Document Title: 3D Hand-Held Surveillance and Real Time Multi-Modal Recognition Device

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Document No.: 249535

Date Received: December 2015

Award Number: 2009-IJ-CX-K001

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NATIONAL INSTITUTE OF JUSTICE
January, 2011

Attn: Dr. Greene

Re: Award No. 2009-IJ-CX-K001
Final Technical Report

Dear Dr. Greene:

Please find enclosed our Final report per Special Condition 15 of our Award No. 2009-IJ-CX-K001 Cooperative Agreement and associated user guide(s).

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

3D Hand-Held Surveillance and Real Time Multi-Modal Recognition Device

2400 N. Lincoln Avenue
Altadena, CA 91001

January 2011

Final Technical Report, Rev. 1.1

Award No. 2009-IJ-CX-K001

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January

REVISION HISTORY

AUTHOR	REVISION	DATE	COMMENTS
Steinthal	1.0	1/19/11	
Steinthal	1.1	2/7/11	• Added Revision History Table. • Revised Financial Summary, Page 46 • Correct Spelling, Page 42

TABLE OF CONTENTS

1.0 PURPOSE OF REPORT

This final report has been submitted in accordance of Special Condition 16 of our Cooperative Agreement.

ABSTRACT

Development of a law enforcement oriented, cost effective, network centric mobile wireless hand held binocular ID system developed to identify uncooperative persons of interest at ranges of up to 100 meters under uncontrolled lighting and environmental conditions.

Face detection system utilizes existing 2D interagency facial databases with data rich 3D facial recognition technology to accomplish the objective of 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.

2.0 PROJECT DESCRIPTION

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. Proof-of-concept will be accomplished via the construction of a fully functional advanced R&D prototype. The devices shall provide remote passive (facial) identification of personnel or personnel threats based on a given database of information of wanted individuals or group of individuals at intended ranges of up to 100 meters. These systems will 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 allows 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. 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.

The overall goal of this contract in Year1 focused on exploratory 3D imaging algorithm research and implementation and the development and demonstration of a 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 focus of Year 2, with additional funding, will involve further hardware development and embedded software programming towards the development of a production-ready device.

Year 3 is expected to move into a low rate of initial production.

The main technical objectives of this contract were:

Task 1: Hardware Development

Task 2: Development & Implementation of Advanced 3D & 2D Imaging Software

Task 3: Technology Integration

Task 4: Hardware Build-Out: Alpha Testing & Field Testing with LASD

3.0 SUB-CONTRACTOR SUPPORT

StereoVision Imaging, Inc. initially identified the following sub-contractors to support our program efforts:

- **Omniperception, Ltd (OmniP)** (http://www.omniperception.com) assists in the development of 2D facial recognition software development. OmniP's products and solutions are based on a powerful in-house intellectual property portfolio and an on-going technology partnership with the world-famous Centre for Vision, Speech and Signal Processing at the University of Surrey, Guildford, England.
- **L1 Identity Solutions, Inc. (L-1)** (http://www.l1id.com). L1 is a biometric system integrator leader. L1 offers a comprehensive set of products and solutions for protecting and securing personal identities and assets around the world. Similar to OmniP, L1 is assisting us in the development of a complete end-to-end system solution for our Mobile ID program.
- **Gaea Corporation**. Dr. Rodney Goodman, on SVI's Advisory Board for several years, is also founder and CTO of the Gaea Corporation

(http://www.gaeacorporation.com/). provides technical due diligence and advanced technology consulting to government, industry, and commerce. Dr. Goodman, a former full Professor of Electrical Engineering at the California Institute of Technology (Caltech) for 16 years, is a Fellow of the IEEE.

- **Applied Color Science (APC)** was SVI's digital imaging partner. APC original intent was to provide a video pipeline for SVI that converted pixels into high quality images. This subcontracted defaulted on its agreed upon statement of work and SVI turned to **Cheshire Engineering** for needed support.

During the course of this program, SVI identified L-1 is our biometric partner over OmniPerception. L-1's 2D face identification engine was deemed more compatible with SVI's than OmniP. Thus teaming with L-1 was the appropriate decision.

4.0 TECHNICAL GOALS AND OBJECTIVES

Shortly after the kick-off meeting, functional and performance goals and objectives were agreed upon between a law enforcement representative and the contractor. The following table outlines a snap shot of the key performance criteria.

The key parameter beyond the identification performance criteria is range. As it turns out, range is primarily a hardware issue though software techniques can assist in hardware limitations. To increase range, hardware becomes heavy and cumbersome as is addressed within this final report. Custom optics and hardware design are required to increase range

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
	3D SURVEILLANCE AND FACIAL IDENTIFICATION SYSTEM SPECIFICATIONS						
VuCAM NIJ -001	Identification	Facial Identification Distance	Operational	The system shall identify an object (face) at this distance under daylight conditions.	100 meters		50 meters
VuCAM NIJ -002	Identification	Identification Response Time	Operational	Time it takes for the end user to request an identification to the time an identification is posted	15 sec	10 sec	5 sec
VuCAM NIJ -003	Identification	False Alarm Accept Rate (FAR)	Environmental	The ratio of the number of false acceptances divided by the number of identification attempts.		0.01	
VuCAM NIJ -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
VuCAM NIJ -005	Identification	False Rejection Rate (FRR)	Environmental		0.13		0.103
VuCAM NIJ -007	Surveillance	Binocular Magnification	Operational	End user to comfortabley view object with magnification	10x	8x	7x
VuCAM NIJ -008	Surveillance	Binocular Objective Diameter	Operational			41mm	
VuCAM NIJ -009	Surveillance	Binocular Exit Pupil	Operational			3mm	
VuCAM NIJ -010	Surveillance	Binocular Field of View	Operational	74m at 1000m		4.3°	
VuCAM NIJ -011	Surveillance	On-Board User Interface	Operational	Membrane Pad user interface shall contain the following controls and indicators for operation.		1) Power On/Off Switch 2) Power On/Off indicator 3) Request for Identification Button	
VuCAM NIJ -012	Surveillance	User Interface	User Interface	The PC based user interface shall contain the following controls and indicators for operation.			
VuCAM NIJ -013	Surveillance	External Communications (Input & Outputs)	Electrical/Software	Wireless - WiFi or Bluetooth		50m Range	10m
VuCAM NIJ -014	PC	Facial Recognition Detection Class Visual Indicator	Software	PC will be tethered to Surveillance Device via Wireless Interface. All detection and classification algorithms will run on the PC. PC will display results.		PC to Identify Object Under Surveillance Upon Demand via User Interface	
VuCAM NIJ -015	PC	On-board Self Test & Diagnostics	Software	The PC workstation software 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.	
VuCAM NIJ -016	PC	Warm up time	Operational	Warm up time. Time to boot-up external computer and run diagnostics.		5 minutes @ 25 C	
VuCAM NIJ -017	PC	On-board Raw Data & Event Logging & Data Storage	Software	PC server will store all revelant parameters and identification results		Retrievable via PC USB port	
VuCAM NIJ -018	Database Enrolment	Database Enrolment Station	Software	Ability to Create & Manage a 2D Facial Databse		ISO 19794-5 Compliant	
VuCAM NIJ -019	Database Enrolment	Size of Library	Software	Number of Faces in the Database	1000	50	10
VuCAM NIJ -021	Surveillance	Operating Temperature Range	Operational		40 C		0 C
VuCAM NIJ -022	Surveillance	Fastening	Mechanical	Hand Held Device. The device shall be tripod mountable			
VuCAM NIJ-023	Surveillance/PC	Battery Life	Electrical/Software	There will be separate battery power supplies for the stand alone PC and the sureveillance device	4 Hours	2 Hours	1 Hour
VuCAM NIJ -024	Surveillance/PC	Weight	Mechanical	Weight of the entire system	10 lbs	5 lbs	2 lbs
VuCAM NIJ -025							
VuCAM NIJ -026	PC	Software and Database File Updates	Software	The unit server software and associated data files shall be upload/download capable in the field via a commercial standard communication port and protocol.		USB 2.0	

TABLE 1: Performance Specifications

.5.0 TECHNICAL DESCRIPTION

SVI has introduced a novel approach to facial recognition. Although traditional 3D imaging techniques utilized for facial identification emit structured (IR) light to obtain a 3D model of the face; SVI utilizes 3D segmentation techniques to extract an unknown face from three dimensional space. Once the face is properly segmented, 2D algorithms are then used for identification and results are posted against a known 2D facial database, see Figure One. This enabling technology promises to reduce false alarm rates and increase overall identification success rate as seen over prior techniques by reducing the detection search space for the face thus increasing probability for detection

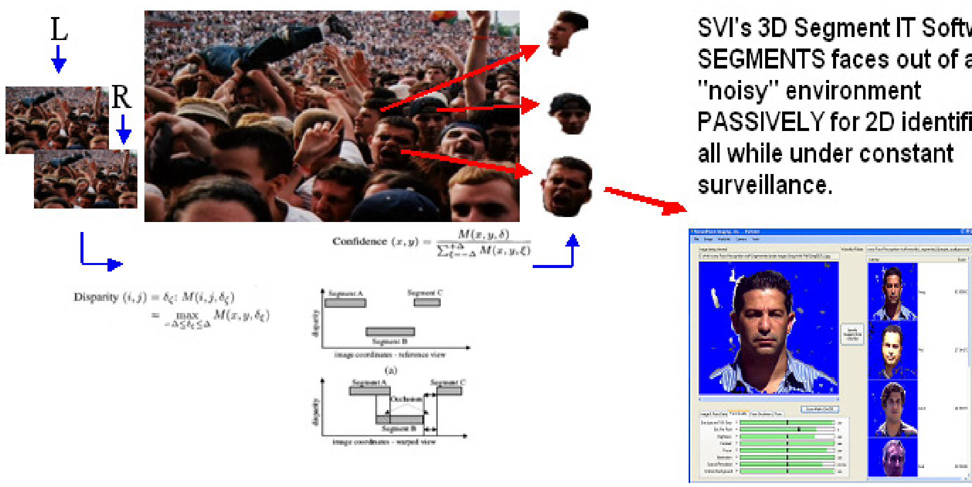


FIG. 1: 3D Segmentation and 2D Identification

In addition this technique allows for increased range detection and is realized in a hand-held format intended for stand-off detection.

<u>Product Technology Proposed Use Model</u>

It has been proposed to integrate SVI's proprietary technology into binocular optics. Binoculars are stereoscopic by definition and the integration of a stereoscopic imaging system is readily possible. This "product technology" would allow the end user to have a "person of interest" under surveillance at will and facial identification upon demand. Thus integrating surveillance operations with biometrics.

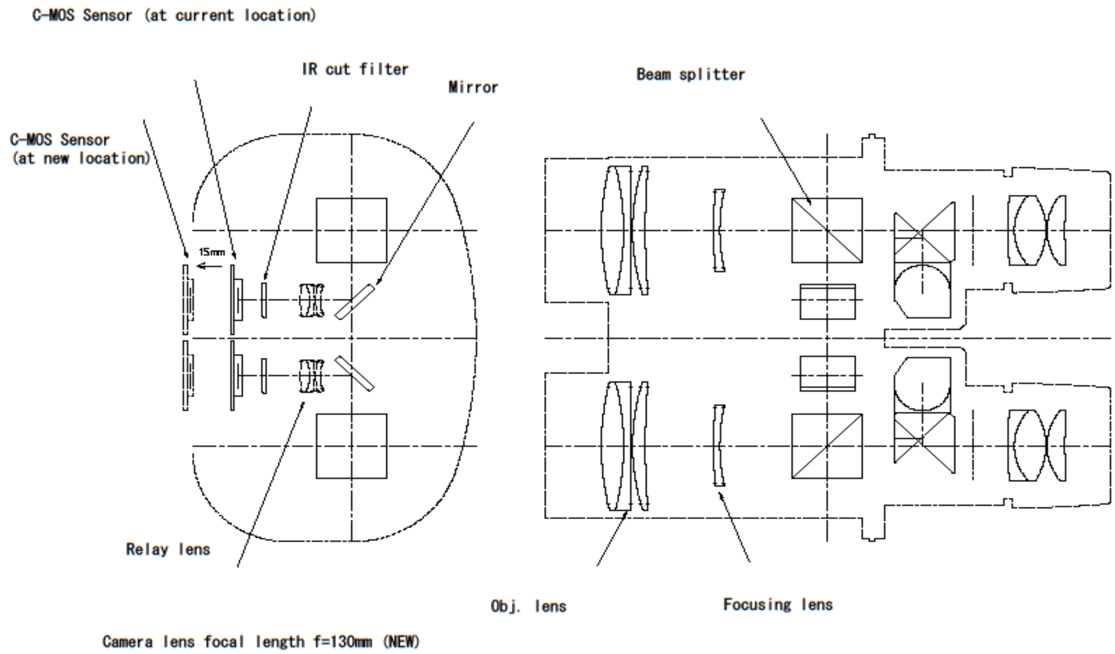


FIG. 2: Product technology proposed use model. Binocular-based Device Optics. Integration of a stereoscopic imaging system into binoculars with moderate magnification. This would allow surveillance tactics at will and facial identification upon demand.

Further, through this level of system integration, it is envisioned that the end user can assist in the identification process by positioning him or herself for the best pose and illumination situation possible due to portable nature of the device.

Quality metric information is sent back to the device operator from the PC Server, i.e. good or bad. If bad, the end user repeats the operation.

In fact, it is envisioned that image quality factors could be overlaid within the field of view of the binocular optics to automatically indicate the best possible image is being captured for further processing.

FIG.3: Example of product technology use model.

Real Time Hand Held Portable Surveillance Use Model:

Utilize End Users (Human Brian) To Dynamically Position "Target" For Proper Pose and Illumination

Utilizing real time image quality metrics with information overlaid within field of view of binocular optics

Segmentation Further Assists in Pose & Illumination Issues AND thus Identification

Face Recognition Multi-Step Process

Facial recognition is a multi-step process. Each step of this multi-step process is, of course critical, and can be quite complicated. Poor image quality, pose and illumination are the dominate issues that can cause poor results. Illumination issues are a direct function of environmental conditions. SVI & our strategic partners have spent considerable amount of time developing algorithms that not only deal with ever-changing environmental conditions but also with the expectation that the "probe" or unknown image will be of poor quality.

FIG.4: SVI & SVI's subcontractors facial recognition technology is a multi-step process beginning with stereo capture, segmentation, face localization, biometric feature extraction and then identification against a 2D facial database

The following steps outline SVI's multi-step approach to facial recognition are discussed in more detail below:

Long Range Stereo Image Capture
Calibration
Calculating and Generating Disparity Maps
Auto-Segmentation
Face Detection
Face Localization
Face Normalization
Facial Feature Extraction
2D-3D Conversion
Multi-Dimensional Recognition Algorithm

Long Range Stereo Image Capture

Biometric data is initially captured in stereo. The "rule-of-thumb" for adequate facial recognition regarding image quality is the need for a minimum of fifty (50) pixels of information between the eyes. Image quality is extremely important for proper facial identification. In fact, if ISO19794-5 image quality factors are not compliant, such as focus and illumination, are not met there is no identification. The end user must capture another image or preferably a sequence of images.

FIG.5: Example of image quality factors that are reported-these are 2D images, i.e., images have not been segmented. Note the image on the right has a poor focus. The black bars are suggested ISO 19794-5 thresholds. We have a lumped parameter referred to as a reliability score. If the reliability score is not greater than a pre-determined threshold the identification process stops. End user must try to capture a higher quality image.

As far as some design rules to determine the best optical system for image capture, first order geometric optics can be utilized to determine the desired f# of the optical system as well as the physical size and resolution of the imaging chip required to reach this design constraint.

A spread sheet analysis program was developed to assists in the process of identifying commercial-off-shelf components for stereo capture. The following table is an example:

PARAMETERS	SLR	Point and Shoot	SLR	SLR
	Scenario A	Scenario B	Scenario C	Scenario D
	Olympus E420 or E-3	Canon Powershot G9	Nikon D300	Canon 40D
Object Distance [m]:	100	100	100	100
Focal Length [mm]:	400	160	450	470
Objective Lens [mm]:	29	29	29	29
Imager Size [mm]:	18	7.6	23.6	22.2
# of Pixels:	3648	4011	4288	3888
Calculate Pixel Size [um]:	4.93	1.89	5.50	5.71
Eye Spacing [inches]:	2.5	2.5	2.5	2.5
Baseline Spacing [cm]	25	25	25	25
SUMMARY RESULTS				
F#:	13.79	5.52	15.52	16.21
Imaged Object Size [m]:	4.50	4.75	5.24	4.72
Diff. Limited Spot Size [um]:	9.93	3.97	11.17	11.67
Optical Limiting Frequency [cycles/mm]	100.72	251.81	89.53	85.72
Imaging Limiting Frequency[cycles/mm]:	202.67	527.76	181.69	175.14
Ratio Imaging Resolution / Optical Resolution	2.01	2.10	2.03	2.04
Imager FOV[degrees]:	2.58	2.72	3.00	2.71
Pixel Count / Linear Meter:	811	844	818	823
Pixel Count / Linear Foot:	247	257	249	251
Pixel Count / Eye Spacing:	51	54	52	52
GOALS				
Facial Recognition				
# Unique Optical Features / Eye Spacing:	26	26	26	26
System Paramaters Satisfy Nyquist Criteria?	YES	YES	YES	YES
Pixel Count / Eye Spacing > 50 ?	YES	YES	YES	YES
	~~	~~~~~~~~~	~~~~~~~~~	~~~~~~~~~
Meets System Parameters?	TRUE	TRUE	TRUE	TRUE
3D Segmentation				
Disparity Resolution [m]:	0.49	0.47	0.49	0.49

TABLE 2: System Parameters can be manually entered such as distance, focal length, size of imaging chip, resolution, etc. and the number of pixels between the eyes and disparity resolution are calculated amongst other factors as shown in the summary results of the table.

The table clearly shows, as expected, the trade-offs between the physical size of the imaging chip and focal length of the system. That is, in general, as the imaging chip increases in size, the focal length must be longer to achieve the accuracy needed for facial recognition. Of course smaller imaging devices have trade-off's regarding signal-to-noise (SNR) and the required use of high definition optics so typically larger objective lens would be required and proper F# to assure optical resolution matches pixel spacing.

In addition Table Two calculates the theoretical disparity resolution of the system given the input parameters for a monochrome sensor. For a RGB sensor array this factor is nearly 3x the calculated value. The disparity resolution is the minimum distance objects (faces) can be segmented and is a function of the distance from operator to target, baseline separation, focal length, and pixel spacing. The following chart illustrates these trade-off scenarios.

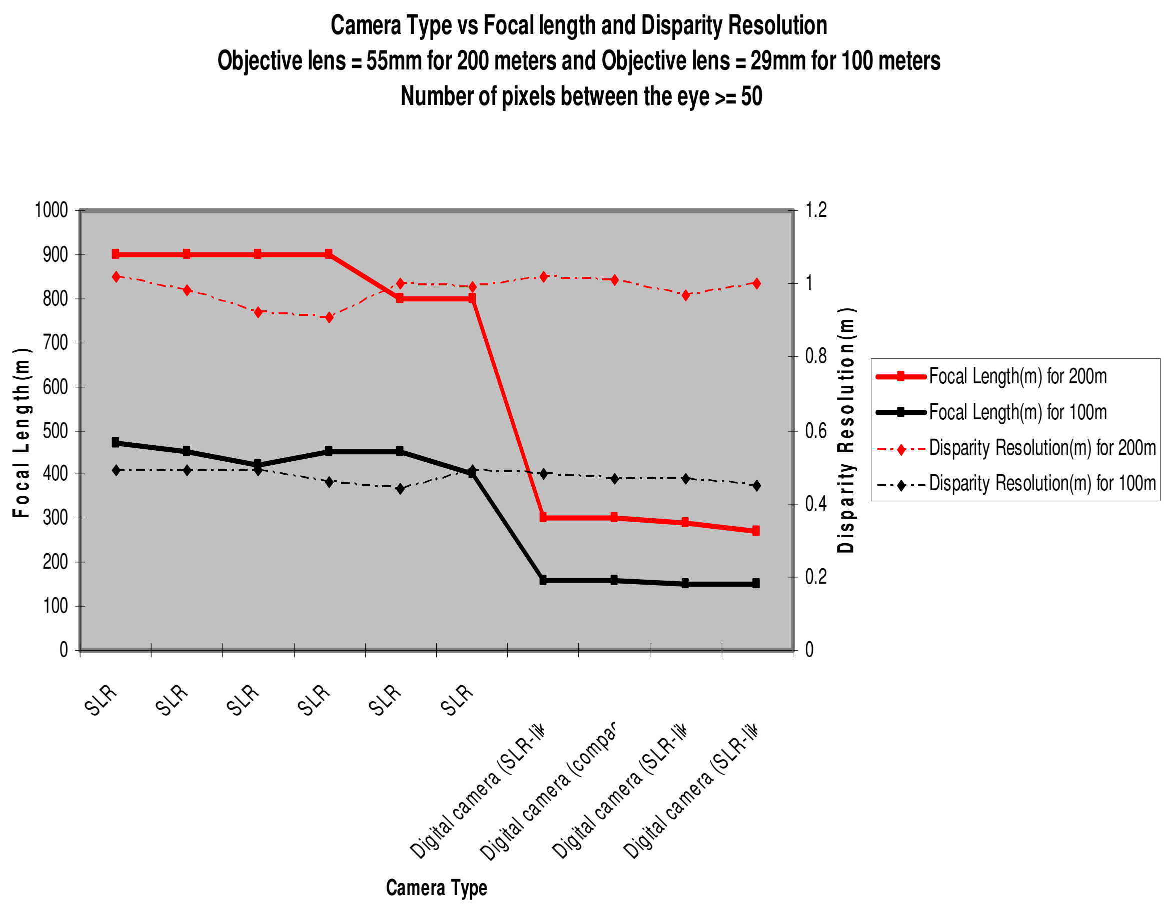


FIG. 6: Trade-off chart between required focal length and imaging chip/resolution. Typically SLR digital cameras have a very large imaging chip than the point and shoot cameras. Focal lengths greater than 300mm become unpractical to be realized as a hand held device.

