single image pair through standard image files (*.tiff, *.jpg, *.png). From the main application window click on the **Load Image Pair** button. The **Images Prealigned** checkbox should be left unchecked. This is only used when the left and right images have already been aligned with some other program outside of Disparity Calculator. Disparity Calculator performs the necessary alignment.

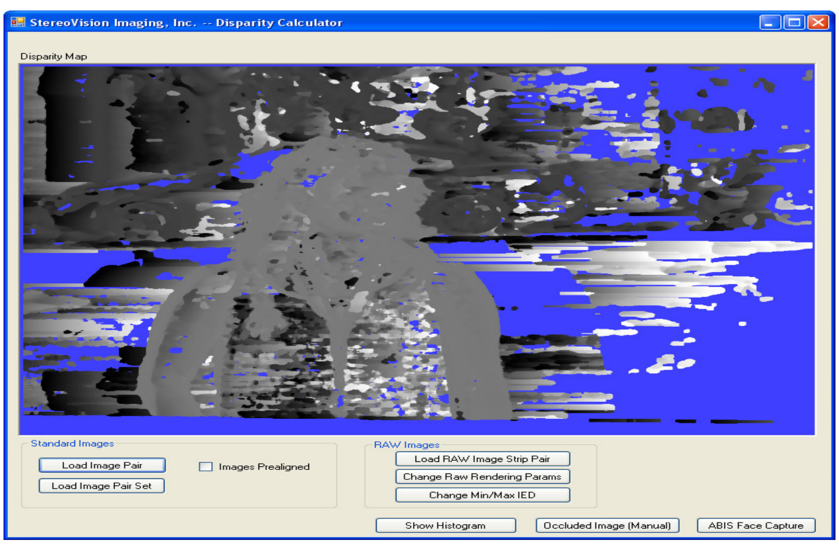


FIG .4 : The disparity map is the first image that's displayed after clicking Load Image Pair and selecting the files that make up the pair.

Please make sure to import the corresponding right image with the left, i.e. 0001L_0.tiff with 0001R_0.tiff

Histogram

For each disparity, there are a certain number of pixels in the disparity map that share that value (i.e. that shade of gray). The histogram represents a count of the number of pixels at each disparity across the entire disparity range.

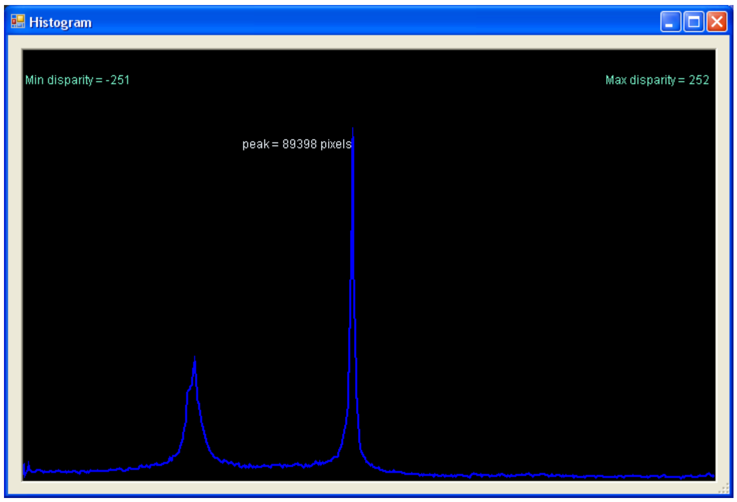


FIG. 5

Figure Five shows the histogram associated with the disparity map from Figure Four. You will notice 2 distinct peaks in this histogram. This can be rendered by clicking on **Show Histogram**. Each peak represents an object (or collection of objects) at a certain distance away from the 3DMobileID™ binoculars.

Occluded Images

The final goal of the segmentation process is to generate an occluded image. The occluded image consists of the original image with certain portions visible and certain portions masked. We're interested in leaving the portions of the image associated with the peaks in the histogram as visible, and the rest as masked. This allows us to view certain objects at a certain distance, while masking out everything else.

