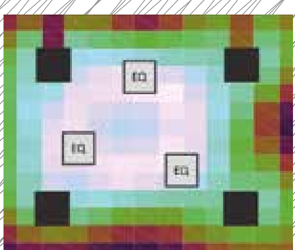
DSPE MIKRONIEK

2017 (VOL. 57) ISSUE 6

PROFESSIONAL JOURNAL ON PRECISION ENGINEERING

- THEME: **PRECISION IN AGRO**
- **DSPE OPTICS WEEK 2017** REPORT
- **2017 PRECISION FAIR** IMPRESSIONS
- ACTIVE **VIBRATION** CANCELLATION



MIKRONIEK IS A PUBLICATION OF THE DUTCH SOCIETY FOR PRECISION ENGINEERING WWW.DSPE.NL

PUBLICATION INFORMATION

Objective
Professional journal on precision engineering and the official organ of DSPE, the Dutch Society for Precision Engineering. Mikroniek provides current information about scientific, technical and business developments in the fields of precision engineering, mechatronics and optics.
The journal is read by researchers and professionals in charge of the development and realisation of advanced precision machinery.

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Publisher
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Subscription
Mikroniek is for DSPE members only.
DSPE membership is open to institutes, companies, self-employed professionals and private persons, and starts at € 80.00 (excl. VAT) per year.

Mikroniek appears six times a year.

ISSN 0026-3699

The main cover photo (representing the Trimbot counter-rotating cutter blades) is courtesy of WUR. Read the article on page 5 ff.

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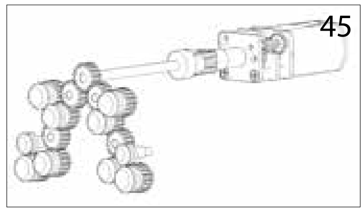
2017



FEATURES

EDITORIAL

GROWING HIGH-TECH PARTNERSHIPS

The long-term perspective of the high-tech industry demands continuous innovation, hence cooperation between industry and knowledge institutes. Creating a network where high-tech companies, either large or small, and institutes can find technology partners is the main goal for High Tech NL, established in 2013, which now incorporates some 160 members and 30 partners (non-high-tech members, regional development agencies, sector organisations and clusters both in the Netherlands and beyond). It cover ‘traditional’ high-tech domains such as micro/nano electronics, but also ‘emerging’ fields like robotics. Besides these fields of attention, High Tech NL executes the Human Capital Agenda for the top sector High Tech Systems & Materials.

Up until now, many people who are active in high-tech started their careers in industrial conglomerates such as Philips or Stork; easy collaboration in an open atmosphere is still part of their DNA. But these companies no longer cover a broad range of activities and all of their people are gradually retiring. My ambition is for High Tech NL to cater for such an ecosystem as a ‘virtual conglomerate’, where people and companies can easily engage with one another as if they were working within one big company.

For this high-tech ecosystem, our country is famous and unique. However, it is not enough to be just part of this ecosystem; for successful innovation you have to maintain solid, long-lasting partnerships. This even holds for financial partnerships. Whereas investors in start-ups in, for example, software have an exit horizon of, say, two years, for high-tech (hardware) start-ups this may well have to be seven or even ten years. Alignment with financial partners that share this vision on a longer financial horizon for the high-tech industry is one of our aims.

The same applies to technological partnerships. That’s why at the beginning of this year High Tech NL took the initiative to bring together industrial companies and scientific institutions in Holland Robotics, the successor to the earlier, stranded initiative of RoboNed. Our aim is to take national collaboration between science, industry and robotics entities to a higher level by enabling industry-driven roadmap development. We have identified business opportunities in agrifood, medical, logistics and inspection/maintenance applications, combined with a technological focus on the underlying domains, such as mechatronics, artificial intelligence (machine learning) and vision technology. We are currently working on a position paper addressed to the Dutch government.

In a similar vein, I have discussed the need for collaboration with DSPE president, Hans Krikhaar. DSPE focuses on deepening promotion of precision engineering, while High Tech NL takes a broad perspective on high-tech. At the crossroads of the two approaches we can strengthen each other. This editorial kicks off our collaboration and knowledge exchange, and the next step can be, for instance, a DSPE representative giving an in-depth presentation of precision engineering topics at a High Tech NL meeting. This could include a discussion of robotics in the cross-over of high-tech with the agrifood sector.