Another "rule-of-thumb" regarding the ability to integrate a stereoscopic imaging system into binocular optics is to maintain a focal length of less than 300mm. Greater lengths become unpractical to realize as a hand-held device.

Calibration

Calibration is an important step when working with stereo images concerning stereo matching. When two different imaging chips capture images of the same object from different positions, many factors can affect the stereo correspondence between the two images. If the cameras are not properly calibrated then stereo correspondence cannot be found.

Even if the imaging chips are very tightly registered mechanically there is still a little rotational, vertical difference between the images captured. Even if the shift in position by a micron the results can be disastrous. To account for this the most common approach used until now had been to capture an image of a chart with known scale. Once that is done, an exhaustive approach is utilized where each point in one image is matched with the corresponding point in the second image, manually. Using these set of points a transformation matrix is calculated which is then used each time the images are captured using the device.

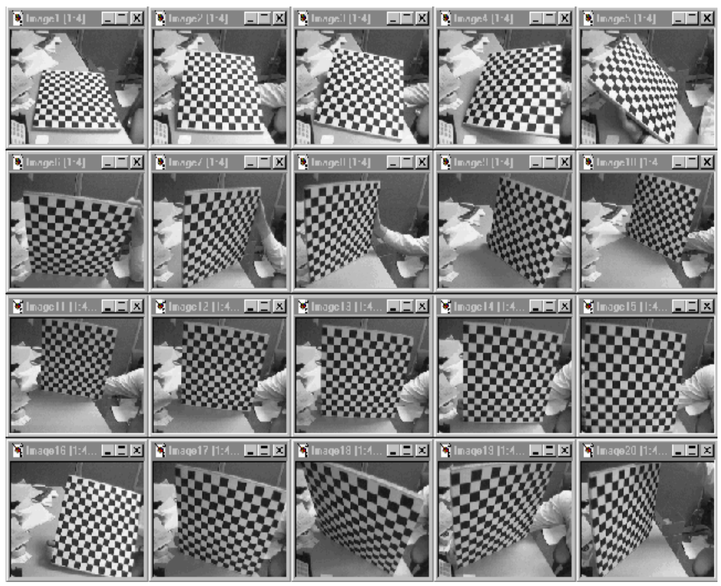


FIG 7. : Step 1- Example Capturing a checkerboard for calibration

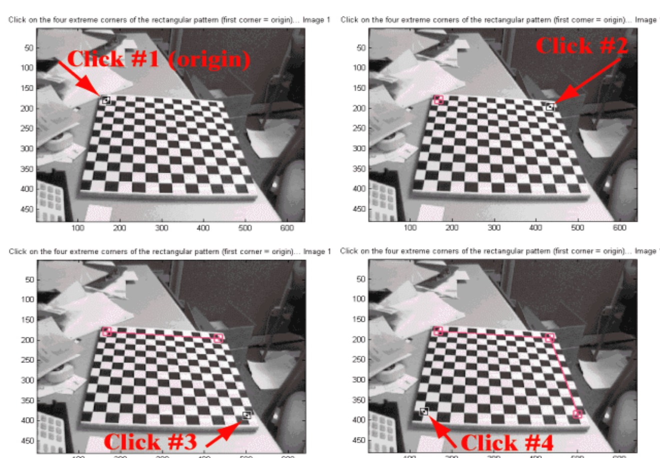


FIG.8 : Step 2 - Manually marking up corners, needed to calculate transformation matrix

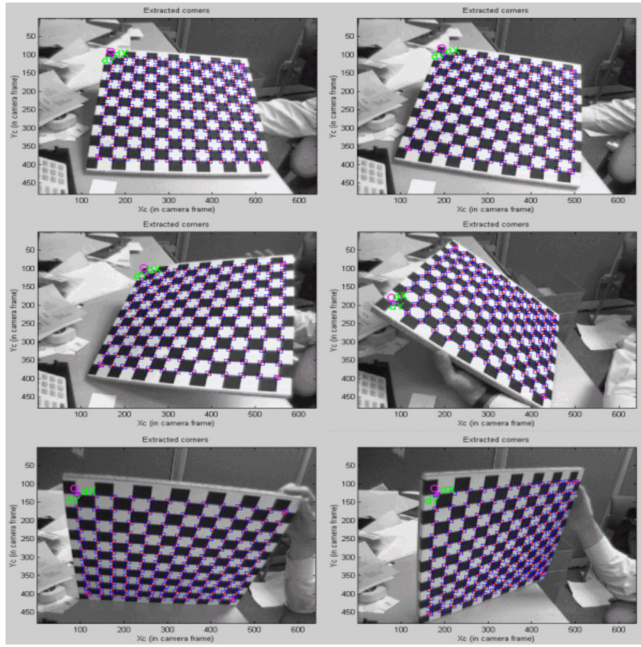


FIG.9: Step 3 - Extracted points after calibration and creating a transformation matrix

The disadvantages of using this technique are:

- The match points have to be manually marked up in both images before calculating the transformation matrix
- This transformation matrix is specific to specific device. For every different unit a different transformation matrix is calculated.
- If the unit is not mechanically stable and if the cameras are moved even a little, then whole process has to be repeated.
- To apply this approach, system parameters need to be known apriori.

Harris Corner Detection Algorithm

SVI has found a way to go around this exhausting labor intensive approach by adopting the Harris Corner Detection algorithm and performing a calibration (also called auto-alignment in software terms) automatically in our software. This approach has the following advantages:

- The whole process is automatic. No human intervention is required.
- Even if there are vibrational induced shifts or a little movement, the algorithm is able to find the right match and correct the images of any discrepancies.
- The approach is independent of system parameters. All that is needed are two stereo images for this approach to work.
- The same algorithm calibrates the images for any unit.

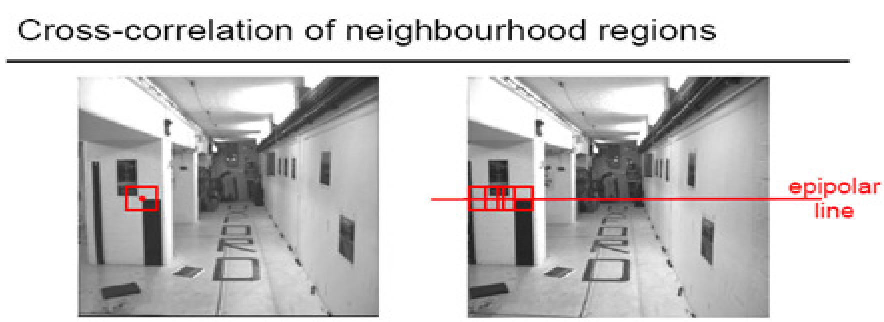
The corner detection algorithm is an algorithm in computer vision to detect and describe local features in images. The features extracted from one of the two stereo pairs are matched against each other to find *k* nearest-neighbors for each feature. A transformation matrix is automatically generated and applied to the second image for near perfect alignment.

Calculating and Generating Disparity Maps

Once the data is captured and calibrated, distance measurement information can now be calculated. There are several methods to determining distance either in a passive or active mode. Actively, one could utilize either interferometry or time-of-flight techniques.

SVI has implemented the passive triangulation method in which the geometric relations between the object, the sensor and a known baseline are used for the calculation of distance. The baseline in this case is the separation of the two refracting telescopic (binoculars). Once the images are calibrated to eliminate registration and other systematic errors, epipolar lines are generated (epipolar lines are parallel straight lines in both left and right images) and the stereo correspondence problem is solved by implementing a *dense* pixel-based search algorithm.

The outcome is the ability to identify a horizontal *disparity* for each pixel and then to produce a *disparity map*. The disparity algorithm SVI utilizes consists of a 5x5 masks along the epipolar lines of each imaging array. By computing a *normalized cross-correlation* of neighborhood *intensity* and utilizing *Sum of Absolute RGB Differences (SAD)* as the metric in determining the disparity at a given point the corresponding pixel is found. That is, the corresponding regions in the left (L) and right (R) image that has the minimum SAD gives us the disparity at that point.



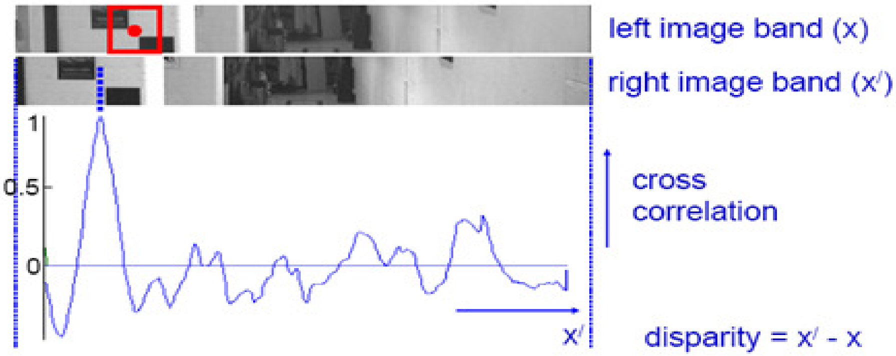


FIG.10: Stereo correspondence example. Once the epipolar lines are created a 5x5 pixel mask runs along the line on the corresponding channel. The search algorithm calculates the sum of the differences as a metric to find the corresponding pixel.

The following rules apply:

- In regions with repetitive or no texture (e.g., white T-shirt), no reliable disparity estimate can be made. It is better to produce a sparse disparity map than a wrong one.
- Instead of just seeking the minimum SAD, we kept track of the three smallest values.
- The minimum SAD value is found and compared with the adjacent SAD values on both sides to see if they are greater, and hence the minimum is unique.
- The third smallest value is checked, because there are pixels whose SAD is nearly equal for two neighboring disparities. These "double minima" are perfectly valid and occur frequently between regions that differ in their integer disparity by one.

To eliminate false matches due to occlusions, a valid correspondence must match in both directions To eliminate the occluded points we implemented a *Right-Left Consistency Check*. That is, the right-left disparity for the corresponding pixel in the right image must point back to the pixel in the left image. i.e.

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

The disadvantage is higher computational cost, in our implementation it takes approximately 20%-25% of the total computing time; however, a much higher quality, but sparser, disparity map is obtained:

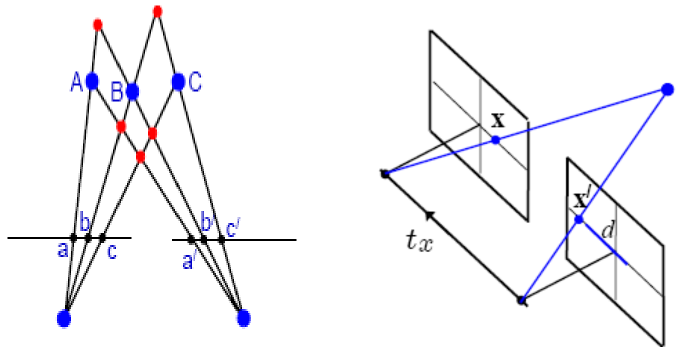


FIG.11: Triangulation. Once the corresponding pixel is found, data can be triangulated to determine distance passively on a pixel-to-pixel basis.

Once the disparity map is complete a range map can be generated.

Compute *Range Map* from disparity map: ***R* = *f* . *B* / *d*** where
R = range,
f = effective focal length,
B = camera baseline,
d = disparity.
Range resolution error proportional to R^2 : $\boldsymbol{dR = R^2\, \delta d / f \,.\, B}$

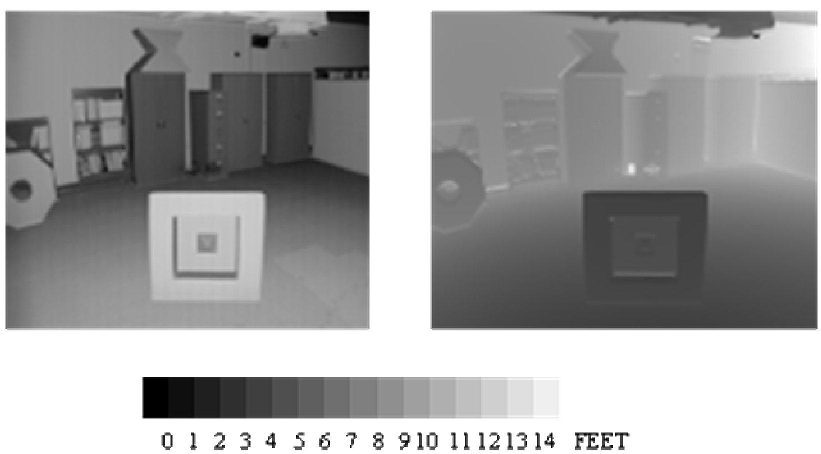


FIG 12 : Example of a grey-scale range map. Darker grey is closer to the light grey objects.

Median filtering is a well-known technique for removing noise from images and the elimination of outliers. In weakly textured regions the signal to noise ratio is low and often some pixels are rejected although the disparity can correctly be estimated in the neighborhood. Present technique: The value of an output pixel is determined by the median of the neighborhood pixels. A 15 by15 mask is used in our code.

3D Segmentation

Using the left and right images, as mentioned above the correlation between the images is computed and a depth map is generated. Using the depth map, a histogram can be produced which represents the number of pixels there are in an image with the same disparity (analogous to distance). This information can be plotted as a histogram as shown below, in Figure Thirteen.

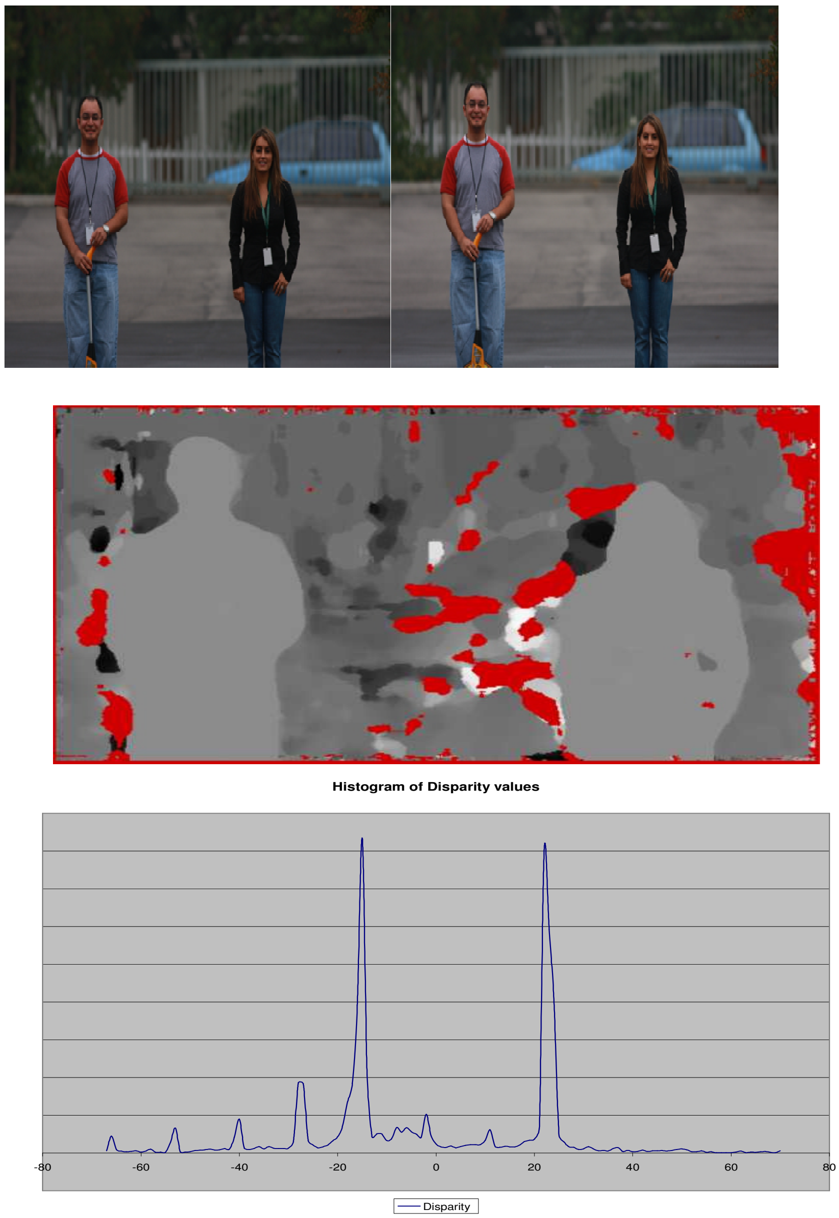


FIG 13: Step One – stereo image capture. Step Two – calculation and generation of a range map (red indicates areas where the disparity could not be found). Step Three – production of the disparity map. One peak represents the background and the other peak represents the foreground containing the people

In this histogram above, since each disparity corresponds to a different distance, we can easy infer foreground from background. Using this information the foreground and background is automatically separated for further 2D processing which in effect limits the search space for identification, thereby reducing false negatives.

FIG. 14: Example of auto-segmentation. 3D segmentation limits the search space and reduces the possibility of false negatives

Automatic Face Detection

Finding a face in an image is a computationally demanding task and has been drastically reduced by our automatic 3D scene segmentation approach. It is obviously critical to the automation of face recognition systems. Typical face detector algorithms utilize a machine-learning technique employing Support Vector Machines (SVMs) for face detection in digital images. Using this advanced pattern recognition technique, faces can be efficiently and accurately detected independent of position and size. The underlying SVM models are obtained through a training procedure applied to a large number of image samples of face and non-face patterns. The extensive sample set covers different age, gender and race groups. . The algorithm is based on a frontal pose +/-10 degrees.

Automatic Eye Localization

Following on from the automatic face detection stage is the stringent requirement of automatic eye localization. Typical approaches comply with the ISO standard and uses the centers of the eye sockets as the reference points for the subsequent stages of the face recognition process, for example consistent image cropping to create ISO Token images. The localization engine uses several different algorithms for eye localization. One of these is a multi-stage SVM with weighted-sum fusion. Similarly to the face detection process, underlying SVM models are obtained through a training procedure applied to a large number of eye and non-eye image samples.

In the localization stage, the model is used to synthesize face samples to be compared with the local image evidence. The model parameters are optimized to iteratively improve the fit between the synthesized sample and the local image pattern.

FIG. 15: Example of automatic eye localization of auto-segmented objects. These segmented objects are then "fed" one at a time into the 2D engine and compared against a 2D database of faces for identification.

Manual Localization Tool

Under ISO-compliant conditions, automatic face detection and eye localization algorithms operate reliably. However, in less-constrained conditions where the image quality may be poor or the subject is not looking directly at the camera, then a manual check and adjustment may aid in the localization process. This ensures that the centers of the eye sockets are accurately localized and enables the subsequent face recognition processes to continue reliably. This option has not been included into our final deliverable.

Geometric Normalization

The geometric normalization stage enables automatic pose correction given the eye coordinates output by the eye localization process. The normalization process transforms the face region into a defined co-ordinate system where position, size and orientation is fixed.

Photometric Normalization

The photometric normalization stage enables automatic correction for lighting variations and is based on a dynamic range compression method. The images for a given face are adjusted to maintain an approximately constant intensity distribution independent of the environmental conditions.

StereoVision Imaging, Inc.
Award # 2009-IJ-CX-K001

Template Generation

Face recognition technology is based on a statistical pattern recognition framework. Within this framework, we can employ different transformation techniques for mapping of raw features to representations optimised for discrimination. Examples of such techniques are Linear Discriminate Analysis (LDA) and Client-Specific Linear Discriminant Analysis (CSLDA, an OmniPerception proprietary technology). In the recognition, facial features are extracted and weighted depending on their expected contribution to the face recognition process. Features that make a specific face unique are accentuated whereas other features are suppressed. The method aims to achieve as high separation as possible between clients represented by feature vectors in a high-dimensional space, sometimes referred to as "face space".

Following the geometric and photometric normalization stages, the resulting multi-dimensional image is input to the template generation (or enrolment) process. The aim of this process is to extract the final feature set representing the face, and to compute the weighting of these features.

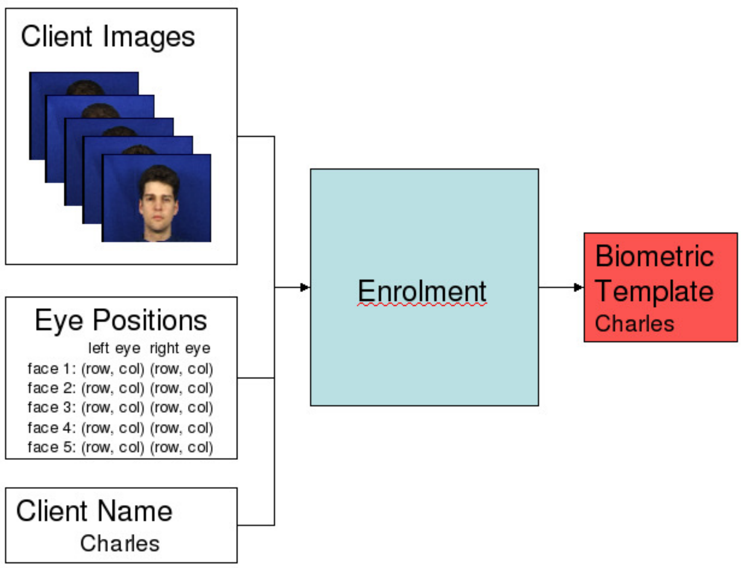


FIG. 16: 2D facial database enrollment process

In addition, during the identification process a 2D-3D multiview enrollment is performed. The 2D-3D technology finds landmark points on the input (2D) facial image, creates a 3D facial model, and renders 2D facial images as views of the 3D facial model at different pose angles. Multi-view enrollment uses these synthetic views to enhance the enrollment database of the watchlist. Thus creating a more pose invariant system and assists in addressing other stand-off identification issues such as illumination and expression.

