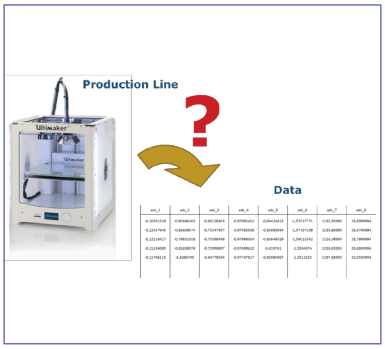
The 3DPrinterLivingLab@Virtual Vehicle

Exploring (big-)data-driven manufacturing innovations in a lightweight environment

BIG RESEARCH DATA TRANSFER



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Main actors

- Virtual Vehicle Research Center (operator of the 3DPrinterLivingLab)
- UNIs and/or RTOs (interested in manufacturing data analytics who want to replicate the 3DPrinterLivingLab concept)
- Industry partners (aiming to explore machine learning on non-sensitive production data)
- Researchers (who seek access to non-sensitive manufacturing data)

Thanks to paradigms such as Industry 4.0, Smart Factories, or Industrial Internet, manufacturing has become a prominent application domain for Big Data technologies. However the availability of high volumes of manufacturing data from real production lines as open data is a major challenge. The 3DPrinterLivingLab has been designed as a lightweight approach at Virtual Vehicle to support researchers in developing and demonstration data-driven manufacturing innovations, which can be summarized under the machine-learning umbrella. To achieve this, a 3D printer as a lightweight production machine has been equipped with multiple sensors and thereby transformed into a “big data generator”. Being heavily used by other researchers at Virtual Vehicle the 3DPrinterLivingLab has already generated high volumes of manufacturing data, which has been used in a multitude of collaborative data science experiments together with another research organization, and even shared via zenodo.org in an open science like way.

Process Main Stages

The 3DPrinterLivingLab and the respective data-to-knowledge processes can be easily replicated by other research organizations to engage a wider number of researchers in applying and demonstrating big data technologies to solve industrial manufacturing challenges.

STAGE 1 – SET-UP A 3DPRINTERLIVINGLAB

First of all a low cost manufacturing process technology has to be identified, which is capable of generating a significant amount of process data. Second the selected manufacturing process technology has to be analyzed, and as a consequence the domain specific challenges have to be sufficiently understood by data scientists. Third computational access to input and output data of the manufacturing process has to be established via appropriate interfaces. Fourth the feasibility of integrating various sensors to monitor important events within the production process has to be investigated. Fifth, an appropriate state of the art information system for aggregating manufacturing process data and eventually corresponding quality data has to be set up to facilitate data-driven scientific discovery.

STAGE 2 – USE CASE DEVELOPMENT & DATA GENERATION

The 3DPrinterLivingLab has already been used to implement and demonstrate a broad spectrum of real industrial use cases ranging from the application of smart glasses, and industrial learning, to machine learning on manufacturing big data to deepen process understanding. Currently the amount of manufacturing process data generated in the 3DPrinterLivingLab is about 4GB / 12 hours of operation. This allows many different types of use cases to be investigated and experienced in the 3DPrinterLivingLab.

STAGE 3 – DATA ANALYTICS & KNOWLEDGE GAIN

Exploring correlations and causalities between process data and quality data is a current hot topic of data-driven innovations in factories. Manufacturing process experts expect to increase their knowledge on how machine and process parameters influence the quality of a produced part. They expect to receive better decision support and to detect possible problems already at an early stage. One already implemented use case involves detecting events which can have a negative influence on the production quality

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by assessing the generated process data. This includes e.g. the automatic detection of vibrations caused by people walking by printer or by a ringing smartphone placed near the printer by analyzing the accelerometer sensory data collected during a print job.

STAGE 4 – DATA SHARING WITH OTHER RESEARCHERS

To outline the full potential of the 3DPrinterLivingLab – the provision of manufacturing data as open research data for the scientific community – the corresponding data set of accelerometer sensory data collected during this experiment has already been published on zenodo.org (Zernig et al 2016: doi.org/10.5281/zenodo.54574) following the principles of open science promoted by the European Commission. This allows other researchers interested into manufacturing data analytics to easily replicate conducted experiments, evaluate their findings, and increase their knowledge. Moreover it will enable sustainable collaborations through Big Data and Science 2.0.

Touchpoints & Bottlenecks

TOUCHPOINT 1 – THE PHYSICAL 3DPRINTERLIVINGLAB

The physical 3DPrinterLivingLab it is a physical space, where researchers of different domains can meet with others (including representatives from industry) to discuss data-driven challenges as well as to explore the impact of applied data analytics and visualization technologies to the manufacturing domain.

TOUCHPOINT 2 – VIRTUAL ENVIRONMENT

The 3DPrinterLivingLab has also a virtual environment, which is the data repository containing all the captured sensor, process, and quality data. The captured process data is currently aggregated into a PostreSQL database running on a virtual server. Researchers can access the data though interfaces with their favorite analytic tools including e.g. MathLab or R to explore it and to develop prototypical implementations.

