Fault Detection by Upgrading Control Charts with Change Point Detection Function

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Magic Leap

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Agenda

- Magic Leap & Optics Manufacturing 1.
- 2. DMAIC problem solving with JMP tools
- 3. Our Challenges in Control Phase
- 4. Upgrading Control Charts with change point 5. Detecting and Diagnosing Faults
- 6. Case Studies & JMP Demo
- 7. Takeaways

AWORD where the physical and digital are one









Magic Leap





Up to 70° FOV

Best image quality

Color uniformity

Dynamic dimming



High yield (RTY) and process capability using JMP statistical tools

The optical lens is a critical component of Magic Leap 2, enabling best-in-class image performance

- The optical lens goes through 25+ complex processes and metrology stations during the manufacturing process
- It is tested over 100+ critical-to-quality (CTQ) parameters
- Each individual process needs to reach high 99% yield targets to attain 90% Rolled Throughput Yield (RTY) targets
- The process requires extremely precise fault detection, which JMP tools have helped us monitor and analyze





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Precise placement and alignment

- High-yield process that achieves 99%+ RTY on 22 CTQs or KPIs
- The Lithography patterning operates between tight control limits
 - Less than 20 nanometer film thickness
 - Less than 1 arcmin rotational alignment Ο
 - Less than 100 micrometer drop placement Ο
 - Less than 500 micrometer template alignment Ο
- The tolerances are extremely small (for reference Human hair is 20 to 100 um)

Imprint Lithography requires precision placement and alignment that are indistinguishable to the human eye



Figure: A unique Imprint Lithography process that involves precise wafer placement, resist drop placement, and alignment

Change point dashboard optimizes problem-solving process



- 8D problem statement
- Project Charters
- Goal plots

Measure

M

- Goal plots
- Process capability
- Process stability
- Summary tables

Analyze

- Fish-Bone diagram
- Pareto plot
 - Multivariate methods
- Correlation Matrix

- profiler Response screening
- DOE and Prediction Process capability •

Change point Dashboard makes our control phase efficient

A

Escalation before Change point control chart dashboard	Escalation after Char
 Operator monitors yield dashboard and identifies the yield loss Operator reports to technician to looks into faults If Tech unable to resolve, escalates to Engineer Engineer analyzes control charts data using control charts alarms and trends. Manually joining the outputs and inputs correlation 	 Operator and Technic If changes found, the change and diagnose Implement corrective
 Engineer diagnoses the fault Engineer implements corrective actions 	coming together to minimi



Improve

Control

- Control charts
- Time series diagnostics
- Change point detection

nge point control chart dashboard

ician monitor change point dashboard on shop floor ey look into correlation of inputs with before and after e the issue e actions

model where operators, technicians, and engineers are all ize faults

Journey from traditional control charts to change point detection dashboard

Evolving from "yield is below baseline today" to "no changes(variation) found in the process"





Change Point Detection

- Excellent in detection of
- abrupt drifts
- No CTQs-to-inputs
- correlation
- But no time series

