Hitchhiker-like suckerfish: soft robot clings to underwater surfaces

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Beihang University REPORTER

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Hitchhiker-like suckerfish: soft robot clings to underwater surfaces

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Trend-Setter and Future-Creator: Building a World-Class University Rooted in China

Editor’s note: In celebration of the 65th anniversary of the founding of Beihang University, an article by Academician Xu Huibin, President of Beihang University, was published in the world’s leading journal Science (20 October 2017, Vol. 358, Issue 6361), introducing Beihang University to the world’s scientific community.

2017 marks the 65th anniversary of Beihang University. In October 1952, the Beijing Institute of Aeronautics, now known as Beihang University, was established by merging the departments of aeronautics from eight top Chinese universities, including Tsinghua University and Peiyang University. Beihang was the first institution of higher education in aeronautics and astronautics established after the founding of the People’s Republic of China in 1949. The aspirations, history, and development of Beihang University are closely aligned with China’s growth, rejuvenation, and social progress. Since its founding, the university has consistently ranked among China’s key academic institutions. Currently, it encompasses three campuses with over 30,000 full-time students and nearly 4,000 faculty and staff. In 2016, its grand vision of “building a world-class university rooted in China” was put forward. In 2017, Beihang was chosen to participate in the “Double First-Class” plan, which includes major support from the Chinese Ministry of Education and other government departments to build a world-class university with world-class disciplines.

The Beihang University culture

Characterized by world-class faculty, high-caliber innovators, and first-rate scientific research, top universities around the world are expected to make significant contributions to the development of human civilization and social progress. Beihang University is no different and is committed to a global outlook, characterized by innovation and the development of state-of-the-art technologies that will establish it as a premier, forward-looking institution. Building upon its contributions to Chinese society, the university is forging a path toward world-class status based on its unique characteristics.

Beihang University prioritizes the cultivation of exceptional students, adhering to the ideology of “nurturing top students into first-class talents”. Through its two-pronged approach of building both knowledge and technical
In 2017, Beihang University is undergoing the largest reform in its academic structure since its inception. It will continue to uphold the ideals of being “student-oriented, knowledge-based, integrated, innovative, and open” by establishing the Beihang Institute, which will focus on supporting freshmen and sophomore students. These students are admitted to the university based on their aptitude in general disciplines, and will be nurtured with a general education in a broad range of subjects. In addition, resources are being distributed across the university to integrate and coordinate the development of different schools with the aim of cultivating multidisciplinary leaders with strong aspirations, knowledge, vision, and a truth-seeking spirit. Many of China’s most talented students aspire to enter Beihang, but only about 3,000 of the nearly 10 million candidates who take the annual nationwide college entrance examination qualify for admittance.

Enriching research excellence

Academic research is paramount at Beihang University. Establishing a solid scientific foundation and innovative capacity that caters to the country’s national strategic needs is therefore a high priority. In 2017, in ShanghaiRanking’s Global Ranking of Academic Subjects, Beihang University ranked second worldwide and the top nationwide in aerospace engineering. With respect to research on cutting-edge technologies, the university ranks among the top schools in China. It has received a record 11 national-level awards for its scientific accomplishments in recent years, affirming the success of the “Beihang model” for scientific innovation. Beihang remains committed to strengthening basic research and enhancing innovative capacity. Many high-level basic research findings have been published in top international peer-reviewed journals such as *Science* and *Nature*, exemplifying Beihang’s leading role in many fields, including bionic interfaces, thermoelectric materials, and quantum measurement. The university consistently generates academic discoveries that advance many disciplines, averaging at least one significant scientific finding every one to two months.

Encouraging interdisciplinary interactions

In the interests of pursuing cutting-edge, cross-disciplinary scientific research, Beihang University is dedicated to better integrating its engineering sciences expertise with the life and medical sciences, and has made a strategic decision to expand this mission. Part of this initiative is the Innovation Institute of Interdisciplinary Medicine-Engineering, which the university hopes will attract world-class scientists to establish China’s “Silicon Valley” for medical and engineering sciences, encompassing the Beijing-Tianjin-Hebei region but having a global influence. Nobel Laureates such as Alan J. Heeger, Albert Fert, and Thomas C. Südhof have already visited and developed close working ties with Beihang. Professor Südhof launched the “2017 SCI-Beijing Plan” together with clinical experts on spinal cord injury, aimed at benefiting millions of patients with spinal injuries. Contributions from the Beihang team led by Li Xiaoguang include the development of “spinal cord reconstruction tubes” that offer a new perspective on the treatment of patients with paraplegia. In another example of cross-disciplinary research, Liu Hong from Beihang presided over the construction of Lunar Palace 1, China’s first (and the world’s third) integrated, self-contained, experimental facility for long-duration ecosystem research. This project is among the 10 major successes coming out of China’s program to import top talent. In May 2017, an experiment using Lunar Palace 1 (codenamed “Lunar Palace 365”) was begun. It is a one-year, multiperson trial intended to provide scientific support for manned deep-space exploration.

Attracting top talent

Beihang University is also working unceasingly to re-invigorate its world-class faculty by bringing in top research talent, providing plentiful resources, and striving for excellence in all endeavors. Since its founding, the university has drawn faculty with distinguished academic backgrounds from internationally renowned universities such as the Massachusetts Institute of Technology, Imperial College London, Stanford University, and the University of Oxford. In recent years, Beihang has highlighted the leading role that senior faculty have played in elevating cross-disciplinary international research there, as well as supporting international researchers driven to address the most intractable scientific issues. The university has attracted three
Nobel Prize winners, eight eminent academicians from the U.S. National Academy of Engineering, Academia Europaea in London, U.K., the Royal Society of Edinburgh in Scotland, and 26 experts from China’s Thousand Talents Plan. In addition, three university professors were recently elected as academicians of the Chinese Academy of Sciences as well as five from the Chinese Academy of Engineering, and more than 30 professors are involved in various national high-level talent programs, such as the Changjiang Scholars Program and Distinguished Young Scholars Program. The Vision Forum for International Young Scholars—a symposium for early career scientists—has provided a pipeline to Beihang for outstanding students from top institutions, including Harvard University, the Massachusetts Institute of Technology, the University of Cambridge, and the University of Oxford.

