EDITORS' CHOICE

Ten robotics technologies of the year

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In this Editorial, we identify 10 exciting robotics developments and technologies, ranging from original research that may change the future of robotics to commercial products that enable basic science and drive industrial and medical innovations.

–**Guang-Zhong Yang, Robert J. Full, Neil Jacobstein, Peer Fischer, James Bellingham, Howie Choset, Henrik Christensen, Paolo Dario, Bradley J. Nelson, Russell Taylor**

1. Boston Dynamics' Atlas doing parkour.

The performance of the 1.5-m, 75-kg Atlas keeps surprising us, jumping over a log in stride with one leg while jogging and jumping over wooden boxes with no break in pace. These feats add to walking on challenging terrain, keeping its balance when disturbed, standing up, lifting and manipulating objects, and executing a back flip like a gymnast (*1*). Marc Raibert's Boston Dynamics team remains the masters of robotic balance and propulsion. Raibert observes that "the mechanical system has a mind of its own, governed by the physical structure and laws of physics." Atlas uses its vision system to align itself and to measure distances to the parkour obstacles. Although Raibert admits that not all trials could be successfully mastered, he hopes that the demonstrations serve as an inspiration for what robots can do in the near future.

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IMAGE CREDITS: 1, ATLAS ROBOT IMAGE COURTESY OF BOSTON DYNAMICS; 2, INTUITIVE SURGICAL INC.; 3, L. A. CICERO/STANFORD NEWS SERVICE; 4, (4); 5, (6); 6, C. BICKEL/ SCIENCE, DATA: E. KOPPERGER AND F. C. SIMMEL/TECHNICAL UNIVERSITY OF MUNICH; 7, SKOPEI FILMS/@TU DELFT; 8, BIODESIGN LAB/HARVARD UNIVERSITY; 9, UNIVERSAL ROBOTS A/S; 10, SONY ELECTRONICS.

Robotic surgery represents one of the most important surgical innovations in recent years, and procedures such as radical prostatectomy are increasingly performed by using a robotic approach, implying many benefits. More robotic platforms are emerging, and increased clinical uptake depends on whether issues such as cost effectiveness and barriers to wider clinical accessibility will be further addressed. Da Vinci is an early pioneer and a global market leader, and Intuitive Surgical continues to push the boundaries of surgical robotics. Through a single 2.5-cm cannula and small incision, the newly launched da Vinci single-port system allows the surgeon to control three fully wristed, elbowed instruments, combined with an articulated endoscope for deep-seated lesions (*2*).

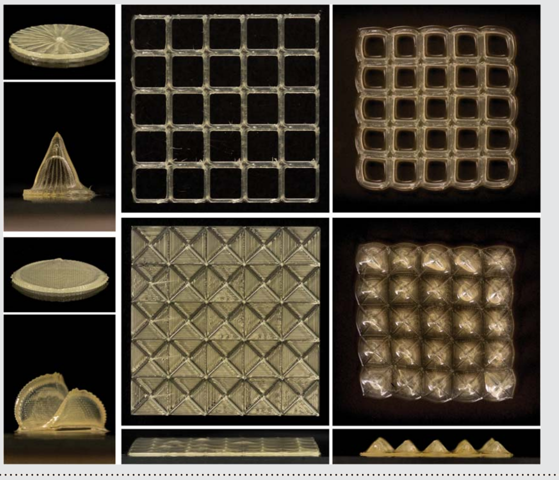
2. Intuitive Surgical's da Vinci SP platform.

3. Soft robot that navigates through growth.

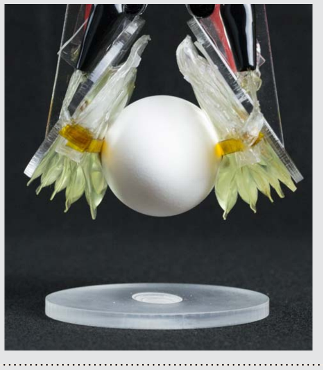
Navigation by growth at the tip opens a new direction for robots. Imagine if the growth of a vine, neuron, or fungal hyphae could be scaled up, sped up, and made steerable. The investigators took a tube of soft material that is folded inside itself but, when pressurized, grows outward as material at the front of the tube is pushed outward (*3*). This brilliant design idea addresses several grand challenges in robotics and exemplifies the use of bioinspired design by extracting a general biological principle and using it as an analogy to advance engineering beyond what is possible in nature. The soft robotic design allows obstacle avoidance in complex, unstructured environments, which holds promise for navigation in pipes and conduits, medical devices, and in exploration and search-and-rescue robots.

One of the grand challenges of robotics is to explore new materials and fabrication schemes for developing power-efficient, multifunctional and compliant actuators. 2018 saw many new developments in this burgeoning research area across different disciplines. Versatile shape-morphing liquid crystal elastomeric actuators have been used before, but this publication shows how the elastomers can be fabricated with 3D printing using high operating temperature direct ink writing with spatially programmed nematic order (*4*). These actuators demonstrated the ability to lift significantly more weight than other liquid crystal elastomers reported to date. The technique promises large area designs and dynamic functional architectures for soft robots.

4. 3D-printed liquid crystal elastomers for soft robotics.



