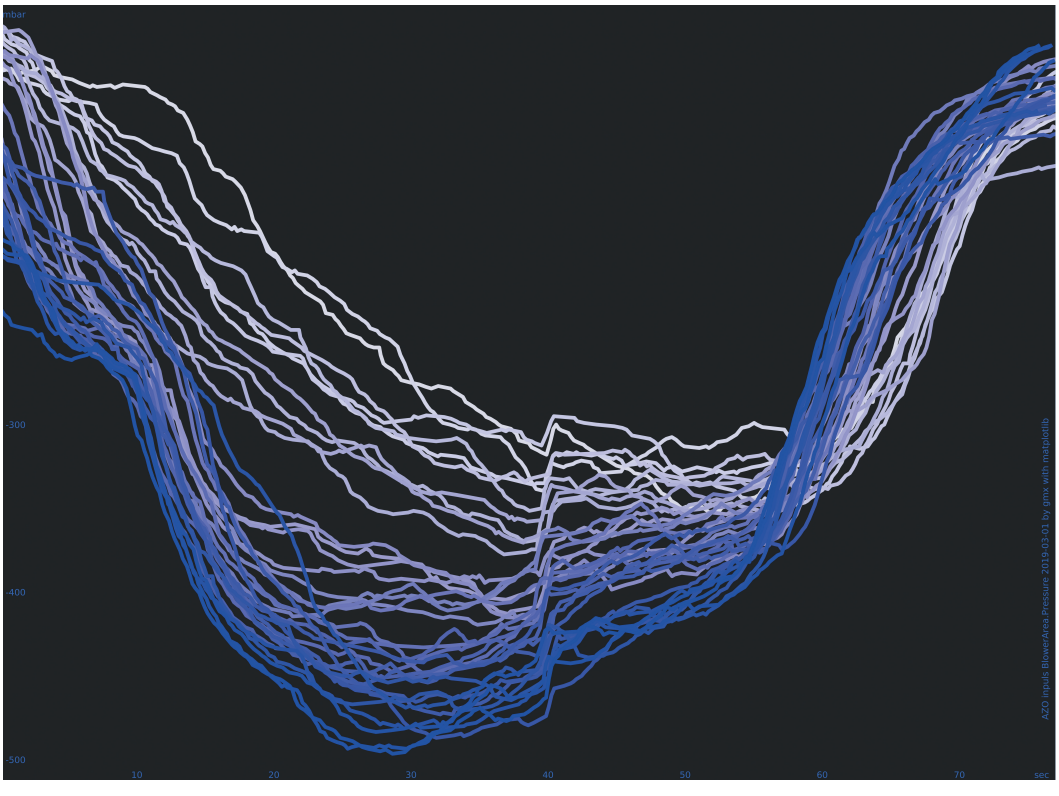
Prometheus Should Handle It

Smarter Material Conveying through Automated Trial-and-Error

Pneumatic conveying of a raw material from the silo to the processing line does not sound like a very spectacular task. But in everyday routine, problems often occur – for example if the supplier or raw material is changed, or simply if ambient conditions, such as the temperature or humidity change during the course of the day. The manufacturer AZO from Osterburken, Germany, is pinning its hopes on software that uses artificial intelligence to find the optimum operating point.



Pressure curve of the Prometheus system: during "reinforcement learning", the AI algorithm varies the conveying parameters and immediately checks the result © AZO

We want to get away from the parameter-based conveying that we use now, with fixed speeds and fixed changeover points," is the vision of Steffen Günter (**Fig. 1**), Head of the R&D Department at AZO, who is responsible for automation. The question of whether artificial intelligence (AI) methods can be used for bulk solids conveying was investigated by the company in early 2018, in a research project together with the VDMA and RWTH Aachen University, Germany. The research project was completed in 2019. Since then, AZO, as the successor, has been overseeing the Prometheus project on its own. "Our scientific partner recognized fairly quickly that it is not possible to use conventional processes, such as image recognition with robots."