Beihang University is firmly rooted in China, however, and maintains its focus at home while still seeking collaborations abroad. Implementation of the “university-to-university, professor-to-professor, and student-to-student” development strategy has helped to build Beihang’s network for international exchange and cooperation, significantly growing the university’s influence and competitiveness abroad. Beihang has established long-term, stable partnerships with nearly 200 well-known institutions of higher education, first-class research institutes, and multinational companies. It has joined numerous international alliances and academic organizations, including the International Astronautical Federation, the Top Academic Network for Developing Exchange and Mobility (TANDEM), and the Association of Sino-Russian Technical Universities, in addition to founding a number of high-end international cooperative ventures, such as the Sino-German Joint Software Institute and the Sino-UK Joint Laboratory for Space Science and Technology. In 2005, the Sino-French Engineering School of Beihang University was established, becoming recognized as a preeminent example of Sino-French collaboration in higher education. In 2017, the School of General Engineering was founded, which strives to be a model for international education in the field of general engineering. The following centers have also been established at Beihang University: the Regional Center for Space Science and Technology Education in Asia and the Pacific, the Asia-Pacific Space Cooperation Organization Education and Training Center, and the BeiDou International Communication and Training Center. Meanwhile, the Beihang BeiDou Silk Road Institute has been founded jointly with top universities in countries along the ancient land and maritime trading routes known as the Silk Road, marking the initiation of the BeiDou Navigation Satellite System service to the One Belt, One Road Initiative.

Beihang University prides itself on faculty and staff who are passionate, motivated, and accountable. It is a campus where Chinese culture meets the West, science is interwoven with art, history and innovation coexist, and enthusiasm and inspiration work synergistically to spark creativity. At Beihang, dreams bloom at every stage, and important destinations can be reached from every path. Over the past 65 years, the Beihang vision has been passed down from generation to generation, and many fruitful achievements have resulted. This vibrant national key university continues to forge a path unceasingly toward its goal of achieving a world-class standard in education and research, while remaining deeply connected to its domestic roots.
Beihang University Held the 3rd Vision Forum for International Young Scholars

On December 25-6, 2017, the 3rd Beihang University Vision Forum for International Young Scholars was held in the Vision International Cultural Exchange Center. The Forum was sponsored by Beihang University and organized by the Human Resource Department, the International Research Institute for Multidisciplinary Science, and the Institute for Economics and Business. Around 100 young scholars from world-class universities and research institutions including Harvard University, the University of Oxford, the University of Cambridge, and Stanford University gathered at Beihang and participated in the Forum.

Cheng Jiwei, Professor and Deputy Secretary of the CPC Beihang University Committee, Fang Jiancheng, Vice President of Beihang University and Academician of the Chinese Academy of Sciences, and Wang Yunpeng, Professor and Vice President of Beihang University attended the opening session, which also had scientists and scholars with titles of honor from a variety of disciplines, and Deans and Secretaries from the Schools. The opening session was presided over by Cheng Jiwei and Guo Lei, Professor and Executive Vice Dean of the International Research Institute for Multidisciplinary Science.

In his opening speech, Vice President Fang Jiancheng expressed his gratitude and extended greetings to the young scholars who had travelled long distances. He pointed out that China has put forward in due course the overall plan for building world-class universities and first-class disciplines, which indicates the country, in a “new era”, has greater expectations for higher education institutions to carry on the mission for the elevation of morality and cultivation of personality, and to develop through innovation. A new wave of development is coming, and the contribution of talents plays an important part. Beihang University highly values the contribution of talents and makes efforts to provide them with the best opportunities. The Vision Forum is a stage for young scholars to showcase their academic achievements.

He pointed out that Beihang, aiming at world-class standards, keeping
Beihang University Vision Forum for International Young Scholars, planned to be held twice a year, aims at advancing the frontier of sciences and promoting scientific research across disciplines and success of young scholars. The Forum creates a suitable platform and a network of academic exchanges for outstanding young scholars worldwide and to build a talent team with world-class competitiveness. In providing support for the development of talents, Beihang University Vision Forum for International Young Scholars, planned to be held twice a year, aims at advancing the frontier of sciences and promoting scientific research across disciplines and success of young scholars. The Forum creates a suitable platform and a network of academic exchanges for outstanding young scholars worldwide and to build a talent team with world-class competitiveness. In providing support for the development of talents,
Professor Wenfei Fan was Honored Membership of Academia Europaea

Professor Wenfei Fan was elected Member of Academia Europaea in August, 2017, due to his “outstanding achievements as a researcher”.

Professor Wenfei Fan has made fundamental contributions to both foundations and practice of data management. He is recognized for initiating the formal approach to scalable querying of big data, reshaping the field of data quality, and opening up the field of constraints for semi-structured data. He developed a bounded evaluation theory for querying big data. Based on the theory, a new query evaluation paradigm has been developed, and is verified by industry to be able to improve the performance by orders of magnitude. He proposed a parallel computation model based on simultaneous fixpoint computation with partial evaluation and incremental computation. It is able to parallelize existing sequential (single-machine) graph algorithms, and makes parallel graph computations accessible to a large group of users. He established foundations for each and every of the five central issues of data quality (data consistency, accuracy, timeliness, completeness and entity resolution). He proposed a now standard notion of conditional dependencies that apply to data cleaning, and developed a package of practical methods for improving data quality. He was a pioneer of the field of integrity constraints for XML and graphs, now a mature area well represented in the full spectrum of database research. His work is characterized by developing theories that go beyond theory papers and find practical applications in industry products and standards.