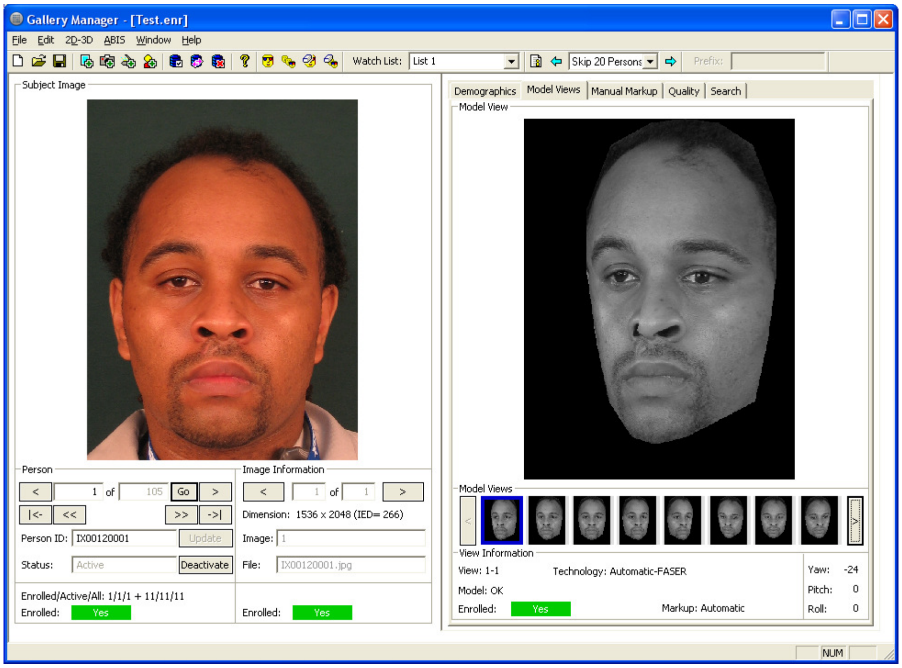


FIG 17: Example of the 2D-3D Enrollment Process. Image on the left is a typical 2D image being enrolled into the system. Image on right is the 2D-3D conversion. The multiview enroller automatically generates 11 views from the single 2D image and enrols all these synthetic images into the watchlist.

Identification / Watchlist Search

In the identification process, a template is generated from an incoming probe images and compared with the templates stored in the "watchlist". The watchlist is sorted based on similarity with the probe image as shown in Figure Eighteen. If the system is setup to operate in a semi-automatic mode then the images corresponding to the most similar model templates are retrieved and displayed on a screen. The identity of the probe image is then determined by an operator by manually comparing the shortlist images (Rank1-Rank10) with the probe image. If the system is setup to operate in a fully automatic way, the identity of the probe image is the identity corresponding to the most similar model template, assuming that the similarity score is above a given threshold.

Note that the technology can also be used in verification mode. In contrast to the identification mode, the verification process requires a claimed identity and the task of the recognition system is to verify that claim. In this alternative mode, the template generated from the probe image is only compared to the watchlist templates of the claimed identity. The verification is considered successful if the resulting similarity score is above a given threshold.

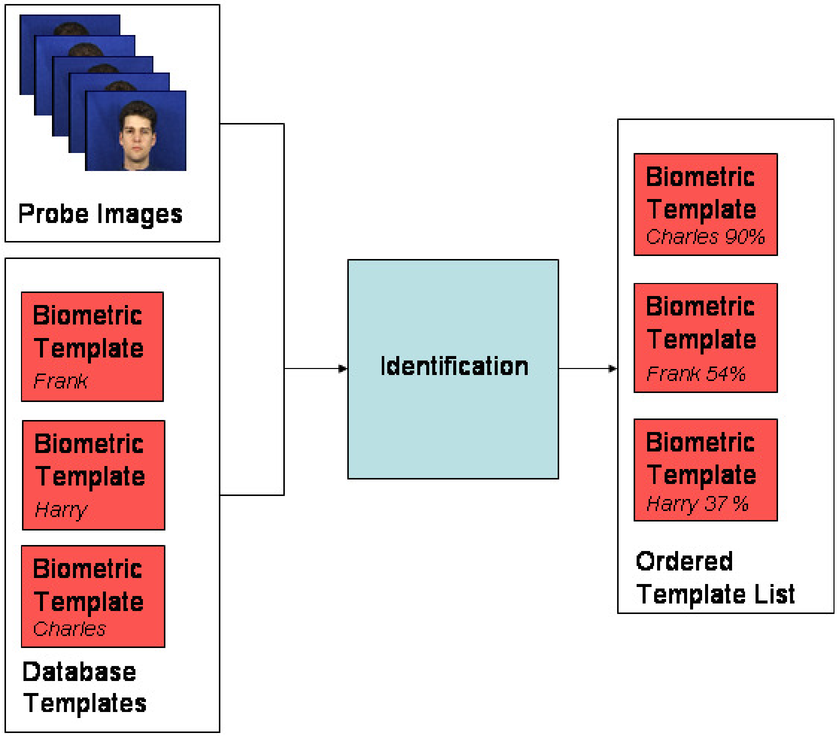


FIG. 18: Identification Process

6.0 HARDWARE BUILD-OUT

Due to the limited Phase I funding available, SVI modified its commercial 3D Digital Binocular product (the 3DVuCAM™) and associated stereoscopic electronic imaging platform to provide the proof-of-concept integration of surveillance operations and stand-off face detection in lieu of a complete re-design which would be required for a Phase II production-ready device.

NIJ				
Optical System Analysis				
	VuCAM		**NEW DESIGN**	
PARAMETERS				
	Scenario A	**Notes**	**Scenario B**	**Notes**
Object Distance [m]:	100		100	
Focal Length [mm]:	72		130	**Need to increase Focal Length to 130mmm**
Aperature[mm]:	15		23	
Horizontal Imager Size [mm]:	6.55		6.16	
# of Pixels (Horizontal) :	2048	3.2MPixel Array from Micron (MT9T001)	3678	10 MPixel Array from Micron (MT9J001) at 15fps
Calculate Pixel Size [um]:	**3.20**		**1.67**	
Eye Spacing [inches]:	2.5		2.5	
Baseline Spacing [cm]:	5		5	
SUMMARY RESULTS				
F#:	4.80		5.65	
Imaged Object Size [m]:	9.10		4.74	
Diff. Limited Spot Size [um]:	3.46		**4.07**	
Optical Limiting Frequency [cycles/mm]	289.43		245.79	
Imaging Limiting Frequency[cycles/mm]:	312.67		597.08	
Ratio Imaging Resolution / Optical Resolution	**1.08**		**2.43**	
Imager FOV[degrees]:	5.21		2.71	
Pixel Count / Linear Meter:	225		776	
Pixel Count / Linear Foot:	69		237	
Pixel Count / Eye Spacing:	**14**		**49**	
Hyperfocal Distance[mm]	**168842.748**		**892631.494**	
Approx. Near DOF [m]	**63**		**90**	
Approx. Far DOF[m]	**245**		**113**	
GOALS				
Facial Recognition				
Diffraction Limited?	YES		YES	
# Unique Optical Features / Eye Spacing:	13		20	
System Paramaters Satisfy Nyquist Criteria?	NO		YES	
Pixel Count / Eye Spacing > 50 ?	NO		NO	
	~~		~~~~~~~~~~	
Meets System Parameters?	FALSE		FALSE	
3D Segmentation				
Disparity Resolution [m]:	**8.88**		**2.58**	
Disparity Resolution [ft]:	**29.14**		**8.45**	

TABLE 3: Existing hand-held stereoscopic imaging system vs. modified NIJ system to allow for face capture up to 100 meters from point of use.

The main challenge was the retrofit of a longer focal length (120mm vs. 72mm) and a smaller, higher resolution imaging chip (1/2.3-inch optical format, 10MP CMOS photoarray vs.1/2-inch 3MP photoarray). The custom "relay" optics was fitted without major changes to the overall physical size.

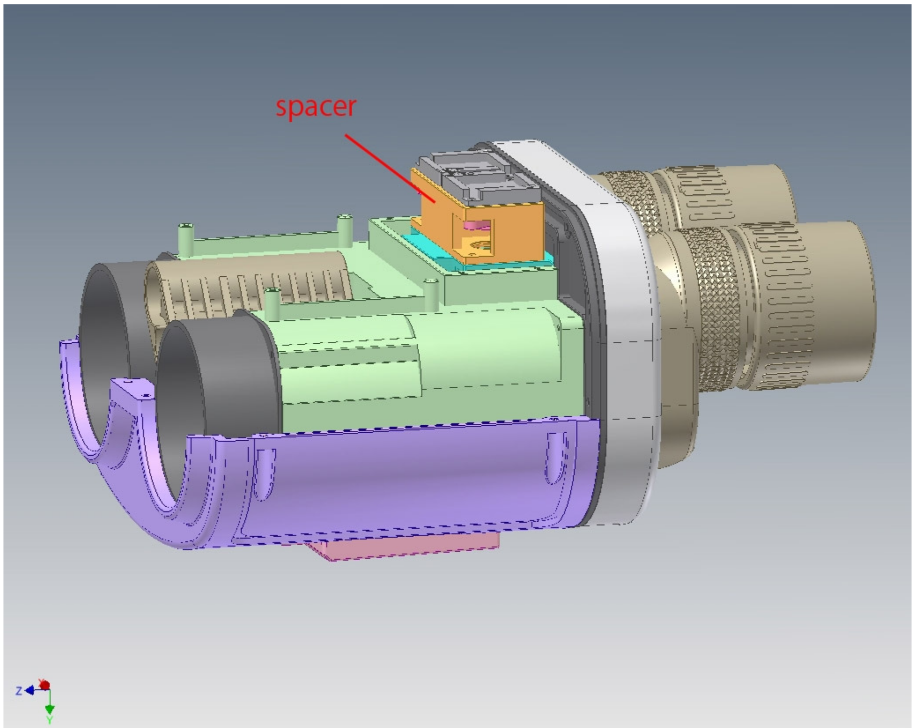


FIG. 19: Bottom side top view of modified binoculars. Additional 0.5" Spacer (in orange) along with custom "relay" optics was required to increase camera system focal length to 130mm

Also trade-offs between ideal optical performance had to be decided regarding focus, optical spot size and depth of field.

Auto-focusing was beyond the scope of this first Phase, so the relay optics was designed to give the best performance over the 50-100 meter range.

To achieve the best sharpness the device, the device has pre-defined settings the end user can manually select to move the relay optics focal point.

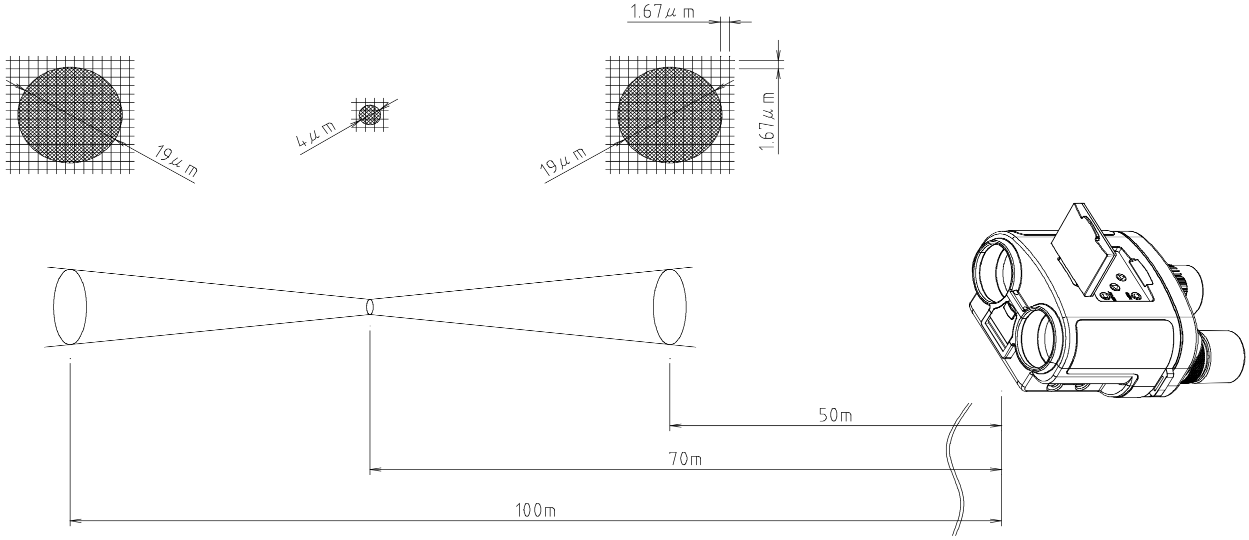


FIG: 20 : Depth of Field of new optical system. Spot size increases when subject is at different distances. Pixel spacing is 1.67um so system is non-ideal.

The device allows for 8x magnification viewing which is adequate to have a group of individuals under surveillance at 100 meters. To perform an identification, end user positions the device so that the unknown individual is positioned within retical markings (the retical is 10% of the total binocular FOV) and presses the 'Shutter' button. A short 3D video clip is obtained and sent to our PC Server running all the application software (video pipeline, face capture, face find, feature extraction). The connection is a direct wired USB interface. Wireless connection is possible but we were not able to accomplish this task with Phase I funding.

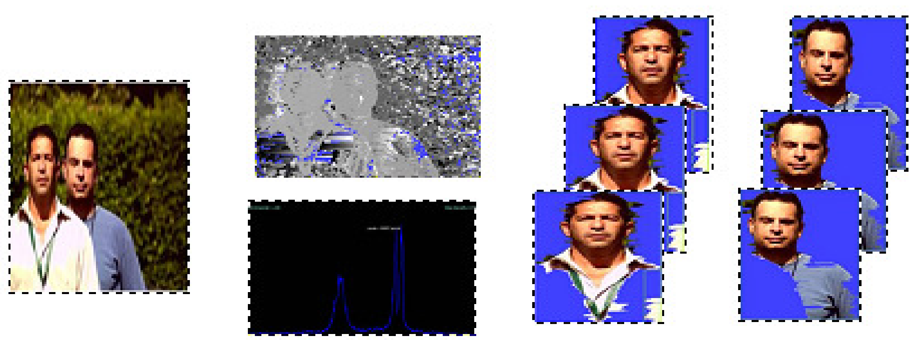
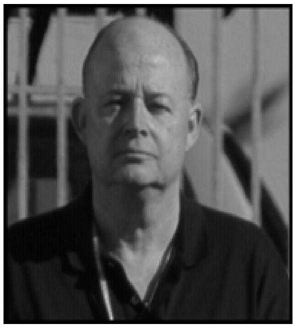


FIG. 21: Example of individuals captured, via 3D video clip, through the binoculars optics at distance. Faces are automatically segmented and tagged. Each frame of the video sequence is checked for quality. If quality is good enough, the respective frame passes onto identification. Only the "best" match is presented to the end user.

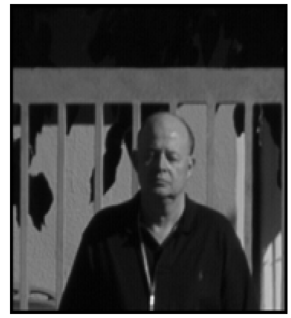
A quality assessment signal is immediately returned to the operator. If the image quality of the video clip was not acceptable, the end user repeats the operation. If successful, the PC posts & logs the results in the server database as an event log

Below is a typical image captured through our optics as a function of distance as well as the typical pixel count between the eyes.



50m

75m



100m

DISTANCE [m]	DOF [m]	PIXEL COUNT BETWEEN THE EYES
50	47 - 53	99
100	89 - 115	49

FIG.22: Typical image quality captured via our high-definition binocular optics

Disparity Resolution

The disparity resolution is defined as the minimum distance our 3D system can separate "objects" out of three dimensional space. The theoretical disparity resolution is a primarily function of the baseline separation between the binoculars left / right refracting telescopes, distance from object, and pixel spacing.

Figure 23 is a chart of an actual measured disparity resolution at 75 meters versus the theoretical calculated values.

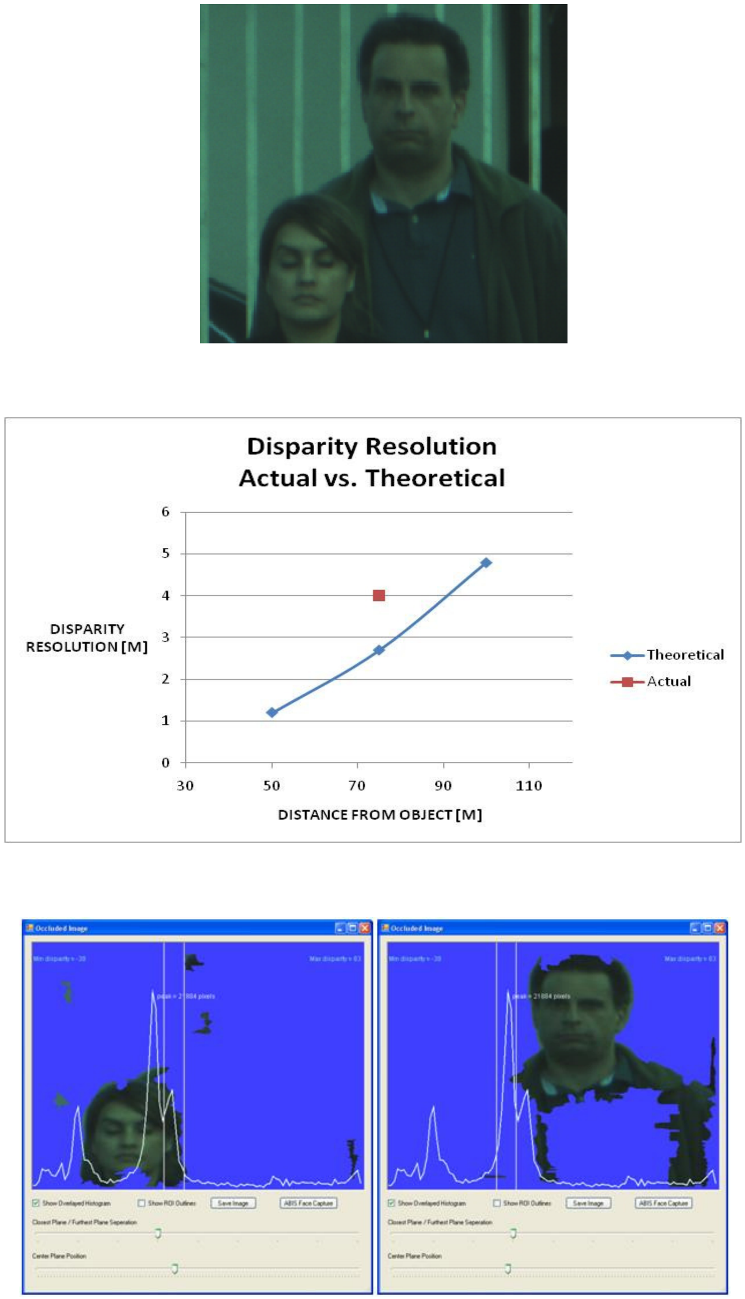


FIG. 23: At top, actual image captured at 75m with two individuals spaced 4m apart. Theoretically, we should be able to separate objects at ~3m as shown in disparity chart. Bottom Row: Actual separation at 4 meters.

Electronically, under contract, SVI utilized its legacy electronic stereoscopic imaging platform (main board) and redesigned our daughter boards to support the identified 10MP CMOS photo arrays needed for proper face detection at up to 100m from point of use and developed customized firmware to support the new imaging chips as well as to add 3D video capture capabilities, please see Figure 24.

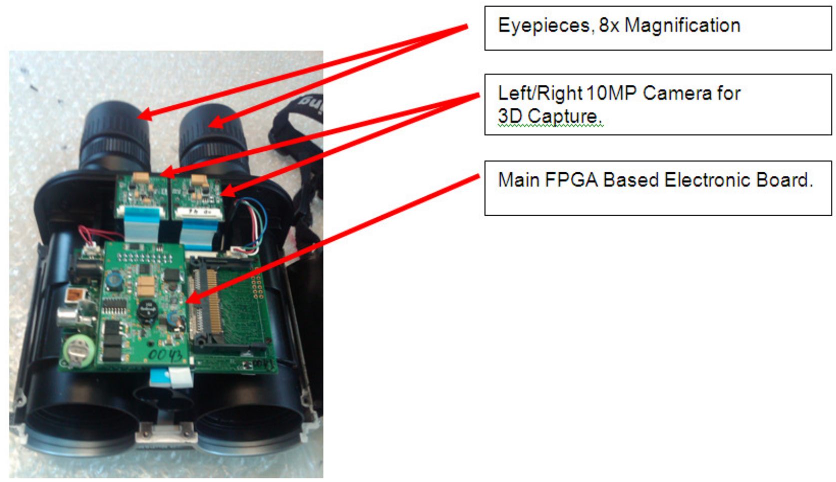


FIG. 24: Internal image of electronics develop under contract (unpackaged).

7.0 SYSTEM INTEGRATION & ARCHITECTURE

SVI and its subcontractors have developed a network-centric workstation / server application.

The workstation or mobile workstation is defined as the 3D FRT Binoculars and associated client based software which performs the 3D face capture and subsequent quality metric assessment.

Currently the server performs the identification and database management functions (enrollment, event logging, etc.) including managing alarm alerts & email notifications. The client & server software can reside on a single PC and can be readily customized via an XML interface.

