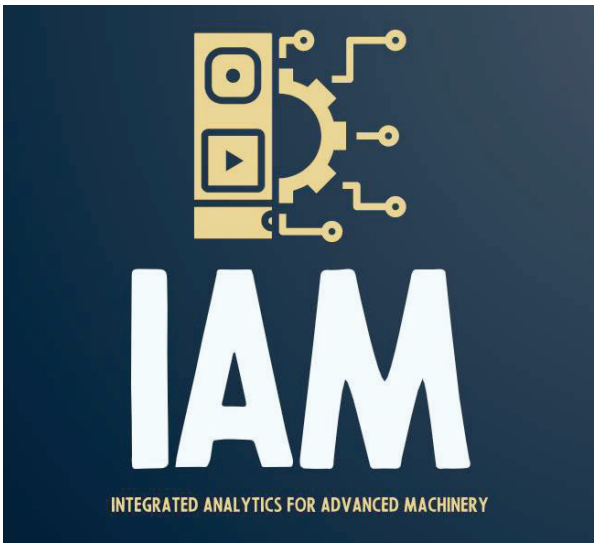
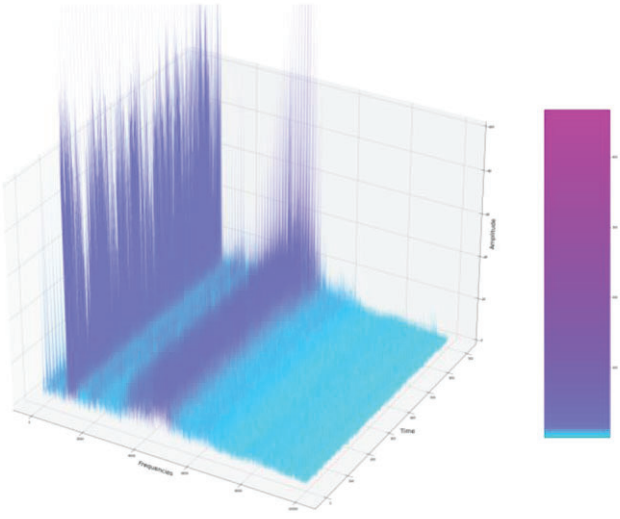
Integrated analytics for advanced machinery – IAM





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1 Sammanfattning

Manufacturing requirements on high-valued and high-accuracy products depend on the improved flexibility of production processes. Digitization and industrial analytics as well as their integration into manufacturing systems are key aspects of flexible production. It is imperative for enhancing the effectiveness and competitiveness of the industry, especially in western social market economies. The essence of the project was to enable an improved resource utilization through disturbance-free manufacturing resulting in sustainable production.

The IAM project aimed to:
1. Identify the operational behavior of advanced manufacturing machinery
2. Make use of the information to build a physics-based digital model of the machinery
3. Link the operational behavior through data analytics to maintenance activities and machinery performance

The final goal was an integrated analytics approach to analyze, predict and optimize manufacturing machinery. The project outcomes will be demonstrated through case studies in industrial environments. Research dissemination activities were performed to not only raise the knowledge and motivation for the novel concept in industrial applications, but also to enable a continued implementation of the concept; e.g. in terms of the integration of software tool to utilize the project results.

The consortium put together experienced research and industrial partners with rich expertise in all key areas of information technology and manufacturing processes from complementary areas: Sensor and data acquisition systems (SPM), Manufacturing systems (AB Volvo, GKN and Volvo Cars). The research partners, KTH (project coordinator) and Chalmers are two of the top Swedish research centers in manufacturing with the responsibility to educate next generation engineers to integrate analytics in the industrial environment.

2 Executive summary in English

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3 Bakgrund

The strategic goal for industry to achieve a flexible production is to create processes, which can produce customized products that meet customer requirements within cost and other managerial constraints. The selected manufacturing processes will have a long-term effect on the efficiency and flexibility of the production as well as on the cost and quality of the products. The selection of the right processes, operations and machines depends on the ability to control and optimize their capabilities; which in turn depends on the digitalization.

Digitalization is transforming manufacturing industry towards smart factories [1], which can accomplish shorter quality control loops and adapt faster to volatile demand. One extensive survey, conducted in Germany [3], identified, that proper solutions in industrial analytics are believed to increase revenues by +33.1%, customer satisfaction by +22.1% and product quality by +11%. It was also identified that the most important application of *Industrial Analytics* is the predictive and prescriptive maintenance of machines (79%) over the next 3 years.

In this transformation, measurement information-based analytics as well as fast and flexible measurement systems play significant roles. Well-composed analytics together with flexible and fast measurement systems can significantly increase the extraction of knowledge [2]. Which enhances the spread and integration of measuring and sensor systems into production.

Measurement information-based analytics must be composed of a deep insight into both the physical (low-level) and the organizational (high level) domain. The physical domain includes the insights into the production machinery and the applied measurement system. This is essential for the understanding of the acquired data. Both off-line [4] and on-line [5] measurement approaches exist to track the condition of machinery. Many limitations of existing off-line and on-line solutions were addressed by the innovative measurement solutions of KTH IIP (KTH Royal Institute of Technology, Department of Production Engineering) (for details see WP3).

Within the organizational domain, the purpose of the applied analytics framework must be clear and usable within the production organization. Data models and services-based methods are necessary to create value from the acquired information in production. Process planning and maintenance departments are potential shareholders of advanced analytics on machinery. In [6], time series analysis is used to predict future failure times and in [7], a framework is developed for connecting the monitoring of machine conditions to possible failure states. Today, there is no fully integrated information digitalization platform implemented in an industrial environment.

