Image Registration in Mammography

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Abstract:

Breast cancer is the most common type of cancer affecting women worldwide. Breast image registration, an imaging diagnostic technique plays an important role in the detection and the subsequent treatment of mammographic tumours. This paper gives an overview of various kinds of current state-of-the art breast image registration techniques. A follow-up image feature-based process is also discussed.

***Keywords* – Breast cancer, Correlation, Feature-based , Image registration, , Intensity-based, Modality, Non-rigid, X-ray**

I. INTRODUCTION

IMAGE registration has many uses in medicine such as multimodality fusion, image segmentation, deformable atlas registration, functional brain mapping, image-guided surgery, and characterization of normal versus abnormal anatomical shape and variation. The fundamental assumption in each of these applications is that image registration can be used to define a meaningful correspondence mapping between anatomical images collected from imaging devices such as computed tomography (CT), magnetic resonance imaging (MRI), cryosectioning, etc[29].

BREAST CANCER is the second leading cause of cancer deaths in women today and is the most common cancer among women, excluding nonmelanoma skin cancers. According to the American Cancer Society, about 1.3 million women will be diagnosed with breast cancer annually worldwide and about 465,000 will die from the disease.

Breast cancer rates decreased by about 2% between 1998 and 2007, according to the Society. However, this decrease was only among women aged 50 and older. Deaths from breast cancer have decreased too since 1990, likely from earlier detection and advances in treatment. About 1 in 35 women die from breast cancer in the United States[25].

Probability of Developing Breast Cancer Within the Next 10 years	
By age 20	1 out of 1,760
By age 30	1 out of 229
By age 40	1 out of 69
By age 50	1 out of 42
By age 60	1 out of 29
By age 70	1 out of 27
Lifetime	1 out of 8

Source: Among those cancer free at age interval. Based on cases diagnosed 2000-2002. "1 in" are approximates. Source: American Cancer Society Breast Cancer Facts & Figures, 2008-2009. [25]