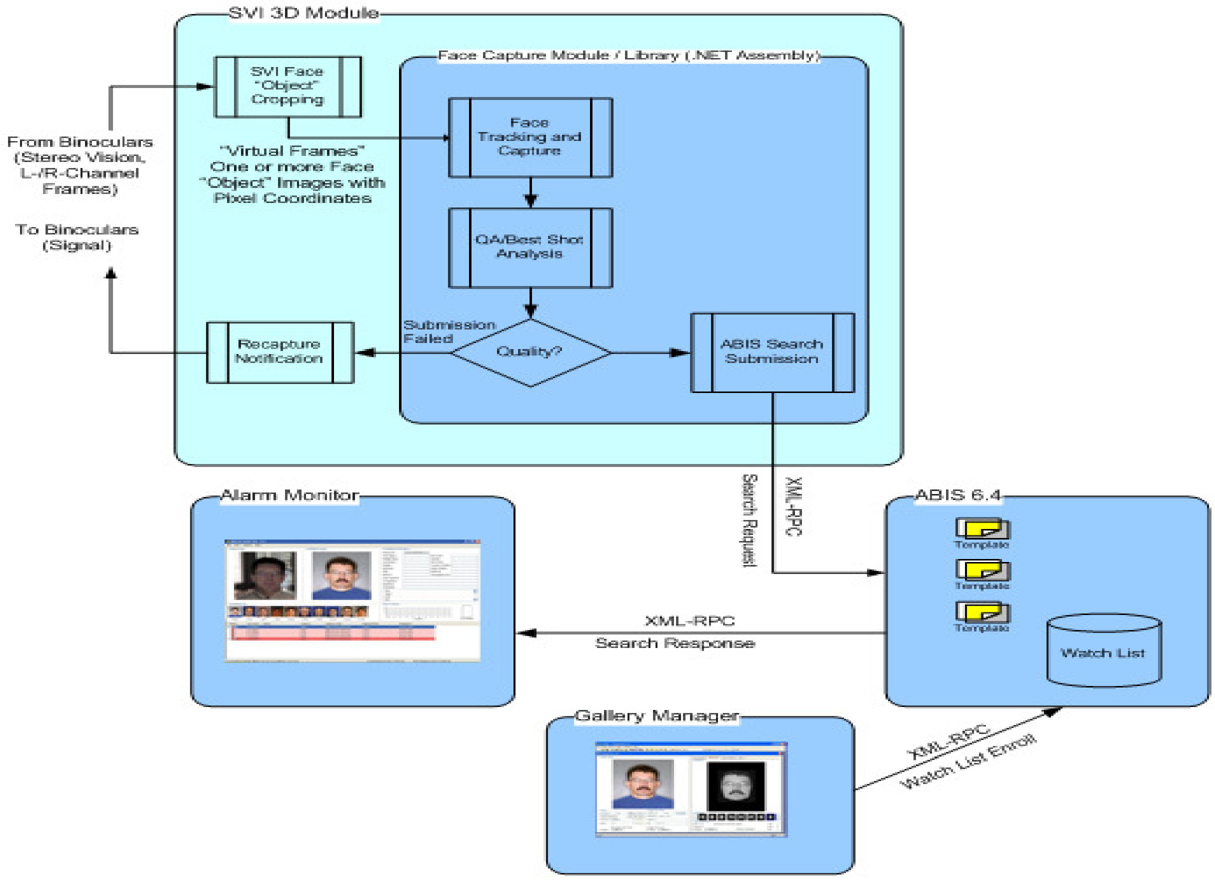


FIG. 25: Network-Center System Architecture

Once the images are automatically segmented, the segmented object is automatically identified one object at a time. The slide bar under the segmented scene can be selected and dragged to move to the other object for auto-identification.

SVI collectively decided to utilize all information collected to obtain the best overall performance on any given test run. That is, 2D information captured from the binocular left channel and right channel is "submitted" into the L-1 identification engine for ID as well as our 3D segmented images, "winner" takes all. This is invisible to the end user. The end user only receives the final result.

Identification results are presented in terms of Rank1 through Rank 10 with an associated score. The score is –log (FAR) where FAR is the False Accept Rate. As an example, if one were to take a probe and a candidate the score will give a probability of these images belonging to different identities. For instance, if the score is 5, the probability will be 1 in 10^5. This score has been extended to be used in identification (1:N) with some sophisticated normalization techniques.

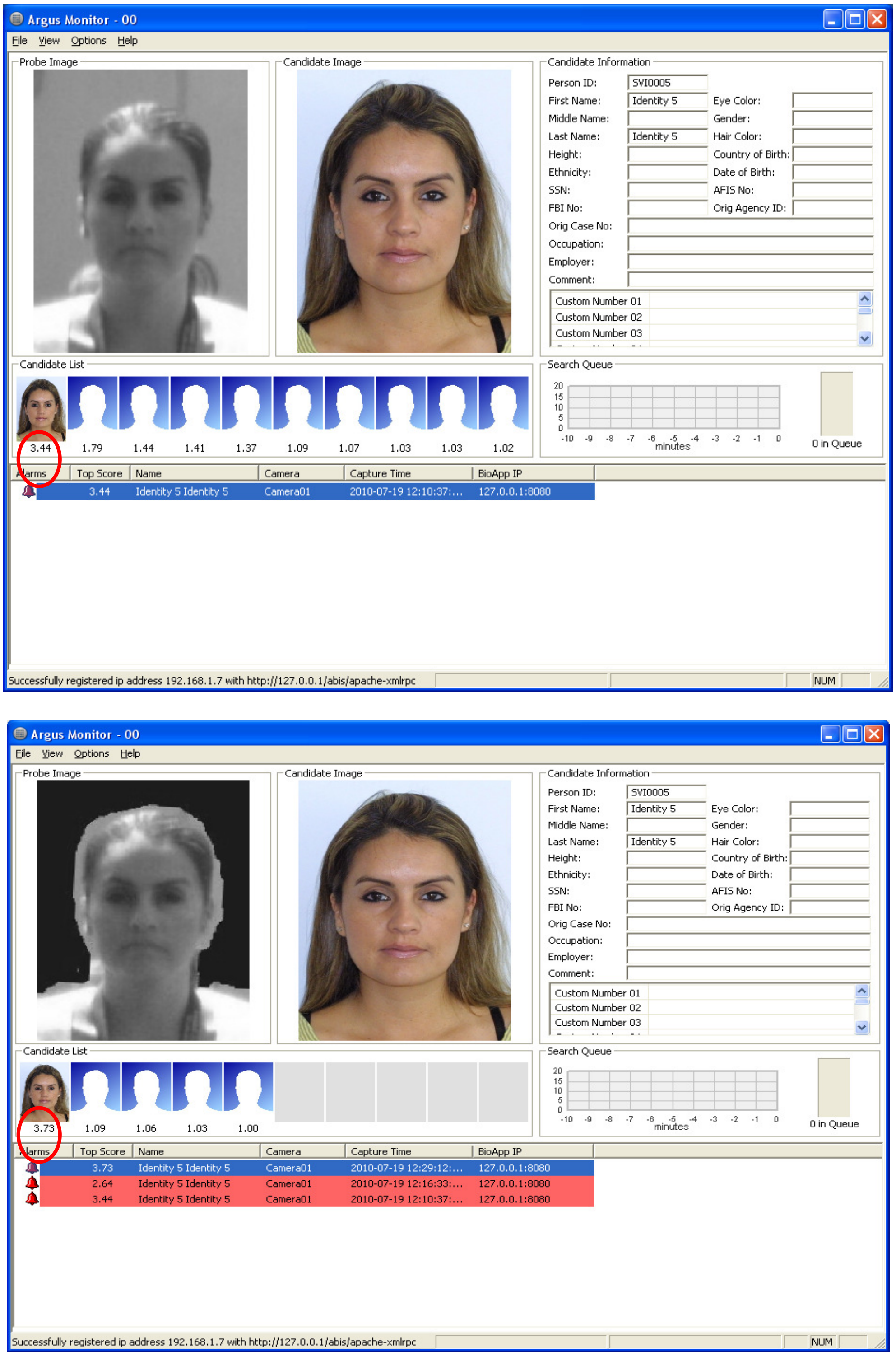


FIG. 26: Example of a score returned from a 2D image (3.44) versus a 3D segmented image (3.73) of an image captured outdoors at 100m. The image quality is identical. The end user result is the top score.

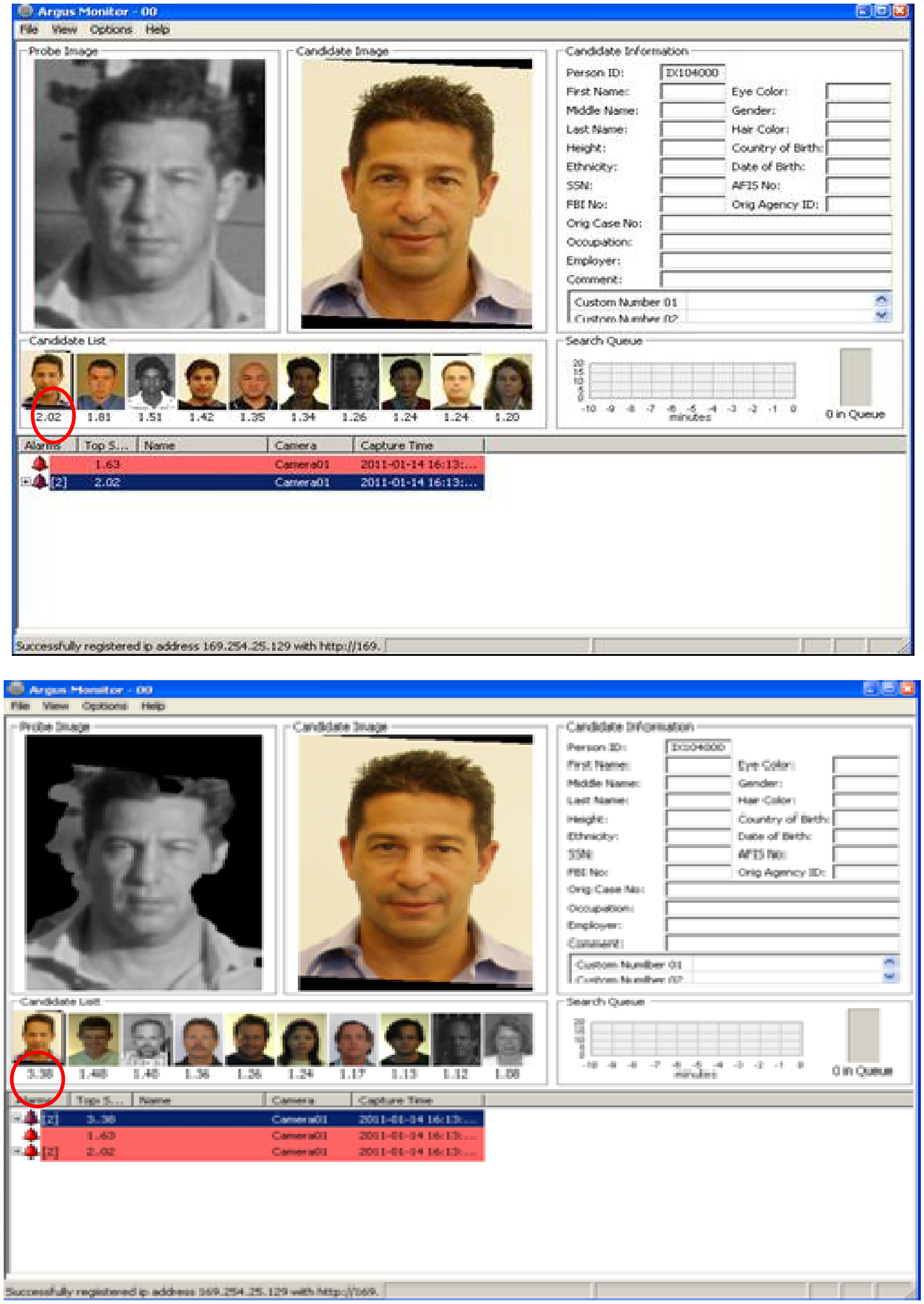


FIG. 27: Example of a score returned from a 2D image (2.02) versus a 3D segmented image (3.30) of an image captured outdoors at 100m. The image quality is identical. The end user result is the top score

8.0 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 115 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 50m
    vi. Single Individual, 0 +/- 10 degree pose within database
    vii. Single Individual, 0 +/- 10 degree pose outside database
    viii. Group of Individuals (2-3), 0 +/- 10 degree pose within disparity resolution
    ix. Group of Individuals, 0 +/- 10 degree pose outside disparity resolution

2. Outdoor Field Testing at 75m
    i. Same format as 50m test protocol

3. Outdoor Field Testing at 100m
    i. Same format as 50m test protocol

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 1350 images of 135 different subjects shall be enrolled into our database. As noted we have utilized publicly-available subset of the Color FERET dataset containing over 200 different subjects to assure validity of our results.

Dataset	Distance	# Subjects	# Images
SVI	3 m	13	144
Color FERET Set I	Unknown	100	1200
Color FERET Set II	Unknown	100	1200
	SUM:	**213**	**2556**

Table 4: Model image datasets.

All probe images were captured outdoors under uncontrolled environmental daylight conditions ranging from sunny, partly sunny, partly cloudy, cloudy and shade. The images shall be captured at three (3) different distances: 50 m, 75 m and 100 m.

Dataset	Distance	Condition	# Subjects	# Images
Clients	50 m	Uncontrolled	24	360
	75	Uncontrolled	17	255
	100 m	Uncontrolled	15	225
Impostors	50 m	Uncontrolled	7	105
	75 m	Uncontrolled	5	75
	100 m	Uncontrolled	8	120
		SUM:	**76**	**1,140**

Table 5: Probe image datasets.

All images captured outdoors w/SVI's 3D advanced prototype.

In the following sections, we shall detail the estimated performance of the identification system. We shall report performance for two different identification scenarios: the closed-world and open-world identification scenarios. In the former case, the probe images are captured from known subjects only (i.e. subjects represented in the Watchlist) whereas, in the latter case, the probe images shall be captured from known and unknown subjects. In this report, known subjects shall also be referred to as *clients* and unknown subjects as *impostors*.

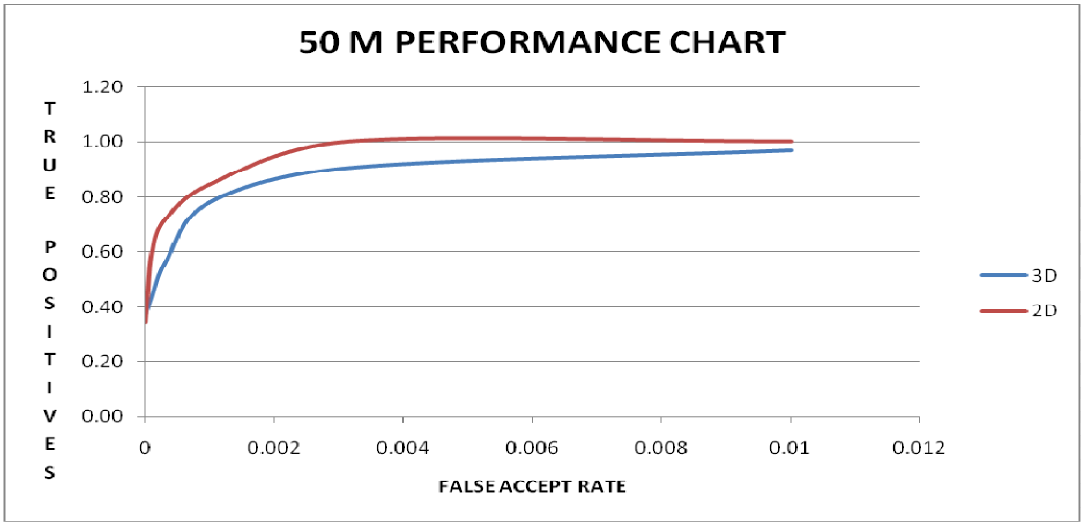
We express the closed-world performance of the system using the Rank-1 and Rank-10 identification rates. When identifying a probe image, the model templates in the Watchlist are sorted based on similarity with the template computed from the probe image. The Rank-1 identification rate is the percentage of tests where the model template at the top position has the same identity as the probe template. The Rank-10 identification rate, on the other hand, is the percentage of tests where a model template with the same identity as the probe template occurs within the top 10 positions. Furthermore, we shall list the rejection rates. The rejection rate is the percentage of enrolments where it was not possible to generate a template (due to e.g. a failure in the face detection or eye localization).

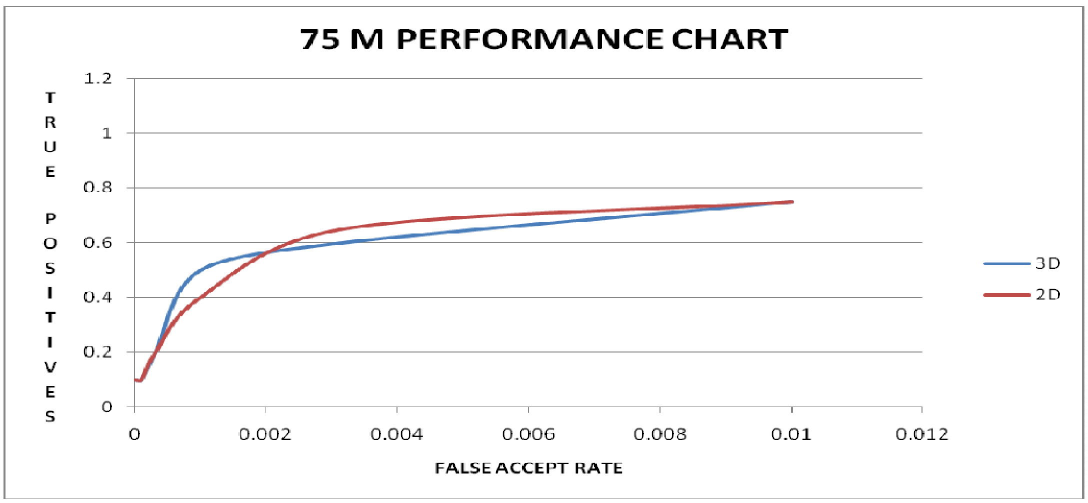
Finally, we shall illustrate the relationship between identification rate comparing our 3D segmented images with identical 2D images as a function of distance.

In the open-world scenario, we shall express the performance of the system using the False Rejection Rate (FRR) and False Acceptance Rate (FAR). The FRR is the percentage of client tests where the score was below a given threshold. The FAR is the percentage of impostor tests where the score was equal to or above a given threshold. Typically, we report the FRR at a fixed FAR, e.g. FAR equal to 10%, the so-called Crossover Error Rate (CER).

Closed-World Results on Uncontrolled Probe Data

In this section, we shall list the experimental results obtained on probe data acquired under uncontrolled environmental conditions of 2D left/right images and our 3D segmented images as a function of distance and database size. All results resulted as Rank-1 identification unless otherwise noted in the raw data posted in Appendix I (Raw Data).





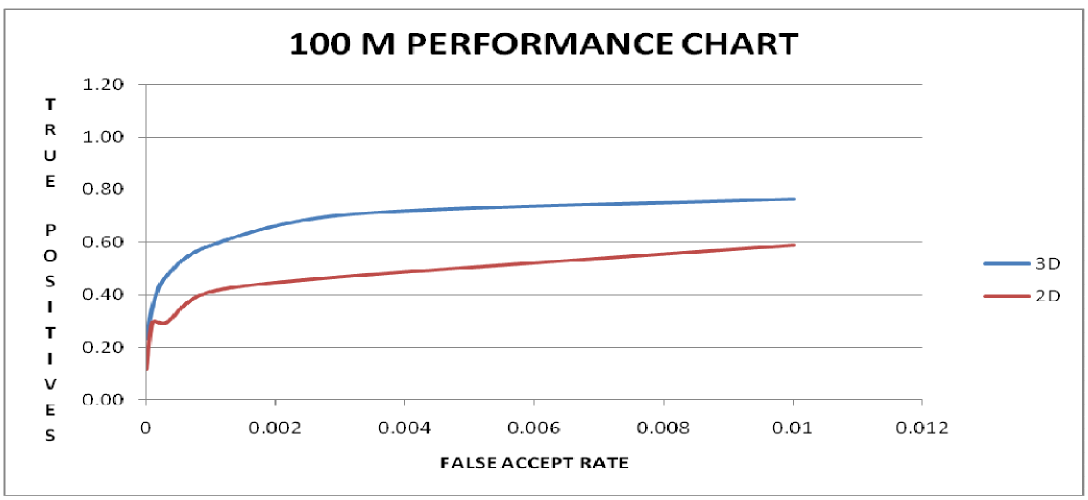
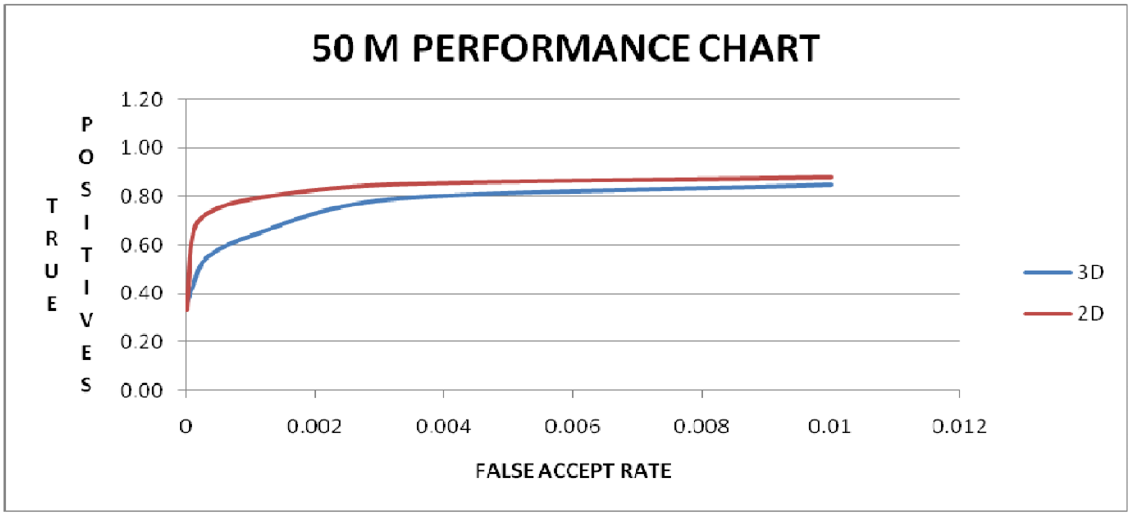
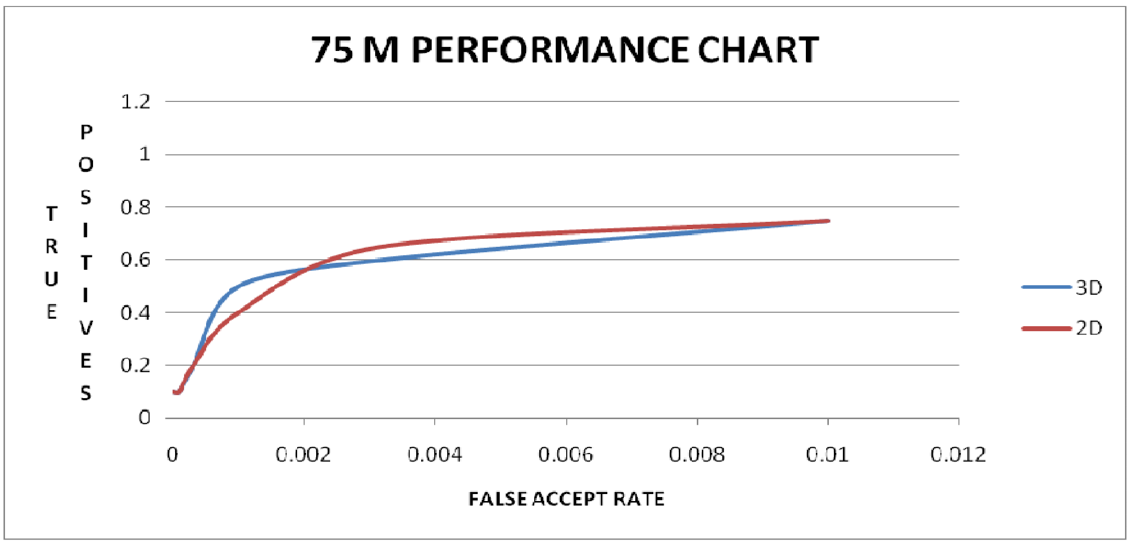


