CPS: Small: Mitigating Uncertainties in Computer Numerical Control (CNC) as a Cloud Service using Data-Driven Transfer Learning

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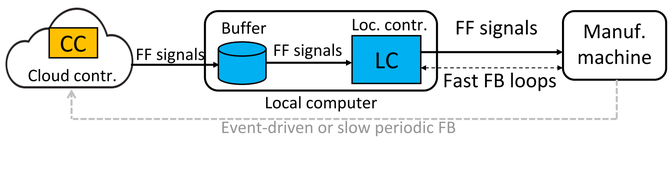
- CNC is a **critical feature** in manufacturing machines; it automatically controls the machines based on a set of programmed instructions
- Traditionally, CNC is run on a **local computer** that is physically tethered to the controlled machine
- We envision a future where manufacturing machines are controlled remotely over the internet via **cloud-based CNC (or C-CNC)**

Strategy for C-CNC

- Run *advanced* feedforward (FF) control algorithms in the cloud
- Pre-calculate FF control commands and buffer them to reduce delays
- Retain fast feedback (FB) loops in local computer
- Provide slow feedback from machine to cloud to correct FF controller



Some Benefits of C-CNC

- Improve performance (e.g., speed and accuracy) of CNC at low cost using advanced algorithms
- Enable machine-to-machine learning and data sharing

Some Challenges of C-CNC

- Poor control due to unpredictable internet latency
- Inaccurate control in the presence of uncertainty, due to heavy reliance on FF control

Technical Solution

- Switch from CC to backup LC whenever uncertainty is high (when there is high probability for inaccurate or poor control)
- Learn from condition monitoring signal (slow FB) and past failure data to predict when to switch from CC to LC to avoid poor/inaccurate control
- Use slow FB to calibrate/update CC to reduce uncertainty

Intellectual Merit

Address shortcomings of existing transfer learning methods in:

- Predicting failure events from a combination of condition monitoring and past failure data
- Calibrating physics-based models with functional parameters from condition monitoring data

Broader Impact on U.S. Industry

- U.S. is poised to gain huge advantages from a transition to C-CNC because U.S. is by far the market leader in cloud-based services
- Translation of C-CNC to industry will be facilitated through collaboration with a U.S.-based company

Broader Impact on Education and Outreach

- New educational curriculum at the University of Michigan to increase the U.S. talent pool in cybermanufacturing and data analytics
- Outreach to middle schoolers in Detroit using demonstration of transfer learning on a CPS: a 3D printer controlled by a remote brain (C-CNC)

Opportunity to leverage U.S. superior leadership in cloud services ($200 billion industry) to regain U.S. leadership in national-security-critical CNC and machine tool production industry