Food producers face the challenge of feeding nearly nine billion mouths in 2030. Here, the Dutch agrifood sector can play a crucial role, in collaboration with our high-tech industry for developing innovative machines and processes, helping the agrifood sector to achieve significant cost reductions, reduce the time-to-market and promote sustainability. But it takes time for both sectors to understand each other’s language and way of working. We are now involved in a European research project where the application of collaborative robotics (cobotics) in food processing is being investigated. DSPE members, seize the opportunity...

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CROSS-OVER BETWEEN HIGH-TECH AND AGRI- & HORTICULTURE

Food producers face the challenge of feeding nearly nine billion mouths in 2030. Here, the Dutch agrifood sector can play a crucial role, in collaboration with the high-tech industry for developing innovative machines and processes, helping the agrifood sector to achieve significant cost reductions, reduce the time-to-market and promote sustainability. Wageningen University & Research is a key player in this field, making, for example, the cross-over to high-tech for developing robots in agricultural and horticultural applications.

EDITORIAL NOTE

Input for this article was provided by Wageningen University & Research professor Eldert van Henten and staff members Jochen Hemming, Bart van Tuijl, Joris IJsselmuiden and Rick van der Zedde. Their support is acknowledged.

The agenda has been set by the Technology Roadmap High Tech to Feed the World (HT2FtW) [1] (Figure 1). By applying high-tech systems and materials along with new ICT applications, the agricultural and food sectors will be better able to handle the major societal challenges which they face. In addition, this will improve the competitiveness of these sectors in the Netherlands and create opportunities to export the new systems and applications. Conversely, the high-tech sectors are challenged to find solutions to problems that so far have obstructed the application of these systems, such as the non-uniformity of products, the sometimes harsh operating conditions and the limited innovation budget (ultimately as a consequence of low food prices in the supermarket).

HT2FtW has been developed to stimulate cooperation between all sectors concerned through cross-overs. The application fields breeding, horticulture, agriculture, animal production, ingredients, food products and machinery for food processing are intertwined with technological developments in the field of materials, data acquisition, data analysis and usage, automation and control, and system architecture and integration. This calls for fundamental and applied research in interdisciplinary programmes.

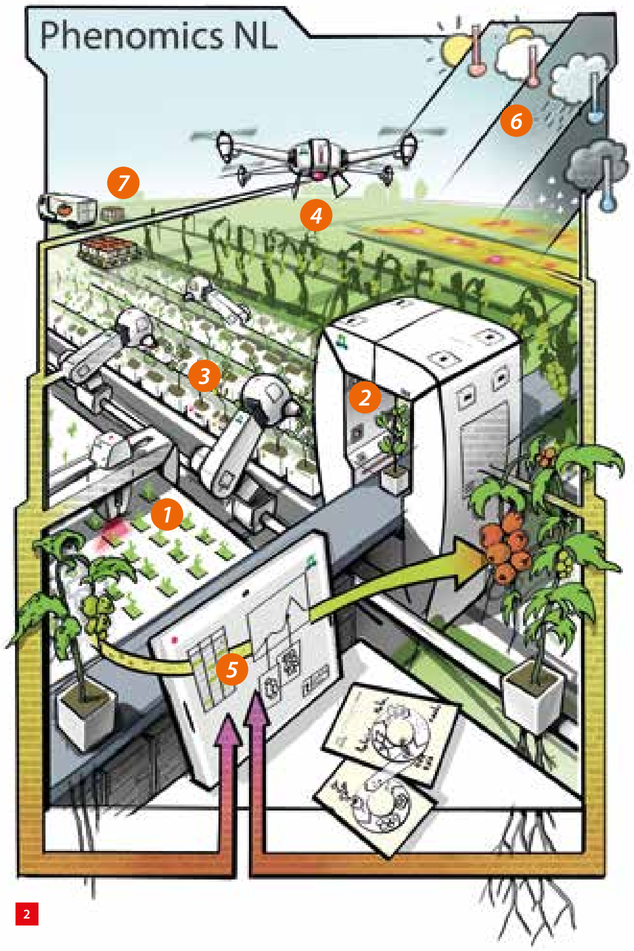
1 *The HT2FtW roadmap was published in 2015 and has been integrated in the innovation calendars of four Dutch top sectors: High Tech Systems & Materials, Agri & Food, Horticulture & Starting materials, and ICT.*

The HT2FtW roadmap (2015) was compiled by a consortium of high-tech companies, knowledge institutions and government to strengthen the cross-over collaboration and innovation. One of the key players is the 4TU federation, which comprises the three traditional Dutch universities of technology (Delft, Eindhoven and Twente) and Wageningen University & Research (WUR).

