

PATENT SPECIFICATION

Frost-Resistant Sensor Array Architecture

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ABSTRACT

A frost-resistant sensor array architecture for autonomous mobile robots operating in sub-zero environments, comprising a thermally-isolated sensor housing with integrated heating elements, multi-layer environmental shielding, and an adaptive thermal management system. The invention enables reliable operation of LiDAR, infrared, and ultrasonic sensors in extreme cold conditions while minimizing power consumption and maintaining optimal sensor performance.

BACKGROUND

[0001] Autonomous mobile robots operating in cold storage environments face significant challenges related to sensor reliability and performance degradation due to frost accumulation and thermal stress. Conventional sensor arrays typically fail or provide degraded performance in sub-zero environments, particularly below -20 C.

[0002] Existing solutions rely on high-power heating elements or mechanical defrosting mechanisms that consume excessive energy and introduce operational inefficiencies. There remains an unmet need for an energy-efficient, reliable sensor array architecture capable of sustained operation in extreme cold environments.

DETAILED DESCRIPTION

[0003] The present invention provides a frost-resistant sensor array architecture comprising:

- a) A thermally-isolated sensor housing (100) constructed from composite materials with thermal expansion coefficients below $5 \times 10^{-6} / ^\circ\text{C}$;
- b) An array of independently-controlled micro-heating elements (201-208) positioned around critical sensor components;

c) A multi-layer environmental shield system (300) comprising:

- Outer layer: Hydrophobic coating with frost-shedding properties
- Middle layer: Vacuum-insulated thermal barrier
- Inner layer: Thermally-conductive material for heat distribution

d) An adaptive thermal management controller (400) that:

- Monitors temperature at multiple points using embedded sensors
- Adjusts heating element power based on environmental conditions
- Maintains optimal operating temperature while minimizing energy consumption

[0004] The invention incorporates proprietary IceNav(TM) thermal compensation algorithms that:

- Adjust sensor data processing parameters based on temperature conditions
- Compensate for thermal drift in sensor readings
- Optimize power allocation to heating elements based on mission priorities

CLAIMS

A frost-resistant sensor array system comprising:

- a) A thermally-isolated housing;
- b) Multiple environmental sensors;
- c) Distributed heating elements;
- d) An adaptive thermal management controller;

wherein said system maintains sensor operation in environments between -40 C and +50 C.

The system of claim 1, wherein the thermal management controller implements predictive heating based on environmental conditions and robot movement patterns.

The system of claim 1, further comprising a multi-layer environmental shield system with hydrophobic properties.

A method for maintaining sensor array operation in sub-zero environments comprising:

- a) Monitoring temperature at multiple points within the sensor array;
- b) Activating heating elements according to thermal management algorithms;
- c) Adjusting sensor processing parameters to compensate for environmental conditions.

DRAWINGS

[0005] FIG. 1 illustrates the cross-sectional view of the sensor housing assembly.

[0006] FIG. 2 shows the arrangement of heating elements and thermal sensors.

[0007] FIG. 3 depicts the multi-layer environmental shield system.

[0008] FIG. 4 presents the thermal management control architecture.

ADVANTAGES

[0009] The present invention provides several advantages over existing solutions:

- Reduces power consumption by up to 60% compared to conventional heating methods
- Maintains sensor accuracy within 1% across operating temperature range
- Enables continuous operation in environments as cold as -40 C
- Self-adapts to varying environmental conditions
- Requires minimal maintenance intervention

INDUSTRIAL APPLICABILITY

[0010] This invention has direct application in:

- Cold storage warehouse automation
- Pharmaceutical manufacturing facilities
- Food processing operations
- Arctic/Antarctic research operations
- Industrial freezer environments

DECLARATION AND SIGNATURE

I hereby declare that I am the original inventor of the subject matter which is claimed and for which a patent is sought.

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