Camera Identification using Statistical Process Control Techniques for Anomaly Detection

Digital Futures 2009

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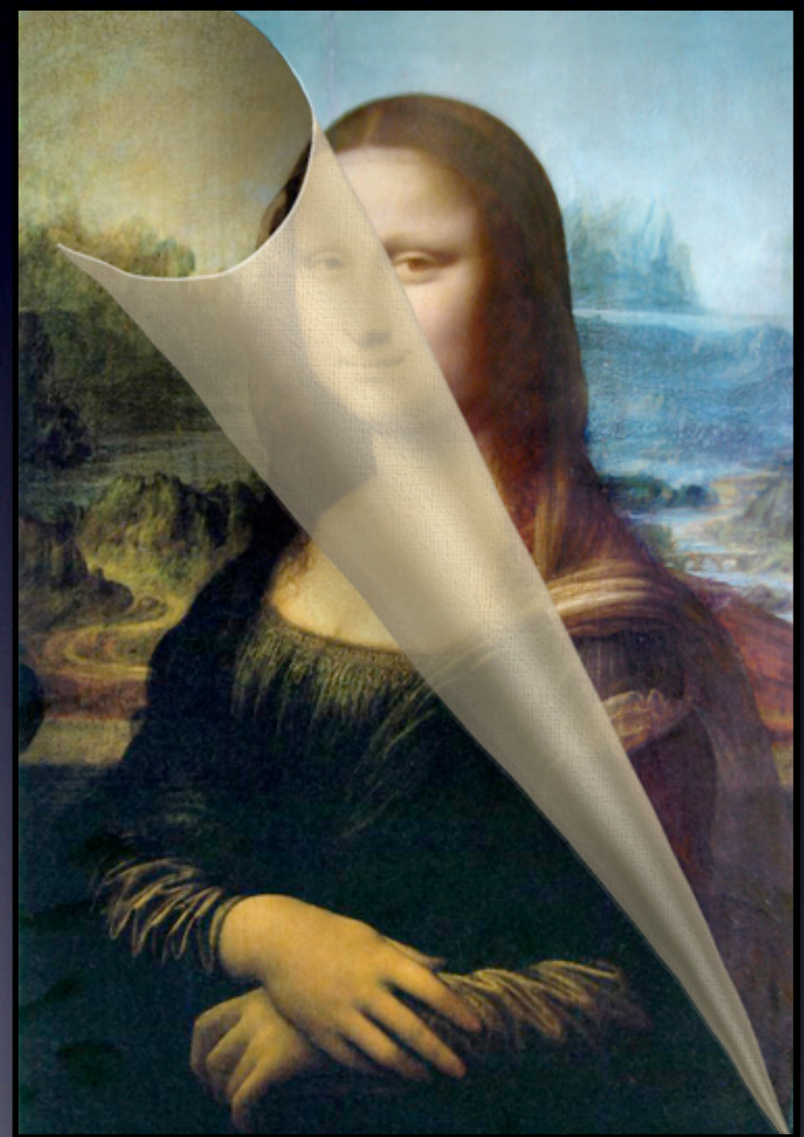
Tasks of Image Forensics*



Source Classification

Camera Identification

Processing History Recovery

Integrity Verification / Forgery Detection

Anomaly Investigation

*M. Chen, J. Fridrich, M. Goljan, and J. Lukas, "Determining Image Origin and Integrity Using Sensor Noise", IEEE Transactions on Information Security and Forensics, vol. 3(1), pp. 74-90, March 2008.

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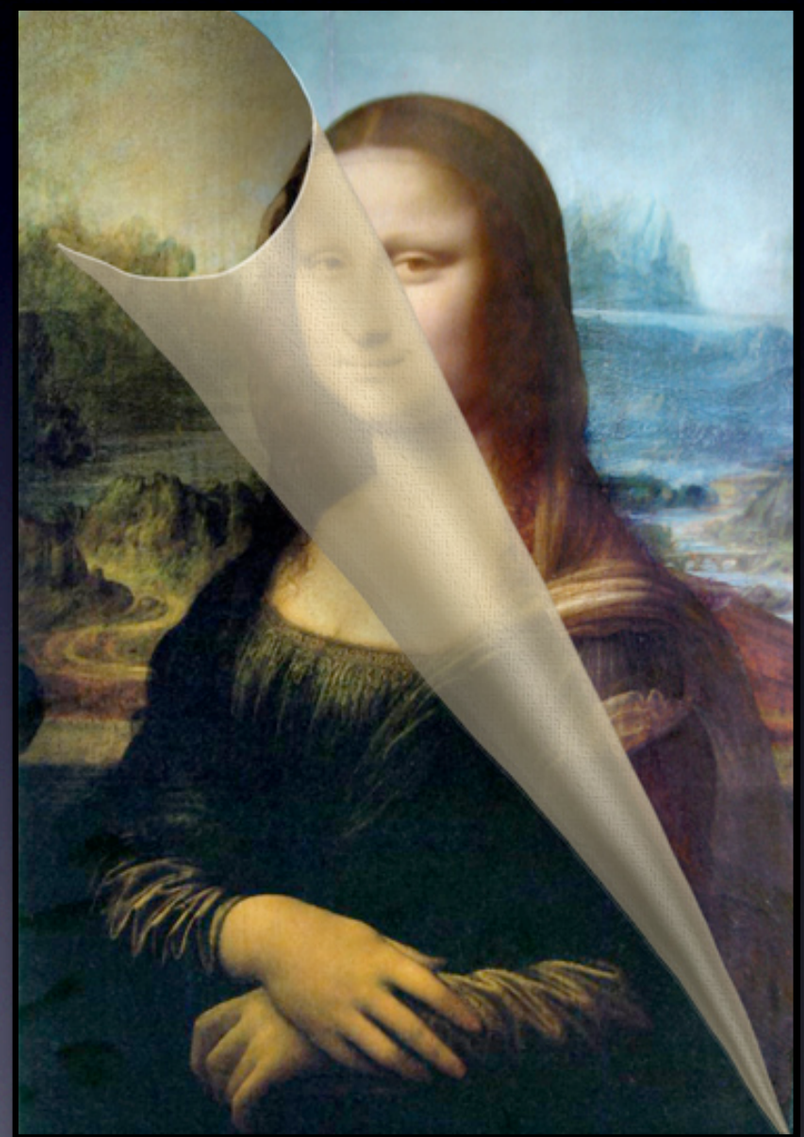

