## Guide to Week 7 readings: non-frictional soft grasping

This week we consider grasping and manipulation with soft and non-traditional contacts. The common theme is that the conventional approach -- fingers with small contacts, uni-sense normal forces, and Coulomb friction limits -- does not apply. Instead, we can now apply tensile as well as compressive forces at the contacts, and the available shear force is not a linear function of the normal force.  
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We divide the readings into three areas and we have 5 people. I suggest 1 person on **Suction** and 2 people each on **Microspines** and **Adhesives**. Can you please put your name next to the paper(s) that you would mainly like to present?

### Grasping with suction (Giorgia)

* Per Giorgia’s suggestion, we start with the paper by by [Maniotra (2007)](https://drive.google.com/file/d/1nZIFsbgjx5-f3-COLI5bcJEOXmO7DtE6/view?usp=sharing) to think about how, in general, grasping with suction can be modeled.
* Then we look at [Mahler, Jeffrey, et al. (2018) "Dex-net 3.0: Computing robust vacuum suction grasp targets in point clouds using a new analytic model and deep learning." *IEEE International Conference on robotics and automation (ICRA)*.] This paper from Ken Goldberg’s group at U.C. Berkeley develops an elastic spring-like model of a suction cup (similar to the grasp stiffness models we looked at) and uses it to predict whether a suction cup will achieve a good grip on an object. [The marked-up copy](https://drive.google.com/file/d/1CFEx8qar6uNB99HyEyicLuALjnTbMPLA/view?usp=sharing) highlights some terminology and citations that are now familiar to us. The second half of the paper goes into a deep learning policy for identifying objects -- which is beyond the scope of this course but interesting.
* We also invite people to think about how one could sense if a grasp actually is good. We can briefly show the new suction cup gripper by Tae Myung Huh et al.

### Grasping with microspines (Syeda, Gianluca)

Insects cimb walls using arrays of tiny spines that interact with small bumps and pits on non-smooth surfaces. Spines have been used for climbing robots and perching UAVs; they can also be used for grasping in special applications.

* We start with: [Jiang H, et al., “[Stochastic models of spine arrays for rough surface grasping,](https://drive.google.com/file/d/1nW9-yweZu0Fg2rYBdJpy0_Z6AwzOUG7n/view?usp=sharing)” IJRR (2018).] This paper describes the basic modeling of spines. Spine/surface contact is inherently stochastic: we cannot say exactly when each spine will make contact with a tiny bump or pit on a surface and we cannot say exactly what the maximum force will be. Nonetheless, we can construct contact limit surfaces (analogous to friction limit surfaces) with the expected value of the maximum wrench that a spiney gripper can withstand. Some examples are shown in Figures (18-20) for different grasping conditions. A second point is that each spine cannot support a large load. So we need many spines. But we also need load sharing so that the first few spines do not fail.
* The paper by [Ruotolo, W., et al. (2019). [Load-sharing in soft and spiny paws for a large climbing robot](https://drive.google.com/file/d/1M2UUh3oWtz22WumrElA9eS_7QqszDc3p/view?usp=sharing). *IEEE Robotics and Automation Letters,* 4(2), 1439-1446.] builds immediately on the previous paper for an application to a large and heavy climbing robot. As noted above, a critical requirement is to achieve load sharing. This paper provides solutions to load sharing in the context of grasping irregular surfaces using multiple tendons per finger and a particle jamming palm.
* A second application of grasping with spines is **ReachBot**.ere are two ReachBot papers in the folder. They are short and can be read/presented together.
  + Chen et al., ReachBot: [A small robot with exceptional reach for rough terrain](https://drive.google.com/file/d/12w_NHHeyATYtXmrug1jcNah81klMf4Gy/view?usp=sharing). (2022). The first ReachBot paper mainly concerns gripper design and describes an early planar prototype.
  + Schneider, et al. “[ReachBot: A small robot for large mobile manipulation tasks](https://drive.google.com/file/d/1xgKGUDGReyWusZtDWaC4Mf2OPNlWzl5j/view?usp=sharing).” (2021). The second ReachBot paper presents a dynamic model. You will recognize that climbing with ReachBot is very much like grasping -- but instead of having unisense fingers that push, we have arms that pull. The wrench matrix terminology will be familiar.

### Grasping with adhesion Neri Niccolò Dei, Radan

* Hawkes et al. “Human climbing with efficiently scaled adhesives.” RSif 2014 explains briefly how gecko-inspired adhesives work and why one cannot just make the tiles larger. Instead one need a load-sharing solution, similar to that needed for spines. It presents such a solution involving a suspension of nonlinear springs.
* Jiang, H., et al. "[A robotic device using gecko-inspired adhesives can grasp and manipulate large objects in microgravity](https://drive.google.com/file/d/13j3_ZJ2R9CU4RYyq4009PhBucpR-ZwNP/view?usp=sharing)." Science Robotics 2, (2017). This paper describes some compliant grippers that use directional gecko-inspired adhesives to grasp large objects in micro-gravity. The idea is that without gravity, a gripper could grasp objects many times large than itself. The grippers use arrays of tiles with gecko adhesives. As with spines, load sharing is important to prevent just a few of the tiles from becoming overloaded. The paper defines 6-dimensional (force, torque) limit surfaces to represent the maximum contact wrench that an array of tiles can support. The analysis is similar to friction limit surfaces with one important difference: we cannot allow any pair of tiles to fail, because that causes a rippling effect that causes the entire array to fail. Therefore we cannot use Minkowski (convex) addition of the limit surfaces from individual tiles. It also leads to some possibly non-intuitive results regarding the optimal arrangement of tiles. Neri Niccolò Dei (1st choice)
* Ruotolo, et al., “[From Grasping to Manipulation with Gecko-Inspired Adhesives](https://drive.google.com/file/d/1CcBYUP1iSJEd8QaabAklFUQTRPWN3B9S/view?usp=sharing),” (2022). This just-completed paper describes a soft hand that uses gecko-inspired adhesives to grasp a wide range of objects, including heavy objects, with low normal forces. The paper describes three requirements and corresponding solutions for efficient grasping with adhesion. Unlike traditional grasping, the magnitude of the available shear force does not depend on the normal force at a contact. However, the concepts of contact wrenches, twists, grasp matrices and grasp stiffness remain valid and are used. In comparison to the specialized solution above, this is more of a typial under-actuated robotic hand with fingers, aimed at grasping a wide range of objects from grapes to pumpkins, on earth.