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ScienceDirect

Procedia Computer Science 159 (2019) 990–1000

Procedia Computer Science

www.elsevier.com/locate/procedia

23rd International Conference on Knowledge-Based and Intelligent Information & Engineering Systems

Design and Development of a Real Time Vision Enhancement System using Image Fusion – an Algorithmic Approach

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Abstract

The images enhanced in different viewpoints can be registered and fused within surveillance systems. Most of the existing systems are not capable of providing a real-time image fusion. This paper embodies the design and application development of a real-time vision enhancement system using real-time image fusion. In feature-based image registration, corners are extracted, and a suitable transformation matrix is derived with which the unregistered frame is transformed. The transformed register- and reference frames are fused with discrete wavelet transform (DWT) based on maximum selection image fusion algorithm. These algorithms are implemented and validated using MATLAB/Simulink. The developed vision enhancement system provides 30 fps, and it is jitter free. The response time of the developed system is 155ms. The execution time of an un-optimized and implemented real-time image fusion algorithm on the DM642 processor stretch to 770ms. A unique experimental setup designed has enabled us to achieve an optimum vision enhancement for security and surveillance applications. The algorithm is further optimized to provide us an average execution time of 740ms. The development of the system is extended to two dissimilar cameras moving in different directions. In the current research, the feasibility and applicability of the real-time vision and fusion systems are explored in various security and surveillance application scenarios.

Keywords: DM642EVM Processor; Image Fusion; Image Registration; Vision Enhancement System; Security Systems

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1. Introduction

Vision-based surveillance has become an important security feature in recent years in crowded areas because of increasing awareness of security threats. Due to non-uniform lighting conditions in such areas, vision and image

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10.1016/j.procs.2019.09.266

enhancement play vital roles. In image fusion analysis, vision enhancement plays a vital role in diversified domains and applications of vision research. Broadly, the domains include medical imaging, microscopic imaging, remote sensing, computer vision, image processing, robotics, geosciences and robot vision. By obtaining information from one or more cameras and fusing, activities can be monitored in crowded areas, buildings, where surveillance is required as a preventive measure. Various streams of image processing require high spectral resolution in a single image. Thus traffic monitoring system and long-range fusion systems use different image processing techniques. Most of the existing systems are not capable of providing the kind of information successfully. Thus there is a need for real-time image fusion systems, which require an automated image alignment. Frequent challenges may have arisen when images are taken from spatially distributed sensors or different viewpoints or at different times. They need to be compared and fused periodically. The images need alignments with one another so that those differences can be detected in the associated image alignments. We address the issues of many related design specifications, by developing a robust system, to achieve an image registration [10] and performance as required in security applications.

The research focuses on real-time image fusion, providing vision enhancement by using specific image registration and fusion algorithms in step by step manner. The main applications motivating this paper are a) Medical imaging, b) Military and Traffic Surveillance Systems and c) Multi-sensor data fusion systems. Particular applications mentioned are remote sensing, medical diagnosis, surveillance systems, and pattern recognition. They illustrate several motivating applications, such as the state-of-the-art for image fusion:

1 Medical Imaging: Image Fusion has got wide importance in medical imaging and diagnosis purpose. For example in medical science magnetic resonance image (MRI) provides more information on anatomical structures whereas computed tomography (CT) offers detailed structures inside the body. So by fusing both images using image fusion techniques information from both of the scans can be easily analysed; hence this application provides a better diagnosis.
2 Surveillance Systems: Surveillance systems are gaining a lot of attention these days where image fusion is a crucial factor. Various places like malls, open streets, banks widely use large surveillance camera technology systems for closely monitoring crimes, as a preventive measure including traffic watcher.
3 Multi-Sensor Data Fusion Systems: Images from various sensors (cameras) are fused for better information which is not possible by analysing single sensor images. A variety of applications like law enforcement, security, medical diagnosis, monitoring environment, mineral resources identification uses this multi-sensor fusion technique. For example in night-time charge-couple device (CCD) cameras can capture only visual information and IR cameras give rich information only of high-temperature objects whereas fusion of two videos provides better perceptibility to the human at any lighting conditions. Hence this multi-sensor fusion detects moving objects during night time in any weather condition.

