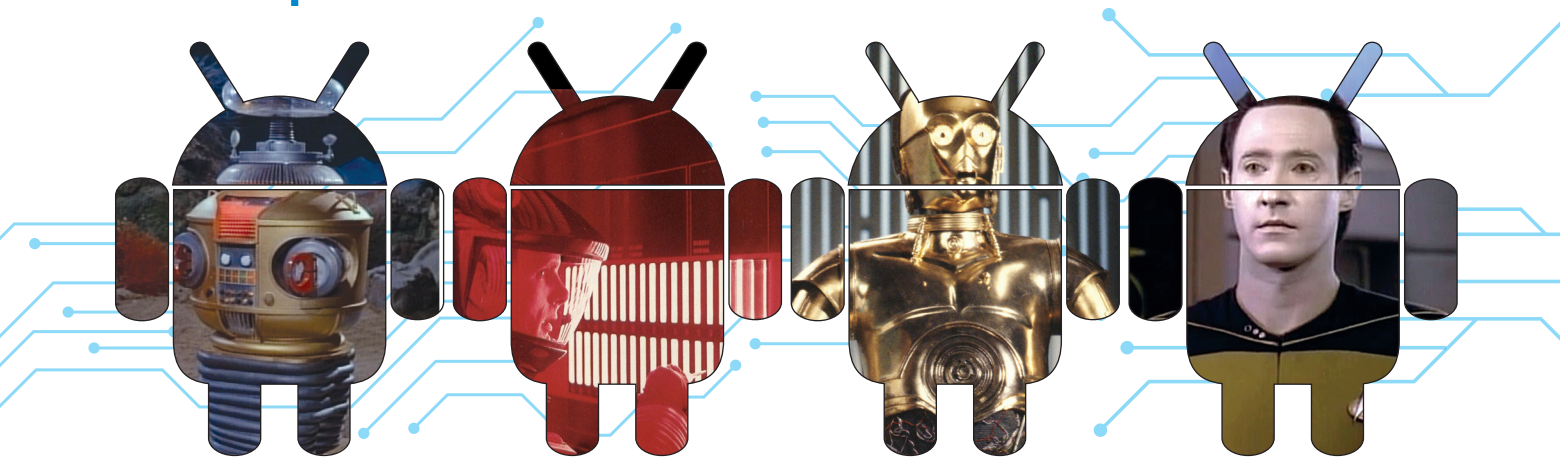
The potential of robots for humankind



I have been interested in robots and robotics since I was very young. The term robot is attributed to the author Karel Čapek through his play *R.U.R.* (*Rossum's Universal Robots*), which includes a factory that makes artificial people called roboti (robots) from synthetic organic matter.[1] Most of us think of robots as mechanical contraptions, but the robots in *R.U.R.* were artificial humanoids grown from a process that produced living, thinking beings.

My interest in robots was stimulated sometime in the 1960s by reading the novel *I, Robot* by Isaac Asimov.[2] Since then, our imaginations have been sparked by other robots, including Gort, the menacing protector in *The Day the Earth Stood Still*;[3] the robot in the television series and movie *Lost in Space* ("Danger, Will Robinson! Danger!");[4] HAL in *2001, A Space Odyssey*;[5] the freakishly violent and malevolent robot Hector in the movie *Saturn 3*;[6] R2-D2 and C-3PO from *Star Wars*;[7,8] and the android Data from *Star Trek: The Next Generation*, and his brothers.[9] Some of the robots have been humaniform (e.g., Gort, Hector, C-3PO, and Data) and others have not (e.g., HAL and R2-D2). I also remember as a teenager reading the comic books about Magnus, Robot Fighter, a human trained by a robot to battle rogue robots in the year 4000.[10]

The robotics imagined by Isaac Asimov followed (for the most part) four laws of robotics that he formulated: "(0) A robot may not harm humanity, or, by inaction, allow humanity to come to harm. (1) A robot may not injure a human being or, through inaction, allow a human being to come to harm. (2) A robot must obey the orders given it by human beings, except where such orders would conflict with the First Law. (3) A robot must protect its own existence, as long as such protection does not conflict with the First or Second Laws." The latter three laws were established in a short story published in 1942, while the zeroth law was added later.[11] Although those laws were far from logically consistent, they provided a basis for limiting people's fears of robots, particularly sentient robots.

