I-ImaS

Workpackage-3:

Update on current progress and preliminary results for the on-chip processing

Amsterdam, 26th – 27th May 2004

Harris Georgiou (WP3/CTI)

WP3 tasks:

1. Acquire a web-available mammographic image database for preliminary analysis
2. Identify a set of suitable texture features for image analysis
3. Evaluate features and select best subsets for further study

Current Specifications:

- Publicly available mammographic databases contain images of optimal-exposure only, usually through AERC.
- Images of sub-optimal exposure must be **simulated** in order to investigate effects on texture features.
- Final set of sub-optimal images must be evaluated by expert physicians in terms of diagnostic quality.

Tasks completed so far:

1. Acquire real mammographic images using optimal exposure settings (DB1).
2. Acquire phantom images using sub-optimal manual exposure settings (DB2).
3. Formulate a realistic exposure simulation model for constructing extensive sets of sub-optimal images from DB1.
4. Use phantom images from DB2 to validate the simulation model.
5. Construct a set of content-rich texture feature functions for image analysis.
6. Apply complete feature function set to both optimal and sub-optimal images (true + simulated) and evaluate performance.
7. Investigate results and select features with smooth & consistent behavior over the entire mammographic image set.

Further work:

1. Image quality assessment by the expert physician over the entire image set.
2. Investigate correlation (mapping) between expert's quality curves and one or more of the selected feature functions.
3. Finalize choices on one or more feature functions and formulate feedback for control loop.

Current Progress Overview:

- **Web-based public mammographic image database**
- Experiment planning & documentation
- Preliminary phantom image database
- SimModel-1A: exposure simulation
- PredModel-1A: texture features extraction
- PredModel-1B: feature quality evaluation versus exposure

Web-based public mammographic image database

Requirements:

- medium- to high-resolution mammographic images
- at least 8-bit grayscale
- sets of similar images (exposure settings, views, etc).

Selected database: **MiniMIAS** [01]

- 322 images of normal and abnormal cases of various pathologies
- digitized at 50μm, resized to 200μm
- final resolution: 1024x1024x8
- created by: Royal Marsden Hospital, London, UK.
- used selected subsets of 20-100 “profile” images as base for simulated images (DB1).

Current Progress Overview:

- ✓ *Web-based public mammographic image database*
- ➢ **Experiment planning & documentation**
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Experiment Documentation

Basic Task:

- document mammographic device specifications
- document experiment settings and environment
- log experiment progress and image acquiring (samples)
- document technical aspects of image quality for each sample
- document clinical aspects of image quality for each sample

Reference Base: [02-05]

- Mammographic device quality assessment reports
- List of technical aspects related to image quality (Technician's QC)
- List of clinical aspects related to image quality (Physician's QC)

Form A: X-Ray Equipment Specifications Assessment

FORM A: X-Ray Equipment Specifications Assessment

Site:		**Survey Date**	
		Medical Physicist	
X-Ray Unit Manufacturer		**Contact**	
X-Ray Unit Model		**Email**	
Last QC Report Date		**Signature**	

Tube Potential	kVp	**Minimum Setting**	**Maximum Setting**	**Step Setting**	**Nominal Setting**
Tube Current		**Minimum Setting**	**Maximum Setting**	**Step Setting**	**Nominal Setting**
	mA				
	mAs				
Focal spot size	µm	**Minimum Value**	**Maximum Value**		**Nominal Value**
Magnification factor		**Minimum Value**	**Maximum Value**		**Nominal Value**
Filter types available		**Mo/Mo**	**Mo/Rh**	**Rh/Rh**	**W/Re**	**Other (specify)**
		Y N	Y N	Y N	Y N	
Filter thickness	mm					
Grid types available		**Configuration 1**	***Configuration 2***		***Configuration 3***
Grid thickness	mm				
Detector type					
Detector size		**Configuration 1**	***Configuration 2***		***Configuration 3***
	cm x cm				
Pixel size	µm				
Number of Pixels	p x p				
Spatial Resolution	lp/mm				
Scan time		**Minimum Value**	**Maximum Value**		**Nominal Value**
	sec				
Effective Exposure Time		**Minimum Value**	**Maximum Value**		**Nominal Value**
	msec				

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FORM A: X-Ray Equipment Specifications Assessment

Matrix size	p x p	**Setting 1**	***Setting 2***	***Setting 3***
Graylevel depth	bits/pixel			
AERC modes available		**Configuration 1**	***Configuration 2***	***Configuration 3***
Optical Density modes		**Minimum Setting**	**Maximum Setting**	**Step Setting**	**Nominal Setting**
Comments					

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Form B: Image Acquisition – Experiment Settings

FORM B: Image Acquisition – Experiment Settings

Site:		Survey Date	
		Medical Physicist	
X-Ray Unit Manufacturer		Contact	
X-Ray Unit Model		Email	
Last QC Report Date		Signature	

Tube Potential		Minimum Setting	Maximum Setting	Step Setting	Nominal Setting
	kVp				
Tube Current		Minimum Setting	Maximum Setting	Step Setting	Nominal Setting
	mA				
	mAs				
Focal spot size		Setting Used			
	µm				
Magnification factor					
Filter type used		Mo/Mo	Mo/Rh	Rh/Rh	W/Re	Other (specify)
	☑	☐	☐	☐	☐	
Filter thickness	mm				
Grid type		Configuration Used			
Grid thickness	mm				
Detector type					
Detector size		Configuration Used			
	cm x cm				
Pixel size	µm				
Number of Pixels	p x p				
Spatial Resolution	lp/mm				
Matrix size	p x p				
Graylevel depth	bits/pixel				
AERC mode	Default: OFF				

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FORM B: Image Acquisition – Experiment Settings

Optical Density mode (AERC: on)	Default: OFF	
Target Used		
Target type		
Target diameter	mm	
Target thickness	mm	
Comments		

Page 2 of 2

Form C: Image Acquisition – Experiment Logging

FORM C: Image Acquisition – Experiment Logging

Site:		Survey Date		Test Set	
		Medical Physicist		Machine ID	
X-Ray Unit Manufacturer		Contact		Target ID	
X-Ray Unit Model		Email		Current Page	
Last QC Report Date		Signature		Total Pages	

EMULSION		SETTINGS				RESULTS					
		Values Set				True Values				Air Kerma	MGD
TestID	Filename	kVp	mA	sec	mAs	kVp	mA	sec	mAs	mGy	mGy

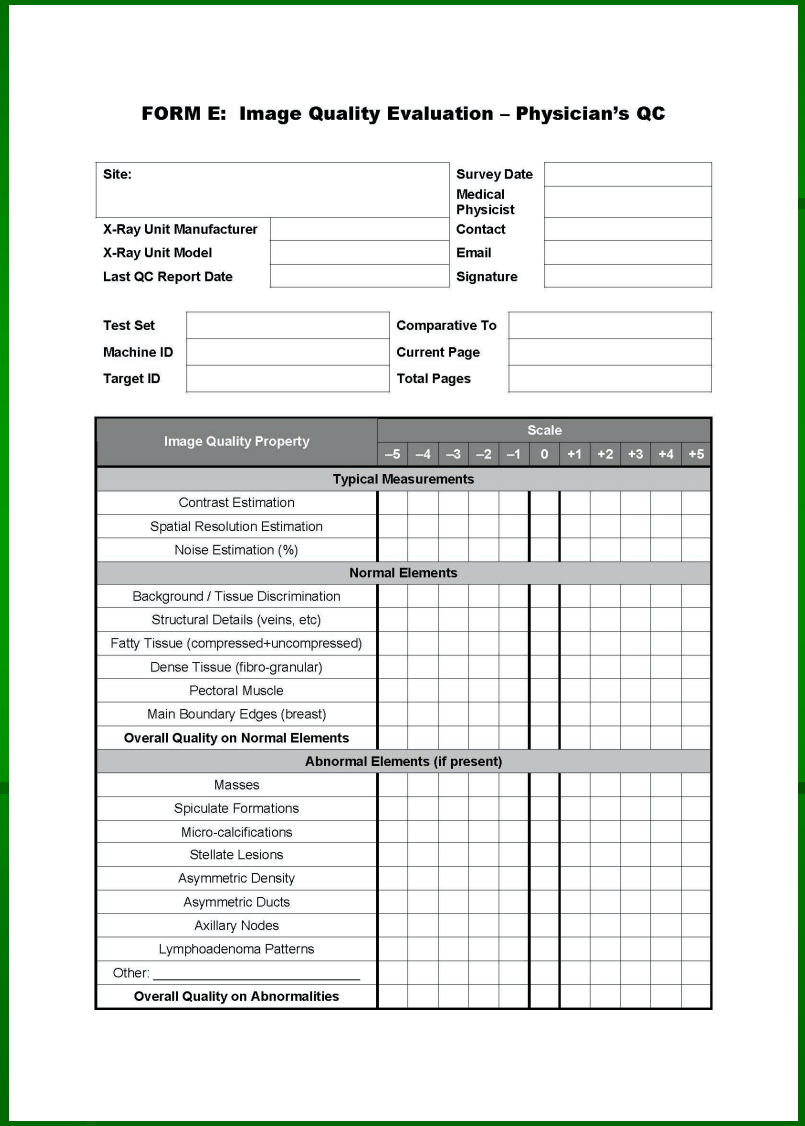
Form D: Image Quality Evaluation – Technician's QC

FORM D: Image Quality Evaluation – Technician's QC

Site:		Survey Date		Test Set	
		Name		Machine ID	
X-Ray Unit Manufacturer		Contact		Target ID	
X-Ray Unit Model		Email		Current Page	
Last QC Report Date		Signature		Total Pages	

EMULSION		IMAGE QUALITY EVALUATION								
		Resolution			Intensity				Noise	Beam Quality
TestID	Filename	SR	Hi-CR	Lo-CR	OD1	OD2	Diff(2-1)	Diff (%)	rms (%)	HVL

Form E: Image Quality Evaluation – Physician's QC



FORM E: Image Quality Evaluation – Physician's QC

Site:		Survey Date	
		Medical Physicist	
X-Ray Unit Manufacturer		Contact	
X-Ray Unit Model		Email	
Last QC Report Date		Signature	

Test Set		Comparative To	
Machine ID		Current Page	
Target ID		Total Pages	

Image Quality Property	Scale										
	–5	–4	–3	–2	–1	0	+1	+2	+3	+4	+5
Typical Measurements											
Contrast Estimation											
Spatial Resolution Estimation											
Noise Estimation (%)											
Normal Elements											
Background / Tissue Discrimination											
Structural Details (veins, etc)											
Fatty Tissue (compressed+uncompressed)											
Dense Tissue (fibro-granular)											
Pectoral Muscle											
Main Boundary Edges (breast)											
Overall Quality on Normal Elements											
Abnormal Elements (if present)											
Masses											
Spiculate Formations											
Micro-calcifications											
Stellate Lesions											
Asymmetric Density											
Asymmetric Ducts											
Axillary Nodes											
Lymphoadenoma Patterns											
Other: _____											
Overall Quality on Abnormalities											

Image Quality Properties (doctor's grading):

- Contrast Estimation (quality)
- Spatial Resolution Estimation (quality)
- Noise Estimation (%)

- Background / Tissue Discrimination
- Structural Details (veins, etc)
- Fatty Tissue
- Dense Tissue (fibro-granular)
- Main Boundary Edges (sharpness)

- Masses
- Spiculate Formations
- Micro-calcifications
- Stellate Lesions
- Asymmetric Density
- Asymmetric Ducts
- Axillary Nodes
- Lymphoadenoma Patterns

Current Progress Overview:

- ✓ *Web-based public mammographic image database*
- ✓ *Experiment planning & documentation*
- ➢ **Preliminary phantom image database**
- SimModel-1A: exposure simulation
- PredModel-1B: texture features extraction
- PredModel-1B: feature quality evaluation versus exposure

Preliminary Phantom Image Database

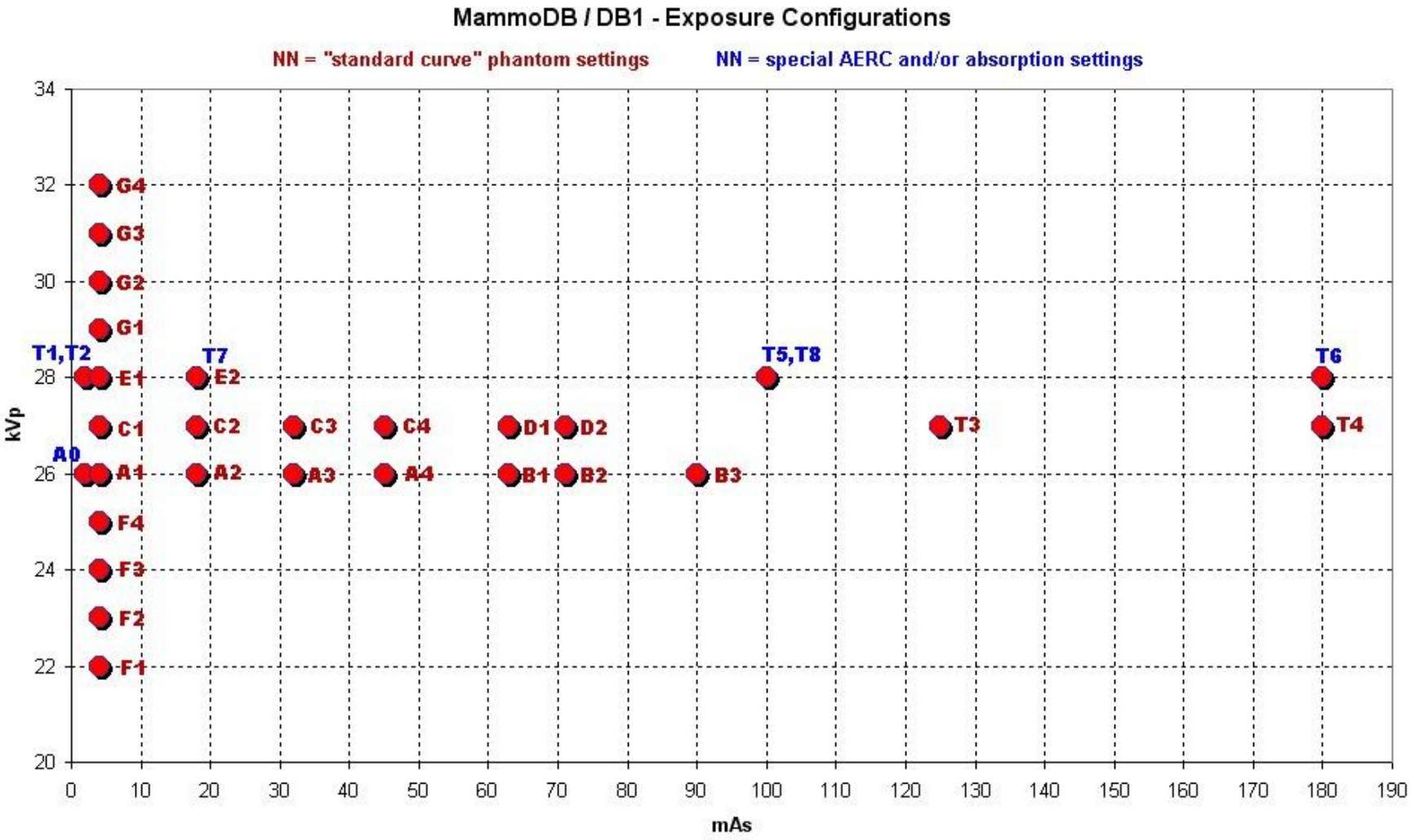
Basic Task:

- Create a reference base for simulated results in order to verify theoretical models (SimModel-1A)
- Use a high-quality phantom suited for mammographic screening
- Document experiments using Forms A-E

Experiment Results:

- Conducted at EUROMEDICA medical center (Athens, Greece)
- Phantom used: Mammochip C141
- Device used: typical analog mammographer
- Parameter ranges used: 25-29 kVp , 4-180 mAs
- Exposure control: manual (selected tests with AERC on)
- Absorption simulation: none (selected tests with absorption layers)
- Total number of images acquired: 32 (DB2)

MammoDB / DB1 : Experiment Planning



Current Progress Overview:

- ✓ *Web-based public mammographic image database*
- ✓ *Experiment planning & documentation*
- ✓ *Preliminary phantom image database*
- ➢ **SimModel-1A: exposure simulation**
- PredModel-1A: texture features extraction
- PredModel-1B: feature quality evaluation versus exposure

SimModel-1A: Exposure simulation

Basic Task:

- Formulate a realistic theoretical model for simulating manual exposure configurations using optimal exposure images.
- Apply simulation model in all (optimal) mammographic images to create simulated (sub-optimal) images (DB1).
- Validate simulation results (DB1) using real phantom images at various exposure configurations (DB2).
- use base set of **20** images, generate **21** exposure simulation for each one, calculate **20** features over **3** box sizes (10, 25, 50), calculate feature **mean** and **stdev** values.

Model Design (parameters): [06-12]

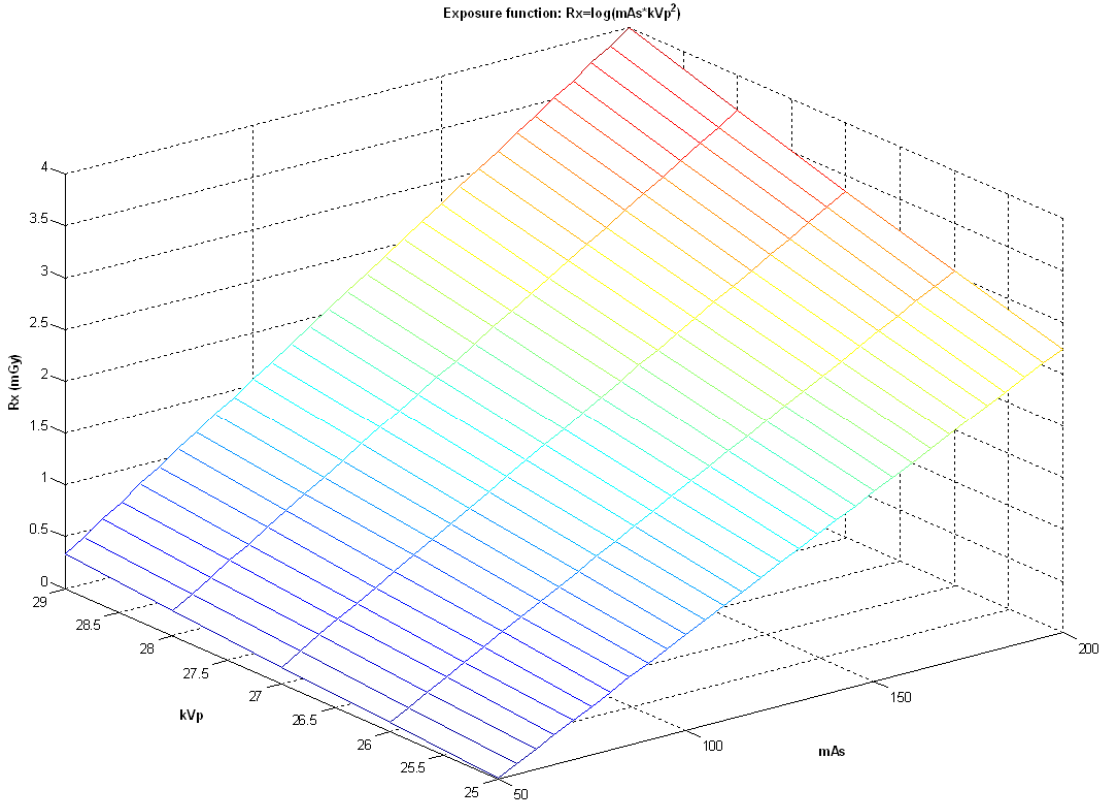
- Rx : Radiation Exposure
- OD : Optical Density of X-ray projected subject
- GL : Gray Value of (digital) sensors
- GI : Greylevel of pixels in the resulting image

