UNIVERISTY OF CALGARY, SCHULICH SCHOOL OF ENGINEERING

INTERTIAL NAVIGATION SYSTEM FOR SEMI-AUTONOMOUS TRAILERS

Swikar Bashyal, Mend-Amgalan Bayartsengel, Gabriela Souza, Saurav Uprety, Thea Vukovic

THE PROBLEM

In order to achieve any degree of autonomy in vehicular applications, it is essential to have precise and continuous positioning capabilities. While the *Inertial Navigation System* (INS) can provide accurate and reliable estimates of a vehicle's position, velocity, and attitude; high-quality INS systems are prohibitively expensive. Some cost as much as a small car, proving to be a high barrier to entry for autonomous systems.

ENGINEERED DESIGN

CadiAt are developing autonomous trailers that are led on the road by a human-driven pilot vehicle. Since the trailers are not physically connected, a virtual "tow" mechanism is necessary so that the trailers can safely follow the lead. This is where our INS comes in.

PHYSICAL COMPONENTS

The INS is composed of a low-cost GNSS and IMU.

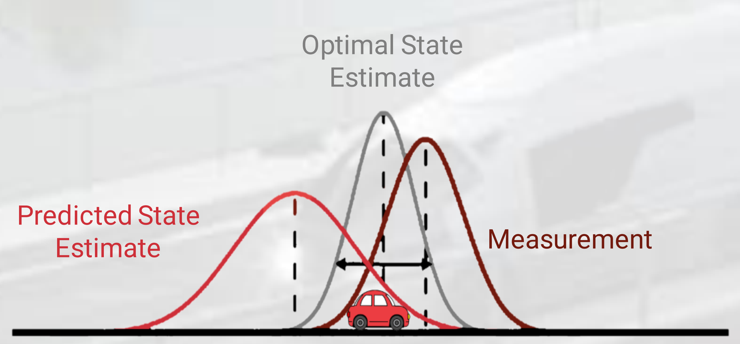
GNSS
Collects position data at 1Hz.

IMU
Collects motion data at 100Hz.

