超音波專題

Ultrasonic strain imaging made by speckle tracking of B-mode image

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Introduction

For centuries, physicians have used palpation to detect abnormal regions of increased elastic modulus (hardness or stiffness) as an indicator of cancer. Because certain type of tissues, such as malignant lesions, have elastic properties that are markedly different from surrounding tissues, elasticity imaging can provide a significant adjunct to current diagnostic ultrasonic methods.

History Review and patent analysis

I. Elasticity imaging

a. Elastography (Elasticity Imaging):

1. Vibration phase gradient sonoelastography: Sato et al (1985), nonlinear interaction between ultrasound and low frequency waves
2. Vibration amplitude sonoelastography: Lerner and Parker(1987), vibrator near the transducer
3. Compression strain sonoelastography:Ophir et al (1991), cross correlation is applied between congruent segments in an A-line pair. The temporal location of the maximum peak of the crosscorrelation function is the estimate of time shift between the two segments (4mm segments overlaping 1 or 2 mm)
4. Multiple step compression strain sonoelastography: O'Donnell (1994): Base-band correlation between A-line pairs is employed to estimate displacement. Multiple steps of compression are used to reduce the speckle decorrelation effect.
5. Inherent strain sonoelastograph: Bertrand and colleaques (1989), a biomechanical strain gauge was proposed using B-scan information and an optical flow algorithm. The tissue deformation on consecutive B-scan images as linear transformation, and these linear transformation can be decomposed into rotation matrices and biaxial translation matrices. By calculating the eigen-value of these matrices in a small region, the strain of that area can be obtained
6. Block matching algorithm to derive elasticity information: Levinson et al (1994).

b. Speckle tracking and motion estimation

1. Ultrasonic speckle motion inherrent to tissue motion: Bertrand (1989)
2. Tissue motion and blood flow estimation with speckle tracking: Trahey et al. (1991): two dimensional speckle tracking technique to measure blood flow and

motion in soft tissue.

