TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. SENSORS INTEGRATED INTO 3D PRINTED OBJECTS

Three-dimensional (3D) printing is a layered, additive manufacturing practice that is increasingly gaining adoption and traction in varied industries (such as aerospace, automotive, healthcare, consumer products, and so on) to more efficiently prototype parts or objects or make them in relatively in limited volumes. 3D printing allows for reducing the tooling and process steps involved in creating parts or objects for testing, prototyping, or manufacturing.

While prototypes of an object can typically provide very useful information about an object's physical, aesthetic, or ergonomic qualities or characteristics, such prototypes do not provide a valid indication about how individuals would interact with the object. Prototyping techniques that enable human-object interaction can facilitate design and development of innovative new products that address key preferences and requirements of users.

Interactivity between people and object prototypes is facilitated by the use of touch sensors to enhance the physical prototypes. However, the use of such sensors after the prototype has been created can disturb the shape of the prototype object or may not be achievable in a prototype with complex geometries. Furthermore, touch sensors can have difficulty in being able to wrap around non-planar objects.

To enable improved human-prototype interaction, researchers at the Human Media Lab of Queen's University in Canada have introduced PrintPut, a process for creating input sensors on 3D printed objects. PrinPut allows shape design and interactivity to occur simultaneously. It embeds interactivity directly into 3D printed objects. By combining physical and interactive sketching in the same process, PrintPut enables sensors to be seamlessly printed onto 3D objects without requiring external sensor hardware.

The key elements of PrintPut include a conductive ABS (acrylonitrile buyadiene styrene) filament, dual-extruder 3D printer, and scripts to generate the conductive geometry. PrintPut's conductive filament allows for incorporating and integrating various capacitive or resistive touch or pressure sensors directly into 3D printed objects. Such sensors include capacitive or resistive buttons, resistive sliders to detect the linear position of a finger along a surface, resistive X-Y touch pad, pressure sensors (such as a galvanic skin response pressure sensor), and flex sensors. Furthermore, PrintPut sensors can also be configured in non-developable surfaces (shapes that cannot be folded into a flat configuration), such as domes, sound wave sliders, or interactive toys with multiple sensors.

"PrintPut: Resistive and Capacitive Input Widgets for Interactive 3D Prints," published in Human-Computer Interaction--INTERACT 2015 (30 August 2015), noted certain limitations to the PrintPut method. PrintPut’s resolution can be limited, since the touch points should be spaced at least 3 mm apart when a large amount of adjacent touch points are used. While this limitation could be surmounted with additional hardware or enhanced signal processing, this type of detailed resolution is likely not required for a disposable prototype. The conductive filament’s material properties and the printer extrusion process can lead to slightly inconsistent conductivity for apparently identical prints. However, baselining the sensor values or adjusting pull-down resistors can help address this issue. It may take longer than desired (around several hours) to print very large 3D models for rapid prototyping applications; although this issue could be addressed via techniques (such as the WirePrint method) that print structures as wireframes that have high resolution sections.

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2. SENSORS FOR OPTIMIZED IRRIGATION AND WATER USE

Sensors are valuable for guiding and automating the irrigation process so that crops can be efficiently given the proper amount of water at the appropriate time. Use of soil moisture sensors for irrigation can considerably reduce the temporal variability in the water content of a substrate by watering based on actual use of crop water. Achieving optimally efficient irrigation, which can significantly reduce water use, is particularly important at this point in time when certain geographic regions, such as parts the West Coast of the United States, have been experiencing a severe drought.

The water content of a substrate can be expressed in terms of the energy status of the water in the substrate (water or matric potential, which can be measured by a tensiometer) or as the amount of water in the substrate (commonly expressed on a volumetric basis, which can be determined by measuring the dielectric constant). Determining the water (or matric) potential of the substrate indicates how easily substrate water is available to plants, but does not indicate the amount of water that is present or available. The volumetric water content of a substrate indicates the amount of water present, but not whether the water is available to plants.

Dielectric soil moisture sensors determine soil moisture by measuring the dielectric constant of the soil, an electrical property dependent on moisture content. A common type of dielectric device is the capacitance sensor, in which the resonant frequency is used along with calibration to gauge the volumetric soil moisture content. Dielectric soil moisture sensors are sensitive to small changes in soil content and can provide precise resolution. However, there is a need for calibration, a relatively small zone of influence, and the possibility of soil salinity influencing the probe's reading.