Professor Wenfei Fan is one of the world’s top “all-around” database researchers. He is one of the two “Grand Slam” title winners who have collected major awards from all four leading international database theory and systems conferences in the history of database research. He is recipient of the Best Paper Award for ACM SIGMOD Conference on Management of Data (2017), the Alberto O. Mendelzon Test-of-Time Award of ACM Symposium on Principles of Database Systems (PODS) for papers with the highest impact over 10 years (2015 and 2010), the Best Paper Award for International Conference on Very Large Data Bases (VLDB, 2010), and the Best Paper Award of IEEE International Conference on Data Engineering (ICDE, 2007). He is the Chair of Web Data Management at the University of Edinburgh, Fellow of the Royal Society of Edinburgh (UK), and Fellow of the ACM (USA).

As Yangtze River Scholar and national expert of Global Talent 1000 Program, Professor Fan has been contributing to state key research projects, and promoting China-based research to the world. His team at Beihang University is currently developing a parallel graph engine (GRAPE) and a system for querying big relations with bounded resources (BEAS). The team is committed to delivering the first big-data analytics systems made in China, and taking the global lead in this important area of computing, both in academia and industry.

Founded in 1988, Academia Europaea is the Academy of Europe. It currently has 3470 members, including leading experts from the physical sciences and technology, biological sciences and medicine, mathematics, the letters and humanities, social and cognitive sciences, economics and the law. Its members are usually from the states of the Council of Europe, and foreign members from other nations across the world.

Election to Academia Europaea is competitive, with a primary criterion for membership: “sustained academic excellence in the candidate’s field” (2009 Regulations, Section 2). A candidate must be nominated by two members of the Academia, one of whom must be resident in a different country from that of the candidate. Nominated candidates are assessed and ranked by committee members of corresponding Section. Individual Section ranks its candidates and submits a report to its respective Class Chair. After a meeting convened by the Class Chair, a moderated, consolidated single class list of candidates is recommended to Council, for election to the Academy.

An organization of eminent, individual scientists and scholars, its membership includes 73 Nobel laureates, 6 A. M. Turing Award winners, and 15 Fields Medal winners. It covers the full range of academic disciplines including humanities, social sciences, natural sciences, and science and technology. The Academy organizes meetings and workshops, provides scientific and scholarly advice, and publishes the ‘European Review’.

(Wang Rui reporting)
CFRP-ECC hybrid for strengthening concrete structures

Carbon fiber reinforced polymer (CFRP) composite has attracted extensive research attention for strengthening concrete structures. International design guidelines have been published for strengthening of concrete structures using externally bonded CFRP systems. This is because CFRP has shown desirable advantages including lightweight, low thermal conductivity, and high resistance to corrosion and chemical attack.

Most of the studies used polymer based materials (like epoxy) as the adhesive for bonding the CFRP to the surface of the concrete structures. Polymer adhesives can be very effective for strengthening when there are no fire related issues. Otherwise, polymer adhesives undergo significant degradation in their mechanical properties (like modulus and strength) when subjected to elevated temperatures in a fire. This is because when the glass transition temperature (Tg) of a polymer is exceeded, the polymer will change from the glassy state to the rubbery state with a significant reduction in mechanical properties. This largely hindered the application of CFRP strengthening for concrete structures which may have fire concerns in their service lives.

This research proposed a CFRP-ECC hybrid as the external bonding layer for strengthening of concrete structures when a structural fire was a concern. Firstly the compression and tension tests were conducted on ECC exposed to elevated temperatures up to 500 degree Celsius. The effects of temperature on the compressive and tensile properties of ECC were investigated. Direct pulled-out tests were conducted to study the interface bonding behavior between CFRP and ECC under elevated temperatures up to 500 degree Celsius. Various CFRP bond lengths were used in the pull-out tests in order to find out the effective bond length of the CFRP-ECC hybrid. Finally, four-point bending tests were conducted on steel reinforced concrete beams strengthened with the CFRP-ECC hybrid.

After 28 days curing time, dogbone-shaped specimens were heated in a muffle furnace. When the target temperature was reached, it was held for one hour to make sure the temperature of the specimens became uniform and stable. Then the specimens were taken out of the furnace and cooled down to the room temperature, after which the tension tests were conducted.
out tests were conducted on a MTS 810 material testing system with a loading capacity of 100 kN.

Three steel reinforced concrete beams were prepared. The first beam was used as reference. The second beam was strengthened with CFRP-ECC hybrid system. The third beam was the same as the second beam except that ECC was replaced with mortar (ECC without PVA fiber).

It was found that CFRP-ECC hybrid has improved performance under elevated temperatures up to 500 degree Celsius. From the theoretical analysis and the flexural testing of the CFRP-ECC hybrid alone, CFRP-ECC hybrid exhibited good potential for strengthening the concrete structures. The results indicate that direct casting of the fresh ECC to the concrete surface is not sufficient to ensure the bonding of the two, even though the surface of the concrete has been prepared with surface treatments beforehand. Therefore, it is highly recommended that shear keys be designed and installed on the concrete surface before attaching the CFRP-ECC hybrid layer. This would effectively secure the bond of ECC and concrete for not only room temperature applications, but also for conditions concerning elevated temperatures.

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Direct pull-out tests were conducted in order to investigate the interface behavior between CFRP and ECC of the hybrid system. In order to study the effect of the embedded length of CFRP on the interface behavior between CFRP and ECC, six embedded lengths were selected as 25 mm, 50 mm, 75 mm, 100 mm, 135 mm and 170 mm. The pull-out tests were conducted on a MTS 810 material testing system with a loading capacity of 100 kN.

Fig 3. (a) Peak pull–out stress versus CFRP embedded length of ECC specimens and (b) temperature effect on the peak pull-out stress of the ECC specimens

Fig 2. Temperature effect on the tensile stress–strain curves (left) and tensile strength and tensile strain capacity (right)

Fig 4. Failure modes of concrete beams: (a) reference beam; (b) beam with CFRP–mortar hybrid strengthening and (c) beam with CFRP–ECC hybrid strengthening

References
Effects of bursty bulk flows on global-scale current systems

Bursty bulk flows (BBFs) are often considered as the products of the near-Earth reconnection which ejects opposite plasma flows at high speed, playing effective and crucial roles in transporting the mass, momentum, and energy in the tail magnetosphere. Following the reconnection, current system often experiences large perturbations and the global magnetic field is reconfigured. Although the MHD model employed in many studies can capture BBFs and associated phenomena, a global view of the 3-D current system commonly follows schematic illustrations inferred from the simulations. Furthermore, due to the lack of kinetic physics in the MHD models, few simulation studies have unveiled the impact of BBFs on the ring current system in the inner magnetosphere.