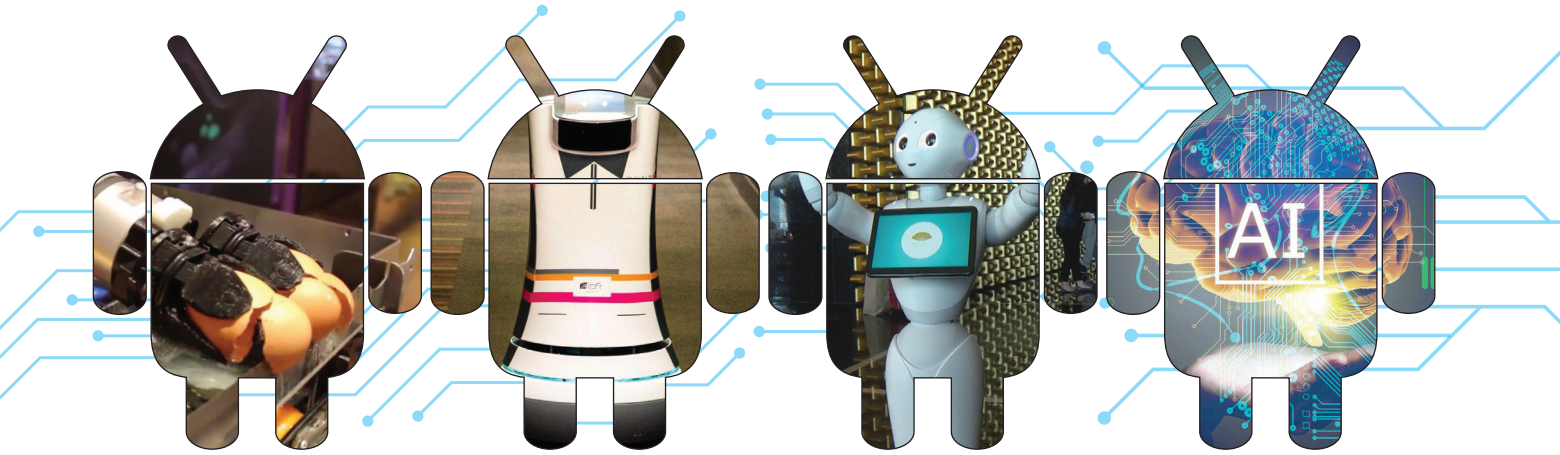
My interest in robotics was peaked again recently while reading a short article in *American Way* (the in-flight magazine of American Airlines) that discussed recent applications of robots in hotels.[12] The article discussed Ausca used at M Social in Singapore; Botlr used at Aloft in Cupertino, Calif.; Tug used at the Sheraton, Los Angeles; and Pepper used at the Mandarin Oriental in Las Vegas. Botir and Tug are used for delivery services. Ausca prepares food, specializing in egg dishes. Pepper works in the lobby, greets guests, and gives directions. Of these, Pepper is roughly humaniform, while the others are not.