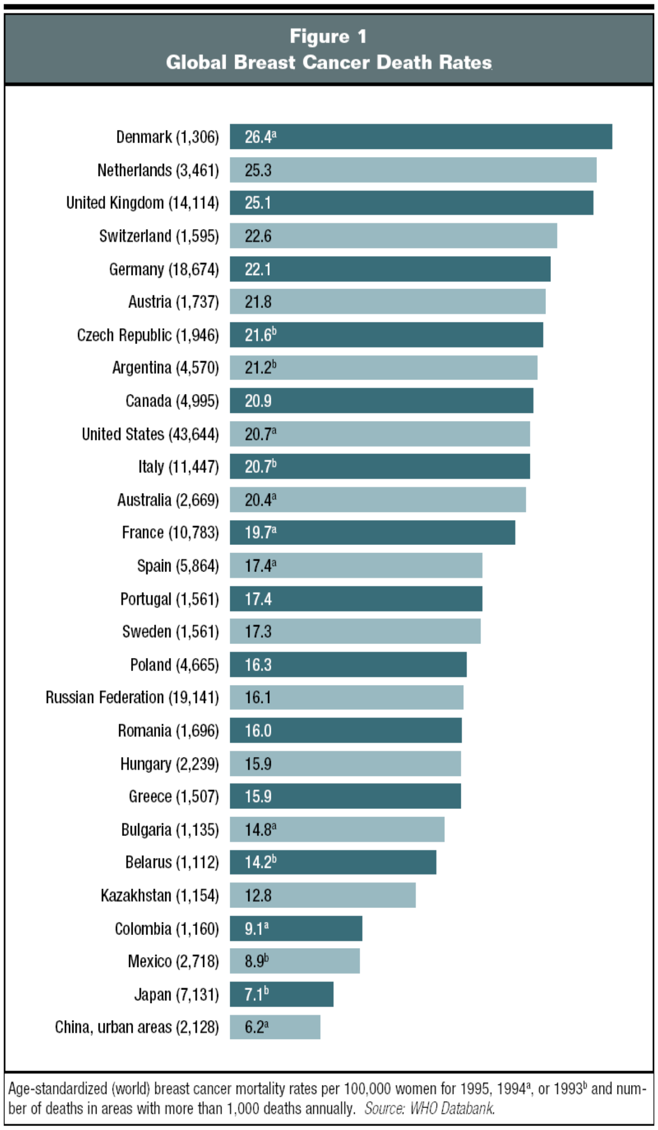

Fig 1 Content in a Mammogram

Breast cancer can have any of 3 types of appearance. The first is that of a small area of tiny calcifications, also known as microcalcifications. The second appearance is of a mass, which will often have irregular borders. The third is distortion of the architecture of the tissue within the breast.

The breast is positioned between two panels and compressed. Two images of each breast are obtained for evaluation: a side (mediolateral-oblique) view and a view from above (cranial-caudal). X-rays penetrate the breast and record the images on film. Different tissues in the breast absorb different amounts of x-rays, producing different shades of black, gray, and white on the film: Fatty tissue absorbs a small amount of x-rays and appears black or dark gray. Normal fibrous and glandular tissues (milk glands, lymph nodes) contain water fluid and absorb a moderate amount of x-rays, and appear light gray. Fibrous and glandular tissues may contain calcium and appear nearly white or white. Cancerous tissue contains watery fluid and sometimes calcium, making small cancers difficult to distinguish from normal breast tissue. As the cancer grows, it appears whiter than breast tissue on film. Comparison with prior mammograms helps the radiologist recognize changes in the patterns of lights and darks on the film that may indicate the presence of small breast cancers.[34]

Asymmetric breast tissue is encountered relatively frequently, having been reported to occur on 3% of mammograms. Asymmetric breast tissue is usually benign and secondary to variations in normal breast tissue, postoperative change, or hormone replacement therapy. An asymmetric area may indicate a developing mass or an underlying cancer. For more accurate work-up and diagnosis of soft-tissue findings at mammography, the American College of Radiology (ACR) Breast Imaging Reporting and Data System (BI-RADS) lexicon provides definitions for four different types of asymmetric breast findings: (*a*) asymmetric breast tissue, (*b*) densities seen in one projection, (*c*) architectural distortion, and (*d*) focal asymmetric densities.[31]

IMAGE REGISTRATION IN MAMMOGRAPHY

Image registration can be defined as a spatial mapping between two images. The goal of registration is to find the optimal transformation or mapping function which will align one image to another. It requires a search strategy to optimize a similarity measure. This similarity measure is determined using certain features of the images. Feature space, transformation, similarity measure, and search strategy compose a typical registration framework[27]. The breast images to be registered may be 2-D (X-ray mammograms) or 3-D (Ultrasound, MRI, Tomosynthesis, PET, CT, etc.). The feature space contains the information in the images that will be used for the matching. This information may be the raw pixel values, i.e., the intensities. Other common features include control points, edges, contours surfaces,statistical features, high level structural and syntactic descriptions, and so on, which need to be extracted in advance. With regard to the breast, anatomical features can be either at the surface or internal. The former include skin boundary[32] and the nipple[28], while the latter include the pectoral muscle, fibroglandular tissue and vasculature. In practice, the extraction of the anatomical features, both at the surface and internal ,helps to locate corresponding control points in both images that can be used for registration. Still other features, like texton (a basictexture element) and texture map can also be found in the literature. On the other hand, intensity based and thin-plate spline (TPS)-based registration methods were also developed. The similarity measure determines the quality of the matching between two breast images.

II. LITERATURE REVIEW

Mammogram registration can be done with images obtained from the same modality (intra-modality) or from 2 or more modalities(inter-modality).

(i) INTRA MODALITY

X-ray Mammogram Registration:

X-ray mammogram registration techniques can be divided into two main categories: feature-based and intensity-based. The boundary between these two is not so clear, however. Some methods combine both techniques, and are classified here as hybrid registration techniques.

