

# 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

## 1 Introduction

- Why do we look at challenges of Manufacturing?

## 2 Challenges in Manufacturing and Quality Control

- Size
- Orientation
- Tolerance
- Time

## 3 Fault Detection using Multivariate Analysis

- Production Model and Anomalies
- Principle Component Analysis
- Testing the robustness of the method



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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.

# Outline

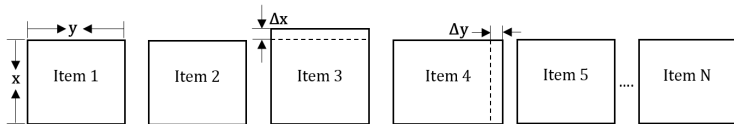
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# Size

Eg: Fasteners, Sub-parts, etc.

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

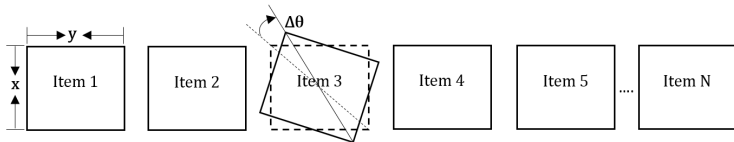


**Figure:** Production batch in which item no.3 & 4 are oversized by  $\Delta x$  &  $\Delta y$  units respectively.

# 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  $\Delta x$ ,  $\Delta y$  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.



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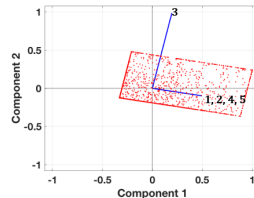
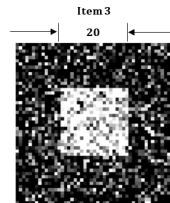
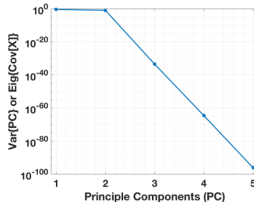
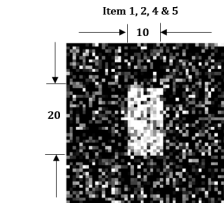


## Size and Orientation



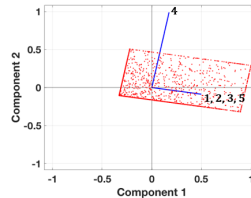
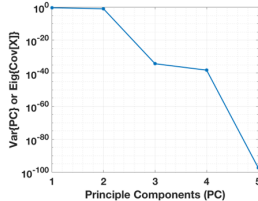
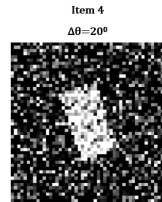
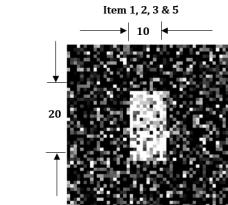
# Anomaly due to change in Size

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



# Anomaly due to change in Orientation

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



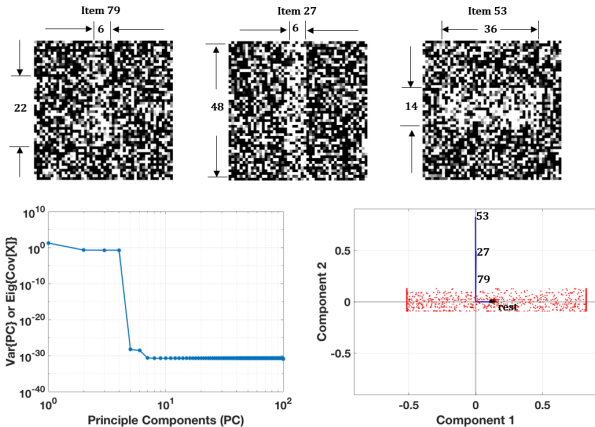
# Robustness of PCA

- `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`



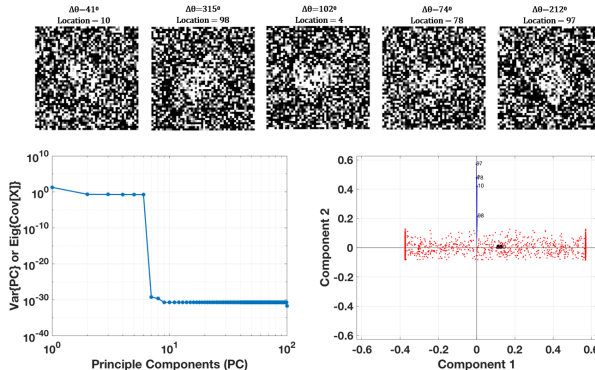
# Robustness of PCA: Size

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](https://github.com/vcangadi1)

*Matlab Codes, Documentation, L<sup>A</sup>T<sub>E</sub>X Slides and Data.*

<https://github.com/vcangadi1/Presentations>