The paper is structured into various sections, and in Section 1, the topic of research, why it is needed and how it is carried out with the brief methodological solution are described. In Section 2, the existing literature control systems and workflows are discussed. In Section 3, the research issues and objectives are described. The proposed systems and development are discussed in Section 4 with various components of the experimental work. The results and discussions are made in Section 5 with certain conclusions and recommendations in Section 6. The future scope of the research is discussed at the end of the article.

2. Review of the Existing Literature

A new visualization paradigm is described in [18], using multispectral and fusion concepts. Low-level image processing is described in [17, 22]. Their approach is based on a gradient domain technique that preserves important local perceptual cues, avoiding aliasing, ghosting and haloing. We present several results by generating surrealistic videos and in increasing the information density of low-quality night time videos. Several video cubes [8] are analyzed for visualizing the information and its interpretation. Various algorithms [21, 15] are written combining exposure and vision focus. Image enhancement techniques are discussed in [2], providing the significance of image fusion in integrating coherent space-temporal information in the dense form. Methods of image fusion and enhancement techniques are described in [24, 16, 1, 12]. The authors propose an algorithmic approach using a mask pyramid that operate in different scales of the image and improve the fused image quality beyond a global selection rule. They provide several examples of mask pyramid method to demonstrate its performance in a variety of applications. A new embedded system architecture is proposed that builds upon the Acadia® II Vision Processor. A new algorithm is proposed whose objective is to improve the results by combining DCT (discrete cosine transform) with adaptive histogram equalization. The experimental results and their comparisons have shown that the proposed algorithm provides a significant improvement over the existing DCT based fusion techniques. Design and development of holographic sighting system used in the defence industry are provided in [14]. The concepts of holographic sight and its operation including the system design aspects of optical, mechanical and electronic parameters are discussed. The current research aims at to design and develop a real-time embedded vision enhancement system using a step-by-step algorithmic image fusion approach for high-end surveillance/traffic applications. The developed vision enhancement system is expected to be computationally efficient with better response times compared with the existing system.

3. Research Problem and Objectives

Most of the existing systems are not capable of providing a real-time image fusion. There is no unique experimental solution so far in the vision enhancement development in multiple domain applications. We explore new opportunities with varying experimental design specifications. A discrete wavelet transform based-algorithm with new workflows has not been tried so far in computing vision enhancements in the context of surveillance systems. We design the experiments with various workflows for obtaining better execution and response times with multiple orientations of the camera, so that vision enhancements are precise.

4. System Design and Development

We intend to develop a system that follows the criteria and design specifications set, as suggested in the following sections. The Vision Enhancement system should provide greater than 25 frames per second. The execution-time of un-optimized implemented real-time image fusion algorithm on the DSP processor should be less than 1 second, which is satisfactory response time to a user. The average execution time of an optimized real-time image fusion algorithm implemented on a digital signal processor (DSP) should be less than 1 second.

4.1. Top Level Design of Vision Enhancement System

For fulfilling the system objectives, the top level design is planned as shown in Fig. 1.

- *CCD Camera:* It shows the input for the Real-time vision enhancement system developed as Hi Focus Color CCD camera which is moving dynamically). The CCD camera has a resolution of 720 X 480 pixels. The acquisition algorithm implemented on a video processor grabs the frames from this camera.
- *Real-Time Vision Enhancement system:* The real-time image fusion algorithm, which is developed and validated using MATLAB is converted into Simulink model so that it can be dumped on to the DSP Video processor via Simulink coder and code composer studio C code generation. Thus DM642EVM DSP runs this vision enhancement standalone application.
- *DSP Video Processor:* The video processing board used in this application is DaVinci DM642EVM Version 3. It's a higher end processor that consumes low power.
- *LCD Display:* To display the final enhanced fused output, video Colour TFT LCD Monitor is used. It is interfaced to video port 2 of DSP video processor successfully.

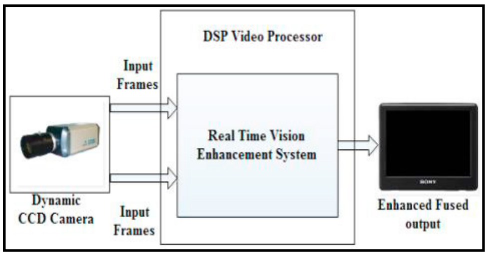

Fig. 1: Top level design of vision enhancement system

4.2. *Low-Level Design of Vision Enhancement System*

We provide the low-level design details of the developed system. The real-time vision enhancement system as shown in Fig. 1 (Top-level diagram) is further divided into sub-blocks as image acquisition, image pre-processing, and image registration and image fusion for getting better results. All these sub-blocks are implemented at algorithm level on the DSP video processor. Then the final enhanced fused video is displayed on a LCD monitor. In the following sections, each sub-block is explained. Fig. 2 shows the complete low-level design details, which are implemented in the following sections.

