UNIVERSITY OF CALIFORNIA, BERKELEY
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INVENTING A SAFER WORLD WITH DRONES

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Imagine a day when a swarm of drones zooms past your window with blaring sirens towards a burning building and extinguishes its flames faster than human firefighters ever could. Or imagine a flying quadcopter rescues a drowning beachgoer quicker than any human lifeguard possibly could. That is the future being invented today in the HiPeR Lab at UC Berkeley. This team of researchers led by Dr. Mark Mueller is working on technologies for Unmanned Aerial Vehicles (UAVs) that aim to make these flying machines as reliable and robust as possible so that humans no longer have to take on dangerous, physically demanding jobs.

The High Performance Robotics Lab (HiPeR Lab) focuses on safety, localization, and design with the aim to enhance a Unmanned Aerial Vehicle (UAV) systems' capabilities by advanced algorithms, mechanical design, and control strategies. The lab pursues these developments through low-level research, or the specific individual components rather than complex macro-systems or projects. The inspiration behind research lab projects and applications come organically from what Dr. Mueller calls the "needs," or the lack of capability in some form of technology. He likens his projects to developing hammers, which would not bring about any useful application until the nails, or the real problems, are found or developed. It is this philosophy of researching ways to fulfill "needs" in our real world that drives innovation in the HiPeR Lab.

Dr. Mark Mueller
Professor in Berkeley's Department of Mechanical Engineering

"Humans no longer have to take on dangerous, physically demanding jobs"

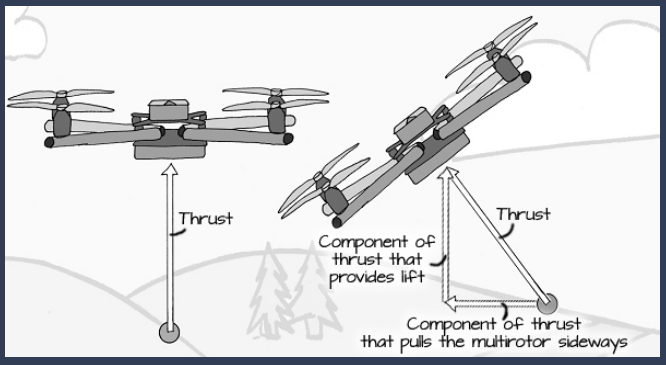
"There is only so much stability and control that can be achieved by updating control algortihms "

Above
HiPeR Lab's Experiment Test Facility

One research project at the lab is an enhanced-stability quadcopter. Within many challenging environments, there are disturbances such as torrential winds and debris hat systems operating in their vicinity must be able to withstand. The most prominent efforts for increasing stability in UAVs have been software based such as a Switching Model Predictive Attitude Controller and an L1 Adaptive Velocity Controller. These controllers employ feedback loops where an input is received and based on how much it deviates from a set value, the controller adjusts to compensate for the deviation. However, there is only so much that can be achieved by updating the control algorithms for existing UAVs as the performance of these controllers is inherently limited by the system's dynamics, sensor noise (inaccuracies caused by external factors), and the available range of control inputs.