Recently, Professor Yiqun Yu and her collaborators from the School of Space and Environment at Beihang University utilized a coupled modeling framework, in which the kinetic physics of the inner magnetosphere represented in a ring current model was coupled to the MHD model, to investigate the BBFs caused by the tail reconnection and their subsequent influences on the global-scale current system, particularly on the ring current. The powerful global model enables a full 3-D view of various current systems and their intermediate relationships.

It is found that the penetrated flows from the tail generate multiple vortices in the inner magnetosphere after they brake, significantly modulating the westward-flowing ring current. The vortices cause radially inward intrusion of the ring current and disturbances on the pressure distribution, which gives rise to field-aligned component of the current system. When the current is largely disturbed towards the high latitude, it is diverted into the ionosphere as a form of field-aligned current (FACs), leading to current eddies there.

Such a diversion of FACs from the inner magnetosphere ring current system, rather than from the tail current widely known as substorm current wedge, is discovered with the aid of a combination of a global MHD model and a kinetic ring current model. The simulation reveals important mesoscale structures in the inner magnetosphere associated with the tail substorm injections, which is very difficult to reconstruct even with multi-spacecraft observations.

Fig. Three-dimensional view of the current systems (colored streamlines) following fast flows from the tail brake around $X=-10$ Re. Two types of vortices (contours in the equatorial plane) are formed, one at the edge of the braking region, and the other in the inner magnetosphere. The westward ring current is disturbed to arch towards high latitudes, giving rise to field-aligned currents (FACs) to be connected to the ionosphere. This connection between the westward ring current and ionosphere current via FACs is new in addition to the substorm current wedge that connects the tail currents with the ionosphere via FACs.

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Reference
Breakthrough in ‘recipe’ for inkjet printing of new graphene-like materials enables high-volume manufacturing of next-generation lasers and optoelectronic devices

In this research, stable black phosphorous (BP) ink with high performance was demonstrated to overcome the obstacles of BP fabrication. The printed BP optical device employed in fiber lasers and detectors presents excellent performance. The research opens up new opportunities for graphene-like material-based optoelectronics and photonics applications, making it possible large-scale manufacturing of next-generation photonic and optoelectronic devices.

Black phosphorous (BP) is a particularly interesting post-graphene new nanomaterial that offers many opportunities for new laser and photonic devices. Yet despite remarkable performance in laboratories, real-world exploitation of this unique material has been hindered by complex material fabrication and its poor environmental stability.

A breakthrough made by Meng Zhang from Beihang University and researchers from the University of Cambridge, Imperial College London and Zhejiang University, now offers hope of overcoming this obstacle. By carefully optimizing the chemical composition through the balance of complex and competing fluidic effects, stable ink compatible with conventional inkjet printing techniques was produced. This ‘recipe’ enabled the production of new functional optoelectronic devices by high-speed printing with excellent print quality and uniformity - just like the printing of intricate graphics or photographs on paper, making possible for the first time the large-scale manufacturing of BP-based photonic and optoelectronic devices.

The researchers’ work demonstrated the benefits of their novel technique by inkjet printing devices that take advantage of BP’s remarkable properties, not least its semiconducting bandgap that can be readily varied by engineering the number of atomic layers and can cover the visible and near-infrared region of the electromagnetic spectrum.

The printed BP-based nonlinear optical devices can be easily inserted into lasers to act as ultra-quick optical shutters, converting a continuous beam of laser radiation into a repetitive series of very short bursts of light (or pulses) highly suited to industrial and medical applications, such as machining, drilling, imaging and sensing. The nonlinear optical device design using BP achieves significantly better performance and operational stability than any other previous demonstrations. The team also demonstrated the ability of BP to act as an efficient and highly-responsive detector of light, extending the wavelength range over which conventional silicon-based photodetectors can operate.

The unique way to exploit this new two-dimensional material opens up many new opportunities for optoelectronics and photonics applications. More importantly, the BP ink can be seamlessly integrated with existing CMOS technologies, the inkjet printing technique developed offering tantalizing prospects of supporting the fabrication of so-called heterostructured materials that aim to capitalize on the benefits of distinct, yet complementary properties of multiple nanomaterial layers through controlled fabrication.

The researchers’ work was published in Nature Communications [8, 278 (2017)].

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Reference

Link to the paper: https://www.nature.com/articles/s41467-017-00558-1.pdf
Hitchhiker-like suckerfish: soft robot clings to underwater surfaces

The ray-finned fish can hold on tight to anything from boat hulls to jumping dolphins, even human divers. Researchers found that remora fish do this with a specially adapted fin on their undersides called a suction disc, which consists of a soft, circular “lip” and linear rows of tissue called lamellae. The lamellae sport tiny, needle-like spinules. The remora fish can use tiny muscles around the disc to change its shape to attach itself to the host; the spinules then provide major gripping power by adding friction to the equation.

Researchers from the Bio-Inspired Soft Robotics Lab of Beihang University used microcomputed tomography (microCT) to scan, segment, and reconstruct a preserved remora, turning to an environmental scanning electron microscope (ESEM) to measure the geometries of over 30 spinele samples. Then, they created a CAD model to help fabricate a multi-material 3D printed prototype with composite lamellae, which were lined with roughly 1,000 laser machined, at-scale carbon fiber spinules. In order to allow the disc to move just like a real remora disc, the researchers embedded six pneumatic actuators — basically little air pockets — that could inflate and deflate on cue.

Like the fish’s specialized sucker, the “biomimetic remora disc” can make a tight seal using the same circular pattern as the fish. And its rows of flaps, dotted with tiny spikes, allow it to raise and lower how close it is to the surface.