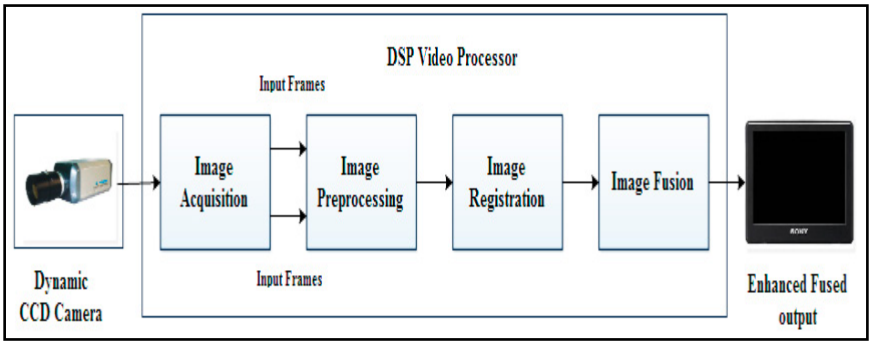

Fig. 2: Low level design of vision enhancement system

The CCD camera is interfaced with the DSP video processor. The image acquisition subsystem initially has to set up with CCD camera properties like brightness, contrast, saturation and resolution, for providing required frames for the next sub-blocks. Then the video frames are captured by an image acquisition subsystem. The pre-processing includes grayscale conversion of frames (so that working on intensity based frames increases the speed of performance), image data type conversions (required as next sub-blocks that can work for only single or double data type frames) and resizing (as they are easy to implement with smaller resolution frames). This is demonstrated in Fig. 3.

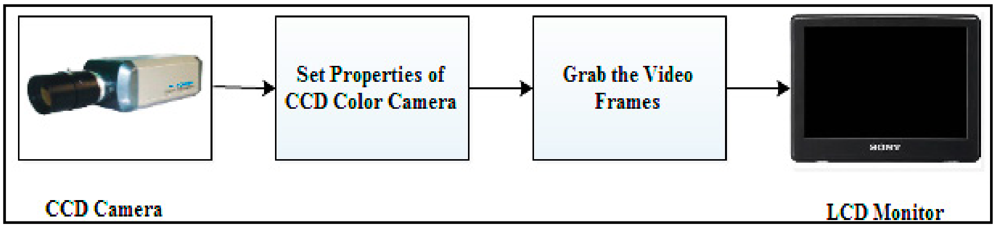

Fig 3. Image acquisition and pre-processing subsystem

The input frames obtained from the pre-processing subsystem are connected to the image registration subsystem for further implementation. Initially, the frames captured from the dynamic camera are given to corner detection block which would detect the maximum required number of corner points from both the frames. These corner points obtained from frames are matched further in corner-matching block for getting putative matching points to get the distance between the frames. Then the distortion between the frames is estimated in transformation estimation block, which would estimate rotation, translation and scale distortion between frames in the form of a transform matrix [10, 9]. The transform matrix is used in geometric transformation and re-sampling blocks. They perform geometric transformation by applying either affine, non-reflective similarity or projective transformations so that both the frames are aligned to the same coordinate system [10]. This is demonstrated in Fig. 4.

The registered frames obtained from image registration subsystem are fed to an image fusion subsystem. In this image fusion subsystem, initially one level two-dimensional discrete wavelet transform of the frames is performed, using the sub-band method by doing row- and column-wise operations to obtain low- and high-frequency components.