Wageningen

WUR's mission is to explore the potential of nature to improve the quality of life. Given the global challenges of population growth, agricultural area decrease and climate change (floods, droughts, new plant diseases), it is important to grow crops that can be cultivated efficiently and have high yields. WUR research groups, combined in the Phenomics NL platform [2] (Figure 2), are currently studying the behaviour of plants at different levels: from model and individual plants to the growth of crops in greenhouses and on the field.

One of the tools used are robots, for which WUR runs the Agro Food Robotics initiative [3], with four research institutes participating: Food & Biobased Research, Plant Research, Environmental Research, and Livestock Research. This covers the application of robots in the complete agrifood chain, from quality inspection of seeds, plants, crops and food products in the lab, greenhouse, field or factory, using computer vision, analytical techniques and handling systems; precision farming; processing and packaging; logistics and big data analysis.



2

Harvesting sweet pepper

An interesting project is Sweeper [4], concerned with the development of a sweet pepper harvesting robot in an ICT Robotic Use Cases project within the European Union's Horizon 2020 programme. Sweeper's main objective is to put the first generation greenhouse harvesting robots onto the market. In modern greenhouses there is considerable demand to automate labour. The availability of a skilled workforce that accepts repetitive tasks in the harsh climate conditions of a greenhouse is decreasing rapidly. In the EU Seventh Framework Programme project Crops [5] extensive research has been performed into agricultural robotics. One of the applications was a sweet pepper harvesting robot (Figure 3).

The Sweeper project involves five partners from four countries, including WUR and sweet pepper grower De Tuindershoek from the Netherlands (system integrator Irmato Industrial Solutions abandoned the project when after bankruptcy it moved over to FMI – for this reason, more technical details cannot be published yet). The consortium integrates a wide-range of disciplines: horticulture, horticultural engineering, machine vision, sensing, robotics, control, intelligent systems, software architecture, system integration and greenhouse crop management. The project will finish in the second half of 2018. First results of constructing and testing the system have been reported [6].

The robot is an assembly of several subsystems, such as a mobile autonomous platform, a robotic arm holding an end-effector for fruit harvesting, and post-harvest logistics. Software modules are based on the Robot Operating System (ROS). The end-effector (gripper) contains sensing tools for detecting sweet pepper and obstacles, and grasping the fruit without the need of an accurate measurement of its position and orientation. A time-of-flight sensor is used to record colour and 3D information simultaneously. To improve the level of robotic cognitive abilities, crop models are applied to approximate the location of sweet peppers. This 'model-based vision' will increase and speed up fruit detection, localisation and maturity rating; a special challenge is occlusion (e.g., peppers 'hidden' behind leaves). It was concluded that robot arm control does not require the initially designed nine degrees of freedom (DoFs). In the current project an off-the-shelf 6-DoF industrial robot arm (Fanuc LR-mate 201iD) is employed; this greatly reduces costs.

Trimming bushes, hedges and roses

Another 'green' Horizon 2020 project [7], TrimBot2020, does not concern a food application but is very interesting from a mechatronical perspective. The aim of this project is to investigate the underlying robotics and vision technologies and prototype the next generation of intelligent gardening consumer robots. The project is focused on the development of intelligent outdoor hedge, rose and bush trimming capabilities, allowing a robot to navigate over varying garden terrain, including typical garden obstacles, approaching hedges to restore them to their ideal tidy state, topiary-styled bushes to restore them to their ideal shape, and rose bushes to cut their flowers.