Regression/ Cause & Effect

- Tool interlocks
- Stopping before failure on CTQs
- Prediction

Visualize the exact moment a change occurred





Introduce and validate a known change







2. Adjust the mean shift by adding an offset



Validate the change usingchange point detection

Find abrupt drifts in metrology tools





Use Case 3

Detect and diagnose faults with ease



		# Multivariate				
ta Filter		4 Correlations				^
avorites 👻			Overlay-T	Overlay-X	Overlay-YFilr	m_Distor
		Overlay-T	1.0000	-0.2121	0.0859	
nclude		Overlay-X	-0.2121	1.0000	0.0652	- 1
ows		Overlay-Y	0.0859	0.0652	1.0000	
		Film_Distortion_Y	-0.1852	-0.1910	0.0246	
(7)	5	Input-1	0.1508	-0.3125	-0.1485	- 18
nase (5)	<u>^</u>	Input-2	0.0335	-0.4188	0.0686	
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L1	126	Input-4	0.1301	0.3327	0.2136	
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		Input-6	0.0720	-0.0867	-0.3706	
OR		Input-7	-0.2554	-0.1105	0.1457	
		Input-8	-0.2980	-0.1270	0.1517	
		Input-9	0.1896	-0.0607	-0.2682	
		Input-10	0.2384	-0.0211	-0.2504	
		Input-11	0.2003	0.2523	0.0850	
		Input-12	0.2338	0.2687	0.0697	
		Input-13	-0.2401	0.0612	0.3269	
		Input-14	0.1865	0.0528	-0.1250	
		Input-15	0.2401	-0.0612	-0.3269	
		Input-16	-0.1865	-0.0528	0.1250	
		Input-17	-0.0454	-0.0345	0.1988	
		Input-18	-0.0720	-0.1023	0.1471	
					F1 1 12 4 12 1	
		input 10	-0.2307	-0.0961	0.1040	3
		# Multivariate	-0.2307	-0.0961	0.1040	>
ta Filter)	Multivariate Correlations	-0.2307	-0.0901	0.1646	> □ ×
ta Filter avorites ▼	}	Correlations	Overlay-T	Overlay-X	Overlay-YFilr	m_Distor
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ta Filter avorites ▼ nclude		Correlations Overlay-T Overlay-X	Overlay-T 1.0000 0.0090	Overlay-X 0.0090 1.0000	Overlay-YFilr 0.0854 0.1084	m_Distor
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ta Filter avorites • nclude rows		Multivariate Correlations Overlay-T Overlay-X Overlay-Y Film_Distortion_Y Input-1	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088	0.1848 Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0904	m_Distor
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ta Filter avorites include rows hase (3) ge t_2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7	-0.2307 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0820 -0.0345	-0.0951 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093	Overlay-YFile 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 1 2 OR	× 32 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8	-0.2307 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0820 -0.0345 -0.0234	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 2 0R	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9	-0.2307 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0345 -0.0234 0.0161	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872 0.0340	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499	m_Distor
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ta Filter avorites nclude rows nase (3) ge 1 2 OR	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-12 Input-13 Input-14 Input-15	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0234 0.0161 0.0350 -0.2377 -0.2340 -0.0204 0.1103 0.0204	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.013 -0.0268 -0.0268 -0.0268 -0.0268 -0.0268 -0.0268 -0.0836 -0.0836	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246	m_Distor
ta Filter avorites • nclude rows mase (3) ge 1 2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-6 Input-7 Input-8 Input-9 Input-10 Input-11 Input-12 Input-13 Input-14 Input-15 Input-16	Overlay-T 1.0000 0.0900 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0820 -0.0820 -0.0345 -0.02340 0.0350 -0.2377 -0.2340 -0.2340 -0.2240 -0.0204 -0.1103	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.0293 -0.1872 0.0340 -0.0268 -0.0226 0.0836 -0.0268 -0.0462	0.1848 Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246 -0.0588	m_Distor
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ta Filter avorites • nclude rows nase (3) ge 1 2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-13 Input-13 Input-14 Input-15 Input-16 Input-17 Input-18	Overlay-T 1,0000 0,0090 0,0854 -0,0919 -0,062 -0,0691 0,0459 0,0055 -0,0445 -0,0820 -0,0820 -0,0345 -0,02340 -0,02340 -0,02340 -0,0204 0,0161 0,0350 -0,2377 -0,2340 -0,0204 -0,1103 -0,1182 -0,1106	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.0293 -0.1426 -0.0268 -0.0268 -0.0226 0.0836 -0.02688 -0.0268 -0.02688 -0.0268 -0.0268 -0.0268 -0.02688 -0.02	0.1848 0.0854 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1249 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246 -0.0588 -0.0558 -0.0556 -0.0558 -0.0556 -0.0558 -0.0556 -0.0556 -0.0556 -0.0558 -0.0556 -0.05	m_Distor

Putting JMP tools in action

Demonstration using Boston housing.jmp, Sample data set found here:



SAS > JMP > 16 > Samples >	Data
~	Date modified
	9/10/2020 6:00 PM
ments	9/10/2020 6:00 PM
g	12/15/2020 6:00 PM
	11/19/2020 6:00 PM
s	9/10/2020 6:00 PM
	11/19/2020 6:00 PM
	11/19/2020 6:00 PM