Control points are the most used features in the registration of X-ray mammograms. Control-point selection requires identification of anatomical feature points in each of the mammograms to be registered. Identification of such points is difficult because of the compressibility of the breast that makes it a non-rigid structure. Because of the lack of rigid structures, very few distinct anatomical landmarks exist. Various efforts have focused on bilateral mammogram registration and temporal mammogram registration. Control points are either selected manually or located automatically on the nipple positions, breast boundary or linear structures within the breast.

Petroudi et al. constructed a texton directory to help the location of control points [14]. Sivaramakrishna et al. [16] proposed a textual transformation to register mammograms non-rigidly. First, the textual transformation is used to convert mammograms into texture maps where control points are selected.

In contrast to the previous studies where the whole breast area was registered, there are also regional breast registration techniques reported .Intensity-based registration methods directly operate on the image pixel values. Brzakovic et al. investigated a three-step intensity-based method for the comparison of a temporal mammogram pair. They first registered two mammograms using the principal axis method, and partitioned them using a hierarchical region-growing technique [4]. Translation, rotation, and scaling were then used for the registration of the partitioned regions. Engeland et al. [5] have implemented and validated four methods for temporal mammogram registration and compared the results. One method is based on the mutual information (MI), while the other three are feature-based registration techniques. They stated that registration by MI outperformed the others. The benefit of MI over the other techniques is that it makes use of the internal structure of the breast, and not just one point or several points on the breast contour. Another advantage of this technique is that it allows rotation, scaling, and shearing. This could correct for compression differences between the previous and the current mammogram and slight rotations of the breast.Hybrid registration methods have been proposed to combine both intensity-based technique and feature-based technique.

Suri et al. [17] proposed a mask-based registration strategy. A mask was first generated using an adaptive segmentation algorithm, then a region of interest (ROI) was extracted from the mammogram using the mask. This was followed by mutual information- based registration, using only the extracted ROI.

Models of breast tissues were developed to incorporate the effect of physical deformation by the imaging plates of the mammography X-ray machine. Wildes et al. [23] proposed a simple physical breast model for registration. The breast is viewed as a set of tissue compartments that are contained within an outer skin. The model assumes the deformation between a pair of mammograms is composed of a set of local deformations that are mutually constrained.

Registration of MR mammograms:

Magnetic resonance imaging of the breast is completely different from X-ray mammography, in that the latter provides anatomical information in a 2-D projection image, while MR mammography provides information on the entire 3-D structure of the breast. This 3-D representation allows the visualization of structures within the breast, their size, shape and spatial relationships with neighbouring structures. Studies show that masses can be detected with MR mammographies that are not visible in X-ray mammograms [8].

Feature-based registration of two corresponding MR breast images involves two stages: control point selection and control points matching. Control points were located randomly, manually, or automatically from edge features or the breast contour [22].

Registration of ultrasound breast images:

Breast ultrasound imaging is a widely accepted in addition to X-ray mammography. Under current standards of practice, the indications for diagnostic breast ultrasound are ([10],[11]): (a) differentiation between cysts and solid masses; (b) evaluation of a palpable mass not visible in a radiographically dense breast with X-ray mammography; (c) evaluation of a mass detected with mammography to obtain additional information; (d) evaluation of inflammation (mastitis).

Registration and compounding of ultrasound images may reduce speckle noise and attenuation artifacts in these images. Registration may also assist the comparison of serial examinations performed on the same patient.

(ii) INTER-MODALITY

Different breast-imaging modalities bring complementary information that can help to establish a diagnosis or assist the clinician for a therapeutic gesture. Researchers have been working on inter-modality breast image registration, and on the design of co-registered multimodality breast imaging acquisition system. Here, we mention X-ray mammography and MRI registration, MRI and ultrasonography registration, positron emission mammography (PEM), PET and CT registration, and registration of X-ray mammography and ultrasonography. Integrated systems have been developed that combine PEM, that is, PET applied to mammographic imaging, and X-ray mammography.