The project partners are the universities of Edinburgh (UK, coordinator), Wageningen, Amsterdam and Groningen

3

2 *The Phenomics NL platform covers seven steps in the plant production chain:*
1. *Insights into plants' stress responses*
2. *Measurements on individual plants*
3. *Quality inspection in the greenhouse*
4. *Measurements in the field (field phenotyping)*
5. *Data analysis of plants*
6. *Research into climate influence*
7. *Post-harvest quality preservation*

3 *The Horizon 2020 project Sweeper uses the technology developed in the EU FP7 project Crops to introduce, test and validate a robotic harvesting solution for sweet pepper in real-world conditions.*

PRECISION FARMING SOLUTION

Precision farming is a farm management approach that uses a wide range of enabling technologies, not only filling the gap vacated by human workers but also significantly increasing productivity through effective and efficient use of available resources. One of these technologies is an aerial robot. A proof-of-concept of an aerial Agrobot and a corresponding docking station technology has been developed and its full functionality has been successfully demonstrated.

ABEJE Y. MERSHA

Introduction

According to a recent report by the world food and agriculture organisation (FAO), the population of the world is expected to grow by 30% in 2050. This increase, together with the continuing mass migration to urban centres, will have a significant socio-economic impact. One of the sectors that is affected by this demographic change and urbanisation is the agricultural sector, which accounts for one-third of the world's GDP.

The population growth, the urban migration as well as the fact that 70% of the world's arable land has already been used, essentially leaves the agricultural sector extremely stretched. The need to feed the ever-increasing population with less manpower and less arable land has necessitated new approaches, such as precision farming. Loosely speaking, precision farming is a farm management approach that uses a wide range of enabling technologies not only filling the gap vacated by human workers, but also significantly increasing productivity through effective and efficient use of available resources. One such advanced technology is an aerial robot. Figure 1 shows the technological evolution of farming.

The use of aerial robots in the agricultural sector has the potential to enable intercropping (combined cultivation) and reduce soil compaction, which greatly contribute to high productivity and environment-friendliness. Considering the growing world population, the use of such new technologies leading to optimal use of resources in an efficient and effective manner is paramount to the perpetuation of life.

In the Twente region of the Netherlands, Machinefabriek Boessenkool and Drone4Agro are two innovative companies that have been striving to develop new technologies for more automated and efficient farming. Machinefabriek Boessenkool has developed an electric tractor, which is distinctly lightweight and has a very small wheel footprint. This leads to a significant reduction in soil compaction, and thus a more effective farming. While such innovations have led to more automated farming processes, these tractors are not fully autonomous (they are still manned). Drone4Agro is currently working towards developing the first fully autonomous aerial Agrobot, which will be employed in precision farming, while completely preventing soil compaction. However, to render the aerial Agrobot fully functional, several new technologies still need to be developed.

One of the most important features of the aerial Agrobot is autonomy. The Agrobot needs to be fully autonomous to

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1 *Evolution of farming: from using animals to tractor deployment to futuristic use of (mega) drones.*

function with little or no human intervention and to carry out specific tasks successfully. This type of autonomy makes the Agrobot appealing for use by ordinary farmers as it needs no expert pilot to fly it or manually replenish its resources (battery and liquid sprays).

This article presents the results obtained in a collaborative project that is aimed at developing a proof-of-concept for an autonomous Agrobot that can tirelessly and reliably operate 24/7. The project consortium members are Research Group Mechatronics at Saxion University of Applied Sciences, Machinefabriek Boessenkoel and Drone4Agro. The project has been partly funded by TechForFuture and RAAK-KIEM Smart Industry.

Goals

The main goal of the project is to develop a proof-of-concept for an aerial Agrobot and a corresponding docking station technology, more specifically:

- an autonomous aerial Agrobot that is capable of carrying out a crop spraying mission, and is able to precisely and robustly land on a docking station;
- a docking station technology that can autonomously replenish energy sources and payloads of the aerial Agrobot.

Within the scope of this project, a small-scale and low-cost multi-rotorcraft aerial robot with vertical take-off and landing (VTOL) capability has been used to develop and demonstrate the desired functionalities.

Approach

For development of the desired technologies, the systems engineering approach using the V-model has been adopted [1]. The V-model is one of the linear methods for methodological design and development of complex systems. Although it is linear, this methodological approach allows iteration.

