Challenges in Manufacturing/Quality Control and Detection of Faults in the Process of Manufacturing by Multivariate Analysis

(Principle Component Analysis)

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Outline

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Why do we look at challenges in Manufacturing?

- Important to check the sanity of the manufacturing.
- Is it producing what it is supposed to be producing?
- Are the analytics used in the decision making are efficient?
  Eg: Confusion matrix.
- What are the cost associated w.r.t. metrology used?
  Eg: Time, Complexity and Design.

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Size

Eg: Fasteners, Sub-parts, etc.

- Items manufactured by one process must be of same/specified size.
- Whole point (!) of production (Custom or Mass).

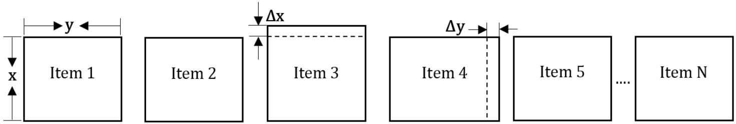


Figure: Production batch in which item no.3 & 4 are oversized by Δx & Δy units respectively.

Orientation

Eg: PCBs, Masks, Sub-parts etc.

- Similarly, items produced by single process must be of same/specific orientation.
- Or no anomaly expected in the orientation.

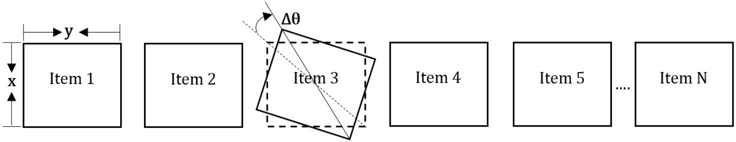


Figure: Anomaly in the production of item no. 3. The item has a defect in its orientation by an angle of $\Delta\theta^{\circ}$.

Tolerance

- Needed for better judgement of quality of product.
  Eg: Allowance for Δx, Δy and $\Delta\theta$
- The errors occurred in measuring the parameters are due to actual physical error or analytical methods used or could be due to vibrations.
- It is important to know the source of error to precisely measure the parameters.

Time

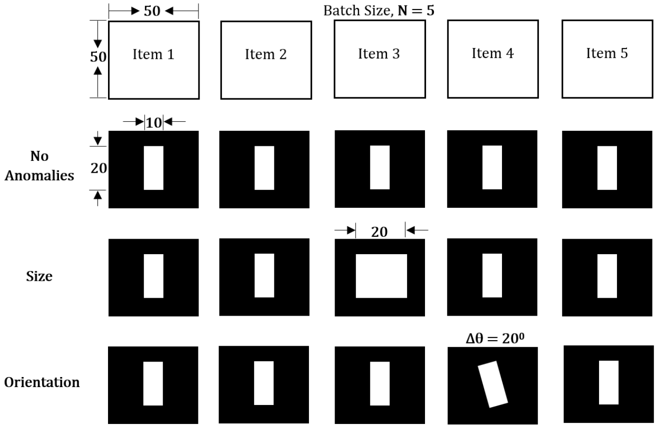
Eg: Sorting in industries

- Very crucial when the throughput is of importance.
  Eg: Japanese recycling industry. 2 tonne in 1 hr.!
- The decision making analytical methods must have low (or no) complexity.
- Linear models are preferable.

Outline

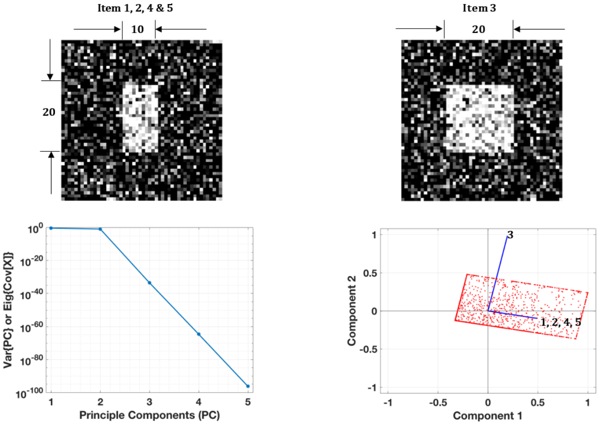
Production Model and Anomalies

Size and Orientation



Anomaly due to change in Size

Batch Size $N = 5$, with Gaussian noise, $\mathcal{N}(\mu, \sigma^2) = \mathcal{N}(0, 0.25)$