Saving Data and Material

This is because machine vision programs are often exposed to many thousands of examples from image databases or simulated data sets to train their discrimination. In material conveying, however, the algorithm can be fed with only relatively few data, since tons of material are physically moved during the measurements – a huge task, which is also expensive, especially if the material cannot be easily reused. In the Prometheus demonstrator set up in Osterburken a different approach was taken: at AZO, the AI system learns to distinguish not categories but a behavior, i.e. to make corrections if the line is not performing op-

timally. In the process, it builds up a wealth of experience with good starting parameters (**Title figure**). It is enough for the learning algorithm to spend just a few minutes on recorded sensor data in order to obtain the first optimization results, which are then repeatedly improved throughout the learning cycle.

Unlike other learning methods, with this machine-learning process the system does not receive any information about what the raw material is, for example whether it is plastic pellets or titanium dioxide, what the bulk density is, or about the material's flow properties. From the sensor data, Prometheus only learns how the particular raw material behaves during conveying. Air velocity and pressure are the key parameters for characterizing the behavior.

"Reinforcement learning" is the technical term for this form of machine learning. The AI algorithm performs a trial by changing the conveying parameters slightly and, in the learning phase, checks whether this has improved the conveying. For this, the technical staff provides a "cost function," a calculation formula which incorporates the sensor data. The new value that is calculated after a change acts as a reward or punishment for the AI system, so that it can decide whether the change was advantageous.

"It is this function that actually performs the magic, and is the most complicated," says Günter. "If it isn't right, then the entire learning algorithm won't work, because the optimization will go astray." Such cost functions can also take different forms in order to implement different operating modes depending on the situation. Is it most important to achieve a high conveying rate or, for example, to keep the energy consumption low, or reduce the stress on the material and system?

Automatically Seeking the Optimum Operating Point

The new control system enables the plant to respond to pressure or velocity changes online during conveying, and to adapt the conveying so that it always remains at the optimum operating point. This is not witchcraft – a human could also find these operating points though this could be extremely time consuming. In principle, the AI automates the trial-and-error process that is necessary to locate an optimum. The test field still contains a lot of sensors, which actually generate a large amount of data, is how Günter describes the state of development. "But the goal is very clear – to find the most informative sensors so that the plant also remains affordable and simple for the end customers."

Fig. 1. Steffen Günter, R&D Department Head at AZO, expects the market-mature industrial product, intended to simplify routine material conveying, to be available for end customers in 2022 © AZO

The hope of reducing costs is still the reason for using AI. The commissioning times of the plants can be reduced, run-in processes shortened, and the customers can bring their products to market faster. When the system is running, its adaptability is another advantage. Since raw materials vary – not only when a supplier is changed. Even changes in ambient parameters, such as pressure or temperature, can severely affect the conveying properties of the material – an extreme case is, for example the outdoor silo, which, during winter, is cold in the morning but may be exposed to the sun at midday. An AI system can automatically compensate such fluctuations.

This sounds good, but, in the Prometheus demonstrator, it is still running on a high-performance PC instead of an industrial controller. "Currently, with Siemens, we are testing a faster controller that is modified for such AI computations," says Günter, about the state of development. "Different operating modes will then be available, and we will be able to switch between them easily." An industrial product for end customers will be available by 2022 at the earliest. This is because one problem currently is that the AI system owes its learning progress to a neural network, the results of which are not inherently transparent. "However, our support staff and customers must understand why a plant acts as it does," says Günter, and refers to the current research work in this field. Work is also currently progressing on the improving the system's response if the basic circumstances change, for example because a sensor is replaced. "We need a very robust algorithm that can handle such changes."

But it will take some time until a Prometheus-based product, which easily and transparently seeks out the particular ideal parameters in material conveying, is available for everyday industrial use. But there are already guide rails in place to ensure that the AI cannot cause any damage: to comply with machine directives and safety regulations, a second system created outside the AI constantly checks whether the values suggested by Prometheus are permissible. ■

Dr. Karlhorst Klotz, Editor

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