By clicking on **Occluded Image (Manual)**, you'll be able to choose what disparity range, and therefore distance range, of the image you'd like to remain as visible. After clicking on **Occluded Image (Manual)**, you should see

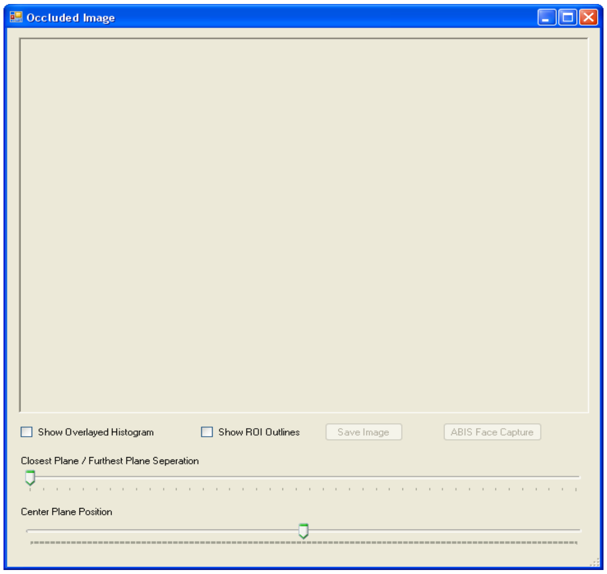


FIG. 6

Click on the **Show Overlayed Histogram** checkbox. This will help visualize what depth range you're selecting as visible. The **Closest Plane** / **Furthest Plane Separation** control bar allows you to select what range of distances is rendered as visible. As you drag the marker to the right, the separation between closest and furthest planes increases providing a greater range of visibility by allowing more of the pixels to be rendered as visible. As you drag the marker to the left, the separation between closest and furthest planes decreases constricting the range of visibility. The **Center Plane Position** control bar allows you to move both the closest plane and furthest plane simultaneously and place them anywhere within the range of depth defined by the histogram's horizontal span. Figure Seven below shows the original image with no occlusions:

FIG. 7

Below, the depth range is set to permit the viewing of either the first subject or second subject. Also, notice that as you progress towards the right side of the histogram, objects closer to the camera come into view; when progressing to the left, objects further away from the camera come into view. The right vertical bar represents the closest plane and the left vertical bar represents the furthest plane. The visible portions of the image consist of pixels whose associated disparities fall within this range. The visible pixels are taken from the left image.

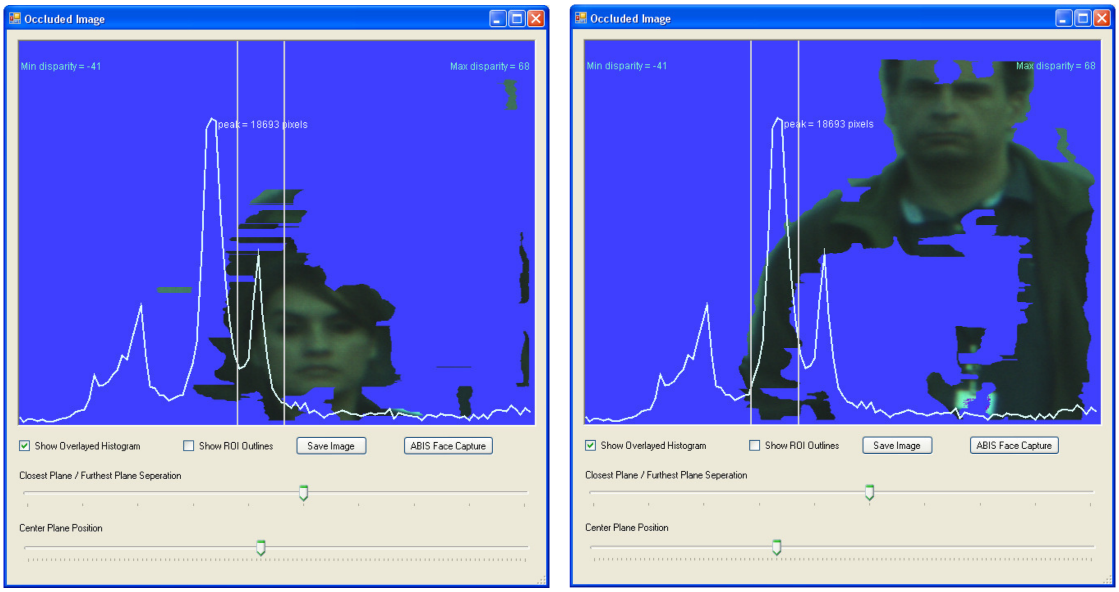


Fig. 8

The current occluded image may be sent to ABIS for an identification attempt by clicking on **ABIS Face Capture**. Note: the overlaid histogram is not sent as part of the image.

APPENDIX III

USER MANUAL

Second Generation Wireless 3DMobileID™
Face Recogntion Binocular System
User Manual

Revision 1

May 28, 2013

STEREOVISION IMAGING, INC.