It has been demonstrated that the visual correlation of PET with morphological procedures, such as CT or MRI, can improve the accuracy of PET alone [3]. PET/CT fusion provides radiologists with the ability to see a lesion with PET technology as well as to localize the lesion with CT technology. A few studies have been conducted on the potential role of PET/CT in the breast cancer.

The clinical significance of an integrated X-ray mammography and breast ultrasound imaging system is based on published evidence that the probability of missing a breast cancer with the combination of mammography and ultrasound is much smaller compared to mammography alone, especially in women with dense breasts. Currently, X-ray mammography is the main tool used for the detection and diagnosis of breast malignancies [22].

III. SHORTCOMINGS OF TECHNIQUES

One of the common most and simplest method of image registration in mammography that is used is the method of Cross- correlation. Pearson’s correlation coefficient is widely used in statistical analysis, pattern recognition and image processing. The most widely recognized disadvantage is that it is computationally intensive. This often limits its usefulness for image registration (i.e. orienting and positioning two images so that they overlap). The correlation coefficient is also extremely sensitive to image skewing and vignetting. Such distortions are prevalent during imaging of micro-calcified tumors. Vignetting is reduction in image intensity near the edges due to optical light collection.

The other drawback is the flatness of the similarity measure maxima. This is due to self similarity of the images. Refer figure for the same. The maxima can be sharpened using edge or vector correlation.

Feature based registration is another major type of registration procedure. The common drawback here is that the respective features are hard to detect and/ or unstable in time. The crucial point of this method is to have robust feature descriptors that are invariant to all assumed differences between the images.

The figure below depicts a mesh representation of two cross-correlated images using MATLAB software. The peak of the mesh representation is the location in the of the pixel which has maximum level of similarity between the two images.

ilarity peak

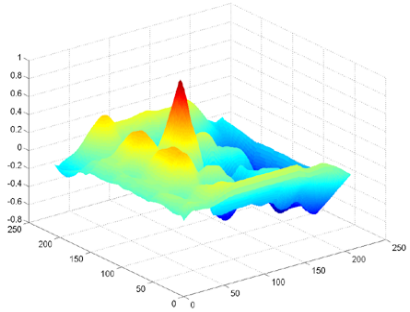

Figure : Mesh projection of correlated images.[2]

Inter modality registration techniques typically employ method of Mutual Information (MI). These too require large computations. To speed up the process, fast optimization algorithms are used. However, in case where images concerned have large rotation or scaling differences, this method fails or either becomes computationally expensive.

Although the speed of computers is growing, the need for reducing the computational tie persists.[26]

IV. FUTURE ASPECTS

To aid the oncologist in assessing the progress made by the patient, we are studying follow up cases. A mammogram performed before and one after the operation on the same modality are registered to analyze the effectiveness of the treatment rendered.

Material: To perform image registration we plan to use a dataset of around 50 patients who have undergone atleast 2 or more mammography procedures.

Method: Image registration is an important task that enables comparative analysis of images acquired at different occasions. We will use a simple and fast registration method that can be applied to mammogram images. It is based on the normalized cross correlation and spatial transformation techniques. We have described an algorithm based on Normalized Cross-Correlation (NCC) is the ideal approach to image registration by template matching. It is believed to give perfect template matching in the images. The Maximum Cross-correlation coefficient values from the NCC plot indicate the perfect template matching with noise and without noise condition. It is based on automatic breast segmentation, automatic control point location, image alignment.[1]

Cross Correlation: The use of cross-correlation for template matching is motivated by the distance measure (squared Euclidean distance) [20]

$$d^2_{f,t}(u,v) = \sum_{x,y} [f(x,y) - t(x-u,y-v)]^2$$

(where f is the image and the sum is over x,y under the window containing the feature t positioned at u,v). In the expansion of d^2

$$d^2_{f,t}(u,v) = \sum_{x,y} [f^2(x,y) - 2f(x,y)t(x-u,y-v) + t^2(x-u,y-v)]$$

the term $\sum t^2(\text{x-u, y-v})$ is constant. If the term $\sum_{x,y} [f^2(x,y)]$ is approximately constant then the remaining cross-corelation term

$$c(u,v) = \sum_{x,y} f(x,y)t(x-u,y-v)$$

is a measure of the similarity between the image and the feature.

