

**Automated Identification and Measurement of Cardiac Anatomy
via Statistical Analysis of Medial Primitives**

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ABSTRACT

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Automated Identification and Measurement of Cardiac Anatomy via Statistical Analysis of Medial Primitives

(Under the direction of Stephen M. Pizer, Ph.D.)

Identification and measurement of objects in 3D images can be automatic, rapid and stable, based on local shape properties derived statistically from populations of medial primitives sought throughout the image space. These shape properties are measured at medial locations within the object and include scale, orientation, endness, and medial dimensionality. Medial dimensionality is a local shape property differentiating sphere, cylinder, and slab, with intermediate dimensionality also possible. Endness is a property found at the cap of a cylinder or the edge of a slab. A model of the cardiac left ventricle during systole is constructed as a large dark cylinder with an apical cap at one end, terminated at the other end by a thin bright slab-like mitral valve. Such a model, containing medial shape properties at just a few locations, along with the relative distances and orientations between them, is intuitive and robust and permits automated detection of the left ventricular axis *in vivo* using Real-Time Three Dimensional (RT3D) echocardiography. The statistical nature of these shape properties allows their extraction even in the presence of noise and permits statistical geometric measurements without exact delineation of boundaries, as demonstrated in determining the volume of balloons and of *in vivo* left ventricles in RT3D scans. The inherent high speed of the method is appropriate for real-time clinical use.

THESIS

Fully automated, rapid and robust identification and measurement of cardiac structures in 3D ultrasound images can be achieved by establishing homologies between clusters of medial primitives and the nodes in a medial model of the heart, using statistical analysis of location, scale, orientation, medial dimensionality, and endness.

*"The poet's eye, in a fine frenzy rolling,
Doth glance from heaven to earth, and earth to heaven,
And as imagination bodies forth
The forms of things unknown, the poet's pen
Turns them to shapes, and gives to airy nothing
A local habitation and a name."*

King Theseus, from *A Midsummer Night's Dream*,
by William Shakespeare

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TABLE OF CONTENTS

Chapter 1	Introduction.....	1
1A.	Goals and Motivation.....	1
1B.	Claims.....	3
1C.	Guide to Chapters.....	4
Chapter 2	Background and Method Overview.....	5
2A.	Imaging of Cardiac Anatomy and Function.....	5
2B.	Approaches to Analyzing Cardiac Shape.....	14
2C.	The Medial Lineage.....	15
2D.	Method Overview.....	16
Chapter 3	Two-Boundary Medial Primitives (Core Atoms)	19
3A.	Defining the Core Atom.....	19
3B.	Unlocalized Spectra of Scale in 2D.....	21
3C.	Extracting Local Medial Properties in 3D.....	31
Chapter 4.	Clustering Core Atoms by Location.....	34
4A.	Artifacts generated by Spatial Sampling.....	34
4B.	Ellipsoidal Voting to Remove Sampling Artifacts.....	35
4C.	Empirical Validation.....	37
Chapter 5	Medial Node Models.....	47
5A.	Homologies Between Core Atom Clusters and Nodes.....	48
5B.	Homologies between Cluster Pairs and Node Pairs.....	49
5C.	Endness.....	50
Chapter 6	3D Echocardiographic Issues.....	56
6A.	Coordinate System Issues.....	56
6B.	Ultrasound Physics Issues.....	62
6C.	Testing Core Atoms on Ultrasound Data.....	67
6D.	Rendering Slices for Manual Tracing.....	70
Chapter 7	Measuring Volume.....	77
7A.	Truncated Wedges: Volumes from Boundary Curvature and Medial Scale.....	78
7B.	Fuzzy Segmentation of the Left Ventricle.....	92
Chapter 8.	Experimental Validation with 3D Ultrasound.....	99