F1:
kVp: [25…29] , mAs: [50…200]
Rx : [0,0128…4,000] mGy

$$Rx: f_1(kVp, mAs) = C_{1,1} \cdot \log_{10}\{(kVp)^2 \cdot (mAs)\} + C_{1,0}$$

$$C_{1,0} = -0{,}897021103$$

$$C_{1,1} = 0{,}000029114$$

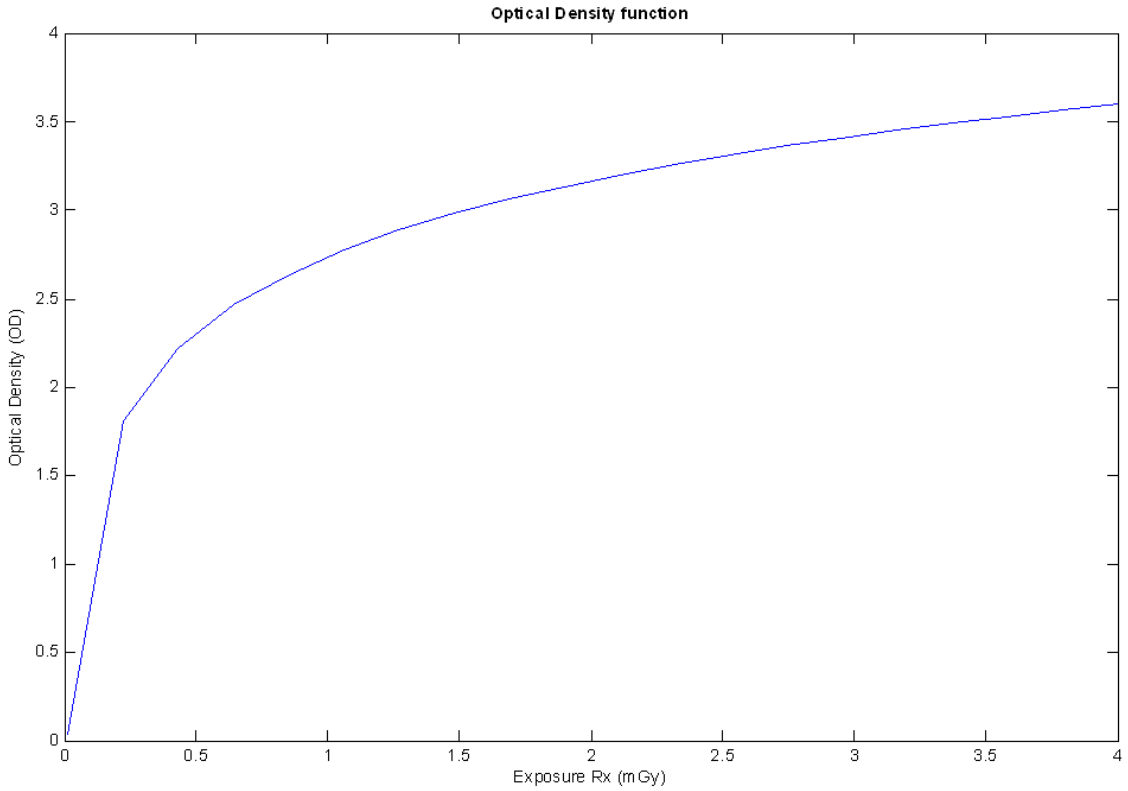


F2:
Rx : [0,0128…4,000] mGy
OD: [0,04…3,60]

$$OD: f_2(Rx) = C_{2,1} \cdot \log_{10}(Rx) + C_{2,0}$$

$$C_{2,0} = 2{,}740896827$$

$$C_{2,1} = 1{,}426939483$$

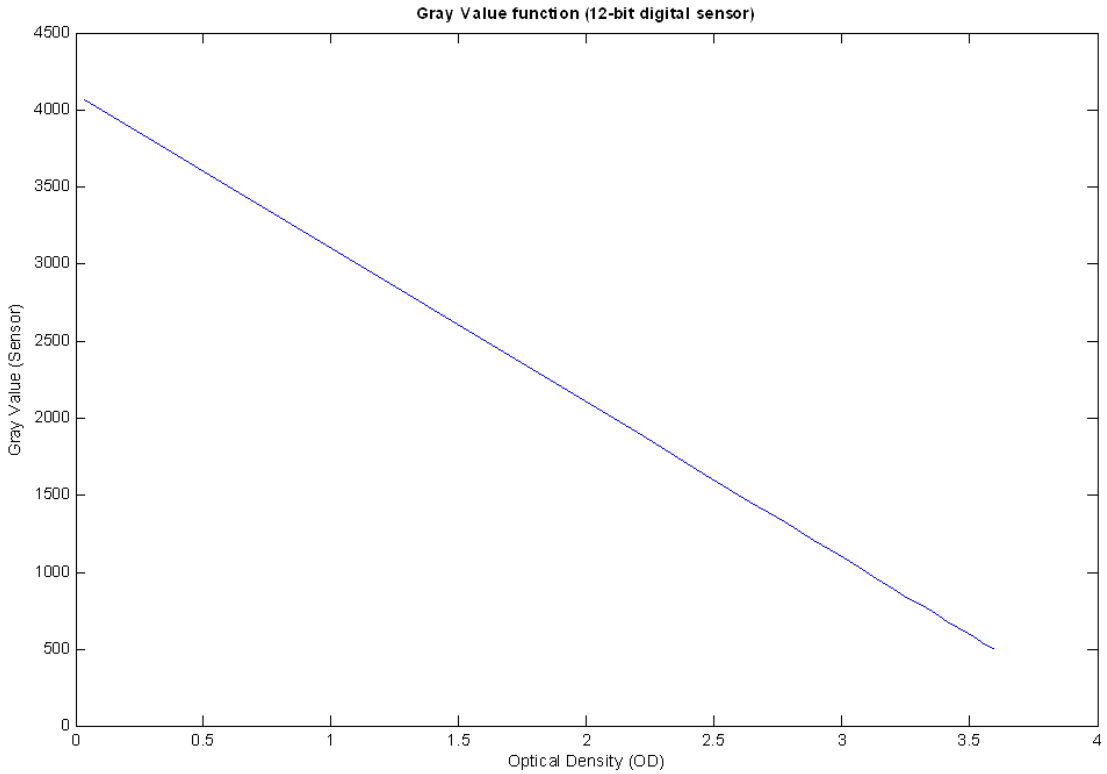


F3:
OD: [0,04 …3,60]
GL: [495 …4069]

$$GL: f_3(OD) = (OD - C_{3,0}) \cdot {}^{1}\!/\!_{C_{3,1}}$$

$$C_{3,0} = 4{,}093060996$$

$$C_{3,1} = -0{,}000996083$$

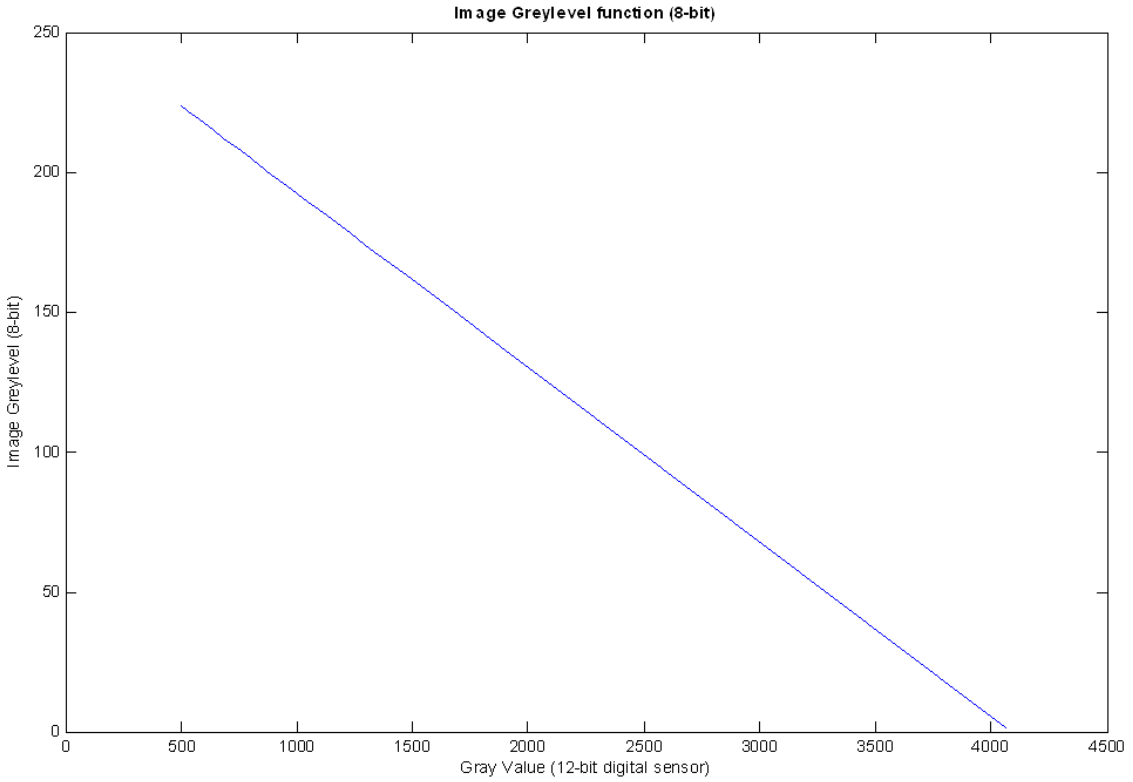


F4:
GL: [4095 ...0]
GI: [0 ...255]

$$GI : F_4(GL) = C_{4,1} \cdot (GL) + C_{4,0}$$

$$C_{4,0} = 255$$

$$C_{4,1} = -0{,}062271062$$



SimModel-1A: Overview

MODEL:

$$\{image_0[x,y]\} \longrightarrow [Rx] \xrightarrow{f2} [OD] \xrightarrow{f3} [GL] \xrightarrow{f4} [GI] \longrightarrow \{image_1[x,y]\}$$

$$\left.\begin{array}{l}\{kVp(0), mAs(0)\} \xrightarrow{f1} [Rx(0)] \\ \{kVp(z), mAs(z)\} \xrightarrow{f1} [Rx(z)]\end{array}\right\} \Rightarrow r = \frac{Rx(0)}{Rx(z)}$$

Inverse Model Functions:

$$GL: f_4^{-1}(GI) = (GI - C_{4,0}) \cdot {}^{1}\!/\!_{C_{4,1}}$$

$$OD: f_3^{-1}(GL) = C_{3,1} \cdot OD + C_{3,0}$$

$$Rx: f_2^{-1}(OD) = 10^{\frac{OD - C_{2,0}}{C_{2,1}}}$$

SimModel-1A: Processing

FULL SIMULATION PROCEDURE:

1. $Input: \{kVp(0), mAs(0)\}, \{image(0)_{x,y}\}, \{kVp(z), mAs(z)\}$

2. $\left.\begin{array}{l}\{kVp(0), mAs(0)\} \xrightarrow{f1} [Rx(0)] \\ \{kVp(z), mAs(z)\} \xrightarrow{f1} [Rx(z)]\end{array}\right\} \Rightarrow r = \dfrac{Rx(z)}{Rx(0)}$

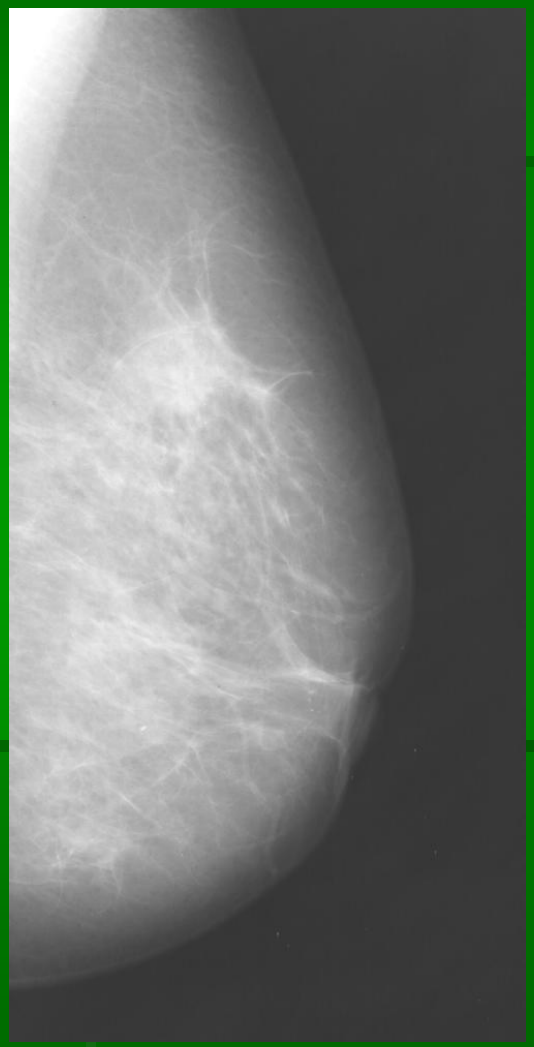
3. $\{image(0)_{x,y}\} \longrightarrow GI(0)_{x,y} \xrightarrow{f_4^{-1}} GL(0)_{x,y} \xrightarrow{f_3^{-1}} OD(0)_{x,y} \xrightarrow{f_2^{-1}} Rx(0)_{x,y}$

4. $Rx(z)_{x,y} = \dfrac{Rx(0)_{x,y}}{r}$

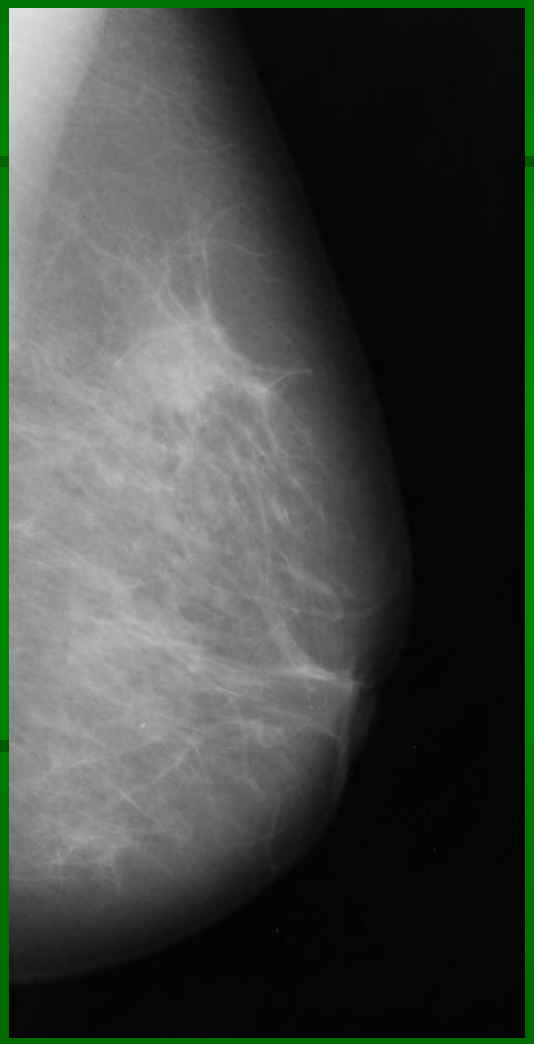
5. $Rx(z)_{x,y} \xrightarrow{f_2} GL(z)_{x,y} \xrightarrow{f_3} GI(z)_{x,y} \longrightarrow \{image(z)_{x,y}\}$

6. $Output: \{image(z)_{x,y}\}$

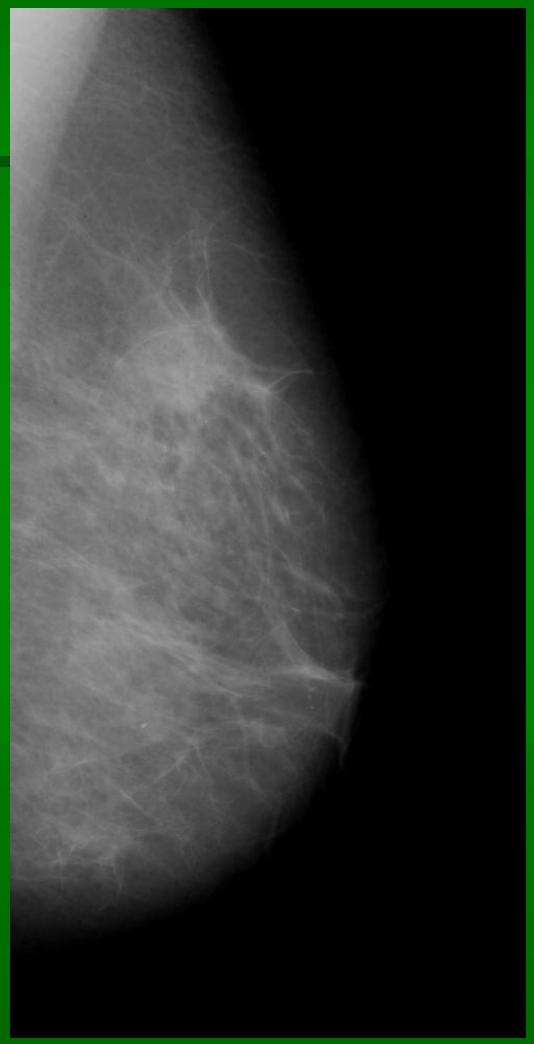
SimModel-1A: Results (samples from DB1)



sim.#1: 25 kVp / 75 mAs



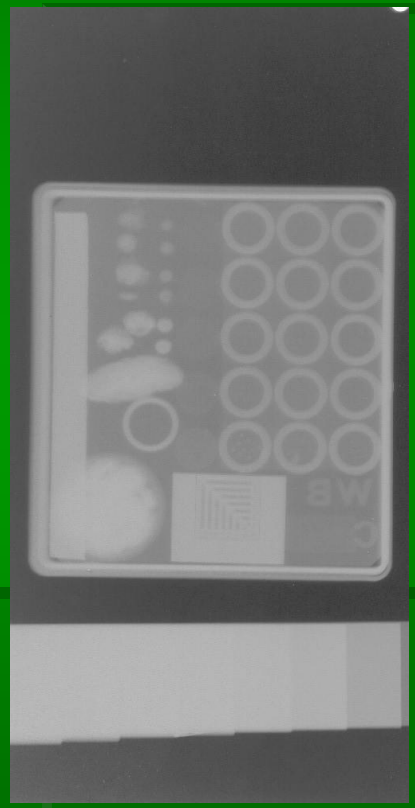
init: 27 kVp / 125 mAs



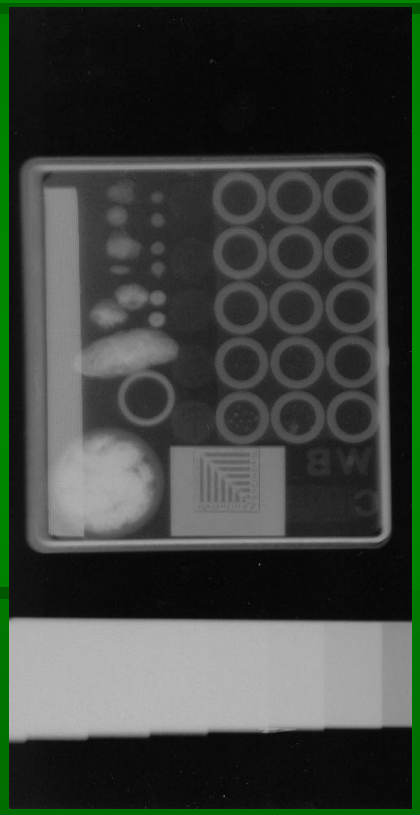
cfg.2: 29 kVp / 200 mAs

SimModel-1A: Validation & Verification (samples from DB2)

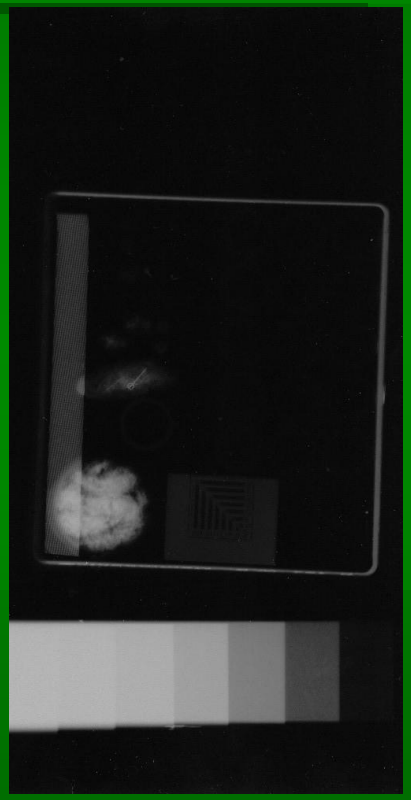
Real experimental phantom images included in DB2:



cfg.F2: 23 kVp / 4 mAs



cfg.A1: 26 kVp / 4 mAs



cfg.G2: 30 kVp / 4 mAs

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- ✓ *Web-based public mammographic image database*
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- ✓ *Preliminary phantom image database*
- ✓ *SimModel-1A: exposure simulation*
- ➢ **PredModel-1A: texture features extraction**
- PredModel-1B: feature quality evaluation versus exposure

PredModel-1A: Texture Features Extraction

Basic Task:

- Formulate a set of content-rich textural feature function, well-suited for mammographic image analysis.
- Use only first-order statistics or functions of low computational complexity [11-17].
- Apply complete set of feature functions over all the available images (real + simulated) and construct analytical profiles.