Use Case 3

Detect and diagnose faults with ease



		# Multivariate				
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		Input-10	0.2384	-0.0211	-0.2504	
		Input-11	0.2003	0.2523	0.0850	
		Input-12	0.2338	0.2687	0.0697	
		Input-13	-0.2401	0.0612	0.3269	
		Input-14	0.1865	0.0528	-0.1250	
		Input-15	0.2401	-0.0612	-0.3269	
		Input-16	-0.1865	-0.0528	0.1250	
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		input 10	-0.2307	-0.0961	0.1040	3
		# Multivariate	-0.2307	-0.0961	0.1040	> □ ×
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ta Filter avorites ▼	}	Correlations	Overlay-T	Overlay-X	Overlay-YFilr	m_Distor
ta Filter avorites ◄		Correlations	Overlay-T 1.0000	Overlay-X	Overlay-YFilr	m_Distor
ta Filter avorites ▼ nclude		Correlations Overlay-T Overlay-X	Overlay-T 1.0000 0.0090	Overlay-X 0.0090 1.0000	Overlay-YFilr 0.0854 0.1084	m_Distor
ta Filter avorites 👻 nclude rows		Correlations Overlay-T Overlay-X Overlay-Y	Overlay-T 1.0000 0.0854	-0.0951 Overlay-X 0.0090 1.0000 0.1084	Overlay-YFilr 0.0854 0.1084 1.0000	m_Distoi
ta Filter avorites • nclude rows		Multivariate Correlations Overlay-T Overlay-X Overlay-Y Film_Distortion_Y	Overlay-T 1.0000 0.0854 -0.0919	Overlay-X 0.0090 1.0000 0.1084 0.0142	Overlay-YFilr 0.0854 0.1084 1.0000 0.0599	m_Distoi
ta Filter avorites • nclude rows		Multivariate Correlations Overlay-T Overlay-X Overlay-Y Film_Distortion_Y Input-1	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088	0.1848 Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0904	m_Distor
ta Filter avorites • nclude rows nase (3)	×	Multivariate Multivariate Overlay-T Overlay-X Overlay-Y Film_Distortion_Y Input-1 Input-2	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446	Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192	m_Distor
ta Filter avorites - nclude rows nase (3) ge	× 32	Multivariate Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3	-0.2307 Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0459	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902	0.1848 Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1249	m_Distor
ta Filter avorites nclude rows nase (3) ge	× 32 126	Multivariate Multivariate Overlay-T Overlay-X Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4	-0.2307 Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0459 0.0055	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882	Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1290	m_Distor
ta Filter avorites - nclude rows - nase (3) ge 1	× 32 126 42	# Multivariate Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5	-0.2307 Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0459 0.0055 -0.0445	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426	Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729	m_Distor
ta Filter avorites - nclude rows - nase (3) ge 1 1,2	× 32 126 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-5 Input-6	-0.2307 Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0455 -0.0445 -0.0820 -0.0820	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.1468	Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499	m_Distor
ta Filter avorites include rows hase (3) ge t_2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7	-0.2307 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0820 -0.0345	-0.0961 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093	Overlay-YFile 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 1 2 OR	× 32 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8	-0.2307 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0820 -0.0345 -0.0234	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 2 0R	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9	-0.2307 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0345 -0.0234 0.0161	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872 0.0340	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 2 0R	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0234 0.0161 0.0350	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.0013	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 -0.0618	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 2 0R	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-11	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0345 -0.0234 0.0161 0.0350 -0.2377	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.0013 -0.0268	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495	m_Distor
ta Filter avorites nclude rows nase (3) ge 1,2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0234 0.0161 0.0350 -0.2377 -0.2340	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.013 -0.0268 -0.0226	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506	m_Distor
ta Filter avorites nclude rows mase (3) ge 1 2 OR	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-12 Input-13	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0234 0.0161 0.0350 -0.2377 -0.2340 -0.2340 -0.2340 -0.2340	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.013 -0.0268 -0.0226 0.0836	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0246	m_Distor
ta Filter avorites nclude rows mase (3) ge 1 2 OR	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-13 Input-14	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0234 0.0161 0.0350 -0.2377 -0.2340 -0.0204 0.0101	-0.0951 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.013 -0.0268 -0.0226 0.0836 -0.0462	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588	m_Distor
ta Filter avorites nclude rows nase (3) ge 1 2 OR	× 32 125 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-12 Input-13 Input-14 Input-15	Overlay-T 1.0000 0.0090 0.0854 -0.0919 -0.0062 -0.0691 0.0459 0.0055 -0.0445 -0.0820 -0.0345 -0.0234 0.0161 0.0350 -0.2377 -0.2340 -0.0204 0.1103 0.0204	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.0088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1468 -0.2093 -0.1872 0.0340 -0.013 -0.0268 -0.0268 -0.0268 -0.0268 -0.0268 -0.0268 -0.0836 -0.0836	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246	m_Distor
ta Filter avorites • nclude rows mase (3) ge 1 2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-6 Input-7 Input-8 Input-9 Input-10 Input-11 Input-12 Input-13 Input-14 Input-15 Input-16	Overlay-T 1,0000 0,0090 0,0854 -0.0919 -0,0062 -0,0691 0,0459 0,0055 -0,0445 -0,0820 -0,0820 -0,0820 -0,0234 0,0161 0,0350 -0,2377 -0,2340 -0,0204 0,1103 0,0204 -0,1103	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.0293 -0.1872 0.0340 -0.0268 -0.0226 0.0836 -0.0268 -0.0462	0.1848 Overlay-YFilr 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246 -0.0588	m_Distor
ta Filter avorites • noclude rows mase (3) ge 12 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-13 Input-13 Input-14 Input-15 Input-16 Input-17	Overlay-T 1,0000 0,0090 0,0854 -0,0919 -0,0062 -0,0691 0,0459 0,0055 -0,0445 -0,0820 -0,0820 -0,0345 -0,0454 -0,0820 -0,0345 -0,02340 -0,02340 -0,02340 -0,0204 -0,1103 -0,1182	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.0293 -0.0268 -0.0226 0.0836 -0.02688 -0.0268 -0.02688 -0.0268 -0.0268 -0.0268 -0.02688 -0.02	0.1848 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246 -0.0588 -0.0246	m_Distor
ta Filter avorites • nclude rows nase (3) ge 1 2 OR	× 32 126 42	# Multivariate Overlay-T Overlay-Y Film_Distortion_Y Input-1 Input-2 Input-3 Input-4 Input-5 Input-6 Input-7 Input-8 Input-9 Input-10 Input-12 Input-13 Input-13 Input-14 Input-15 Input-16 Input-17 Input-18	Overlay-T 1,0000 0,0090 0,0854 -0,0919 -0,062 -0,0691 0,0459 0,0055 -0,0445 -0,0820 -0,0820 -0,0345 -0,02340 -0,02340 -0,02340 -0,0204 0,01103 0,0204 -0,1103 -0,1182 -0,1162 -0,000 -0	-0.0961 Overlay-X 0.0090 1.0000 0.1084 0.0142 0.088 -0.0446 -0.1902 -0.1882 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.1426 -0.0293 -0.1426 -0.0268 -0.0268 -0.0226 0.0836 -0.02688 -0.0268 -0.02688 -0.0268 -0.0268 -0.0268 -0.02688 -0.02	0.1848 0.0854 0.0854 0.1084 1.0000 0.0599 -0.0904 0.0192 -0.1249 -0.1249 -0.1249 -0.1296 -0.0729 -0.1499 -0.1353 -0.1369 -0.0499 -0.0618 0.0495 0.0506 0.0246 0.0588 -0.0246 -0.0588 -0.0549 -0.0588 -0.0588 -0.0588 -0.0549 -0.0588 -0.0556 -0.0588 -0.0556 -0.0588 -0.0556 -0.05	m_Distor