8A.	Identifying the AMV Axis.....	99
8B.	Measuring Balloons with Core Atoms.....	103
8C.	Manual Tracing of LV Volume.....	106
8D.	Computing LV Volume with Core Atoms.....	106
8E.	Testing Fuzzy Segmentation of the LV.....	108
Chapter 9	Conclusions	117
9A.	Claims Revisited.....	117
9B.	Strengths of this Approach.....	120
9C.	Weaknesses of This Approach.....	121
9D.	Future Directions.....	122
APPENDICES	124
	Appendix A - Binomial Kernel and Difference of Gaussians Operator.....	124
REFERENCES	125

LIST OF TABLES

Table 4.1. Mean angular error $\bar{\epsilon}_\theta$ (in degrees) for displacement eigenvector $\hat{\mathbf{a}}_p$, and axial eigenvector $\hat{\mathbf{a}}_a$ (cylinders only).	40
Table 4.2 Actual diameter of test objects, and diameter determined from populations of core atoms (mean and s.d.)	45
Table 6.1 Concerns arising from ultrasound physics, and methods of addressing them.	62

LIST OF FIGURES

Fig. 2.1	A. Conventional 2D ultrasound uses a linear array to steer within a slice, producing a B-mode image. B. Real Time 3D ultrasound uses a matrix array to scan a volume without moving the transducer. C. Two orthogonal B-mode slices, and one C-mode slice (parallel to the transducer) within the 3D ultrasound pyramid.	13
Fig. 2.2	Model of left ventricle and mitral valve	17
Fig. 2.3	Overview of method to find the apex-to-mitral-valve (AMV) axis, with associated chapters and sections where the method is developed. Chapter 8 describes the actual experiment.	18
Fig. 3.1	A. A core atom consists of two boundary points that face each other across an acceptable distance, and a center point at which the core atom is said to be located. B. The search area (gray) for boundary point \mathbf{b}_2 depends on boundary normal $\hat{\mathbf{n}}_1$ and the expected distance between the boundaries.	20
Fig. 3.2	Angle doubling of the orientation vector $\hat{\mathbf{c}}$	23
Fig. 3.3	The two extremes of directionality. A. Core atoms with evenly distributed orientations. B. Core atoms aligned along a 1D ridge.	24
Fig. 3.4	Objects (grey), core atom centers (white) and boundary points (black "+").	25
Fig. 3.5	Rectangular object showing effects of rotation.	26
Fig. 3.6	Objects showing the ability to remove noise and differentiate shapes.	27
Fig. 3.7	Spade showing the effects of rotation.	28
Fig. 3.8	Fundamental shapes (dark gray), corresponding cores (light gray), core atom populations (line segments) and eigenvectors $\hat{\mathbf{a}}_1$, $\hat{\mathbf{a}}_2$ and $\hat{\mathbf{a}}_3$	31
Fig. 3.9	The lambda triangle defines the domain of possible eigenvalues	33
Fig. 4.1	A. Sphere. B. Core atom cloud. C. Sample displaced by $\hat{\mathbf{P}}$	35

Fig. 4.2	A. Cylinder. B. Core atom cloud. C. Sample displaced by \vec{P}	35
Fig. 4.3.	Ellipsoids of three coronal core atom samples coalescing at the true center.	36
Fig. 4.4.	Distribution of samples in lambda triangle for parametric test objects.	38
Fig. 4.5	Number of core atoms per sample vs. displacement from the theoretical core, showing dimensional distortion in the corona.	39
Fig. 4.6	Eigenvalue associated with eigenvector \hat{a}_p for all samples containing greater than 1% of the entire core atom population.	41
Fig. 4.7	Lambda triangle for the sphere showing dimensionality of samples (dots) and the cluster with the most votes (cross).	42
Fig. 4.8	Core atom samples (small symbols) and clustered samples (large symbols) for parametric objects (line = slab, cross = cylinder, 3-axis symbol = sphere).	43
Fig. 4.9	Color mapped onto the lambda triangle.	46
Fig. 4.10	Color version of Fig. 4.8 with color representing dimensionality as mapped onto the lambda triangle in Fig. 4.9.	46
Fig 5.1	Slabs and cylinders have individual orientations relative to the inter-cluster vector, yielding 3 relative orientation parameters for the pair.	51
Fig 5.2	Pairs with one sphere have only 1 relative orientation parameter.	51
Fig 5.3	A pair with two spheres has no relative orientation parameters.	51
Fig. 5.4	Endness, manifested as the end of a stripe, and detected as face-to-medialness by a core ion. In 2D, this is the only type of endness.	52
Fig. 5.5	Endness, manifested by a cap on a cylinder (A) and the edge of a slab (B). Boundary points contributing to endness are labeled b and eigenvectors of core atom cluster labeled a1, a2, and a3 as in Fig. 3.8.	53

