

IMAGE REGISTRATION IN LOW RESOLUTION VISUAL SENSOR NETWORKS

A Thesis by

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The following faculty have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Electrical Engineering.

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DEDICATION

To My Academic Ladder

Vikaasa
Stafford International
Mahatma Gandhi Centenary Vidyalaya
G.D Matriculation Hr Secondary School
Sri Krishna College of Engineering and Technology
Wichita State University

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“When you want something, all the universe conspires in helping you to achieve it.” - Paulo Coelho.

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ABSTRACT

Image registration is the process of integrating data from different coordinate systems into one coordinate system. It is of great interest in video surveillance because of its capability to combine images and generate a larger view of the area under observation, while retaining all the information in the images. This thesis proposes a novel method for registering images obtained from low resolution visual sensor networks by using change detection as a tool for image registration. Two sensors with overlapping fields of view are used to capture images at regular intervals. The images differences are found and significant change is identified using a random threshold. This significant change forms the basis of identifying control points. Once the control points are identified then, the reference image is transformed with respect to the base image using affine transformation. The transformed image and base image are stitched together to obtain the registered image. Experiments using the proposed scheme have shown that precise registration can be achieved.

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Chapter 1

Introduction and Preview

1.1 Introduction

Image registration is the process of integrating data from two images in different coordinate systems into one coordinate system. Registering images results in an increase in resolution of the image, amount of information content about the scene under consideration thus aiding image processing tasks such as object recognition, change detection and face recognition [1]. Image registration has many potential applications such as stereopsis, medical imaging, remote sensing and video surveillance. Amongst these, video surveillance is one of the most important applications of image registration. Video surveillance is important for securing restricted indoor regions in places such as museums, banks, etc. Monitoring such areas is computationally a very intensive task considering the number of sensors that have to be deployed and the amount of time the system needs to spend. Hence, a system that can reduce the amount of information needed to be viewed is mandatory. This thesis work proposes one such algorithm that automates surveillance and makes the process more human friendly.

1.2 Problem Description and Significance

Surveillance over particular restricted regions in places such as museums, banks, etc can not just be accomplished with the help of one sensor. This is due to fact that the entire area cannot be encompassed in the field of view of one camera. This limitation calls for the usage of wireless multi sensor surveillance systems with overlapping fields of view. Monitoring of these systems would be more effective if the multi sensor data is fused together to provide complete information about the area being surveyed. In order to obtain a single image comprising all the information content without any loss, the images have to be registered. Registration is the process of integrating images together by transforming them from their local image coordinates to one common coordinate system.

Many algorithms have been proposed to register images from different sources. In this thesis we propose an algorithm that makes use of change detection as the basis for image registration. Changes in images can be found in many different ways. Here we use the simple and most effective way of image differencing to find the changes in images from sensors with overlapping fields of view. These changes in the images are used to identify the control points and consequently register images. The challenge here lies in identifying the control points and finding their correspondence, especially when the images are of very low resolution.

1.3 Visual Sensor Networks

Visual sensor networks are a group of sensors deployed in an indoor or outdoor area that needs to be monitored. The network can be either centralized or distributed. In a typical outdoor video surveillance set up, high resolution cameras are deployed

over areas of interest. These kinds of sensor networks are needed in busy outdoor scenarios where the content of interest in each frame is very high. A major problem with such systems is monitoring and analyzing the data. It becomes a herculean task to transmit, store and analyze the enormous amount of data. In indoor places like museums, banks, etc where there is not much activity, if a sensor network consisting high resolution video cameras as nodes are deployed, then there will be lot of redundant data with limited information content of interest. In such scenarios, sensors with low resolution connected wirelessly to a computationally powerful base station can be deployed. These sensors along with the host machine take images only when needed. This significantly reduces the data that must be processed and also aids the energy constrained sensors nodes to work for longer periods of time.