Model Design (specifications):

- Apply progressive image scanning on x-axis
- Average calculated feature values per scanning “column”
- Produce simple 1-D transition curves for each feature function

Min value:

$$I_{\min} = \min_{XY}\{I(x,y)\}$$

Max value:

$$I_{\max} = \max_{XY}\{I(x,y)\}$$

Mean value:

$$\mu = \frac{1}{XY}\sum_{i=1}^{X}\sum_{j=1}^{Y} I(x,y)$$

Standard Deviation:

$$\sigma = \sqrt{\frac{1}{(XY-1)}\sum_{i=1}^{X}\sum_{j=1}^{Y}\left(I(x,y)-\mu\right)^2}$$

Skewness:

$$sk = \frac{1}{XY}\sum_{i=1}^{X}\sum_{j=1}^{Y}\left(\frac{I(x,y)-\mu}{\sigma}\right)^3$$

Kurtosis:

$$kr = \left(\frac{1}{XY}\sum_{i=1}^{X}\sum_{j=1}^{Y}\left(\frac{I(x,y)-\mu}{\sigma}\right)^4\right)-3$$

Signal Power:

$$P_{XY} = \sum_{i=1}^{X}\sum_{j=1}^{Y}\left\|I(x,y)\right\|^2$$

Entropy:

$$E = \sum_{k=1}^{100} P_{Ghist(k)} \cdot \log(P_{Ghist(k)})$$

Zero-Crossings count:

$$ZC = \sum\left\{k : (I_k(x,y)-\mu)\cdot(I_{k+1}(x,y)-\mu) \le 0\right\}$$

Surface:

$$S_{XY} = \sum_{i=1}^{X-1}\sum_{j=1}^{Y-1}\left(I(x,y)+1+\left\|I(x+1,y)-I(x,y)\right\|+\left\|I(x,y+1)-I(x,y)\right\|\right)$$

Volume:

$$V_{XY} = \sum_{i=1}^{X}\sum_{j=1}^{Y} I(x,y)$$

Synth.Feature-12:

$$SF_{12} = \frac{(I_{\max} - I_{\min})^2}{\mu}$$

Synth.Feature-13:

$$SF_{13} = \frac{\mu - I_{\min}}{I_{\max} - I_{\min}}$$

Synth.Feature-14:

$$SF_{14} = \frac{\mu}{\sigma}$$

Synth.Feature-15:

$$SF_{15} = \frac{P_{XY}}{\mu^2}$$

Synth.Feature-16:

$$SF_{16} = \frac{\sqrt{S_{XY}}}{\sqrt[3]{V_{XY}}}$$

Synth.Feature-17:

$$SF_{17} = \frac{S_{XY}}{\mathrm{XY}}$$

Synth.Feature-18:

$$SF_{18} = \frac{ZC}{XY}$$

Synth.Feature-19:

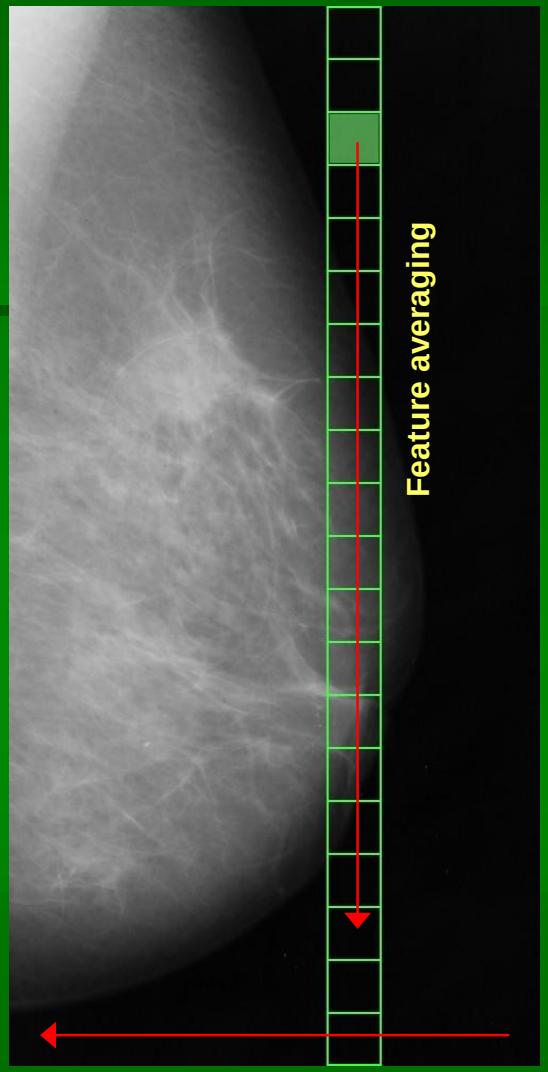
$$SF_{19} = \frac{P_{XY}}{XY}$$

Synth.Feature-20:

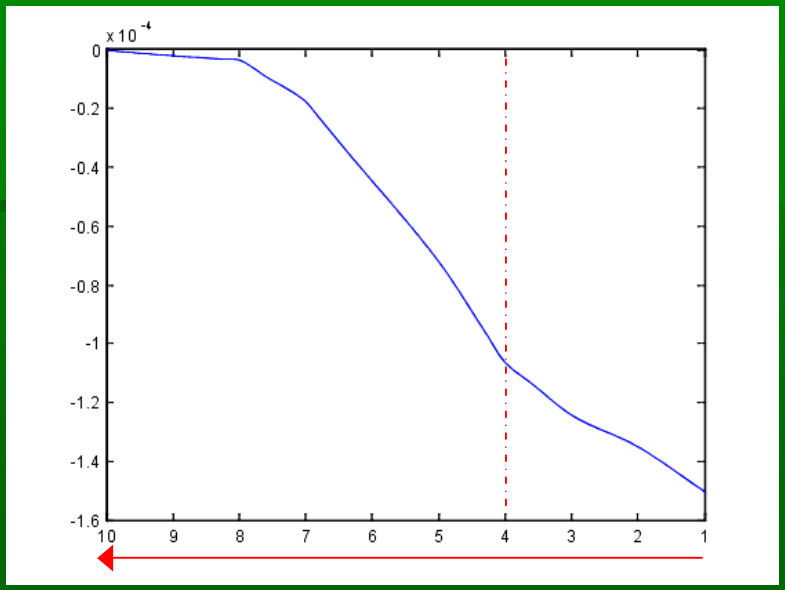
$$SF_{20} = \log\left(1 - \frac{SF_{19}}{255^2}\right)$$

PredModel-1A: Texture Feature Calculation

1. Calculate each feature for a fixed-sized box.
2. Average feature values for current “column”
3. Store mean value and advance to the next “column”
4. Final result is a 1-D curve for each feature function

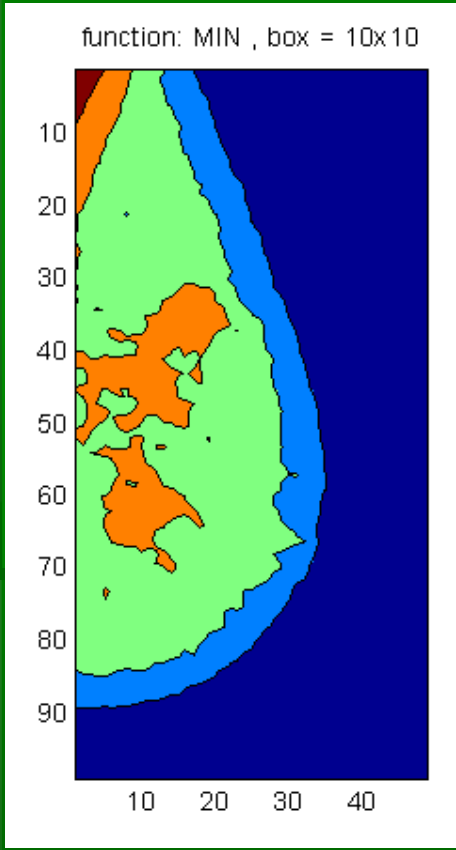


Feature value transition (1-D)

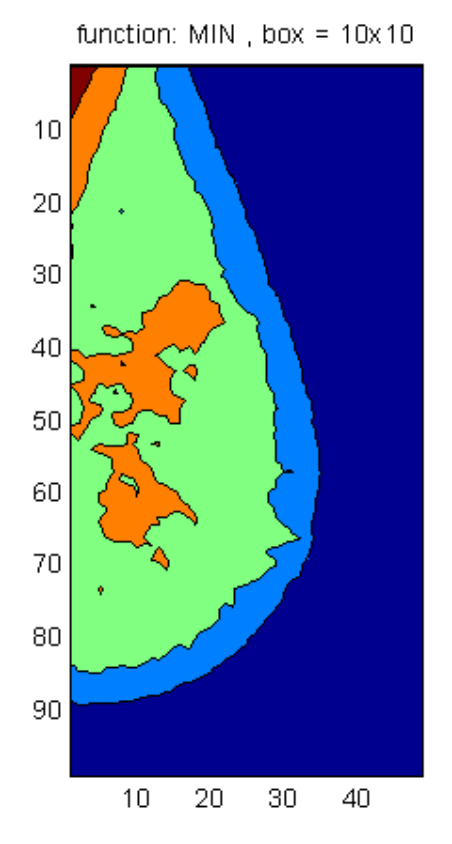


PredModel-1A: Intermediate 2-D results

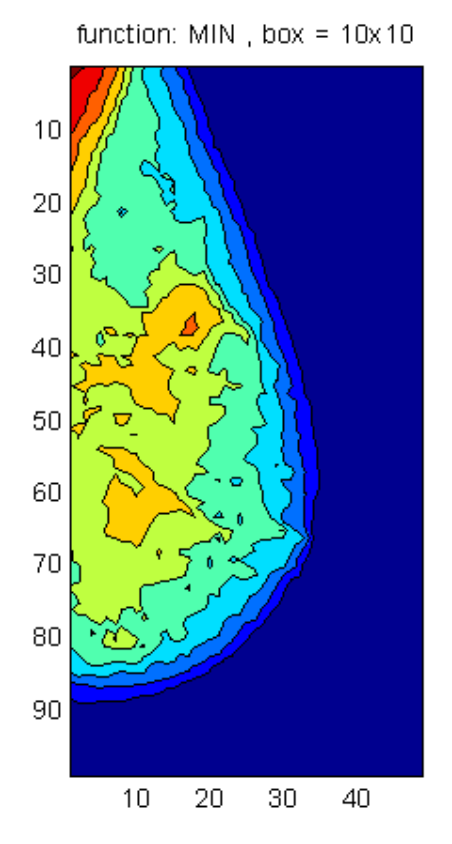
Function: F01 (MIN) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



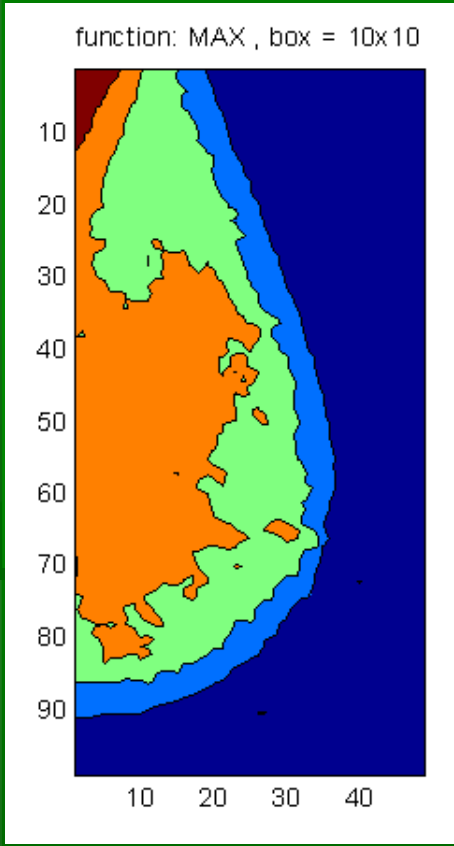
init: 27 kVp / 125 mAs



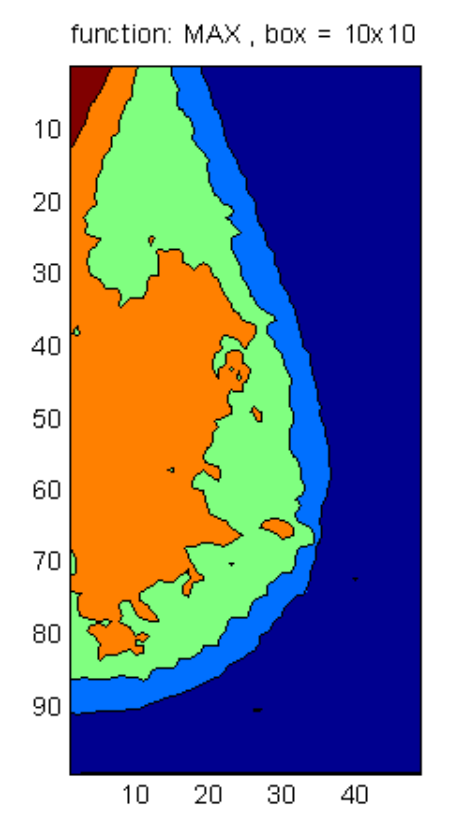
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

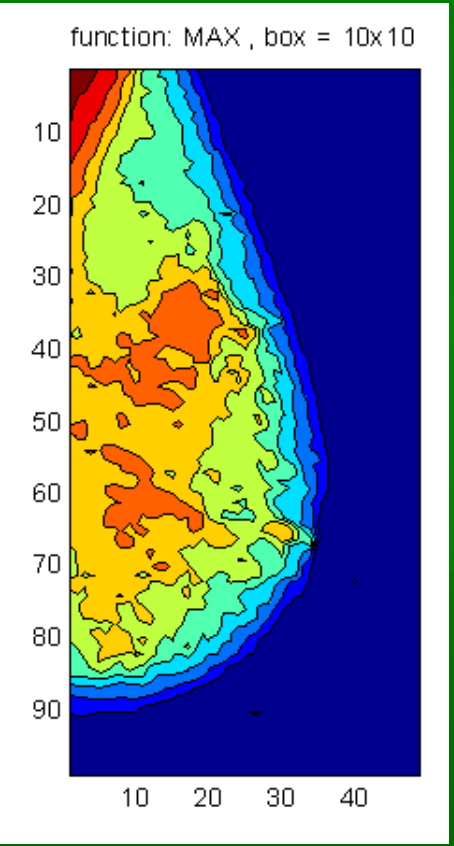
Function: F02 (MAX) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



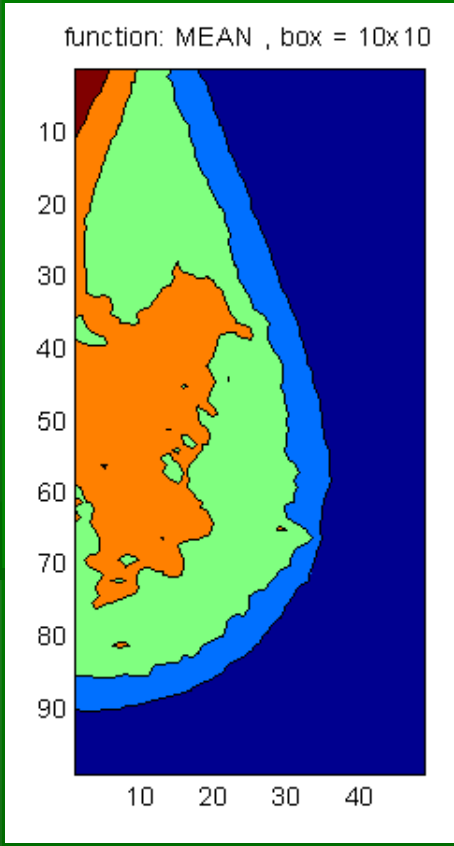
init: 27 kVp / 125 mAs



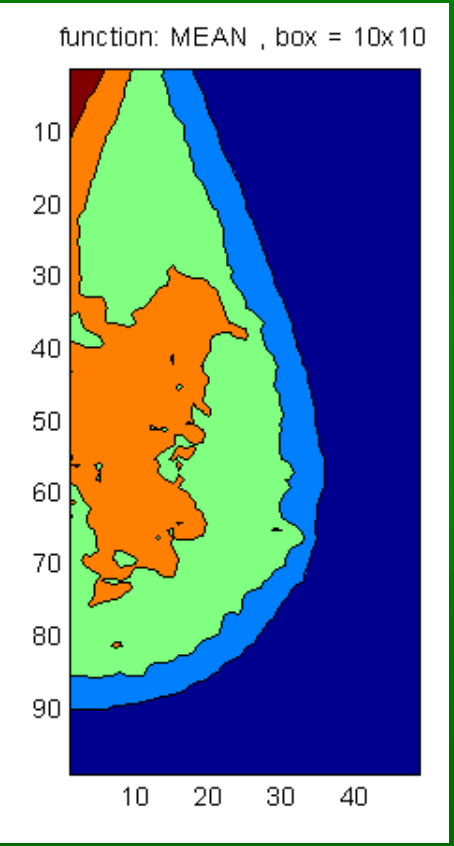
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

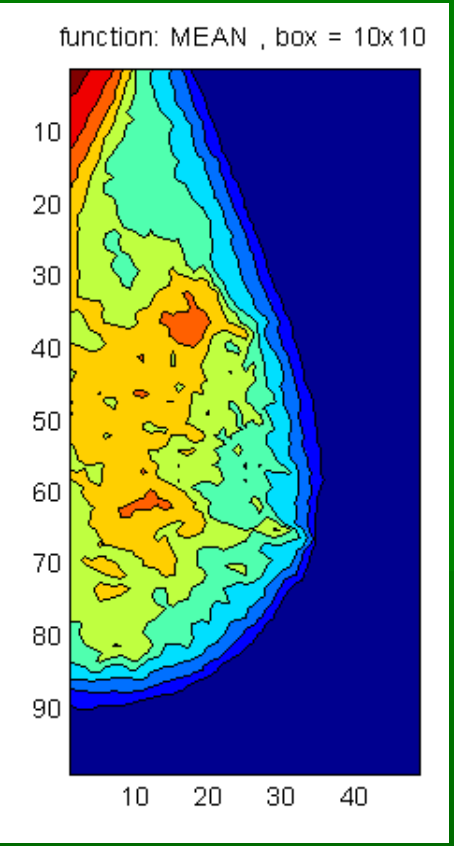
Function: F03 (MAX) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



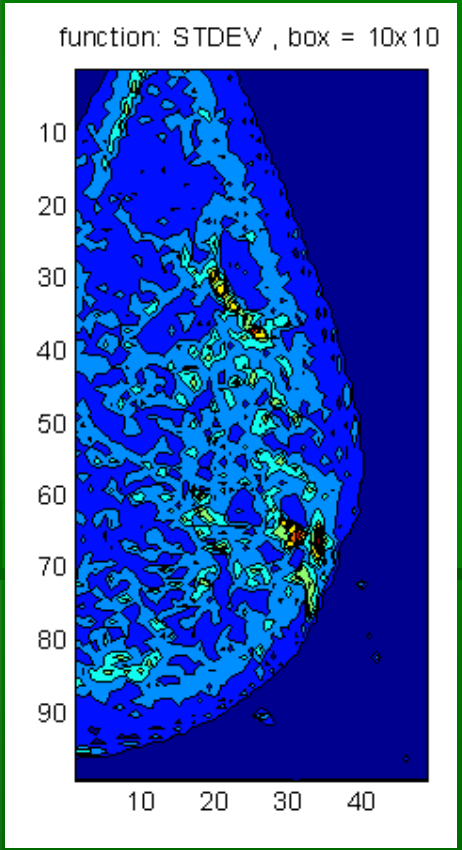
init: 27 kVp / 125 mAs



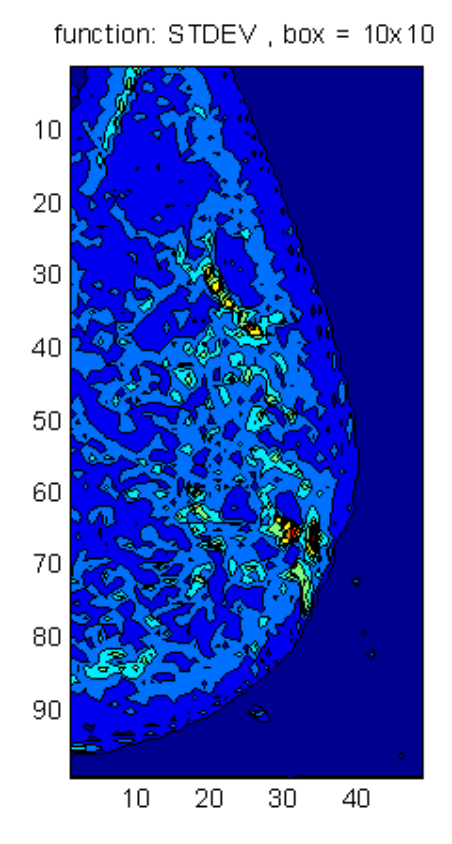
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

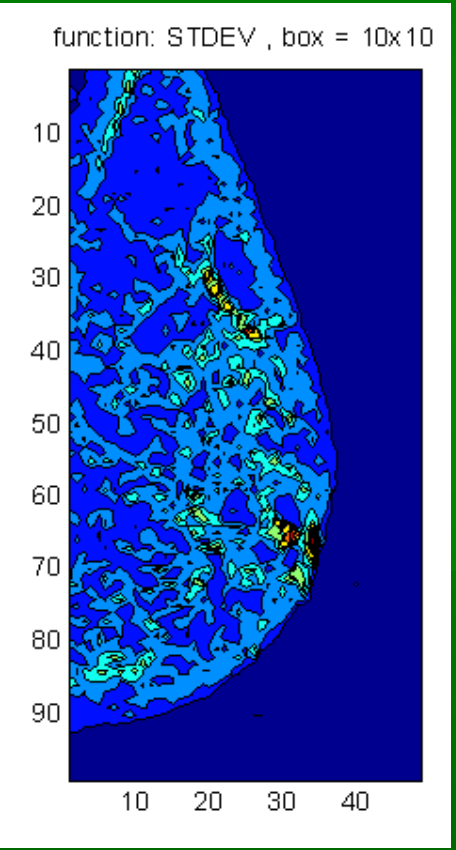
Function: F04 (STDEV) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



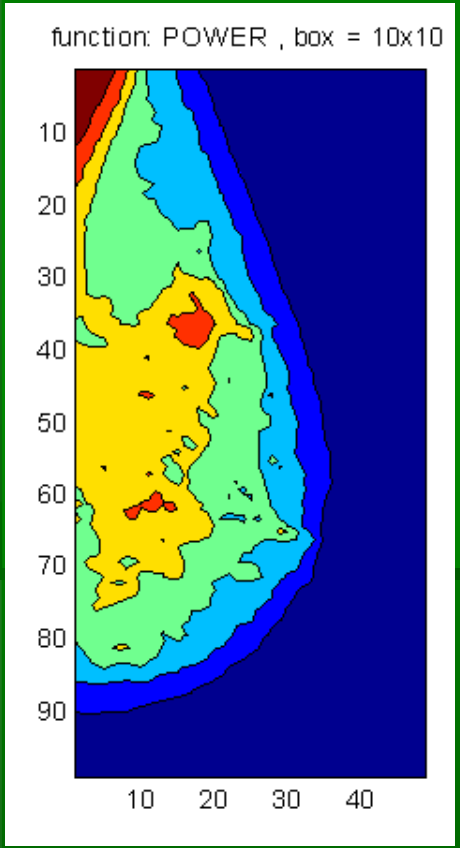
init: 27 kVp / 125 mAs



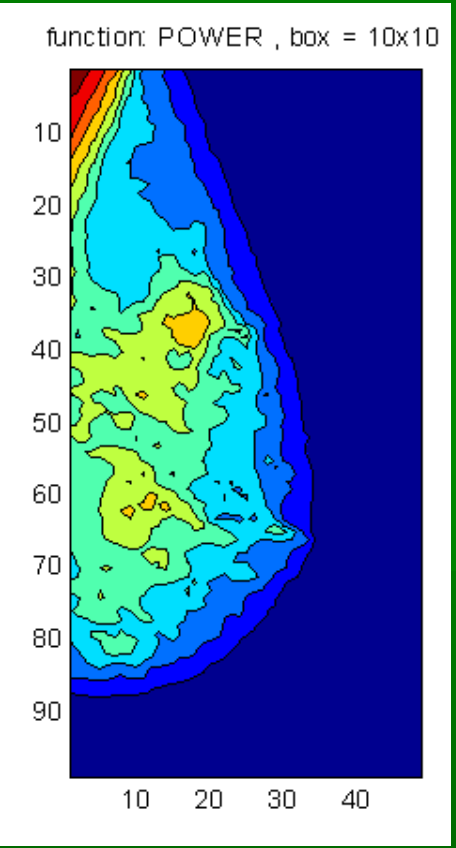
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

