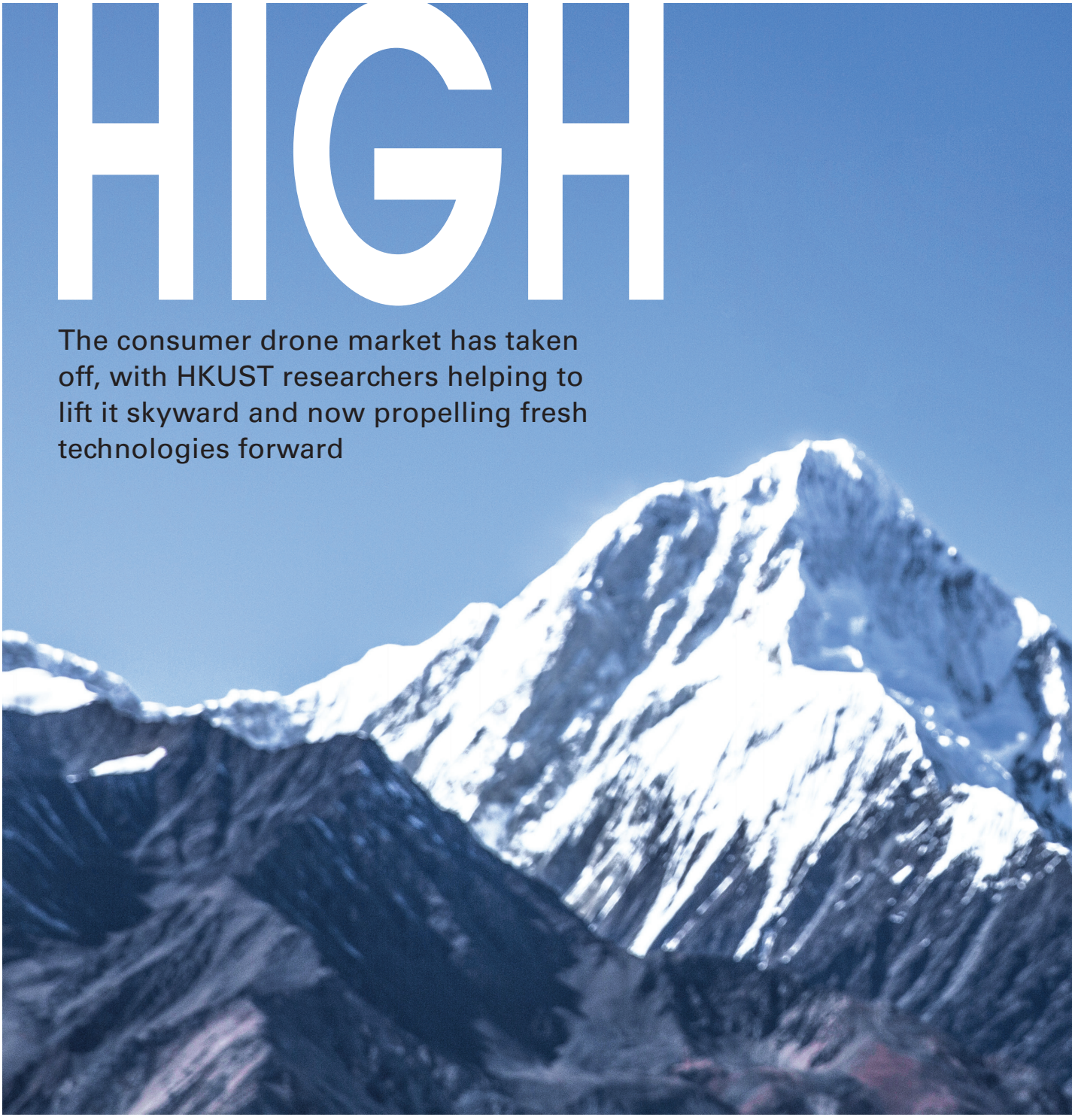
FLYING HIGH

The consumer drone market has taken off, with HKUST researchers helping to lift it skyward and now propelling fresh technologies forward



When the early prototypes of a flying robot were built at HKUST just 10 years ago by then Electronic and Computer Engineering MPhil student Frank Wang, with the help of his supervisor Prof Zexiang Li, peers and colleagues described the creations as "toys".