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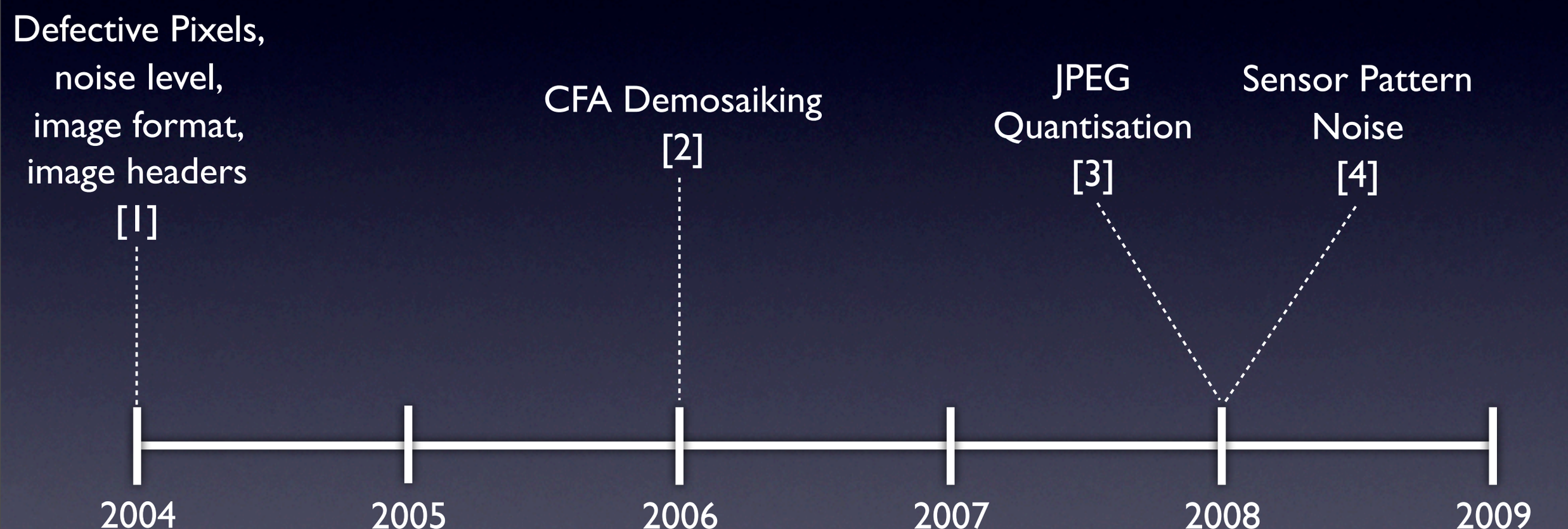
Previous Research



[1] N. Memon, M. Kharrazi, and H. T. Sencar, "Blind Source Camera Identification", International Conference on Image Processing, vol. 1, pp. 709-712, 2004.

[2] Y. Long and Y. Huang, "Image Based Source Camera Identification using Demosaicking", IEEE 8th Workshop on Multimedia Signal Processing, pp. 419-424, 2006.

[3] H. Farid, “Digital Image Ballistics from JPEG Quantization”, TR2006-583, Dartmouth College, 2006.

[4] M. Chen, J. Fridrich, M. Goljan, and J. Lukas, “Determining Image Origin and Integrity Using Sensor Noise”, IEEE Transactions on Information Security and Forensics, vol. 3(1), pp. 74-90, 2008.

Statistical Process Control

"Repeated measurements taken from a process will exhibit variation"

[W. Shewhart (1920s)]

If a process is stable, its variation will be predictable, but *most* processes are not stable

Is the cause for variance under control?

common cause variation / special cause variation

Control Charts used to graphically present degree of variance within a process

Control Charts

Aid in distinguishing between *common-cause* and *special-cause* variation

Series of process measurements taken in time order

Centreline (CL) denotes process mean

Control Limits calculated from variation within data

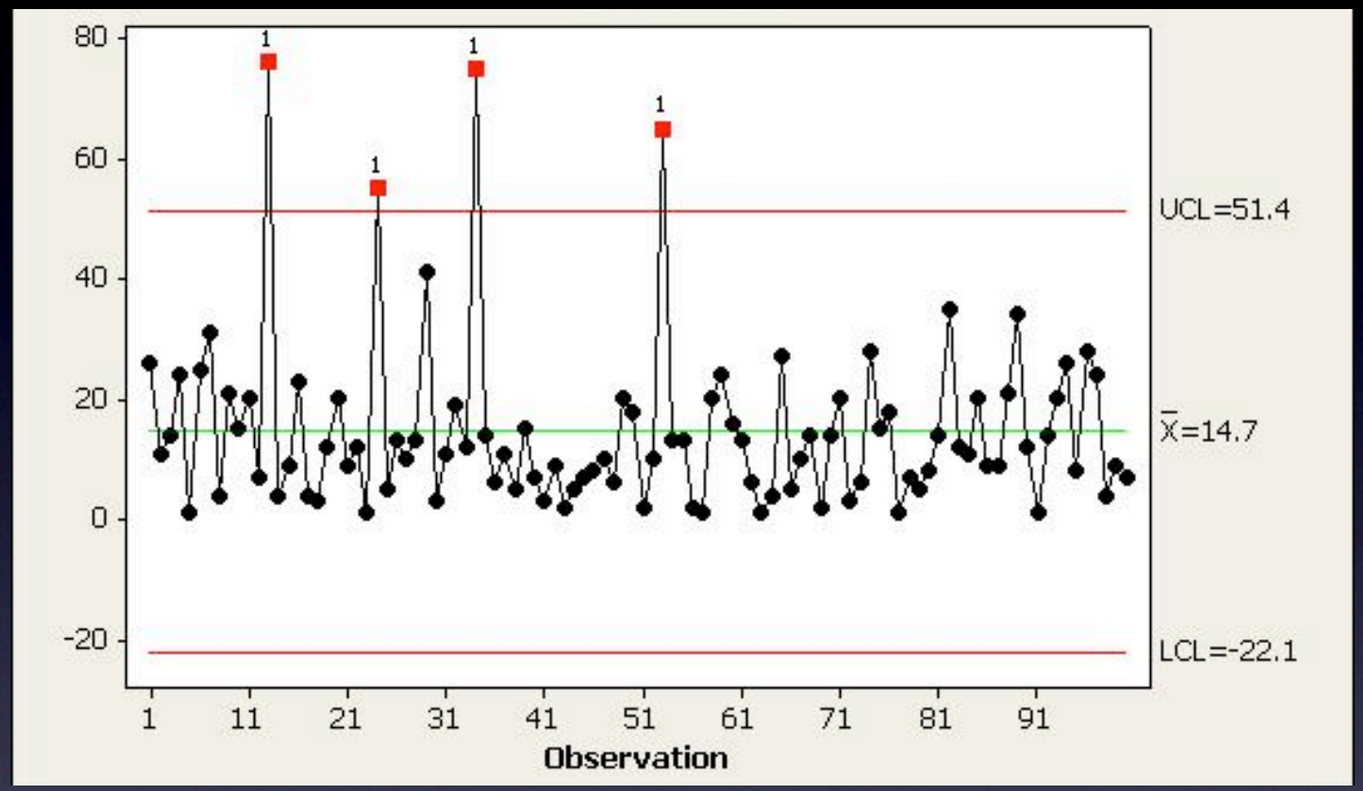
1. *Upper Control Limit (UCL)*
2. *Lower Control Limit (LCL)*