One of the best examples of a low resolution, computationally powerful sensor board is Stargate, developed at University of California at Los Angeles (UCLA) and licensed to Crossbow for manufacturing. Figure 1.1 shows the stargate board. Figure 1.2 shows the stargate board and web camera that form a very efficient sensor node in indoor scenarios where the activity is usually very limited. The combination of Stargate board and the web camera makes the sensor network computationally powerful and efficient. The Stargate sensor boards are connected wirelessly to a host machine which acts as the base station for the sensor network. The sensor is a low resolution conventional web camera with limited field of view. Due to its low resolution, the web camera can take images with limited clarity only. Figure 1.3 shows an image acquired by the Stargate sensor board.

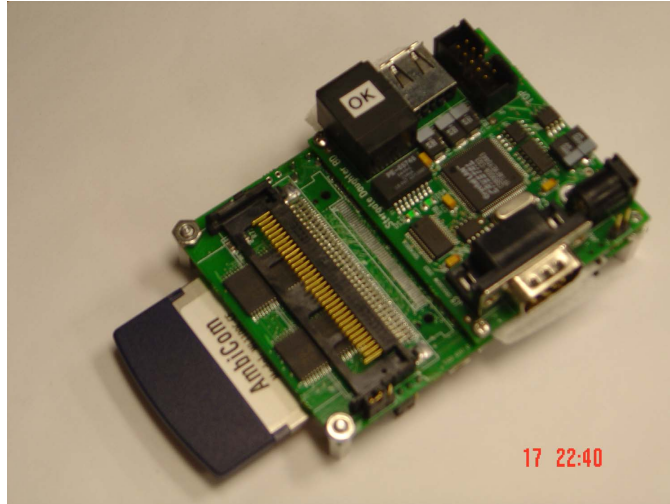


Figure 1.1: Stargate board, a computationally powerful single board computer developed by UCLA and licensed to Crossbow for production.



Figure 1.2: This figure shows the stargate sensor board connected to a web camera that together form an image sensor node.



Figure 1.3: Image taken using the Stargate sensor board.

1.4 Image Registration and Applications

Image registration is a classical problem in the field of image processing. It is primarily used to match or combine two or more pictures taken at two different instants of time, or using two different sensors, or from two different view points [2]. Registration allows to bring two images that are in different coordinate systems into the same coordinate system. Image registration can be classified into two major types. In the first type we have two kinds of registration, multimodal and template . Multimodal registration is registering images of the same scene taken using two sensors, whereas template registration is finding a match for a particular pattern in an image. In the second type we have two classifications which are viewpoint registration and temporal registration. Viewpoint registration deals with registering images taken from different view points, whereas temporal registration relates to registering images of the same scene taken at different times or under different conditions. Image

registration is widely used in many different applications. Specific examples include matching of images for target recognition, combining images from different sensors to get a high resolution image, matching of specific geographical locations from different satellites to get more details about one particular area and in medical diagnosis to get a clearer view for effective diagnosis.

1.5 Application in Visual Sensor Networks

With the advent of a variety of sensors with different capabilities, the need to efficiently process and comprehend the information obtained is vital. The conventional method of monitoring the area of interest using CCTV has become very outdated. The intervention of visual sensors networks, calls for the need to effectively combine the information obtained from different sensors to get one image that has all the needed information from all sensor nodes, instead of having multiple images from each sensor. This necessity leads to image registration, which can be used to combine all the needed information from each image to generate a complete view of the area under surveillance. It will have more information than images from a dome camera in which most of the information in the ends are lost and even the available data is not precise enough to be used for further processing. Image registration can be used to register images of both indoor and outdoor scenarios.

1.6 Major Contributions

In this thesis, a novel algorithm to register two images obtained from two wireless visual sensors has been proposed. The major idea behind this is the usage of change detection for image registration that significantly reduced the complexity

of the registration process.

