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Mechatronic Systems Design
HW1

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The autonomous drone is a new type of mechatronic system gaining popularity nowadays.

1 HARDWARE

Generally, it is based on the traditional multi-rotor configuration like Fig(1.1), where 4 or 6 rotors are placed symmetrically around the central body. The central body contains power supply packages, controling unit and sensing facilities, with carbon fiber shell protecting them away from external dust, moist, or possible damage.

Figure 1.1: Autonomous drone

Usually, a camera is mounted at the bottom for taking pictures or performing vision-based guiding. For professional use, both laser radar and milimeter-wave radar are equipped for advanced perception.

2 COMPONENTS

The most important 3 components are

1. **Sensing Unit**
   Usually, it is composed of accelerometer, gyroscope, barometer, geomagnetic sensor and GPS.These sensors are usually in chip format called MEMS, and can be mounted on the surface of PCB precisely, see Fig(2.1).

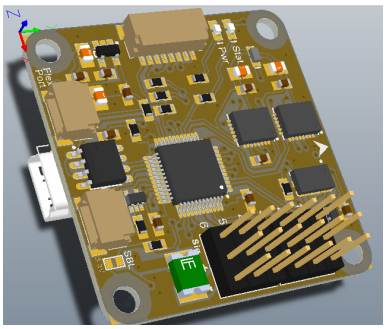

Figure 2.1: Sensing Unit PCB

   a) *Accelerometer*
   It provides the inertial force info, and 3-axis pose(Roll Yaw, Pitch) can be estimated from acceleration in each axis.

   b) *Gyroscope*
   It provides the angular velocity info. It is based on the conservation of angular momentum.

   c) *Barometer*
   It provide the pressure of atomosphere, and height can be estimated.

   d) *Geomagnetic sensor*
   Guiding the **North** direction.

   e) *GPS*
   Global position like longtitude and latitude are provided. Timing is also available.

   In general, sensing unit provides the state of drone.

2. **Perception Facility**
   To provide the infomation of environment, Radar, optical flow and ultrasonic sensor are integrated.

   a) *Laser Radar*
   Usually in shape like Fig(2.2), for sensing obstacles around. It can also be done using an RGB-D camera.

b) *Milimeter-wave Radar*
Barometer may not accurate, Radar has better resolution on determining height.

c) *Optical Flow*
Local positioning and velocity estimation.

d) *Ultrasonic sensor*
Sensing in a specific direction, it has similar function as LiDAR but shorter range.

Figure 2.2: LiDAR

Figure 2.3: Milimeter-wave Radar

3. **Control Unit**
It do realtime response under both internal and external constraints. Signals in PWM form are generated to the electrical speed regulator to drive the motors. Usually, serial PID algorithm is used.

3 SPECIFICATIONS

Usually, this kind of automous drones can be used for agricultural, topographic or transportation purpose. Typically, the diameter ranges from 0.5 to 2m, and weighs 2 to 20kg.
Due to the energy density limit of lithium battery, endurance is usually about 20 minutes.
For safety issues, flight speed is usually lower than 5m/s, and flight height is restricted to 10m.

4 CHALLENGES IN DESIGN AND CONTROL

1. Data fusion.
2. Proper placement to minimize vibration.
3. PID param tuning.
4. Obstacle detection.
5. Reliable wireless communication.

5 FUTURE TRENDS OF DEVELOPMENTS

1. Communication for long range and high fidelity.
2. Advanced and robust control algorithm.
3. Optimized aerodynamic shape design(For agricultural spray).
4. Higher energy density batteries or use gasoline.
5. More mature environment perception.