Dynamic Stability Measurement Device for MaxMover Autonomous Forklift

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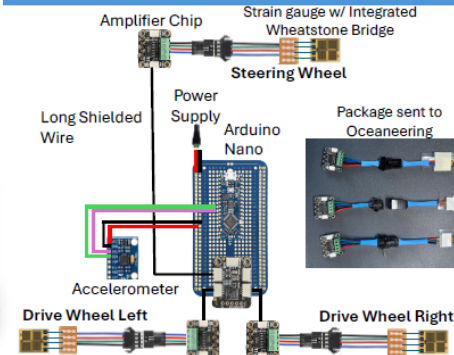
Project Objective

Maximize the travel speed of an autonomous forklift while ensuring tipping does not occur.

- Continuously sense load distribution
- Response time <100ms
- Provide output signal
- System installation under 1 hour
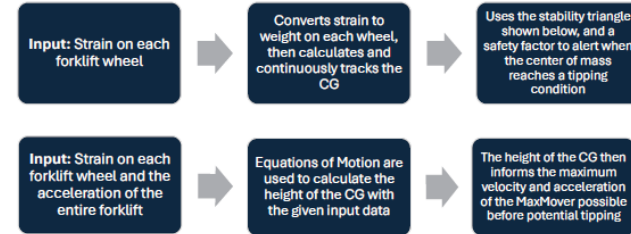- Calibration time under 5 minutes
- System Cost <$5,000
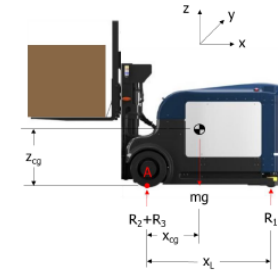
Solution Overview

Device Overview

Amplifier Chip
Strain gauge w/ Integrated Wheatstone Bridge
Steering Wheel
Long Shielded Wire
Power Supply
Arduino Nano
Package sent to Oceaneering
Accelerometer
Drive Wheel Left
Drive Wheel Right

Algorithm Overview

Input: Strain on each forklift wheel → Converts strain to weight on each wheel, then calculates and continuously tracks the CG → Uses the stability triangle shown below, and a safety factor to alert when the center of mass reaches a tipping condition

Input: Strain on each forklift wheel and the acceleration of the entire forklift → Equations of Motion are used to calculate the height of the CG with the given input data → The height of the CG then informs the maximum velocity and acceleration of the MaxMover possible before potential tipping

Testbed

Without the use of a MaxMover on campus to test with, we built a full-scale testbed to test our concept on campus.

Accelerometer: Use the recorded acceleration to find the height of the system's CG, allowing us to predict when tipping will occur using only simple equations of motion.

Strain Gauges: Act as "scales" on each of the 3 wheels to measure how weight is distributed across the forklift.

Adjustable Forks with pole for loading gym plates

Finite Element Analysis of Key Components

FEA was done to select the optimal installation sight for the strain gauges, ensuring our strain gauges would read the correct axial loading of their respective wheel.

Results

Z-CG Derivation

$$\Sum M_A = -R_1(x_L) + mg(X_{CG}) - ma(Z_{CG}) = 0$$

$$Z_{CG} = \frac{-R_1(x_L) + mg(x_{cg})}{ma}$$
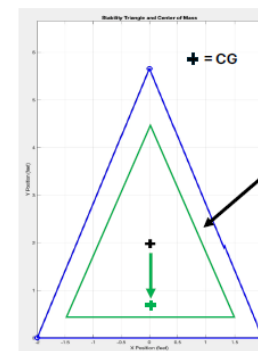
Tipping Acceleration Derivation

$$\Sum M_A = mg(X_{CG}) - ma(Z_{CG}) = 0$$

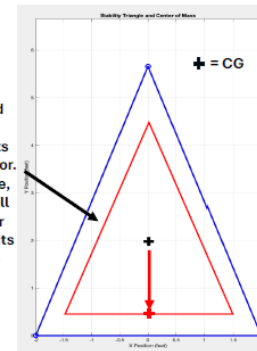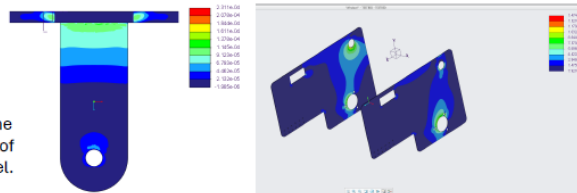$$a_{tipping} = \frac{mg(X_{CG})}{m(Z_{CG})} = \frac{g(X_{CG})}{(Z_{CG})}$$

Live CG Tracker

Below Tipping Acceleration

✚ = CG

SAFE!

Above Tipping Acceleration

✚ = CG

TIPPING CONDITION!

Inscribed triangle represents safety factor. In practice, tipping will not occur until CG hits the blue triangle.

Acknowledgments