Fig. 5.6	Endness introduces an additional parameter into the dual-node metric for matching node pairs to cluster pairs. The additional parameter can be thought of as a normalized endness vector \hat{e} , which is a linear combination of \hat{a}_1 and \hat{a}_2 for the edge of a slab and $\pm\hat{a}_1$ for the end of a cylinder. If both nodes have significant endness, an additional twist parameter may be specified.	55
Fig. 6.1	Spherical and azimuth-elevation coordinate systems each use two angles (θ , φ) and range (length of the large black arrow, not labeled). Cartesian coordinates (x,y,z) also shown.	57
Fig. 6.2	Convolution kernels in physical space used to create core atoms,	60
Fig. 6.3	Resolution cells in conventional ultrasound (A) and matrix-array ultrasound (B).	64
Fig. 6.4.	Coronal densities containing more than 1% of the total number of core atoms.	67
Fig. 6.5	Number of core atoms per sample vs. displacement from the manually placed axis of the balloon and the LV.	68
Fig. 6.6	B-mode slices through balloon (A) and in vivo human heart, showing the nearer boundary points to the viewer for core atoms formed near the manually-determined axes of the objects (LV = left ventricle, LA = left atrium).	69
Fig. 6.7	B-mode slices are the conventional "sector" scans of ultrasound, C-mode slices are parallel to the face of the transducer and Tilted C-mode (or I-mode) scans are arbitrarily oriented.	70
Fig. 6.8	R-mode slice contains voxels at a given range from the transducer.	71
Fig. 6.9	B-mode slice rendered using 2D texture mapping of radial ribbons onto trapezoids.	72
Fig. 6.10	B-mode slice rendered using 2D texture mapping of radial ribbons onto trapezoids.	73
Fig. 6.11	Space-filling RT3D voxel at the center of a grid of 27 neighboring voxel locations, and its projection on the image as a symmetrical hexagon.	74

Fig. 6.12	The intersection of 3 stripes forms a hexagon with opposite sides of equal length.	74
Fig. 6.13	The intersection of 3 stripes forms a hexagon with opposite sides of equal length.	75
Fig. 6.13	Pre-sorting of voxels by distance along an arbitrary axis for rapid selection of orthogonal slices.	76
Fig. 7.1.	The Blum medial manifold of a rectangle (thick dotted lines) is the locus of centers of all medial circles, i.e., those circles lying completely within the rectangle that touch the boundary in at least 2 places.	79
Fig. 7.2	Examples of 3D objects with simple shapes. The "mineral rights" for a surface patch are shown in each case extending orthogonal from the surface half-way through the object to the opposite side.	79
Fig. 7.3	a. Local coordinate system with \hat{t} tangential to, and \hat{n} normal to, the object's boundary. b. Osculating circle with radius F and a sector of that circle corresponding to boundary interval Δs	81
Fig. 7.4	a. Convex boundary segment (thick solid line) and corresponding medial manifold (thick dotted line) at a distance R from the boundary ($F > 0$). Area ΔA approximates the "mining rights" of boundary interval Δs . b. Same for a concave boundary segment ($F < 0$).	82
Fig. 7.5	Rectangle with mining rights extending in thin ribbons	84
Fig 7.6	In \mathcal{R}^3 the mining rights of a surface patch form an osculating wedge	85
Fig. 7.7	Potential errors in the calculation of ΔA for a concave boundary segment.	87
Fig. 7.8	Singular case for convex boundary.	88
Fig. 7.9	Singular case for concave boundary.	89
Fig 7.10	Surface model defining a region of interest (ROI) and an expected ventricular boundary.	93
Fig 7.11	Two independent scales are determined for the ventricular boundary.	93

