Friction Shock Absorbers and Reverse Thrust for Landing in Extreme Conditions

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CONTEXT

- Small multirotors are **not designed to land in hazardeous situations**, such as on inclined surfaces and moving platforms.
  - 2/3 of military drone accidents occur during takeoff and landing.
- Improvements towards the landing phase could ease the use of drones for a variety of applications:
  - Landing on roofs for inspection, surveillance or recharging
  - Landing on moving vehicles for scouting missions or for "last-mile" package delivery
  - Landing on boats in rough seas (e.g. for search and rescue)

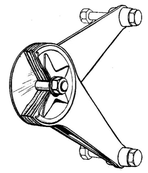
GOAL

Enable small multirotors **to land in extreme conditions:**

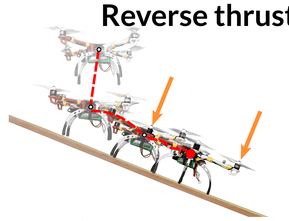
- Inclined surfaces (>40°)
- Fast moving vehicles (>100 km/h)
- High impact velocities (3 m/s)
- Strong winds

GLOBAL STRATEGY

Friction shock absorbers



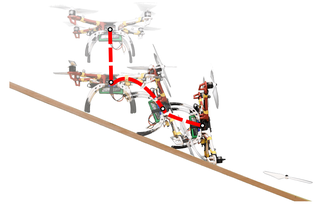
Reverse thrust

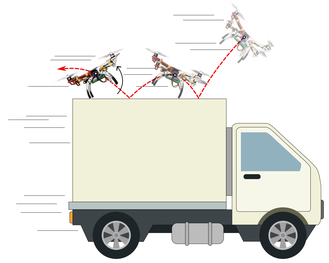


Friction shock absorbers can dampen high velocity impacts and minimize rebounds while **reverse thrust** increases adherance to surfaces.

CHALLENGES

Rigid landing gears cause small drones to **bounce, flip over**, slide down slopes and **fall off** moving platforms.



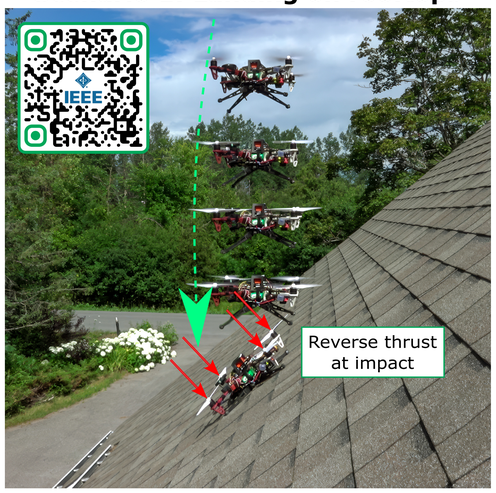


Drag can rapidly build a **relative horizontal speed difference** between the drone and the vehicle that might cause the drone to tip over on contact.

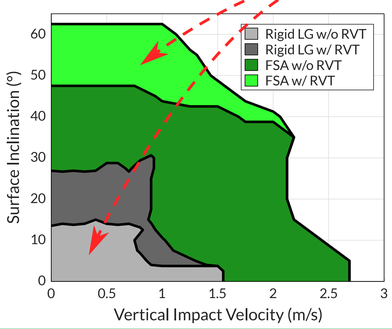
High winds, **gusts** and **turbulence** near fast moving vehicles can disturb the approach and landing phase.