Advances in robots and robotics have required significant developments in many areas of materials science. They have been facilitated by advancements in microelectronics; optoelectronics; microwave and millimeter-wave devices; structural materials, including compliant (i.e., flexible) materials (for soft robotics);[13] haptics (the perception of or sense of touch[14]); and artificial intelligence (AI)/cybernetics.[15,16] Continued advances in robotics and the development of robots require further advances in all of these areas, as well as developments in advanced materials, such as quantum materials.[17]

For some of us, our everyday lives are already being affected by robots and robotics (e.g., a Roomba cleans our floors, self-driving automobiles transport us or goods that we use). In the context of Asimov's four laws, we are currently dealing with two situations in which autonomous vehicles have been involved in accidents, leading to human death. Human-driven automobiles contain sensors and control systems that enhance safety, driving comfort, and ease of navigation. Airplanes have autopilot systems that control flight in the aircraft during some parts of flights, such as during takeoff and landing. Robotics is used in manufacturing, surgery, and dentistry. There are even robotic chefs, although I don't know of any four-star robotic chefs. Whence did all of this arise? Much of the initial impetus for the development of robotics came from science fiction stories, such as those discussed previously, which gave us a sense of their capabilities.

The imaginations of the science fiction masters of the early and middle parts of the 20th century were phenomenal. Sentient robots were created at a time when computers were driven by vacuum-tube technology and had significantly fewer capabilities than today's handheld calculators or cell phones. At the latter end of that time period (1947), transistors came into being,[18] but they were huge by today's nanoscale standards. Prior to 1958,

https://doi.org/10.1557/mrs.2018.117 Published online by Cambridge University Press



integrated circuits did not exist.[19] We've come a long way in the intervening years. It's hard to imagine a human-scale robot with AI based on vacuum-tube technology. But it's possible to imagine a 3D integrated system of chips having significant intellectual capabilities that would fit within a volume similar to a human brain. However, AI (true sentience) requires further developments, perhaps based upon novel computer architectures, or something such as fuzzy logic, or quantum computers, or all of the above coupled with novel materials (see the article on quantum materials by Philip Ball[17]). Lest you think that these musings are mere flights of fancy from my feeble imagination, I note that others have termed the emergence of AI as the "technological singularity" and view that emergence as not being far in the future.[20]

If we create true AIs, it is likely that some of them will reside in robotic systems, and some of those will be humaniform. Some may have bodies and mannerisms similar to humans, such as the android Data,[9] which will require developments not only in AI, but also in software, sensors, haptics, and compliant materials (the so-called soft robotics mentioned previously). Materials researchers will undoubtedly play significant roles in these developments.

If we create AIs in humaniform bodies, including androids, how will we treat them? Will we grant them rights to live among us in freedom and harmony? Or will we see them as less than human and treat them as servants or slaves? Asimov imagined restrictions on robots, but it's not clear how these restrictions would be enabled. Would AIs be powered by software with restrictions written into the code? (Imagine the horror of software bugs.) Would the restrictions be based upon circuit design or a combination of circuit design along with novel materials? Or would we create AIs and attempt to teach them ethics, empathy, and compassion, as we do with children? The latter approach forces us to consider that AIs may demonstrate a similar range of behavioral characteristics as humans, good and bad.

If AI becomes a reality with robotic AIs and intelligent androids, we will likely need to confront these issues. How we accomplish that is likely to determine whether we will live in the dystopian future of *R.U.R.*, a future containing robot overlords voiced by Ken Jennings[21] on the television game show *Jeopardy*, or a utopian future living in harmony with a new species.

I, for one, want advanced robots (not necessarily sentient ones) that will clean my house, prepare my meals, wash and dry and iron my clothes, complete my gardening, and take care of all of my other chores. If it could also mix the perfect drink and bring it (them) to me while I lounge on my deck, all the better. But I don't want a truly intelligent being to be any kind of captive servant. I could use an AI to help me with many tasks (personal and professional), but I would want the arrangement to be mutually beneficial and agreed upon by both parties. It will be interesting to see whether developments in robotics benefit humankind or lead to conflict and some kind of dystopian future dominated by robot overlords. As materials researchers, we have responsibilities for the materials and technologies at play. As human beings, we have responsibilities for the ethical and moral considerations. Our future will be interesting. I am cautiously optimistic that we will make the right choices, and that our research will pave the way toward a brighter future for humanity (and possibly some new friends).

Steve Moss

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