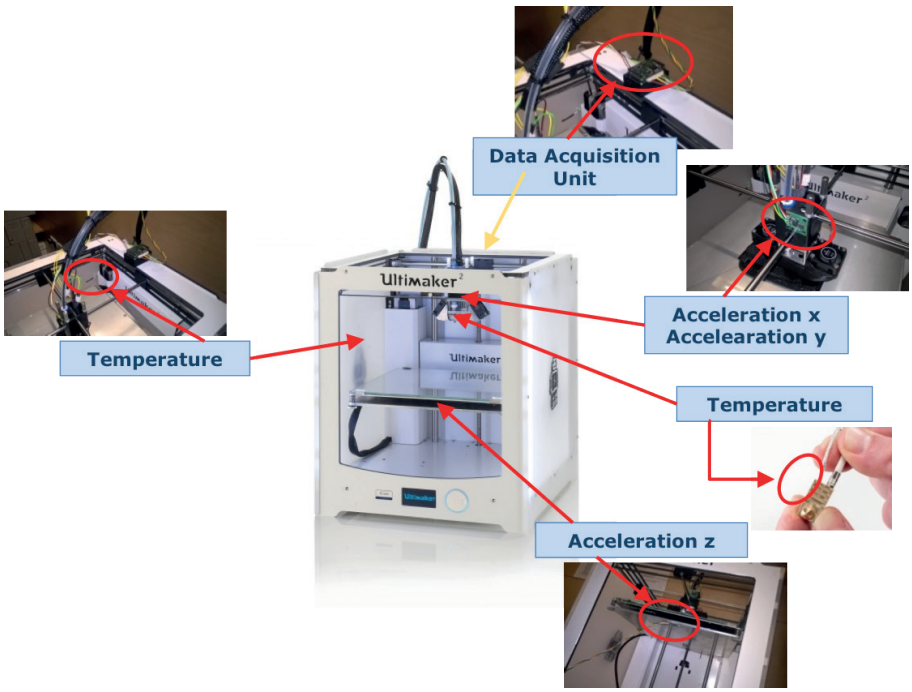
TOUCHPOINT 3 – DATA-SHARING PLATFORMS

The third touchpoint are data-sharing platforms, which are currently promoted on the European Level, including e.g. zenodo.org to name a renowned one, which uses technology developed by CERN for Big Data Management. Sharing generated research data on such platforms will allow other researchers to replicate experiments, which will enable them to learn quickly. Datasets shared on zenodo.org can be cited like a scientific paper. Thereby sharing data can increase the reputation of the sharer.

Success Factors / Barriers

SUCCESS FACTORS

- As a lightweight environment the 3DPrinterLivingLab is a relatively cost-effective way to generate huge amounts of manufacturing data. Both the costs of 3D printers and of wireless sensors are rapidly decreasing while their capabilities are increasing.
- The 3DPrinterLivingLab is a best practice, which can be taken up by other research organizations to allow their employees and/or students taking on data-driven manufacturing challenges in a controlled environment, too.
- Publishing captured manufacturing data as open research data allows other researchers who do not own such a laboratory to benefit from



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open manufacturing research data so that they can tackle practical manufacturing challenges by applying data analytics and machine learning.
- If more research organizations follow this practice, the availability of manufacturing related data will be increased. This will overcome the current lack of open manufacturing process data, allowing more researchers to engage in challenges related to smart factories.
- Since decision makers within factories can be hardly motivated to share their process data from a real production line to a wider scientific community in an open science-like way, this can be a feasible approach. It shows how an application of open science principles can lead to more data-driven (open) innovation.

BARRIERS

- The 3DPrinterLivingLab is currently heavily used for producing prototypical parts in other research projects. Achieving such an adoption is very important to generate enough process data from the 3Dprinter which can be used for data analytics in the latter. However, other researchers have to be motivated to include the feasibilities of a 3D printer for rapid prototyping into their work practices.
- Applying machine learning and data analytics has a high entry threshold. It is important to create a community-of-practice like collaboration between more experienced and less experienced data analytics researchers to quickly realize prototypical data-driven innovations.

Conclusion

Under the umbrella term 'machine learning', data analytics experiences a new renaissance in manufacturing. Exploring correlations and causalities between process data and quality data is a current topic of data-driven innovations in factories.

Two developments increase the pervasion of such digital technologies in manufacturing environments: The availability of more computational resources allows using more complex machine learning models, and new algorithmic approaches for predictive data analysis have been investigated, which can be applied in a broad palette of smart factory use cases ranging from predictive maintenance to advanced process decision support.

The 3DPrinterLivingLab is a lightweight approach, which can enable manufacturing practitioners to experience the adoption of novel ICT-solutions in a living lab environment. They can gain a better understanding on the potentials and pitfalls of implementing data-driven innovations into their factories. The 3DprinterLivingLab is the archetype of a small and flexible manufacturing living lab, which can be set-up very quickly to allow people from all over the world to take on practical data-driven innovation challenges.

The 3D printer has been equipped with sensors including e.g. heat sensors to measure the temperature at the printer head and plate, acceleration sensors to keep track of the printer head's movement, and a camera to have an additional optical inspection of the process. The captured manufacturing process data is aggregated into a PostreSQL database, which makes the 3D printer an archetype for a lightweight smart factory asset to be used in science2science and science2industry collaboration.

DO

- Set-up a community of researchers from different disciplines (i.e. computer scientists for software tasks, electrical engineers for sensor related tasks, data scientists for data analytic tasks, …) and provide them a physical and virtual space to effectively collaborate with each other.
- Engage others in using the 3Dprinter for rapid prototyping, which boosts manufacturing process data generation - a precondition for data analysis and knowledge generation
- Engage with industrial partners to elicit requirements for manufacturing data analytics, which can be explored in the 3DPrinterLivingLab
- Motivate researchers to share generated process data along with knowledge gained from analyzing this data via European data portals so that others can replicate the findings

DON'T

- Don't just focus on the technology, only
- Don't forget about installing a community manager, who will engage others with the new capabilities
- Don't forget about sharing the generated data with others using open standards and platforms to enable success cross-organizational collaborations

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