RESULTS

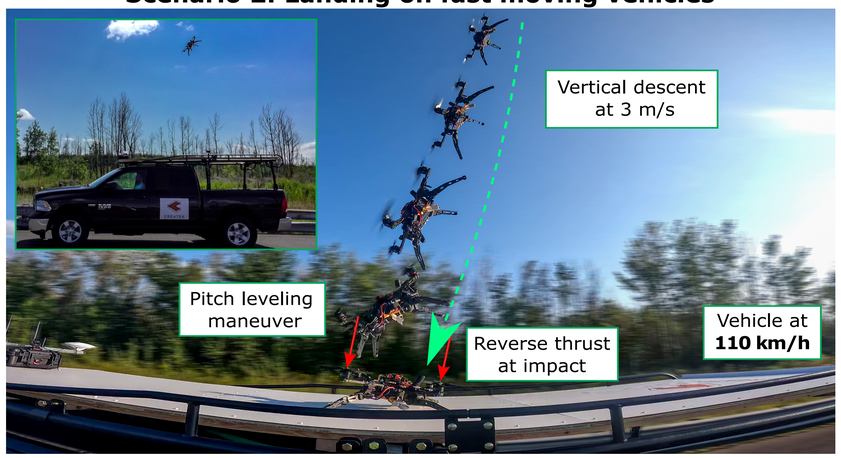
Scenario 1: Landing on rooftops



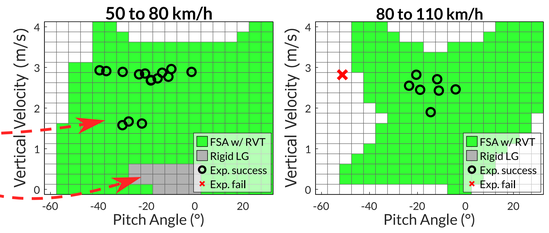
- Land on inclinations of **up to 60°**
- Land at vertical velocities of **up to 2.75 m/s**
- **100% success rate** out of over 40 trials
- **Dynamic model** to simulate the impacts
  - Increased by a **factor of 8!**



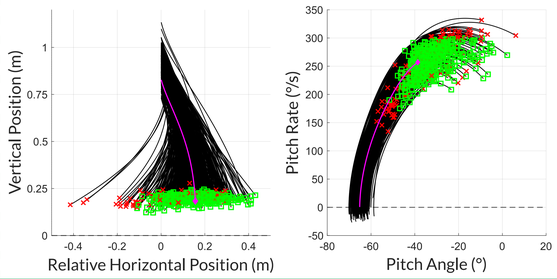
Scenario 2: Landing on fast moving vehicles



- 58 trials at speeds between **10 and 120 km/h, 98% success rate**
  - Descent rate between 1.5 and 3.5 m/s
- **Landing simulations** reveal an increase of the envelope by a **factor of 8!**

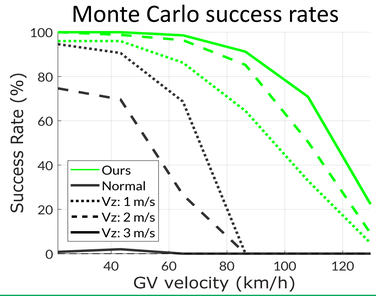


Monte Carlo simulations of landing trajectories at 110 km/h

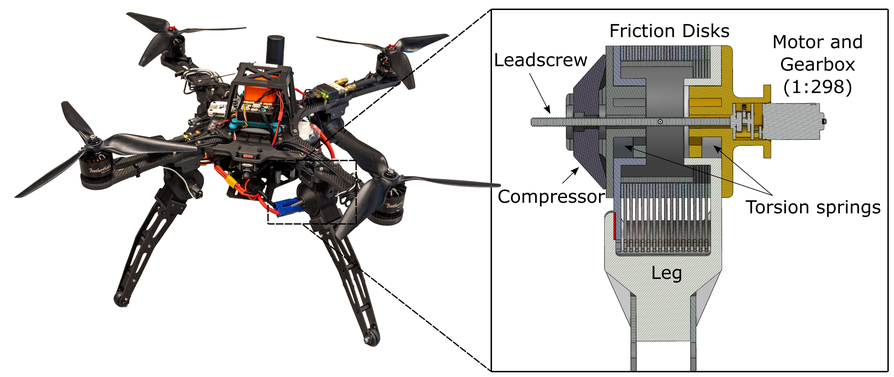


- More **robust** to unpredictable **disturbances**:
  - Wind / gusts
  - EKF variance
  - Road bumps
  - Unexpected GV accelerations
  - Timing errors
  - Model uncertainties

Monte Carlo success rates



HARDWARE IMPLEMENTATION



High-power flying platform

- Thrust-to-weight ratio of 6.5
- High pitch propellers for high speed maneuverability
- Lightweight carbon fiber frame
- Vehicle tracking using **cm-precise GPS** and latency compensation.
- A small DC motor compresses a **series of disks** to create a friction torque in a rotary joint.
- The motor can loosen the joint to reset the landing gear's position.
- Designed for up to **4 m/s** impact speeds.

FUTURE WORK

- Land on **ships** in rough seas
- Land on **icebergs**

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