2400 North Lincoln Avenue
Altadena, CA 90068
info@stereovisioninc.com

1.0 PROGRAM SUMMARY

The first revision of the 3D Binocular Face Recognition System was funded under NIJ Award 2009-IJ-K001. Funding allowed for proof-of-concept ability to develop a man portable system and demonstrate face recognition under uncontrolled daylight environmental conditions from 50-100 meters from point of use. However, some shortfalls included a lengthy list of labor intensive manual operations required to successfully reach an adequate level of performance.

With further funding, The NewGen Wireless 3DMobileID™ Face Recognition Binocular System was developed under NIJ Grant # 2010-IJ-K001, with the intent of reaching a true hand-held, fully automated, viewing device with 'point & shoot' face recogntion capabilities. In addition the NewGen device is now unencumbered by hard wires and operates in a wireless mode only for ease of operation and demonstration.

New Generation (NewGen) 3DMobileID™ System versus Old Generation (OldGen)

Technically, The NewGen device includes a monochrome versus the legacy color imager offering higher sensitivity and allowing for faster optics. In addiion on-board auto expsoure and auto focus algorithms have been realized on a state-of-the art FPGA platform. The key differentiators are listed as follows:

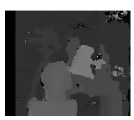
OLD GENERATION	NEW GENERATION
Tripod Only	**HandHeld and Tripod**
Manual Exposure	**Auto Exposure**
Manual Focus	**Auto Focus**
Wired Connection to PC only	**Wireless only (25 ft range max, 10 ft nominal)**
Can Store 3D Video Clips On-Board	**No On-Board Video Storage Capabilities Yet (Future Improvement). New PC Software Must be Running while Operating Device**

2.0 NEW SOFTWARE INSTALLED ON LAPTOP NOTEBOOK COMPUTER

A. There is new SVI 3D Video Capture application installed on the laptop located in the the root of the C drive, file folder labeled: 'SVI3DVideoCapture' . It can be accessed by running the .exe or simply double clicking on the following icon located on the desktop window:

This application must be running to automatically transfer the video clips off the device and store them as .vur files in the root of the C drive in a file folder labeled: '3DMobileID™ _Images'.

B. There is also a new version of the SVI DisparityCalc Application installed on the laptop located in the the root of the C drive, file folder labeled: 'DisparityCalcTest_Monochrome'. It can be accessed by running the .exe or simply double clicking on the following icon also located on the desktop window:



This new version accepts the .vur monochrome files and links into the COTS face recogntion (FR) engine in the exact same manner as before for face recogntion.

3.0 SVI VIDEO CAPTURE PROGRAM OPERATION

3.1 Connecting a 3DMobileID™ Device to Your Computer

A. Connect the USB wireless dongle associated with the 3DMobileID™ device that you wish to use to a USB receptacle on the laptop. The dongle number corresponds to the serial number located on the bottom of each respective 3DMobileID™ device.

B. Power up the device by connecting the power cord from either the +5V battery or the +5V external power supply. After the power-on sequence has completed in less than 30 seconds, a message should pop-up on the laptop screen: "Wireless USB Dongle is Now Connected". If such a message does not appear, put the cursor over the icon on the taskbar that represents the USB dongle – that should show as a green dot in the lower right hand corner of the icon and 2 green quarter circles around it. If the device is connected to the computer when you put the mouse cursor over the taskbar icon, a popup window will open on the screen with the text "Connected to Device". It is necessary for the device to be powered on by plugging it into the battery pack or wall wort before connection to the laptop is possible.