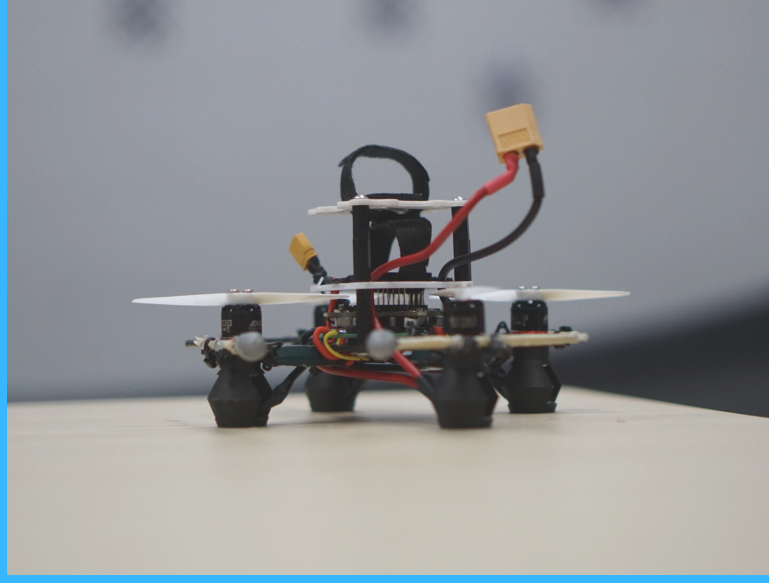
In order to achieve break-through performance and operate in the most challenging environments, Dr. Mueller developed a novel design of the actual vehicle — the addition of a flywheel on the bottom of the quadcopter. This flywheel adds a large source of angular momentum to the vehicle, which increases the magnitude of the thrust force. This increased thrust force makes it much more difficult for strong winds, falling debris, or other dangerous phenomena to disturb the quadcopter due to the additional torque needed to react against this thrust vector and overturn the vehicle, thus allowing it to maintain its thrust direction better than a comparable standard multicopter. The added momentum from the flywheel is like a spinning top, which stays upright more easily when it is spinning rapidly than when it is slowing down. Dr. Mueller hopes that innovations like these make drones more effective in challenging environments such as the wildfires that frequently plague the state of California.

Above
Quadcopter with an added flywheel



Above
Diagram of Thrust Force

Above
Spinning Top



Above
Rechargeable Quacopter

"If everyone has the same background, they'll all probably come up with the same ideas"

Another problem with present-day drones that the HiPeR lab aims to solve is how they simply do not last long enough on a single battery charge in mid-air. It would be very inconvenient for a search and rescue drone to constantly have to return to a charging station to refill its batteries after a single charge, which is only around 10-15 minutes by today's standards. To solve this problem, researchers developed a mechanism for a medium-sized drone to be recharged mid-flight by a smaller drone. How this works is that when the mid-sized drone's battery is almost fully drained, the smaller drone hovers to its current location with a fully charged battery and docks onto a plate mounted on top of the mid-sized drone. The plate contains a circuit that allows power to be transferred from the smaller drone to the mid-sized drone, eventually recharging its battery. Results from a recent test in the lab showed that this charging mechanism was able to extend a quadcopter's flight time by 4.7x, effectively making it hover for almost an hour. This recharging process can be done multiple times to extend flight time beyond the endurance levels of humans today, allowing drones to be more productive than people when faced with heavy tasks.

Above
HiPeR Lab Drone working with CEREBRUS

Dr. Mueller's work extends far beyond the walls of his lab. One example is his contribution in a DARPA-sponsored project called Team CERBERUS. This team, which involves other institutions including University of Nevada, Reno and ETH Zurich in Switzerland, is competing in the DARPA Subterranean Challenge, where teams compete to develop autonomous robots that tackle challenging underground operations. This includes risky tasks like cave exploration and underground mapping, which – given the background of what HiPeR Lab has done at Cal – are fields that suit Dr. Mueller's expertise well. Each organization involved in the team contribute to different types of robots, ranging from two-legged robots, wheeled vehicles, and aerial vehicles. These robots work together simultaneously on the field to complete the competition's challenges, where Dr. Mueller's drones alone would not be enough, making collaboration a key aspect to the project. When talking about this exciting joint research initiative, he expresses the benefit of working with people with different mindsets from all over the world: "If everyone has the same background, they'll all probably come up with the same ideas."

In addition to working with current researchers, Mueller hopes that, in the future, the diversity of those who pursue robotics education and research expands to greater groups in society that are currently underrepresented. He highlights how the members of his research lab are mostly male and how this perpetuates the inward thinking culture of research labs nowadays. The hope is that the increased coverage and application of the innovative ideas and engineering from the HiPeR Lab will reach out to more groups of people and increase the significance of drones in society. The intended result is that more people of different backgrounds with unique problems will work in robotics so that we can not only just "(think) about solutions from as varied (of) a toolbox possible," but also "be aware of more problems that we can find solutions to."