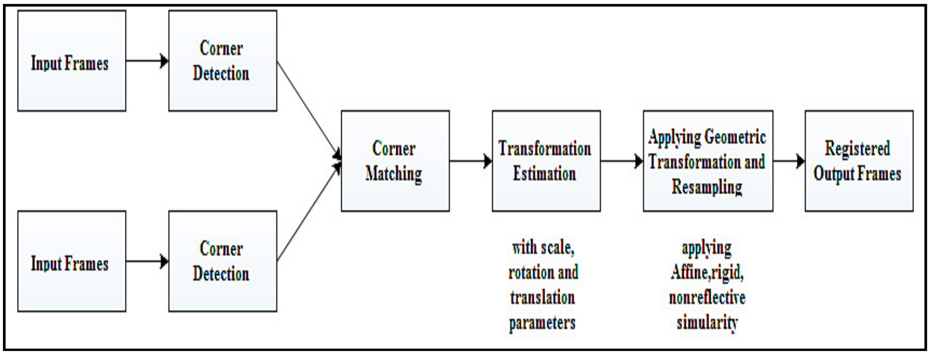

Fig. 4. Image registration subsystem

The pixel-based algorithm is applied for approximations, which involves fusion-based taking on the maximum valued pixels from approximations of wavelet decomposed by sub-bands of frames [4]. Then fusion decision is made for getting a new coefficient matrix. The final fused output is obtained by reconstructing the new coefficient matrix using the inverse wavelet transform [19]. Fig. 5 offers an image fusion subsystem design.

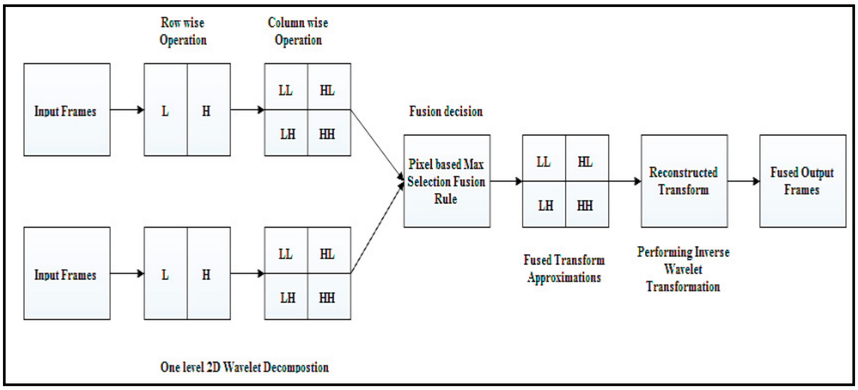

Fig. 5. Image fusion subsystem

4.3. Software Implementation developed of Vision Enhancement System

This section provides the implementation of real-time image fusion in MATLAB for validating the algorithm. Fig. 6 gives flow charts of a developed algorithm that include image acquisition and processing (Figs. 6 a, b and c) steps. Thus the implemented algorithm is validated using MATLAB to develop a standalone video application.

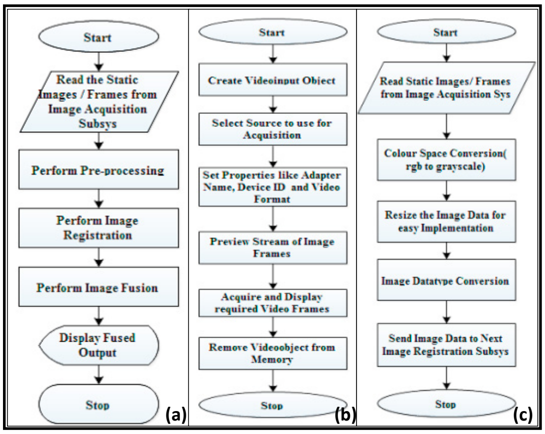

Fig. 6. Flow charts: (a) software for vision enhancement system (b) image acquisition (c) image pre-processing

The implementation starts with reading static images/frames. Next, pre-processing is done using multiple frames. Then feature-based image registration is used for aligning frames to the same coordinate system, which are then fused to get an enhanced output. Video frames are acquired from the recorded video using the data acquisition toolbox available in MATLAB. The acquired video frames are converted into grayscale images and resize to a suitable smaller dimension to speed up the processing time. This part of the section gives a complete detailed flow of image registration.

The system provides the software implementation flow for image pre-processing. Fig. 6c gives the flow of pre-processing performance for acquired input frames. Initially, it starts with reading the static images or frames from the acquisition system (Fig. 6b). Then the static images and frames are converted into grayscale images (intensity frames) as processing intensity images would speed up the process. Ultimately, based on transform estimation, matrix geometric transformation is done to align both frames to the single coordinate system [19].