A wireless visual sensor network with two Stargate sensors was deployed to observe objects of interest. The position of one sensor with respect to the other sensor was not considered. No a priori information regarding the sensor network or sensors was considered. The images of the objects were acquired at time instants t_1 and t_2 by both the sensors. The difference of the images was found and a random threshold was selected to identify just the significant changes in the scene from time instant t_1 to t_2 . The obtained change pixels were dilated to form blobs whose center was chosen as control points. The control points from both the sensor images were compared to find the best correlated points. Once the corresponding control points were obtained the images were transformed using affine transformation that best preserves the information content in them. The transformed images were stitched together to obtain a single image that contained all the information from both the sets of images.

1.7 Thesis Organization

This thesis is divided into 5 chapters. Chapter 1 provides an introduction to the problem being discussed, visual sensor networks, image registration and its application in visual sensor networks. It also discusses the contributions of this thesis. Chapter 2 gives a detailed literature survey in the field of image registration and visual sensor networks. Chapter 3 discusses the theoretical model for the proposed problem. Chapter 4 presents the experimental set up and discusses the results obtained using the proposed algorithm. Chapter 5 gives the conclusions and the scope for future work.

Chapter 2

Literature Review

Image registration is a well understood topic in the image processing literature. It primarily deals with combining images to generate one image that has all the information from the individual images. Image registration has been discussed with respect to many divergent fields. It has been used as a component in variety of applications such as target recognition, remote sensing, stereopsis and medical imaging [1]. A review of recent as well as classic image registration methods is also presented in [2].

2.1 Classification of Image Registration

The registration problem can be divided into two major classes. The first type in the first classification comprises of multi modal registration, which is registration of images of the same scene acquired from different sensors. This is generally used for integrating information obtained from different sensors in order to get improved segmentation and pixel classification. This is widely used in remote sensor data processing. The second type in the first classification is template registration that deals with finding a match for a reference pattern in an image. Typical application include recognizing a pattern, object or model in an image. This is mainly used in

pattern recognition. The second classification includes view point registration dealing with registration of images from different view points and temporal registration to achieve registration of images of the same scene taken at different times or under different conditions. View point registration is generally used to find out the depth of the object or used for reconstruction of shape. It is mainly used in computer vision. Temporal registration is generally used for detection and monitoring of changes or growths. Medical image analysis is a primary application. [1] [2].

2.2 Different approaches to Image Registration

Registration process requires identification of similar areas from different images. Techniques like entropy, mutual information, cross correlation, etc, are used to identify potential similar areas in the images while registering them. An entropy based registration of overlapping views from different cameras, with no a priori information has been proposed in [3]. This algorithm deals with scenarios where there is plenty of motion and change. It is divided into three major steps. In the first step the important features are extracted using change detection followed by entropy based selection and lastly extraction of areas of concurrently changing pixels. The next step is extraction of corresponding feature points between the two images. The final step includes matching of points by rejecting outliers and stitching the images together. Mutual information is used as the basis for image registration in [4]. In this approach, they have assumed that a vector composed of spatial information and intensity has normal distribution. The vector of each corresponding pixel pair is calculated and the mean, variance, covariance and the entropy are also found. Based on the obtained values the mutual information of the two images are found and the images are registered using

that information. In the field of medicine, mutual information is used to register images for detailed diagnosis. A new adaptive framework for local image registration has been proposed in [5]. This compensates all the local distortions and displacements. They use a 2-D adaptive filter framework to identify locally varying system parameters. At each pixel they find the adaptive filter coefficients that adhere to local displacement vector. Then compensation of those fields is done to aid registration. This algorithm mainly aids reliable detection of watermarks while registering, compensate for lens distortion and align multi view images. Another image registration technique based solely on compression of images is discussed in [6]. The reference image is compressed given the information of the base image and the images are then registered based on similarity metrics. Similarity metrics, Kolmogorov version based on standard real world compressors and Shannon version calculated from estimating the entropy rate of images are used to register the images. A novel algorithm to stitch images to obtain a cylindrical panoramic view has been discussed in [7]. This technique is primarily based on affine transformation and refocusing the camera on the strip in the image where the actual merging is taking place.