Identification of instances where data value falls above/below control limit boundaries

Typically two charts: one for displaying shifts in process mean, and another to display extent of variation within the process

Is the process in control? Can the process be improved?

Example of Control Charts



Upper Control Limit typically set as ~3 Standard Deviations **above** process mean

Mean of data values

Lower Control Limit set as ~3 Standard Deviations **below** process mean

95% of all values lie within ±2 Standard Deviations of the mean
~5% False Positive margin

~0.27% False Positive margin when using ±3 Standard Deviations

Any value falling outside control limits are "Out of Control"

Challenge is then to find and fix reason for error

Camera Performance

=

?

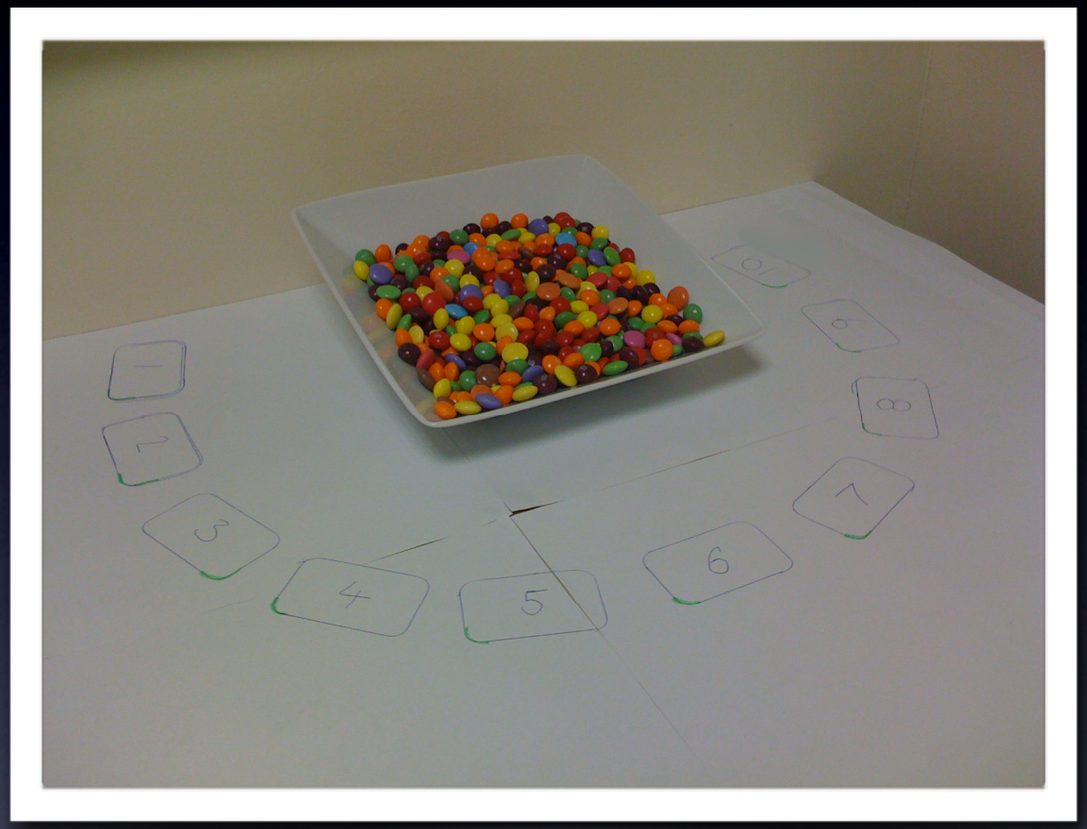
VuPoint Keychain Digital Camera
Resolution: 0.064 MegaPixels

RRP £10

Leica M8 Digital Camera
Resolution: Up to 10.3 MegaPixels

RRP £3,999

Scene 1 (Skittles)



Assortment of Skittles and Smarties used to provide vast colour changes

10 angles for potential cross-comparison of light interpretation

10 shots taken per angle to derive behavioural patterns of each device

Test Cameras

4x
Apple iPhone 3G

Sony Ericsson
W810i

Samsung
NV3

All camera settings set to match the most basic camera (iPhone)
(i.e. 2 MegaPixel Resolution, No Flash, Zoom Out)

iPhone Data

Scene 1, Angle 5

Mean of all shots*

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8	Shot 9	Shot 10
iPhone A	110.20	109.60	109.13	109.11	109.21	101.36	101.72	101.28	101.27	101.69
iPhone B	105.48	106.52	106.76	98.02	98.06	97.73	98.92	96.97	98.45	97.49
iPhone C	104.61	104.65	105.42	105.46	105.67	105.12	105.45	105.55	105.54	105.49
iPhone D	104.45	97.44	97.12	97.05	97.03	97.00	97.43	97.42	97.01	97.01

