Breaking bones and robots

By: Gerald E. Loeb

Posted: Aug. 27, 2013

There are two basic ways to build animals that must support their body weight on land: put rigid structures on the outside or on the inside. Invertebrates such as cockroaches and spiders have exoskeletons – rigid shells that support and protect the squishy stuff (e.g. muscles, nerves, blood vessels) on the inside. Vertebrates such as dinosaurs and humans have endoskeletons – rigid bones with the squishy stuff attached to the outside and covered with flexible skin.

Importantly, there are no large terrestrial animals with exoskeletons. The laws of physical mechanics generate some inconvenient truths as structures scale up in size – biologists call this "allometry". If Mother Nature tried to make a really large cockroach just by scaling up all the dimensions, the strength of the structure would go up by the scale factor to the second power (squared) but the forces to be dissipated during a collision would go up by the scale factor to the third or even fourth power. That is, a cockroach ten times longer than the giant Madagascar cockroach (100cm vs. 10cm) would have a shell that is 100 times stronger but that shell would be subject to forces 1,000 to 10,000 times larger if it ran into something solid.

Putting the squishy stuff on the outside sounds like a dangerous idea, but it actually gives vertebrates the equivalent of the airbag protection in a car. The skin and muscles are much more deformable and elastic than bones, so they can absorb energy upon impact, protecting the relatively brittle bones. The skin can be covered with highly sensitive tactile receptors that signal the nervous system at the moment of impact (even before if you add projecting hairs). The central nervous system can start the relatively slow process of changing the direction of limb motion while the soft tissues absorb the initial blow. You may wind up with a nasty bruise and a sore muscle, but you will likely recover; a broken bone is a death sentence in the wild.

Most robots are built like gigantic cockroaches. Their mechatronic guts are housed inside cylindrical shells made of extruded aluminum or molded plastic. If they collide with a rigid object, something expensive is going to break and it isn't going to heal itself no matter how long you wait. Making those protective shells much thicker is a dead end because they add weight faster than they add strength. It is that very weight and stiffness that makes those impact

forces so nasty. And moving all that weight requires even heftier internal parts like motors and gears.

Engineers hide this fatal design flaw by making sure that industrial robots perform only highly structured tasks on assembly lines "manned" only by other robots. Humans are banned lest they carelessly leave obstacles (including themselves) in the way. So how are we ever going to have personal assistive robots working beside us in our chaotically disorganized homes? No matter how good their machine vision becomes (and it is still quite poor), accidents will happen.

Robots in the human workplace are going to need the equivalent of tactile sensing skin and energy absorbing airbags all over their exterior surfaces. These won't be as pretty as the slick metal and plastic shells and they will add their own weight and challenges for heat dissipation. But you can't beat the laws of physics.

Author: Gerald Loeb is Chief Executive Officer of SynTouch LLC, a World Economic Forum Technology Pioneer for 2014, and Professor of Biomedical Engineering at the University of Southern California.

Image: Typical industrial robot manufactured by KUKA Roboter GmbH.