To test this fishy bot, researchers attached it underwater to a variety of surfaces, some rough, some smooth, some rigid and some flexible. These included real mako shark skin, plexiglass, epoxy resin and silicone elastomer. The robot clung quite nicely to all the surfaces, the researchers found.

The force needed to pull the remora robot off the smooth plexiglass was about 436 newtons, which translates to 340 times the weight of the robot itself. On rougher surfaces, the bot clung a little less tightly. It took about 167 newtons of force to pull the bot off real sharkskin, for instance.

Finally, researchers attached it to a remote-controlled submarine (ROV). When the researchers directed the robot to attach to a submerged material, like plexiglass or sharkskin, the sucker grabbed onto both in less than 4 seconds on average, holding fast until researchers pulled it off. Once stuck, it took 45 kilograms of force to remove it. The disk worked just as well on dry land as it did in water, without any noticeable loss of suction. The researchers said such systems could one day greatly extend the range of robotic undersea explorers.

The development of this unique soft robot could mark a major step forward in several studies, and researches are being conducted to study the ocean bed and the soft-skin creatures living in there. It could easily attach to the skin of sharks and dolphins to study their habits, no matter how fast they’re swimming or deep they’re underwater.

Moving ahead, the team plans to attach their bot to swimming sharks or dolphins to see its real-world applicability.

Reference

Related Links
Science Robotics paper link: http://robotics.sciencemag.org/content/2/10/eaan8072? dikEy+NTIsHhxAoPTLk&keytype=ref&siteid=robotics
MIT Technology Review: https://www.technologyreview.com/the-download/608916/scientists-have-built-a-shark-sucking-robot-that-is-hideous-and-cool/
From spatial to spatiotemporal: salient/primary video object segmentation

Segmenting salient objects in images and videos is a classic problem in the area of computer vision. In recent years, image-based salient object detection (SOD) has achieved impressive success since powerful models can be directly trained on large image datasets by using Random Forest, Stacked Autoencoders and Deep Neural Networks. In contrast, segmenting the most salient object sequence in a video (i.e., Primary Video Object) remains a challenging task. Due to the camera or object motion, the same primary object may co-occur with or be occluded by various distractors in different frames (see Fig 1), making it difficult to consistently pop-out throughout the whole video. The two main problems that prevent the fast growth of this area are summarized as follows:

1) The definition of a salient object in videos is still not very clear. We cannot directly follow the definition of image salient objects;
2) The amount of video data with per-frame pixel-level annotations is much less than that of images, which may prevent the direct end-to-end training of spatiotemporal model, especially the deep models.

To address these issues, we propose the VOS, a large-scale benchmark dataset with 200 realistic videos [1] for video-based salient object detection. To avoid ambiguous annotations, we collected two types of user data: 1) the eye-tracking data of 23 subjects viewing all the 200 videos and 2) the masks of all objects and regions in 7650 uniformly sampled keyframes that are annotated by another 4 subjects. Based on these user data, salient objects in the keyframes of a video are unambiguously annotated as the objects that consistently receive the highest density of fixations throughout the video. To the best of our knowledge, it is currently the largest dataset for video-based salient object detection. Due to this large-scale dataset, it becomes a feasible solution to directly learn a supervised or unsupervised model for video-based salient object detection. Now it is available to the public and can be downloaded from our website (www.cvteam.net).

Based on this dataset, we proposed a novel approach that efficiently predicts and propagates spatial foregroundness and backgroundness within neighborhood reversible flow for primary video object segmentation [2]. The framework of this proposed approach is shown in Fig 2, which consists of two main modules. In the spatial module, the Complementary Convolutional Neural Networks (CCNN) are trained end-to-end on massive images with manually annotated salient objects so as to simultaneously handle two complementary tasks, i.e., foreground and background estimation, with separate branches. By using CCNN, we can obtain the initialized foregroundness and backgroundness maps on each individual frame. However, such maps are not always perfectly complementary. They sometimes leave certain areas mistakenly predicted in both the foreground and background branches (see Fig 2 (d) for the black area in the fusion maps). To efficiently and accurately propagate such spatial imperfect predictions between far-away frames, we constructed neighborhood reversible flow so as to depict the most reliable temporal correspondences between superpixels in different frames. With such flow, the initialized spatial foregroundness and backgroundness are efficiently propagated along the temporal axis. In this manner, primary objects can efficiently pop-out and distractors can be further suppressed. Extensive experiments on three video datasets show that the proposed approach acts efficiently and achieves impressive performances compared with 18 state-of-the-art models.

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Historical development and future prospects of cross integration of computational mechanics and computational geometry

In industry the standard output of geometrical modeling in computer aided design (CAD) is a non-uniform rational B-Splines (NURBS) based B-Rep model, especially for free-form geometries. The predominant method used in the industry for solving structural problems is classical finite element analysis (FEA). This method typically uses linear respectively quadratic polynomials defined over non-overlapping subdomains (the elements) for geometry representation. Thus, for standard design-through-analysis workflow, a complex geometry transformation called meshing is necessary. The analysis is usually performed using a computer aided engineering (CAE) system. Although the geometric transformation can be easily achieved for many applications in solid mechanics, it constitutes a severe bottleneck for structures of highly complex geometry. In such occasions, the process is computationally very expensive, is hard to fully automate, and often leads to error-prone meshes, which have to be improved manually by the user. The transformation task is now estimated to take over 80% of the overall analysis time, and engineering designs are becoming increasingly complex (see Fig 1). Therefore, both design oriented and analysis oriented communities in engineering are urgently expecting for seamless integration between CAD and CAE, which is essentially crosses and integration between computational mechanics and computational geometry.

