Data Analytics for Advanced Vehicle Manufacturing

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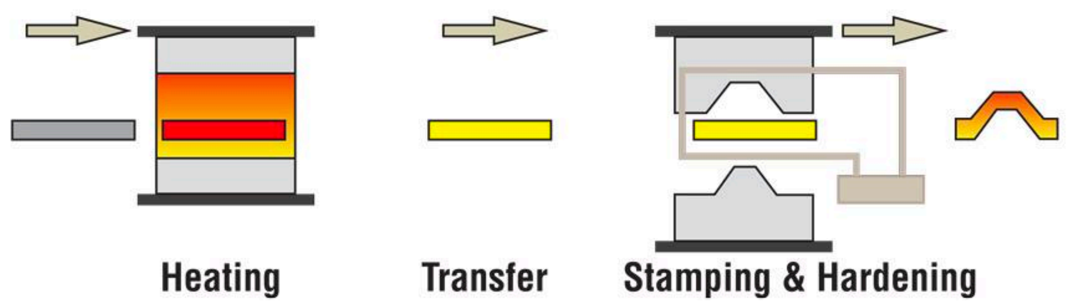
Introduction

Motivation

- In automotive manufacturing, there are large amounts of data generated during the production of a vehicle, and this data can be used to effectively monitor the status of machinery, predict machine failures, and identity root causes of faults.
- New methods are required to find hidden insights within these large datasets to bring improvements to automotive manufacturing.

Objective

- Focusing on the hot stamping process which has become the industry standard in producing the vehicular chassis and frame, a quality control system can be produce to effectively monitor the viability of stamped car parts.



Challenges

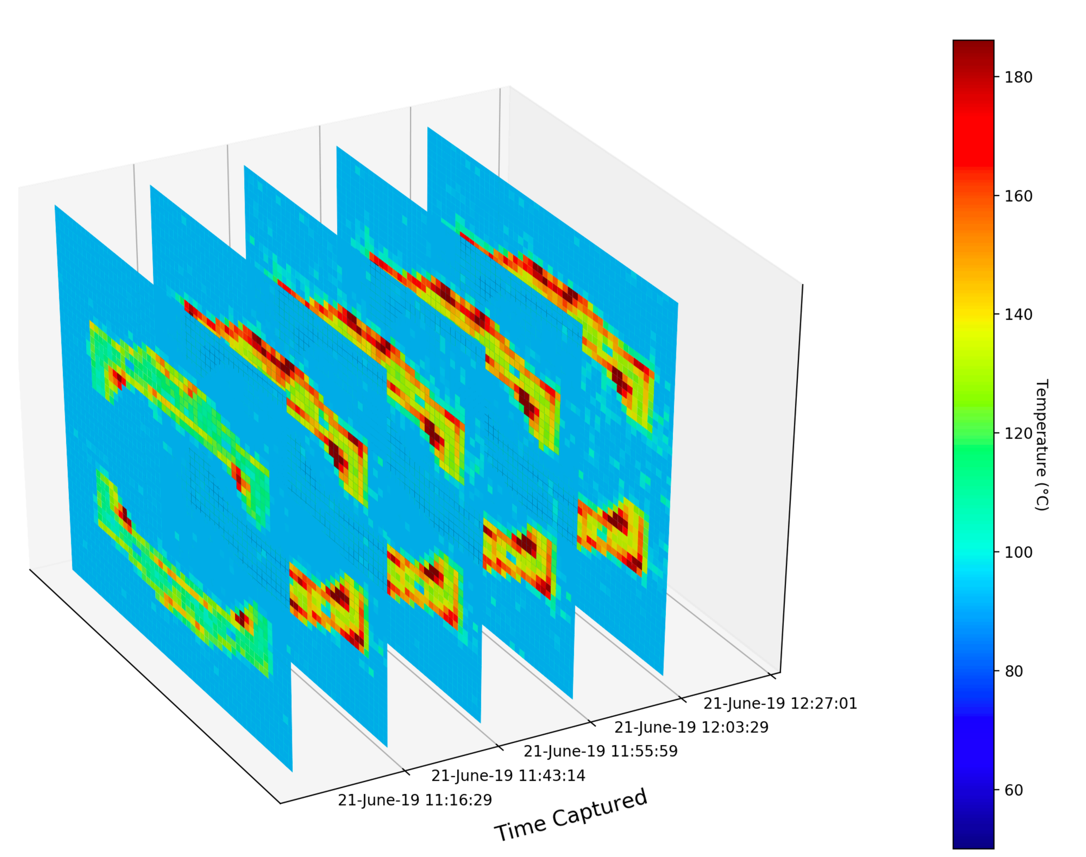
- Dealing with a large amount of unlabeled image data
- Finding a method to detect variability for the hot stamping method