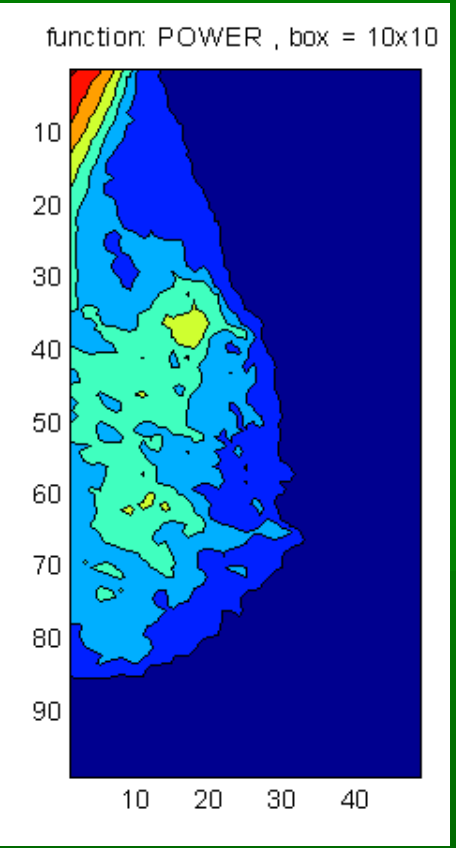
Function: F07 (POWER) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



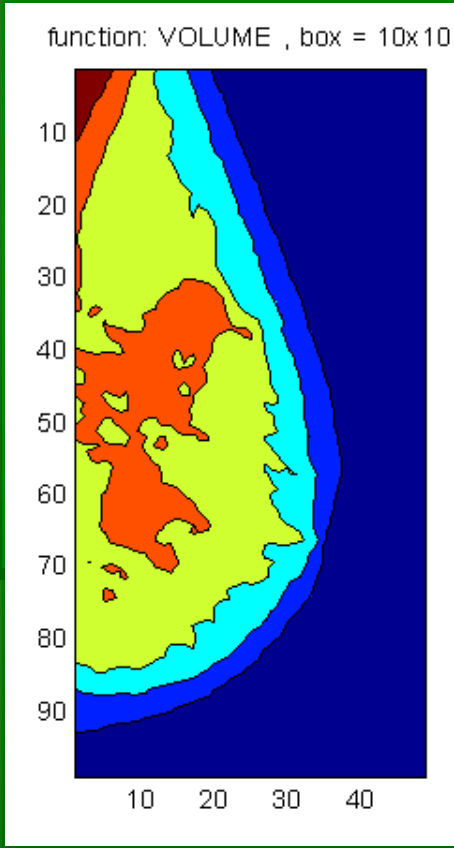
init: 27 kVp / 125 mAs



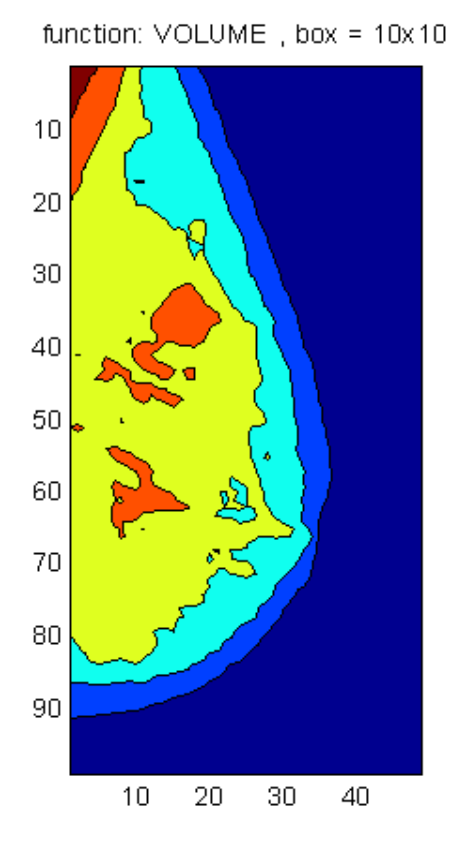
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

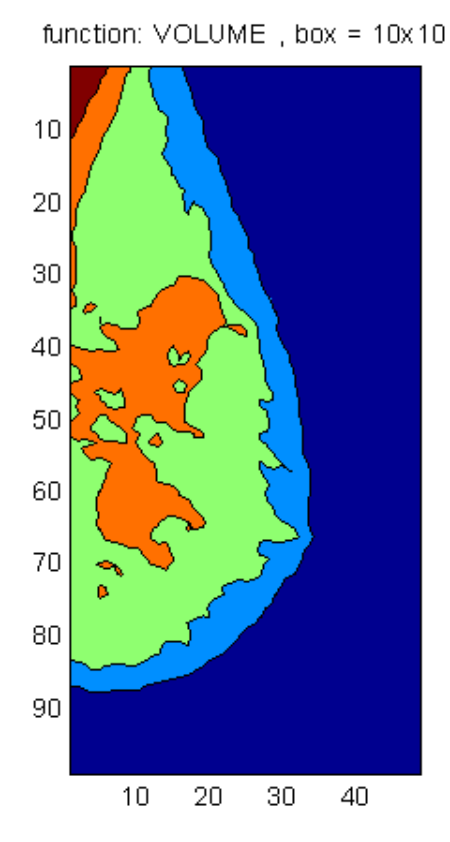
Function: F11 (VOLUME) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



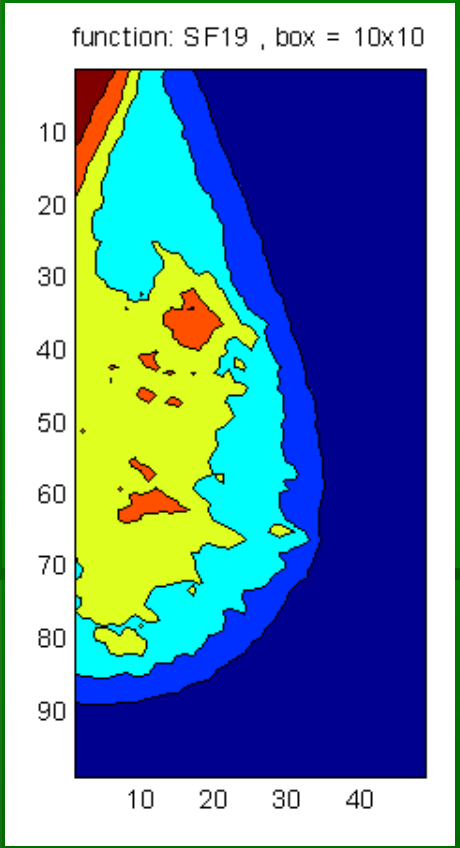
init: 27 kVp / 125 mAs



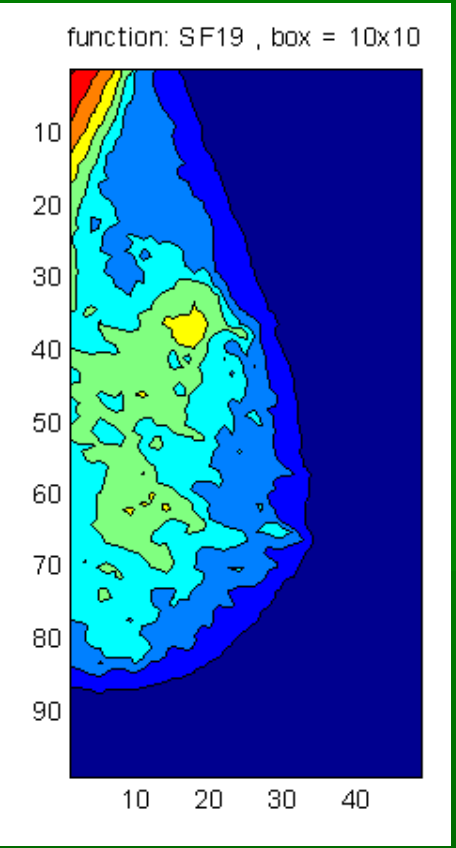
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

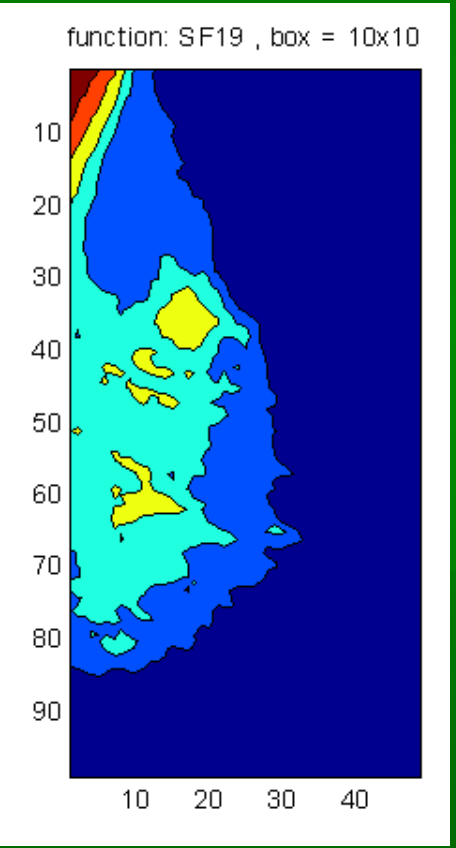
Function: SF19 (Synthetic) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



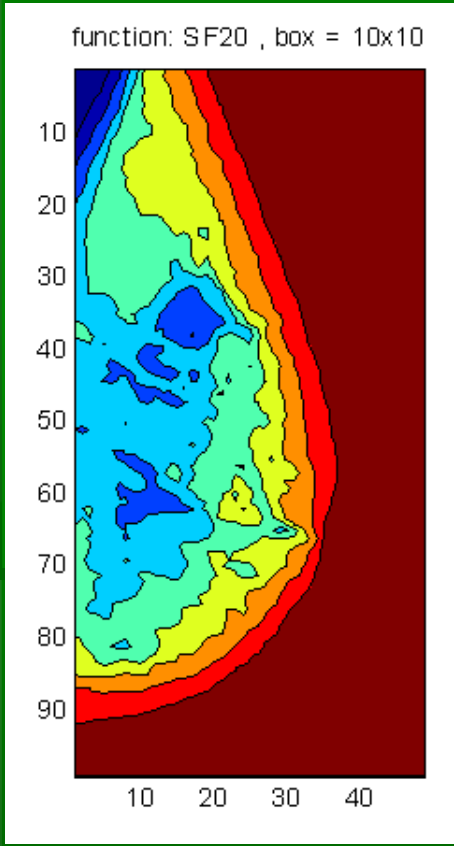
init: 27 kVp / 125 mAs



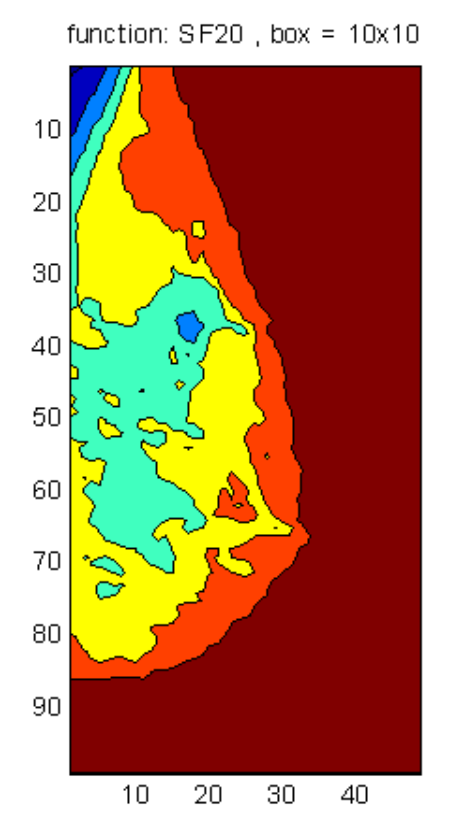
cfg.2: 29 kVp / 200 mAs

PredModel-1A: Intermediate 2-D results

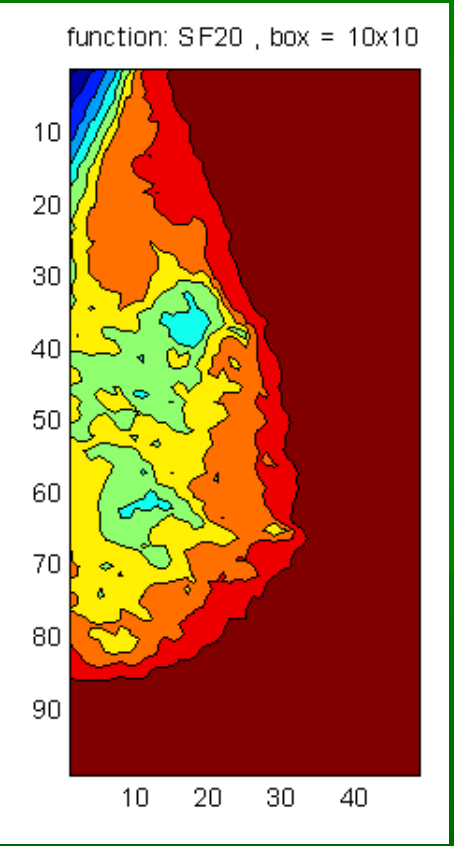
Function: SF20 (Synthetic) / boxsize: 10



sim.#1: 25 kVp / 75 mAs



init: 27 kVp / 125 mAs



cfg.2: 29 kVp / 200 mAs

Current Progress Overview:

- ✓ *Web-based public mammographic image database*
- ✓ *Experiment planning & documentation*
- ✓ *Preliminary phantom image database*
- ✓ *SimModel-1A: exposure simulation*
- ✓ *PredModel-1A: texture features extraction*
- ➢ **PredModel-1B: feature quality evaluation versus exposure**

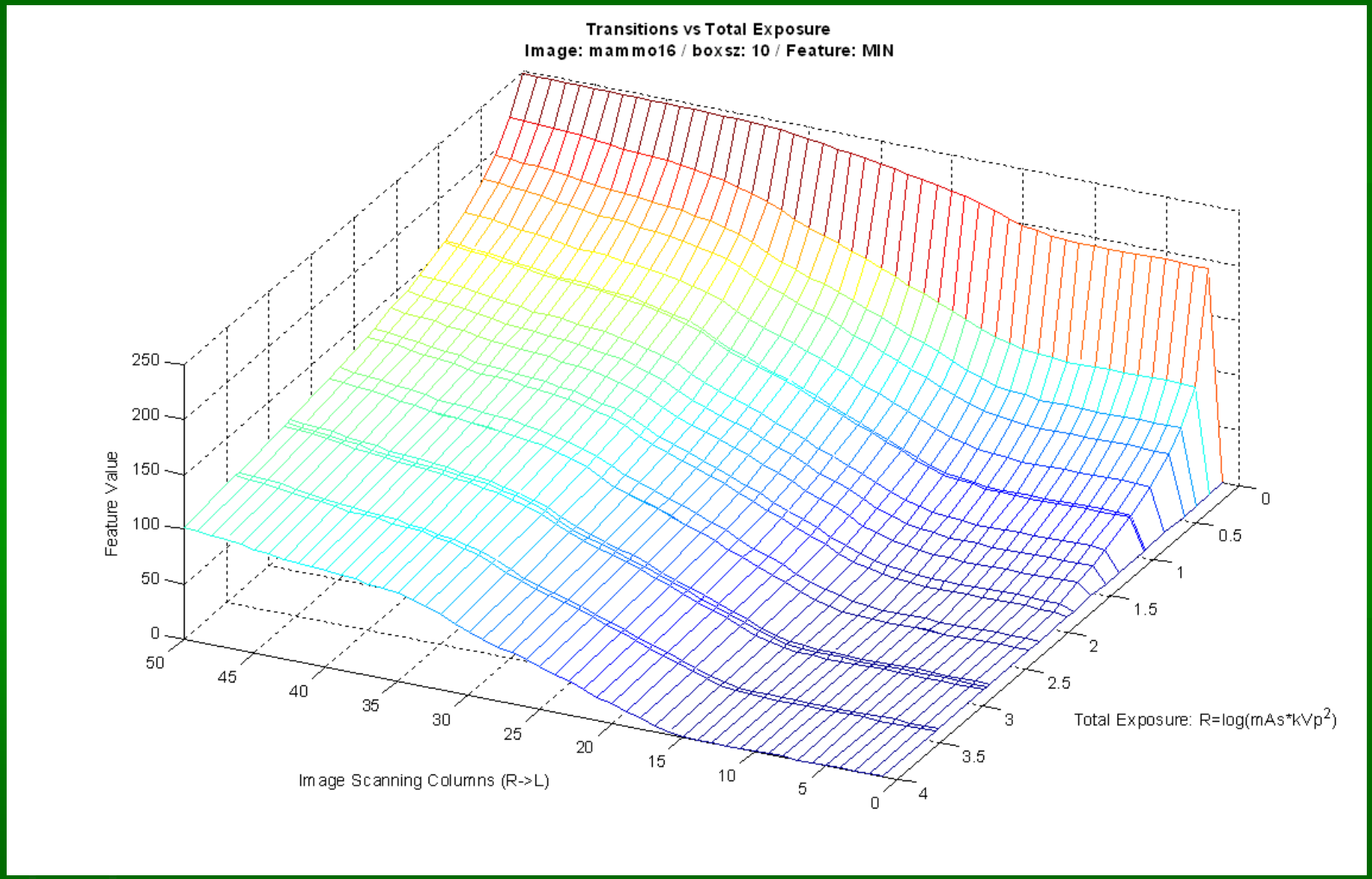
PredModel-1B: Texture Features Evaluation

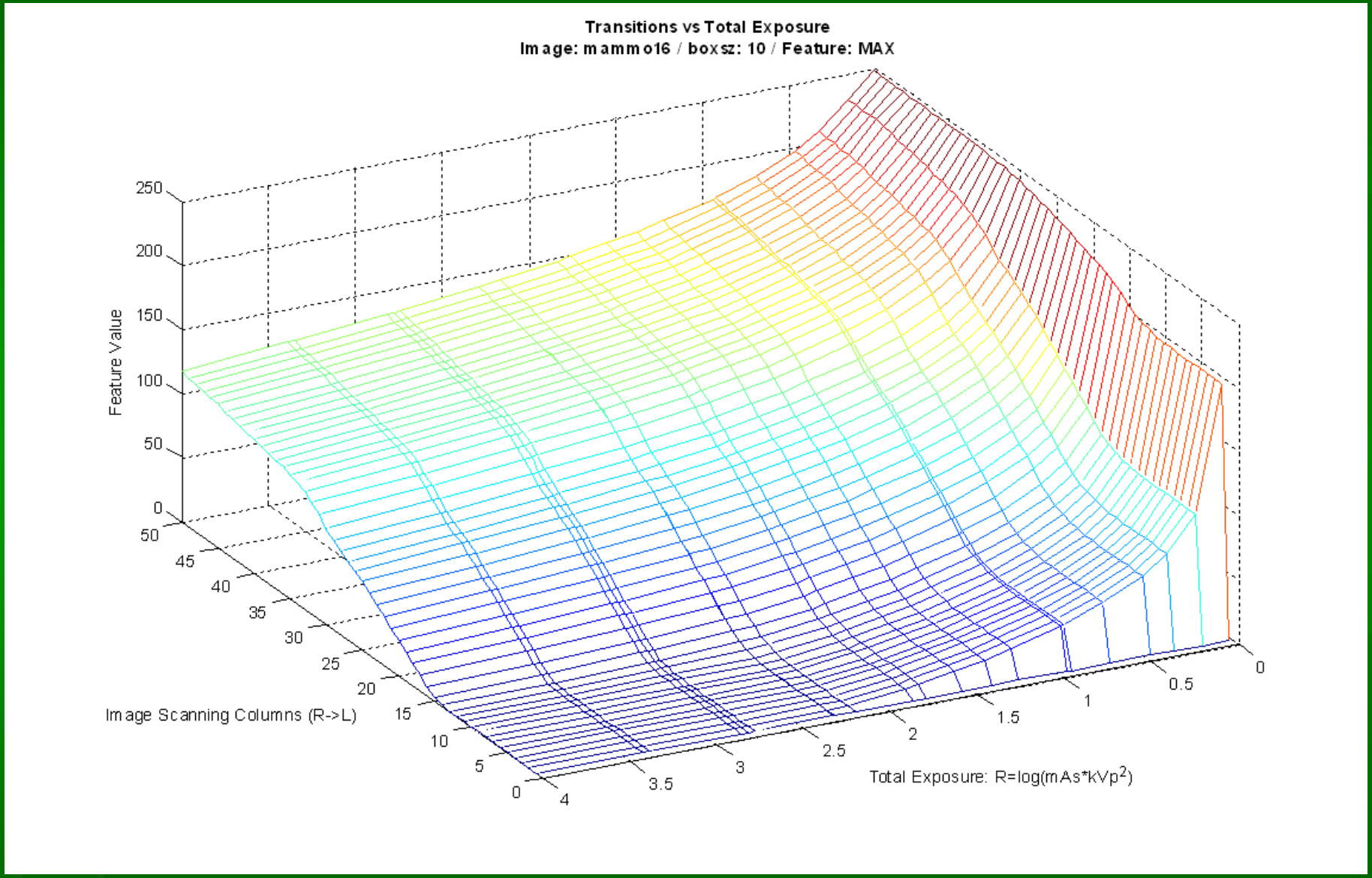
Basic Task:

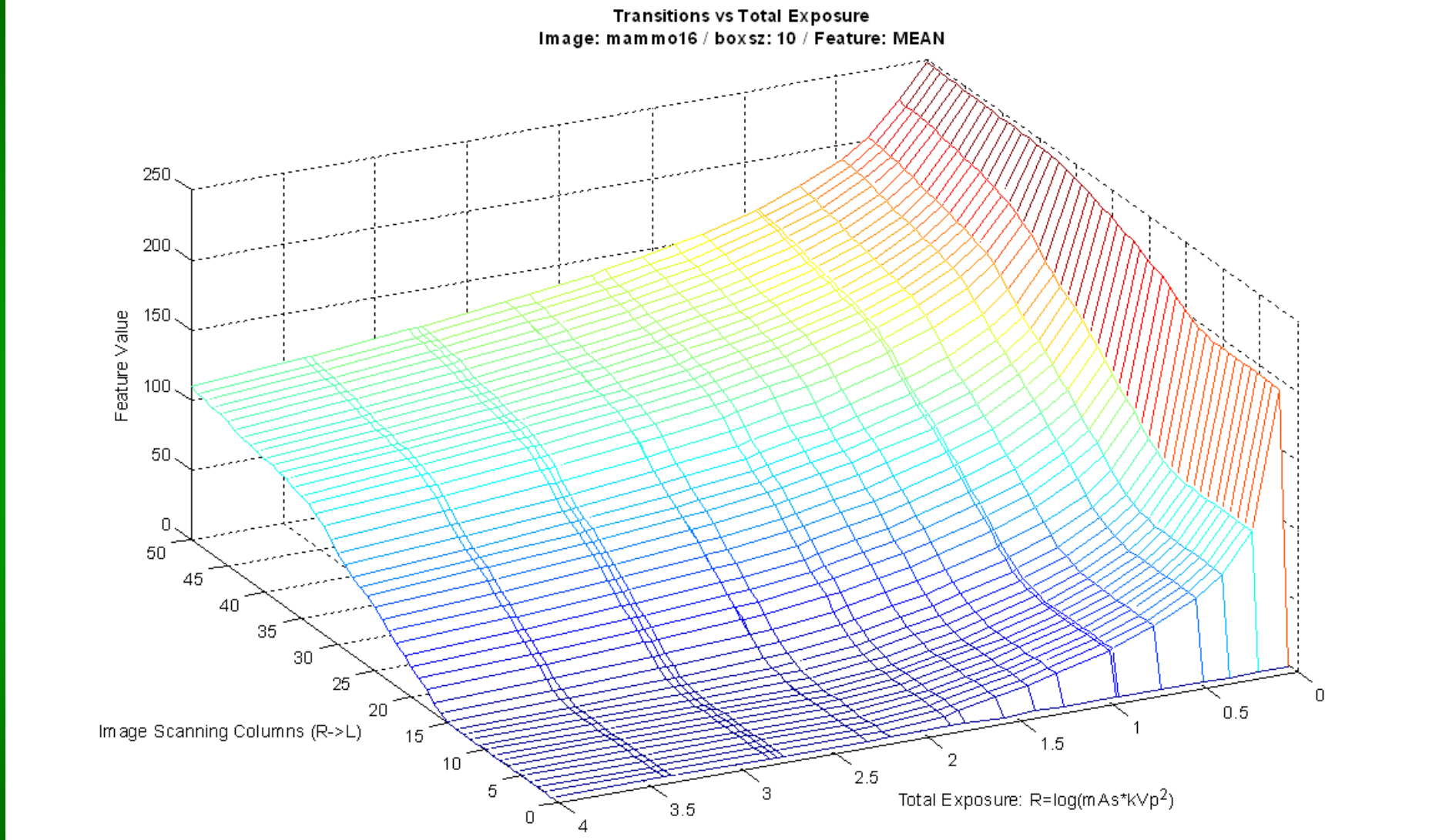
- Investigate feature results from PredModel-1A.
- Identify features with smooth & consistent behavior over the entire mammographic image set.
- Identify features with smooth & consistent behavior over the entire range of exposure settings.

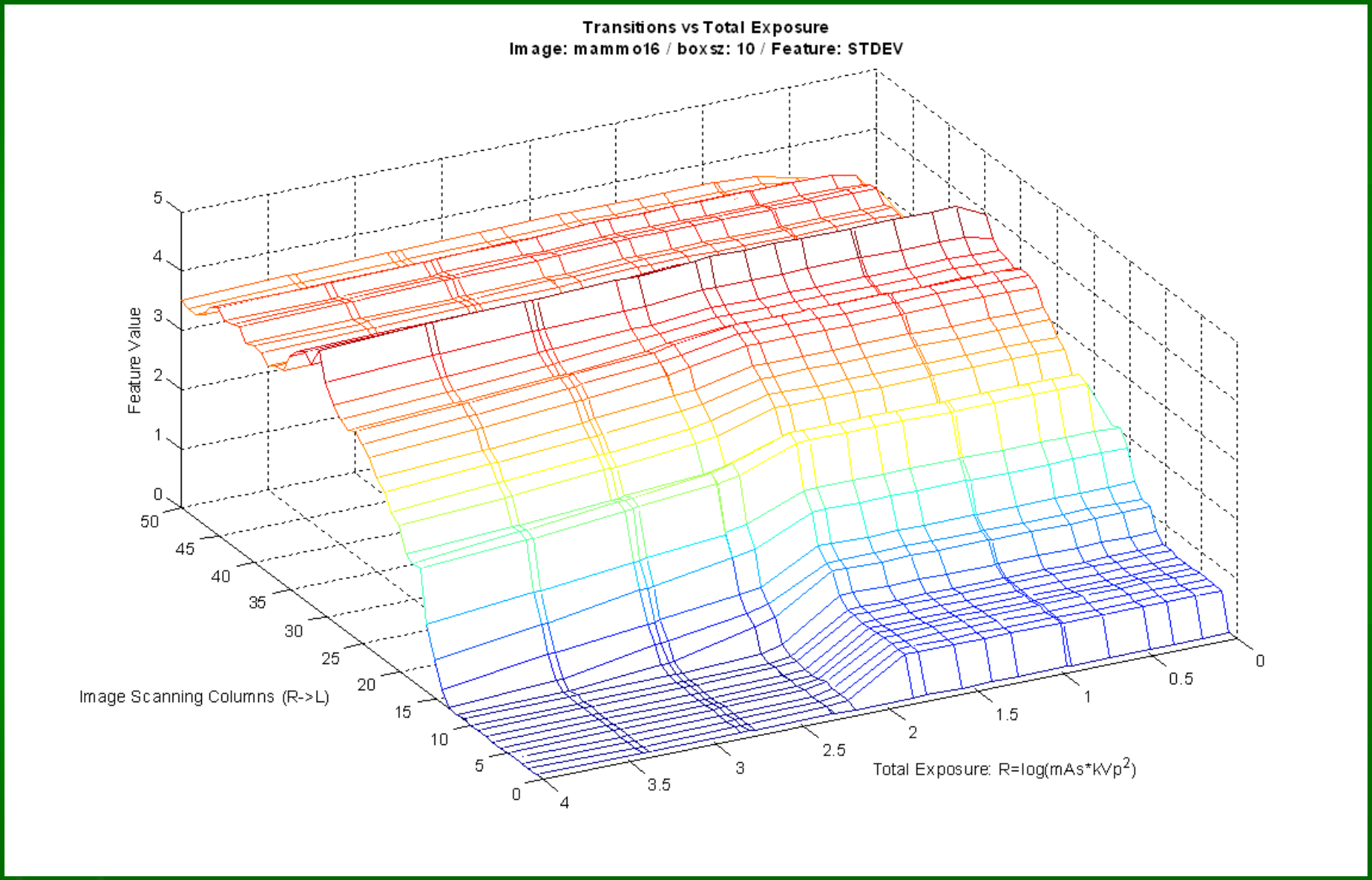
Model Design (specifications):

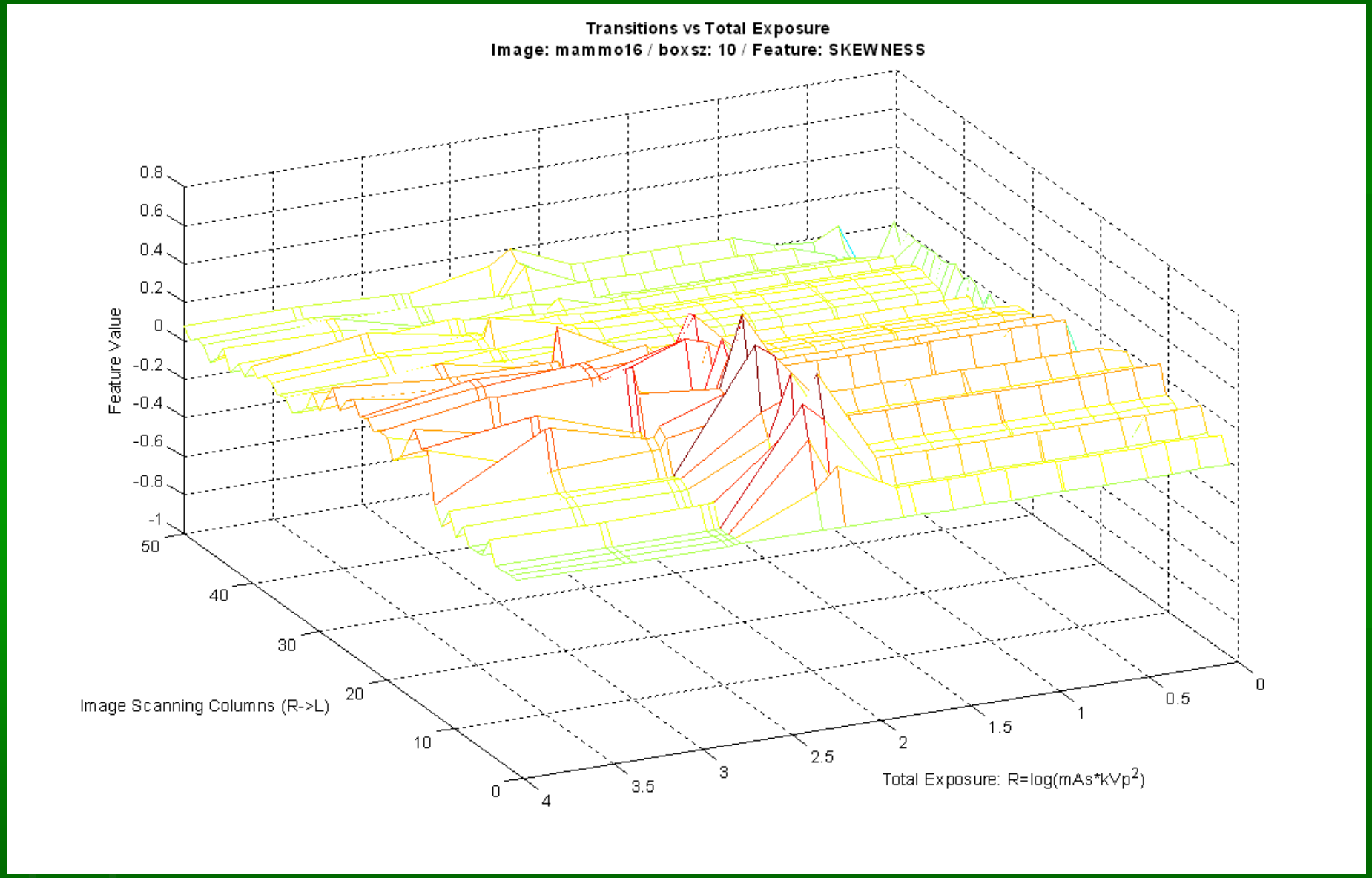
- Analyze feature functions behavior versus exposure.
- Conduct visual evaluation for preliminary selection.
- Investigate both exposure effects and breast tissue detection.

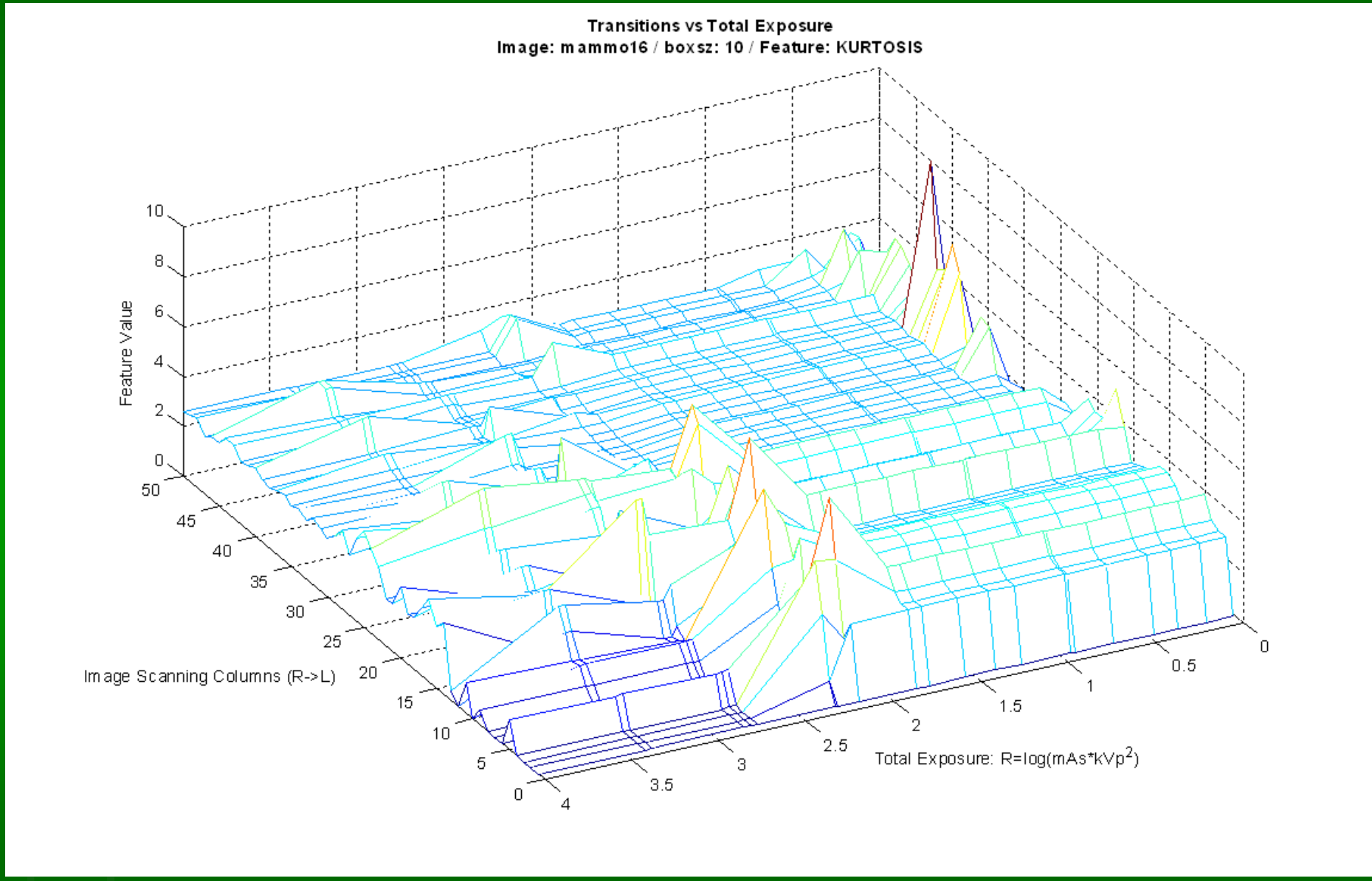

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: MIN
Feature Value
250
200
150
100
50
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp2)
0
0.5
1
1.5
2
2.5
3
3.5
4

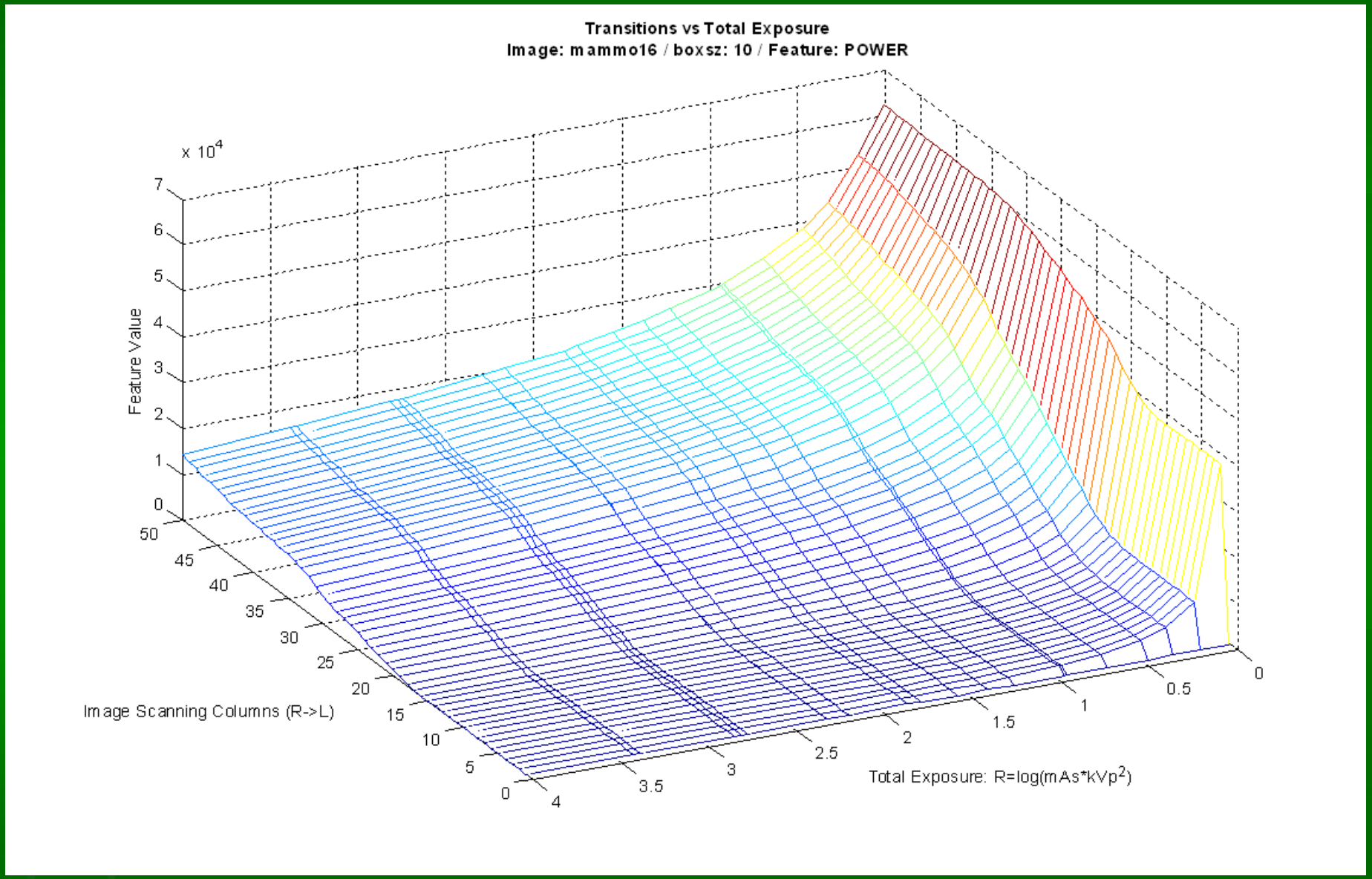

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: MAX
Feature Value
250
200
150
100
50
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0

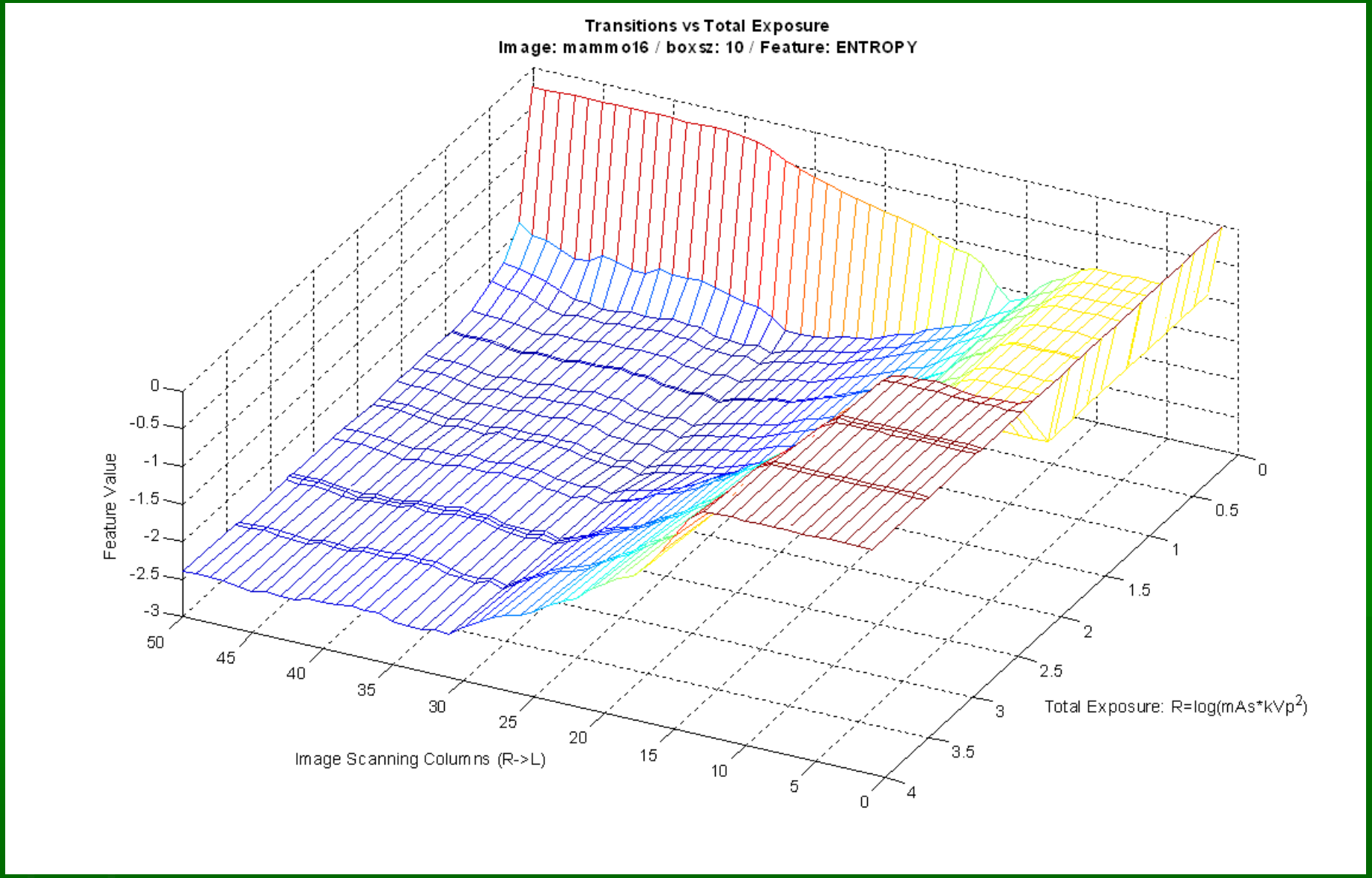

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: MEAN
Feature Value
250
200
150
100
50
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0