FIG. 28: True Positive Identification Rate versus the False Accept Rate for a Watch List Size of 113





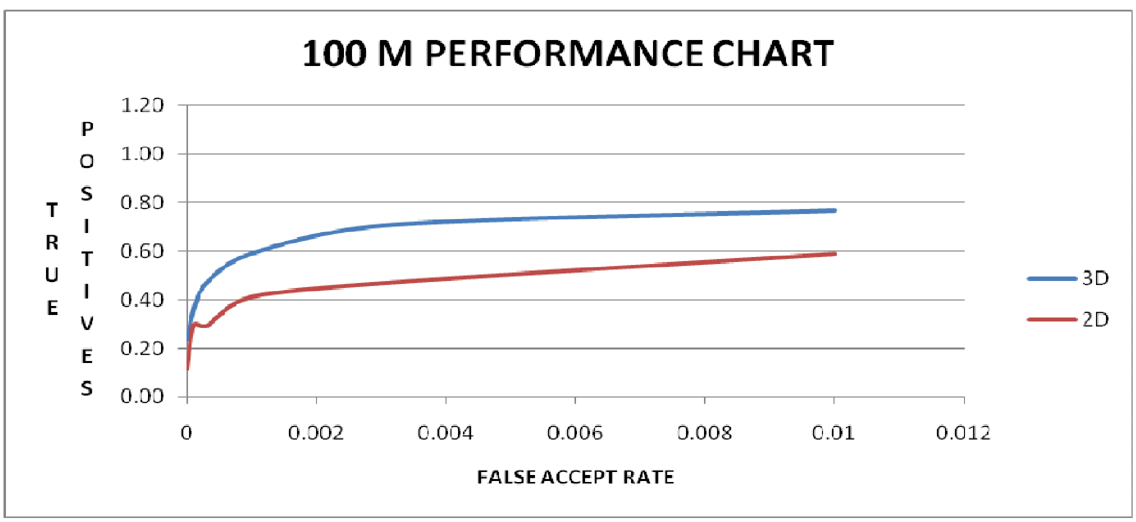


FIG. 29: True Positive Identification Rate versus the False Accept Rate for a Watch List Size of 213

Open-World Results on Uncontrolled Probe Data

In this section, we shall list the open-world experimental results obtained on probe data acquired under uncontrolled conditions for both captured 3D segmented images as well as the left/right 2D images.

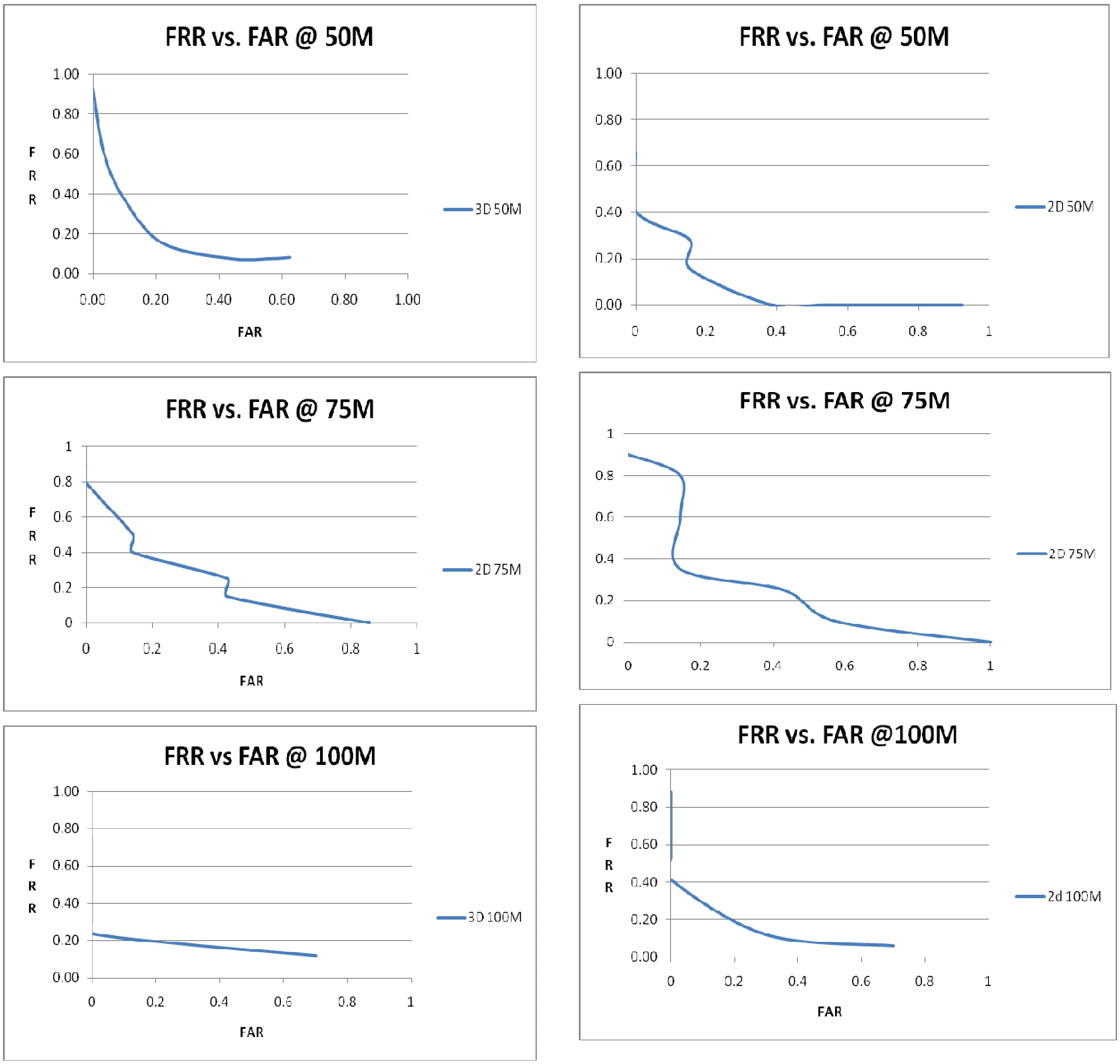


FIG. 30: Open World Results, DataBase Size of 113.

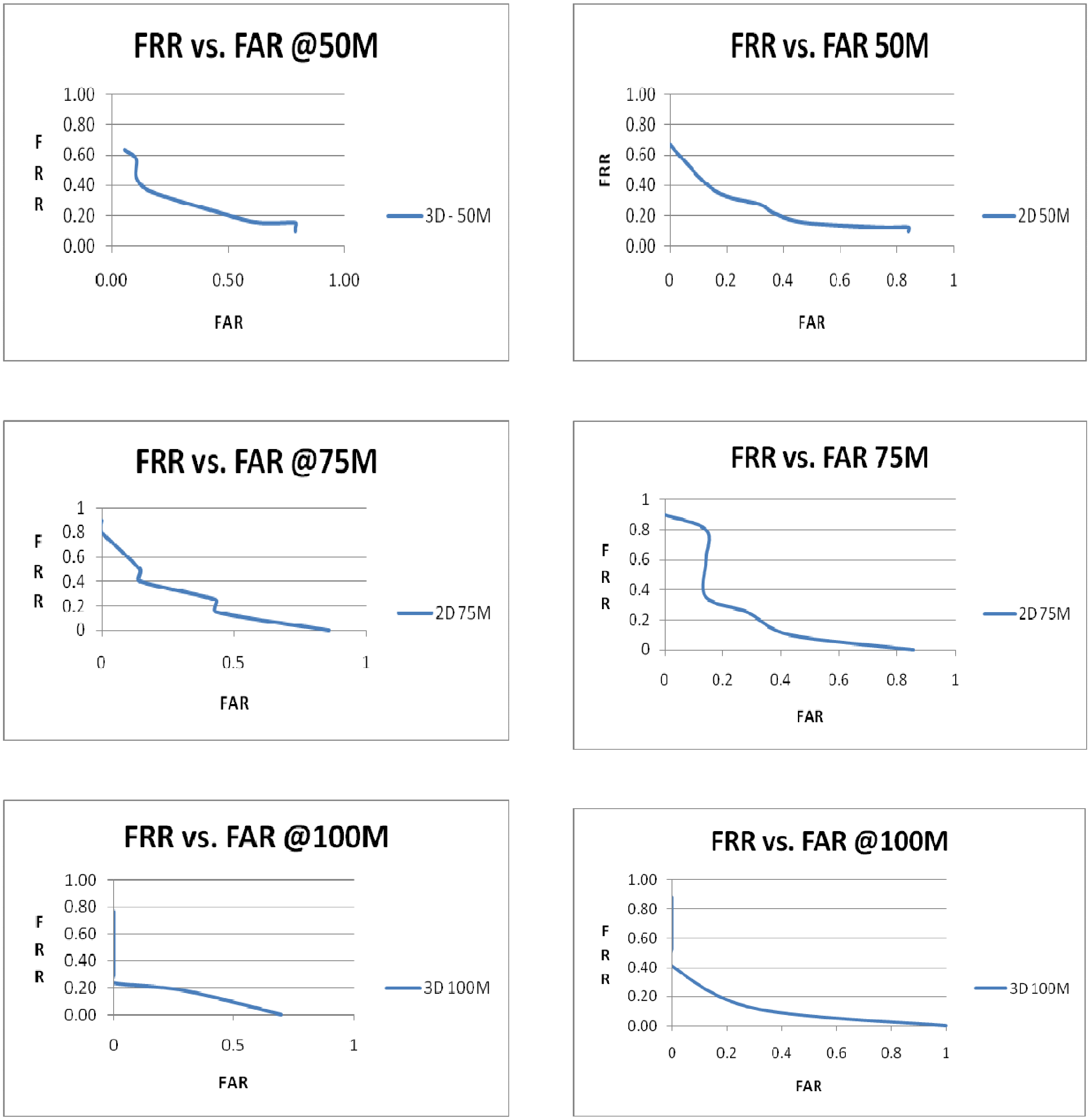


FIG. 31: Open World Results, DataBase Size of 213

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Award # 2009-IJ-CX-K001

9.0 FIELD DEMONSTRATION WITH LASD

Per our contract obligations, SVI hosted a field demonstration with the Los Angeles Sheriff's Department at their Tactical Training Unit in Monterey Park, CA Wednesday , December 14th, 2010. 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, narcotics, etc. mobile surveillance task forces. Invitees represented law enforcement user community.

Also in attendance was Dr. Mark Greene (NIJ) and Mr. Rick Chavez (Biometric Consultant to NIJ) as well as middle and upper management of one of SVI's designated subcontractor's, 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 22 runs were completed. Test runs included individuals enrolled in the database i.e. clients as well as imposters. Results have been rolled-up into the Alpha Results as noted in Section 8 above.

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

[redacted]

[redacted]

[redacted]

10.0 SUMMARY & CONCLUSION

Per SVI's original statement of work SVI has successfully completed its research goals and objectives for this program via the full development and fully operational hand-held stereoscopic viewing and biometric face capturing device. Further with the assistance of SVI's designated subcontractor, L-1 Identity Solutions, Inc., SVI successfully demonstrated and field tested a complete end-to-end Mobile ID client / server application at ranges up to 100m from point of use in conjunction with the Los Angeles Sheriff's Department. SVI's next step shall be to further increase performance via enhancements to image quality. Also as shown in Section 8, doubling the 2D facial database size did not have a significant impact on results.

The following typical results have been summarized below in a tabular format.

Closed World Result Summary

In Table 6, we shall summarize the results for the closed-world identification scenario presented in the previous sections.

FAR [%]	0.001	0.01	0.1	1	10	100
3D @ 50M	0.38	0.44	0.78	0.97	1	1
2D @ 50M	0.34	0.59	0.84	1	1	1
3D @ 75M	0.1	0.1	0.5	0.75	1	1
2D @ 50M	0.1	0.1	0.4	0.75	1	1
3D @ 100M	0.24	0.35	0.59	0.76	0.88	0.88
2D @ 50M	0.12	0.29	0.41	0.59	0.94	0.94

TABLE 6: Closed-world result summary with 2D facial database size of 113.

Open-World Result Summary

Configuration	FRR at FAR =0.10
3D @ 50M	~0.35
2D @ 50M	~0.35
3D @ 75M	~0.60
2D @ 50M	~0.85
3D @ 100M	~0.2
2D @ 100M	~0.3

TABLE 7: Open-world result summary with 2D facial database of 113.

Ground truth data was unavailable at this point in time due to the inability to manual adjust the eye locations. This work effort will be documented within further efforts. It is hypothesize that the 3D segmented images perform better at range due to the smaller face size as compared to the size of the image captured. That is at 50m, the size of the face occupies the majority of the image and as distance increases this is vice-versa thus the eye search engines has a much more difficult task, re: eye localization as distance increases. With 3D segmented images as the face size decreases, performance increases as the search space decreases.

Depending where the end user would like to operate on the ROC curves, predetermined thresholds can be set. These threshold values are further defined in our user manual.

In conclusion, StereoVision Imaging Inc. feels these summary results to be relatively impressive given the varying environmental conditions and distances and effort exerted within the Phase I funds available.

To note, we have no direct comparison with competing technologies. Many technologies fail at these distances. Our 3D segmentation technique has definitely improved results However, in comparison with our published specifications at the beginning of this program we are far from meeting our goals and further data collection is required to statistically determine true performance.

11.0 DELIVERABLES

Per our contract requirements, two (2) fully operational devices have been delivered. In addition our client/server application has been fully installed, tested and operational on a dedicated enclosed laptop.

User guides and manuals are attached within this final report

Devices were shipped discretely within pelican cases and include shoulder straps & carry cases.

Deliverable Check List

ITEM	QTY	NOTES
FRT 3D VuCAM ™	2	
3D VuCAM™ Battery Pack & Charger	1	Make Sure Battery Pack is Set for 3Vdc Output
3D VuCAM™ USB Cable	1	
3D VuCAM™ Carrying Case	2	2 Straps Included
CF Card	2	CF Card Must Remain w/in Device for Proper Use
External Power Supply Adapter	1	
CD	1	Includes Final Report & User Manuals
Customized Laptop & Power Supply Adapter	1	Includes Two Applications: 1) FRT Tracker – Must be tethered to device for proper use 2) Disparity Calculator-Ability to Upload Images Captured from Device

12.0 CONTRACT CLOSE-OUT FINANCIALS

The following table is breakdown of total projected versus actual funds of used against contract

CATEGORIES	APPROVED BUDGET	*ACTUAL COSTS
Personnel	$258,492	$282,623
Fringe Benefits	$35,182	$30,519
Travel	$13,068	$2,541
Equipment	$53,941	$38,715
Supplies	$5,600	$4,891
Subcontractors	$95,000	$115,658
Other	$22,150	$27,355
Misc.		$3,601
TOTAL	**$483,433**	**$486,698 ***

***contract overrun**

13.0 PHASE II

Beyond image enhancements, SVI is looking for further funding to provide NIJ with fully automated systems for a comprehensive evaluation. Funding is required to move technology to a production-ready status. Currently there are undesired features such as the need for a tripod due to image stabilization issues, need for an external power supply, the need to manual select proper exposure and the need to manually select the proper distance the object is from target i.e. 50, 75 or 100 meters +/- 5%.

These issues can be readily resolved with proper electronic platform implementing power management, invoking auto-exposure and auto-focus algorithms as well as addressing user community ergonomic /packaging issues.

Further wireless connection to client software is a must. It is envisioned, per user community suggestion, due to the new 4G network, a dedicated client application can reside on, as an example, an iphone Android operating system. Iphone, in turn, connected to server where our face recognition / database resides. "Answer" returned to iphone.

In addition disparity resolution can further be improved (2-4x) implementing sub-pixel calculation techniques

APPENDIX I

RAW DATA

StereoVision Imaging, Inc.

FRT Test Results

Database Size 113

50 METERS

IRB DATA SET	FILENAME	3D RESULTS	2D RESULTS	COMMENTS
8	16	2.21	3.69	
9	51	12.71	13.24	
9	52	11.98	10.64	
9	53	2.88	3.02	
9	60	7.85	6.79	
9	61	7.23	7.07	
11	11	3.16	4.1	
12	4	2.28	2.89	
12	7	2.93	2.95	
12	11	3.16	4.1	
Demo	1	7.04	6.11	Updated database
Demo	2	16.85	12.16	
Demo	4	5.87	6.95	
Demo	5	3.04	3.01	
Demo	7	3.25	3.79	
Demo	21	5.29	4.23	
Demo	22	3.01	3.62	
Demo	23	3.99	4.14	New Photographer
13	83	2.75	2.75	Rank 2
13	90	2.73	3.49	
13	93	1.87	2.57	Rank 3 (3D), Rank 2 (2D)
13	98	6.45	7.07	
13	99	4.12	4.72	
13	100	5.98	7.62	
13	102	3.38	4.25	Rank 2 (3D)
13	106	7.02	5.18	
13	109	3.76	3.29	
13	110	4.15	3.81	
13	114	3.04	2.62	
13	128	3.54	4.1	
13	129	6.93	6.64	
13	130	3.79	4.71	
8	10	1.51	1.29	Imposter
8	15	1.9	1.66	Imposter
10	2	2.31	1.75	Imposter
10	6	1.84	2.87	Imposter
10	10	1.51	1.29	Imposter
12	18	2.39	1.47	Imposter
Demo	3	5.96	3.86	Imposter
Demo	6	2.74	3.66	Imposter
Demo	8	2.27	2.18	Imposter
Demo	9	3.25	2.43	Imposter
Demo	10	2.77	2.54	Imposter
13	107	2.99	2.9	Imposter

75 METERS

IRB DATA SET	FILENAME	3D RESULTS	2D RESULTS	COMMENTS
8	13	3.21	2.04	
8	17	1.56	1.07	Wrong Exposure; Changing exposure setting
8	18	3.55	3.17	Exposure better; Changing exposure setting
8	19	2.06	1.69	Changing exposure setting
8	20	3.36	2.75	Changing exposure setting
9	54	5.76	5.57	
9	55	3.82	3.6	
9	62	2.63	3.16	
9	63	2.27	2.12	
10	13	3.21	1.82	
11	12	1.04	2.57	Rank 2 in 3D
12	12	1.04	2.57	Rank 2(3D)
Demo	11	3.13	3.16	
Demo	12	15.83	10.13	
Demo	15	3.13	1.52	
13	95	1.72	3.45	
13	97	1.19	1.41	
13	115	2.37	2.75	
13	116	3.35	2.73	
13	121	2.64	3.61	
IMPOSTER				
8	11	1.3	1.49	Imposter
10	7		1.24	Imposter; No 3D
10	11	1.3	1.49	Imposter
12	19	1.4	1.9	Imposter
Demo	13	3.49	3.75	Imposter
Demo	14	2.28	2.28	Imposter
13	117	2.12	2.13	Imposter

100 METERS

IRB DATA SET	FILENAME	3D RESULTS	2D RESULTS	COMMENTS
9	56	5.35	6.77	
9	57	5.08	4.93	
9	58	2.81	2.66	
9	64	4.32	1.67	
9	65	7.63	5.41	
9	66	6.39	4.34	
9	67	3.21	1.45	
11	13	1.2	1.09	false alarm
12	13	1.2	1.6	3D false alarm
Demo	16	3.31	2.42	
Demo	18	5	3.25	
13	103	3.82	1.84	
13	105	1.49	1.68	Rank 2
13	119	2.99	3.3	
13	120	3.89	4.34	
13	122	2.33	1.66	Rank 2 (3D), Rank 2 (2D)
13	124	1.54	2.34	
IMPOSTER				
8	9	1.51	1.29	Imposter
8	12	1.13	1.25	Imposter
10	3	1.55	1.59	Imposter; Eye spacing 30 pixels
10	5	1.59	1.4	Imposter; Eye spacing 28 pixels
10	8		1.07	Imposter; No 3D
10	9		1.39	Imposter; No 3D
10	12	1.13	1.25	Imposter
Demo	19	1.35	1.83	Imposter/3D False negative
Demo	20		1.22	Imposter/ No 3D / 2D False negative
13	123	1.39	1.63	Imposter

APPENDIX II

LICENSING AGREEMENT

StereoVision Imaging, Inc.