Data

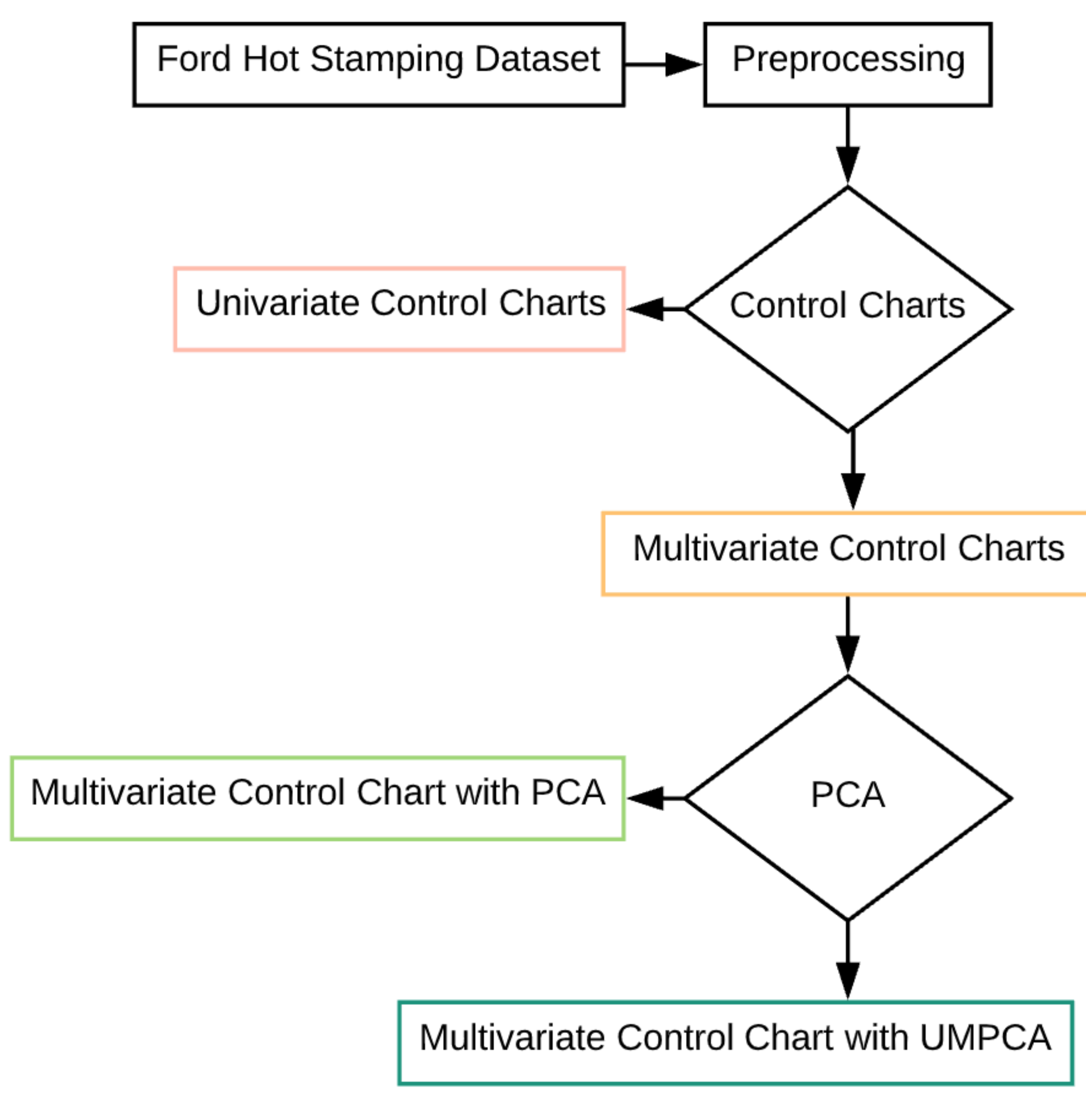
Dataset

- 1902 images of hot stamped parts from the Ford Motor Company
- Images are captured in 13 to 30 second intervals with 2 parts in each frame
- 100 images of the same part were used to train the models