The first crosses and integration between computational mechanics and computational geometry happened when the concept of isoparametric analysis was proposed in the 1960s. Isoparametric elements are adopted in most commercial codes now. After Non-Uniform Rational B-Splines (NURBS) was proposed in the 1980s, computer aided design (CAD) developed fast and became a new independent subject. Then design and analysis gradually became independent, and a new cross research field named mesh generation was born. The discussions on the importance of integrating modeling and computation began at the beginning of their moving toward independence, although it essentially had just a limited influence on engineering practice until the concept of isogeometric analysis (IGA) was proposed in 2005. Seamless integration between CAD and CAE has now become one of the core issues that need to be addressed in advanced manufacture. The developmental level of advanced manufacture is an important indicator of core competitiveness of a country. Thus, IGA initiated a new wave of research and, within just 12 years, introduced a vast variety of results, opening a new view on future concepts for design and simulation. The IGA concept comes from isoparametric analysis. It heralds a second wave of deep crosses and integration between computational mechanics and computational geometry.

Modern industry develops for higher, faster and more refined directions. The accompanied computational solid mechanics presents high accuracy, self-adaptiveness, high efficiency, strong non-linearity, and multi-scale phenomena. The conventional low-order schemes of finite element method met with difficulties in dealing with such problems. The high-order schemes have to be adopted, which requires high-order meshes that raise new requirements on the crosses and integration between computational mechanics and computational geometry. Our research integrated the fundamental theories of computational mechanics and computational geometry and proposed the Non-Uniform Rational Lagrange (NURL) functions, so that both theories can use the same bases functions. Based on this work and our work on high-order schemes earlier, we got the support of National Natural Science Fund and external sources of project-based funding to develop software that seamlessly integrates CAD and CAE (Fig 2). The information required in the process of mesh generation is adequately considered and retained in the process of geometric modelling in our codes, including the information needed in

Fig 1. Engineering designs are becoming increasingly complex, making analysis a time consuming and expensive endeavor. (Courtesy of General Dynamics / Electric Boat Corporation)
Thus, deep crosses and integration between computational mechanics and computational geometry can be accomplished. With the support of another project funded by the NSFC, we integrated analytical and numerical method and proposed the differential quadrature hierarchical finite element method (DQHFEM). We solve the numerical stability and computational efficiency problem of high-order schemes, the problem having been confusing the computational mechanics circles since the proposal of the finite element method. On this basis, we further solve the problem of high-order mesh generation by integrating with IGA. The DQHFEM only needs to generate meshes once, which greatly simplifies the bottleneck problem of pre-process that restricted the application of FEM. The DQHFEM integrated with the seamless integration of CAD and CAE technologies can accomplish high accuracy, self-adaptiveness, high efficiency, strong non-linearity, and multi-scale analyses. The high accuracy (Fig 3) and self-adaptive capabilities of the DQHFEM have advantages in frontier research such as attitude control simulation of space telescope (needs accuracy about 8 significant digits) and 3D printing simulation (needs self-adaptiveness). The DQHFEM is not sensitive with mesh distortion (Fig 4), and can reach much higher accuracy (Fig 5) using much less degrees of freedom (DOFs), which are important in multi-scale (has singularities) and strong non-linearity (needs a lot of iterations) simulations.

References
Regulation of polymer topological structure

The regulation of polymer topological structure is an important research direction in polymer synthesis chemistry. The common topological structures of polymers include linear structure, branched structure, hyperbranched structure, star structure and ring structure. Polymers have a variety of topological structures depending on the position of the polymer chains, for example, linear, comb, ring, hyperbranched and so on. The properties of polymers with the same chemical composition depend largely on their topological structure. By changing the topology of the polymer can be obtained different properties of polymers, so finding a simple and easy method to control the polymer topology has been a hot research topic to the polymer scientists for a long time.

Among the polymers with various structures, the linear polymer is a more transparent one, and its synthesis method is simple. Because of special structure and a spherical annular branched structure, and surface characteristics of multi functional groups, cyclic polymers and hyperbranched polymers have some unique chemical and physical properties. However, the vast majority of cyclic polymer and hyperbranched polymer synthesis methods are more complex and thus difficult to prepare, which restricts the application of cyclic polymers and hyperbranched polymers.

Recently, Professor Yuzhou Liu’s research group from the School of Chemistry of Beihang University reported their work utilizing Piers-Rubinsztajn reaction, for the first time, to form a series of cyclic polymers from simple organic silanes, as evidenced by various analysis techniques. Meanwhile, their work for the first time demonstrated the feasibility of using cyclic polymer to direct the assembly of inorganic particles, and also presented the first stable circular gold nanoparticle assembly which is soluble in organic solvents.

In recent years, with the continuous research and development in the field of polymer synthesis, the incorporation of constrained cyclotetrasiloxane into polymers has been proven to be key for a wide range of functional materials, including thin-film electrolyte, self-healing, thermal stable materials, high oxygen-permeable films, spreading reagents, liquid crystals and so on. However, the combination between the constrained siloxane rings with cyclic polymers hasn’t been investigated due to the lack of efficient way of constructing cyclotetrasiloxane ring containing cyclic polymers, and therefore the use of cyclic polyoligosiloxane polymers.

Scheme 1. (A) The cyclotetrasiloxane formation between dihydrosilane and dialkoxyysilane compounds. (B) The proposed cyclotetrasiloxane subunits formation based on reaction (A) and then their intermolecular reaction to form cyclic polyoligosiloxane polymers.
At the same time, Professor Yuzhou Liu and his team successfully synthesized a hyperbranched polymer with the in 6-membered cyclotrisiloxane constrain ring (HBP-1) from simple organic silane monomer by using Piers-Rubinsztajn reaction. The preparation of hyperbranched polymer is appealing but is hindered by the lack of control of intramolecular cyclization, which usually leads to the formation of inert loops. The team succeeded in deliberately directing the intramolecular cyclization into the formation of highly constrained and thus reactive rings, which were then used for arm attachment. In this way, simple and efficient synthesis of a hyperbranched bi-block polymer (PSt-HBP-1) and tri-block polymer with incompatible arms is realized (JHBP-1) and its potential application in self-assembly is demonstrated with the formation of interesting giant toroid structures.

