ON OUR RADAR

HUMANS IN THE LOOP: Advances in Robotics and Autonomous Systems

By Frank DiMeo Jr.

Law #1: A robot may not injure a human being, or through inaction, allow a human being to come to harm.
Law #2: A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
Law #3: A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

— Isaac Asimov, Laws of Robotics from ***I, Robot***, 1950

If you must break the law, do it to seize power: in all other cases observe it.

— Julius Caesar, Roman General and Statesman, 100-44 BC

We are at the edge of a Cambrian explosion in robotics and autonomous systems. Capabilities being demonstrated by government-sponsored research organizations and backyard hobbyists alike are incredibly impressive, from biomimetic robotic birds to Unmanned Aerial Vehicles (UAVs) built from LEGO® bricks. Progress in this new era will be fast moving, commercially driven, and a result of unprecedented integration — to the point of blurring the distinction between hardware and software.

Despite our collective fascination with robotics and autonomous devices both real and fictional, they will for the foreseeable future remain deterministic machines, governed not by Asimov's laws but by a combination of economics and programming. Robotics and autonomous systems will be embraced whenever the risk-adjusted return on investment for developing and deploying them is compelling.[1] The philosophical question, "Will humans be in the loop?" can be answered definitively: "Yes, humans will always be in the loop," with the tacit acknowledgement that "in the loop" means responsible for the programming, algorithms, and decision-making implementation of robotics and autonomous systems. It does not mean that a human will be informed of, let alone be able to respond to or override, the outcomes that occur in the milliseconds between data collection and direct action. This suggests the possibility that we may be entering a post-informational age, where the ability to program and automate behaviors in response to information surpasses in value the mere possession of information.[2] Human programmers ultimately will be the ones responsible for upholding or breaking Asimov's laws and, to Caesar's point, to what end?

The recent growth of robotics in combat theaters has been well described[3] and is representative of the potency of the combination of economics and programming. Beyond the battlefield,[4] there are significant Intelligence Community applications and implications inherent in the anticipated expansion of robotics and autonomous systems. IQT is well-positioned to play a pivotal role in shaping the development of robotic and autonomous systems for the Intelligence Community's specific needs and anticipating the implications of the technology as it unfolds in real time. With deep expertise in physical, biological, information, and communication technologies, IQT has first-hand experience investing in robotic and autonomous systems, which directly informs a strategy for addressing both the pragmatic and strategic issues surrounding development in this area.

For the purposes of IQT's strategic approach, robots and autonomous systems can be described by their ability to exhibit "agency," the capacity to act in the world. This includes physical agency (i.e. the ability to move or manipulate physical objects) coupled with intellectual agency (i.e. a control system that responds to inputs and stimuli from its environment and takes independent responsive action). By this definition, the famous clock of London, Big Ben, would not be considered robotic or autonomous despite its legendary reliability and complex chime sequence. However, the alarm clock that actively evades you by rolling away when you try to hit the snooze button would fit the criteria. The concepts of physical and intellectual agency fit nicely with the reductionist viewpoint that everything can be classified as hardware or software; "atoms" or "bits" so to speak.

With robotics and autonomous systems defined by their ability to exhibit physical and intellectual agency, the technical challenges and opportunities in the field can be further classified into four highly overlapping categories: power, processing, platforms, and payloads (Figure 1).

