Cloud-based assistance system for AI-cognition supported in-process control in steel production

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Summary

The publicly funded KIKA-IPK project (German abbreviation for “AI cognition supported assistance system for in-process control in manufacturing”, see acknowledgements) aims to provide a cloud-based platform as a standard for industrial AI applications. This platform will interconnect industry partners and AI 3rd-party service providers in such a way that specific problems in production can be analyzed via this platform in a standardized way. The resulting AI application either will be available to the industrial customer remotely or deployed to the on premise system for offline use.
The particular goal of the research project is the development of an AI cognition supported assistance system for in-process control, which enables a more resource efficient process and material configuration through self-learning correlations of signal characteristics with process properties. The machine operator's empirical knowledge of the connection between tangible quality features on the one hand and process characteristics on the other is modelled by machine learning methods. This is demonstrated by the example of additive manufacturing of steel parts.

Key Words

In-process Control, B2B Cloud Service, Artificial Intelligence, Process Data Streaming, Wire Arc Additive Manufacturing (WAAM), 3DMP®

Introduction

The advancement of AI technologies has spurred an increase in demand for AI services in various industries. Organizations looking to leverage these technologies require large amounts of computing resources and specialized expertise. There are already various AI cloud services in the global market, providing IT resources, but industrial expertise is not the core business of these players.
This was the starting point for the KIKA-IPK consortium of seven partners to develop an industrial solution. In addition to PSI Metals, the consortium consists of Technical University Berlin, two AI service providers and three industry partners (one WAAM machine manufacturer and two partners from the pharmaceutical sector) [1].

The described cloud platform offers a solution for remote AI processing by providing the necessary infrastructure, computing power, and storage capacity. However, the even more important goal is, bringing together the industry partner with their peculiar problem and the right AI expertise to resolve it.

Exemplary description of the workflow

But what is the advantage of such a cloud platform e.g. for steel production?
A melt shop wants to improve its liquid metal temperature control by optimizing the process parameters in steelmaking. All attempts with conventional methods have failed because the interaction of the different influencing factors is not understood due to its complexity and variance. An ideal application for machine learning and a solution generated by it, e.g. as described in [2] (see figure 1). The steel mill usually cannot solve the problem itself as it lacks own AI competences.

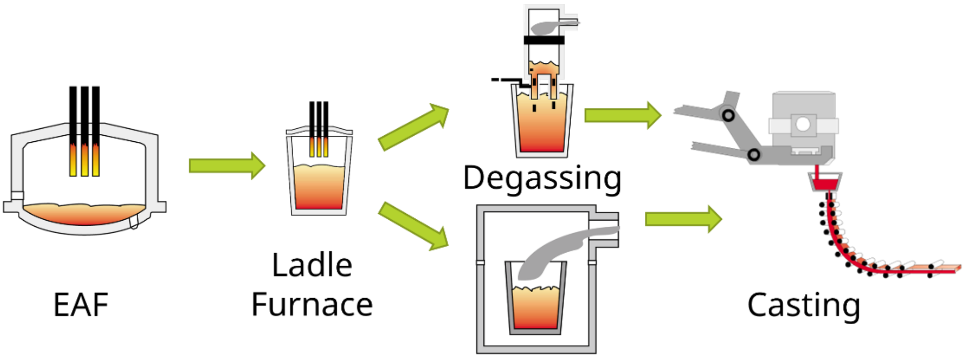

Figure 1: Temperature guidance according to [2]

- First, an AI service provider must be found which is capable of understanding the underlying business process. The steel plant enters the AI Cloud Platform and searches there for a suitable AI service provider. It has the possibility to roughly describe the task and to present this as an offer to certified AI service providers. If there are several service providers who are interested in this order, the right one can be found on the basis of references (or the offered price). It is also possible to ask several service providers in parallel for a solution especially if they use different approaches like CNN or RNN [3] as neural networks.
- The service provider has to get an overview of the exact framework conditions because he must know which data is available and which may still need to be collected. Through the platform, however, a large part of the joint work can take place there.
- If the steel plant has a suitable MES/QMS (Manufacturing Execution System/Quality Management System) in which the required data is already available, it is streamed directly to the AI cloud server via a secured channel [4]. Without such an infrastructure, there is the alternative of bundling the data streams themselves and sending them to the cloud server via the Kafka protocol.