Normalized Cross Correlation

There are several disadvantages to using (1) for template matching: [20]

- If the image energy $\sum_{x,y} f^2(x,y)$ varies with position, matching using (1) can fail. For example, the correlation between the feature and an exactly matching region in the image may be less than the correlation between the feature and a bright spot.
- The range of $c(u,v)$ is dependent on the size of the feature.
- Eq. (1) is not invariant to changes in image amplitude such as those caused by changing lighting conditions across the image sequence.

The *correlation coefficient* overcomes these difficulties by normalizing the image and feature vectors to unit length, yielding a cosine-like correlation coefficient

$$[t(x-u),(y-v)-t]^2$$

$$\sum_{x,y}[f(x,y)-\overline{f_{u,v}}]^2\sum_{x,y}¿^{0.5}$$

$$¿$$
$$¿$$
$$¿$$

$$\frac{\sum_{x,y}[f(x,y)-\overline{f}_{u,v}][t(x-u,y-v)-t]}{\substack{¿\\ \gamma(u,v)=¿\\ ¿}}$$

where $\bar{t}$ is the mean of the feature and $\bar{f}(u,v)$ is the mean of $f(x,y)$ in the region under the feature. We refer to above as *normalized cross-correlation*. Although it is well known that cross correlation can be efficiently implemented in the transform domain, the normalized form of cross correlation preferred for feature matching applications does not have a simple frequency domain expression. Normalized cross correlation has been computed in the spatial domain for this reason [20].

Expected results:

This study will give end results which will help us visualize the changes in the cancerous tumor seen in the mammogram pair that has been registered. This should also help us approximate the %reduction in the size and thus indirectly the effectiveness of the therapy rendered. These results should not only be useful to the oncologist but to the patient alike.

V. CONCLUSIONS

Image registration in mammography though widely being researched, still has discrepancies **due** to the non rigid nature of the breasts, thus making similarity measurements difficult due to different compressibility.

With alarming rise in the number of women suffering from breast cancer, regular screening and follow up is common. To analyse the developments in the successive mammograms, follow up image registration serves as a good option.

Normalized cross co-relation, though not oone of the best techniques for registration, should provide acceptable results.