Tensor Data



Building Models



Multivariate Control Chart

$$T_i^2 = n(\overline{X}_i - \bar{\bar{X}})\bar{S}^{-1}(\overline{X}_i - \bar{\bar{X}})^t$$

T_i^2 - the weighted distance of any observation from the target (the mean under stable condition)

n - sample size of each rational subgroup

$\overline{X}_i$ - the vector of samples means for the i^{th} rational subgroup

$\bar{S}^{-1}$ - inverse pooled sample covariance matrix

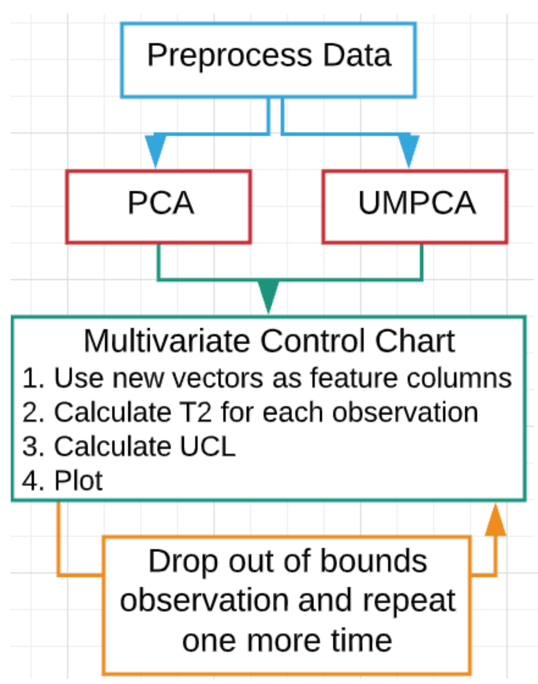
$\bar{\bar{X}}$ - the pooled vector of sample means calculated using the n observed sample mean vectors