3. Internal displacement and strain imaging using speckle tracking: O'Donnell (1994).

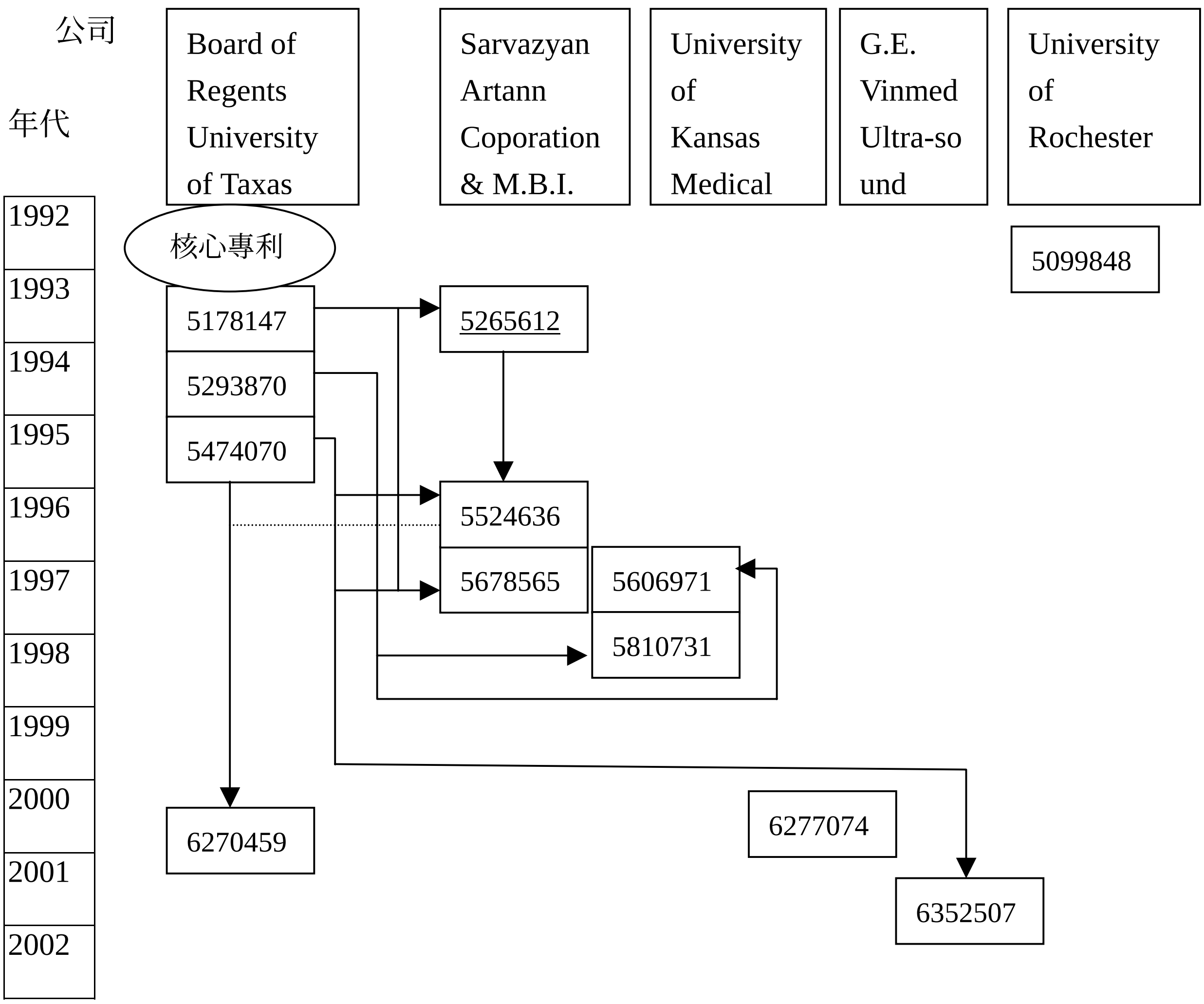
c. Strain estimation

(Stress is uneasy to defined, elasticity image is often showed as strain image)

1. Cross correlation of consequent A-line
   a. RF data (Ophir, 1993) time shift calculated by cross-correlation of maximal peaks of the segments between A-line,
      strain = time shift / duration of the segment
   b. baseband data (O'Donnell, 1994): phase shift of demodulated echo signals
2. Speckle tracking of B-mode image: Block matching algorithm (Levinson, 1994; Yeung, 1997)

d. Patent analysis

引證族譜圖



First, Parker invented the method of vibration elasticity imaging. Core patent of compression elasticity imaging was developed by Ophir et al. in the next year, then Sarvazyan continued to invent some real instruments such as intra-cavity elasticity imaging and stress estimating device. University of Kansas invented a method for motion estimation of biological tissue later alone.

專利請求保護的範疇

一階分類	二階分類	Device	Method	Apparatus	System	Process	小計	合計
Compression strain image	Compressibility		5178174	5178174			6	16
			5293870	5293870				
			5474070	5474070				
	intracavity	5265612					1	
	Tissue deformation		6352507		6352507		2	
	Motion estimation		6277074	6277074			2	
	Stress estimation		5524676	5524676			4	
		5678565	5678565					
	Lateral elastogram		6270459				1	
Vibration strain image					5099848		5	5
		5606971	5606971					
		5810732	5810732					

II.超音波斑點追蹤的文獻回顧

關於超音波的斑點追蹤(Speckle Tracking)，其方法亦同於在數位視訊處理中所使用的位移估測(Motion Estimation)，在美國專利中，如果以 “ speckle tracking “ 作為關鍵字來搜尋，所顯示的專利不但數量極少，而且並不是在探討斑點追蹤的方法，反而是將斑點追蹤當成一已知的技術，應用於三維定位方面。

因此，關於斑點追蹤的專利文獻回顧上，改以 “ Motion Estimation “ 此關鍵字來作分析、整理，由於相關的專利數實在太多，因此只挑選專利名稱有 “ Motion Estimation “ 的關鍵字才予以考慮，其中發現一有趣的現象，所有收錄的文獻中，