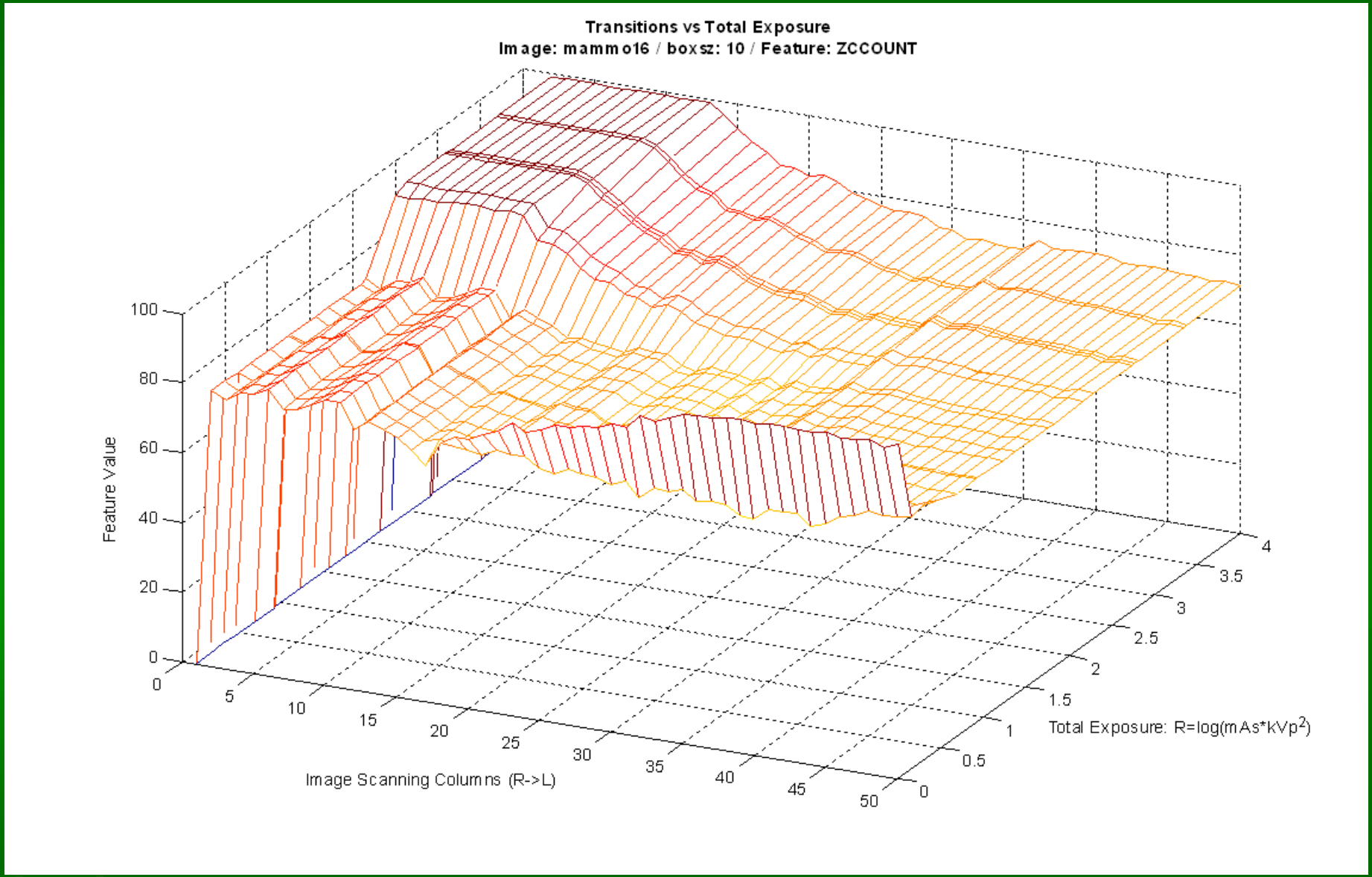

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: STDEV
Feature Value
0
1
2
3
4
5
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp^2)
4
3.5
3
2.5
2
1.5
1
0.5
0

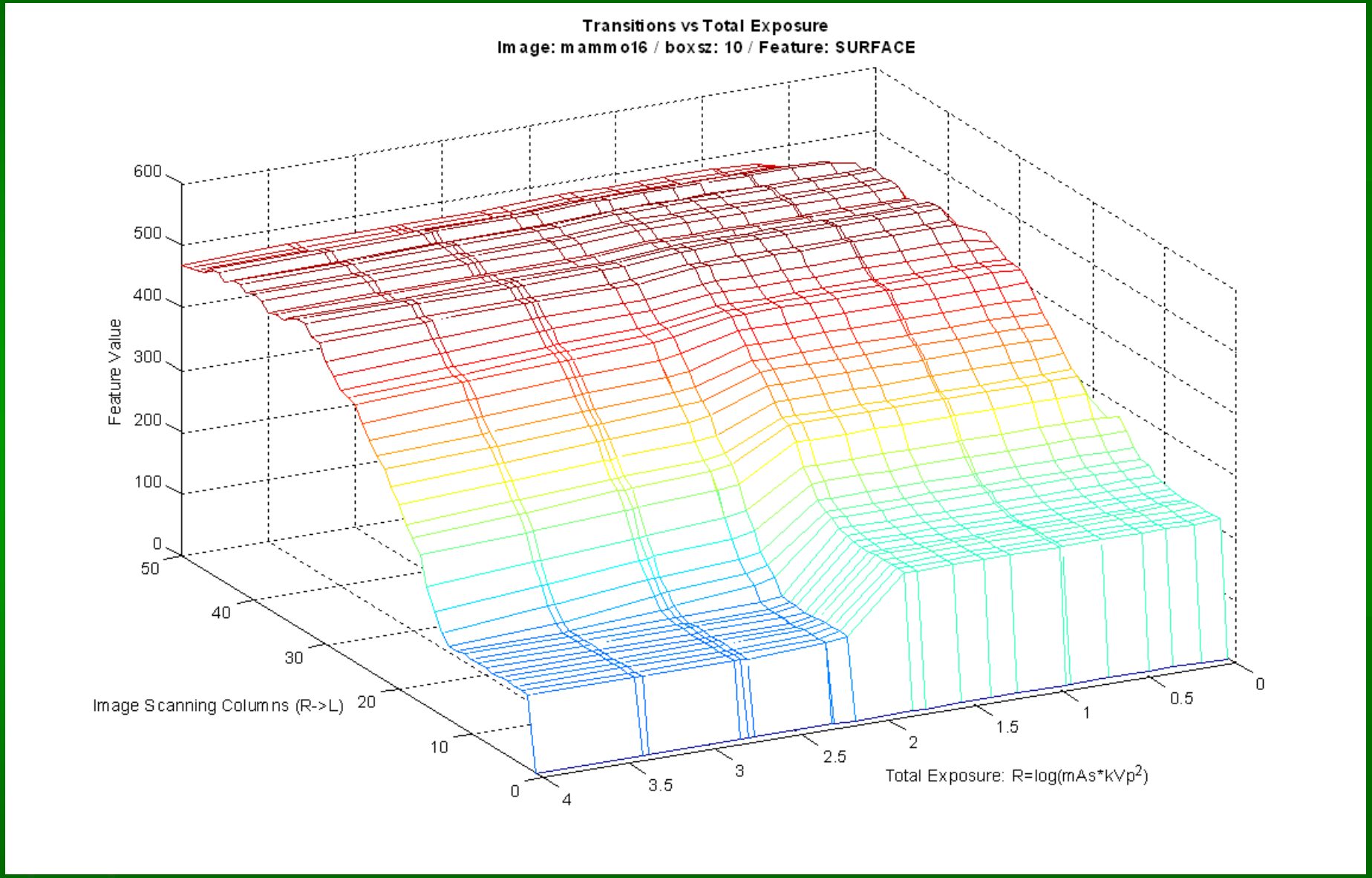

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SKEWNESS
Feature Value
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Image Scanning Columns (R->L)
50
40
30
20
10
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0

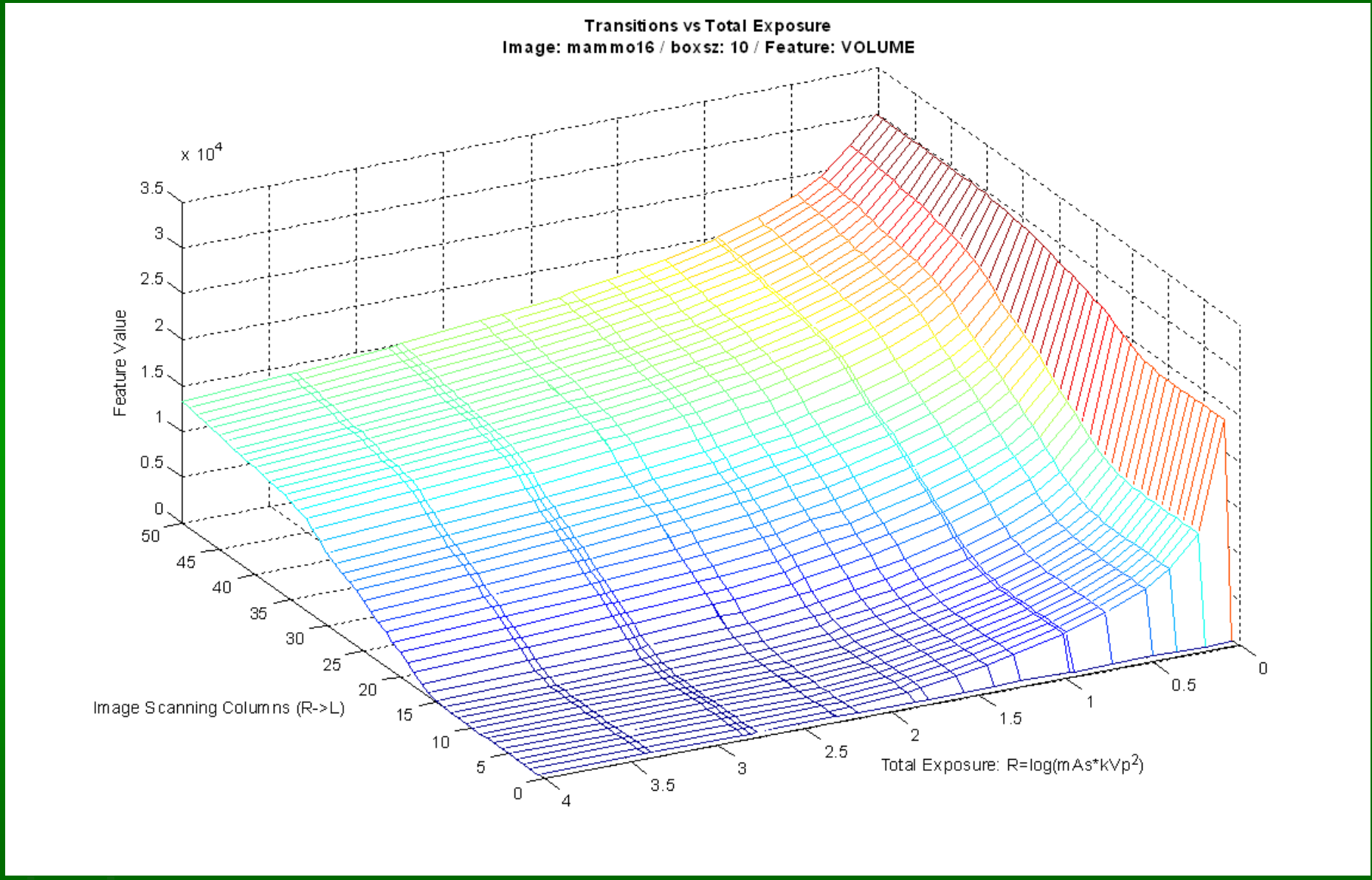

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: KURTOSIS
Feature Value
10
8
6
4
2
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0

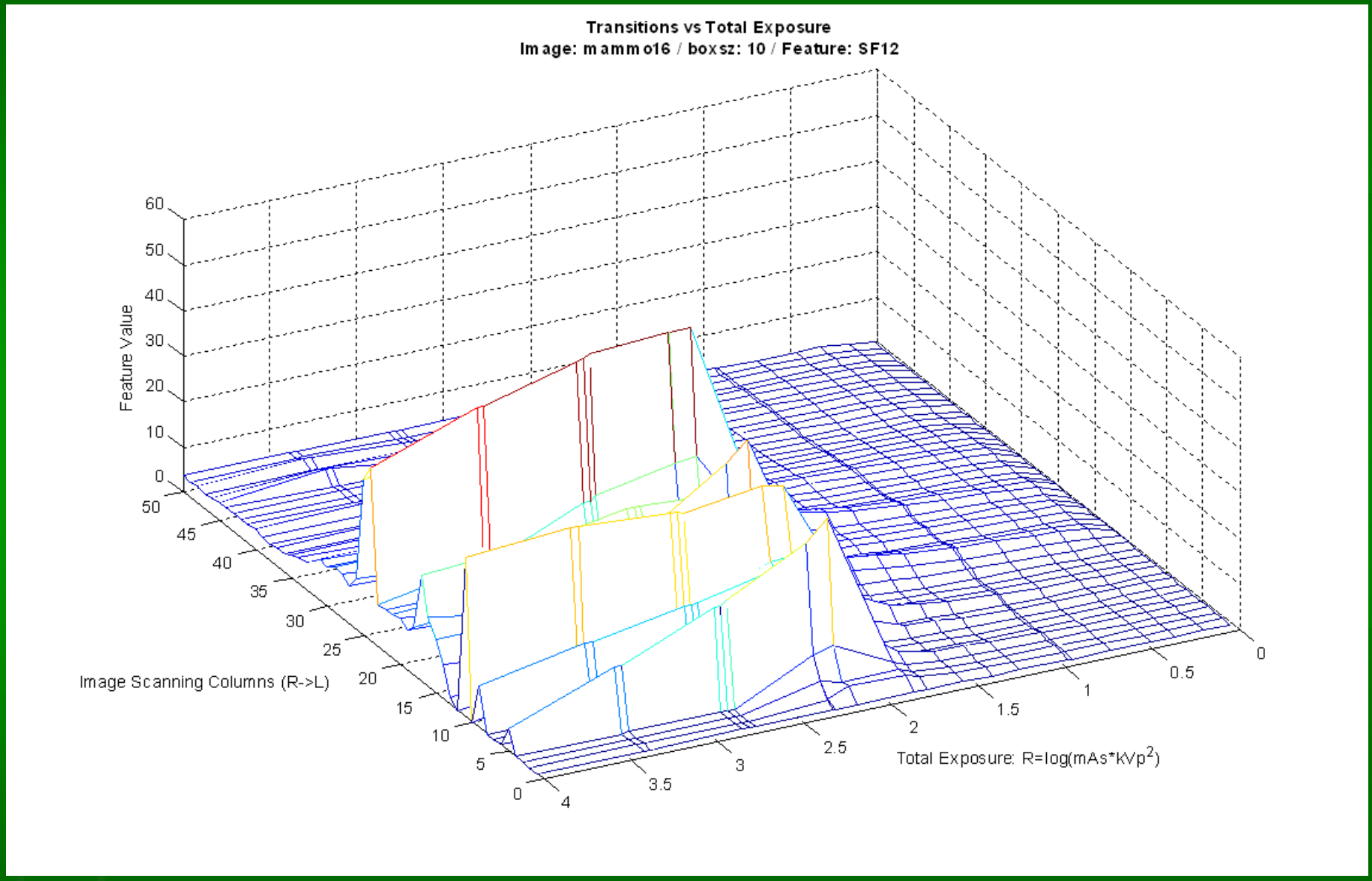

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: POWER
x 10^4
Feature Value
7
6
5
4
3
2
1
0
50
45
40
35
30
25
20
15
10
5
0
Image Scanning Columns (R->L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Total Exposure: R=log(mAs*kVp^2)

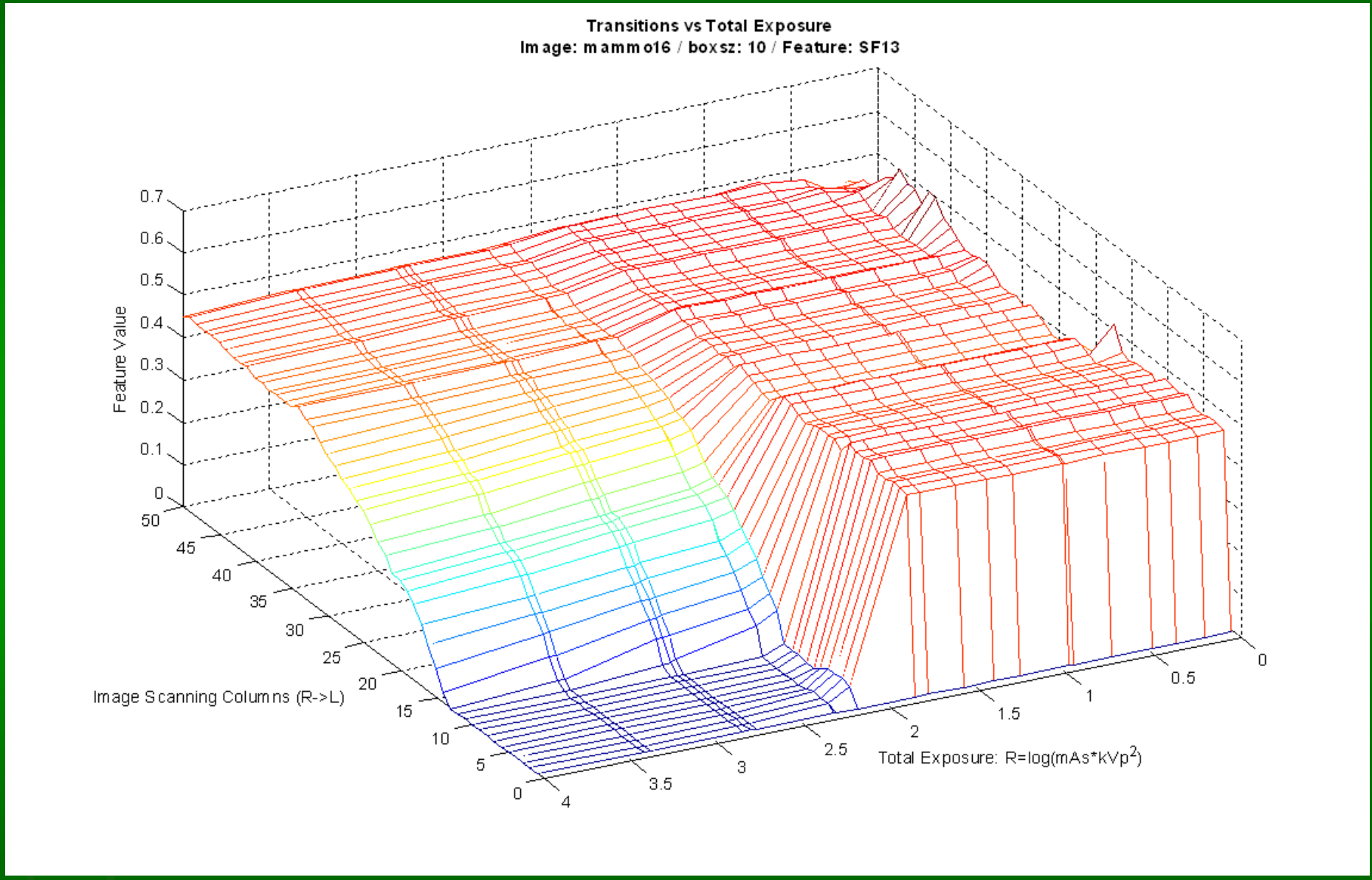

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: ENTROPY
Feature Value
0
-0.5
-1
-1.5
-2
-2.5
-3
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp^2)
0
0.5
1
1.5
2
2.5
3
3.5
4