2.3 Image Registration in Remote Sensing

Registration of images from remote sensors and satellites is a very important application in image processing and it has its own challenges and demands. Two contour based approaches to image registration is discussed in [8]. One is based on identification of region boundaries and the other is based on identification of edges to match images. These algorithms are mainly for registering multi-spectral and multi sensor images. The first algorithm can be used for registering images such as Landsat and

Spot satellites in which the contours are well preserved. It is based on chain code correlation and shape similarity criteria such as invariant moments. Closed contours and open salient segments along the open contours are matched separately. The next algorithm is an elastic contour matching scheme based on active contour model. This technique is generally used for registering optical images with synthetic aperture radar images. A detailed study of various registration algorithms in remotely sensed images has been presented in [9]. As a first step in integrating multiple registration algorithms into a rule based artificial intelligence systems, this paper presents particular techniques for remote multi sensor image registration. In the same paper techniques such as Intensity-Hue-Saturation (IHS) are discussed and arguments on why a single algorithm cannot effectively produce a good registration result in remote sensor imagery and why algorithms have to be combined to get the desired results are presented. A survey of image registration in remote sensing and design and development of different components of registration has been presented in [10]. In this paper, the authors have also developed a web based application to register images acquired by different remote satellite sensors. They divide the registration process into three components, namely feature extraction, similarity measure and strategy for registration. They do a detail survey and try different combinations of various available methods in each of the above mentioned components. Based on this study, they provide 3 registration methods to choose from in their web based image registration tool box for registering remote sensor images. An automated image registration method for high resolution satellite images is discussed in [11]. Hierarchical image matching has been used for registering images. A hierarchical pyramid is used for feature matching in order to enhance the accuracy of the matching algorithm and also to reduce the

computational complexity.

2.4 Medical Image Registration

Medical image registration is a large field and is of considerable importance in detailed diagnosis in a patient. A detailed survey of medical image registration techniques is presented in [12]. Nine criteria are used to divide the medical image registration techniques. They are Dimensionality, Nature of registration basis, Nature of transformation, Domain transformation, Interaction, Optimization procedure, Modalities involved, Subject and Object. These nine criteria cover all possible image registration techniques that has evolved so far. A method for image registration in medical imagery by enhancing mutual information is presented in [13]. This technique is best for registering images from MRI and CT scans of the skull. As the preprocessing step, the noise is removed and the images are normalized to the same size. Then the initial point is found out with the help of center of gravity of the image and then the images are registered by maximizing the mutual information.

2.5 Visual Sensor Networks

Visual sensors are increasingly being used in all kinds of applications. A sensor can be a high resolution camera or even a web camera. Multi tier sensor networks, in which different types of sensors are deployed at each level are becoming increasingly popular [14]. A multi tier system may have a very poor resolution cyclops camera as the first tier, a low resolution web camera as the second tier and very high resolution camera with PTZ capabilities as the last tier. Kulkari et al in their paper have discussed the challenges and feasibility condition of a three tier system that consists of vibration

sensors in its first tier, cyclops camera in its second tier and stargate boards attached to web cameras as the final tier. This kind of system helps save power consumption, improves the functionality and helps cover a wider area. Power consumption plays a very critical role in wireless visual sensors. Visual sensors generally consume huge amounts of power since the amount of data transmitted by them is more. Margi et al present a study on the tradeoffs in power consumption, processing time for different tasks in wireless visual sensors networks and analysis of power consumed in [15].

In this thesis an image registration algorithm that uses change detection as a tool for registration, thereby making the entire registration process simple is proposed.

Chapter 3

Proposed Algorithm for Image Registration

Consider a scenario of sensor network in which there are two sensors deployed over a restricted area under surveillance. The two sensors have significant overlap in their fields of view. Other, *a priori* information regarding the position of sensors, height of one sensor with respect to the other, and degree of overlap between the sensors are not considered. The sensors are assumed to be taking images continuously at regular intervals of time. The main aim of the algorithm is to automatically register the images without any manual intervention leading to the creation of a single image that has all the information from the images. The proposed image registration algorithm can be divided into three major steps as discussed below.