Subsequently one level two dimension discrete wavelet transform is applied to both reference and registered frames obtained from image registration subsystem. The wavelet transform is obtained by decomposition using row- and column-wise operations. That is, an independent wavelet decomposition of the two frames is performed until level one to get an approximation (LL) and with detail (LH, HL, HH) coefficients. The pixel-based algorithm is applied, which involves fusion-based-take on the maximum valued pixels from approximations of source frames [20]. Then fusion decision is made to select the maximum pixel values thus to get a new concatenated fusion matrix. The final fused frames are reconstructed using the inverse wavelet transform.

4.4. *Hardware Implementation Flow*

In this section, we describe the design and development process, furnishing complete details of a hardware implementation of the vision enhancement using the real-time image fusion application. Simulink is used for implementing real-time image fusion and port it onto the DM642EVM video processor. The designed Simulink model generates C code automatically with the help of RTW and Embedded Coder available in MATLAB/Simulink [3]. Fig. 7 represents an interface mechanism between MATLAB, CCS and DM642EVM DSP. The developed model is ported onto DM642EVM DSP processor with MATLAB Embedded Coder and Code Composer Studio. The ported vision enhancement system is tested for its functionality with various designed test data.

Finally, a code is generated and downloaded in the current project including all board specific header files and source files. This project is built in CCStudio and an output file generated is loaded into DM642 DSP chip, and the project is run for results.

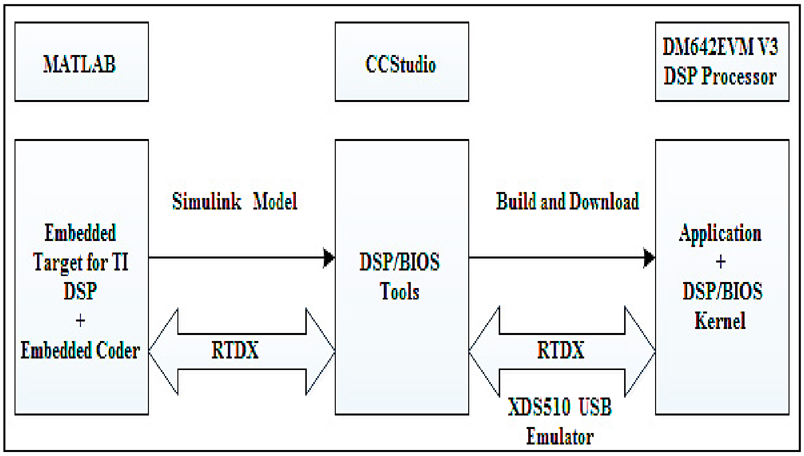

Fig. 7. Interfacing flow between MATLAB (2012), CCS (v3.3) and DSP

4.5. *Simulink Model for Real Time Image Fusion*

As described in Fig. 8, we provide an in-depth view of video registration and fusion algorithm Simulink model, including important blocks in the following sections:

