Integrating AI and Machine Learning in Process Control

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1 Introduction

Artificial Intelligence and Machine Learning (Further abbreviated as AI) are buzzwords that are raising a lot of interest in manufacturing.

Applying AI is not easy and should not be taken lightly. In this whitepaper, we will explain how you can take the first steps in AI and what the prerequisites to applying AI are.

2 Process Control

Before we can describe how AI can improve process control, we need firstly to establish what process control is.

We can show a process in a schematic way as follows

A product is good and can be sent to the customer when all product characteristics are within specification. A powerful technique to control product characteristics is Statistical Process Control (SPC) which has been applied to the manufacturing process since 1924.

Using SPC

Based upon SPC, we can establish when a process has a special cause of variation and we can also investigate the cause and improve the process. When we find that a process setting or characteristic is causing issues, we control the process characteristic (like temperature) with control technology so that it will never exceed a predefined range.

In our dream state of Zero Defect production, by just monitoring the process characteristics we are 100% sure the product characteristics simply can only be OK.

But now comes the reality…

Using DOE

If there are only direct relations, this is easy. With our standard DataLyzer tools we quickly manage to analyze the settings and correlations. But in some cases, there are interactions and we cannot easily find the optimum setting and correlations between the settings in the process and the characteristics of the produced product.

A well know technique to find the optimal setting of a process is via Design of Experiments (DOE). DOE is also a technique which has been available for almost 100 years. What we try to find in DOE is the relation between material, tooling, process settings, process characteristics and product characteristics.

Product characteristics can only be measured after the process and it is often costly to measure it. This means we are often too late and it is expensive to measure products.

Measuring the Process instead of the product

If we find a perfect correlation between process characteristics, settings, material tooling and the product characteristic we can measure the process characteristics instead of the product.

Measuring the process is often easier and cheaper than measuring the product.

This means that we can easily measure 100% and find out earlier that something is going wrong.

A requirement during DOE is that the amount of changes in the process are kept to a minimum because special causes of variation will make the outcome of the experiment more or less worthless.

3 Why AI?

AI works by combining large amounts of data with fast, iterative processing and intelligent algorithms, allowing the software to learn automatically from patterns or features in the data.

If you establish a model of a production and you define a desired outcome (good product) then the model can learn from processing vast amounts of data how to get at the desired outcome. This allows AI to assist humans and enable:

- quality checks when characteristic cannot be measured
- 100% quality check of the process instead of sample checks on products
- Better understanding of important process characteristics/process settings
- interventions to prevent scrap

The application of AI to determine the desired outcome is recognized by two approaches:
1) Assistance in interpretation of quality characteristics and
2) Quality prediction.

Assistance in interpretation of quality characteristics

Examples are vision systems where AI is used more and more to assist in and improve quality control. A different example is when AI is used when it is impossible to properly measure a quality characteristic.

A well-known example where quality inspection based on a measurement is useless is the inspection of floor tiles. To inspect if floor tiles have internal cracks, the operator ticks on the tile and based on the sound the operator knows if the tile has internal cracks and needs to be rejected.

Until now, it has not been possible to “measure” the sound and accept or reject the tile based on a specification. AI has already proven a long time to be very successful in this situation, the sound is fed into a model and the operator tells the model whether a tile is good or bad. Based upon learning, the model can establish if a tile is good or should be rejected.

Quality prediction

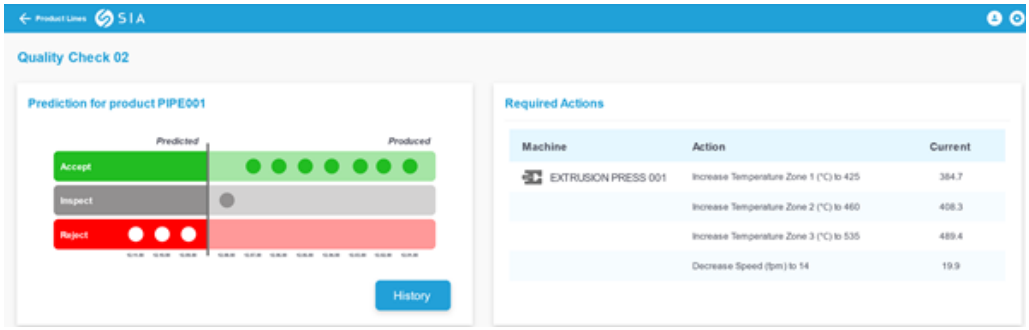
In a similar way, we can use process characteristics to predict the outcome of the quality characteristic or failures of a machine. Some examples include:

- Based on the deviation in cycle time in an injection moulding process, failures can be predicted
- Based on process characteristics like temperature, speed, tool lifetime and kinematics, the quality of a machining process can be predicted or established, even before the product is measured.

Because process characteristics can be easily measured, we can predict the outcome of a process or are even capable of correcting a process to prevent an incorrect outcome.

If we are able to find a correct model with a high predictability of the result, we would improve quality, reduce inspection, prevent rejects and if rejects cannot be avoided prevent extensive machining time processing a product which will be scrapped anyway.

A probable output of AI would be



4 Does AI Always Work?

Would you trust a product where the product is not measured at all but only the process characteristics are monitored?