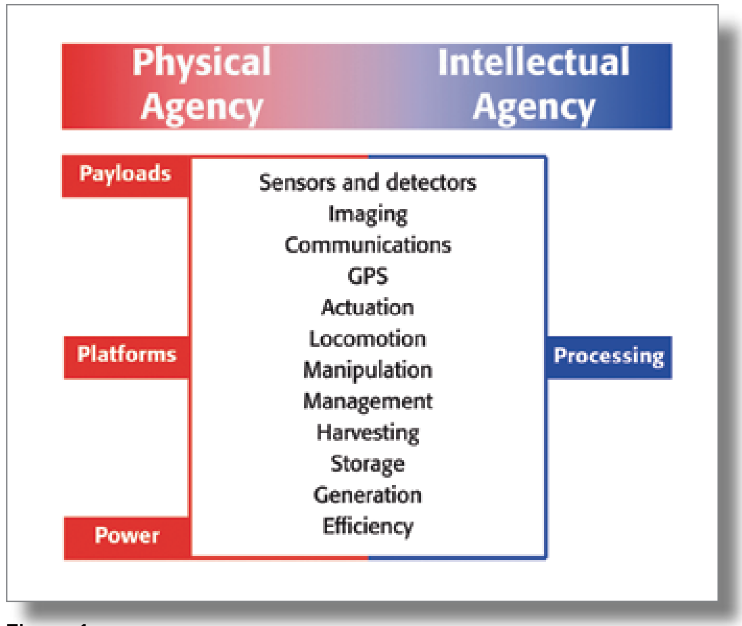

Figure 1

Power and Processing

Power management and processing capability are the foundations of robotic and autonomous systems. Ultimately, the power budget defines the mechanical agency and determines the limits of performance for duration, distance, speed, size, weight, payload capacity, etc. Equivalently, the processor capability governs the intellectual agency. The size, power consumption, and capability of one or more microprocessors go hand-in-hand with the power budget. Recent advances in robotic and autonomous systems are the direct result of power densities and energy harvesting capabilities increasingly coupled with improvements in the computational efficiencies of microprocessors and other microelectronics. Pushing the frontiers of power storage, management, and energy harvesting on all scales will remain an open challenge, but will require concrete gains over existing solutions to gain acceptance.

Platforms

The available energy dictates the form factor and mission space for a physical platform, which is the backbone of a robotic or autonomous system. This is how physical agency is manifested, through propellers, wheels, legs, arms, and a myriad of other components. Platform technology has benefited tremendously from advances in lightweight structural materials and improvements in multiphysics, computer-aided design, and simulation. Beyond the design stages, software/firmware development of algorithms to control, calibrate, and compensate are critical to the integration of the mechanical components. There remains substantial open space in the area of novel platforms. In addition to the various creative permutations on tracks and wings, biomimetic platforms continue to make impressive strides (see, for example, Dr. Hylton's article in this issue), and should continue to provide a wellspring of innovation and hybridization concepts.

Payloads

Payloads, as defined here, include both internal and external devices. For example, GPS receivers, laser range finders, acoustic sonars, stereo optical cameras, and communications packages that can be used for geospatial location and navigation can be considered internal payloads as they are integral for the system's autonomy. However, more task-oriented devices such as water samplers, radiation detectors, or electro-optic video feeds to a remote operator can be considered more traditional payloads or external devices. Core internal devices will continue to shrink at an impressive pace in size, weight, and power consumption, and increase in capability to the point that they are expected to become commoditized. This is good news for systems builders and consumers, but challenging for domestic component producers. This suggests these devices will migrate to offshore contract manufacturers. Opportunities will be available for higher level, mission-specific functional devices of reduced size, weight, and power consumption and for incorporating more computing at the edge.

Implicit in the development of robotic systems and autonomous devices is the desired characteristic of dependability. Dependability includes measures and expectations of reliability, integrity, interoperability, security, uptime, safety, ruggedness, etc. While dependability is critical for acceptance and highly non-trivial to achieve and demonstrate, it is often considered late in the development stage. As the field continues to mature, dependability of all components — hardware, firmware, and software — will need to be "designed in" as early as possible and not as an afterthought to be upgraded in the field.

These are thrilling times to be a technologist. It is not a question of if robotics and autonomous systems will become pervasive, persistent, and ubiquitous, but simply a matter of when and what the details will look like. It will assuredly also contain some surprises. We are at a point where more and more of our futuristic concepts are becoming manifest in universities, laboratories, garages, and companies worldwide. Most of these scientists, engineers, and hobbyists share an optimism that developing robotic and autonomous systems technology will result in a net positive towards the goals of peace and prosperity. In the end, robots are closer than you think, but not what you imagined. They are tools, extensions of who we are, but deterministic nonetheless, governed by economics and algorithms. They will continue to evolve with increasing complexity, and like all tools, will create both new opportunities and new threats. Q

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REFERENCES

[1] "Seven Questions for the Age of Robots", Jordan B. Pollack, Yale Bioethics Seminar, Jan 2004

[2] The Intelligethics Age, a contraction of Intelligence and Ethics (principles that govern behavior), seems to fit as a possible moniker for this particular vision of the Post Informational Age.

[3] See for example, Wired for War, by P.W. Singer, 2009

[4] The recently announced National Robotics Initiative is another example of going beyond the battlefield. It is telling that this program as unveiled by President Obama, was deemed critical for national economic defense, as key to growing our domestic manufacturing base, not for traditional Department of Defense applications, per se.