In a development that can enhance the capabilities of sensors for crop monitoring, irrigation, and water conservation, researchers at the University of California, Davis, have developed a suite of sensors that can enhance effective irrigation and provide real-time plant stress information to a computer or mobile device. The technology, embodied in the LeafMon sensing device, is available from Cermetek Microelectronics (USA).

Conventional soil sensors, which sense water at a certain depth, may not accurately determine if a crop really needs water, since orchard and vineyard crops have extensive root zones. Therefore, a plant may not be suffering, although the soil is dry near the surface; moist soil is no guarantee that the plant has sufficient water.

University of California at Davis researchers helped develop pressure chambers that improve accuracy by determining how hard a plant works to pull moisture from the soil. Moreover, the researchers have made a further advancement by designing a suite of sensors, which is attached to shaded leaf and is capable of measuring varied key parameters that impact a plant's water needs: leaf temperature, light, wind speed, relative humidity, and air temperature. Such sensors interface with a wireless network to provide continuous, real-time information. The ability to continuously read plant-water stress can allow growers to customize their irrigation. For example, certain crops, such as grapes, may especially benefit from a particular level of stress at different points during the growing season.

Moreover, to further improve crop quality and yield, the sensor could be used in conjunction with other advanced irrigation methods based on remote sensing; for example, to verify or fine-tune satellite-based irrigation schedules.

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3. ACHIEVING 3D VISION FROM A DIGITAL CAMERA

Various technologies are used to achieve 3D vision or depth sensing, including stereoscopic vision (in which two cameras are used to obtain a left and right stereo image), structured light (which projects pattern projects a pattern of light onto a 3D scene and infers or computes depth and the 3D structure from the deformation or distortion of that light pattern), and time-of-flight (in which a light pulse is transmitted from an emitter (laser or LED [light-emitting diode]) to an object, and a receiver detects the reflected pulse and determines the distance of the measured object by calculating the travel time of the light pulse from the emitter to the target and back to the receiver).

Traditional 3D imaging in digital cameras typically requires taking multiple images at various distances and recording images and scenes in with two slightly offset lenses. This process for 3D photography is cumbersome and expensive, requiring twice as much data as that for a 2D image.

Researchers at Duke University have discovered a very efficient way to create high-quality 3D images in ordinary digital cameras without requiring additional hardware. The researchers leverage the sensors used for optical image stabilization (which can include angular rate sensors [also known as gyros] or accelerometers) to detect camera vibrations and motion to compensate for the camera's motion.

The researchers demonstrated the 3D imaging capability in a proof-of-concept laboratory experiment using a small deformable mirror that provides a reflective surface for directing and focusing light. The research revealed how equivalent technology in digital cameras (the image stabilization and focusing modules) could be leveraged to attain similar results without the need for additional hardware.

The experiment was aimed at deriving depth-of-field information from a single obtained image rather than using traditional 3D imaging techniques requiring multiple images, without experiencing any compromises in image quality. This visualization method, when integrated into cameras or other optical technologies, has potential to enhance core functions, such as image stabilization, and boost the speed of autofocus, for improved picture quality.

The team, led by David J. Brady, professor and leader of Duke's Imaging and Spectroscopy Program, was able to surmount the difficulties of previous single shot approaches for 3D image capture, which were susceptible to degraded two-dimensional (2D) image quality or hardware complexity. The Duke researchers developed an adaptive system that could accurately extract 3D data while also being able to capture a full resolution 2D image without requiring a significant system change, such as switching out a lens.

Image stabilization modules are used in contemporary digital cameras to remove jitter and compensate for the motion of the camera by rapidly moving the lens. The image stabilization hardware, moreover, can also alter the image capture process and record additional information about a scene. With proper software and processing, this additional information can unlock the third dimension.

The camera is enabled to record 3D information by being programmed to perform the following operations simultaneously: sweeping through the focus range with the sensor, collecting light over a set time period via an integration process, and activating the stabilization module.

As the optical stabilization is activated, it wobbles the lens to move the image in relation to a fixed point. This phenomenon, in connection with the focal sweep of the sensor, integrates the information into a single measurement in a manner that preserves the image's details while giving each focus position a different optical response. The images that would have been acquired at various focal settings are directly encoded into the measurement based on where they reside in the depth of field.