Various aspects of the aerial Agrobot and the corresponding docking station technology have been developed within a span of one year by groups consisting of students and researchers with various technical backgrounds within Saxion University of Applied Sciences. The design phase of this project consisted of functional and technical designs using the user and system requirements as inputs. Various concepts that partially or fully fulfil the requirements have been first drafted and compared based on the relevant metric. Once a final concept had been chosen, technical designs of the chosen concept were elaborated and realised.

The aerial robot platform used in this project is the Parrot AR Drone 2.0 Power Edition [2], see Figure 2. Parrot AR drone is a commercially available quadrotor platform,

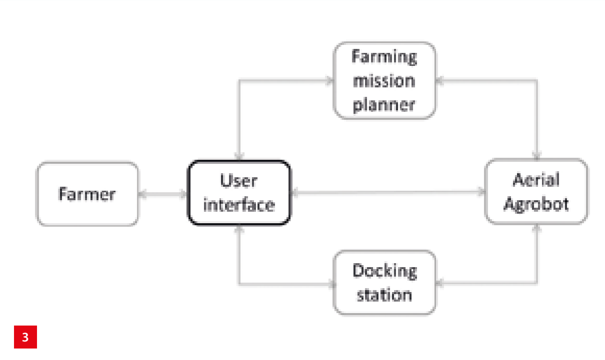
2 *Parrot AR drone.*

which is equipped with a 9-DoF (degree of freedom) inertial measurement unit (IMU), pressure sensor, ultrasonic altimeter sensor and frontal and bottom cameras. It has a 1 GHz 32-bit ARM context A8 processor, which runs the onboard controller. This platform has been chosen for its low-cost, robustness and relative safety when flying it in a confined environment close to people. The remainder of the mechanical parts for this project have mainly been 3D printed in the research group's lab.

During the course of this project the open source Robot Operating System (ROS) has been used as the main software development framework [3]. Besides other merits, ROS naturally allows modularity, facilitates the reuse of code with little or no adaptation, and permits the concurrent reuse of resources and the distribution of computational loads. Moreover, it is widely supported by a large and growing community.

Overall system architecture

The proposed farming technology using aerial robots is composed of the farmer, the aerial Agrobot, the docking station, the farming mission planner and the user interface, see Figure 3. The farmer is the user of the technology who is ultimately responsible for the farming mission and has the ability to start/abort the mission. The farmer is primarily supposed to be a specialist in farming, not in piloting the Agrobot. The farming mission planner can be a specific farming-related software program and/or hardware tool that may need to be mounted on the Agrobot for a specific mission.
The aerial Agrobot is the robot which carries out the actual mission. It is equipped with the appropriate sensors, actuators, processing unit, intelligence and autonomy to carry out the mission without the need for human intervention. The docking station, on the other hand, is an easily transportable station which is equipped with the necessary infrastructure to replenish the energy source and the mission-specific payload of the Agrobot. The farmer plans the mission, monitors the mission's status, the states of the Agrobot and the docking station using an intuitive user interface. The farmer can also control the Agrobot and the docking station using the user



3 Overall system architecture.

interface. Although all subsystems in the overall architecture are crucial, the focus in this project lies on the aerial Agrobot and the docking station technology.

Turning Parrot AR drone to Agrobot

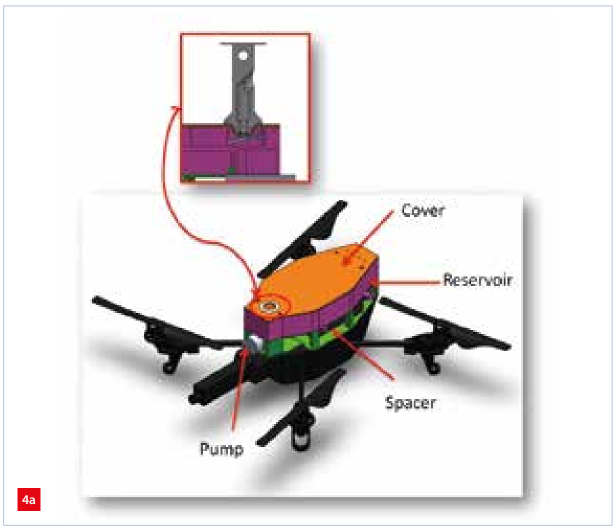
The most important requirement of the aerial Agrobot is its ability to autonomously carry out a crop spraying mission. This mission entails fundamental modification of the hardware and software of the original Parrot AR drone. For the spraying mission, the Parrot needs to be equipped with a liquid reservoir to transport the liquid payload and a pump to spray crops. Moreover, liquid level sensors, communication module and microcontroller are needed.