REFERENCES

1. Balasubramanian B, Dr. Porkumaran K., PET/CT and MR Image Registration using Normalized Cross Correlation Algorithm and Spatial Transformation Techniques (IJCNS) International Journal of Computer and Network Security, Vol. 2, No. 5, May 2010.
2. Biswas K.S. ,Correlation based Image Registration, IIT Kharagpur, 1998.
3. Bird RE, Wallace TW, Yankaskas BC (1992) Analysis of cancers missed at screening mammography. Radiology 184(3):613–617
4. Brzakovic D, Vujovic N, Neskovicand M, Brzakovic P, Fogerty K (1996) Mammogram analysis by comparison with previous screenings. In: Doi K, Giger ML, Nishikawa RM, Schmidt RA (eds) Digital Mammogrphy'96, Elsevier, Amsterdam 20. Chandrasekha
5. Engeland S, Snoeren P, Hendriks J, Karssemeijer N (2003) A comparison of methods for mammogram registration. IEEE Trans Med Imaging 22(11):1436–1444
6. Forstner, W.,A feature based correspondence algorithm for image matching, Int'l Arch. Photogramm. Remote Sensing, 26: 150-166(1986)
7. Goshtasby, Ardeshir., 2D & 3D Image registration for medical,remote sensing and industrial applications
8. Heywang SH, Wolf A, Pruss E, Hilbertz T, Eiermann W, Permanetter W (1989) MR imaging of the breast with Gd- DTPA: use and limitations. Radiology 171(1):95–113
9. Hough, P.V.C., A method and measure for recognizing complex patterns, US Patent 3, 069,654, Dec 18,1962
10. Jackson VP (1990) The role of US in breast imaging. Radiology 177(2):305–311
11. Jackson VP, Reynolds HE, Hawes DR (1996) Sonography of the breast. Semin Ultrasound CT MR 17(5):460–475
12. Moskowitz M (1995) Breast imaging. Saunders, Philadelphia
13. Noe, K.N. *Deformable Image Registration for Use in Radiotherapy Using GPU Acceleration.*Dept of Computer Science, Aarhus Univerity, Denmark. Oct 2009
14. Petroudi S, Brady M (2004) Textons contours and regions for improved mammogram registration digital mammography. In: IWDM 2004, June 2004, Springer, Chapel Hill
15. Pratt, W.K., Correlation techniques for image registration, IEEE Trans. Aerospace & Electronic Systems, 10(3): 353-358(1974)
16. Sivaramakrishna R (1997) Breast image registration using a textural transformation. University of Manitoba
17. Suri JS, Guo Y, Sun Y, Danielson T, Janer R (2005) Combining adaptive segmentation approach for improving multiresolution image registration on X-ray mammograms acquired using Fischer's fused full field digital mammography and ultrasound system (FFDMUS). In: IASTED BioMED 2005, Feb 2005 Innsbruck, Austria
18. Van Den Dool Riaan, Image Processing Tools, Stellenbosch University, May 2004.
19. Weszka J.S., A survey of threshold selection techniques, Computer Graphics and Image Processing, 6:259-265(1978)
20. Weszka J.S & A Rosenfeld., Histogram Modification for threshold selection, IEEE Trans. Systems, Man, Cybernetics, 9(1): 38-52(1979)
21. Wildes RP, Asmuth JC, Hunter DM, Kopans DB, Moore RH(1996) Change detection in serial mammograms for the early detection of breast cancer research report FR-0008. The National Information Display Laboratory, January 1996
22. Williams M.L., R.C Wilson & E.R.Hancock, Deterministic search for relational graph matching, Pattern recognition, 32:1255-1271(1999)
23. Yujun Guo Æ Radhika Sivaramakrishna Cheng-Chang Lu Æ Jasjit S. Suri, Swamy Laxminarayan Breast image registration techniques: a survey Med Biol Eng Comput (2006) 44: 15–26

24. Zitova B., Flusser J., Image Registration methods: A survey., Dept of Image Processing.,Academy Sciences of Czech Republic Jun 2006.

25. American Cancer Society Breast Cancer Facts & Figures, 2008-2009.
26. 2) American College of Radiology. Breast Imaging Reporting and Data System (BI-RADS) 3rd ed. Reston, Va: American College of Radiology, 1998.
27. 3) Brown LG (1992) A survey of image registration techniques. ACM Comput Surv 24(4):325–376.
28. Chandrasekhar R, Attikiouzel Y (1997) A simple method for automatically locating the nipple on mammograms. IEEE Trans Med Imaging 16(5):483–494.
29. Christensen G.E, Johnson H.J., Consistent Image Registration, IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 20, NO. 7, JULY 2001.
30. Curtis Mettlin, PhD, Global Breast Cancer Mortality Statistics.
31. Kopans DB, Swann CA, White G, et al. Asymmetric breast tissue. Radiology 1989; 171:639-643.
32. Mandelblatt JS, Cronin KA, Bailey S, et al. Effects of mammography screening under different screening schedules: Model estimates of potential benefits and harms. Annals of Internal Medicine 2009;151(10):738–747.
33. Ojala T, Nappi J, Nevalainen O (2001) Accurate segmentation of the breast regions from digitized mammograms. Comput Med Imaging Graph 25:47–59
34. Swierzewski S.J., Physician-developed and –monitored. Aug 15 1999

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