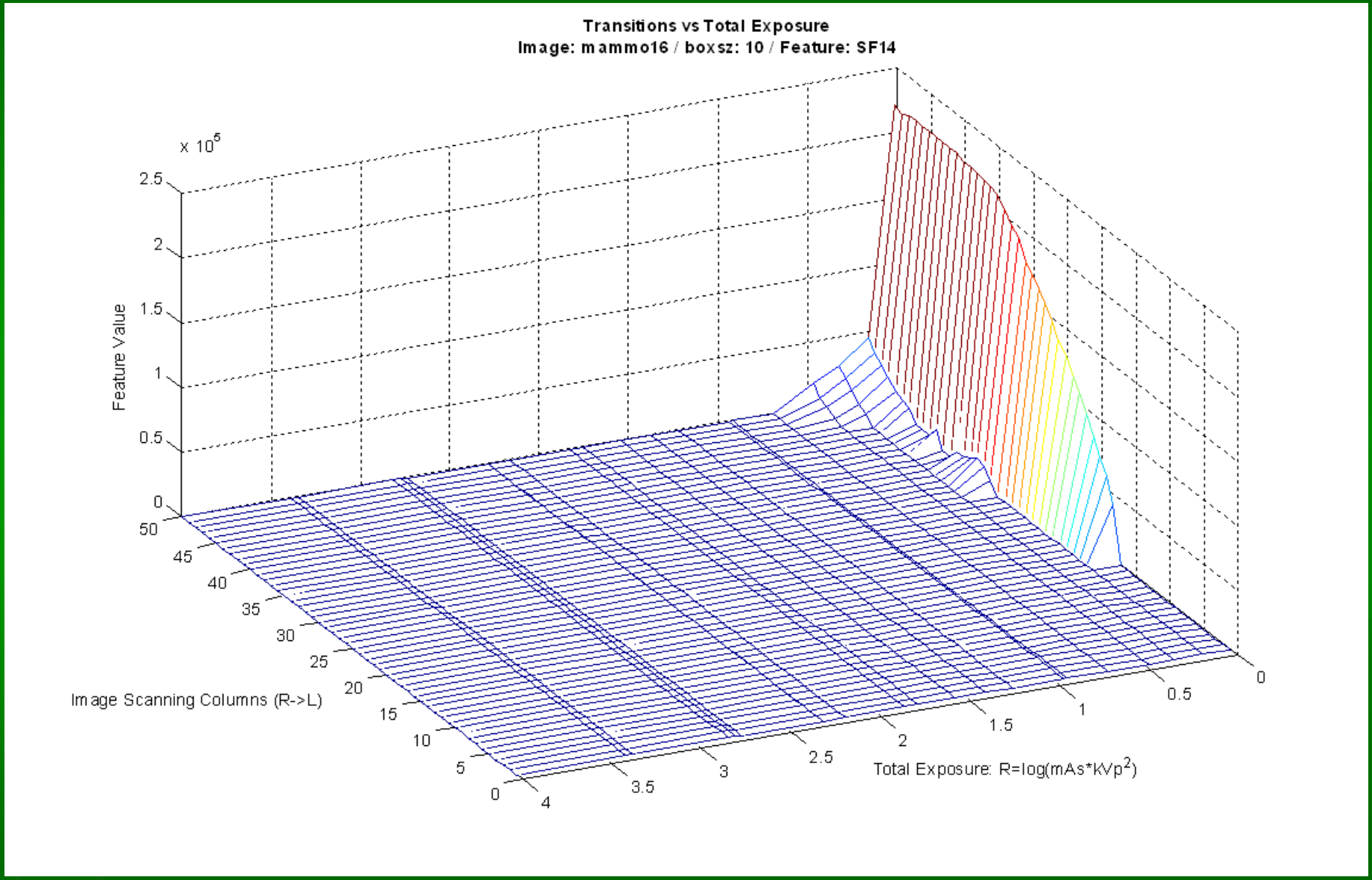

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: ZCCOUNT
Feature Value
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
45
50
Image Scanning Columns (R->L)
0
0.5
1
1.5
2
2.5
3
3.5
4
Total Exposure: R=log(mAs*kVp2)

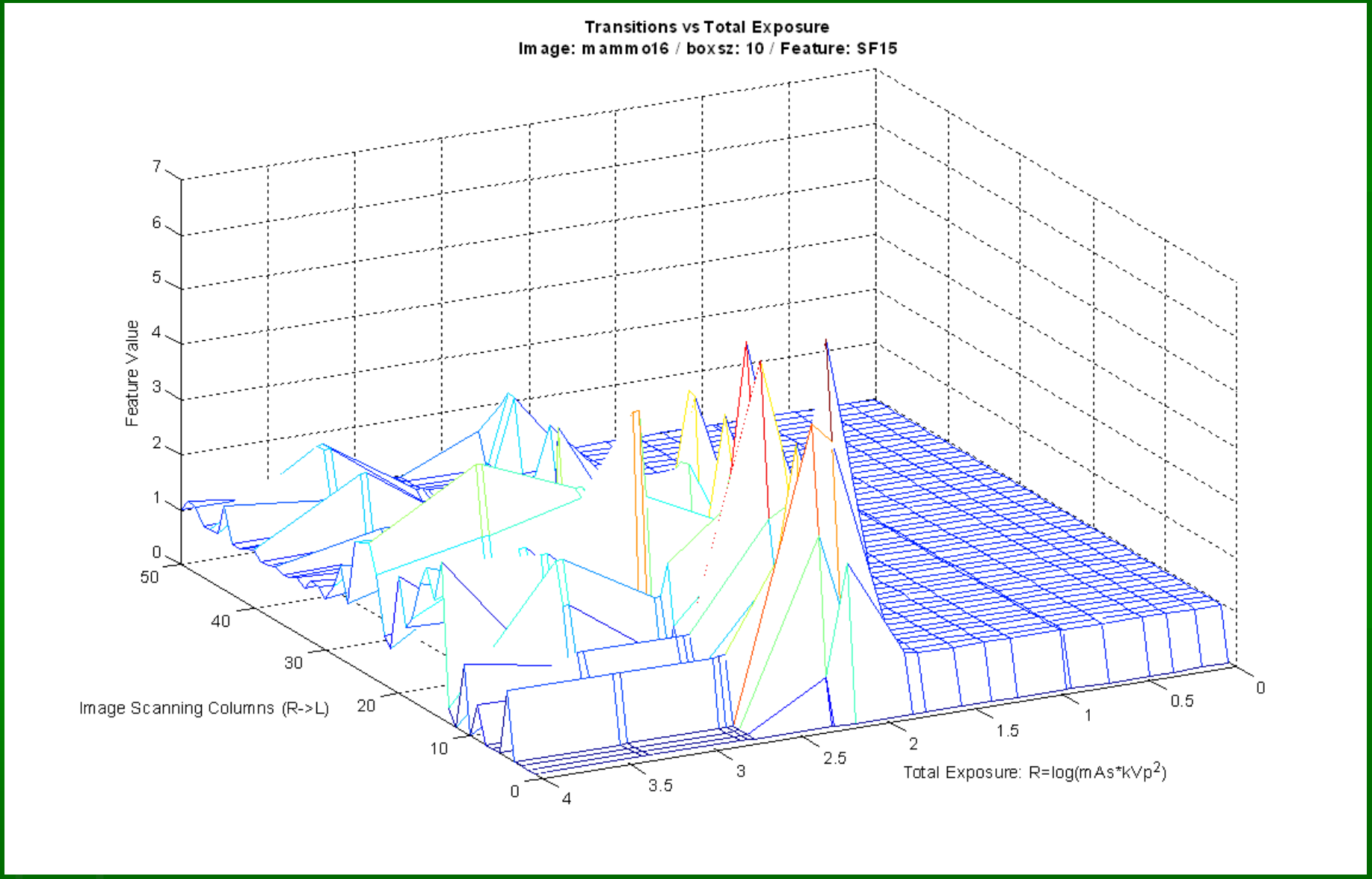

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SURFACE
Feature Value
600
500
400
300
200
100
0
Image Scanning Columns (R->L)
50
40
30
20
10
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0

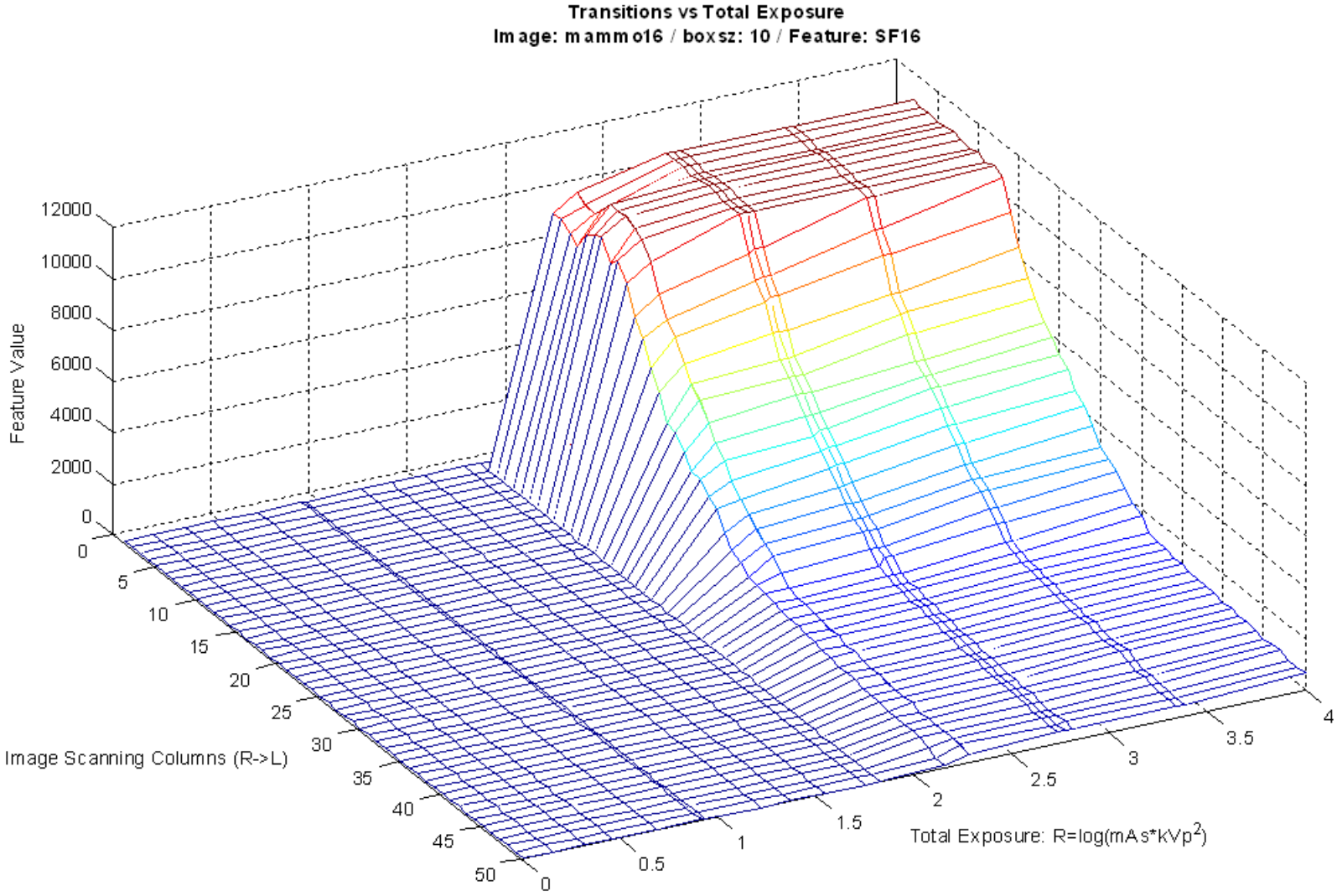

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: VOLUME
x 10^4
Feature Value
3.5
3
2.5
2
1.5
1
0.5
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp^2)
4
3.5
3
2.5
2
1.5
1
0.5
0

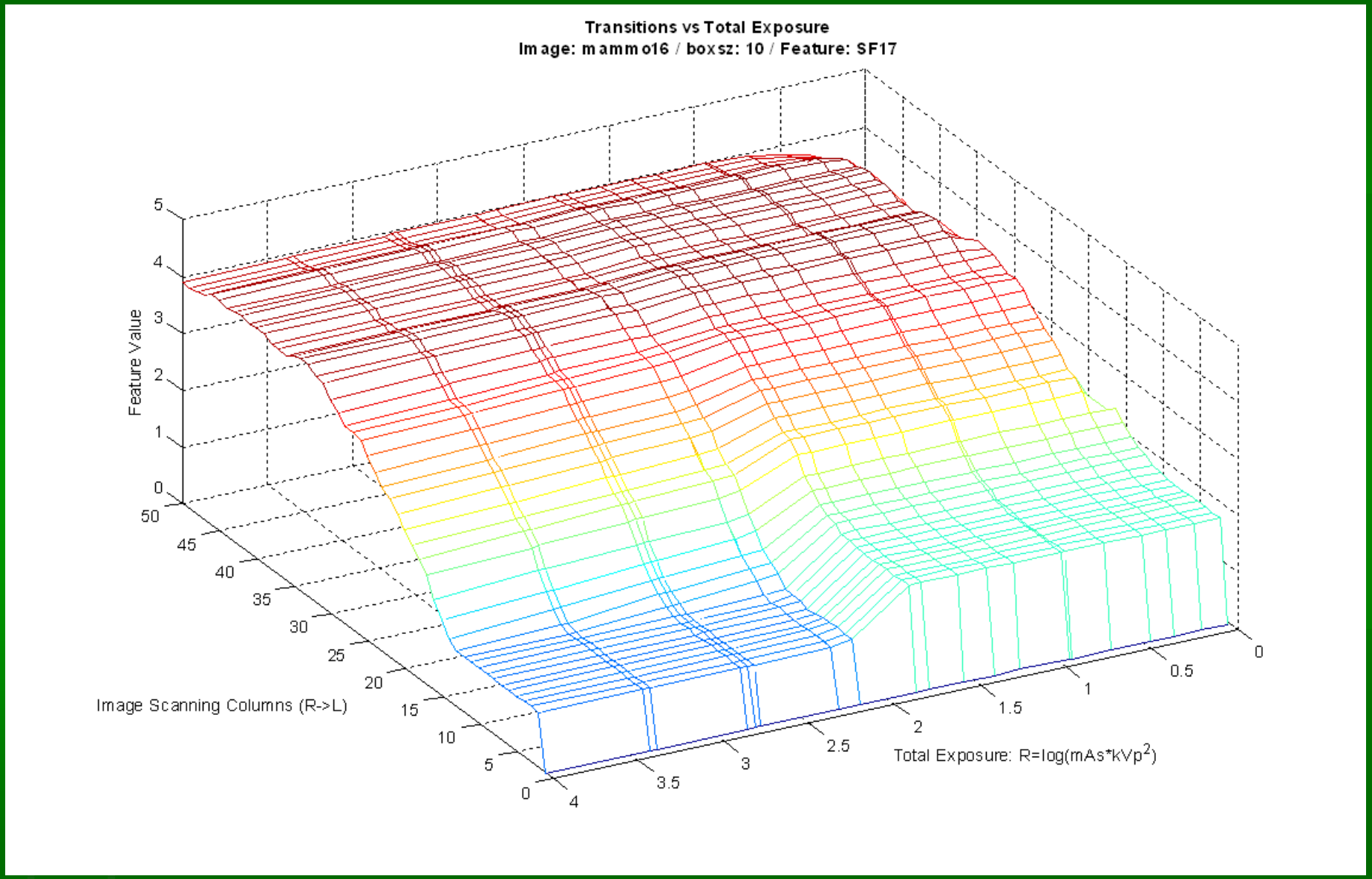

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF12
Feature Value
60
50
40
30
20
10
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp^2)
4
3.5
3
2.5
2
1.5
1
0.5
0

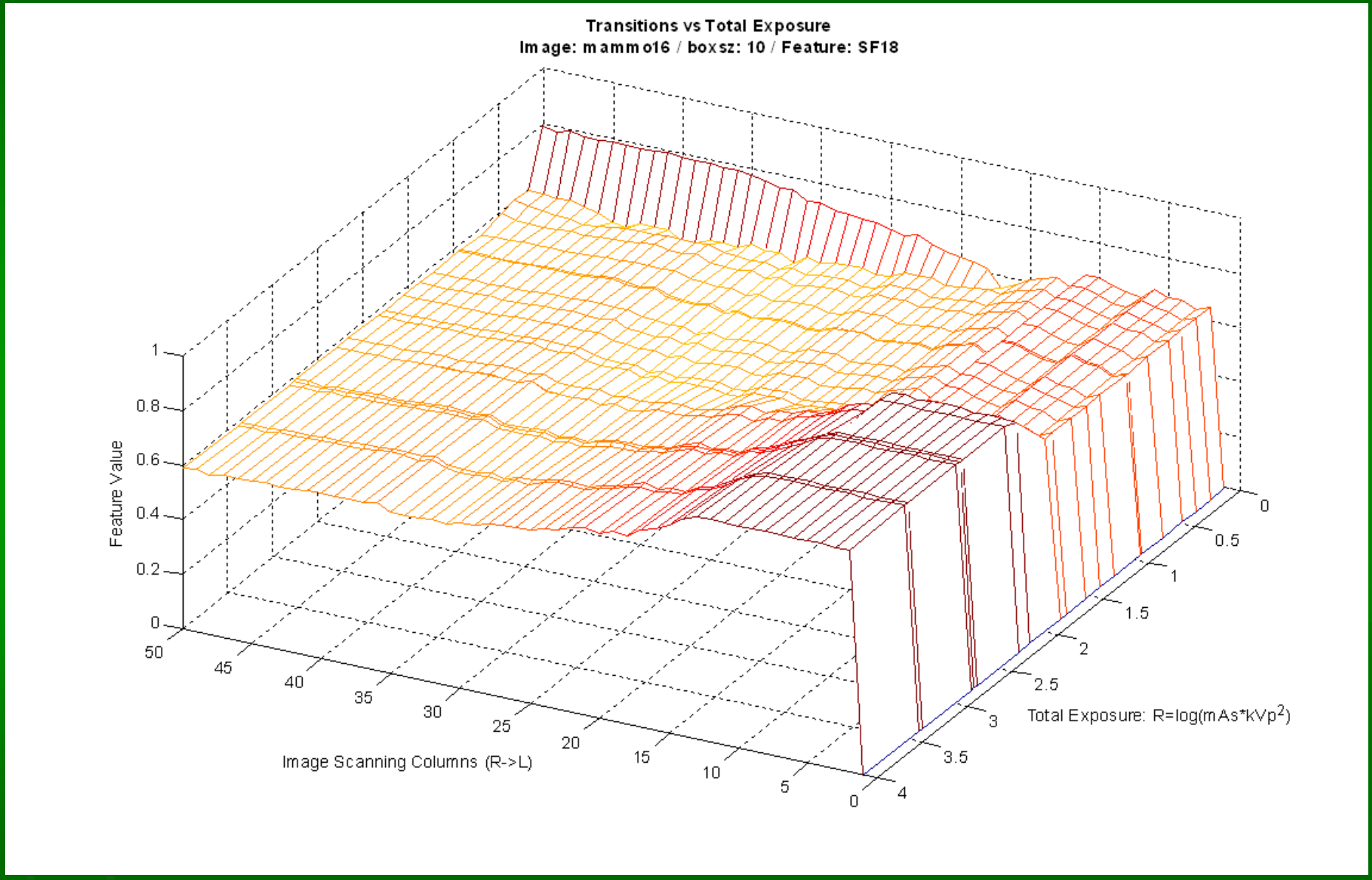

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF13
Feature Value
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp^2)
4
3.5
3
2.5
2
1.5
1
0.5
0

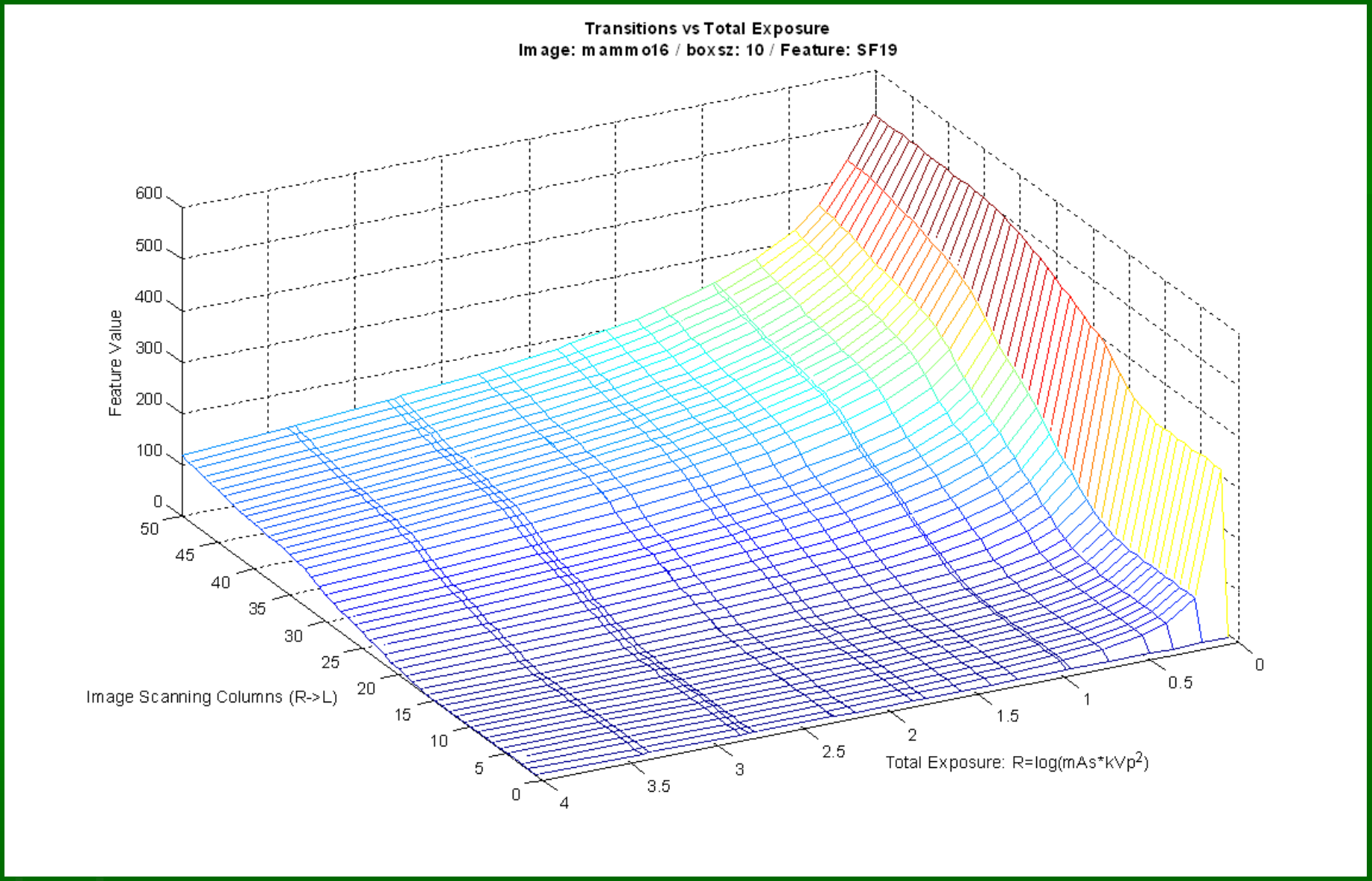

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF14
x 10^5
2.5
2
1.5
1
0.5
0
Feature Value
50
45
40
35
30
25
20
15
10
5
0
Image Scanning Columns (R->L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Total Exposure: R=log(mAs*kVp^2)