2400 N. Lincoln Avenue
Altadena, CA 91001

3D Hand-Held Surveillance and Real Time Multi-Modal Recognition Device

January 2011

User Manuals

Award No. 2009-IJ-CX-K001

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January 2011

The FRT 3DVuCAM™ offers 8x angular optical magnification with an integrated 10MP stereoscopic imaging system.

Overview of the System

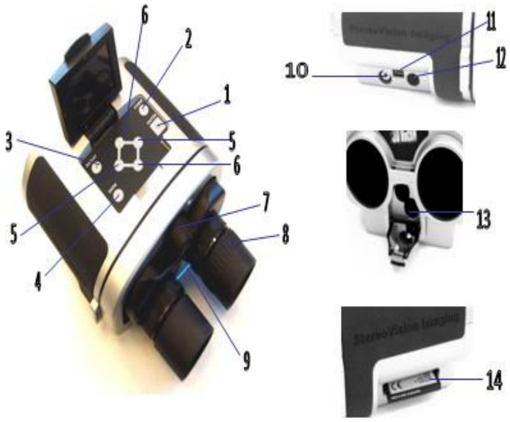
The patented design allows end user to place a “person-of-interest” within the retical markings for identification. The imaging pixels only corresponding to the retical marking are captured from the internal CMOS photo arrays.

The device was designed for portability and ease of use. A single press of the shutter button captures a short 3D video clip. However the following MANUAL settings are required (future efforts will automate these settings)

SETTINGS	DESCRIPTION	COMMENTS
***Manual Focus**	Three (3) Preset Settings: 50, 75, 100 meters	Left, Up, and Right Arrow Keys on Key Pad (See Figure One,
Manual Exposure	See Appendix I Manual Settings Look-up Table	User Must Type in Proper Exposure Settings and Gain Per Appendix II Table via the Camera Menu As Described Below
External Battery Pack	Please Use Specified 3V Battery Pack	Future Efforts Will Move Away from External Pack and Run off Internal Batteries
Hard Wire (USB) Interface to PC	Please Use Specified USB Cable	Future Efforts Will Move Away From Hard Wire to Wireless Connection

***PLEASE NOTE: EITHER LEFT, UP AND RIGHT ARROW KEY MUST BE PRESSED IMMEDIATELY AFTER POWER-UP TO ENTER INTO PROPER FRT OPERATING MODE**

HIGHLY RECOMMENDED DEVICE TO BE MOUNTED ON A TRIPOD TO AVIOD ANY IMAGE BLURRING AFFECTS



1	Shutter Button – Captures 3D Video Clip . Press & Hold Button Until ‘Beep’ is Sounded while placing “person-of-interest” in retical marking. THEN release button to capture. Hold device steady until second “beep”.
2	- Turn ON: Press to turn on. - Turn OFF: Press for 3 seconds. - Menu escape key functionality when pressed after power on
3	Display Button - View images on flash card.
4	Enter Button - To enter LCD menu or used whenever requested by the interface.
*5	a. Left and right arrows to navigate in and out of the menu interface. b. Navigate between different images present on the flash card in Display mode.
*6	a. Up and down arrows to navigate up and down of the menu interface. b. Navigate between left/center reticule/right image of the one single image in Display mode.
7	Manual Focus Knob: N/A

8	Focusing by rotating the rims on the left and right eye.
9	Push both the eye-pieces from this position to adjust for inter-ocular distance (distance between the eye) .
10	Video Port. (optional)
11	High Speed USB 2.0.
12	3Vdc power input port.
13	2 AA batteries to be inserted as indicated on the panel inside the battery holder. **DEVICE TO BE POWERED EXTERNALLY ONLY**
14	Compact flash card slot. Goes in upside down, like shown in the picture on page 4. **NOTE: CF CARD MUST BE INSERTED FOR PROPER USE**

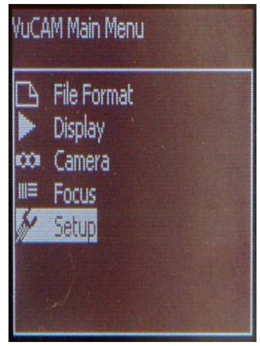
*** PLEASE NOTE: LEFT, UP, AND RIGHT BUTTON MUST BE SELECTED FOR FOCUSING IMMEDIATELY AFTER POWER-UP.**

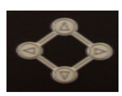
THEN NORMAL ARROW KEY USAGE IS POSSIBLE AFTER PRESSING DISPLAY BUTTON (4).

PRESS ‘POWER’ BUTTON ANYTIME TO ESCAPE AND TO CHANGE FOCUSING SETTINGS.

StereoVision Imaging, Inc.
Award # 2009-IJ-CX-K001

Menu Operations



- Press ENTER button to view the Main menu.
- Use  to navigate through the menu.
- Press POWER button to come out the menu anytime.
- Press DISPLAY button to view images on the card.
  - Use  to navigate through images and to view left, center and right images of the same shot.
  - Press ENTER to delete any image.
  - Press POWER to come out of display mode.

PLEASE NOTE: EITHER THE LEFT, UP, OR RIGHT ARROW KEY MUST BE SELECTED IMMEDIATELY AFTER POWER-UP BEFORE THESE MENU OPERATIONS WORK PROPERLY

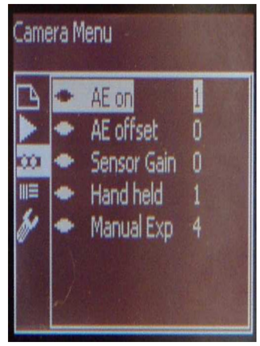
File Format

Format	0: Captures only Jpeg. 1: Captures only Raw. VUR format. Needs DCRAW to convert to Adobe RAW standard. Contact SVI or download the software from: http://www.aim-dtp.net/aim/digicam/dcraw/dcraw2ps.htm 2: Captures both Raw and Jpeg.
Quality	Set the quality parameter for Jpeg. Default = 85. Higher quality factor would mean lower compression and larger file size.
Small Crop	0: 2048 by 1536 image size captured. 1: 640 by 480 image size captured, centered at the center of the image.

Display

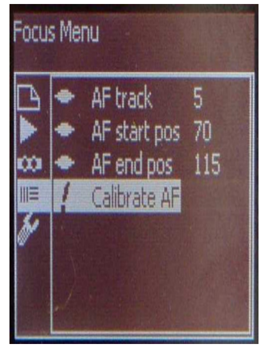
LCD timeout	Number of seconds after which the LCD will become dim to save power.
Contrast	Change the contrast of the LCD.
Beep	Turn ON/OFF the beep sound on pressing menu buttons.

StereoVision Imaging, Inc.
Award # 2009-IJ-CX-K001



Camera

AE ON	Auto Exposure. 1: ON 0: OFF, manual exposure takes into effect.
AE Offset	Increase or decrease brightness/shutter speed in the image.
Sensor Gain	● Increase or decrease brightness/shutter speed in the image. 1 step is equivalent to 0.5EV steps. (EV=Exposure Value) ● Optimal is “4” when too cloudy/stadium and if the VuCAM says “Too Dark”. ● If Gain set too high(7-10) then noise will come in. ● See AE offset for another option.
Hand held	● VuCAM will not take picture if “Too Dark”. Use a Tripod and set handheld = 0. ● See Sensor Gain and AE Offset, if do not want to use Tripod.
Manual Exp	Set AE ON = 0, to use manual exposure. 1 step is equivalent to 0.5EV steps.



Focus

AF Track	N/A
AF start pos	N/A
AF end pos	N/A
Calibrate AF	N/A

PLEASE NOTE: FOCUSING IS SET AT PRE-DETERMINED DISTANCES OF 50m, 75m, and 100m ONLY

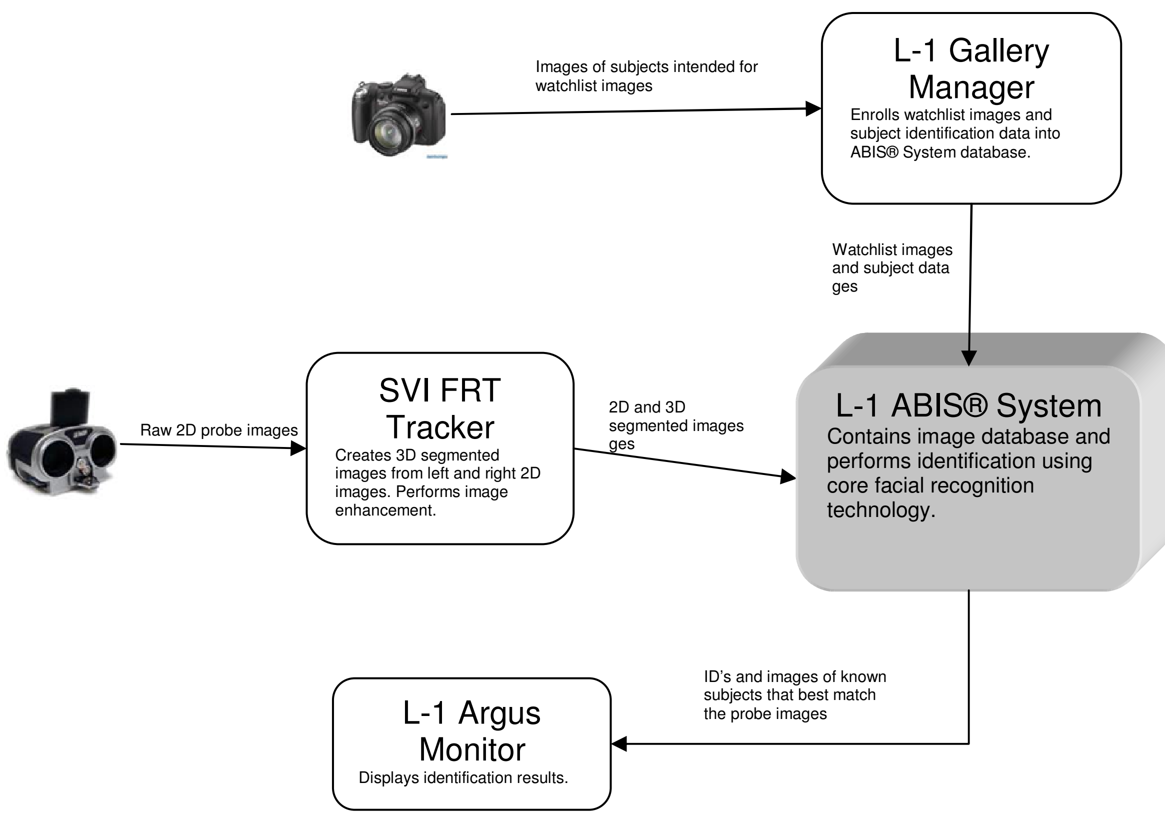
Setup

Set Defaults	All the user settings will be replaced by factory defaults.
Update Firmware	To change to a new software upgrade.

The FRT Tracker application is used to perform identification of a face in an image captured through the stereoscopic FRT 3DVuCAM™. The captured image is compared against a database of images containing the faces of known subjects. If a close match is found, the results are displayed to the user.

Overview of the System

StereoVision Imaging's software system is based on the L-1 ABIS® System for facial recognition. Images taken from the FRT 3DVuCAM™ are routed to the FRT Tracker application where 3D segmented images are generated. The 2D and 3D segmented images are then routed from the FRT Tracker application to the ABIS® System back-end for identification. Results of the identification are shown through L-1's Argus Monitor application.



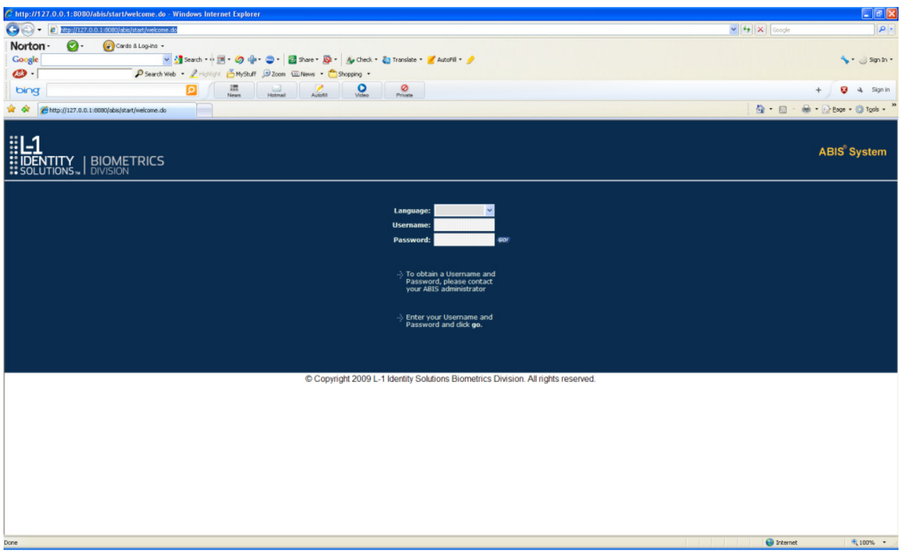
Software System Setup

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

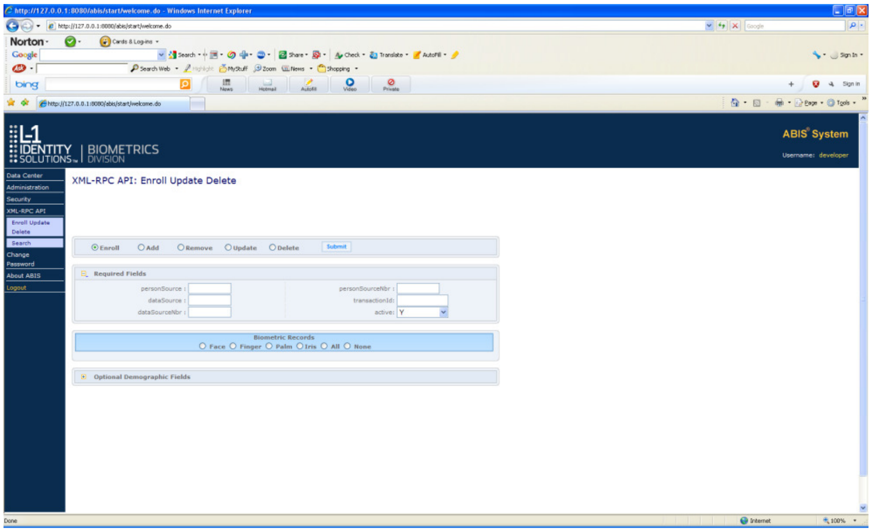
Launching the L-1 ABIS® System

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

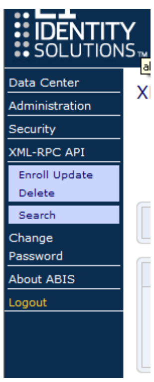
You should see the web page below:



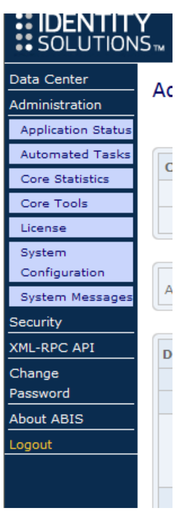
For the **Username** field, enter *developer*. For the **Password** field, enter *password*. Click on **Go!**. You should see something similar to this after clicking on **Go!**:



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

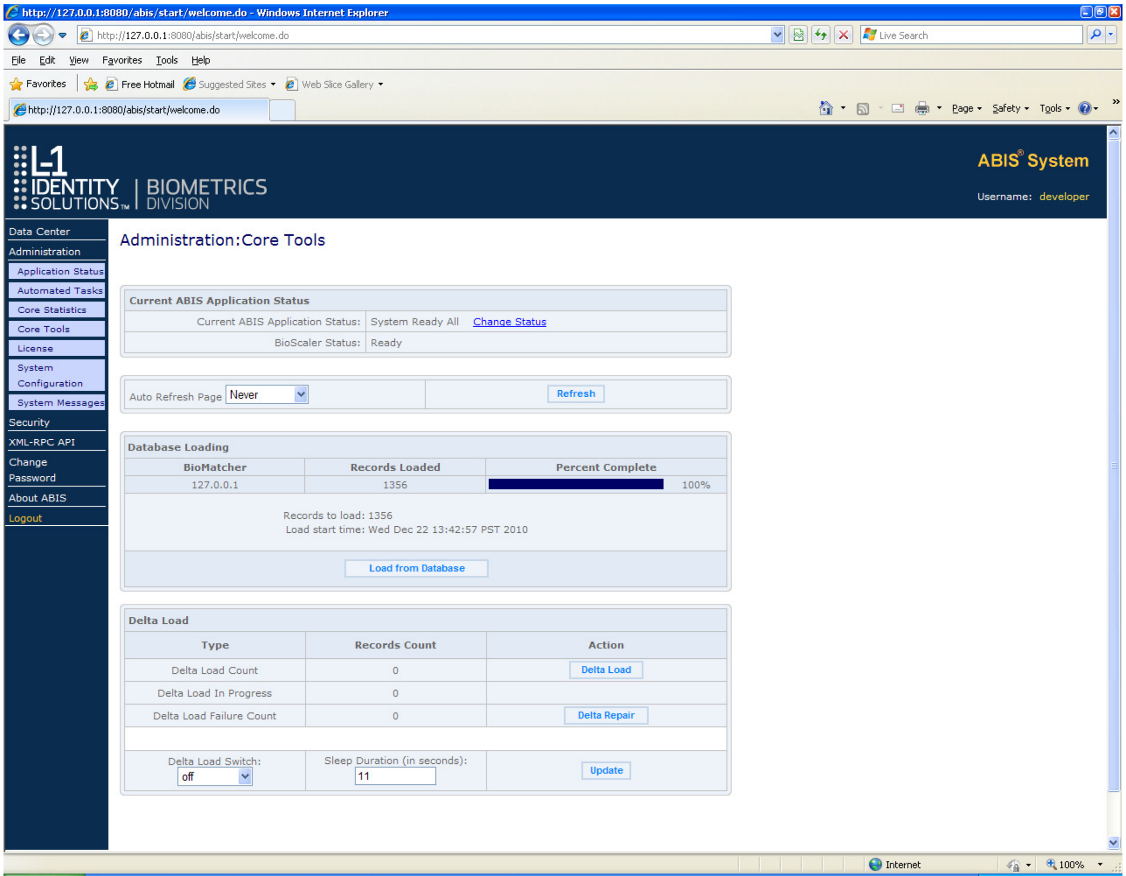


Click on **Administration**, and then from this menu:



StereoVision Imaging, Inc.
Award # 2009-IJ-CX-K001

Click on **Core Tools**.