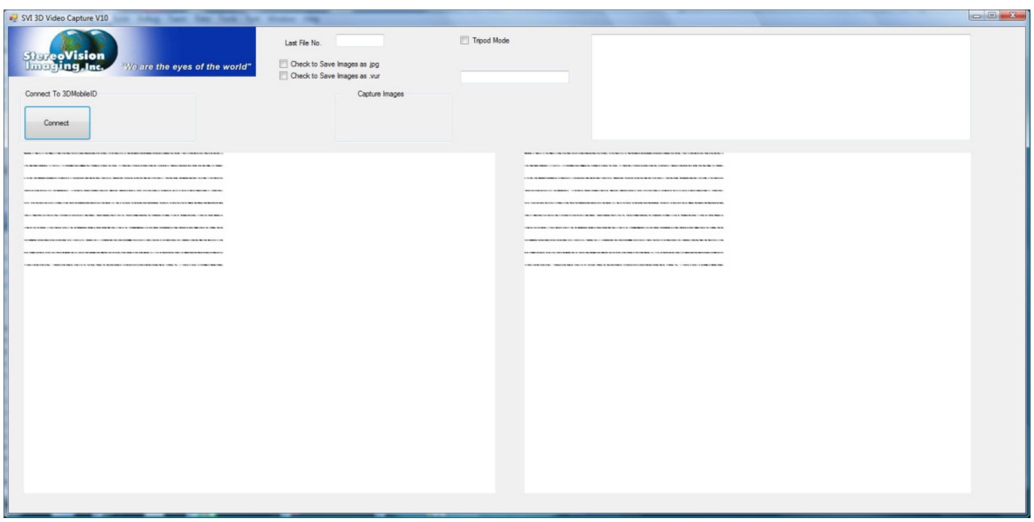
3.2 Starting the Program

To start the SVI 3D Video Capture program, double click on the desktop shortcut

near the bottom of the desktop that looks like a pair of binoculars. The title under the icon reads "SVI 3D Video Capture".

3.3 Main Window

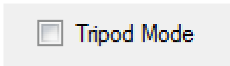
The main window of this program appears as below when the program is first started.



3.4 Specification of Tripod Mode

The 3DMobileID™ device has 2 capture modes – handheld mode and tripod mode. In handheld mode, the device requires a fair amount of nominal light to operate properly and thus has a limited daylight operating range. In tripod mode the device is assumed to be on a tripod. This mode will allow for extended daylight operation usuage if desired. It is essential that if the unit is handheld and not on a tripod, the device must be in handheld mode and vice-versa.

To put the device into Tripod mode, check the checkbox:

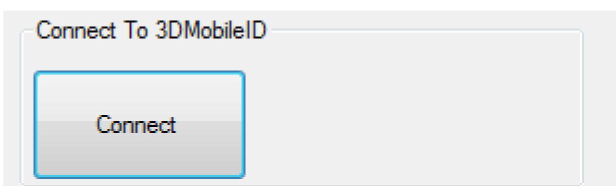


near the top of the screen and to the right of last file number before attempting to connect the program to the device. If this box is checked when a connection or reconnection between this program and the device is attempted, the device will be set to tripod mode during the connection process. If the checkbox is not checked, the device will set into handheld mode.

Once connection between this program and the device is made, tripod mode cannot be changed and the checkbox is grayed out. If the user puts the device into tripod mode, makes a connection with this program, and at a later time removes the device from the tripod, this program must be terminated, restarted and reconnected to the device with the tripod mode checkbox unchecked.

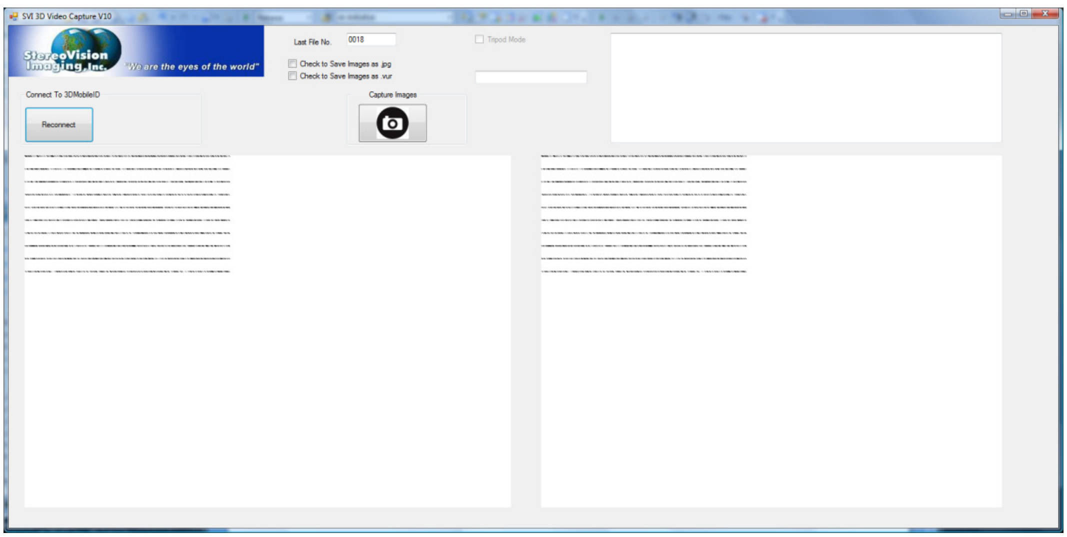
3.5 Connecting the Program to the Device

To initiate communication between this program and a device currently powered on and connected to the computer, click the button labelled "Connect" under the text heading "Connect to 3DMobileID™ ".