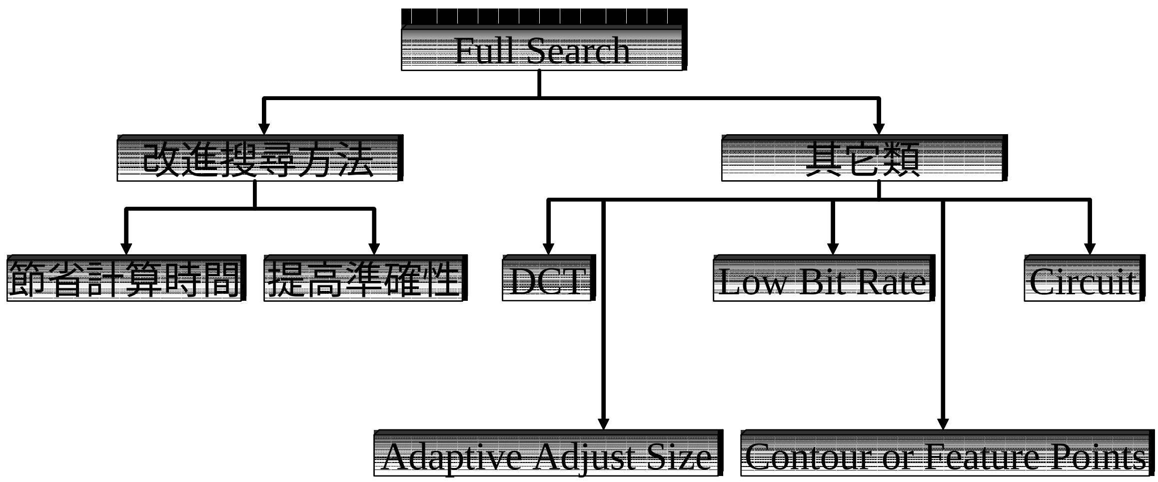
有關位移估測的專利數有 174 篇，而如果只從 1996~2002 年來挑選的話，竟還有 155 篇，因此推測這是由於近年來數位視訊的蓬勃發展，如 MPEG-1、MPEG-2 甚至 MPEG-4，而位移估測更是其中關鍵的技術，使得大家的注意力開始集中於這個領域。

下表為專利請求保護範疇的分類表：

	Circuit	Method	Apparatus	System	合計
簡省計算時間	1	18	4	3	26
提高準確性	0	6	1	0	7
其它類	9	57	37	19	122
合計	10	81	42	22	155