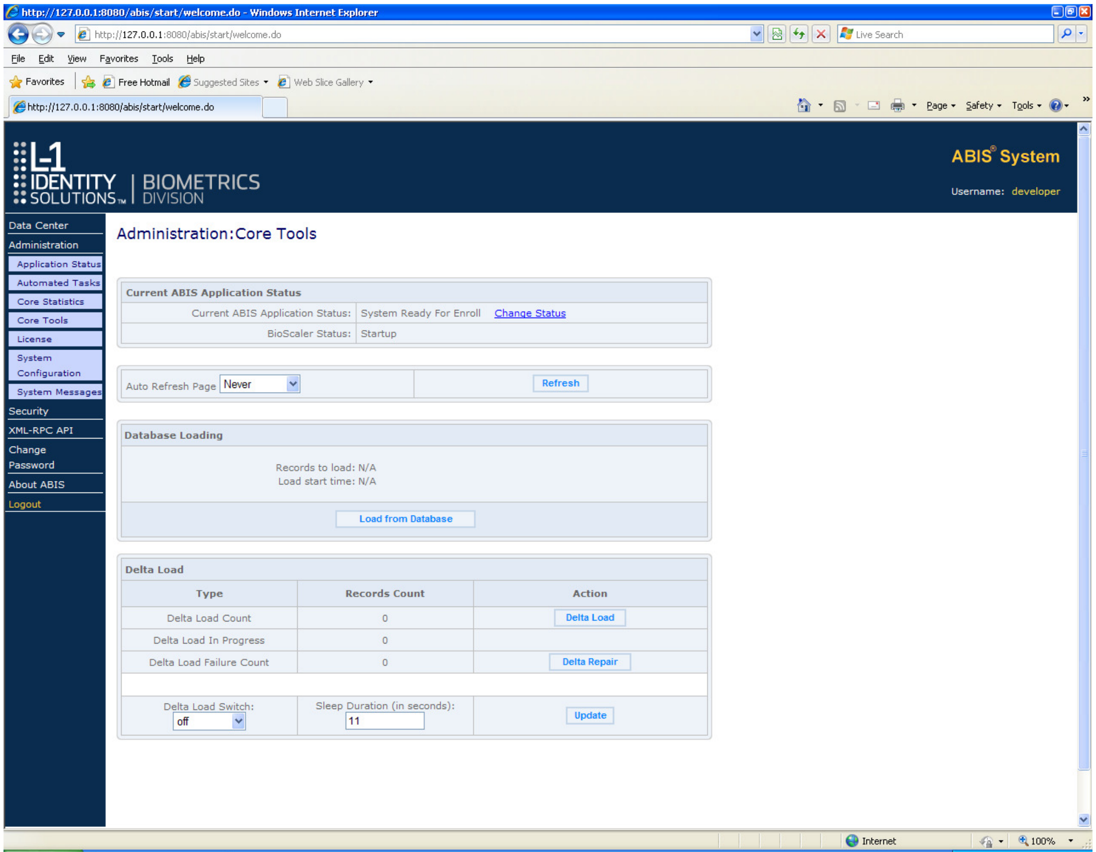


The web page above illustrates a machine with its ABIS® System core in its running state. Two things that confirm it's in this state are:

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

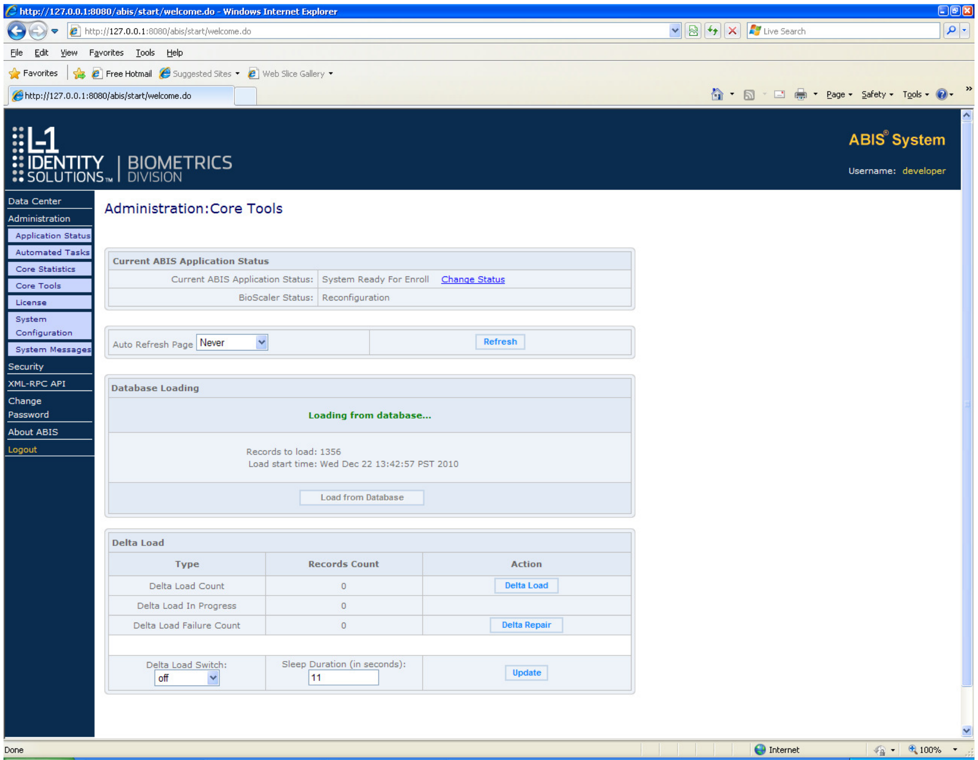
If the page shows up in this state, then this is a confirmation that the database is fully loaded and the ABIS® System is running. (NOTE: Don't worry about the number of records under **Records Loaded** as this count shown above may or may not be the same as what you see on your machine at the moment. 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:

StereoVision Imaging, Inc.
Award # 2009-IJ-CX-K001



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:



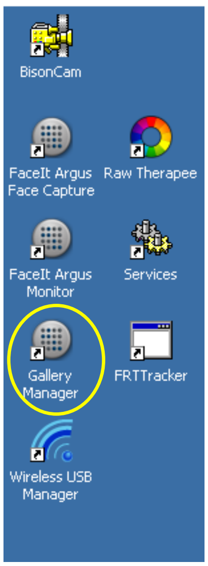
Waiting a minute or two for the database to load may be required. While this page is displayed, you can click on the **Refresh** button to update the display to show what percentage of the database has been loaded so far. Click **Refresh** until it displays a progress bar showing 100% (wait at least 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.

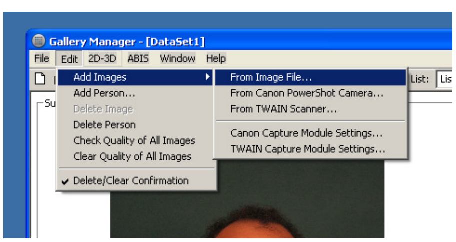
Note: For more detailed information on the ABIS® System, refer to the *080-613-L_ABIS_Search_Engine_6.5.1_Administration_Guide.pdf* document available upon request.

Adding Images to the Database

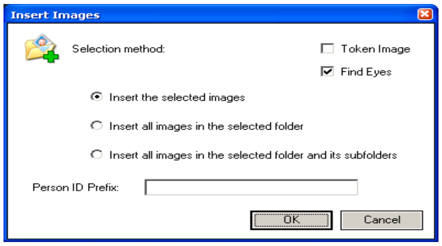
Before attempting to identify subjects from image captures, you'll need to make sure the subjects you're trying to identify are in the ABIS® System database. Here, a series of steps will be presented to outline the process of enrollment for a single person with one image. First, you'll need to have an 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.



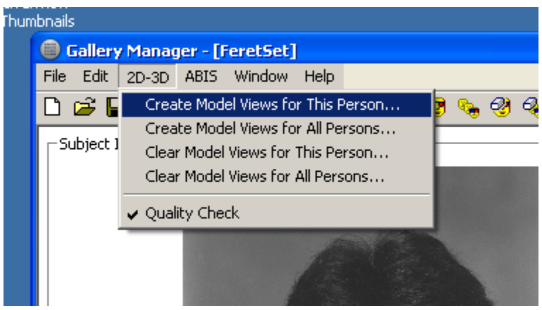
Once the Gallery Manager application window is up, click **Edit → Add Images → From Image File…**



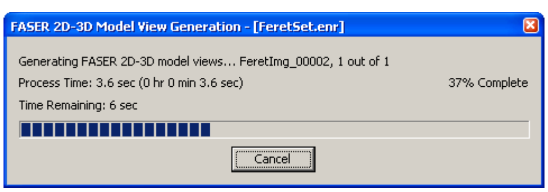
From the following window, make sure **Insert the selected images** is selected and **Find Eyes** is checked. Then click OK.



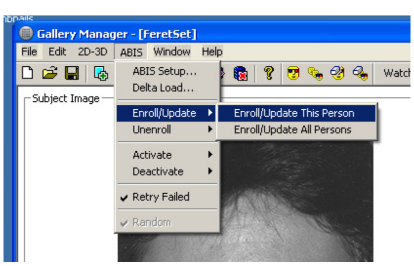
From the list of files displayed, select the single image file associated with the identity, then click Open. Make sure the image just selected shows up in the **Subject Image** sub-window, then click on **2D-3D → Create Model Views for This Person**.



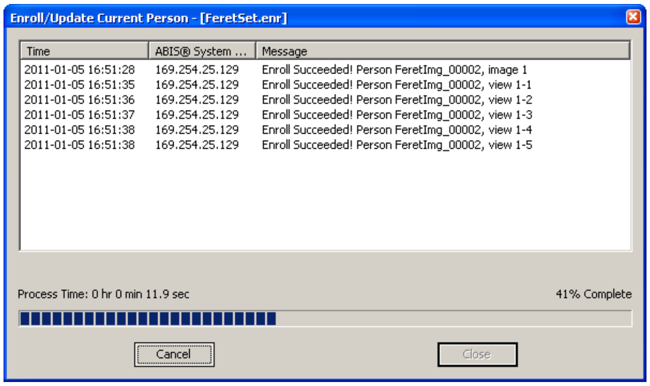
This will generate a set of 3D images associated with the initial image that reflect the face at different positions.



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.



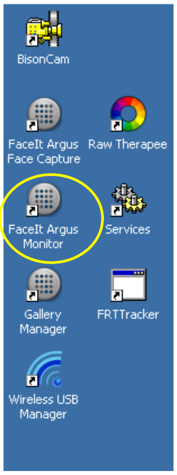
A progress window will show up indicating the enrollment status. Upon completion of the enrollment, click on the Close button.



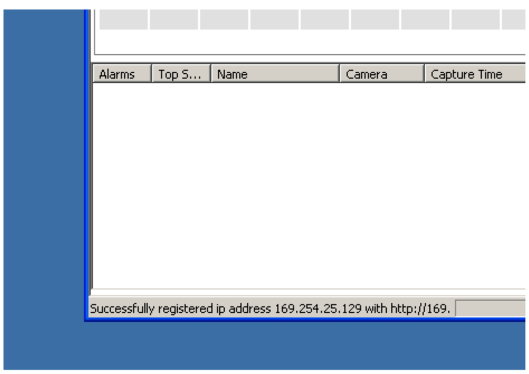
The person just enrolled is now in the database and ready for identification.
Note: For more details on the enrollment process, refer to the *080-637-D_GalleryManager_User_Guide.pdf* document available upon request

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.



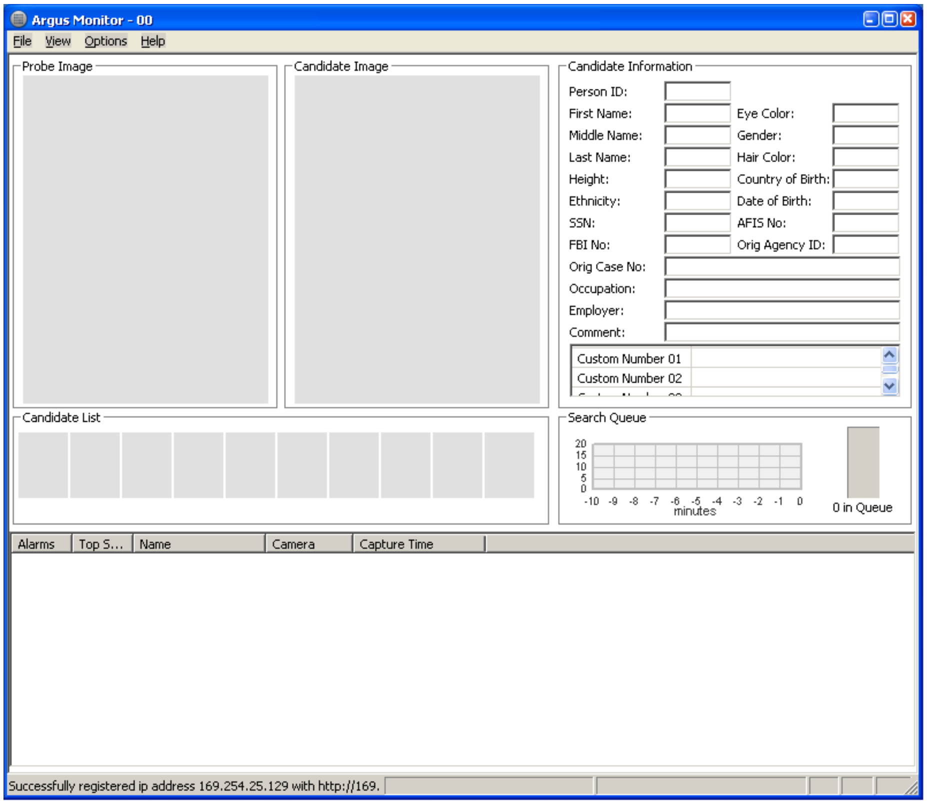
Once launched, the monitor needs to register itself with the ABIS system. This may take 15 to 20 seconds. Once this is done, the status is displayed on the bottom left corner of the application's window:



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:

The image below is of the Monitor application with a moderate size window:

StereoVision Imaging, Inc.
Award # 2009-IJ-CX-K001

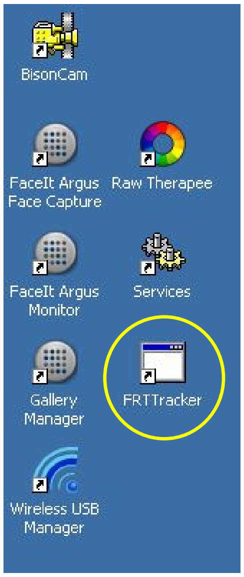


The above window will be filled with facial images as they are captured from the camera. You can now proceed with launching the FRT Tracker application. Note: For more detailed information regarding the Monitor application, refer to section 6 of the *080-105-H_FaceIt_Argus_6.4_User_Guide.pdf* document.

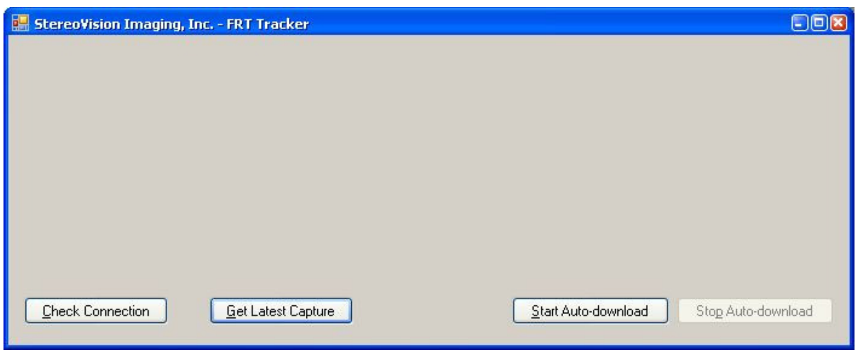
Launching FRT Tracker

The FRT Tracker program is responsible for retrieving images from the FRT 3DVuCAM™ and passing them to the ABIS System for identification. Since it retrieves images from the FRT 3DVuCAM™,

PLEASE NOTE: You will need to make sure the FRT 3DVuCAM™ is connected to a power source, powered on, and connected to the laptop via USB cable. To start this program, double-click on the **FRTTracker** shortcut located on the left-hand side of the desktop.

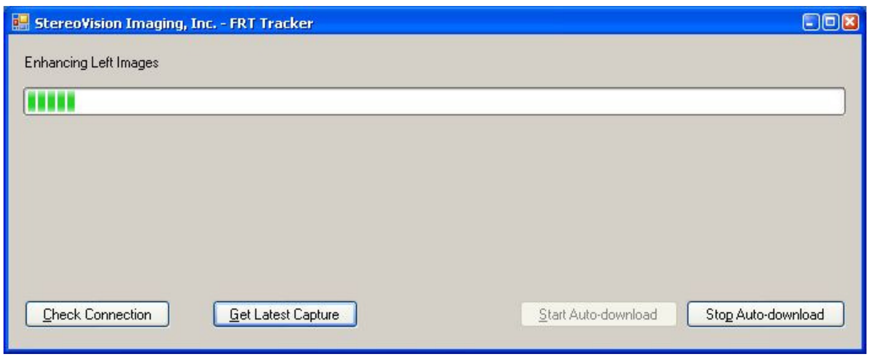


After launching this program, you should see the following window:

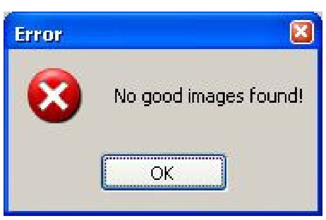


Once the FRT 3DVuCAM™ is powered and connected to the laptop, you may click on the **Check Connection** button to ensure that communication to the FRT 3DVuCAM™ from the laptop is unhindered. You should see the following notification:

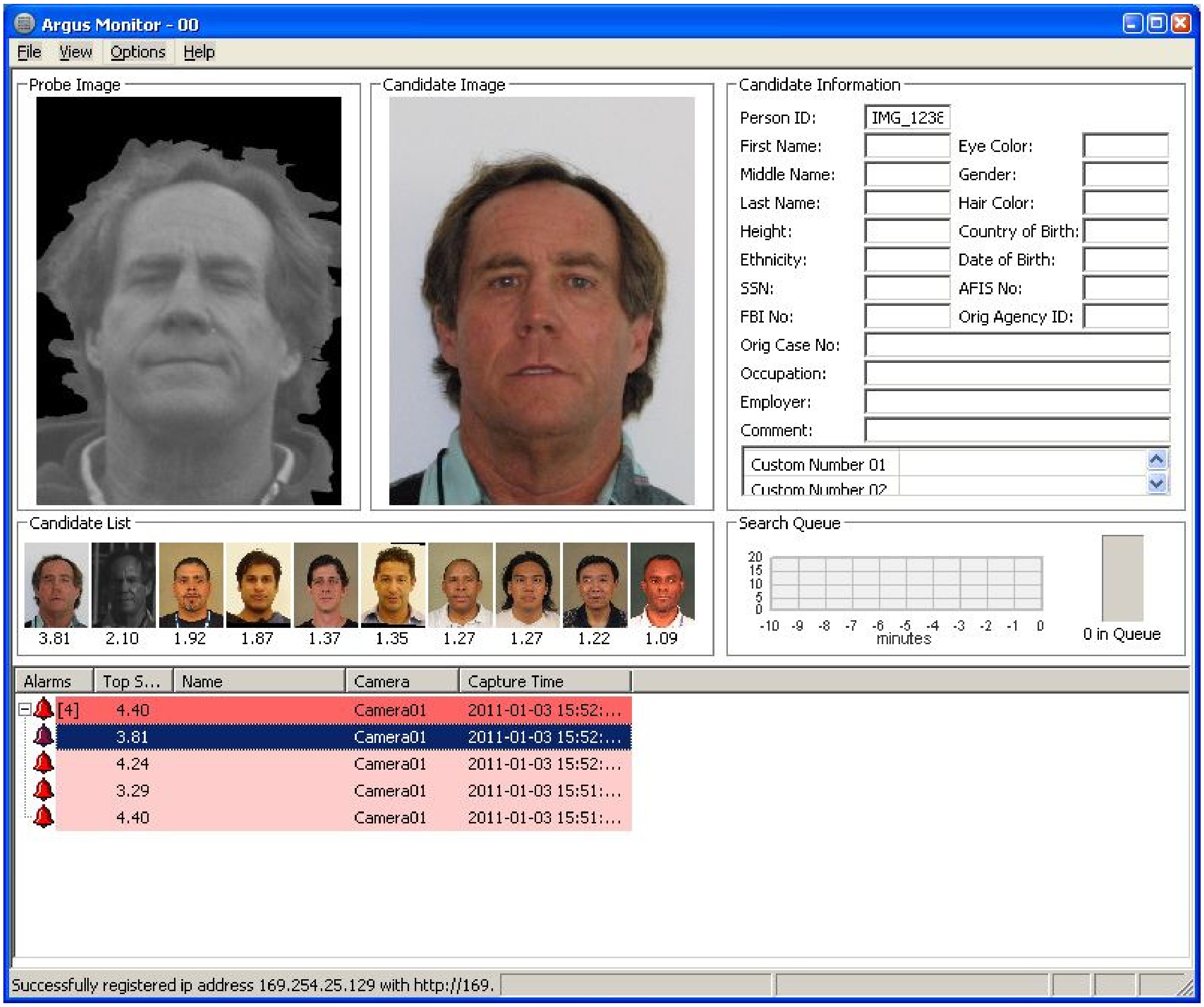
With the FRT Tracker program running and the 3DVuCAM® powered and connected, you're ready to capture images. Click on the **Start Auto-download** button to prepare the program for image captures. Now, capture an image of a subject with the VuCAM in the range of 50 meters to 100 meters away from the VuCAM. Note: The subject should already have an image enrolled in the database. After the image has been captured, the program will automatically download the image data from the camera. You should see it respond with a status and progress display.



If all the frames are of poor quality or do not contain any faces, the following notification will appear:



If one or more images contain recognizable faces, the L1 ABIS System will perform an identification matching the probe image with an image in the database, and you should see a response in the Monitor application similar to that below


Argus Monitor - 00
File View Options Help
Probe Image
Candidate Image
Candidate Information
Person ID: IMG_1238
First Name:
Eye Color:
Middle Name:
Gender:
Last Name:
Hair Color:
Height:
Country of Birth:
Ethnicity:
Date of Birth:
SSN:
AFIS No:
FBI No:
Orig Agency ID:
Orig Case No:
Occupation:
Employer:
Comment:
Custom Number 01
Custom Number 02
Candidate List
3.81 2.10 1.92 1.87 1.37 1.35 1.27 1.27 1.22 1.09
Search Queue
20 15 10 5 0
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0
minutes
0 in Queue
Alarms | Top S... | Name | Camera | Capture Time
[4] 4.40 Camera01 2011-01-03 15:52:...
3.81 Camera01 2011-01-03 15:52:...
4.24 Camera01 2011-01-03 15:52:...
3.29 Camera01 2011-01-03 15:51:...
4.40 Camera01 2011-01-03 15:51:...
Successfully registered ip address 169.254.25.129 with http://169.

StereoVision Imaging Inc
Disparity Calculator Guide

The Disparity Calculator application serves almost the same function as FRT Tracker. It generates 3D segmented images from the left/right 2D images, and sends them to ABIS for identification. However, it's intended to be more of an analysis tool presenting more information about the generation of 3D segmented images. **HOWEVER,** rather than automatically downloading images from the 3DVuCAM®, the Disparity Calculator receives user-selected image files as input.