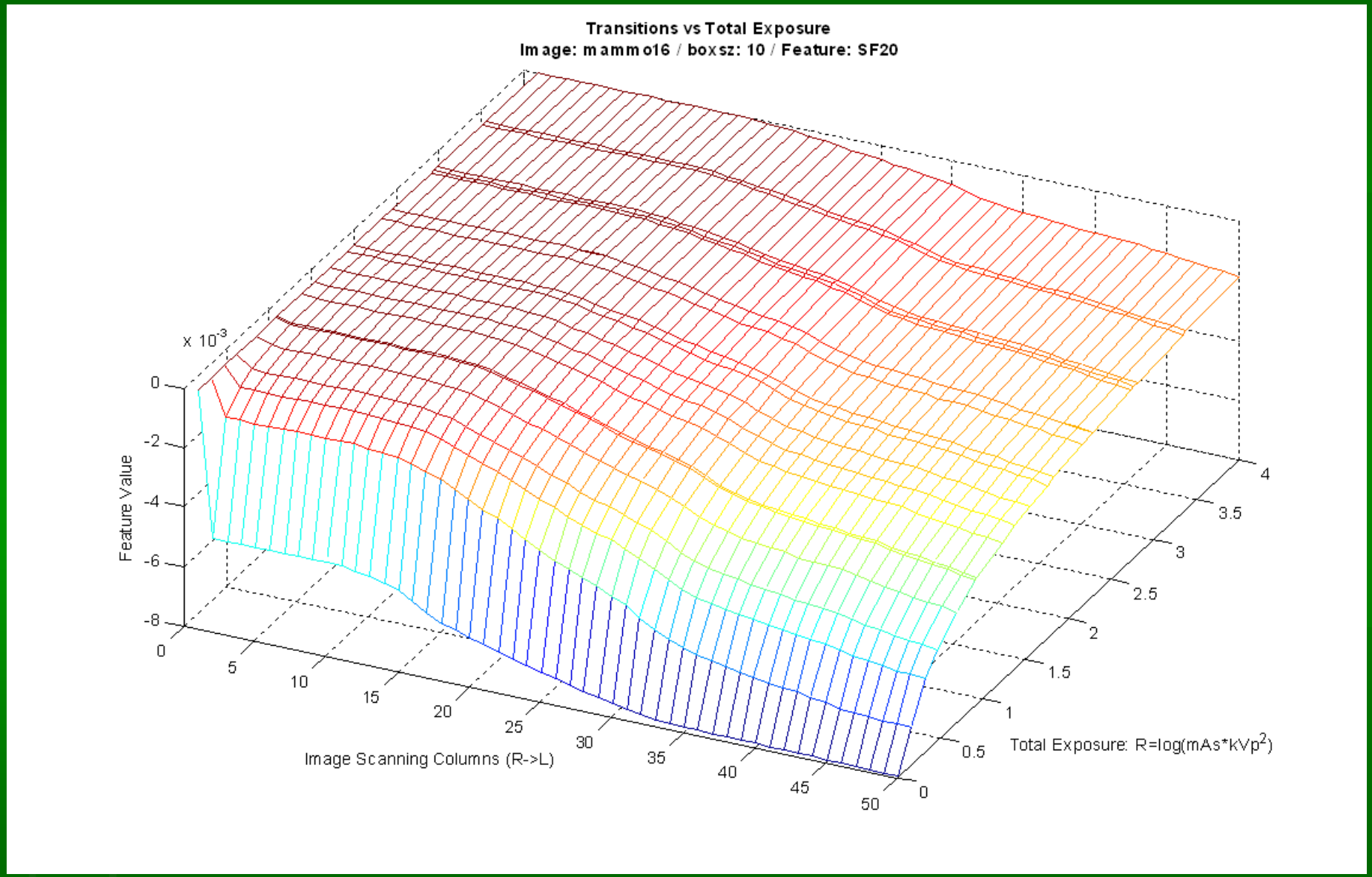

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF15
Feature Value
0
1
2
3
4
5
6
7
Image Scanning Columns (R->L)
50
40
30
20
10
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0

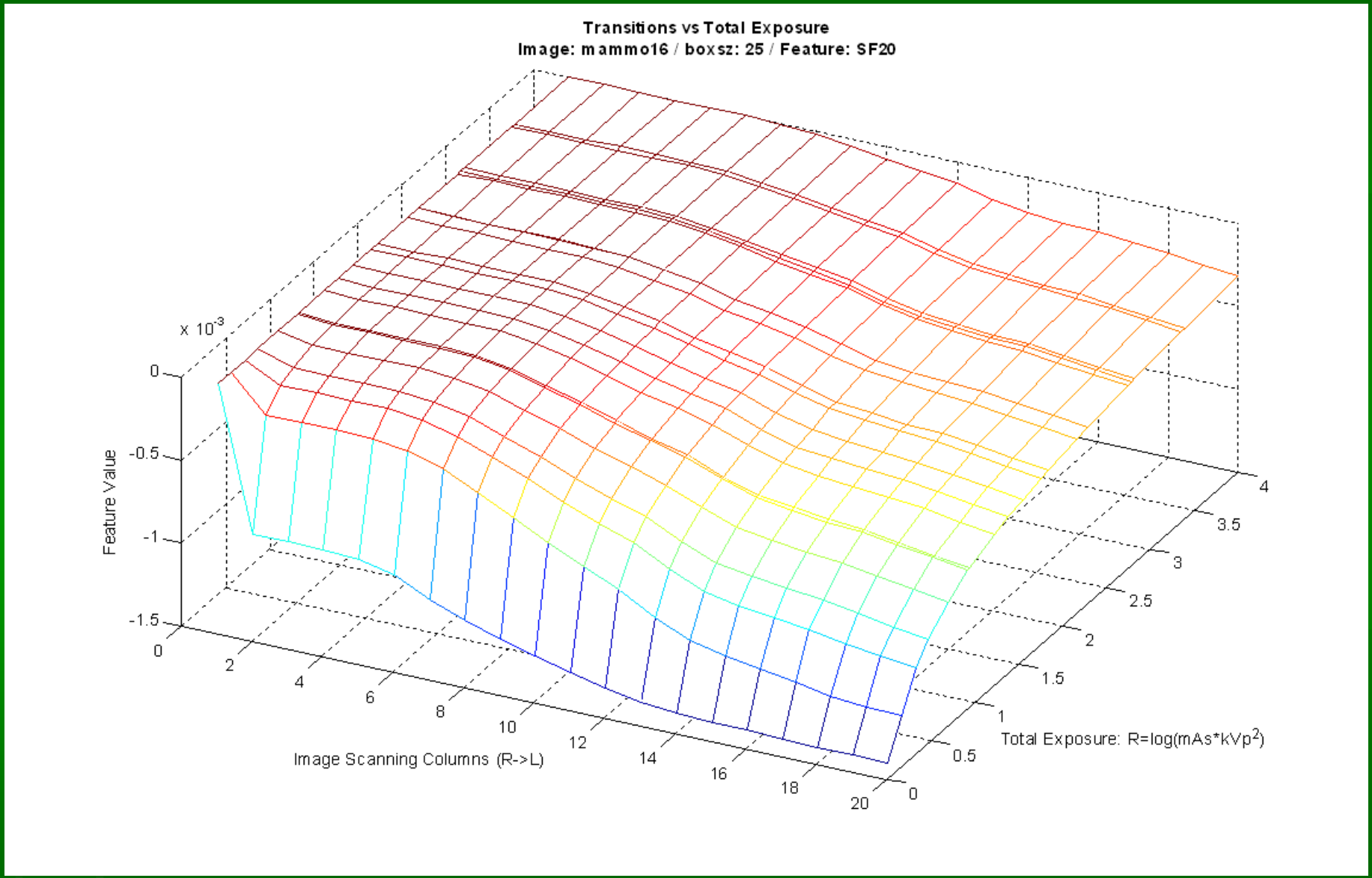

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF16
Feature Value
12000
10000
8000
6000
4000
2000
0
Image Scanning Columns (R->L)
0
5
10
15
20
25
30
35
40
45
50
Total Exposure: R=log(mAs*kVp2)
0
0.5
1
1.5
2
2.5
3
3.5
4

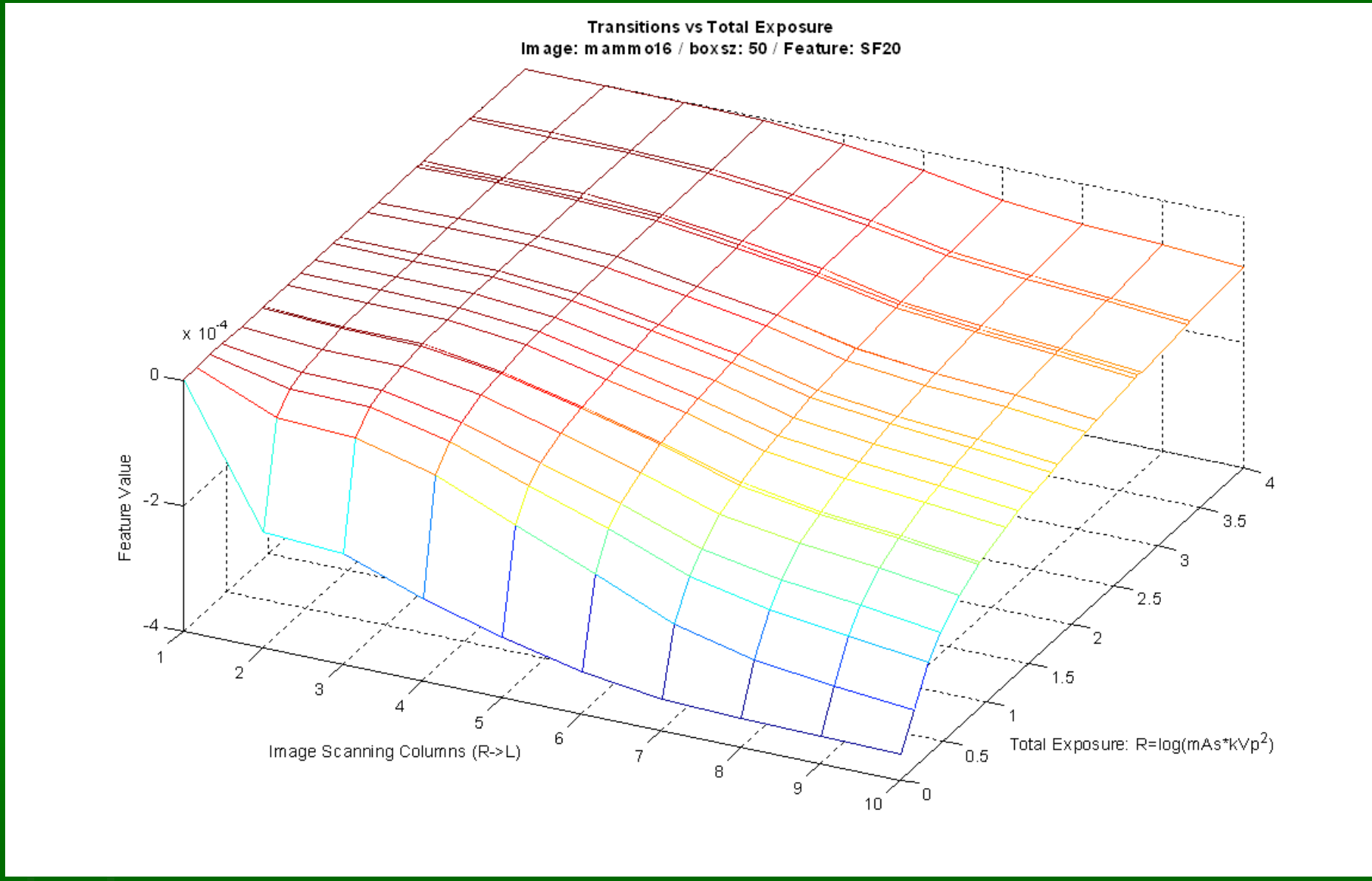

Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF17
Feature Value
0
1
2
3
4
5
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp2)
4
3.5
3
2.5
2
1.5
1
0.5
0


Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF18
Feature Value
1
0.8
0.6
0.4
0.2
0
50
45
40
35
30
25
20
15
10
5
0
Image Scanning Columns (R->L)
0
0.5
1
1.5
2
2.5
3
3.5
4
Total Exposure: R=log(mAs*kVp2)


Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF19
Feature Value
600
500
400
300
200
100
0
Image Scanning Columns (R->L)
50
45
40
35
30
25
20
15
10
5
0
Total Exposure: R=log(mAs*kVp^2)
4
3.5
3
2.5
2
1.5
1
0.5
0


Transitions vs Total Exposure
Image: mammo16 / boxsz: 10 / Feature: SF20
x 10^-3
0
-2
-4
-6
-8
Feature Value
0
5
10
15
20
25
30
35
40
45
50
Image Scanning Columns (R->L)
0
0.5
1
1.5
2
2.5
3
3.5
4
Total Exposure: R=log(mAs*kVp^2)


Transitions vs Total Exposure
Image: mammo16 / boxsz: 25 / Feature: SF20
x 10^-3
0
-0.5
-1
-1.5
Feature Value
0
2
4
6
8
10
12
14
16
18
20
Image Scanning Columns (R->L)
0
0.5
1
1.5
2
2.5
3
3.5
4
Total Exposure: R=log(mAs*kVp^2)


Transitions vs Total Exposure
Image: mammo16 / boxsz: 50 / Feature: SF20
x 10^-4
0
-2
-4
Feature Value
1
2
3
4
5
6
7
8
9
10
Image Scanning Columns (R->L)
0
0.5
1
1.5
2
2.5
3
3.5
4
Total Exposure: R=log(mAs*kVp^2)

PredModel-1B: Feature evaluation for boxsize=10

BOX=10	F01	F02	F03	F04	F05	F06	F07	F08	F09	F10	F11	SF12	SF13	SF14	SF15	SF16	SF17	SF18	SF19	SF20	Sum
Mammo_01																					0
Mammo_02																					0
Mammo_03		√																			1
Mammo_04										√							√				2
Mammo_05	√																			√	2
Mammo_06	√	√	√								√								√	√	6
Mammo_07	√	√	√				√				√								√	√	7
Mammo_08	√	√	√				√				√		√						√		7
Mammo_09	√	√	√							√	√						√		√		7
Mammo_10	√	√	√				√				√		√						√	√	8
Mammo_11	√	√	√				√				√						√		√	√	8
Mammo_12	√																√				2
Mammo_13	√	√	√				√				√		√						√	√	8
Mammo_14										√							√				2
Mammo_15	√	√	√				√				√		√						√		7
Mammo_16	√	√	√				√				√								√	√	7
Mammo_17		√	√				√				√						√		√		6
Mammo_18	√						√				√								√	√	5
Mammo_19	√																			√	2
Mammo_20	√	√	√				√				√								√	√	7
Sum	14	12	11	0	0	0	10	0	0	3	12	0	4	0	0	0	6	0	12	10	

PredModel-1B: Feature evaluation for boxsize=25

BOX=25	F01	F02	F03	F04	F05	F06	F07	F08	F09	F10	F11	SF12	SF13	SF14	SF15	SF16	SF17	SF18	SF19	SF20	Sum
Mammo_01																					0
Mammo_02																					0
Mammo_03																				√	1
Mammo_04										√							√				2
Mammo_05	√		√				√				√								√	√	6
Mammo_06	√	√	√				√				√								√	√	7
Mammo_07	√	√	√				√				√								√	√	7
Mammo_08	√	√	√				√				√								√		6
Mammo_09	√	√	√				√			√	√						√		√		8
Mammo_10	√	√	√				√				√								√	√	7
Mammo_11	√	√	√				√			√	√		√						√	√	9
Mammo_12																				√	1
Mammo_13	√	√	√				√				√								√	√	7
Mammo_14										√							√				2
Mammo_15	√	√	√				√			√	√		√						√		8
Mammo_16	√	√	√				√			√	√						√		√	√	9
Mammo_17	√	√	√				√				√								√		6
Mammo_18	√	√	√				√				√								√	√	7
Mammo_19											√									√	2
Mammo_20	√	√	√				√				√								√	√	7
Sum	13	12	11	0	0	0	13	0	0	6	14	0	2	0	0	0	4	0	13	12	

PredModel-1B: Feature evaluation for boxsize=50

BOX=50	F01	F02	F03	F04	F05	F06	F07	F08	F09	F10	F11	SF12	SF13	SF14	SF15	SF16	SF17	SF18	SF19	SF20	Sum
Mammo_01	√		√				√												√		4
Mammo_02																					0
Mammo_03	√	√																	√	√	3
Mammo_04										√	√						√			√	4
Mammo_05	√	√	√				√				√								√	√	7
Mammo_06	√	√	√				√				√								√	√	7
Mammo_07	√	√	√				√				√								√	√	7
Mammo_08	√	√	√				√				√								√	√	7
Mammo_09	√	√	√				√			√	√						√		√	√	9
Mammo_10	√	√	√				√				√								√	√	7
Mammo_11	√	√	√				√				√								√	√	7
Mammo_12	√										√									√	3
Mammo_13	√	√	√				√				√								√	√	7
Mammo_14											√										1
Mammo_15	√	√	√				√			√	√						√		√	√	9
Mammo_16	√	√	√				√			√	√								√	√	8
Mammo_17	√	√	√				√				√								√		6
Mammo_18	√	√	√				√				√								√	√	7
Mammo_19	√	√	√				√				√								√	√	7
Mammo_20	√	√	√				√				√								√	√	7
Sum	17	14	15	0	0	0	15	0	0	4	17	0	0	0	0	0	3	0	16	10	

PredModel-1B: Preliminary Assessment

Best feature functions:

- F01: “MIN”
- F02: “MAX”
- F03: “MEAN”
- F07: “POWER”
- F11: “VOLUME”
- SF19: (normalized power)
- SF20: (normalized exposure)

Local feature combination:

- Averaging over the “column”
- Unbiased over partial results

Basic Conclusions:

- Averaging partial feature values over “columns” produce unbiased results.
- Most feature functions can be calculated directly over the entire “column”.
- Best features relate to sums over pixel values or squared pixel values.
- Larger box sizes produce more consistent results.
- Processing complexity grows proportionally with number of pixels in the box.
- First order statistics can also be used successfully for breast tissue detection.

PredModel-1B: Feature Functions Complexity

MATLAB sample:

```
function npower=func_SF19( I )
    npower = sum(sum(I.^2))/(size(I,1)*size(I,2));
```

C/C++ sample:

```
int func_SF19( unsigned char *pixel, int boxsz )
{
    int    i, j, sum=0, px, npower;

    for ( i=0; i<boxsz; i++ )
        for ( j=0; j<boxsz; j++ )
        {
            px = *(pixel+(i-1)*boxsz+j);
            sum = sum + px*px;
        }

    npower = sum / (boxsz*boxsz);
    return(npower);
}
```

PredModel-1B: Feature Functions Complexity

x86 Assemply sample:

```
    ...
DSEG     SEGMENT

BOX_SZ   DW       50
ICOUNT   DW       50
JCOUNT   DW       50
SUM DW    0
NPOWER   DW       0

DSEG     ENDS
    ...

FUNC_SF19        PROC

    PUSHA

    MOV   SUM,0

L1: CMP   JCOUNT,0
    JNG   L0

L2: CMP   JCOUNT,0
    JNG   L1
    MOV   DI,JCOUNT

    MOV   BX,ICOUNT
    SUB   BX,1
    MUL   BX,BOX_SZ
    MOV   AX,PIXEL[BX][DI]
    MUL   AX,AX
    ADD   SUM,AX

    SUB   JCOUNT,1
    JMP   L2

    SUB   ICOUNT,1
    JMP   L1

L0: MOV   AX,BOX_SZ
    MUL   AX,AX
    MOV   CX,AX
    MOV   AX,SUM
    DIV   CX

    MOV   NPOWER,CX

    POPA

    RET

FUNC_SF19        ENDP
```

Current Progress Overview:

- ✓ *Web-based public mammographic image database*
- ✓ *Experiment planning & documentation*
- ✓ *Preliminary phantom image database*
- ✓ *SimModel-1A: exposure simulation*
- ✓ *PredModel-1A: texture features extraction*
- ✓ *PredModel-1B: feature quality evaluation versus exposure*

Further Progress Requirements (WP3):

- Finalize Forms A-E for experiments planning & documentation
- Finalize choices on mammographic device and subject (phantom) for experimental acquisition of new image database (DB3).
- Create a thorough set of real mammographic images (DB3) from experiments conducted at devices that closely resemble the target system, using extensive documentation and logging (Forms A-C).
- Image quality assessment by experts for all images in DB3, using extensive documentation (Forms D-E).
- Finalize sensor & DSP chips specifications and processing resources availability (space + time) for on-line image analysis.
- Investigate the possible use of embedded test patterns throughout the DB3 experimental images, in order to produce an unbiased base for global image properties (background noise, exposure, etc).

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