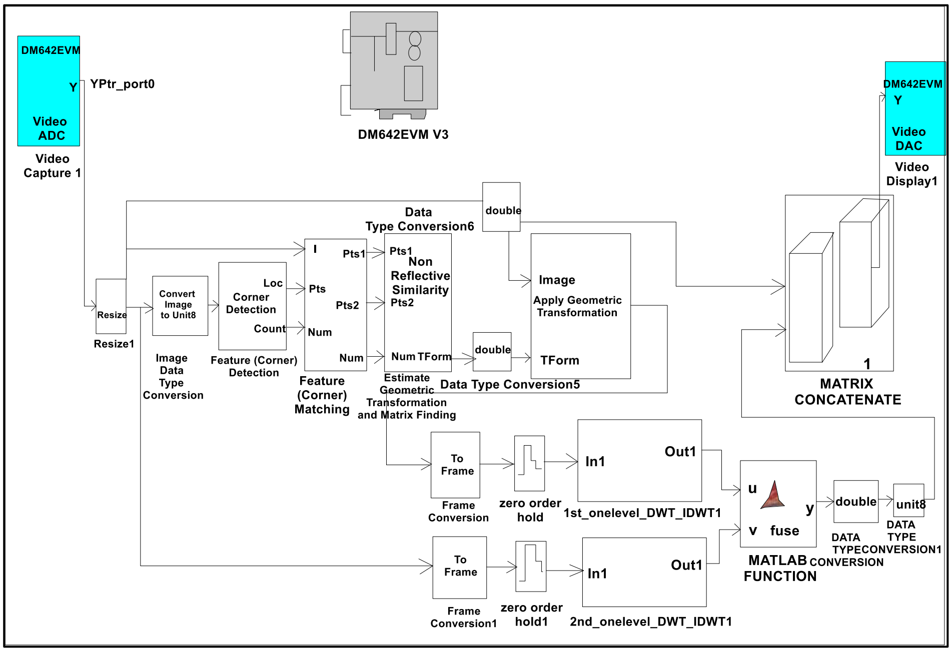

Fig. 8: An overall Simulink model for real time fusion

Video Display Block: It is DM642 EVM Video DAC used for a Video encoder to display video. For this video application block parameters' mode is set to NTSC 720X480 Y.

Corner Detection Block: The module calculates corner metric matrix and finds corners in frames. The block parameters are set as a method to local intensity comparison, intensity comparison to 0.001, maximum angle to be considered at a corner (in degrees):157.5, output to corner location, the maximum number of corners: 150, the Minimum metric value that indicates a corner: 0.01.

Corner Matching Block: It finds out matching corners in the current and previous video frames. The Block parameters are set as block size used in corner matching to 9. The maximum number of points to 150, Maximum feature difference for matching points to 81.

Estimate Geometric Transformation Block Features: This module finds the transformation matrix that maps the largest number of points from Pts1 to Pts2. The block parameters are set as Transformation type to non-reflective similarity, Enable Find and exclude outliners, Method to Random sample consensus (RANSAC), Distance threshold for determining inliers (in pixels): 2.5, Determine the number of random samplings using: Desired confidence, Desired confidence (in %): 99.9, Maximum number of random samplings: 1000 and When Pts1 and Pts2 are built-in integers, set transformation matrix data type to single.

Apply Geometric Transformation Block: It applies a projective or affine transformation to an image. The block parameters are set as Transformation matrix source to the Input port, an Interpolation method for calculating pixel value(s): Bilinear, Background fill value: 0, Output image size and position: same as the input image, Process pixels in the whole input image.

To Frame Block: It specifies the sampling mode of the output signal. For this application, the image fusion sub model accepts only frame based inputs, so this block is set to frame based.

Zero-Order Hold Block: This block is used to convert continuous to discrete signal as DWT block allows only discrete data. Sample time is set to -1 or INF.

DWT Block: This is inbuilt Simulink block used for calculating DWT of input frame or decomposing into sub-bands. The parameters are set as wavelet order to 2, and some levels to 1 and output to single port.

Embedded MATLAB Function: This block is used for implementing image fusion rule of max pixels selection. This is easily implemented, and code generation is done successfully.

IDWT Block: This is an inbuilt Simulink block, used for calculating inverse wavelet transform to reconstruct fused output.

5. Results and Discussions

We test the developed real-time image fusion algorithm, as discussed in the design and development section, with suitable test data, such as static input images, recorded video file frames and with live video frames.

5.1. Presentation of Matlab Results of Static Graphic Images

The developed MATLAB code is tested with various designed test cases on static images and stages of implementation, giving step by step result as shown in Fig. 9. It provides the results of the reference image, unregistered image, registered image and finally fused image.

Fig. 9. Resultant graphic images (a) reference (b) unregistered (c) registered (d) fused

The results are tabulated with calculated image quality metric values as obtained in the final fused output. The calculations provide fused image quality and their distortion estimations. We further discuss the image quality measures as furnished in Table1.

TABLE 1. IMAGE QUALITY MEASURES

Image Quality Measures	Static Images	Recorded video frames (dwt based av. fusion)	Recorded video frames (dwt based max select fusion)
PSNR(dB)	+24.56534	+22.72750	+24.24678
MSE	229.05804	349.72754	228.91583
RMSE	15.13466	18.70100	15.11166
Entropy FO	6.89873	6.91030	6.81177
Universal IQI	0.80632	0.79391	0.88562
EME	11.18711	8.32163	11.10636
PCC(R Vs. F)	14859.8663	14446.19786	16074.22653
SNR(dB)	0.46595	0.37190	0.64738
MAE	5.60040	6.53723	3.08234

5.2. Simulink Results of Live video frames

Fig. 10 provides the screen-shots of results obtained from developed image registration and fusion Simulink model. It shows the reference and registered frames, which are output to the image registration subsystem and with final fused output. Thus the video frames from a live webcam (image acquisition system) are tested with various designed test cases on the developed Simulink model.