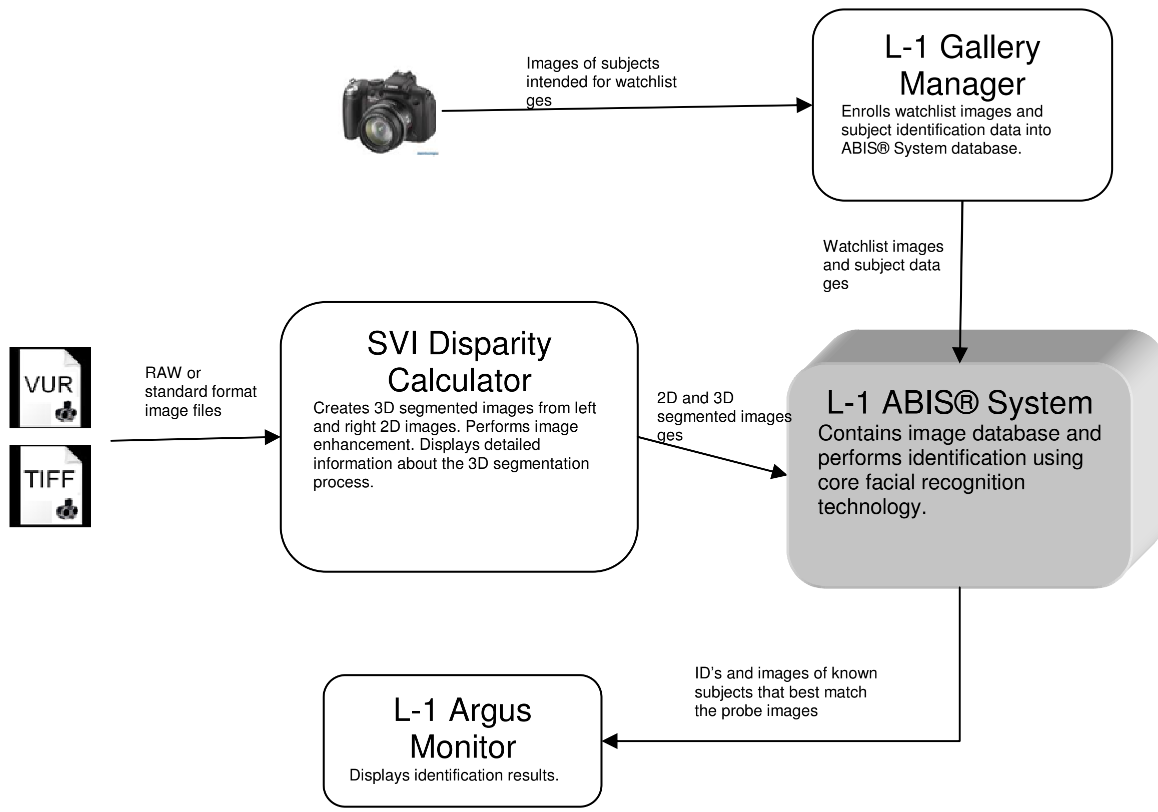


Figure 1

Launching Disparity Calculator

A shortcut for Disparity Calculator exists on the left side of the desktop. Double-click this to launch.

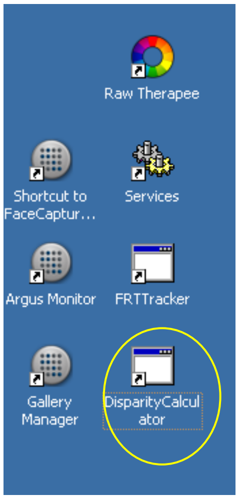


Figure 2

Loading RAW image files

Regarding raw image files: when an image is captured from the 3DVuCAM®, it ‘s saved onto the compact flash card as a pair of files: LEFTXXXX.VUR, RGHTXXXX.VUR where XXXX represents a 4 digit number. Each of these files contains a set of 5 frames, comprising a sequence spaced approximately 70 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 LEFTXXXX.VUR and RGHTXXXX.VUR where XXXX is the same numeric ID for both files (ex: LEFT0003.VUR and RGHT0003.VUR).

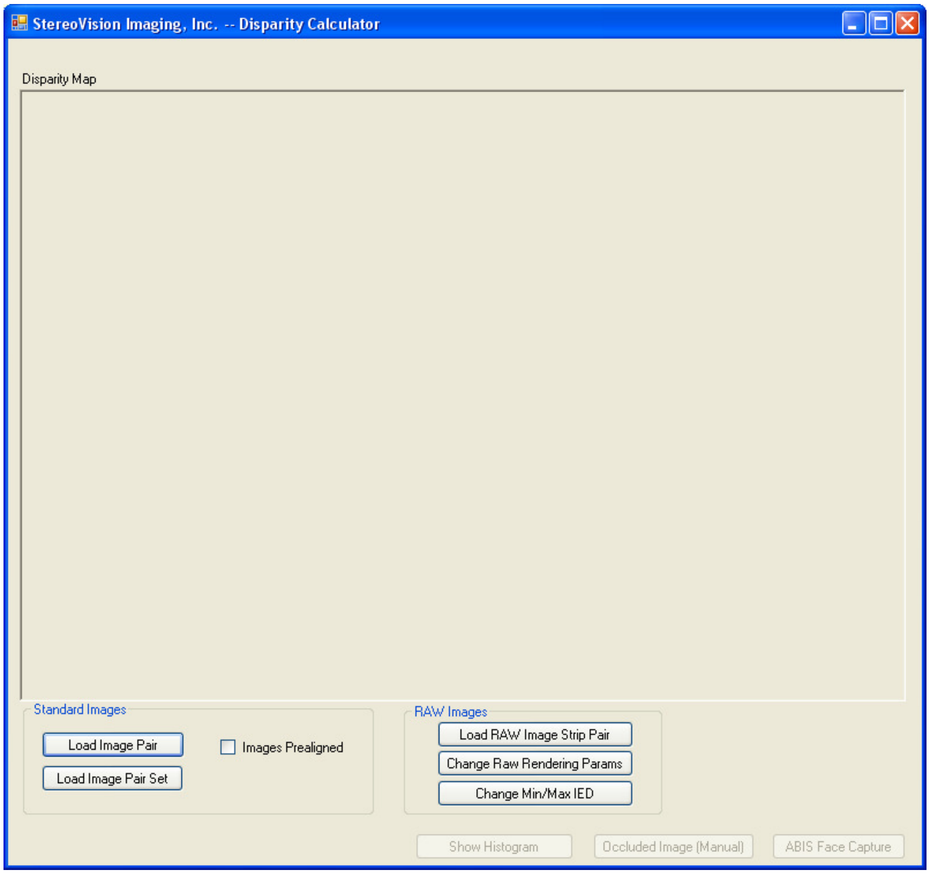


Figure 3

After selecting both files, the application will continue processing the image data for each frame in the image strip pair. Upon completion, you should see a window similar to that in figure 4.

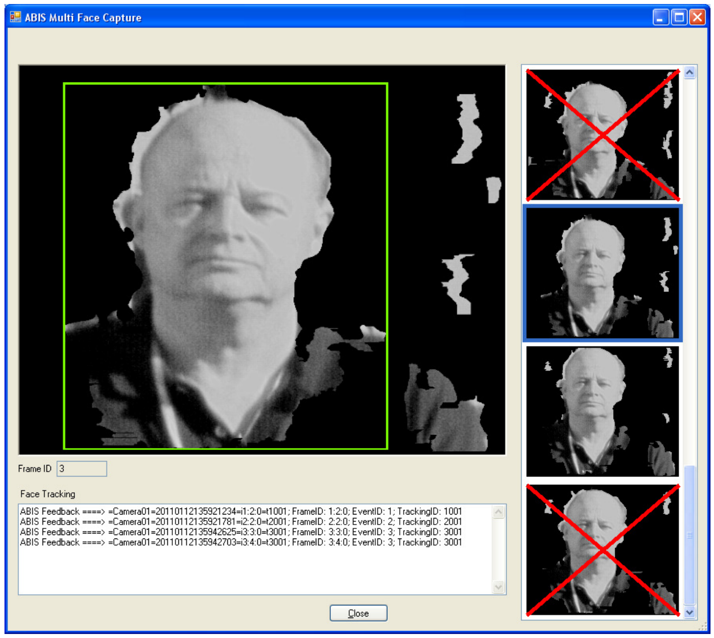


Figure 4

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 15 images displayed on the right side. At the top of the list, the first 5 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 5 frames down are the those taken from RGHTXXXX.VUR raw file. The last 5 frames are those that involve the 3D processing of both LEFTXXXX.VUR and RGHTXXXX.VUR. The window displayed above shows these images.

All 15 of these frames are sent to the ABIS System for identification, just as is done in FRT Tracker. From each set of 5 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 5. 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.

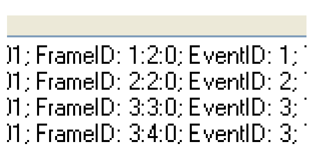


Figure 5

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You'll notice 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 LEFTXXXX.VUR and RGHTXXXX.VUR are saved as standard .tiff image files. Each frame is saved as a separate file. You should see files with the names LEFTXXXX_0.tiff, LEFTXXXX_1.tiff, LEFTXXXX_2.tiff, LEFTXXXX_3.tiff, and LEFTXXXX_4.tiff, located in the same folder as the RAW files that were loaded. The same naming scheme applies for RGHTXXXX.VUR.

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).

The 3D Segmentation Process

The process of segmentation starts off with an image pair. When capturing an image using a stereo camera, you end up with an image from the left portion of the camera and an image from the right portion. What gives us the perception of depth is the spacing between correlating points on both the left and right images.

Left Right

Figure 6

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For instance, if you have a point in a scene that projects light onto a left image sensor and a right image sensor you'll notice that where that point shows up on the left sensor versus the right sensor will depend on its distance from the image sensors. Figure 7 is a top-down view of such a scenario. You'll notice that the light projecting from some point in the distance strikes the left image sensor and right image sensor at different positions. In this case, it strikes the left sensor at a position from the left edge denoted as x_l. It strikes the right image sensor at a position from the left edge denoted as x_r. The difference between these two values (i.e. $x_l - x_r$) is known as the *disparity*.

Figure 8 is a similar view. However, the point in the scene is much closer to the image sensors than that of figure 7. When comparing figure 7 with figure 8, you'll notice that the difference in distance for some point in the scene also results in a difference in disparity. Thus, by calculating disparity for correlating points, we can determine the distance for a point in the scene. This is actually done for all points in a scene generating what is known as a *disparity map*.

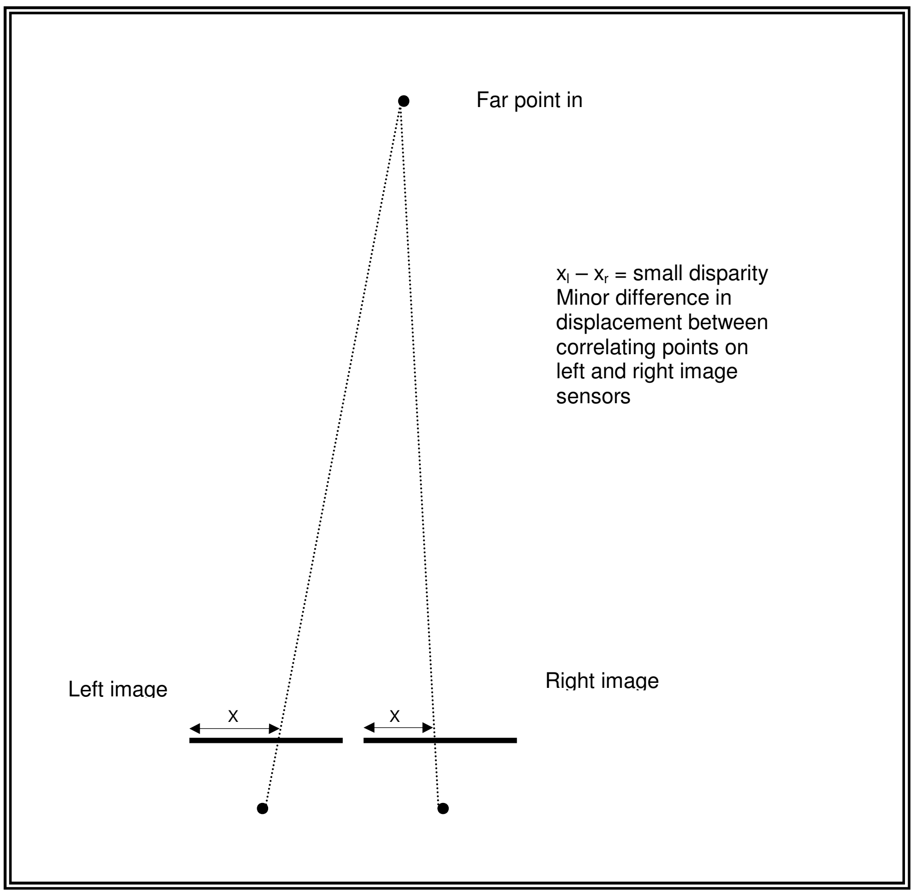

Figure 7

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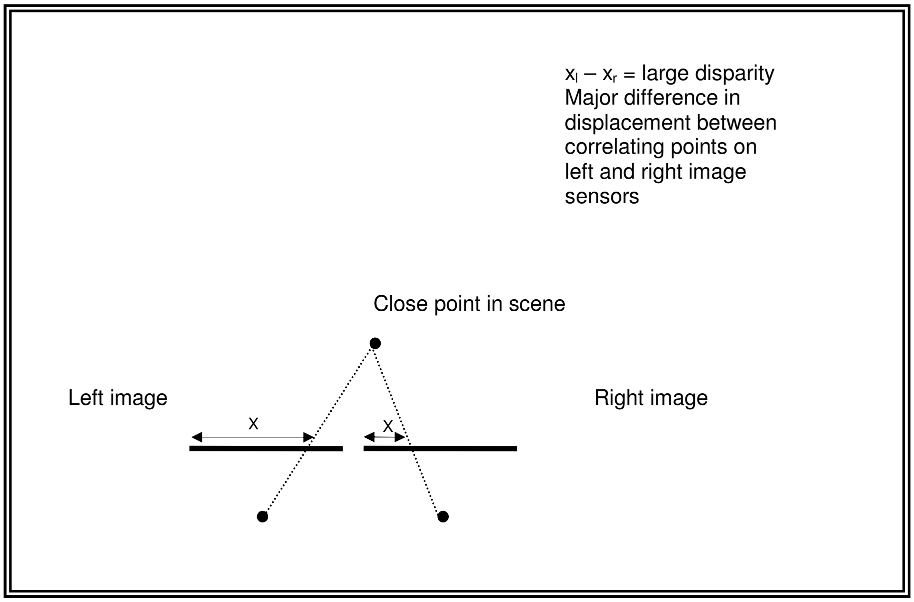

Figure 8

The disparity map can then be displayed with each point's disparity represented as shade of gray in a gray scale format. Figure 9 shows a sample disparity map where the more distant the point, the darker the pixel.

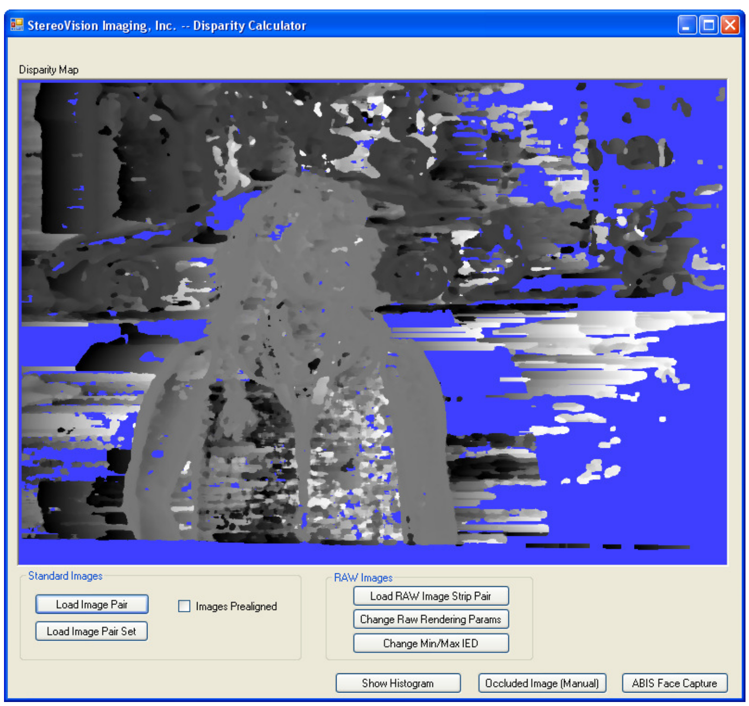

Figure 9

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

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.

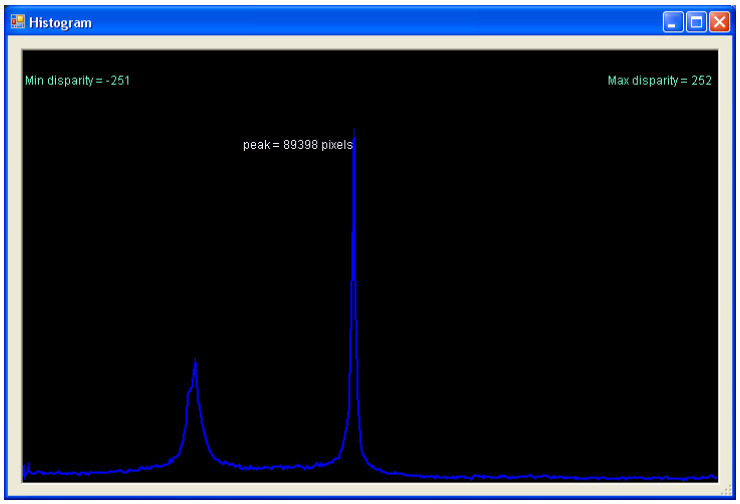

Figure 10

Figure 10 shows the histogram associated with the disparity map from figure 9. You'll notice 2 distinct peaks in this histogram. This can be rendered by clicking on **Show Histogram**. Each of these represent some object (or collection of objects) at a certain distance away from the stereo camera.

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

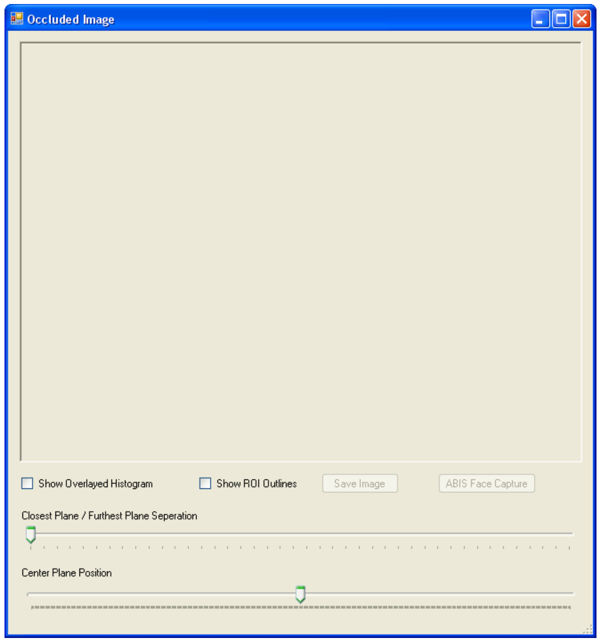

Figure 11

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 12 below shows the original image with no occlusions:

Figure 12

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.

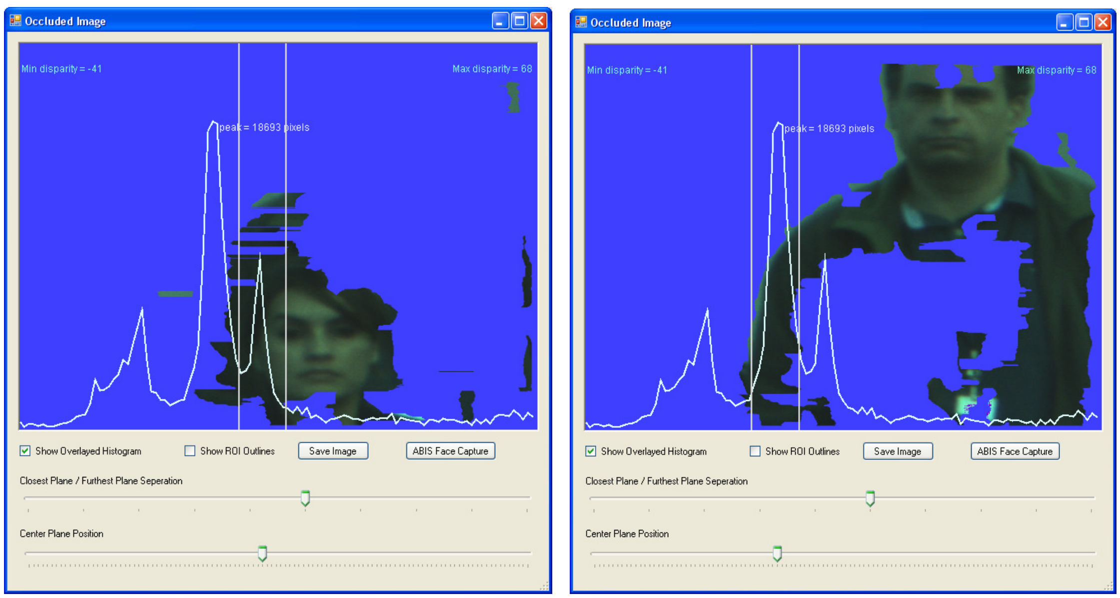

Figure 13

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 I

MANUAL EXPOSURE SETTINGS

Look-Up Chart

CONDITION	MANUAL SETTING	GAIN
Sunny	5-6	0
Partly Sunny	7	0
	7	1
Partly Cloudy	7	2
	7	3
Shade	8	3
	9	3

APPENDIX II

SYSTEM QUICK START-UP GUIDE

FRT 3DVuCAM™ Device

- Place Device on a Tripod Stand & Power Device Utilizing External Battery Back
- Adjust the eye pieces to compensate for the distance between the eyes.
- Place the object of interest within the reticule looking through the 3DVuCAM™
- Adjust the left/ right eye focus using rims on the right eye piece.
- Turn ON the 3DVuCAM™ by pressing POWER button.
- Select the LEFT, UP or DOWN arrow key on membrane pad for a 50, 75 or 100m object capture respectively.
- Select proper exposure by referring to Look-up Chart in Appendix I of User Guide & Selecting proper selection through device menu selecting 'Camera' – 'Manual Exp' and/or 'Sensor Gain'
- Prepare to capture a 3D video clip by pressing SHUTTER button down unit hear first beep.
- Hold the 3D VuCAM™ steady, pointing at what you are focusing, then release SHUTTER button till beep is sounded for capture.

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.

- If directly connected to FRT 3DVuCAM™ double click on the 'SVI FRT Tracker' icon to launch application

  - Select "Start AutoDownload" command button

- If uploading pre-stored (.vur images stored) on the laptop double click on the 'SVI DisparityCalculator' icon to launch application

  - Select "Load RAW Image Strip pair" to upload images

.

Please Note: Example prestored stereo images are found in the C:/IRB Data file. Images should be loaded as right image first then left even though application request vice-versa.