The Fusion of Robotics and Our Environment: the Development of the Robobee

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Over the course of this generation, technology has become increasingly entwined with human systems, so much so that our daily lives are now totally dependent on technological systems. However the future will be defined not just by how technology and humans are merging, but by how human created technologies and the natural systems and environments of this Earth will become inseparable as a new hybrid system. This process will begin as artificial organisms designed by humans are introduced into the biosphere. Research on cockroaches has shown that individual robots can interact with and influence the collective action of a group of live organisms (2007, Halloy). With this as a precedent it does not seem too far fetched to speculate that in the near future other types of artificial organisms will be introduced into the Earth’s environments, coexisting with, if not partially supplanting some populations of natural organisms. This phase shift will not be as conspicuous as you may think; most of the robotic organisms under development today are being built to be only about the size of insects. Scientists are working on this scale because of the maneuverability and social interaction offered by insects as a subject (Piore, 2014). The first foray into this new age is currently occurring at Harvard University, where a team of scientists has been working to create a robotic bee (Wood, 2012). Still in the beginning stages of the project, the ultimate aim is to create a robotic bee capable of sustained flight, with a compact power source, and complex interactions with the numerous other robotic members of its “hive.” Though the project’s leaders do not believe their technology should be used to supplant natural populations of bees, I believe that once this technology is perfected its merging with the natural systems of this Earth will be inevitable and irreversible.

The robobee project was in part inspired as native honeybee populations in the US were beginning to decline (see Figure 2). In response, scientists speculated about what it would take to build an artificial colony of bees that were capable of assuming all the tasks live honeybees accomplish (Wood, 2013). The developers envision their invention as having many more uses as well, including search and rescue, hazardous area exploration, surveillance, and weather and traffic monitoring (Robobees, 2014). However achieving these goals poses many challenges, as a robobee would have to weigh less than a gram, a 100th of the weight of the world’s current smallest flying robot (Wood, 2013). Within that strict weight limit, the robot would have to contain a power source, an electronic brain and sensory system, and a means
of flying that can cope with unpredictable natural stressors. Besides recreating an entire bee colony, the project has the goals of spurring development in the field of micro technology; such as efficient and compact power supplies and other micro-scale robotic systems. Recently, there has been a growing interest in the development of micro air vehicles like the robobee, thanks to their many practical applications (Abrar, 2013).

The science behind the entire project is based on the complex physiology and population biology of the honeybee. The honeybee has evolved over the course of many millions of years to its current state as both a highly efficient flying organism and social insect. Bee flight is especially impressive, with several unique adaptations that allow them to remain airborne for extended periods (California Institute of Technology, 2006). To cope with unexpected turbulence, their wings are not rigid but can passively deform in response to wind gusts, thus making their wings more durable and energy efficient (Shang, 2009). The bee brain and sensory systems are also complex and well developed. During flight, a bee can determine the speed at which it is moving as perceived by each of its eyes independently. Balancing the velocity of these separate images allows a bee better control over their flight speed when moving between obstacles, as well as when coming in for a landing (Srinivasan, 1996). But the characteristics of an individual bee are vastly overshadowed by their capabilities as a whole. A colony with thousands of members is able to distribute tasks and work together towards maintenance of the hive. A honeybee worker returning to the hive from foraging can communicate the location of food resource, all by moving its wings and legs in what is known as a dance (Visscher, 1982). These behaviors and traits keep the hive functioning throughout the year. Honeybees inhabit most every environment on this earth, except for the poles and other extreme environments, a testament to their durability and the advantage living in a hive confers to them.