From the academia side, KTH represents the “physics-based” approach with the development and utilization of various production equipment test methods, which was demonstrated in the EU COROMA project (grant no. H2020-FoF-2016.723853). The focus of these previous works was to provide tools and methods for a better utilization of information on capability of

production machinery. In close collaboration with Chalmers University of Technology these tools and methods will be merged with modelling from the organizational domain (Big Data Analytics in Manufacturing).

4 Syfte, forskningsfrågor och metod

By developing and implementing a well-orchestrated synergy between sensors and measurement instrumentation, combined with the use of an efficient model-based analysis of information it is expected that the project will generate accurate predictions of the machining throughput (surfaces, tolerances etc), mean time between failures and potential error sources. These predictions will make it possible to introduce prescriptive maintenance with targeted actions that will limit or event prevent the error before it occurs. By the means of integrated analytics, manufacturing, from design to maintenance, will be transformed from experience-based to information/knowledge based.

5 Mål

It is well known in industry, that flexibility and productivity are specifically affected by frequent disturbances and product quality issues related to set-ups (change-overs) and introduction of new products. The main idea of the IAM project was to develop, conduct and demonstrate integrated analytics and visualization within the area of Swedish component manufacturing; including OEM suppliers of manufacturing machinery and sensor systems by creating a unified platform including an advanced information analyzing system for production.

By combining appropriate sensors and measuring equipment in an integrated ″intelligent″ model, it will be possible to achieve an overall identification of physical properties (capability) of machinery such as machining systems (machine tools and cutting process). Therefore, the essence of the project is to enable an improved resource utilization through disturbance-free manufacturing resulting in sustainable production. The final goal is an integrated analytics approach to analyze, predict and optimize manufacturing machinery.

6 Resultat och måluppfyllelse

In alignment with the project application IAM Project deliverables could be summarized into three main categories. 1) A framework that helps pilot users to identify the operational behavior and choose critical system features to monitor. The framework also provides suggestion for measuring instruments, appropriate sensors and sensor placements to reduce the uncertainty of collected data. 2) A methodology that links the operational behavior through data analytics to maintenance activities and machinery performance, e.g. the effect of linear axes degradation of machine tools to the manufactured components accuracy. 3) A model-based analysis software demonstrated through implementations and use cases by the partner companies for trend tracking of machine tools components, e.g. wear of component.

7 Spridning och publicering

7.1 Kunskaps- och resultatspridning

Hur har/planeras projektresultatet att användas och spridas?	Markera med X	Kommentar
Öka kunskapen inom området	X	Industrial analytics, advanced sensor utilization, machine learning, simulation and modelling
Föras vidare till andra avancerade tekniska utvecklingsprojekt	X	Hybrid modelling utilizing physics based modelling and machien learning
Föras vidare till produktutvecklingsprojekt		
Introduceras på marknaden		
Användas i utredningar/regelverk/ tillståndsärenden/ politiska beslut		

Finns kopplingar till andra interna/externa projekt som kan påskynda introduktion eller ge större genomslag?

7.2 Publikationer

E. Iunusova et al, Condition monitoring of rolling element bearings: benchmarking of data-driven methods, NEWTECH 2020 IOP Conf. Series: Materials Science and Engineering 968 (2020) 012002, 09-11 September, 2020

K. Szipka, Uncertainty Management for Automated Diagnostics of Production Machinery, 2020 (English) Doctoral thesis

E. Iunusova et al, Early fault diagnosis in rolling element bearings: comparative analysis of a Knowledge-based and a Data-driven approach", (submitted manuscript)

P. Lucchese, Uncertainty propagation for machine tool life cycle cost assessment in case of different maintenance strategies, Master thesis, 2021

M. Klang, Analysis of CNC Controller Data Based on the Mechanical Characteristics of Machine Tool Feed Drive Systems, Master thesis, 2021

8 Slutsatser och fortsatt forskning

The project consortium outlined further development possibilities among which the increased TRL level of the solution in order to perform volume deployment of the analysis is one key consideration. The project consortium plans to apply for a follow up grant application within a year after closing the project.

9 Deltagande parter och kontaktpersoner

GKN Aerospace Engine Systems (GKN)
AB Volvo
Powertrain Engineering AB (Volvo Cars in the beginning of the project)
SPM Instrument AB (SPM)
Chalmers University of Technology (Chalmers)
KTH Royal Institute of Technology (KTH)

[1] Brynjolfsson E, McAfee A 2014 The second machine age ISBN 978-0-393-23935-5 W.W. Norton & Company Inc.
[2] VDI/VDE-GMA 2011 Technologie-Roadmap für die Messtechnik in der industriellen Produktion, VDI Verein Deutscher Ingenieure e.V.
[3] Industrial Analytics 2016/2017, The current state of data analytics usage in industrial companies - A collaboration of: Digital Analytics Association Germany and IoT Analytics GmbH
[4] Schwenke H., et. al. (2008), Geometric error measurement and compensation of machines−An update. Annals of the CIRP 57(2): 660‑675.
[5] R. Teti, K. Jemielniak, G. O’ Donnell, D. Dornfeld, Advanced monitoring of machining operations, CIRP Annals, Volume 59, Issue 2, 2010, Pages 717-739, ISSN 0007-8506,
[6] Moura, M., Zio, E., Lins, Didier.I., Droguett.E. (2011). Failure and reliability prediction by support vector machines regression of time series data. Reliability Engineering and System Safety, vol. 96, pp-1527-1534
[7] Yam, R.C.M., Tse, P.W, Li, L., and Tu, P. (2001). Intelligent Predictive Decision Support System for Condition-Based Maintenance, International Journal of Advanced Manufacturing Technology, vol.17, pp. 383-391