- Once the data is on the server, further possibilities exist: on the one hand, the data is forwarded directly to the AI service provider for further processing using its specialized hardware and software. On the other hand, the platform itself also offers tools to prepare the data for training of the AI. These include e.g. labelling tools or data augmentation. The training itself will also be possible on the server to enables smaller providers, e.g. from the university sector, to contribute their expertise.
- There are also several possibilities for the application of the trained neural network. Usually, the solution should then be installed at the customer's site. If an appropriately prepared MES is available, the new system can also be stored directly in the MES via AI industrial cloud platform or even send the necessary information to the MES directly from the cloud server. If a corresponding agreement between the parties exists, the production data will continue to be streamed to the server and the network will continue to be re-trained with the respective current data, thus allowing a continuous adaptation of the system to changed boundary conditions.
- If several AI service providers are competitively commissioned with the task, the platform also offers the possibility of benchmark evaluation in order to compare the efficiency of the different approaches.

Cloud Server Architecture

The cloud server platform is built on a PSImetals Service Platform architecture, where data is exchanged between partners via Kafka streams, which are SSL encrypted. The user access to the server is realized with a web interface, where all necessary actions can be performed. Below the web UI, a dockerized micro service architecture is found, managed by Kubernetes. Internal communication between the services is performed via a bus structure, based on the PSIbus.

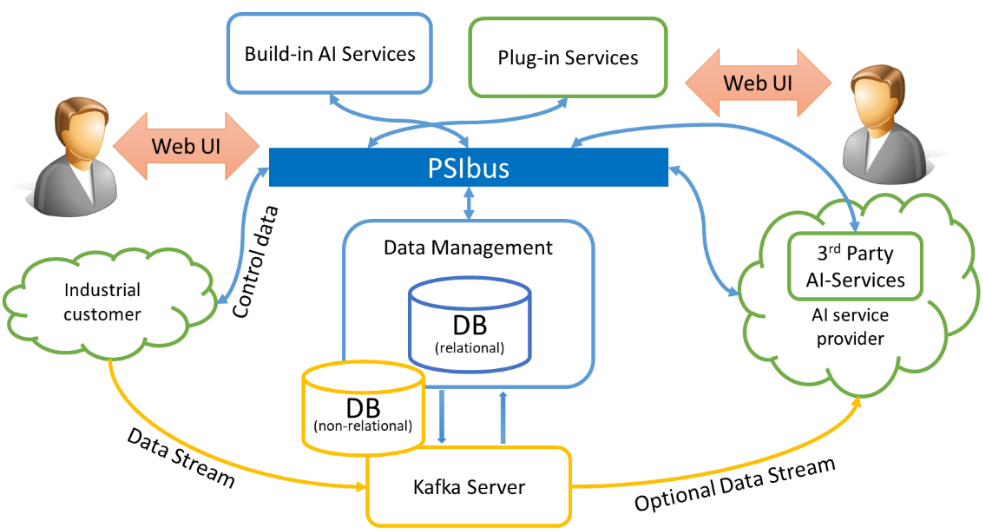

Figure 2: Architecture of KIKA-IPK Cloud Service

Since larger amounts of data have to be processed and performance plays an important role in the execution of the AI service, a hybrid database approach is used which only stores minimal data in a relational database and in which the majority of the data is stored non-relationally.
The cloud server platform offers a range of AI services related to machine learning, like pattern recognition on videos and recorded data streams, data augmentation, or labeling. The platform has a flexible design that allows customers and providers to choose the services they require, and also to plug-in own services via a well-defined API either on server site or via VPN protected TCP/IP connection remotely on the providers own hardware.