Yet in 2009, their unmanned miniature helicopter successfully made the world's first autonomous flights to survey Mount Everest, helping to contribute to the commercialization of a disruptive technology that has since opened the way for an amazing range of innovative civilian applications in fields as diverse as aerial photography, search and rescue, and even, potentially, book deliveries. Uses should continue to expand with the latest advances in such technology, led by researchers at HKUST.

Key Breakthrough

The quadrotor drones that Frank, Prof Li, and their team built – less than one meter in diameter, sophisticated and easy to operate – brought together important progress in motion control, communication and navigation technologies. In doing so, they fast-forwarded a global consumer and business sector expected to grow to US$4-5.6 billion by 2020, according to market estimates.* The drone industry is now dominated by DJI, the company that Frank launched in 2006, with the help of Prof Li.

The key technological breakthrough was achieved when Frank's research at HKUST employed control technologies for low-altitude flying. This built on the motion control applications that HKUST faculty members had been developing for machine tools in the manufacturing industry. However, the motion control requirements of an unmanned aerial vehicle (UAV) – as drones or flying robots are also called – are much more challenging because of unpredictable conditions in the three-dimensional environment of the air. This is where Frank, and the faculty members who supported him, exerted their expertise.

The flight controller they developed provided stability for the flying robot, operating in real time and fast enough to handle the dynamics of the platform. Hover accuracy, and agility to rapidly change orientation or altitude without becoming unstable, and robustness in strong wind conditions allowed the UAV to support further applications beyond Frank's original joy of flying model

** PR Newswire, MarketsandMarkets*

"The drones that we usually speak about these days are essentially a flying platform that can fly at low altitude and low speed, with very sophisticated functions. With that platform you can do a lot of things, seen by the many uses that are rapidly emerging"

PROF MICHAEL WANG

Professor of Mechanical and Aerospace Engineering, Electronic and Computer Engineering, Director, HKUST Robotics Institute

Leading the Way

HKUST researchers are making landmark advances in unmanned aerial vehicle technology

2006

MPhil student Frank Wang and the team developed HKUST's first autonomous flying robot.

2009

Prof Zexiang Li and his research team's unmanned drone made the world's first high-altitude autonomous flight at Mount Everest.

2010

Postgraduate students, Frank Wang and Jianyu Song, flew their unmanned autonomous helicopter across the Yarlung Zangbo Grand Canyon, Tibet, the world's deepest canyon.

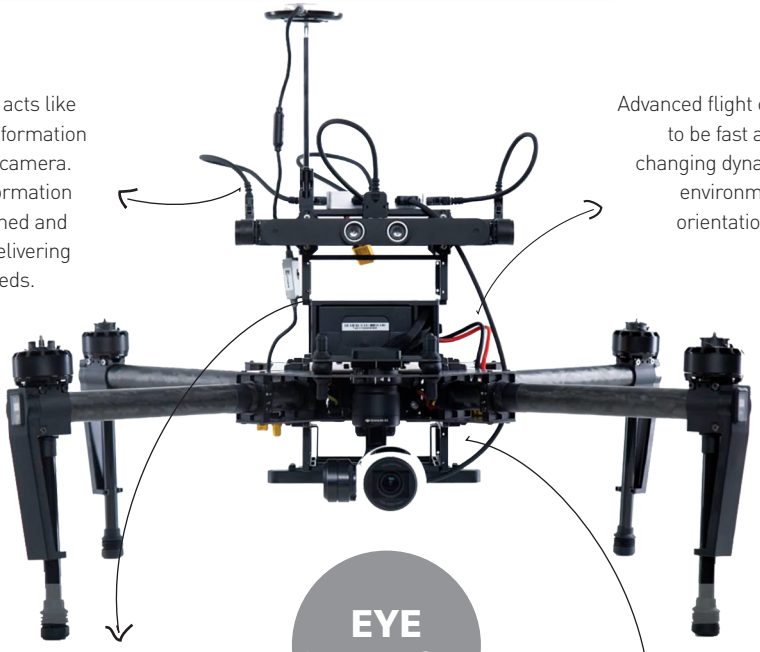
Going **Solo**

Eye

On-board computer vision system acts like the eye of the drone, processing information at 50Hz – faster than a cell phone camera. Through visual-inertial fusion, information from the drone's camera is combined and processed by an inertial sensor, delivering increased accuracy at greater speeds.