Fig. 10. Graphic frames (a) reference (b) registered (c) fused

5.3. *Performance Analysis*

We analyse the performances by comparing the average execution time of optimized and un-optimized video registration and fusion code. Table 2 provides the comparisons. If mixed units are used, the units for each quantity are explicitly stated in the equation given in [16, 2].

TABLE 2. PERFORMANCE COMPARISON ANALYSIS

Video Registration and Fusion	Average Execution Time (m sec)
Un-optimized code	770
Optimized code	740

- Since DM642 Video Display block (Video DAC) is used with NTSC mode set and dumped on the Video processor, confirming that the developed Vision Enhancement system gives 30 Frames per second that met the system specifications, as considered.
- The Response time of the developed Vision Enhancement system is obtained as 155ms (milliseconds).
- The developed system is jitter free as the priority of video processing task spawned is set as 15 to give the highest priority and no other high priority tasks are present for preemption.
- The average execution time of un-optimized Real-time image fusion algorithm implemented on the DSP processor is 770ms.
- The average execution time of optimized real-time image registration and fusion algorithm implemented in the DM642 Video Processor is 740ms.

6. Conclusions

In this paper, we develop the vision enhancement system and implement on the DM642EVM Video Processor for surveillance applications. The feature-based Image registration and DWT based maximum selection image fusion are used for vision enhancement purpose.

The developed real-time image fusion algorithm is tested and validated for static images, recorded video frames and live video from webcam using MATLAB/Simulink. Also, the image quality metrics like PSNR, MSE, IQI, Entropy, are calculated for showing the quality of the fused image output. Then the developed model is ported onto the target DM642EVM V3 Processor and Code Composer Studio.

The developed vision enhancement system gives 30 frames per second. The wavelet transformed images have very good spectral quality, justified by the image quality measures calculated. The developed vision enhancement system on the DM642 Video processor is computationally efficient with a response time of 155ms for the user. The un-optimized and optimized real-time image fusion algorithm implemented on the DM642 processor gives the average execution time as 770ms and 740ms respectively.

7. Future Scope and Opportunity

Real-time and low power embedded video processors have delivered applications of location awareness and enhancement. The processors support the integrated surveillance and processing requirements for weapon mounted locations, handheld ranges and target finders, unmanned air or ground platforms. Real-time visualization of objects is an important aspect in which a feature needs an interpretation without fuzzy. Remote sensing and interpretation of satellite imageries have several applications too to remove such ambiguities. Aerial surveillance, multi-sensor vision and enhanced fusion vision system are needed in military applications. Real-time embedded vision has applications in the airborne surveillance applications such as search and rescue missions, border security, wildfire and oil spill detection, target tracking/detecting such as drugs and weapons within baggage at the airports.

Acknowledgement

We express our sincere gratitude to Professor N. D. Gangadhar, HOD, CE and S.N. Nagananda Asst. Professor-EEE, M. S. Ramaiah School of Advanced Studies, Bengaluru, India for their timely guidance and assistance. We acknowledge Chandan N, Department of Computer Engineering, MSRSAS, Bangalore, India and Naveen K.S, System Controls Technology Solutions Private Ltd, Bangalore, India for their contributions and discussions.

References

[1] Bedi S.S, Agarwal Jyoti, Agarwal Pankaj, (2013) "Image fusion techniques and quality assessment parameters for clinical diagnosis: A Review", International journal of advanced research in computer and communication engineering Vol. (2), issue 2, pp. 1153-1157, February 2013.

[2] Burt, P. Zhang, C. and Van der Wal, G. (2007) Image Enhancement through Contrast Normalization," Military Sensing Symposium, February 6, 2007.

[3] Chandana, M. S. and Naveen, A.K. (2011) A Hybrid Multi-focus Medical Image Fusion Based on Wavelet Transform", *International Journal of Research and Reviews in Computer Science* 2(4), pp. 948, 2011.

[4] Castro, E. D. and Morandi, C. (1987) Registration of translated and rotated image using finite Fourier transform", *IEEE Transactions on Pattern Analysis and Machine Intelligence* 9(5), 700–703,1987.