If the device is not successfully communicating with the computer when connection with this program is attempted, the following 2 message boxes will pop up in sequence:

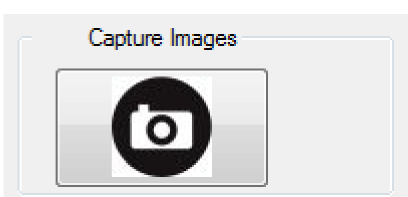
Click on the “OK” button on both to clear them. If this situation occurs, please exit the program, make sure the computer is talking with the device, restart the program and try again. When successful connection of this program with the device has been accomplished, the main window appears as follows:



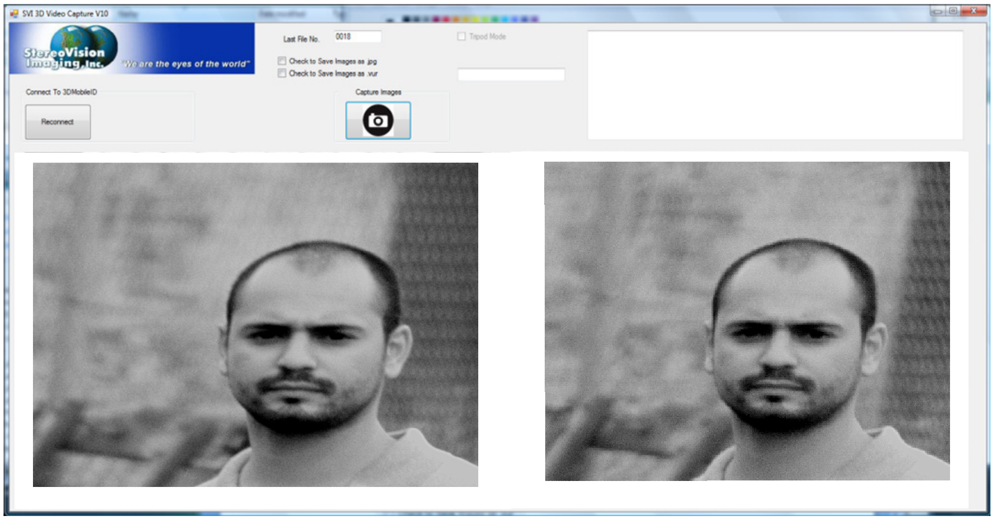
Notice the image of a camera that has appeared under the label “Capture Images”.

3.6 Capturing Images

To capture a video stream of six (6) images on each channel, click on the button:

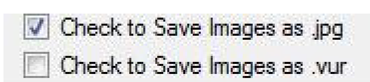


After a few seconds, the first image captured from each channel will appear in the two image panes of the program in the lower portion of the screen, as shown in the following picture. Note the left image shown is from the left channel, the right image shown is from the right channel.



3.7 Saving Images to Disk Files

There are 2 disk file formats that image streams can be saved in, JPEG and VUR. JPEG represents standard JPEG-formatted and compressed files with filename extension .JPG, and VUR is a proprietary uncompressed file format with filename extension .VUR. VUR files are used as inputs into the program DisparityCalcTest. To save files in JPEG format check the box labelled "Check to Save Images as .jpg", as shown below.



Please note that when the option to save JPEG images is selected, only the first of the 6 images received from each channel is written to a .JPG file.

To save image files in the VUR format, check the lower box next to "Check to Save Images as .vur". A separate video stream of 6 images is written to each of the 2 VUR files . Files for the left channel are created with a name such as nnnnL.VUR; the files for the right channel are named nnnnR.VUR, where "nnnn" represents a 4-digit number that is monotonically increasing. The letters "L" and "R" represent the channel, left or right respectively.

All disk files created during the capture process will be placed in the folder "C:\3DMobileID™ _Images". Note that in that folder there will usually be a file named "CurCount.bin". This file contains the file number of the files written for the last capture operation in a binary format. Feel free to move files containing captured images from this folder into other folders or drives to keep them organized by subject; however it is recommended that you not delete or move the file CurCount.bin so that each file captured (and later processed) will have a unique sequence number even if the SVI 3D Video Capture program is stopped and restarted. If CurCount.bin is deleted or removed from the folder "C:\3DMobileID™ _Images", then the next file to be created after the program is restarted will be 0001.