*Mean calculated in spatial domain for all colour planes

Apple iPhone Data

Scene 1, Angle 5

Mean of all shots*

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8	Shot 9	Shot 10
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iPhone D	104.45	97.44	97.12	97.05	97.03	97.00	97.43	97.42	97.01	97.01

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*Mean calculated in spatial domain for all colour planes

Sony Ericsson W810i Data

Scene 1, Angle 5

Mean of all shots*

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8	Shot 9	Shot 10
Sony Ericsson W810i	127.65	126.53	126.75	128.00	127.93	128.19	128.06	126.78	126.74	127.96

*Mean calculated in spatial domain for all colour planes

Samsung NV3 Data

Scene 1, Angle 5

Mean of all shots*

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8	Shot 9	Shot 10
Samsung NV3	132.00	131.89	131.92	131.95	131.97	131.95	131.99	131.98	132.04	132.03

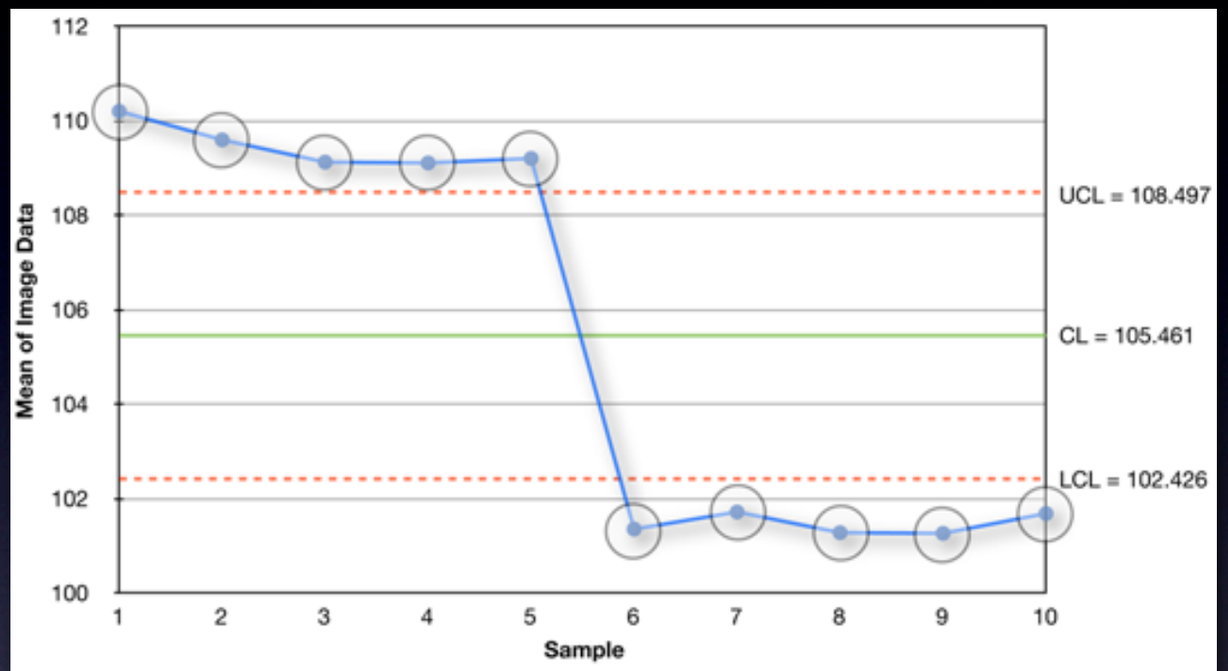
0.11 0.03 0.03 0.02 0.02 0.04 0.01 0.06 0.01

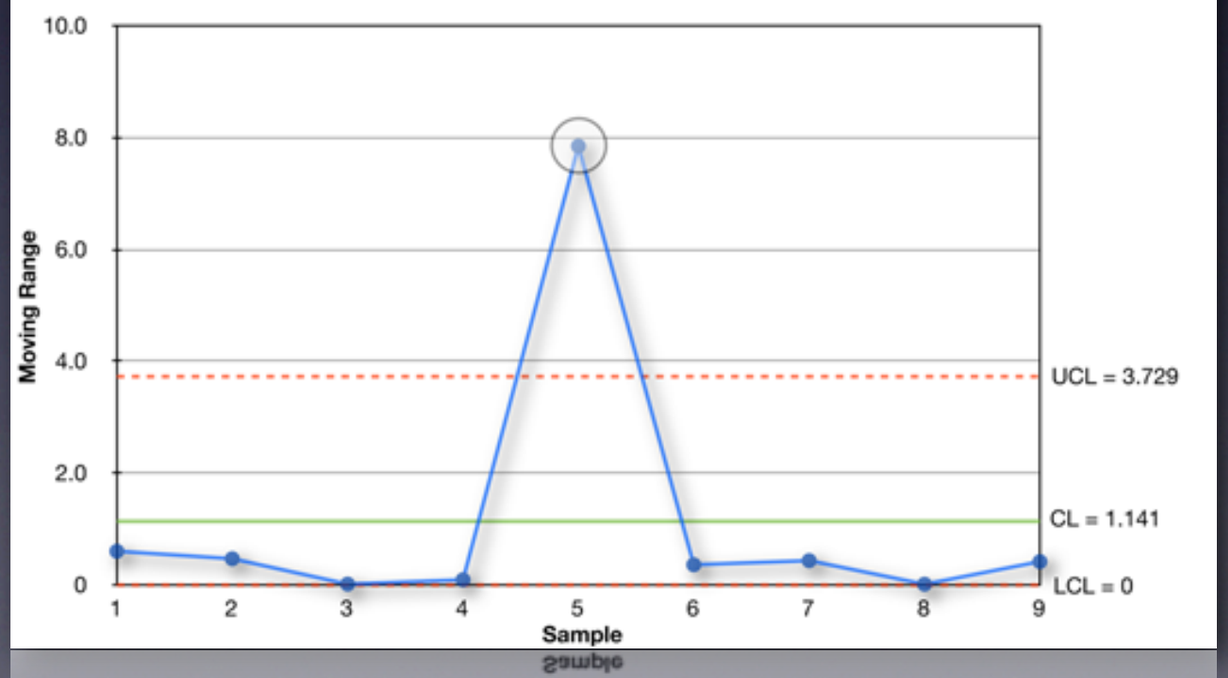
To plot *Moving Range* charts:
Calculate range between neighbouring values