3.1 Image Acquisition and Change Detection

Let the two sensors be S_1 and S_2 and the images from S_1 be the base images and the images from S_2 be the reference images. Let, I_{11} , I_{12} be the images acquired by S_1 at time instances t_1 and t_2 respectively. Let, I_{21} and I_{22} be the images collected by S_2 at t_1 and t_2 time instances respectively. All the images acquired are 256×256

in size. In the proposed algorithm change detection is used as the basis for image registration. This helps in identifying control points in the reference and base image to further register the images. Changes may take place due to the appearance or disappearance of objects, displacement in the location of objects and due to motion in the scene. Changes if any, are reflected in the second set of images. Let D_1 and D_2 be the difference images from the two sensors such that $D_1 = |I_{11} - I_{12}|$ and $D_2 = |I_{21} - I_{22}|$. The change are identified using simple image difference method. From the difference, we need to identify location where high changes took place. This is done by setting a random threshold Th_1 for both the difference images. A process for adaptively setting threshold to identify significant pixels is discussed in [16]. If a pixel in difference images exceed Th_1 , then it is considered significant, else insignificant. These images SD_1 and SD_2 which contain significant pixels form the basis for control point selection.

3.2 Control Point Selection

SD_1 and SD_2 are logically divided into $32 \ 8 \times 8$ blocks. Each block is checked for significant pixels. If a block contains a significant pixel, then the number of other significant pixels in its neighborhood of 5×5 window is counted and if the count exceeds 20, then the point is marked as a potential control point. Through this step we identify all the potential control points in each block. In order to avoid clustering of control points, in each block only one control point that has the largest sum of intensity change in its neighborhood is selected as the control point. Let C_{1i} be the control points obtained from SD_1 and C_{2j} be the control points obtained from SD_2 where $i = 1, 2, \dots, n$ and $j = 1, 2, \dots, m$ where n is the total number of control points in

I_{12} and m the total number of control points in I_{22} . The control points may be located in the overlapping as well as non-overlapping fields of view since, change can occur in any part of the image. The use of change detection as the basis of control point selection makes the entire process of control point selection very simple. Once the control points are determined the next step is to identify the correspondence between the two sets. This is done by comparing each control point in the reference image to every control point in the base image. The comparison is done by finding the correlation between every possible pair of control points. The correlation coefficient ($\rho_{C_{1i}, C_{2j}}$) between any two control points (C_{1i} and C_{2j}) can be expressed as

$$\rho_{C_{1i}, C_{2j}} = \frac{cov(C_{1i}, C_{2j})}{\sigma_{C_{1i}} \sigma_{C_{2j}}} \quad (3.2.1)$$

where, $\sigma_{C_{1i}}$ and $\sigma_{C_{2j}}$ are the standard deviations of the pixels around the control point and $cov(C_{1i}, C_{2j})$ is the covariance of considered pair of control points. The points that are best correlated are considered as the corresponding control points. These points are used for transforming the reference image to the same spatial coordinates of the base image. Let LC_{1k} and LC_{2k} be the corresponding control points in the images, where $k = 1, 2, 3 \dots p$ and p is the total number of corresponding points.

3.3 Transformation and Registration

The third step in the proposed algorithm is the transformation of the reference image with respect to the base image. Image transformation can be done using different techniques. In the proposed technique, we use affine transformation. While using affine transformation, parallel lines and straight lines are preserved whereas the x and y dimensions can be scaled and sheared independently. So, considering the

fact that the location and orientation of the sensors with respect to one another are unknown, affine transformation is more suitable in our context. In our case, we know LC_{1k} and LC_{2k} , and the transformation matrix has to be determined. Let $[u_k, v_k]$ be the coordinates of the matched control points in the base image and $[x_k, y_k]$ be the coordinates of the corresponding control point in the reference image. The transformation matrix T is defined as follows,