Flight controller

Advanced flight control enables the flying robot to be fast and agile, and to respond to the changing dynamics of the three-dimensional environment of the air, rapidly changing orientation or altitude without becoming unstable.



EYE
IN THE SKY

Brain

Advanced HKUST motion planning algorithms, including autonomous navigation, state estimation and perception technologies, increase the sensitivity of the flying robot and its ability to respond to its environment within 20 milliseconds of real time. This means the flying robot can independently plan its flight path.

Gimbal camera stabilizing device

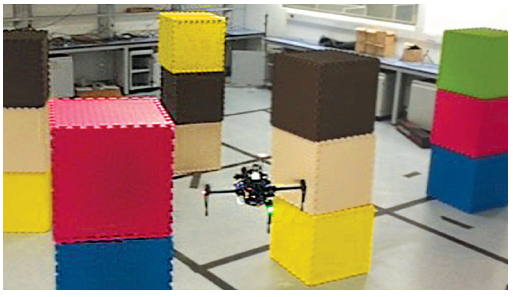
This device, coupled with communication technology, has enabled aerial photography and high-definition video to be shot and streamed from 200 meters in the air to a tablet computer in an office or at home.

2011

Frank Wang, Prof Zexiang Li and their team built a quadrotor drone, less than one meter in diameter, carrying a camera to capture stills and motion, with GPS navigation and communication data links.