Maybe, if the supplier has proven that with a very high accuracy product characteristics can be predicted based on process characteristic. This height of the accuracy determines key, as it remains a balance in costs, such as determining how many sample checks to make. But still, do results of the past guarantee the same results in the future?

In case of process failures (downtime) or out of control situations, the outcome is basically unpredictable. In traditional process control, in case of downtimes or statistical out of control conditions, you need to remove the root cause and assure the problem will not return.

AI has the same problem when the process monitored is haunted by failures and out of control situations. Result is that AI has difficulties to perform when these occurrences cannot be identified in the measured data.

So as long as the model is not predicting the outcome with 100% confidence and the system is affected by failures and out of control situations, it is recommended to combine traditional techniques with the application of AI.

Another reason to keep measuring products is that the model will improve by learning. To be able to learn, the model needs to be fed with quality results.

In some cases, AI will hardly work. For example, if key process characteristics are not measured or the material coming into the process is completely different every time; it becomes very hard to establish a model. If we, for example, use material from a quarry, the quality might strongly deviate depending where we mine the material from. This would require the model to receive information of the material characteristics.

Establishing and validating a model is not always easy and might take a lot of time with an unpredictable outcome.

5 DataLyzer solution

How does DataLyzer offer AI solutions to be integrated in the process control solution DataLyzer already offers with SPC and OEE?

DataLyzer is typically recording product characteristics (SPC) and downtime information (OEE).

To establish the machine learning model, process characteristics and tooling information need to be measured. This can often be done in the SPC system as well.

High frequency data measurement

If process characteristics need to be measured in a high frequency, SPC is less suited. In that case, Inmation can be used. Inmation is a DataLyzer partner which offers a connectivity layer which collects data from any source and stores the information in a Big data (Mongo) database.

This basically means that we can record data from any production situation to be fed into the AI model.

For this purpose, DataLyzer works together with Bright Cape, who have developed an AI module called the Smart Industry Assistant. (SIA).

SIA can be used to analyze a model and validate if the quality result can be predicted. But SIA can also be used to control the process continuously.

So, what will a specific implementation look like? Let's explore an aerospace example of a milling process:

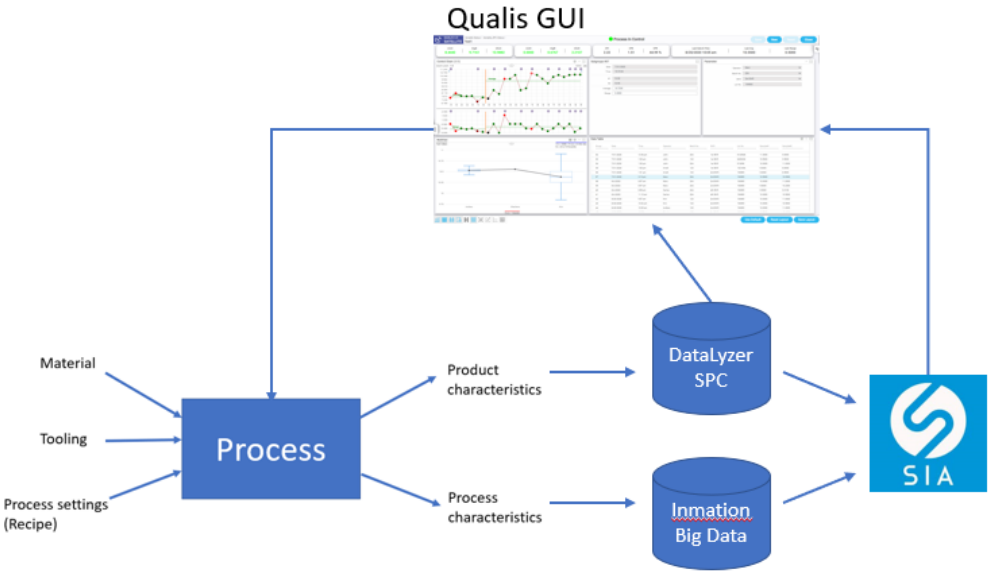
An aerospace example

In the first step, we establish the quality characteristics which should be monitored as the outcome of the process. These quality characteristics can, for example, be measured with a CMM. DataLyzer will import the CMM data automatically in the Qualis SPC module.

In the second step, we will establish all process and tooling characteristics which will affect the quality. These characteristics will be stored in the Big data database in the required frequency. We can for example read process data directly from the PLC.

Both product and process data can then be fed into the SIA system and the model for the process can be developed and trained.

If the model is validated, we can use the same method to monitor the production process in real time and inform the operator if the process tends to go out of control and indicate if a produced product is out of specification.



The Qualis 4.0 Satellite module can be used as an interface for the operator. The system will show the status of all characteristics monitored using SPC but can also show alarms from the SIA analysis.

Based upon both SPC results and SIA alarms, the operator can then correct the process and record changes.

Data will be continuously fed into the model resulting in improved predictability.

In this whitepaper, we have explained how DataLyzer is working with partners Inmation and Bright Cape to realize a state-of-the-art practical solution for process control where SPC, OEE, Big data and AI are integrated.

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