$$T = \begin{pmatrix} sc & -ss \\ ss & sc \\ t_x & t_y \end{pmatrix} \quad (3.3.1)$$

where $sc = scale * \cos(\theta)$ represents the homogeneous scaling and rotation, $ss = scale * \sin(\theta)$ also represents homogeneous scaling and rotation, θ is the angle of orientation of the control point in the reference image with respect to the control point in the base image and t_x denotes the translation along the x axis and t_y denotes the translation along the y axis [17], [18]. The transformation can be expressed as follows,

$$[u_k, v_k] = [x_k, y_k, 1] * \begin{pmatrix} sc & -ss \\ ss & sc \\ t_x & t_y \end{pmatrix}. \quad (3.3.2)$$

Since there are six unknown parameters, there must be a minimum of three control points to find the transformation. So, we can derive a minimum of six equations from the transformation matrix. Depending on the number of control points, the following equations can be derived

$$u_k = (sc * x_k + ss * y_k + t_x) \quad (3.3.3)$$

$$v_k = ((-ss) * x_k + sc * y_k + t_y). \quad (3.3.4)$$

For example, if there are three pairs of control points in both the images, then there will be a total of six linear equations. In general, the set of linear equation can be written as

$$U = X * T \quad (3.3.5)$$

where U and X represent the control points and T represents the transformation matrix. The transformation matrix can be computed as follows

$$X^{-1} * U = T. \quad (3.3.6)$$

From the transformation matrix, we can determine the location of the sensors and orientation of one sensor with respect to the other. Once the images are transformed the control points in the reference image should be mapped into the transformed reference image in order to register them. This is achieved by applying the first two phases of the algorithm to the transformed images from sensor S_2 . Hereby the control points in the transformed reference image are obtained. Now, the transformed reference image and the base image are stitched together with the help of the control points. The stitching is done by identifying the location of the first pair of corresponding control points in the base image and the transformed reference image. Using this location the images are appended together to get a single image containing all the information from both images.

Chapter 4

Experimental Results and Discussions

4.1 Experimental Set Up

The experimental set up consists of two visual sensors along with a host machine. Each sensor comprises of a Stargate sensor board along with the Phillips Logitech Pro 4000 web camera. Stargate is a powerful single board computer with enhanced communication and sensor signal processing capabilities. It was developed by Intel and was licensed to Crossbow for production [19]. The Stargate board works on LINUX and also supports TinyOS based wireless sensor network technology. The web camera can take images with an image resolution 1.3MPixels. The sensor board can communicate with the host machine in many different ways. The Stargate can be directly connected to a host machine through a serial port, the board can also be connected by giving the board and host machine a static IP address. This way the data from the sensor can be accessed securely by the host machine. The stargate board can also be connected to the internet using an *RJ45* cable and it can be accessed by an internet enabled host machine using MOTEVIEW, which is a GUI used to view

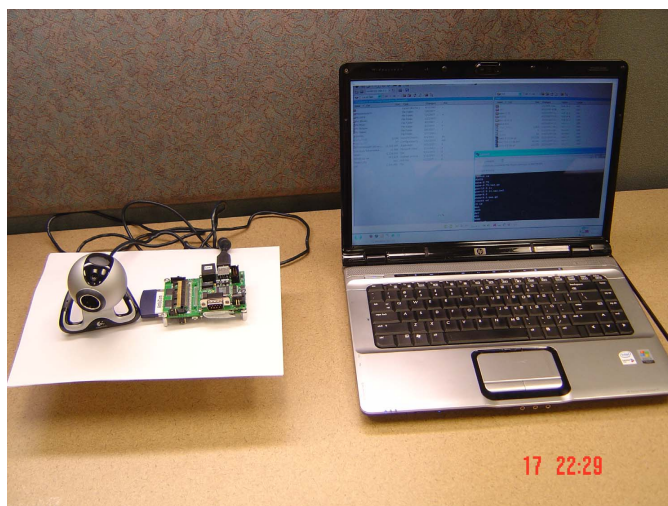


Figure 4.1: This figure shows a stargate sensor consisting of the stargate board and web camera connected to the host machine in a self managed mode.

remote sensor images. In addition Stargate is equipped with an IEEE 802.11a/b wireless card. For the experimental analysis, the sensor board was connected wirelessly to the host machine and the sensor board and the host machine were assigned static IP addresses. It can also be connected to the internet wirelessly. The host machine used for the experiments was a HP Pavilion laptop, with 2G RAM. The images received by the host machine are registered using MATLAB. Figure 4.1 depicts one stargate sensor board and host machine connected wirelessly in a self managed mode.