5. Muscle-mimetic, self-healing, and hydraulically amplified actuators.



Peano-HASEL provides a soft actuator that is transparent and self-sensing, with controllable linear contractions up to 10%, a strain rate of 900% per second, and actuation at 50 Hz (*5*). The actuator uses both electrostatic and hydraulic principles to provide linear contraction upon application of a voltage without the need for pre-stretching the material or any rigid frames. The HASEL (hydraulically amplified self-healing electrostatic) actuator (*6*) is strong and versatile but cheap to produce, according to the authors, who only used a facile heat-sealing method with inexpensive commercially available materials to produce this promising technology. Remarkably, this actuator is able to lift more than 200 times its weight.

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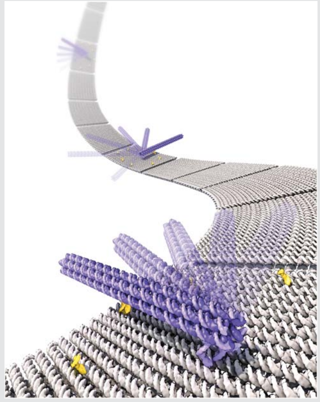
6. Self-assembled nanoscale robot from DNA.

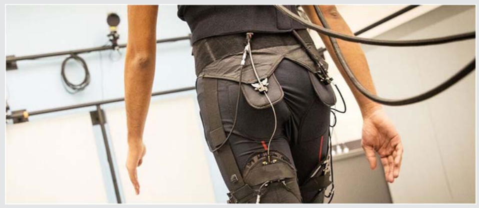


DNA origami can form different shapes at the nanoscale. By controlling a self-assembling DNA origami structure combined with a system of latches formed by single-stranded DNAs, precise nanoscale movement is now possible under an externally applied tunable electric field (*7*). These nanoscale robotic systems can be used in parallel for electrically driven transport of molecules or nanoparticles over tens of nanometers or more. The robot enables programmable synthesis and assembly of materials from the bottom up. Its positioning state may also be used as a molecular mechanical memory.

7. DelFly nimble bioinspired robotic flapper.

Many bioinspired robots serve a dual purpose, namely, developing advanced technologies with practical applications and unveiling the principles used by nature to build and program living beings. Here, we see the design of a remarkable, tailless, untethered, autonomous, programmable, small (28 g), flapping aerial vehicle with exceptional agility capable of performing 360° roll and pitch flips with angular accelerations up to 5000° s^{-2} (*8*). Although it is over 50 times the size of a fruit fly and does not mimic the wing morphology or kinematics of any specific natural flyer, the robot can serve as a novel physical model to test how flying organisms perform flight control. Surprisingly, the DelFly Nimble could accurately reproduce the rapid escape maneuvers of fruit flies even with no explicit control of all its rotation axes. We consider it a paradigmatic example of "science for robotics and robotics for science" and expect that it will advance the development of flying robots.

8. Soft exosuit wearable robot.



When it comes to wearing an exoskeleton for everyday life, most people do not want to resemble Iron Man. A lightweight, stretchy exosuit offers new ways of integrating fabric design, sensing, robotic control, and actuation to increase a wearer's strength, balance, and endurance. Potential applications include assisting the elderly in enhancing their muscular strength, supporting their mobility and independence, and rehabilitating children and adults with movement disorders due to stroke, multiple sclerosis, or Parkinson's disease. Human-in-the-loop control optimization further allows seamless integration of the robot with human, providing personalized control strategies and adaptation (*9*).

9. Universal Robots (UR) e-Series Cobots.

From research laboratories to assembly lines and logistics to surgical guidance, the UR robotic arms are becoming ubiquitous despite their unassuming appearance. The company is developing an ecosystem around its core products, and their new e-Series collaborative robot launched in 2018 echoes the general trend in collaborative automation and learning from hands-on demonstration rather than specialized programming (*10*). With enhanced safety features and force/torque sensing, we expect to see more intelligent human-robot interactions in a diverse range of environments where robots can seamlessly learn and collaborate with human operators.

10. Sony's aibo.

The return of aibo, Sony's toy dog first introduced nearly 20 years ago, is welcomed by many, and not just because of its new appearance, enhanced voice understanding, and its improved ability to learn from its owners (*11*). In addition, the robot has been developed with Sony's increasing awareness of the role robots can play in childhood learning or as a companion for the aged, particularly those with neurodegenerative diseases. Understanding the perception, interaction, and expectations of the people around the robot and developing robot behavior and personality that are context aware (not dependent on pre-scripted programs and with personalization and adaptation) are interesting topics in social robotics.

IMAGE CREDITS: 1, ATLAS ROBOT IMAGE COURTESY OF BOSTON DYNAMICS; 2, INTUITIVE SURGICAL INC.; 3, L. A. CICERO/STANFORD NEWS SERVICE; 4, (*4*); 5, (*6*); 6, C. BICKEL/*SCIENCE*, DATA: E. KOPPERGER AND F. C. SIMMEL/TECHNICAL UNIVERSITY OF MUNICH; 7, SKOPEI FILMS/@TU DELFT; 8, BIODESIGN LAB/HARVARD UNIVERSITY; 9, UNIVERSAL ROBOTS A/S; 10, SONY ELECTRONICS.

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