The researchers used a relatively long exposure time to compensate for the set-up of the equipment. To emulate the operation of a camera, a beam splitter was required to control the deformable lens. This extra step sacrificed about 75% of the light received. However, light loss should not be an issue and considerably faster exposure times should be possible when the approach is transitioned to a completely integrated camera without a beam splitter.

The researchers processed a single exposure taken with this camera and obtained a data cube, a computer file that included both the focused 2D image and a depth map. The depth map data describes the focus position of each pixel of the image.

A depth map for the entire scene can be constructed, as this information is already encoded into the single measurement.

A commercial 3D graphics engine is used to process the image and depth map. The resulting image can be used to determine the optimal focal setting for subsequent full-resolution 2D shots, in the manner of an autofocus algorithm, but from only one image. Synthetic refocusing may be used on the resulting 3D imagery to display the scene as viewed at different depths by a person.

Although the work was performed in a laboratory setting with surrogate technologies, the researchers believe the techniques utilized could be applied to consumer products, resulting in a more efficient autofocusing process while adding a third dimension to traditional photography.

"Image translation for single-shot focal tomography," published in *Optica*, Vol. 2, Issue 9, pp. 822-825 (2015), describes the researchers' findings. This document noted that the adjustment of longitudinal lens position has been a conventional means of addressing focus and depth of field. The Duke researchers demonstrated that the dynamic control of the transverse and longitudinal position of the lens can allow for decoding focus and extending depth of field without degradation of static resolution. The results suggest that optical image stabilization systems may be employed for autofocusing, extended depth of field, and 3D imaging.

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4. SPECTRUM SENSING IN COGNITIVE RADIOS

The increased use of wireless devices has led to the jamming and gridlock of wireless communication signals across the network. The use of spectrum for wireless communication is limited, as the devices use only a part of the predetermined range of frequency.

A cognitive radio (CR) is a radio frequency transmitter/receiver designed to intelligently detect whether a particular portion of the radio spectrum is currently in use, and to access the temporarily-unused spectrum very rapidly, without interfering with the transmissions of other authorized users. A cognitive radio system can address the need to use the entire spectrum in all frequency ranges, which would result in improved management of network congestion and provide a high-speed wireless communications with less interference. Cognitive radio technology could improve spectrum efficiency by allowing an unlicensed user to use dynamically the temporarily vacant spectrum of the licensed band assigned to primary users without harmful interference or collisions to them.

Spectrum sensing is considered the most crucial task to establish cognitive radio networks. There are several challenges (or sources of uncertainly) in spectrum sensing in CR networks, including channel uncertainly, noise uncertainly, and sensing interference limit. A key challenge is that the secondary users need to detect the presence of primary users in a licensed spectrum and be able to quit the frequency band as rapidly as possible if the corresponding primary radio emerges in order to avoid any interference to primary users. Another key challenge in spectrum sensing is to develop techniques to successfully detect very weak primary user signals.

Spectrum sensing techniques can be categorized in terms of classical spectrum sensing, cooperative spectrum sensing, multiple antenna sensing, and MIMO (multiple input, multiple output) spectrum sensing. Non-cooperative spectrum sensing occurs when a cognitive radio acts on its own. The cognitive radio configures itself based on the signals it can detect and the information with which it is pre-loaded. Classical spectrum sensing techniques include energy detection, matched filter detection, and cyclostationary feature detection.

The energy detection method detects the presence or absence of a signal by measuring the received power of the signal. The received signal is compared to a threshold that depends on the noise floor. The energy detection technique can be applied regardless of the type of primary signal and is straightforward to implement.

Matched filter detection is considered as optimal method for detection of primary users when the transmitted signal is known. In this method, a linear filter is designed to maximize the output signal to noise ratio (SNR) for given input signal. Matched filtering can take a short time to achieve spectrum sensing under a certain value of the probability of false alarm or the probability of misdetection; although it is complex to implement.

The cyclostationary feature detection method for detecting primary user transmissions exploits the cyclostationary features of the received signals. A cyclostationary signal has statistical properties that vary cyclically with time.

In a cooperative cognitive radio spectrum sensing system, sensing will be conducted by a group or network of cognitive radios that share the information they obtain with each other. Cooperative sensing relies on variations in signal strength at different network locations. Although more complicated than a single, non-cooperative system, cooperative spectrum sensing has certain benefits, such as increased agility, reduced false alarms, more accurate signal detection. This scheme is based on the tenet that a large network of radios that exchange sensed information with one another can more effectively detect a primary user than can be accomplished using individual spectrum sensing.