4.2 Acquisition of Images by Sensors

Two stargate sensors are used to acquire images. The sensors are placed at unknown angles and heights with respect to each other. Each sensor views the objects under observation from a different angle. The fields of view of the sensors



(a)



(b)

Figure 4.2: This figure shows two images (a), (b) acquired from image sensor S_1 . Figure (a) was acquired at time instant t_1 and Figure (b) at time instant t_2 . The second image has some noticeable change, such as displacement in the position of the mobile phone and lock.

had some overlap between them, but the range of overlap was unknown. Also, each sensor takes images at same instants of time. The sensors are controlled wirelessly in a self managed mode using the host machine. The images taken by sensor S_1 and S_2 at time instants t_1 and t_2 are shown in Figures 4.2 and 4.3 respectively. The images acquired by S_1 are termed as base images and those acquired by S_2 are termed as reference images. The first image in the figures is taken at time instant t_1 and the second image is taken at time instant t_2 with some change in it as opposing to the image acquired at time instant t_1 .

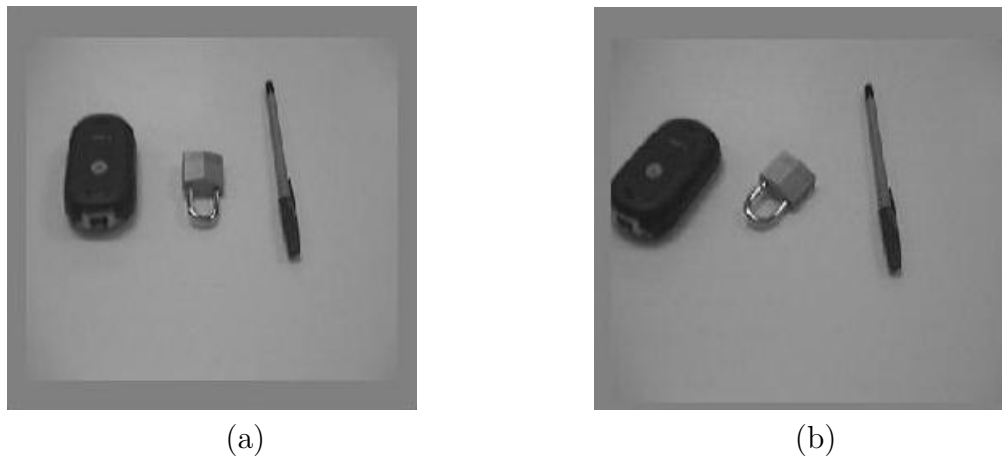


Figure 4.3: This figure shows two images (a), (b) acquired from image sensor S_2 . Figure (a) was acquired at time instant t_1 and Figure (b) at time instant t_2 . The second image has some noticeable change, such as displacement in the position of the mobile phone and lock.

4.3 Change Detection, Control point Selection and Registration

The change in each set of images formed the basis of identification of control points, which are required to transform the reference image with respect to the base image. In order to identify the significant change pixels, a random intensity threshold of Th_1 was set. Pixels having intensity value greater than Th_1 were identified as significant change pixels. Figure 4.4 depicts the significant change images SD_1 and SD_2 .

The significant change image formed the basis of identification of all possible control points in the image. Figure 4.5 depicts all possible control points identified in both images.