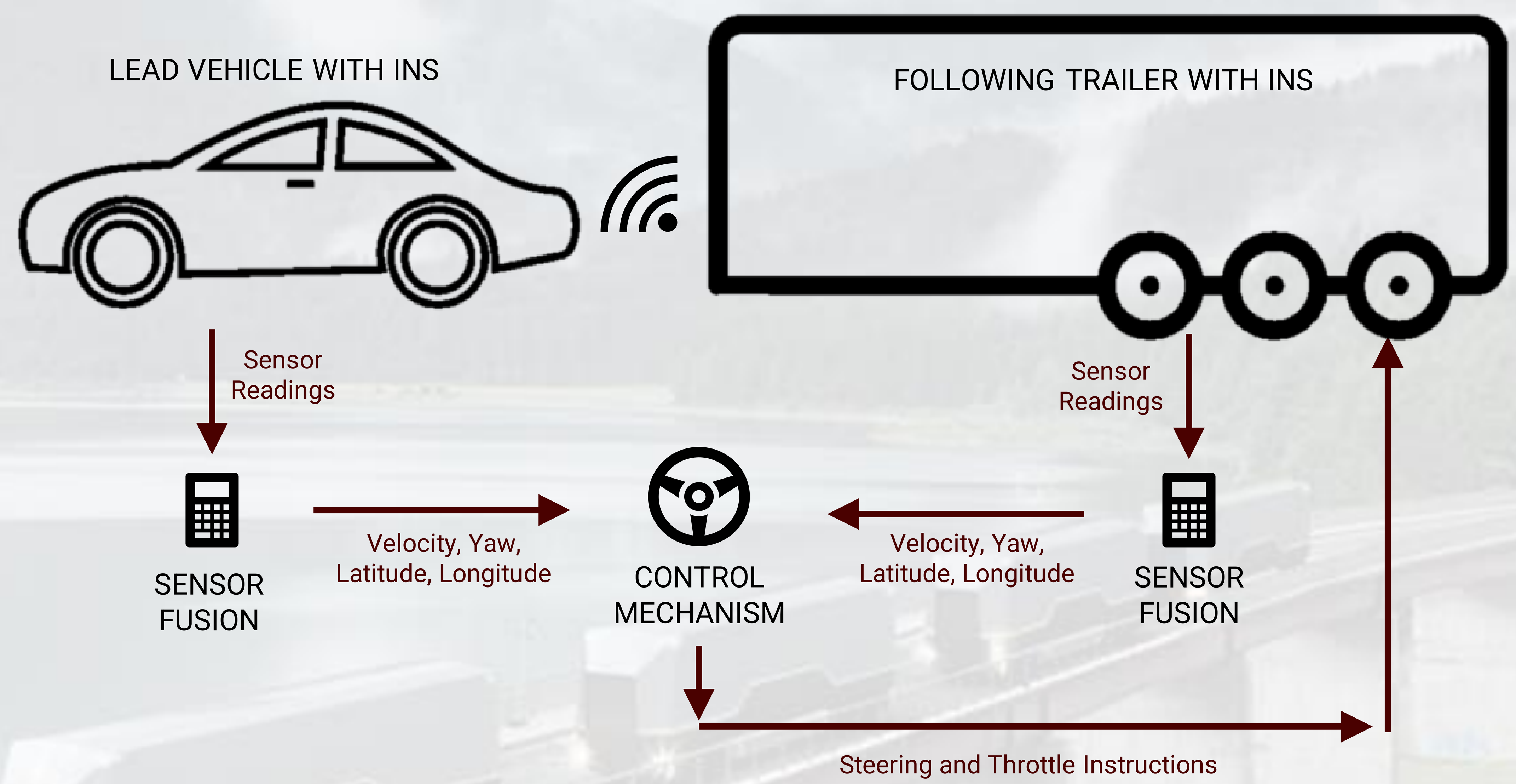
When combined, the INS collects position and motion data at 100Hz.

SENSOR FUSION ALGORITHM

The Kalman Filter is a mathematical algorithm that combines a series of GNSS and IMU data readings to predict the optimal position of the vehicle.



ACCURACY	Creates a probabilistic model of the system, accounting for measurement uncertainty and flaws in system dynamics
ADAPTABILITY	Swiftly adapts to changes in measurement and system dynamics to produce optimal results in real-time
EFFICIENCY	No reliance on historical measurements for operation. Requires little resources and low-computational power
FLEXIBILITY	Can be easily modified to suit higher-grade sensors. Functional for both linear and non-linear systems
REDUCED ERROR	Minimizes errors caused by system noise as a result of interference, measurement error, and environmental factors



CONTROL MECHANISM

Controllers use the trajectory given by the sensor fusion algorithm to compute driving instructions for the following trailer, resulting in a more robust navigational system. Longitudinal and lateral controls were implemented.

LONGITUDINAL (PID) CONTROL
Controls velocity and acceleration.

LATERAL (STANLEY) CONTROL
Controls turn angles and lane changes.