*Mean calculated in spatial domain for all colour planes

X-Moving Range Control Charts

iPhone A: Angle 5





X Chart Calculations

$$UCL_X = \overline{X} + 3\hat{\sigma}_X = 105.461 + (3)(1.011) = 108.497$$

$$\overline{X} = \frac{\sum_{i=1}^{10} X_i}{10} = \frac{1054.613}{10} = 105.461.$$

$$LCL_X = \overline{X} - 3\hat{\sigma}_X = 105.461 - (3)(1.011) = 102.426.$$

R_m Chart Calculations

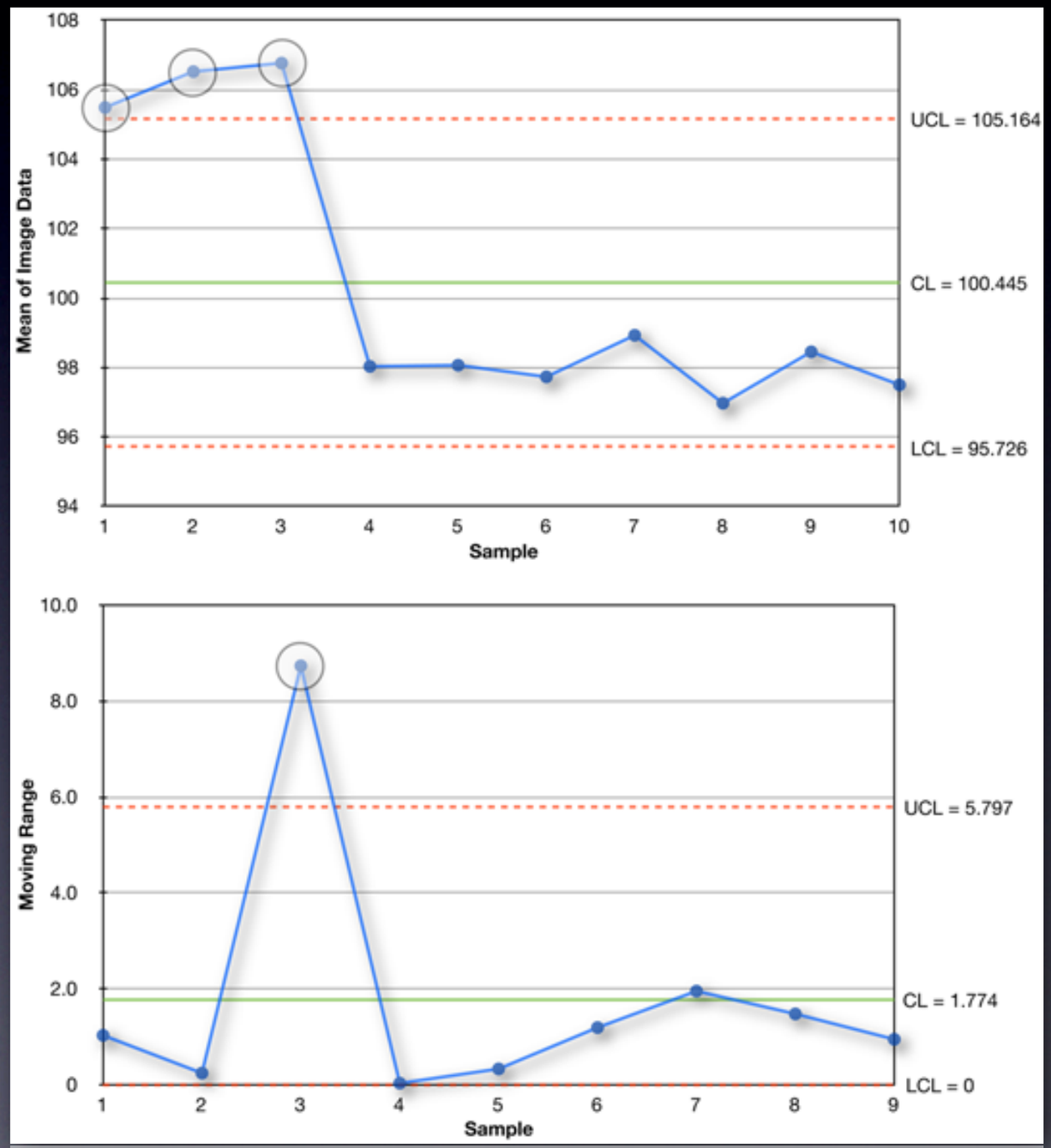
$$UCL_{R_m} = D_4\overline{R}_m = (3.27)(1.141) = 3.729$$