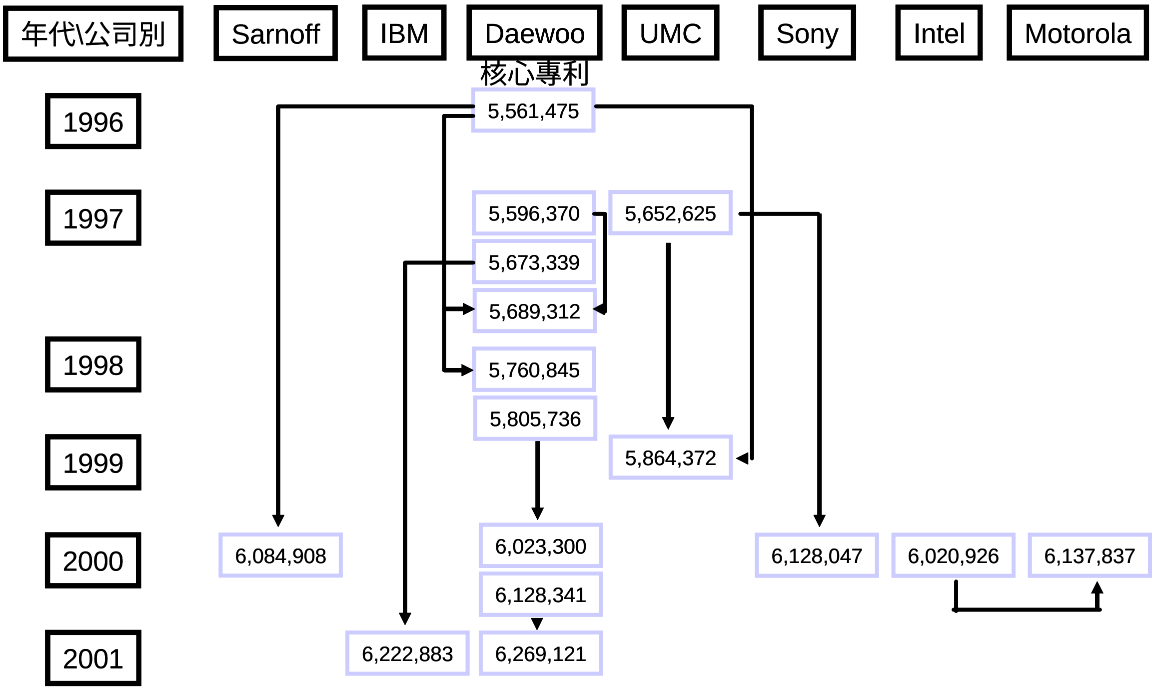
由上表得知目前研究的重點在於如何改善原本使用 full search 的搜尋方式，如簡省計算時間、或提高搜尋結果的準確性，更廣為大家研究的部份為使用其它不同的搜尋方法，或是在電路設計上做改進，因此，我想位移估測的關鍵技術在於如何尋找出效能更好或是與眾不同的方法，而不是在於電路或是裝置、系統的設計，也造成此方面的專利數少了許多。

下表是整個位移估測的演進流程圖：



傳統上，是使用影像區塊比對法對影像上的每一點做搜尋(Full Search)，而自然而然的就會研究如何做些改善，如改進搜尋方法方面，可探討如何簡省計算時間，一般所採用為階層(Hierarchical)或多層式(Multi-Level)的搜尋，在提高搜尋結果的準確性上，可將影像解析度從整數的像素改為半個像素，至於其它更廣為大家研究的部份，不一定能對傳統的方法做出改善，但可以提供一另類思考的方向，如將影像轉為 DCT domain 下處理，或是利用影像上物體的邊緣或特徵點來做為輔助搜尋的工具，也可對搜尋的範圍、搜尋視窗的大小以及比對區塊的大小做可調式的處理，甚至使用 low bit rate 或是在電路設計上做改進，這些都是大家目前感興趣的領域。