Multiple antenna sensing can enhance the probability of detection. Through the use of multiple antennas, spectrum sensing could be conducted in more dimensions, increasing the radios degree of freedom for determining the spectrum environment.

In single input multiple output (SIMO) multiple antenna spectrum sensing, there is one antenna at the primary user and multiple antennas at the secondary user. In MIMO spectrum sensing, multiple antennas are utilized at both the primary user and secondary user. This technique can enable more effective sensing of vacant bands.

A key challenge in cognitive radios is the high computing power required to provide the speed necessary to execute an algorithm to operate the waveform. Another challenge has been the inability to analyze the available band in a short time and in a cost effective and energy effective manner. Furthermore, it has been challenging to be achieve spectral agile device that can identify and opportunistically use the unused or under-used spectral resources.

Promising initial application opportunities for cognitive radios include prevention of military (such as Air Force) planes from signal jamming or interference from attack aircraft, as well as assuring wireless communications for soldiers on the battlefield

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5. RECENT PATENTS IN THE FIELD OF DRONES

Drones, which are usually referred to as unmanned aerial vehicles (UAVs), can be fully autonomous or remotely controlled. Operating without an on-board human pilot, drones combine various sensing and communication technologies. The different types of sensors employed by remote controlled or fully autonomous drones can include LiDAR (light detection and ranging), image sensors/cameras, proximity sensors, acceleration sensors, RADAR (radio detection and ranging), and chemical sensors. To make drones more suitable for civilian applications such as package delivery, there is interest in sensors, such as infrared or ultrasonic sensors, to help the drone avoid obstacles. While drones were initially developed for military purposes, they are poised to significantly impact multiple industries or applications, such as security and surveillance, aerial surveying, retail, commercial, pipeline investigation or monitoring, law enforcement, IT, disaster management and environmental protection, transportation, and agriculture.

Because of the growing interest in drones among various industries, from 2014 onwards, there is an uptrend in the patent filing scenario for drones. There is a growing interest in certain technologies such as autonomy, data fusion, communication security, endurance, imaging, data transfer, and cooperative control of multiple UAVs.

The patent filing scenario under drones can also be analyzed with respect to the focus area or the applications, such as drones for commercial, aerial filming, package delivery, and surveillance, miniaturized and military purposes. Governments across various countries are sponsoring drones for defense applications, while private companies or startups are focused toward commercialized applications of drones. Various companies are investing in drone startups as the application scope for drones is widening. In addition, crowd funding has become a popular source for smaller startups that focus mainly on commercial drones for hobbyists. Patents and applications related to both military and commercial applications for drones are expected to grow.

The patent filing scenario also indicates that the current trend is to develop autonomously operated drones with integrated intelligence achieved with the help of data fusion from various different sensor sources. Autonomously operated drones will have opportunities in military missions as well as in civilian applications.

North America is a major market for development and commercialization of drones for commercial and military and purposes. Asia Pacific is an emerging, expanding market for development and commercialization of drones and it is expected to gain speed from 2017 onwards.

A recent patent relative to drones (WO/2015/135951), assigned to G.A.M. PROGETTI DI GUZZARDI ANDREA E GUFFANTI MARCO SNC, pertains to the structure of a rotating-wing drone, which includes a supporting structure and a structure for protecting the propellers.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Rotating-wing drone, with intrinsically protective and accident prevention supporting structure	17.09.2015; WO/2015/135951	G.A.M. PROGETTI DI GUZZARDI ANDREA E GUFFANTI MARCO SNC	GUZZARDI, Andrea	The invention relates to the structure of a rotating-wing drone (30), made of an expanded resin having a density of from 20 to 100 g/1, obtained through expansion of pre-expanded granules inside a mold. The structure comprises a supporting structure (20), a structure for protecting the propellers (35) and a base (22), as well as means (42,45) for fastening photographic equipment or the like.
Broadband access system via drone/UAV platforms	10.06.2015; EP2880423	UBIQOMM	JALALI, Ahmad	The present disclosure describes the system and methods for providing broadband internet access to homes and enterprises using a network of aerial platforms such as drones/UAVs/balloons. Drones form and point beams toward ground terminals in different areas in a space division multiple access scheme. Ground terminals search for the drone from which they receive the strongest signals. Drone and ground terminals comprise of methods and systems to calibrate receive and transmit antenna elements. Drone radio sub-system keeps track of the drone's position and orientation changes and adjust drone's antenna beam accordingly to point to the same location on the ground as the drone moves. Depending on the changes in drone's position and orientation, the drone radio subsystem may switch the antenna aperture and/or the antenna fixture that is used to form a beam toward a specific ground terminal. Drones communicate with the terminals using a space and time division multiple access scheme.
Method and apparatus for dynamic swarming of airborne drones for a reconfigurable array	11.08.2015; US09104201	Unnikrishna Sreedharan Pillai	Unnikrishna Sreedharan Pillai	A method, system and apparatus to detect when one or more airborne unmanned aerial vehicles (drones) are close to each other, and to take necessary actions to maintain a minimum distance between drones as well as a maximum distance among the drones in a dynamic environment by automatic navigation. A computer method and apparatus for holding a group of drones in a swarm formation by maintaining the group centroid of the group of drones within a tolerance of a predetermined location is also disclosed. Additionally, methods to move a swarm of drones along a predetermined path while maintaining the swarm formation of the drones is also disclosed.

