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# Predictive analytics in quality assurance for assembly processes: lessons learned from a case study at an industry 4.0 demonstration cell

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**Abstract**

Quality assurance (QA) is an important task in manufacturing to assess whether products meet their specifications. However, QA might be expensive, time-consuming, incomplete, or delayed. This paper presents a solution for predictive analytics in QA based on machine sensor values during production while employing machine-learning models based on logistic regression in a controlled environment. Furthermore, we present lessons learned while implementing this model, which helps to reduce complexity in further industrial applications. The paper's outcome proves that the developed model was able to predict product quality, as well as to identify the correlation between machine-status and faulty product occurrence.



*Keywords:* Machine-Learning; Predictive Quality; Production; Quality Assurance; Logistic Regression

## 1. Introduction

**(AP:**

- **Products' quality must always be guaranteed.**
- **In certain cases (especially in series assembly production) there is a delay between quality inspection and end of the production process high potential for producing scrap**
- **By doing quality inspection based on samples, there is still a risk of sending NOK parts to customers**
- **The cost of quality checks might be expensive**
- **Quality assurance is normally done at the end of production (for assembly processes)**
- **Early prediction of the production's quality would help to decrease the amount of scrap and the risk of sending NOK parts to customers**
- **Variable predictions by using machine learning models is currently widely used in diverse fields due to its accurate predictions with the data collected from the machines, prediction models can be implemented for specific predicted values**

)

## 2. Related Works

### 2.1. Quality check in production

The quality control of production processes and products is one part of the general quality management and contains the measures and activities needed to fulfill the quality requirements [? ]. Currently there are three main concepts: off-line quality control, statistical process control and acceptance sampling. Off-line quality control is the first step in the quality control, because it starts in the developing and designing phase of a new product or process. The main goal is to select and adjust the process parameters in a way to minimize the deviation between the production outputs and the desired results. Thus the process parameters don't have to be determined while production begins and the possibility of defect products decrease. The statistical process control (SPC) is used for a target-performance comparison. In case of a discrepancy between target and performance, the SPC is taking remedial actions. This concept of quality control also provides information on whether a new product can also be produced using the existing production process. If a real-time application is needed, e.g. to execute corrective actions due to product quality discrepancies, online statistical process control can be used [**?** ]. The third concept is represented by the acceptance sampling. ... The quality characteristics of a product can be classified as variables or attributes. Variables are measurable characteristics, which are shown as numbers. On the contrary, attributes are not measureable and can only take the value go or no-go. Often, even if the quality characteristics of a product are measureable, a go/no-go differentiation is faster and cheaper.

**(AP:**

- **How quality check is done in production**
- **Concepts and sampling plan**
- **Attributive vs Variable measurements [VM has higher measurement accuracy, reason why it's better to use regression model]**

**)**

### *2.2. Predictive analytics in production*

**(AP: Predictive analytics as concepts. Implementation in production**

- **Predictive Maintenance**
- **Scheduling**
- **Other**

**If happens to be something with P.A. Quality Check**

- **Predictive analytics in production focusing in QA**
- **Existing approaches and methods**

**Note: Ideal is to find a gap in the literature, that proves why do we do it and why it is important )**

## 3. The case industry 4.0 demonstration cell

The demonstration cell is a demonstrator representing a general assembly process and is essentially composed of assembly lines, a universal robot and a wide range of sensor technology. The following use case is implemented: shown is a stylized assembly process where two disks are to be stacked on top of each other. The quality of the pseudo products is predicted on the basis of the concentricity of both parts to be joined and the optimum operating point. The demonstration cell is configured to imitate certain situations that occur in real applications. For example, it is possible to simulate failures in the motors, problems with the conveyor belts or incorrect positioning of an object by the robot arm, which causes anomalies in the vibration sensors, temperature rise, fluctuations in the air pressure system and other deviations. Due to its manageable size and high degree of scalability, findings gained with the demonstration cell can be transferred to various real assembly processes and use cases.

Fig. 1. The industry simulation cell. **(MW: TODO: Find image.)**

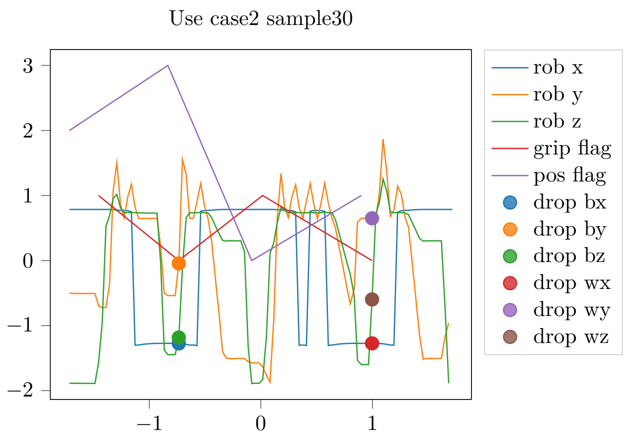


Fig. 2. Robot arm movement patterns. We show the movement of the cell's robot arm, its grippers and an encoding of the overall position in the system. The changes in the grip flag are triggered, when the gripper opens or closes. Zero indicates an open, while one indicates a closed gripper. The position flags marks the state of the cell's arm. 0 means the black disk is in store, one that the black disk is in the gate, two that the white disk is in store and three that the white disk is located in gate.

**(AP: What is the demozelle and why it is relevant as study case Description of the assemble process in the Demozelle Incl pictures )**

## 4. Methods

Data is collected from the demonstration cell and analyzed

### *4.1. Measurement*

### *4.2. Machine Learning*

We compare Support Vector Machines (SVM), Multilinear Perceptrons [**?** ] as well as Random forests in the task of quality prediction.

## 5. Experiments

### *5.1. Recording the data*

### *5.2. Classifier optimization and testing*

The robot's position at disc drop is marked in Figure **??**. The quality prediction problem is framed as a classification task.

| | |
|---|---|
| Support Vector Machine | 95.% |
| Multilinear Perceptron | 95.% |
| Random Forest | 100.% |

Table 1. Method comparison for our annomaly detection task using the industry demo data test set.

The input vectors which we feed into our classifiers consists of the arm positions at the disc drops for both discs in three dimensions, as well as the largest recorded belt speed of all three belts. The interpretation of the quality measurement is used as the training target. It can be good or bad which we encode as zero and one.

We work with a total of 132 measurements. Each containing arm and belt data logs of individual cell runs. 20 samples are set aside at random for testing purposes, leaving 112 training samples. The random number generator seed is set to one in order to ensure the train and test set splits are identical for all experiments.

We compare a total of three different classifier architectures on the data. A Support Vector Machine (SVM), a multilinear perceptron and a Random Forest structure. All three methods are trained using standard hyperparameters. [1] Results are shown in table **??**. For 55 of the total 132 samples quality measurements indicate a problem. This sets the baseline over the entire data set, that would be obtained by simply labeling all samples as good. Over the entire data set, we require to classify more than 58.3% of the data correctly. The test set contains eight incorrect samples. We would therefore expect any naive classifier to produce a 60% accuracy, which we have to beat. In Table **??**, we observe that this is indeed the case for all three approaches evaluated here. The random forest performed best in this case.

## 6. Conclusion

### *6.1. Lesson Learned*

**(AP: explain experiences by doing the research)**

## 7. Conclusion

[1] In order to allow exact reproduction of these results source code is available at `https://github.com/manubrain/Demo-Cell-Classification`