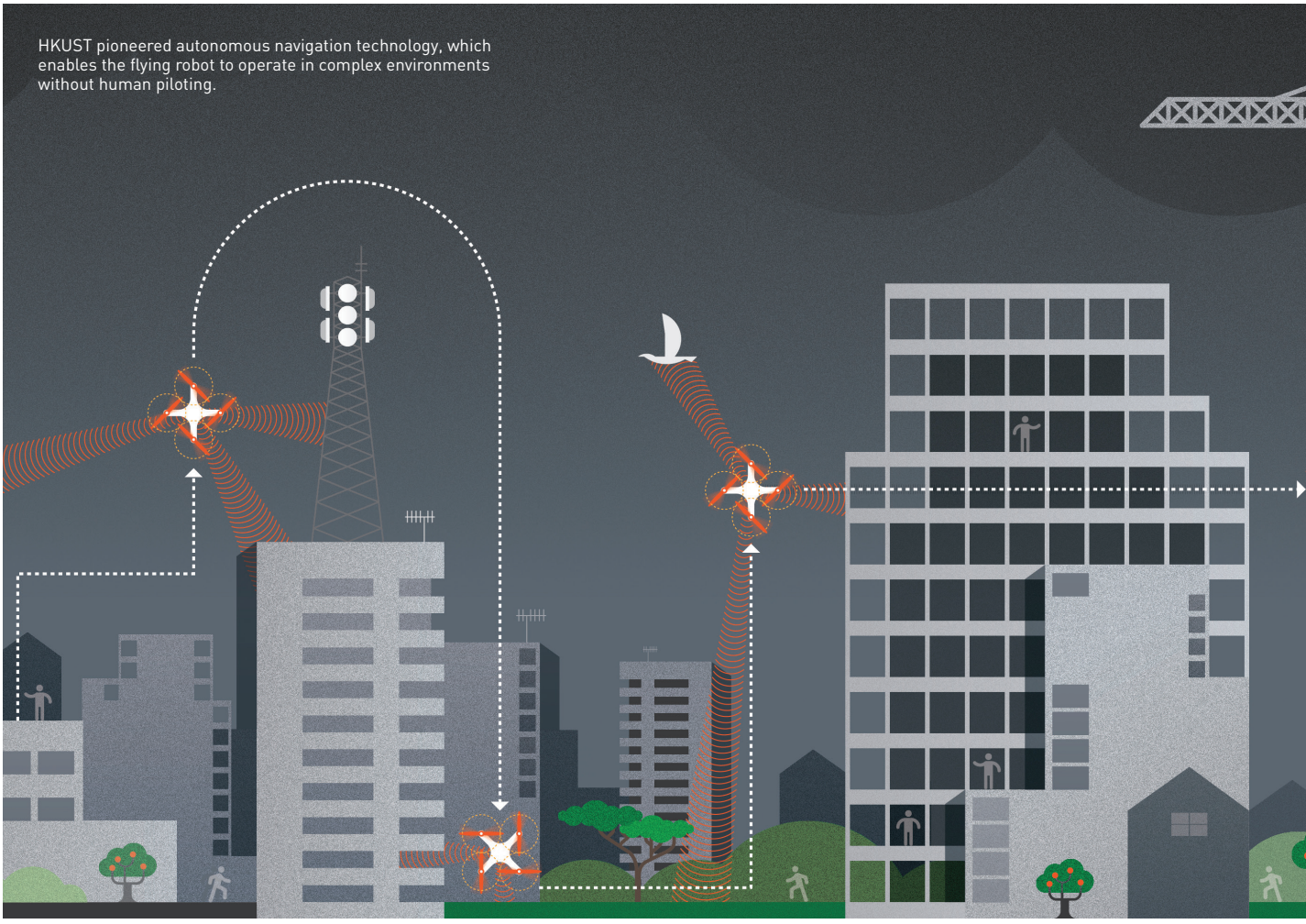
2014

HKUST PhD student Guyue Zhou developed a flying robot prototype with vision navigation, giving rise to the UAV Guidance System.



2015

Prof Shaojie Shen developed technology to free UAVs from GPS control, equipping the flying robot with its own intelligence to navigate more autonomously and respond more independently to real-time conditions.



HKUST pioneered autonomous navigation technology, which enables the flying robot to operate in complex environments without human piloting.

aircraft. The first was to carry cameras for aerial photography and movie making. GPS navigation, their gimbal camera stabilizing device, and communication data links enabled high-definition video to be shot and streamed from the robot flying 200 meters in the air to a tablet computer.

Far-reaching Autonomous Systems

HKUST is now a global leader in UAV technology. Building on this success, Autonomous Systems and Robotics is among the University's five strategic areas for development. Prof Michael Wang, Director of the new HKUST Robotics Institute, explained that the field involves many aspects of technologies from different disciplines. The Institute seeks to facilitate University-wide activity embracing electronic, mechanical, aerospace engineering, computer science, business and education. For UAVs, the Institute's focus will be further enhancement of the technologies involved to extend business and civil uses.

Prof Shaojie Shen, Department of Electronic and Computer Engineering, is among those leading such advances. He returned to his alma mater in 2014 after completing doctoral studies at the University of Pennsylvania because of HKUST's strong connections with industry, including DJI, Texas Instruments and cell phone chip company QUALCOM, among others. The particular challenge that Prof Shen is interested in is how to free UAVs from GPS control, so they can sense and evaluate the environment, and respond intelligently to situations they find while on their flight missions. Drones currently on the market still depend on people to ensure their safety in the air.

Indoor Flights

The solutions now being tested, for which patent applications are already filed, will give UAVs the sensitivity to fly indoors in

> “In two to three years, the flying robot will have the mobility to dive into forests and send medicines to people. This is not science fiction. It will happen”

PROF SHAOJIE SHEN
Assistant Professor of Electronic and Computer Engineering

cluttered spaces, and even fly through a skyscraper window. They will also be equipped with perception capabilities, utilizing algorithms to know what they need to do next – fundamental technology that will underpin future drone applications in complex environment, such as post-disaster recovery and close-range inspection of infrastructure.

The autonomous navigation technology is already enabling the vehicle to avoid most obstacles in the laboratory setting at HKUST. Testing is now underway to ensure its full reliability for commercial use, in which it will need to sense and avoid anything from a mountain to an electric wire. The applications for this new level of mobility and control are almost limitless.