$$UCL = \frac{(n-1)^2}{n}\beta_{\alpha,\frac{p}{2},\frac{(q-p-1)}{2}}$$

$$q = \frac{2(m-1)^2}{3m-4}$$

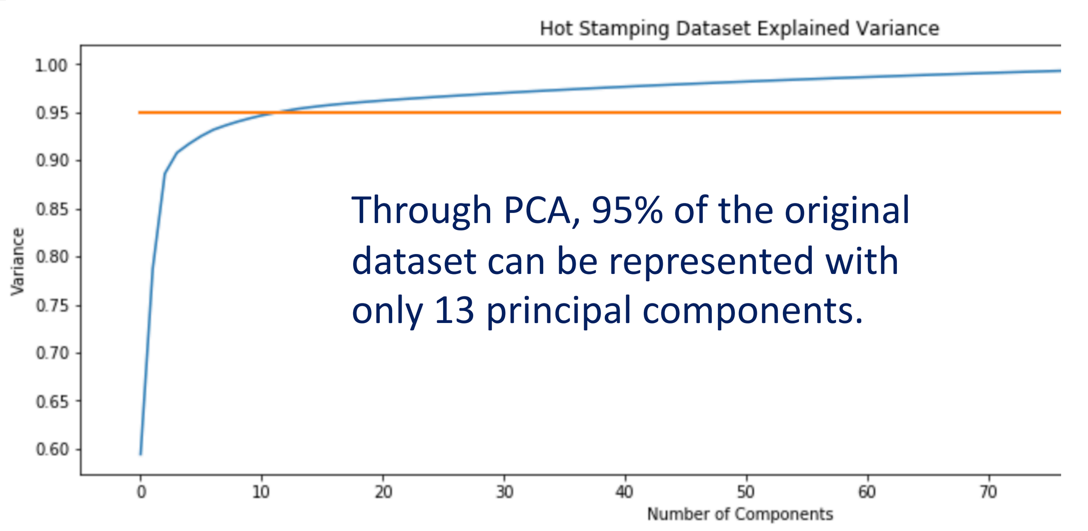
LCL = 0

The Process

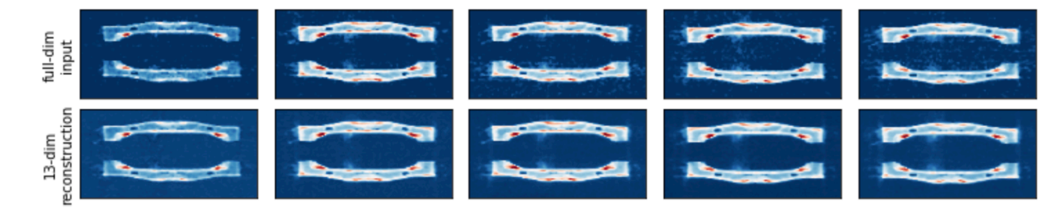


Drawback to using PCA is the images must be converted from a 2D structure to a vector which present two issues: **1.** Requires large amount of computational power to reshape the images **2.** Any spatial pattern of the images will not be properly accounted for in the new dimensionally reduced dataset. UMPCA solves this by directing finding tensor to vector projections from the images.

PCA

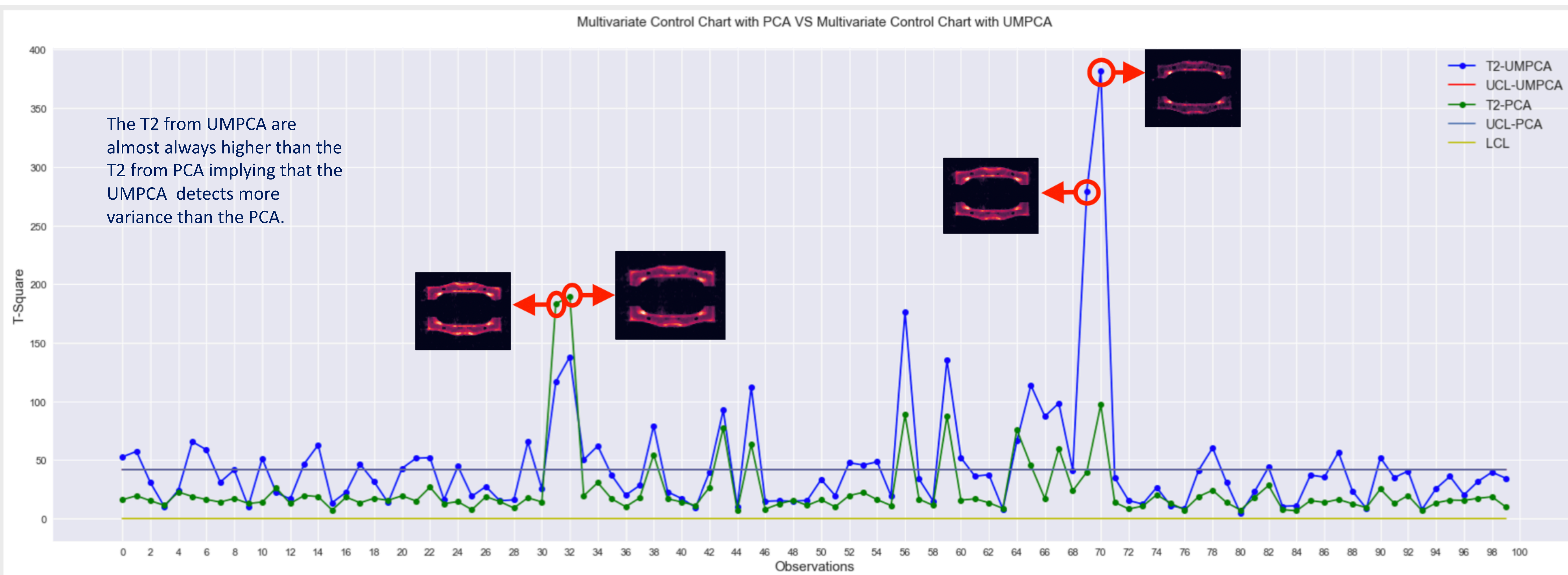


Through PCA, 95% of the original dataset can be represented with only 13 principal components.



It is hard to discern the difference between the original image and the image reconstructed using the 13 new components.

PCA vs UMPCA



Conclusion

A quality control system is developed to detect anomalies in production for the automotive manufacturing technique: hot stamping.

By comparing classical techniques such as univariate and multivariate control charts with dimensional reduction and feature extractions tools like PCA and UMPCA, the best model was determined to be UMPCA with Multivariate Control Chart.

References

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