Note that the file number of the last file set saved appears in a text box on the program's main screen above the 2 check boxes that select type of file. This text box is labelled "Last File No." as shown below.

4.0 OPERATION OF THE 3DMobileID™ DEVICE

Power ON

To apply power to the device, plug either the +5V batter or +5V power adapter into the power receptacle on the left side of the unit when the device is held right side up. After applying power to device, there should be 3 signals to the user:

1. A short low-frequency beep during which the LED briefly blinks green.
2. A louder medium-frequency beep accompanied by the RED LED going on for about 1 second.
3. Three short high-frequency beeps about ½ second apart during which the LED does not blink.

Power OFF

Only the SHUTTER button is active on the keypad. To power down, simply remove power plug.

Normal operation

If the device is connected to the SVI 3D Video Capture program, when the device is not capturing images the green LED should blink approximately twice per second to indicate the device is operating normally.

To capture a 3D Video clip, press and hold the SHUTTER button until a short beep is sounded about 2 seconds later to indicate that automatic exposure and focusing are completed. Then release the SHUTTER button to initiate the capture of six images from each channel and transmission of those images over the wireless communication channel to the program "SVI 3D Video Capture" running on the connected PC. The first of the six images on each channel are displayed on the main window, and if saving the images to disk files in JPEG format is specified, the first image from each channel are also written to JPEG disk files. If saving files in VUR format is specified, these files will be written containing all 6 images from each channel. A second short beep is sounded when transmission to the PC is completed.

Error conditions

1. When capturing video, if the LED becomes solid red and one long beep of approximately 2 seconds is heard, that indicates an auto-focus error. No images are captured in this situation. When this occurs, it is recommended that you cycle power on the device to clear it (waiting 10 seconds when the device is off) and also to restart the 3D Video Capture application PC application.

2. If the user attempts to start a video capture before 5 seconds have elapsed since the end of the previous capture, the device will ignore the attempt until the 5 second interval has elapsed.

3. If 2 short beeps are sounded shortly after pressing the SHUTTER button to initiate the capture of video images, there is not enough light for auto-exposure to work properly. In that case, no images will be captured. Suggest tripod mode.

Suggested Operational Usage

1. Person of interest must be positioned with the retail marking.

2. In Hand-Held mode please hold the device as stable as possible.

3. The shutter button is a two mode operation:

    a. First when initially depressed auto-focus and auto-exposure are performed. It is suggested to try to get as much of the body i.e. shoulders/face in the retical during this mode. Otherwise face may not be captured with proper focus. Once completed buzzer beeps signifying device ready for capture. This mode can take 1-2 seconds.

    b. Capture Mode. While the button is still depressed from the step above, one can then move the device and place face directly in the retical and release button. This capture mode is extremely fast, less than 0.5 sec.

This may require some practice.

APPENDIX IV

QUICK USER GUIDE

3DMobileID™ Device

- Launch 3D video Capture Utility
- Place appropriate WUSB dongle in computer USB port
- Place Device around neck or on a tripod Stand & Power Device Utilizing External 5V Battery Back and make sure device is connected properly to computer via wireless dongles.
- Adjust the eye pieces to compensate for the distance between the eyes.
- Place the object of interest within the reticule looking through the 3DMobileID(TM) device.
- Adjust the left/ right eye focus using ocular adjustment
- Prepare to capture a 3D video clip by pressing SHUTTER button down unit hear first beep.
- Hold the device steady, pointing at what you are focusing, then hold SHUTTER button down till you hear a beep. Make sure face is within the retical and release button to capture a 3D video clip. Buzzer chirps again indicating operation over.

Loading 2D Database

- Turn on Laptop (power switch located on upper RHS of keypad)
- Open Internet Explorer, Select 'Work Offline' command button the Select the following ABIS IP address from the pull down list box: http://127.0.0.1:8080/abis. Click the 'Connect' button when prompted.
- Log in as "developer" with "password" as the password
- Click on '*Administration*' then '*Core Tools'* from menu and then Click on the '*Load from Database'* command button in the center of the main page

- Wait a couple minutes and press “Refresh” button to assure 100% download. This step may need to be repeated.

- Minimize Internet Explorer

Launching Application(s)

- Double Click on the ‘Argus Monitor” icon on the Desktop to launch application. Restore down this application as a separate window to view the desktop.

- To import .vur files for face recognition double click on the ‘SVI DisparityCalculator’ icon to launch application

    - Select “Load RAW Image Strip pair” to upload images