Working with Industry

In addition, a number of companies that have their origins in robotics and autonomous system breakthroughs achieved by

> “Our top priority should be what kind of skills we want to equip our students with so they become a major force in advancing technology, industry and the economy – not just to set up their own companies but to change the world”

PROF ZEXIANG LI

Professor of Electronic and Computer Engineering, and Director, HKUST Automation Technology Center

Soaring **Together**

HKUST students have explored the potential of drone technology in recent international competitions.

In November 2015, a team of research students led by Prof Shaojie Shen won first prize in the International Aerial Robotics Competition, Asia/Pacific. The team used the latest autonomous navigation technology to enable the flying robot to move a number of ground robots out of the contest field.

Meanwhile, a HKUST-led team of Hong Kong undergraduates demonstrated an innovative application for drones at the 2015 Global Grand Challenges Summit, organized by the Chinese Academy of Engineering (CAE), US National Academy of Engineering and UK Royal Academy of Engineering. 15 elite teams, rigorously selected from China, the US and the UK, competed to create novel solutions. The competition was hosted by CAE in Beijing in September 2015.

The cross-disciplinary group of undergraduates presented innovative ideas and a business plan to develop drones to inspect high-rise buildings and civic structures. The entry involved a unique integrated system that could autonomously survey a building or structure using advanced simultaneous localization and mapping technologies. Thermal imaging and sensor fusion technology would enable it to recognize surface cracks and abnormality for disaster prevention and mitigation. The team was awarded third place, sharing this prize with MIT, for their impressive ideas.

Frank Wang (left) with his mentor Prof Zexiang Li.

HKUST students and their academic mentors are both benefiting from and supporting future innovation in a university-industry model, facilitated by leading international practices in intellectual property and technology transfer.

DJI is the best-known example and model for others, with an on-going relationship with HKUST. Today, DJI has grown to employ more than 5,000 people in different locations around the world. It now funds several scholarships for HKUST graduate students to pursue robotics research and several graduates have gone on to take up leading positions with the Shenzhen-based company.

Other companies co-founded by faculty and students in the area of automation include Googol Technology Limited, now a leading motion control company in China, and QKM Technology, which is pioneering the use of robotics for the assembly of smartphones and other small precision electronic products. The Zhuhai Yunzhou Intelligence Technology Limited is another successful company established by HKUST students. It develops unmanned surface vessel used for environmental protection, hydro-geological mapping and cleaning maintenance.

> “HKUST was fundamental to DJI’s development. During my studies, I was encouraged by my professors to pursue my lifelong passion for flying devices. Little did I envision then that my fantasy could realize the commercialization of a disruptive technology”

FRANK WANG

HKUST BEng 2006, MPhil 2011,
Founder and CEO, DJI

HKUST Robotics Institute **into the Intelligent Machine Age**

Robotics has the potential to be as transformative for manufacturing and society as the internet has been on our daily life and work. Robots can empower people in their daily lives, across work, leisure and domestic needs.

Economies around the world are pinning their hopes that robots will play a key role in the next generation of manufacturing, to increase efficiency, address labor shortages, and free people from work that is dull, dangerous, or dirty.

However, manufacturers face many obstacles. In the “3C” industries of computing, communications, and consumer electronics, for example, robots need to manipulate tiny parts in confined spaces with far greater precision than in well-established uses in the automobile industry. And as with unmanned aerial vehicles, there is a demand for them to be ever more intelligent in the industry and societal tasks they take on.

“To address these challenges, a totally new and innovative approach is needed to design robots,” said Prof Michael Wang, Director, HKUST Robotics Institute.

The interdisciplinary Institute builds on 25 years of cutting-edge engineering research at the University. Scientists across engineering departments will bring together leading research in areas ranging from manufacturing system design and statistical process control to advanced visual and audio interfaces and networked sensing, estimation and control.

The Institute also provides broad education in the science and technologies of robotics, and incubates innovative start-ups with the potential to propel the knowledge economy of the region to new heights.