Science and Technology Facilities Council

Scientific Computing

Machine Learning set to create quality improvements in manufacturing processes

Quality failures in fabricated metal products created using Computer Numerical Control (CNC) machining are being reduced, thanks to new AI Machine Learning software from experts at STFC Scientific Computing.

A critical element of the advanced, high-value manufacturing sector, CNC directs sophisticated machines to laser-cut, shape and finish high-quality, precision pieces efficiently.

The CNC sector globally is expected to grow to USD 115 billion by 2027[1]. However, quality issues can account for 25%-30% of a company's turnover when materials scrappage costs are combined with the costs of staff rework, delays in shipments, and other expenses.

The Challenge

The machining process, the machines themselves, and the friction with the materials being laser-cut, cause temperature fluctuations resulting in deviations in the precision of the cuts. The temperature of the machines must be finely calibrated to ensure the quality of the finish but, historically, it has been extremely difficult to predict and mitigate temperature-induced quality lapses.

CNC is typically used to create pieces for industries such as aerospace, automotive and nuclear, where the margin for error is minuscule. An estimated 75% of geometrical and dimensional discrepancies in finished products are due to temperature fluctuations.

STFC Scientific Computing's AI for Science team collaborated with Emerging Data Technologies (EDT) to develop machine learning software that enhances the calibration of CNC machine temperatures. The EDT project encompassed 15 CNC machines from various manufacturers, each of which behaves slightly differently in terms of temperature fluctuations.

> **"Significant sums of money are involved in subpar machining. An SME manufacturer in the precision manufacturing sector with a £10million turnover and a scrap rate of just 3% faces materials wastage of £300,000 per annum. Improvements of 50% in materials wastage would save them £150,000 a year."**
>
> **George Jones,** Founder of EDT

EDT

[1] transparencymarketresearch.com/computer-numerical-controls.html

Our Approach

EDT was awarded a UKRI-Innovate UK i2F (Industry Impact Fund) research grant to work with STFC Scientific Computing on the project, termed 'Machine Learning for predicting quality failures within advanced manufacturing'. EDT aims to deploy data science to build AI systems to overcome real-world problems.

> **"Without AI being used in CNC machining to measure and gauge temperature fluctuations, huge reliance is placed on experienced machine operators. However, due to the unpredictability of the machines themselves, variations in room temperatures, differences in metal composition and other factors, there are more errors compared to when AI software is used."**
> **Samuel Pinilla Sanchez**, Senior Data Scientist, STFC Scientific Computing

The AI for Science team explored a variety of Machine Learning models to tackle the challenge, including Long Short-Term Memory (LSTM), Gaussian Processes, and Transformers.

A number of work packages tested various combinations, followed by the writing and scheduling of Python scripts and running models, which ultimately led to statistical testing for LSTM and Transformer models. The AI for Science solution, which provides the most accurate predictions, uses a sparse transformer in conjunction with an LSTM. In addition to improving the software program itself, enhancements were also made to the datasets used to train the Machine Learning program.

Whilst EDT used an existing AI software program to predict temperature variations, it was based only on a window of 9 points in the past. This covered approximately 20 minutes of historical data, captured ahead of the machine that was next used. EDT's previous solution also only used data from single machines to train its software. The new solution instead groups the data from EDT's 15 CNC machines into three groups by brand and trains the Machine Learning program on the larger dataset.

STFC Scientific Computing's AI for Science software is adaptable to the data period needed by the CNC operator. It can use either 10 days of historical data or the last 12 hours of data, combining information from multiple machines of the same brand.

Benefits

The much larger datasets used in the AI for Science Machine Learning program brings significant improvements of around 50% to the temperature predictions.

Analysis of the absolute prediction errors show that they are significantly smaller with the new software, at just -2 to +2, whereas previously they were at -4 to +4 (around a 40% improvement in the prediction of the temperature).

The AI for Science software ingests data from the machine in real-time into the neural network whilst the machine is in use, to calculate temperature predictions in real-time.