$$\overline{R}_m = \frac{\sum_{i=1}^{9} R_{mi}}{9} = \frac{10.27}{9} = 1.141.$$

$$LCL_{R_m} = D_3\overline{R}_m = (0.0)(0.294) = 0.0$$

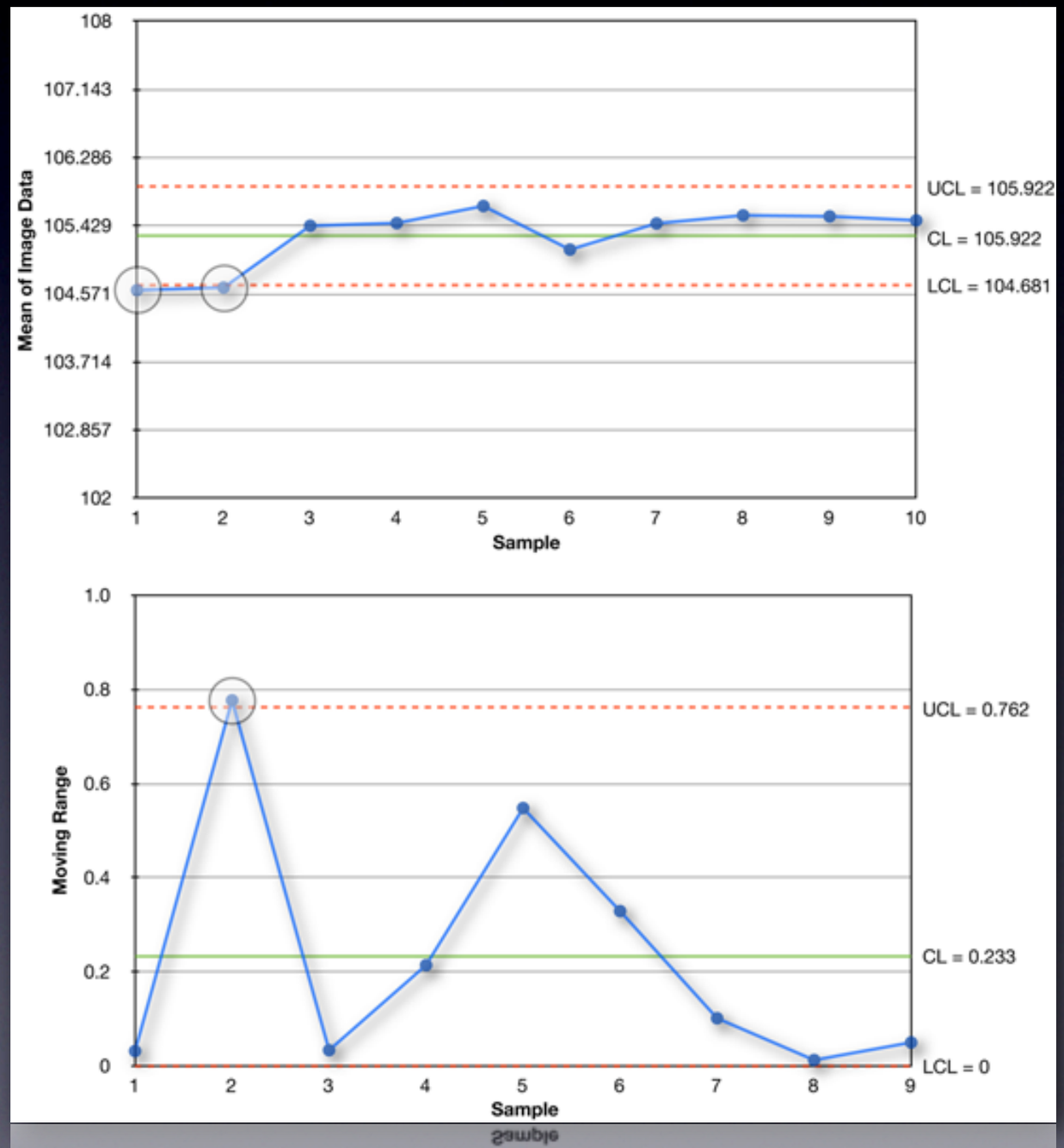
X-Moving Range Control Charts

iPhone B: Angle 5



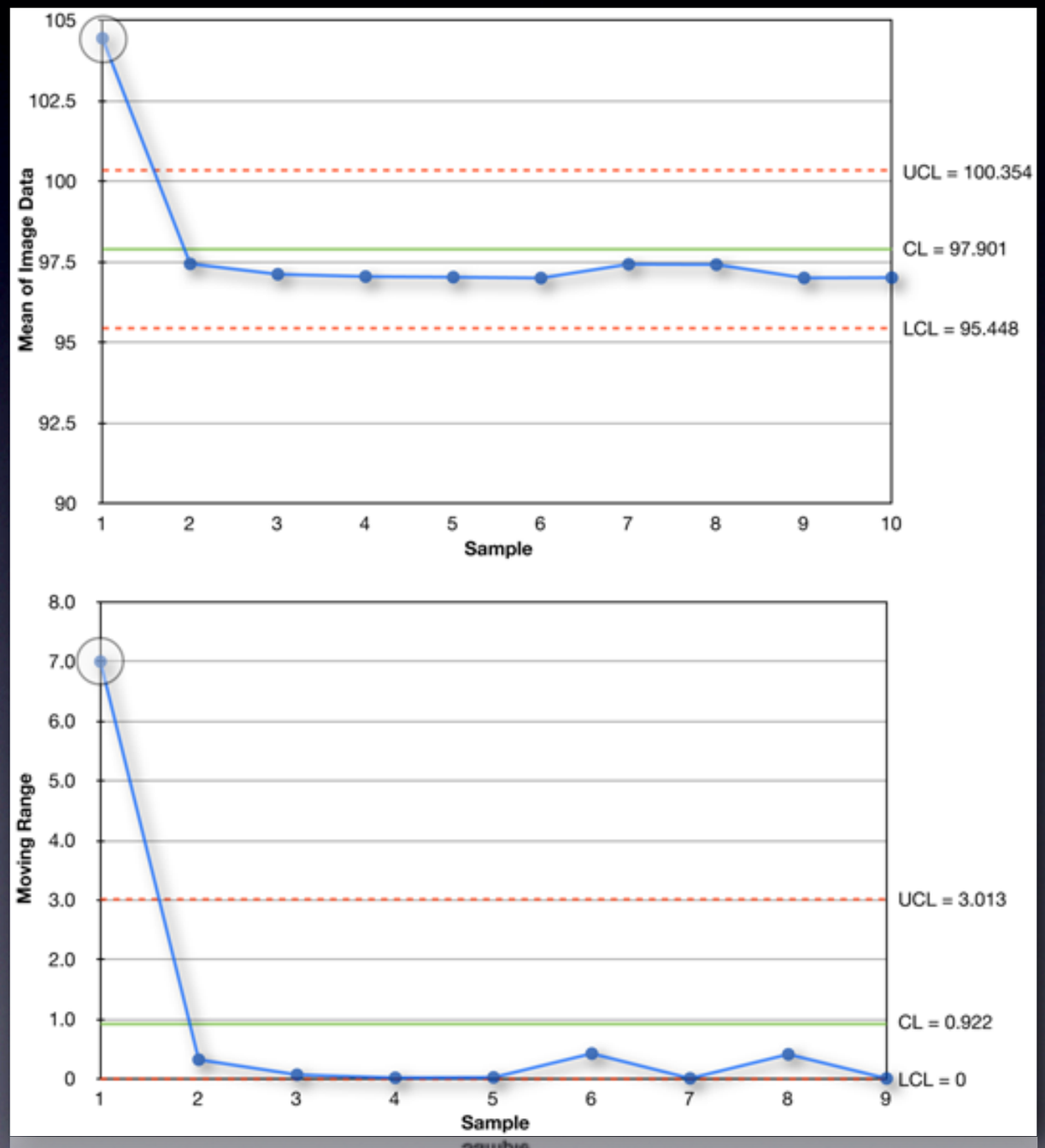
X-Moving Range Control Charts