Professor Yuzhou Liu’s team reported for the first time the utilization of Piers-Rubinsztajn reaction for the one-step synthesis of cyclic polysiloxanes with novel structural features. Specifically the B(C6F5)3 catalyzed coupling reaction between various organic tris(dimethylsiloxysilane and trialkoxysilane compounds generates a series of cyclic polysiloxanes with cyclotetrasiloxane subunits. The thiolated cyclic polymer is also shown effective in directing the circular assembly gold nano particles. The presence of constrained rings on the backbone is unprecedented and may bring opportunities for novel applications of these cyclic polymers.

Scheme 2. The sequential polymeric chain formation and cyclization led to cyclotrisiloxane—terminated hyperbranched polymer 1 (HBP-1).

Fig 2. TEM images of circular gold clusters coated on the surface of 14 (the insert shows the vial containing the purple CH2Cl2 solution of the gold nanoparticle assembly).

Fig 3. Comparison between different ways of making Janus-type branched polymers

Scheme 3. The preparation of JHBP-1 by ring opening reactions of the cyclotrisiloxane rings on HBP-1

Fig 4. (A–C) The AFM imaging of the self—assembled PSt–HBP–1 on the surface of silicon spin—coated with the chloroform solution of PSt–HBP–1. Image A is from the low concentration sample and images B and C are from high concentration samples. (D–F) The AFM imaging of the self-assembled JHBP–1 on the surface of silicon spin—coated with the chloroform solution of JHBP–1. Image D is from the low concentration sample and images E and F are from high concentration samples.

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References
The drying of liquid droplets

The drying of liquid droplets is a daily life phenomenon, yet is actually a complicated scientific problem, which has long held a special interest in scientific research. Droplets made of Propylene glycol (PG) and water placed on glass show complex motions; various deposition patterns have been found in the drying of liquid droplets that contain nonvolatile solute. How to control the final deposition patterns and the direction of the droplet motion is an important technique in various industry manufacturing processes, and also is an interesting multi-disciplinary problem in physics, chemistry, materials and so on. The study of this problem has wide applications in the fabrication of micro-fluid devices, self-cleaning, inject printing, and heat conduction, etc. Although tremendous experimental studies have been reported, the theoretical studies are very few resulting in the fact that the understanding of this problem is still at a preliminary stage.

We proposed a theoretical model for the drying of liquid droplets, which is based on the Onsager variational principle. We gave mechanisms behind the formation of various deposition patterns and for controlling the direction of the droplet motion. The advantage of this model is that we obtained a first order evolution equation that is much simpler to be solved than the convention Navier-Stokes equation. Our work about the drying of liquid droplets has been published in Phys. Rev. Lett.

Results show that the droplet moves from high evaporation side to low evaporation side, and from high surface tension side to low surface tension side. When droplets subject to asymmetrical surface tension and evaporation rate, evaporating droplets show attraction-repulsion-chasing behaviors. When two droplets are close to each other, the vapor density is higher in the middle region than the outside area, resulting in asymmetrical evaporation rate that actuates the droplet motion. The mechanism of droplet motion induced by an asymmetrical evaporation rate is new, and gives a new way of controlling the droplet motion.

We also investigated the deposition pattern of drying liquid droplets. We predicted that the deposition patterns can be controlled by the evaporation rate and the moving ability of the droplet contact line. For a single droplet, we showed a continuous transition of the deposition pattern from “coffee-ring” to “volcano-like” and to “mountain-like” patterns. When the contact line is pinned, the inner fluid flow induced by evaporation convects solutes to the contact line, forming the coffee-ring pattern. Oppositely, when the contact line moves freely, the inner fluid flow moves inward and convects solutes to the center of the droplet. When the contact line moving ability is in between pinned and freely moving, the solute deposits in a place between the original contact line and the center, forming the volcano-like pattern.

We further studied asymmetrical ring patterns of two neighboring drying droplets. We demonstrated that the gradient of evaporation rate along droplets is the main reason of forming asymmetrical deposition patterns for two neighboring droplets. Our model predicts that by controlling the evaporation rate combined with varying the contact line friction, fan-like and eclipse-like deposition patterns are obtained.

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References
Beihang University Calls for Global Talents

1. About the University

Founded in 1952, Beihang University (BUAA) is the first higher education institution featuring aeronautics and astronautics established after the founding of the People’s Republic of China in 1949. As one of the top research universities in China, Beihang University is under the supervision of the Ministry of Industry and Information Technology. Ever since its founding, Beihang has been the university given priority for development, one of the first 16 National Key Universities, and one of the 22 universities to establish graduate schools since degree system was reintroduced in the 1980s. It was one of the first universities to be funded by China’s government initiated “Project 211” and became a member of “Project 985” in 2001. In 2013, Beihang University became one of the first National Collaborative Innovation Centers in “Program 2011”. In 2017, Beihang was chosen as “Class A University” in the “Double First-Class” plan, which includes major support from the Chinese Ministry of Education and other government departments to build a world-class university with first-class subject areas.

Beihang University is committed to providing high-level education and research to better foster innovation and creativity in order to cultivate leaders who contribute to the development of the nation and the world. At Beihang, academic prosperity and distinctiveness are created in a wide range of subject areas including sciences, engineering, economics, management, humanities, law, philosophy, education, medicine and art. Engineering, material science, physics, computer science, and chemistry rank top 1% in the Essential Science Indicator database, with engineering ranking top 1‰, which marks its competitiveness in building world-class subject areas. There are 8 degree programs for priority development (tied for seventh in the nation), 8 fields of study (second level disciplines) for priority development in the nation, 9 programs of study for priority development in Beijing, and 10 programs of study for priority development related to national defense. There are 7 national first-class programs of study (tied for sixteenth in the nation) including aerospace science and technology, materials science and engineering, mechanics, instrument science and technology, software engineering, computer science and technology, and control science and engineering. According to results of the fourth round of assessment of programs of study nationwide released in December 2017, Beihang University has 14 programs of study listed in Class A. Aerospace science and technology, instrument science and technology, materials science and engineering, and software engineering are listed as A+ (the number of A+ programs tied for eleventh in the nation).