[5] Deepali, A.G. Dattatraya, B. S. (2011) Wavelet based image fusion using pixel based maximum selection rule", *International Journal of Engineering Science and Technology,* 3(7), pp. 0975-5462, 2011.

[6] Flusser, J. and Zitova, B. (2003) Image registration methods: a survey", *Image and Vision Computing* 21, pp 977–1000, 2003.

[7] Hall, D.L. Liggins, M. E. and James, L. (2008) Handbook of Multisensory Data Fusion Theory and Practice", 2 edit. CRC Press, 2008.

[8] Klein, A.W. Sloan, P. Finkelstein, A. and Cohen, M. F. (2002) Stylized video cubes. In ACM SIGGRAPH Symposium on Computer Animation, 15–22, 2002.

[9] Kumar, S. D., and Parsai, M. P. (2012) Different Image Fusion Techniques –A Critical Review", *International Journal of Modern Engineering Research (IJMER)* 2(5), pp 4298-4301, 2012.

[10] Li, H., Manjunath, B.S. and Mitra, S.K. (1995) A contour-based approach to multisensory image registration", *IEEE Transactions on Image Processing* 4(3), pp. 320–334, 1995.

[11] Manjunath, B. S. Chellappa, R. and Malsburg, C. (1992) A feature based approach to face recognition", *IEEE Conference on Computer Vision Pattern Recognition*, pp. 373–378, 1992.

[12] Mohamed, M. A., and B. M. El-Den. (2011) "Implementation of image fusion techniques for multi-focus images using FPGA", IEEE 28th National Radio Science Conference (NRSC), Cairo, pp. 1-11, 26-28 April, 2011.

[13] Naidu, V.P.S. and Rao, J.R (2008) Pixel-level Image Fusion using Wavelets and Principal Component Analysis", *Defence Science Journal* 58(3), pp. 338-352, 2008.

[14] Nimmagadda, R. M, Kumar, P.R., and N. Raghavender, N., (2010) Design and Development of Holographic Sighting System used for small arm weapons in Close Quarter Battle situations, 4th IEEE International Conference on Digital Ecosystems and Technologies (IEEE DEST, 2010).

[15] Pei, Yijian, Huayu Zhou, Jiang Yu, and Guanghui Cai, (2010) "The improved wavelet transform based image fusion algorithm and the quality assessment", IEEE 3rd International Conference on Image and Signal Processing (CISP), vol. 1, pp. 219-223, 16-18 Oct. 2010.

[16] Singh, J. and Banga, V.J, An Enhanced DCT based Image Fusion using Adaptive Histogram Equalization, International Journal of Computer Applications (0975 – 8887) Volume 87 – No.12, February 2014 Amritsar, Punjab, India.

[17] Smith, S. and Brady, J. S. (1997) A new approach to low level image processing. Int. Journal of Computer Vision 23, 1, 45–78, 1997.

[18] Socolinsky, D. and Wolff, L. (1999) A New Visualization Paradigm for Multispectral Imagery and Data Fusion. In Proceedings of IEEE CVPR, 319–324, 1999.

[19] Sroubek, F. Flusser, J. Zitova, B. (2010) Image Fusion: Principles, Methods, and applications", *International Conference on Computer Graphics and Imaging,* pp. 800–870, 2010. -19

[20] *Spectrum digital DM642EVM DSP Video processor Technical Reference Manual, Rev. B,* 2011.

[21] Sufi, A. Zhang, D. C. and Van der Wal, G. (2011) A Single Algorithm Combining Exposure and Focus Fusion," ICIP, Brussels, Belgium, September, 2011.

[22] Van der Wal, G. S. (2010) Technical Overview of the Sarnoff Acadia II Vision Processor," SPIE Defence, Security, and Sensing Conference, Subconference 7710: Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications, Orlando, April 2010, Proc. SPIE 7710, (2010).

[23] Vekkot, S. and Shukla, P. (2009) A Novel Architecture for Wavelet based Image Fusion", *World Academy of Science, Engineering and Technology* 57, pp. 372-377, 2009.

[24] Zhang, D. C. Chai, S. and Van Der Wal, G. (2011) Method of Image Fusion and Enhancement Using Mask Pyramid, 14th International Conference on Information Fusion Chicago, Illinois, USA, July 5-8, 2011.