“Milou”: Vision Based Autonomous Snowplow

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Introduction

Project Milou formerly known as “SnowJoke” is a cost-effective autonomous snowplow robot platform. It can plow snow up to 15 centimeters deep. This year, we have overhauled its electrical and control system to achieve a modular design and better on-board computing capability. We have replaced an outdated FPGA control system with one using a more modern and faster microcontroller. In addition, we have introduced to standardize the software packages on the robot allowing more students to use this platform to learn about robotics and autonomous vehicles. The previously used ultra wide band localization system has been replaced by visual odometry and visual localization to achieve better flexibility in the robot’s operating environment.

← **SnowJoke**

→ **Milou**

Team Composition

Frank (Chude) Qian is a fourth year Electrical Engineering student currently pursuing his master degree in Electrical Engineering with a robotics focus in robot vision and autonomous vehicles. Currently Frank leads CWRU’s Autonomous Vehicles Lab operation.

Kay (Kaiyi) Chen is a second-year Electrical Engineering student focusing on robotics. She is currently the research assistant in CWRU’s Autonomous Vehicles Lab. Her research interest is bio-inspired robotics.

Drew Borneman is a fourth-year computer engineering student. His focus is computer systems engineering.

Ziyi Huang is a fourth-year electrical engineering student. His focus is circuit design and electrical engineering.

Mechanical Design

Milou is designed for snowplowing:

- **Chassis** made of 1” square steel tubing with an estimated strength of 5 tons
- **Motors** are rated to support and move a total of approximately 750 lbs
- **Frame** is designed to have a very low center of gravity to enhance plowing output
- **Skid steering** allows the robot to have maximum manuverability

Milou Chassis Design

Plug-N-Play Control Box Design

One of the biggest improvement of the platform is its new modular designed control box. It can be used on other robot too.

Milou Integrated Control Box

The control box consists:

- 3 Designated power input Anderson Powerpole SB50 connector
- 2 Designated Harting motor connector
- 2 Designated RS422 Encoder Receiver
- Designated Power cutoff
- 1 RJ 45 Ethernet IN
- 1 RJ 45 Ethernet OUT
- 3 USB 3.1 Gen2 I/O
- 1 HDMI 2.0 Connector
- 4 Programmable Switch Select
- 1 Onboard display unit for debug
- On board wifi and ethernet

Control Box I/O

Low Level Control/Safety Design

To improve Safety and Compatibility, firmware was re-designed

Isolated Power Supply

- Isolated 12V auxiliary power for all control systems (Computer, Microcontroller, Estop Control) and infotainment system (On board display, Onboard Networking)
- Dedicated 24V motor power with high reliability circuit breaker
- Improved grounding for preventing ground loops and reducing noise in the control box

Milou Integrated Estop Control module

Estop Module

- Dedicated hardware circuit to track Estop Signal and control contactor.
- Observes Estop Button, Remote Receiver Channel 3, Microcontroller
- Tested to fail open in case of component failure
- Easy to replace in event of failure

Microcontroller Module (Teensy 3.6)

- 32bit 180 MHz ARM Cortex-M4 processor with floating point
- Interrupt capability on all inputs for faster response
- Dedicated daughter board for RS422 signal decoding
- RGB Indicator for robot state (RC/EStop/Autonomous)
- Highspeed serial for debug and communication with ROS

Milou Microcontroller

Navigation/Control workflow

Overall Control Design

The Overall control follows ROS→Teensy→MotorController three-tiered design.

Navigation & Localization

The Intel Realsense camera series was chosen as our main sensor system for its reliability and setup simplicity. In addition, since the RGBD and IMU are from the same product family, inter-compatibility is maximized. The RGBD and Visual IMU sensors tend to perform better than traditional RGB and IMU sensors.

Project Commercial Implementation

Overall Design

We suggest implementing multiple robots in a collaborative snowplow system with an overhead camera guidance system.

Localization Explanation

We propose a localization system using an April Tag on the robot and n overhead camera to perform localization. The April tag will be able to provide both robot pose information and robot ID information. The April tag system also allows expandability for multiple robots to collaboratively plow the snow.

Example Overhead Localization System

Power Usage per Robot

- Approximately 1 kJ of energy to plow a 1x1m square of snow 5 cm deep
- Estimate 1580m^2 of area to cover a Standard NHL Hockey rink, a total of 1580KJ will be needed regardless of the number of robots

Clearing Speed per Robot

- Each robot can maximally plowing 2m^2/s, assuming no robot collaboration, requiring a minimum of about 15 (±5) minutes. (1580m^2/2m^2)/(60sec/min)=13.1667min)

Cost Analysis

- Each Milou robot platform costs ~$3,000 USD to manufacture
- Six6 4k camera monitoring systems with streaming costs about $1000 USD
- A computing system for performing robot localization costs about $3000 USD

Allowing 20 minutes of plowing time, the system will cost about $7000 USD. For 10 minute plowing time the cost increases to about $10,000 USD.

Presented: ION 2020 Autonomous Snowplow Competition

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