It is quite notable that the control points are mostly near the edges and

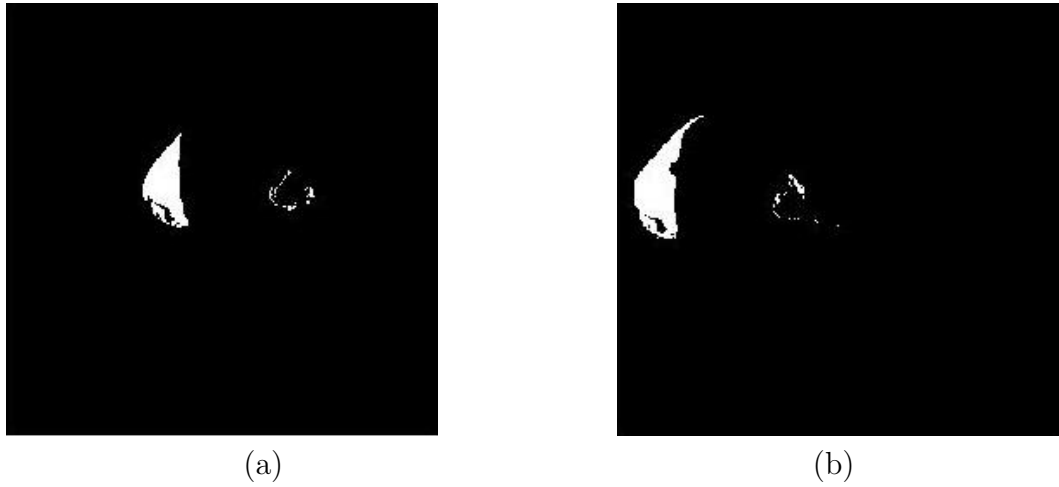


Figure 4.4: This figure shows two images with significant change (a), (b) acquired from image sensor S_2 and S_2 respectively. Significant change in each image was identified using random threshold Th_1 .

there are similar control points in the base and reference image, which is of primary importance to identify the correlated control points.

Figure 4.6 shows the correlated control points in the base image and transformed reference image. The transformed image is obtained by transforming the reference image with respect to the base image using the obtained control points. The best correlated control points identified using correlation coefficient are depicted in Figure 4.6. This image shows three best correlated control points in the base image and transformed reference image.

Figure 4.7 shows the registered images. The images in Figure 4.7 were stitched together using the location of control points. The registered image in Figure 4.7 has all the objects in both the images. From this image it can be observed that control points obtained with change as the basis can be used to register images to a good degree of precision.



(a)



(b)

Figure 4.5: This figure shows two images (a), (b), with all possible control points marked with a “*” on them. It is explicitly evident that the control points are mostly located on the edges and there are similar control points in both the images.



(a)



(b)

Figure 4.6: This figure shows two images SD_1 and SD_2 with best correlated control points marked with a “*” on them. Image (a) is the base image and image (b) is the transformed reference image.



Figure 4.7: This figure shows the final registered image using the proposed image registration algorithm. It can be observed that a good degree of precision can be obtained in registration using this algorithm.

Chapter 5

Conclusions and Future Work

5.1 Conclusion

In this thesis, a novel image registration algorithm based on change detection was proposed. This algorithm can be specifically used for low resolution image sensor networks. The usage of change detection as a tool simplified the image registration process to a great extent. The algorithm used simple image difference and a threshold to detect significant changes in consequent images from each sensor. The control points were then identified by logically dividing the images into blocks and looking for significant change pixels in each block. The obtained set of control points from base image were compared with control points obtained from reference image using correlation coefficient and the best correlated control points were identified. These were then used to transform the reference image with respect to the base image. Lastly, the images were stitched to obtain the registered image having all the information from both input images.

5.2 Future Work

In this thesis, the threshold to identify significant change was set in a random manner. In the future, the algorithm can be modified to use estimation theory to identify separate thresholds for each set of image being registered. The experiments for this work was carried out with the sensors in a wireless self managed mode. Instead, multiple sensors can be made to communicate with the host machine using the internet.

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