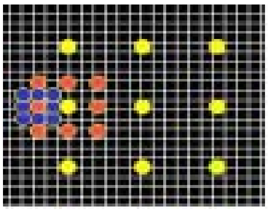
下表為引證族譜圖：



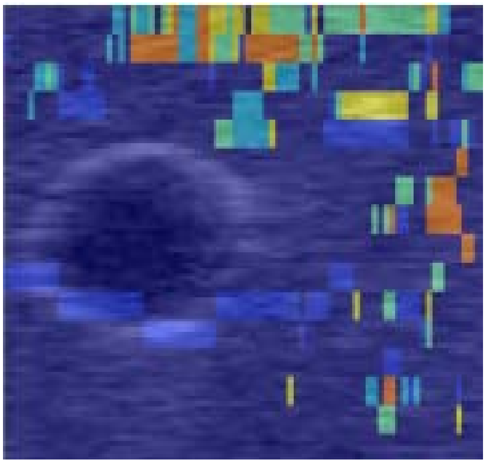
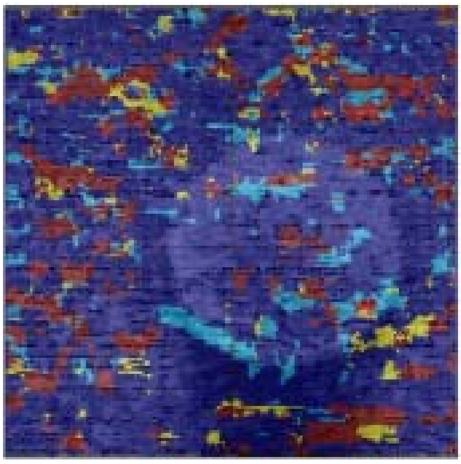
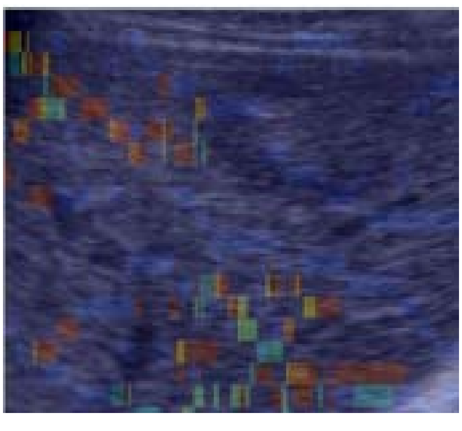
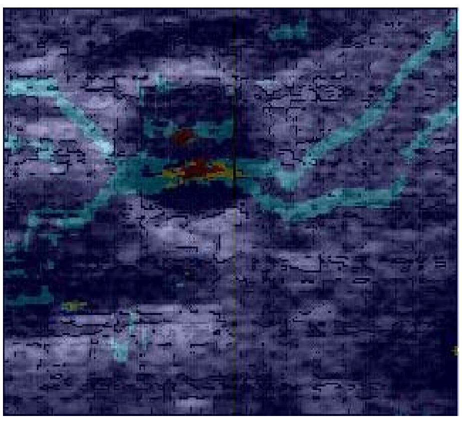
其中的韓國大宇(Daewoo)電子在位移估測上的專利數有 15 篇最多，其次為 IBM，而大宇公司的核心技術為在 1996 年所發表的使用

可變動的比對區塊大小來做位移估測，而由實際的經驗可得知比對區塊的大小不但會影響搜尋結果的準確性，更會影響計算速度，因此，此專利的研究為近年來大家所熱衷的主題，所以才會被大家廣泛的參考。

Material and Method

1. Target of study: breast tumor and heaptic tumor, the elasticity data are already known in these 2 kinds of tumor.
2. Strain estimation by speckle tracking:
   Block matching algorithm:
   Multiple level matching (time saving method): 3 levels, 9 points estimation per level
   
3. Elasticity Imaging:
   a. axial elastogram: segment: 35-40 pixels/10mm, 2-3mm per segments
   b. lateral elastogram: can be easily shown by our method.
4. Analysis of interface of tissue structure and boundary condition

Preliminary Result

1. Phantom
   a :Cystic lesion in breast phantom
   
   b: sponge ball in agar
   
2. Tissue
   a. Hepatic tumor
   
   

Reference:

1. Yong-Sheng Chen, Yi-Ping Hung, Chiou-Shann Fuh 、Fast Block Matching Algorithm Based on the Winner-Update Strategy 、IEEE Trans on Image Processing 2001；10 (8): 1212-1222.
2. Yeung F, Levinson SF, Parker KJ. Multiplevel and motion model-based ultrasonic Speckle tracking algorithms. Ultrasoud in Med. & Biol 1998; 24(3): 427-441.
3. Gao L, Parker KJ, Lerner RM, Levinson SF. Imaging of the elastic properties of tissue-a review. Ultrasoud in Med. & Biol 1996; 22(8): 959-977.
4. Ophir J, Cespedes I, Ponnekanti H, yazdi Y, Li X. Elastography: a quantatative method for imaging the elastocity of biological tissures. Ultrasonic imaging 1991; 13;111-134.
5. O'Donnell M, Skovoroda AR, Shapo BM, Emelianov SY. Internal displacement and strain imaging using ultrasonic speckle tracking. IEEE Trans. Ultrason. Ferroelect Freq. Contr. 1994;41(3):314-325.