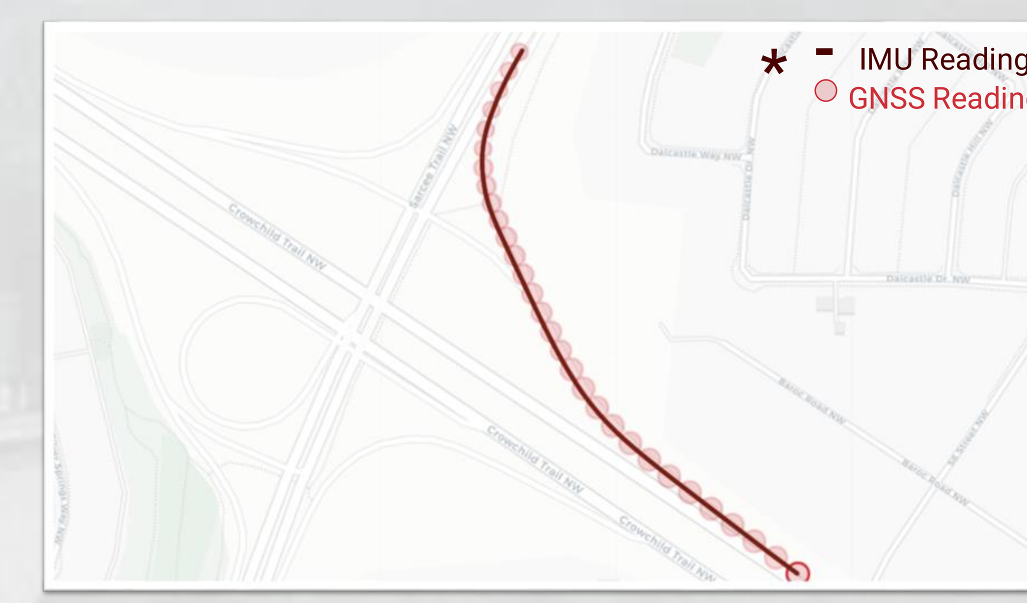
Both controllers automatically and continuously apply error correction to the system.

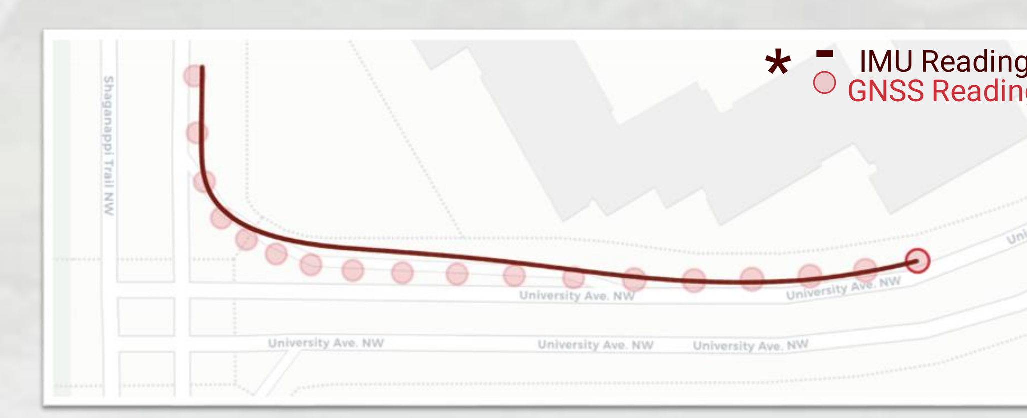
OUR SOLUTION

LOW COST	INS featuring low-cost *Global Navigation Satellite System* (GNSS) receiver, and *Inertial Measurement Unit* (IMU)
EFFECTIVE	Sensor performance enriched through extensive Kalman Filtering Algorithm infused with land-vehicle kinematic constraints.
INNOVATIVE	Lead vehicle trajectory used as reference for follow vehicle
ROBUST	Follow vehicle robust "trailing" through control algorithms for throttle and steering angle
TESTED	INS based solution tested as sole-driver of autonomy for driver-led autonomous trailers and validation of results using autonomy simulation and real-world data

PRODUCT BENEFITS

Our INS provides a high-bandwidth position, velocity, and orientation solution even during GNSS signal outages; while successfully capturing dynamic vehicular maneuvers.





* *IMU readings were estimated without the use of the GNSS to simulate a signal outage. GNSS readings are shown for reference*

Our INS is functionally comparable to existing systems on the market at a fraction of the price.

PRODUCT	BIAS INSTABILITY	HEADING ACCURACY	OBSERVED POSITION ACCURACY	COST
OUR INS	10 Degree/hr	0.3 Degree	1.0-1.5m	$80
VN-200 GNSS/INS	5-7 Degree/hr	0.2 Degree	1.0-1.5m	$3200
SPATIAL-ADVANCED NAVIGATION	3 Degree/hr	0.2 Degree	0.020m	$3190

SCHULICH School of Engineering
CADIAT