Using Pearson's Correlation Coefficient to understand root causes



Correlations						
	mvalue					
mvalue	1.0000					
crim	-0.4830					
zn	0.3243					
indus	-0.4882					
nox	-0.4852					
rooms	0.8055					
age	-0.5720					
distance	0.3942					
radial	-0.2838					
tax	-0.4107					
pt	-0.1253					
b	0.2816					
Istat	-0.7501					

Phas	se Te	mplate Change Over	LoadPortId	LoadPortId FVT B	Station FVT / LithoPostInspe
Change_Poin	t_1 Ten	nplate_X_MM040	lp3	lp3	A1
Change_Poin	t_2 Ten	nplate_X_MM039	lp2	lp2	B1
Before_Chan	ge		lp1	lp1	
Before_Ch	nange Tei	mplate_X_MM039	lp2	lp2	A1
Before_Ch	nange Tei	mplate_X_MM039	lp2	lp2	A1
Before_Ch	nange Tei	mplate_X_MM039	lp2	lp2	A1
Before_Ch	nange Tei	mplate_X_MM039	lp2	lp2	B1
Before_Ch	nange Tei	mplate_X_MM039	lp2	lp2	A1
Before_Ch	nange Tei	mplate_X_MM039	lp3	lp3	A1
Before_Ch	nange Tei	mplate_X_MM039	lp2	lp2	A1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	B1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	A1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	A1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	A1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	B1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	A1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	A1
Before_Ch	nange Tei	mplate_X_MM039	lp1	lp1	A1
Before Ch	nange Ter	mplate X MM039	lp1	lp1	B1

Once we know the exact time of the fault – correlate to non- numerical data sets such change over time, idle time, PM

Detecting and diagnosing faults at same time using change point dashboard

- JMP's change point detection dashboard has been extremely helpful on the MFG shop floor to easily determine abrupt changes (faults)
- Integrating change points into traditional control charts gave us better visual understanding on the shop floor
- The dashboard's ability to demonstrate correlation of inputs and CTQs helps us diagnose issues faster
- We are then able to prevent future faults by understanding the root cause of changes
- Change point detection can be used in ANY time series data analysis through JSL scripting

Change point detection control chart dashboard monitor and diagnose at the faults at the same time

Thank you