Docking device of a drone on a vehicle and vehicle associated with such a device	29.07.2015; EP2899128	NEXTER SYSTEMS	SAUTET JEAN-YVES	L'invention porte sur un dispositif d'accueil (1) pour drone (10) destiné à être embarqué à bord d'un véhicule (100) caractérisé en ce que le dispositif d'accueil (1) comporte: un support (12) destiné à supporter un drone (10), un moyen d'élévation (20) du support (12) destiné à déplacer le support (12) entre une position basse située au voisinage d'une base du moyen d'élévation (20) et une position élevée, au moins un plot aimanté solidaire de la base du moyen d'élévation (20), plot aimanté destiné à coopérer avec un élément d'arrimage magnétique (22) solidaire d'un drone pour assurer l'arrimage de ce dernier en position basse. L'invention vise également un véhicule associé à un tel dispositif.
Rotating-wing drone, with intrinsically protective and accident prevention supporting structure	17.09.2015; WO/2015/135951	G.A.M. PROGETTI DI GUZZARDI ANDREA E GUFFANTI MARCO SNC	GUZZARDI, Andrea	The invention relates to the structure of a rotating-wing drone (30), made of an expanded resin having a density of from 20 to 100 g/1, obtained through expansion of pre-expanded granules inside a mold. The structure comprises a supporting structure (20), a structure for protecting the propellers (35) and a base (22), as well as means (42,45) for fastening photographic equipment or the like.
Broadband access system via drone/UAV platforms	10.06.2015; EP2880423	UBIQOMM	JALALI, Ahmad	The present disclosure describes the system and methods for providing broadband internet access to homes and enterprises using a network of aerial platforms such as drones/UAVs/balloons. Drones form and point beams toward ground terminals in different areas in a space division multiple access scheme. Ground terminals search for the drone from which they receive the strongest signals. Drone and ground terminals comprise of methods and systems to calibrate receive and transmit antenna elements. Drone radio sub-system keeps track of the drone's position and orientation changes and adjust drone's antenna beam accordingly to point to the same location on the ground as the drone moves. Depending on the changes in drone's position and orientation, the drone radio subsystem may switch the antenna aperture and/or the antenna fixture that is used to form a beam toward a specific ground terminal. Drones communicate with the terminals using a space and time division multiple access scheme.
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Docking device of a drone on a vehicle and vehicle associated with such a device	29.07.2015; EP2899128	NEXTER SYSTEMS	SAUTET JEAN-YVES	L'invention porte sur un dispositif d'accueil (1) pour drone (10) destiné à être embarqué à bord d'un véhicule (100) caractérisé en ce que le dispositif d'accueil (1) comporte: un support (12) destiné à supporter un drone (10), un moyen d'élévation (20) du support (12) destiné à déplacer le support (12) entre une position basse située au voisinage d'une base du moyen d'élévation (20) et une position élevée, au moins un plot aimanté solidaire de la base du moyen d'élévation (20), plot aimanté destiné à coopérer avec un élément d'arrimage magnétique (22) solidaire d'un drone pour assurer l'arrimage de ce dernier en position basse. L'invention vise également un véhicule associé à un tel dispositif.

Exhibit 1 lists some of the patents related to drones.

Picture Credit: Frost & Sullivan, WIPO

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