**Proceedings of the Canadian Society for Mechanical Engineering International Congress**
**32nd Annual Conference of the Computational Fluid Dynamics Society of Canada**
**Canadian Society of Rheology Symposium**
**CSME-CFDSC-CSR 2025**
**May 25–28, 2025, Montréal, Québec, Canada**

# Sensor Integration to create a digital twin framework of a pre-existing robot

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ABSTRACT *(USE STYLE: HEADING 1)*

The rapid development of digital twins presents new opportunities and challenges in mechatronics, robotics and sensing. The digital twin concept can be traced back to the early 2000s, specifically to Michael Grieves' work in product lifecycle management (PLM) and manufacturing at the University of Michigan. In 2002, Grieves introduced the foundational elements of the digital twin, conceptualizing a virtual object mirroring a physical product with a bidirectional communication channel. Following this trajectory of innovation in digital twin technology, this research explores the behaviours of the preexisting unmodified autonomous ground robot, exemplified by a robotic snow blower being developed to support the maintenance of the iconic Rideau Canal Skateway in Ottawa, Canada partnership with the National Capital Commission and Carleton University, to enhance its performance and adaptability of its system by developing and implementing a digital twin, integrating sensor data within a mechatronic framework for monitoring the mobile robot under harsh winter operating conditions.

A key aspect of this research is the implementation of sensors to link the physical robot and its digital twin to monitor the robot's behaviour. Various sensors, including inertial measurement units, rotational speed encoders, voltage sensors, current sensors, and reflective infrared optical sensors, can be integrated into the pre-existing, unmodified robotic system. These sensors capture real-time data on the robot's state, including position, velocity, acceleration, and battery energy consumption. This data is then transmitted to build the digital twin, enabling continuous synchronization and accurate representation of the physical robot's behaviour and state of the system. The importance of sensor integration in digital twin development for robotics opens opportunities to predict failures and provides predictive maintenance opportunities for the system.

Integrating sensor data acquired through cloud database programs like Arduino Cloud and accurate system modelling within environments such as MATLAB Simscape was used to help understand and optimize robot behaviour. This integration facilitates real-time data acquisition and analysis, enabling future observations and enhancements to the digital twin's reliability. The combined capabilities of real-time sensor integration, accurate system modelling, and simulation offer a robust approach to analyzing and predicting robot behaviour.

In conclusion, this research demonstrates one step toward implementing the digital twin to facilitate risk-free virtual testing and validation of control algorithms, safety functions, and operational configurations within a simulated environment. Studying the sensor's behaviours can control the long-run cost of system maintenance and allow for real-time status checks and remote operation.