Design and Simulation of Compliant Tensegrity Robots for Planetary Exploration

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The Dynamic Tensegrity Robotics Lab (DTRL) at the NASA Ames Research center is actively researching the design, control, and locomotion of tensegrity robots for planetary exploration. The advantage of using a tensegrity robot emerges from the fact that it behaves as a *structured soft robot*. This term, structured soft robotic system, comes from the fact that tensegrity systems are traditionally comprised of rigid compression elements connected by a network of compliant tension elements. This network allows for global force distribution and varying amounts of compliance. Figure 1 shows a basic representation of this global distribution on the Spherical Under-actuated Planetary Exploration Robot or SUPERball. Cable 2 is kept constant while the length of cable 1 at the opposite side of the robot is increased linearly [1].

In the context of planetary exportation, the structure's passive global force distribution coupled with actively adjustable compliance gives the robotic system the ability to handle Entry, Descent, and Landing (EDL), locomotion, and unexpected environmental impacts. The DTRL has developed several prototype robotic platforms as well as an open source simulator[1] to explore different aspects of how tensegrity robotics can achieve these goals [1], [2]. Our most recent hardware prototype is the Spherical Under-actuated Planetary Exploration Robot or SUPERball, shown on the right of Figure 2. Prior prototypes have been used to demonstrate basic rolling capability, the ability to pack flat and actively deploy, the ability to survive landing forces when falling at 15 m/s, and general robustness to applied loads and shocks. Furthermore, the NTRT simulator has been validated through motion capture and functional comparisons against the prior hardware prototypes.

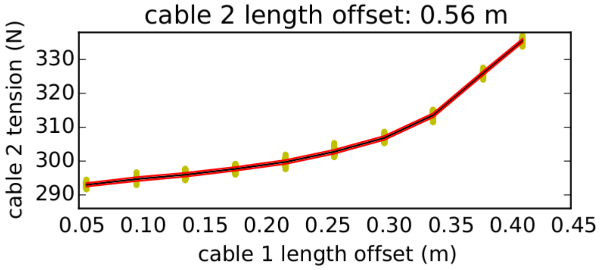

Fig. 1. Force distribution through SUPERball's tensile network. The plot shows the non-linear effect on the tension measured on a cable (2) one end of the robot while linearly decreasing the equilibrium length of a spring-cable assembly (1) on the opposite end of the robot.

Future generations of SUPERBall will be designed to survive the full range of landing forces and also be capable of robust all terrain locomotion. The robustness to impact provided by a tensegrity robot changes the risk profile of future planetary exploration missions and opens up a broad new range of exploration options.

REFERENCES

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[2] K. Caluwaerts, J. Despraz, A. Işçen, A. P. Sabelhaus, J. Bruce, B. Schrauwen, and V. SunSpiral, "Design and control of compliant tensegrity robots through simulation and hardware validation," *Journal of The Royal Society Interface*, vol. 11, no. 98, 2014.

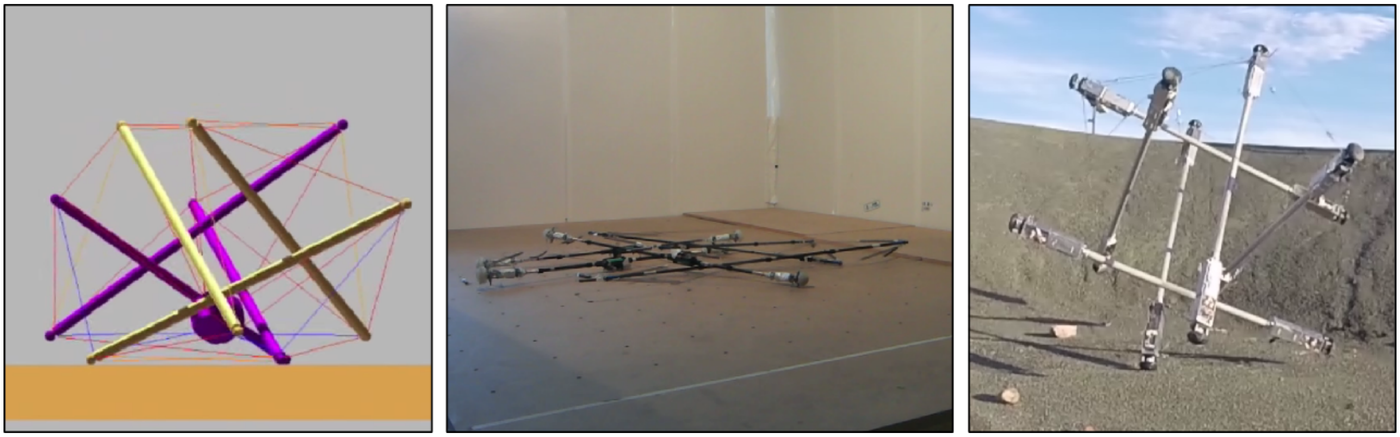

Fig. 2. **Left:** SUPERball drop test with payload in the NTRT simulator. **Center:** The lightweight ReCTeR robot actively folded. **Right:** SUPERball bouncing up after rolling down a hill.

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[1] NTRT is available at irg.arc.nasa.gov/tensegrity/NTRT