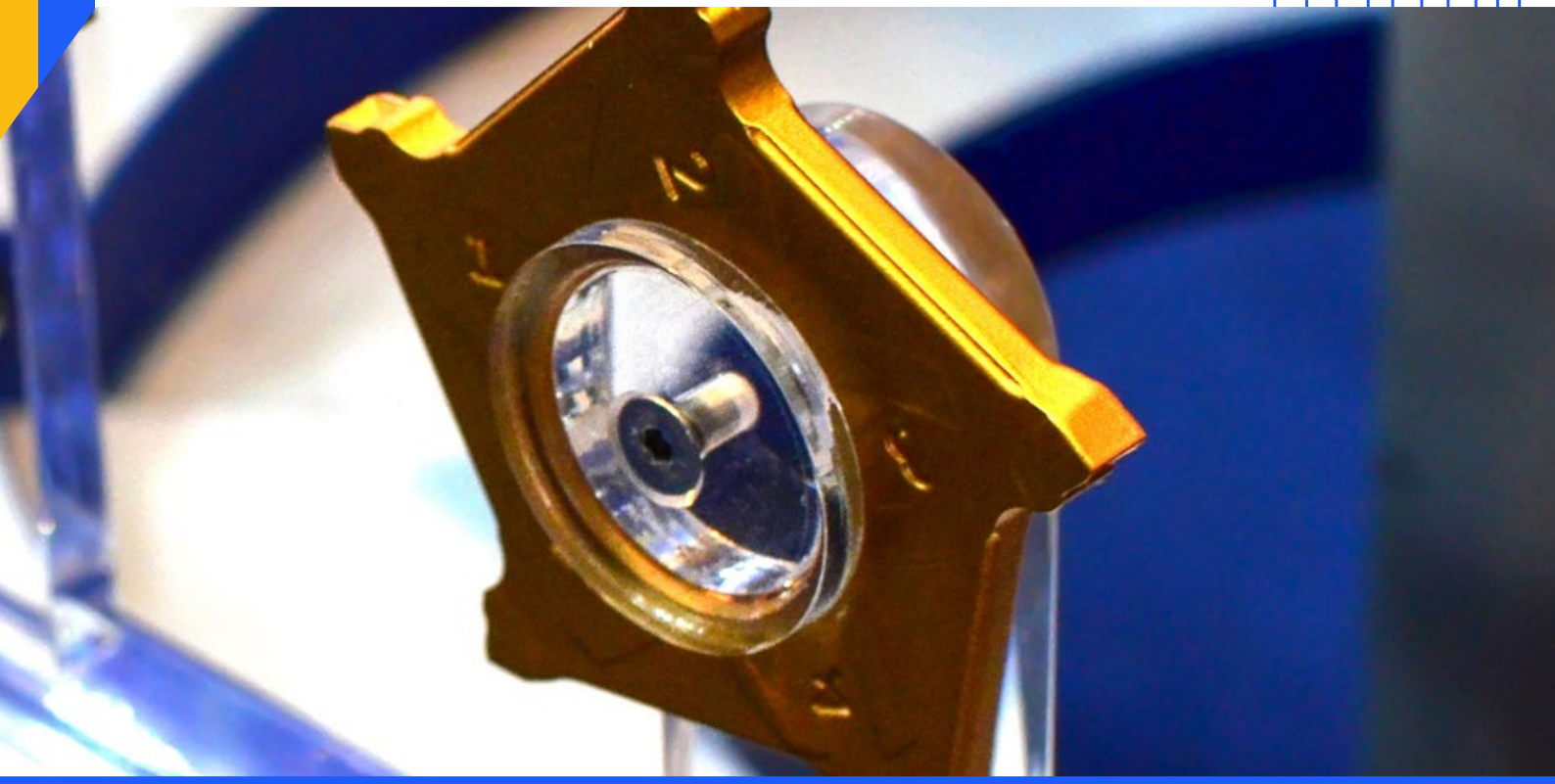
The software works with any machine brand, allowing it to be used across all 15 of EDT's current machines, even though they are from different manufacturers.

The Future

As part of the i2F grant, the Machine Learning methodology developed for EDT is exclusive to them for 5 years. Having this important intellectual property secured gives them a major competitive advantage during this period.

The STFC Scientific Computing team

Jia Bia and Samuel Pinilla Sanchez, with collaborators Marion Samler and Siu-lun Yeung



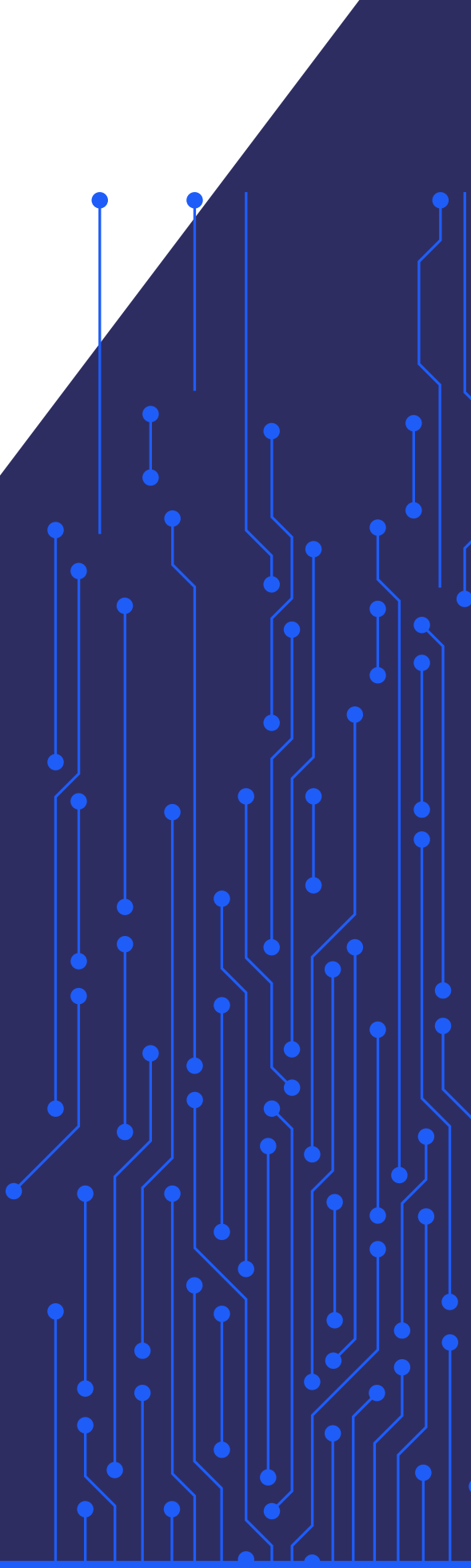
Science and Technology Facilities Council

Scientific Computing

Further Reading:

Application of Machine Learning in the Precise and Cost-Effective Self-Compensation of the Thermal Errors of CNC Machine Tools – A Review

tinyurl.com/2s3cb25d



More information:

Dr Jeyan Thiyagalingam: t.jeyan@stfc.ac.uk