Fig 7.12 Probability p_L of a voxel being within the ventricle, given φ and r	95
Fig 7.13 Function for computing a voxel's $p_i(j)$ from its intensity $I(j)$ given the weighted mean intensity \bar{I} over the ROI.	96
Fig 7.14 The A operator for computing aggregate probability $p_A(j)$ from $p_L(j)$ and $p_i(j)$ is linear, continuous, piece-wise smooth.	97
Fig. 8.1 Using a statistical model of medial primitives to automatically identify the axis of the cardiac left ventricle in Real Time 3D ultrasound data. A scale of 1 cm is shown in D.	100
Fig. 8.3. Core atom clusters in a balloon (from the inside boundary of the intensity ridge) identified as cylindrical along the axis of the balloon, although a significant number of core atoms actually formed vertically through the balloon as well.	103
Fig. 8.4 Radius of fluid-filled balloons determined automatically using core atoms to analyze 3D ultrasound images, compared to radius of the same balloons determined by weight assuming a spherical shape. (x) outer facing boundary, (+) inner facing boundary, (o) weighted average of inner and outer boundaries, with weight determined to minimize RMS percent error by volume to 6.5%.	104
Fig. 8.5 Proposed correction for measurement with core atoms displaced from the center.	105
Fig. 8.6 A. Color version of Fig. 8.1B with color mapped from lambda triangle as in Fig. 4.9. B. Color version of Fig. 8.1C. C. Automated surface map for the LV.	107
Fig 8.7 Region of interest (bright) and LV surface model (dark) superimposed on ultrasound data.	108
Fig. 8.8 The probability $p_L(j)$ for each voxel with values ranging from 1 (white) inside and 0 (black) outside the expected ventricle.	109
Fig. 8.9 The aggregate probability $p_A(j)$ for each voxel with values ranging from 1 (white) to 0 (black).	110

Fig. 8.10	A. Manual tracings. B. Corresponding set of labeled voxels with white symbolizing $p_T(j)=1$ and black, $p_T(j)=0$	111
Fig. 8.11	Training data	112
Fig. 8.12	Test data compensated with slope and intercept from regression on training data	112
Fig. 8.13	Delta Volume for test data computed as difference from the mean for automated vs. manual volumes for all 65 scans.	113
Fig. 8.14	Training data	115
Fig. 8.15	A. Training data	116
Fig. A.1	Results of applying binomial kernel in 2D, shown with dark outline after an even number of applications.	124
Fig. A.2	Difference of Gaussian (DOG) for binomial kernels (dark outline in Fig A.1).	124

LIST OF ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
AMV	Apex-to-Mitral Valve (axis)
ECG	Electrocardiogram
CO	Cardiac Output
CT	Computerized Tomography
DSR	Dynamic Spatial Reconstructor
GBPT	Gated Blood Pool Tomography
LA	Left Atrium
LV	Left Ventricle, Left Ventricular
m-reps	medial representations
MNM	medial node model
MRI	Magnetic Resonance Imaging
MUGA	Multiple Gated Acquisition
MV	Mitral Valve
RA	Right Atrium
RMS	Root Mean Squared
ROI	Region of Interest
RT3D	Real Time Three-Dimensional
RV	Right Ventricle
SPECT	Single Photon Emission Computerized Tomography
SV	Stroke Volume

LIST OF SYMBOLS

\mathbf{x} or $\underline{\mathbf{x}}$	vector (in the sense of a location)
$\bar{\mathbf{c}}$	vector (in the sense of an oriented distance)
$\hat{\mathbf{v}}$	normalized vector (orientation)
\mathbf{C}	matrix
a	scalar
$[a, b]$	range from a to b
F	operator or function
$O(n^2)$	order n^2
\mathfrak{R}^m	m - dimensional space of real numbers