iPhone C: Angle 5



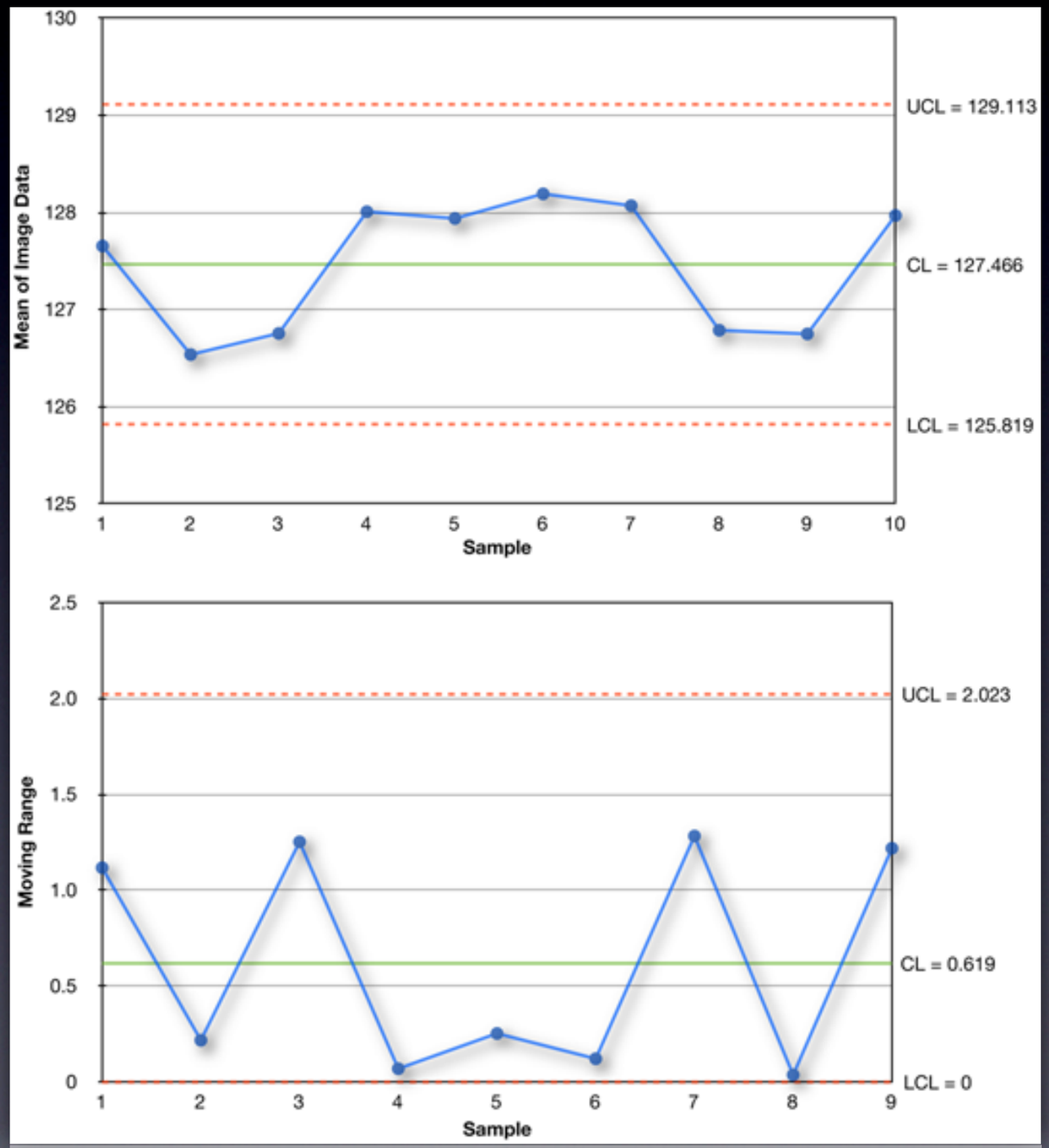
X-Moving Range Control Charts

iPhone D: Angle 5



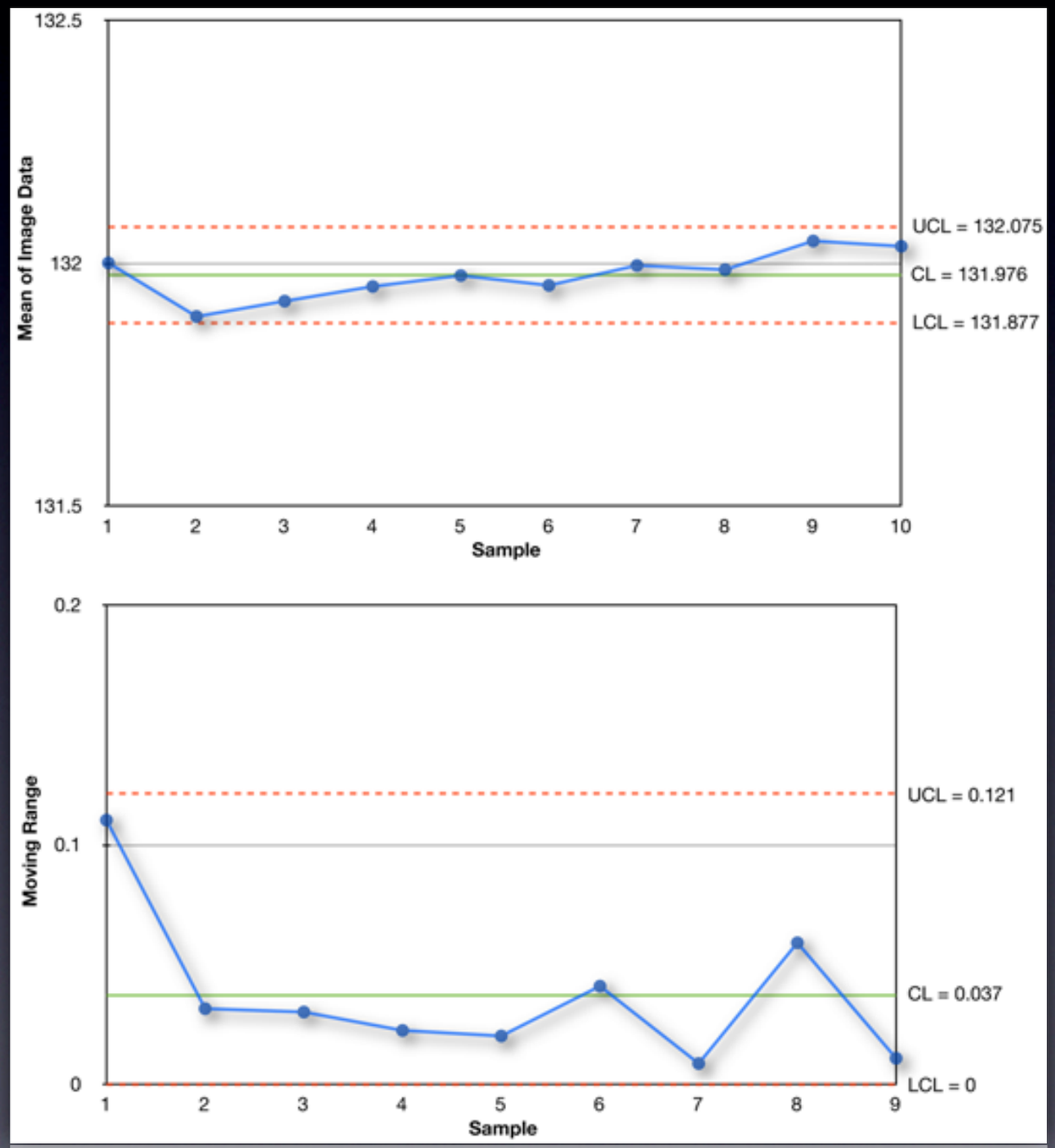
X-Moving Range Control Charts

Sony Ericsson W810i: Angle 5



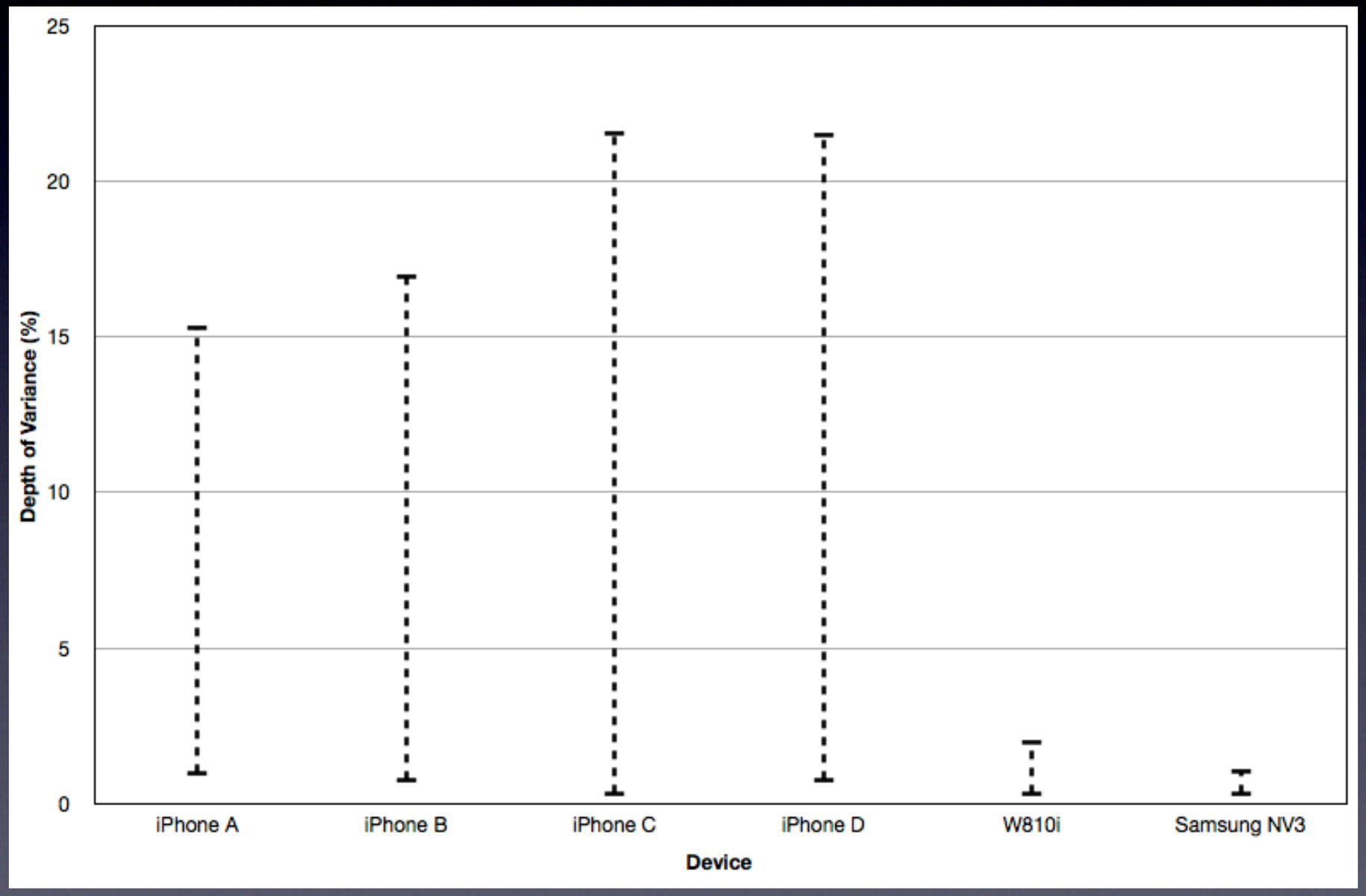
X-Moving Range Control Charts

Samsung NV3: Angle 5



Depth of Variation

Per-camera



Summary

- Control Charts can help derive quality of a camera's image acquisition process
- Anomalies in the process are highlighted through control charts
- Honing in on the cause of these anomalies, ultimately solves Camera Identification problem