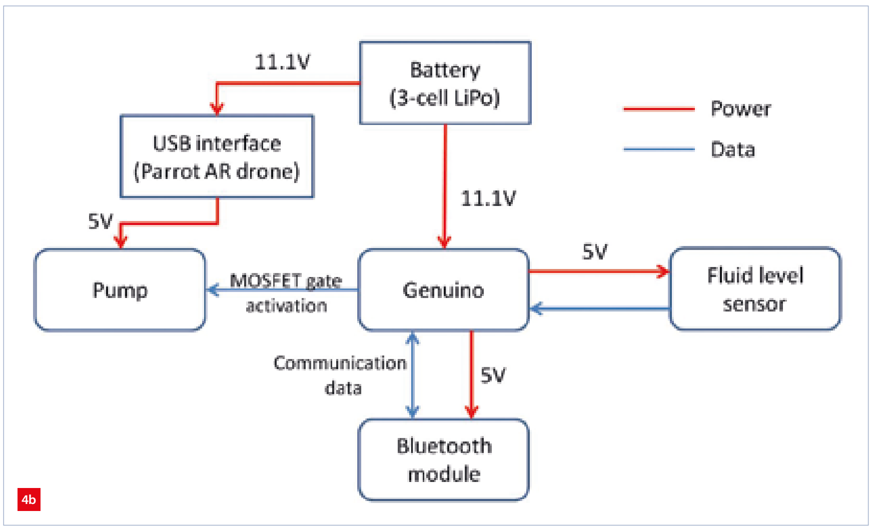
Since the maximum payload capacity of the Parrot is very low, experimentally determined to be 205 g without the protection hull, it is essential to reduce the weight of the additional onboard infrastructure. Figure 4a shows the 3D-printed liquid reservoir. The cover of the filling point has a hinge system that prevents any spilling of the fluid when the Agrobot is in operation. During refilling the hinge is pushed down and after refilling it will return to a closed position by means of a torsional spring placed inside the reservoir. The spacer on the bottom is a part created to make room for the battery and other additional hardware components.
The additional electrical components include a 5 V PWM-driven pump, a fluid level sensor based on fluid conductivity, and a bluetooth module to communicate with the ground station. A Genuino microcontroller is used to control the pump, read sensory data and monitor the battery level, see Figure 4b. In addition to their desired functionalities, the motivation for choosing these components is their low power consumption and low mass. The total mass of all the printed parts is 110 g, and the combined mass of the Genuino, the bluetooth module and the pump is 38 g. As a result, the maximum weight of the fluid payload cannot be more than 57 g.

For autonomous flight to accomplish the spraying task, the AR drone ROS driver [4] as well as a modified version of the TUM_ARDrone [5] ROS packages have been used. The TUM_ARDrone package is capable of monocular simultaneous localisation and mapping (SLAM). The visual odometery is fused with the IMU and the ultrasonic sensor to obtain a more accurate estimation of the pose of the Agrobot in the environment. These estimates are in turn used as input to the cascaded PID controller realised to control the position and the yaw of the robot [6]. For robust landing, vision-based tag detection algorithms have been developed to more accurately estimate the pose of the landing area on the docking station. Figure 5 shows the aerial Agrobot during a spraying mission.

The lifeline for energy and payload replenishing

The primary use of the docking station is to provide a lifeline to the Agrobot by replenishing its energy and payload supply so that it can continuously perform its mission. In this project, the two main functional requirements of the docking station are its ability to recharge the battery and refill the liquid payload of the Agrobot. The main technical requirement is its ability to tolerate a landing accuracy of 2 cm and 10°, i.e., the station should be able to refill and recharge as long as the Agrobot lands within the aforementioned tolerance. In the first





4 Modifications to the Parrot AR drone.
(a) Mechanical.
(b) Electrical.