Intrinsic Force-Torque Sensor System for a Next Generation Snake Robot

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Introduction

- A new snake robot is to be developed at NTNU.
- The new snake robot will be an indented test-platform for Hybrid Obstacle Aided Locomotion (HOAL).
- Snakes utilize obstacles in the unstructured environment to locomote. Effective HOAL is an important milestones towards the future goal of fully autonomous snake robotics.

F/T sensors and HOAL

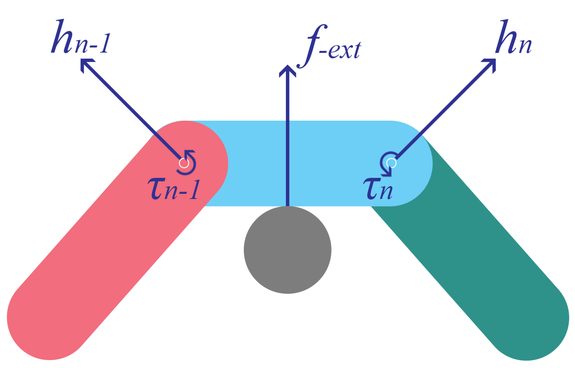

Fig. 1: Forces and torques applied on a 2-jointed 2D-snake pushing up against an object

$$F_R \approx 0$$

$$\Sigma F = ma \quad (1)$$

$$f_{ext} = ma - h_n - h_{n-1} \quad (2)$$

- Multi-axis force-torque measurement is a central aspect regarding HOAL.
- By comparing the measured to the force applied on 2 joints (h_n and h_{n-1}) in 2(or 3) dimensions, an external force vector can be estimated (2) [2][3].
- The sum of all external force vectors would equal a path of locomotion.
- By regulating the motor torque, using a torque sensor as feedback, the snake would be able to regulate the size and direction of each external force vector. Thereby, the path of locomotion [2][3].

F/T specifications for a snake robot

Specification sheet

Subject	Value	
Heigth	<40mm	
Diameter	<60 mm	
Weight	As light as possible	
Measurements	F_x, F_y, F_z	M_z
Capacity	ca. $20N$	ca. $3Nm$
Safe overload	> $20N$	> $3Nm$
Oper. temp. range	$0C$ to $60C$	
Price	<20 000 NOK	
Delivery time	< 4 weeks	

- The sensor system must be small enough to be applicable as an intrinsic solution.
- Needs to measure the relevant strain-axis with high accuracy and little hysteresis.
- Needs to withstand the highly demanding environment of a snake robot, in terms of temperature and force/torque range.
- Specifications were determined based on previous research at NTNU, conversations with the HOAL-team, and available solutions on the market.

Test results

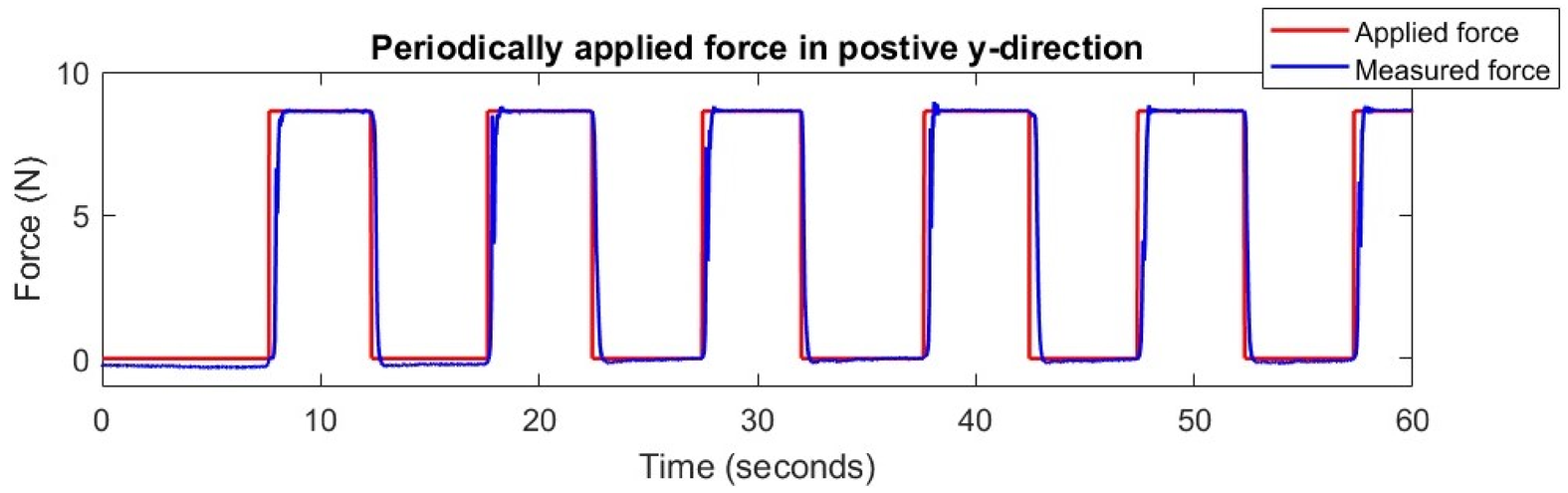

Fig. 2: Results from one of the experiments were a periodic force was applied

The market

Findings regarding the market for suitable force-torque sensors:

- 6-axis F/T transducers with acceptable dimensions are highly expensive.
- The demand for these sensors are low, therefore most sensors must be ordered/produced on a reserved quota.
- A cost effective solution is to join 2 transducers that together meets the minimum required axis of measurement.

The Sensor Solution

- Dubbed the Sandwich Solution.
- Based on commercially available transducers.
- Combines a 3-axis force sensor with a 1-axis transmission type torque sensor.
  - K3D40 3-axis force sensor(bottomn Fig. 3) [5].
  - TRT-50 1-axis torque transducer (top Fig. 3) [4]
- Measures: F_x, F_y, F_z and M_z
- Found to likely be the most cost-effective commercially available solution.

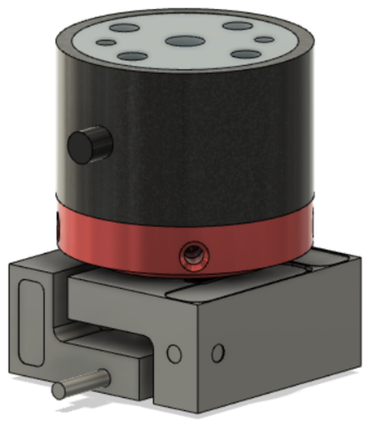

Fig. 3: The Sandwich Solution, 3-axis force and 1-axis torque sensor

Sandwich Solution specifications

Subject	Value	
Heigth	58.4 mm	
Diameter	57mm	
Measurements	F_x, F_y, F_z	M_z
Capacity	$\pm 50N$	$\pm 5Nm$
Safe overload	$\pm 100N$	$\pm 7.5Nm$
Rated temp. range	$15.6C$ to $60C$	
Op. temp. range	$-20C$ to $70C$	
Price estimate	20 871 NOK	

Discussion

Discussing the sensor system's performance

- High accuracy.
- Low time-delay.
- Redundant and reproducible measurement signal with little to no hysteresis.
- Minor crossfeed between the measurement axis.
- Increasing temperatures has a minor influence on the measurement signal.

References

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