The robobee project hopes to emulate the traits that have made natural honeybees so successful (Wood, 2013). The current robobee model employs flexible, flapping wings to cope with air turbulence much like a live honeybee would. These wings are powered by two sets of actuators of artificial muscles, mimicking how an actual muscle would contract. This system allows the robobee to generate powerful wing strokes to keep it airborne, while at the same time allowing it to execute tight flying maneuvers (Wood, 2013). These wings are mounted on an incredibly light and compact body, thanks to an ingenious method developed by the team. The bee’s exoskeleton is 3D printed flat in consecutive layers of material. The body then folds upward and locks into place (O’Brien, 2012). The team has said the idea behind this process came from children’s popup books, which manage to fit a lot of detail into a very limited space. However, having the robot achieve flight is only one part of the project. The brain of the robobee must be able to process a myriad of external stimuli while maintaining the internal systems of the robot. To make the electronic brain more efficient, the team is supplanting traditional algorithmic processes with a system modeled after the firing of
neurons and synapses in an actual bee brain. Though this system is more variable, it will allow an individual robobee to exhibit more adaptive behavior to cope with the unexpected scenarios it would face in nature (Blustein, 2010). The strict size, weight and power limit of an individual robobee body constrains the power a single robot can have. However this is compensated for by how the individual will be able to interact with hundreds if not thousands of other individual robobees. The ability of many small individual robots to work together and accomplish tasks has been demonstrated in numerous other studies. Though an individual robot may not know the collective goal, they will each have their own small task, allowing a swarm to work together to manipulate a large object or cover a large area (Rubenstein, 2013). The Harvard team is working on implementing such behaviors into their robobees, allowing the hive to communicate and work together.

Though the Harvard team has stated that they do not intend for robobees to be permanently introduced into the environment in place of live bees, I believe a partial supplanting of natural bees to be an unavoidable outcome of the development of this technology (Robobees, 2014). The team does acknowledge that they believe the robobee should be flying independently in the lab within a few years, and that their invention will be in widespread use five to ten years after that (Wood, 2013). There are numerous potential benefits to deploying robobees in our environments. First, it will allow humans to maintain agriculture dependent on bee pollinators even as those natural populations collapse as a result of climate change. Farmers would be able to purchase their own robobees and program them to pollinate their own crops. Robobees deployed in the wild would allow humans to monitor weather conditions, animal populations, as well as rapidly respond to natural disasters. However these possibilities are not without their downsides. Supplanting natural bees with artificial ones may hold unpredictable consequences for our environment as a whole. Though their use may benefit us, what of the numerous other organisms in the environment that depend upon interactions with honeybees? There are many organisms that rely on honeybees as their primary food source, such as the wasp Philanthus bicinctus (Dukas, 2005). These animals would surely suffer from a decrease in the number of honeybees, and would not be able to prey upon robobees. There is also the concern that robobees may be used to conduct surveillance, violating a person’s privacy without the victim having any knowledge of its occurrence. This fear is not new, as this has been a concern since the advent of unmanned aerial vehicle technology. The United States has used UAVs abroad as weapons of war, and now some government agencies and police departments are putting them into use domestically for surveillance purposes (Wall, 2011). The development of robobees is most likely of interest to these entities, since a smaller drone means it will be less noticeable and more effective at surveillance. However, many critics have voiced concerns that the increased use of drones for these purposes will breach the privacy of individuals, dehumanizing them in the eyes of the authorities (Wall, 2011). Though the potential downsides are numerous, I believe in the future we will
work out ways to solve these issues, with the positives of robobee development and implementation far outweighing the cons.

![Harvard robobee](http://wyss.harvard.edu/staticfiles/ourwork/br/popup-mems-350x262.jpg)

**Figure 1.**
This image demonstrates the “pop-up” construction of the Harvard robobee. Consecutive layers are laser cut and printed flat and fused together with heat and pressure. The entire structure is then folded upwards into a 3D shape. This shape is locked into place by submergence in liquid metal, which bonds to the structure’s joints. The robobee can then be removed from the assembly scaffolding.

![Graph showing US honeybee colonies](https://web.duke.edu/nicholas/bio217/spring2008/mcconville/pollinatorstatus.html)

**Figure 2.**
This graph displays the number of US honeybee colonies, in millions, on the y-axis vs. year on the x-axis. It clearly shows the decline in honeybee populations that has been occurring in the past several decades. This graph reveals the need to find a solution to this problem. Robobees present a possible solution.

Works Cited