KIKA-IPK Demonstrator as one project goal

The KIKA-IPK project is at mid-term and aims to produce two operable demonstrators, one of them 3D metal printing of large volume components.
The project partner GEFERTEC [01], a machine manufacturer for metal additive manufacturing, uses Directed Energy Deposition (DED) process, specifically Wire Arc Additive Manufacturing (WAAM) to 3D print large metal components. It develops the process such that printed component's expected quality can be predicted during the build-up and, if necessary, intervenes in a regulating manner to readjust and stabilizes the process. Else, the unstable process leads to a higher number and/or severity of defects, which endangers the component qualification. Another project partner, the AI service provider Gestalt Robotics [02], analyses the problem together with Gefertec, taking into account the findings presented in [5] and [6].
For this purpose, Gefertec collects all accruing data as a stream on its own Kafka server. From there, the data is streamed to the cloud server in bundled form and with the exact time stamp. So far, the cloud server only serves as an intermediary station and intermediate storage for the data; the data processing is carried out directly by the AI specialist.

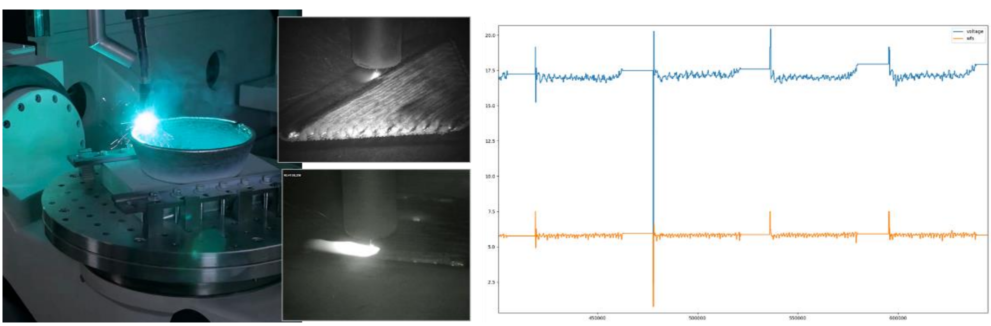

Figure 3: Additive manufacturing process, camera systems with high resp. low light exposure and recorded process parameters of demonstrator 1 within KIKA-IPK project [source: Gefertec]

It is already known that the number of spatters and the length of the weld pool have an influence on the final part quality, both of which can be seen on a continuously recorded video. In a first step, a neural network is trained to recognize the weld pool and the number and direction of the spatters with the help of the video. This result is

added as a further data stream to the other process data (such as welding voltage or feed rate).
Furthermore, after each layer (production step), this layer is optically analyzed. Another image recognition identifies potential and actual defects in the layer. This information is then used for automatic labelling of the process parameter ensemble in order to train the final network.
During the welding process, all process data and the video of the welding process continue to be recorded and sent as a data stream directly to the server. There, the video is first analyzed by the AI in real time and another data stream is generated with the parameters derived from the video.

Figure 4: Example of real-time spatter (green) and weld pool (yellow) recognition using faster RCNN [source: Gestalt Robotics]

The analysis of this new data stream, in combination with the other process parameters, then allows control of the product quality during the manufacturing process. For this purpose, the result of the data analyzed online is sent back to the user as a stream with an index of the expected product quality and recommendations for action (e.g. changed feed rate, etc.). There, these recommendations can be automatically transferred to the welding head, which can then readjust during the welding process. At the same time, the user has a detailed report on the quality of the component at the end without the need for time-consuming analysis procedures.

Conclusions and Outlook

The cloud server platform's target are industrial customers in general and metals producers with an appropriate MES/QMS in particular, who need to solve technical problems using AI and as well the corresponding AI service providers. The platform's value proposition is that it provides the necessary infrastructure for the remote delivery of the required service. At the same time, the platform interconnects industry partners and AI 3rd-party service providers in a transparent and standardized way. Producers can advertise their problem on the portal. Certified AI service providers under a general NDA view the problem statement and may request additional information before submitting a proposal. The industrial partner can then accept one or more proposals. In cases where multiple service providers work on a problem, benchmarking is done for the customer to compare the quality and performance of the services provided.

The quality of the AI services offered is directly related to the quality of the AI service providers. Therefore, in addition to capturing direct customer satisfaction, an objective score is developed, composed of processing or response time, solution efficiency, and result quality.
Since it is a B2B platform, it will not be possible for private individuals to register as users. AI service providers undergo special controls (such as references) to register.
In perspective, this cloud service will lead to AI applications, both as a one-time problem solution and as a steady service, being made available quickly and easily, and also to smaller specialized AI providers gaining faster access to industry customers.

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