Safety System — General Principles

RTK positioning · four-layer safety detection · cascaded fallback protection

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The mower does not rely on any single sensor for safety. Instead, it uses a four-layer safety detection design with multi-level redundancy. During normal operation, all four layers work simultaneously. If a sensor or signal at any layer becomes abnormal, the system prioritizes stopping the machine or switching to degraded operation, so that risk is never left to the next layer alone.

A simple way to explain it to customers: the mower's safety system works like a "multi-layer safety net." The first layer ensures positioning is trustworthy; the second ensures the mower stays on route; the third fuses LiDAR, radar and camera to detect obstacles in advance; and the fourth provides the final physical protection in extreme situations.

Layer 1: RTK Positioning Integrity Check

The mower operates along a pre-planned route using RTK centimeter-level positioning. When the RTK signal is stable, the machine can accurately determine whether it is within the working area and whether it is following the prescribed path. If the RTK signal is affected by trees, buildings, obstructions, or electromagnetic interference, the system judges the positioning as "untrustworthy."

The safety strategy in this situation is:

- Stop movement first, to avoid continuing to drive when position is uncertain;
- If positioning cannot be restored for an extended period, remain stopped and prompt for inspection.

> **What you can say to the customer** — The first safety layer is "positioning integrity." If the mower cannot confirm its exact position, it will not keep driving blindly. It stops immediately and resumes work only after positioning is restored.

Layer 2: Route Deviation Detection

On the premise that RTK positioning is trustworthy, the system continuously compares the current position against the planned route. When the machine deviates from the planned route by more than 1.5 meters, the system determines that it has left the safe working area or that the path is abnormal, and immediately triggers a stop. This layer prevents the machine from straying into non-working areas due to positioning drift, wheel slip, terrain changes, or external interference.

> **What you can say to the customer** — The second safety layer is the "route boundary." Even if positioning is normal, as soon as the mower deviates more than 1.5 meters from the planned route, it stops moving, preventing it from entering non-working areas.

Layer 3: Multi-Sensor Obstacle Avoidance (LiDAR + Radar + Camera)

The third layer fuses three complementary sensors to perceive the front and surrounding environment in real time:

- LiDAR builds precise distance and contour data for nearby obstacles;
- Radar continuously measures object distance and speed, and works reliably in rain, fog, dust and low-light conditions;
- Camera provides visual recognition of obstacle type and the surrounding scene.

The three sensors cross-confirm one another. When the fused system detects an imminent collision risk ahead, the machine slows down in advance and stops. Compared with a physical bumper, this is an active perception layer: it completes obstacle avoidance before any actual contact, reducing the probability of collision. Sensor fusion also means that when one sensor is temporarily degraded — for example, the camera in strong backlight or the LiDAR in heavy rain — the other sensors still provide effective coverage.

Advantages of this layer:

- Recognizes static obstacles;
- Recognizes dynamic obstacles;
- Radar maintains detection in rain, fog, dust and at night; camera supports visual scene recognition;
- Not limited by boundary wires — suitable for wire-free (no-boundary) working scenarios;
- Maintains reliable perception at night, in backlight, and under tree shade through multi-sensor cross-confirmation.

> **What you can say to the customer** — The third safety layer is "active obstacle avoidance." The mower continuously watches the environment ahead through LiDAR, radar and camera working together. As soon as it is about to approach an obstacle, it stops in advance — rather than stopping only after hitting it.

Layer 4: Bumper Strip Mechanical Protection

The bumper strip is the final physical safety protection. If the fused LiDAR/radar/camera perception layer fails to trigger avoidance in time due to extreme obstruction or other abnormal conditions, the bumper strip triggers an immediate stop the moment the machine physically contacts an obstacle.

Characteristics of this layer:

- Does not depend on complex algorithms;
- Very short response path;
- Suited as a last-resort safeguard at extremely close range;
- Protects both the machine itself and surrounding objects.

> **What you can say to the customer** — The fourth safety layer is the "mechanical fallback." Even if none of the earlier sensors trigger in time, the bumper strip stops the machine the instant it touches an obstacle, preventing further damage.

How the Four Layers "Take Over in Sequence"

Layer	Detection Target	Trigger Condition	Safety Action
Layer 1	RTK positioning integrity	RTK signal untrustworthy / positioning abnormal	Stop movement, wait for recovery
Layer 2	Route deviation	Deviation from planned route exceeds 1.5 m	Stop movement, prevent boundary breach
Layer 3	LiDAR + radar + camera obstacle avoidance	Fused sensors detect imminent collision with an obstacle	Slow down in advance and stop
Layer 4	Bumper strip	Physical contact with an obstacle	Immediate emergency stop

The complete logic

1. Normal conditions: all four layers work simultaneously; the machine operates steadily along the planned route.
2. RTK abnormality: Layer 1 intervenes first; the machine stops to avoid driving with untrustworthy positioning.
3. Positioning normal but path abnormal: Layer 2 intervenes, preventing the machine from leaving the working area.
4. Path normal but obstacle ahead: Layer 3 (fused LiDAR + radar + camera) performs advance obstacle avoidance.
5. First three layers all fail to trigger in time: Layer 4 (bumper strip) provides the final protection.

Simplified customer-facing script

This safety system is not a single protection — it consists of four independent detection layers with cascaded fallback protection. Layer 1 ensures "I know where I am"; Layer 2 ensures "I haven't drifted off course"; Layer 3 ensures "there is no danger ahead"; Layer 4 ensures "even if I hit something, I can stop."

If a customer asks, "What happens if one layer fails?", you can answer: the system was designed with single-point failure in mind. For example, when RTK is untrustworthy, the machine will not keep driving relying on positioning; within Layer 3, the LiDAR, radar and camera cross-confirm one another, so one sensor being temporarily degraded does not disable the whole layer; and if the perception layer is abnormal, route-deviation detection and the bumper strip still serve as fallback protection.

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