A large number of renowned scientists and professors including many young and promising scholars with profound attainment are contributing their wisdom and intelligence to the development of the University. Among them are 3 Nobel laureates, 24 academicians of the Chinese Academy of Sciences or the Chinese Academy of Engineering, 27 Global Talent 1000 national experts, 31 “Program 973” chief scientists, 75 Changjiang Scholars, 48 recipients of “National Science Fund for Distinguished Young Scholars”, 3 awardees of National Excellence in Teaching, 56 Global Youth Talent 1000 scholars, and 38 recipients of “National Science Fund for Outstanding Young Scholars”. Significant contributions have been made by Beihang University faculty members. A number of outstanding faculty members have been awarded First Prizes of national level science and technology awards or become prominent scientists and chief engineers.
The innovative capacity that meets the national strategic needs is a high priority for Beihang University, which enhances basic, forward-looking, and strategic high-tech research, gathers together key elements to innovation to break technology bottleneck, and, at the intersection of industry, academia, research and application, builds top innovation platforms and research groups. The total amount of scientific research activities is increasing. The per capita amounts of research expenditure rank number 1 among higher education institutions in the country. It has 9 State Key Laboratories, 4 National Engineering Research Centers, 66 provincial or ministerial-level key laboratories, 6 Innovative Research Groups of the Natural Science Foundation of China, 12 Innovative Research Groups of the Ministry of Education, 6 Innovative Research Groups of National Defense Science and Technology, and 7 Innovative Research Groups of the Ministry of Science and Technology's Key Research Areas of the Innovative Talents Promotion Plan. Since the “10th five-year plan” period, Beihang has been awarded more than 60 prizes from the three major science and technology awards at national level, including 12 national First Prizes, and 3 Second Prizes of National Natural Science Award in 13 years, which sets the record for a university receiving the highest level of national science and technology awards in consecutive years and affirms the success of the “Beihang model” for scientific innovation. Beihang remains committed to strengthening basic research and enhancing innovative capacity. Breakthroughs have been made in both the quality and quantity of papers published in top international journals including *Science* and *Nature*.

“We have started the journey toward the sky and clouds high and far, our world lit up with achievements like the bright stars”. Standing at a new historic starting point, while adhering to its traditions, principles and philosophy, Beihang University will further broaden its horizon in planning for the future, making new breakthroughs in promoting cross disciplinary innovation, fostering creative mind with elite education, constructing top talent teams, setting the trend for science and technology development, as well as expanding international cooperation. With one heart and one mind, and to forge ahead with determination, the University will quicken its pace in building a world-class university rooted in the homeland of China, with Beihang Dream a major force in realizing the Chinese Dream of the great rejuvenation of the Chinese nation. We sincerely welcome outstanding scholars worldwide to join us in this process.

2. Subject Areas for Recruitment

Materials science and engineering, information and communications technology, electronic science and technology, electrical engineering, control science and engineering, power engineering and thermal physics and engineering, aerospace science and technology, mechanics, computer science and technology, software engineering, mechanical engineering, management science and engineering, mathematics, systems science, biological and medical engineering, transportation engineering, civil engineering, reliability engineering, instrument science and technology, optoelectronics engineering, physics, nuclear science and technology, chemistry, environmental science and engineering, geophysics, interdisciplinary medicine-engineering, and other cutting-edge, cross-disciplinary or emerging research areas.

3. Qualifications and Benefits

(1)Qualifications

a. All candidates are expected to comply with laws, rules and regulations of the People’s Republic of China, with academic integrity and high ethical standards.

b. Candidates, who should be under the age of 40 (see official program announcement for further details), should be doing research in the field of natural sciences, engineering, or technology.

c. Candidates, at the time of filing the application, must have more than 36 consecutive months of overseas research or work experience (full time), and must have received the PhD degree. Those who keep an employment relationship with domestic institutions and receive salaries while working overseas are not eligible. Applicants with doctoral degree conferred in China shall not exceed the requirement for 3 years mentioned above; applicants
whose doctoral degree has been conferred overseas may exceed the requirement for 3 years, only if they have obtained outstanding results in research or have significant achievements. In this case, the employer should attach a statement to the application explaining why the applicant is qualified.

d. At the time of filing the application, the applicant must have a full-time teaching and/or research appointment at a world renowned university, research institution or well-known corporate R & D lab abroad. For those who have been working in China, the time since returning/coming to China should be less than one year.

e. After being admitted to the program, scholars should work in China for over three years.

f. The applicant should stand out among his/her peers in the field or have the potential to become leading talent in his/her field of research.

g. Before the application deadline, students, senior visiting scholars, postdoctoral researchers, and others who have been approved of national scholarship funding and/or whose overseas study and/or research has been funded by the state, are not eligible if they are not complying with scholarship rules and regulations; those who have terminated the funding agreement with relevant parties should provide documentation as justification for eligibility in their application.

(2) Benefits

Beihang University will provide competitive salary, benefits, and research funding to Global Youth Talent 1000 scholars.

a. Salary is based at ¥400,000 per annum (pretax), with potential earnings of up to ¥600,000 (pretax).

b. Housing: apartment for faculty (subject to University policy) or ¥1,000,000 one-time housing allowance (pretax)

c. Research funding: In addition to the national funding of ¥500,000 supplement plus ¥1,000,000 to ¥3,000,000 research funding, the candidate may apply for the University’s faculty start-up funds of ¥1,000,000 to ¥3,000,000.

d. Professional titles: ‘Distinguished’ Research Professor, PhD advisor

e. Resources and support: adequate number of doctoral students and “Zhuoyue” postdoctoral researchers under supervision; office and lab space

f. Family support (subject to national and local policies): high quality “k through twelve” education for children; assistance with spouse’s employment and Beijing permanent residence permit (hukou)
4. Contact

We welcome eminent scholars, both domestic and international, to join us. Individuals should contact relevant Schools to send application materials.

Queries related to policy should be directed to the Human Resource Department.
Tel: 86-10-82317776 or 86-10-82317779
E-mail: rsc@buaa.edu.cn

Other queries should be directed to the appropriate school.
School of Materials Science and Engineering
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E-mail: lyjun@buaa.edu.cn

School of Electronic Information Engineering
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