Anomaly due to change in Orientation

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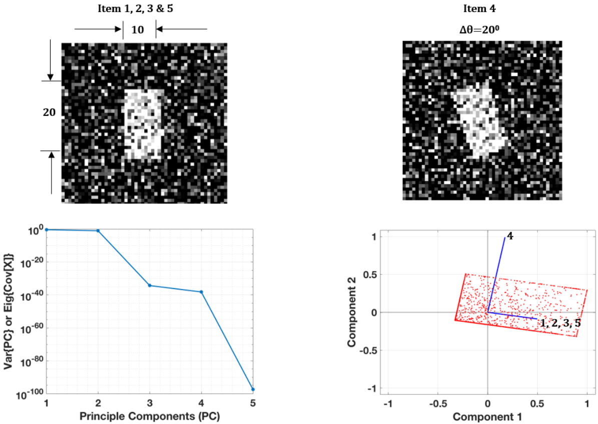

Robustness of PCA

- nfaults=randi([1 5]); % Number of fault parts
  % -----------Random Size of Parts----------
- sz1 = randi([1 r/2], 1, nfaults); % Size rows
- sz2 = randi([1 c/2], 1, nfaults); % Size columns
  % -----------Random Orientation------------
- rt = randi([1 360], 1, nfaults); % Rotation angles
  % -------Random location of faults---------
- Pos = randi([1 N], 1, nfaults); % Locations in stack

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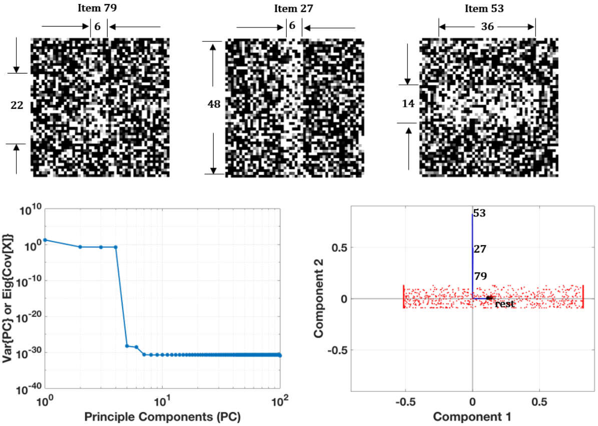
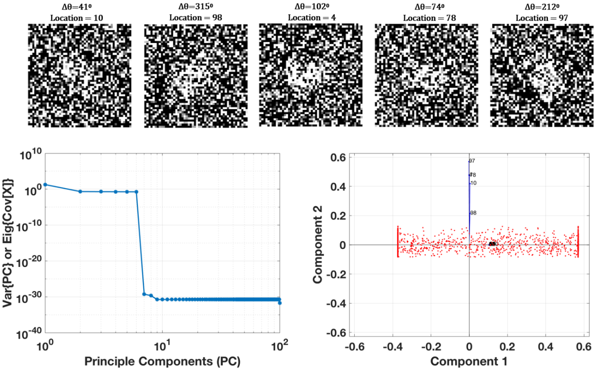
Robustness of PCA: Size

Batch Size $N = 100$, with Gaussian noise, $\mathcal{N}(\mu, \sigma^2) = \mathcal{N}(0, 2)$



Robustness of PCA: Orientation

Batch Size $N = 100$, with Gaussian noise, $\mathcal{N}(\mu, \sigma^2) = \mathcal{N}(0, 2)$



Summary

- The PCA method is robust in identifying abnormalities in the process.
- Random number of faulty images and their locations, $\Delta\theta$ and Sizes have been tested.
- PCA is a linear model. Fast decision maker.
- Simpler, Cost effective metrological method of fault detection in manufacturing and quality control.

- Outlook
  - The extent of abnormalities can be studied in depth in Endmember extraction methods such as Vertex Component Analysis (VCA) and random N-findr extraction.

Open Source Data I

GitHub: vcangadi1
Matlab Codes, Documentation, LaTeX Slides and Data.
https://github.com/vcangadi1/Presentations