Inventor: Robert V. Salinas
Title: Global Sensor Fusion Network for Autonomous Systems with Multi-Sensor Learning, Rapid Adaptation, and Collaborative Knowledge Sharing

1. **Title**
2. **Global Sensor Fusion Network for Autonomous Systems with Multi-Sensor Learning, Rapid Adaptation, and Collaborative Knowledge Sharing**
3. Technical Field
4. This invention relates to autonomous systems utilizing multi-sensor learning and fusion to perform tasks dynamically and adaptively. The invention also includes a global sensor fusion network enabling shared learning and knowledge accumulation among distributed robotic entities, enhancing efficiency, task generalization, and operational versatility.
5. Background of the Invention
6. The growing deployment of autonomous systems across industries such as logistics, manufacturing, healthcare, and environmental monitoring has highlighted the need for more versatile, intelligent, and efficient systems. Current autonomous systems often rely on static programming or single-modality sensors, limiting their adaptability and functionality. Additionally, the lack of collaborative networks restricts the sharing of task-specific knowledge, requiring repeated training for similar tasks across different entities.
7. This invention addresses these limitations by introducing a global sensor fusion network that integrates diverse sensor inputs (e.g., optical, thermal, tactile, and auditory) with advanced AI models for rapid task learning and execution. By sharing knowledge across a distributed network of autonomous systems, the invention accelerates collective learning and task adaptation, enabling robots,

drones, and vehicles to "sense, think, and act" with human-like intuition and flexibility.

8. Summary of the Invention

   a. The invention comprises a global sensor fusion network designed to enhance the adaptability, learning speed, and task generalization capabilities of autonomous systems. Core features include:

   b. Multi-Sensor Fusion: Combines data from diverse sensors (visual, thermal, tactile, motion, and environmental) to create a holistic understanding of the environment.

   c. Rapid Learning Algorithms: Implements reinforcement and transfer learning models to enable autonomous systems to quickly learn new tasks and adapt to novel environments.

   d. Collaborative Knowledge Sharing: Builds a global network where autonomous systems continuously share sensor data, task learnings, and performance metrics, improving the collective intelligence of all connected systems.

   e. Task Generalization and Dynamic Execution: Allows autonomous systems to move beyond pre-defined tasks, dynamically learning, adapting, and performing new functions using integrated sensor inputs.

   f. Applications span industries such as disaster response, autonomous transportation, precision agriculture, environmental conservation, and industrial automation.

9. Brief Description of the Drawings
10. Figure 1 illustrates the overall architecture of the Global Sensor Fusion Network, depicting the integration of autonomous systems, multi-sensor arrays, and cloud-based collaborative knowledge sharing.
11. Figure 2 depicts a single autonomous system equipped with a multi-sensor array, including optical, thermal, tactile, auditory, and environmental sensors.
12. Figure 3 shows the data fusion process within an autonomous system, integrating multi-modal sensor data into a unified understanding.
13. Figure 4 represents the cloud-based knowledge repository and its role in collaborative learning, model sharing, and task generalization.
14. Figure 5 provides a use case example of an autonomous drone detecting and collecting ocean debris through dynamic task adaptation.
15. Figure 6 illustrates edge computing nodes within the network, enabling real-time decision-making with reduced latency.
16. **Detailed Description of the Invention**
17. The present invention, titled "Global Sensor Fusion Network for Autonomous Systems with Multi-Sensor Learning, Rapid Adaptation, and Collaborative Knowledge Sharing," provides a revolutionary framework to empower autonomous systems with advanced adaptability, dynamic learning, and collaborative intelligence. This detailed description ensures that the invention can be fully understood, replicated, and utilized effectively.
18. **Multi-Sensor Fusion Framework**

19. Each autonomous system is equipped with a **multi-sensor array**, designed to capture diverse environmental and operational data. The integration of these sensors is key to creating a holistic understanding of the surrounding environment.

20. **Sensor Components:**

    a. **Optical Sensors:** Utilize high-resolution cameras capable of object recognition, spatial mapping, and environment classification. Examples include LiDAR systems for obstacle detection in autonomous vehicles.

    b. **Thermal Sensors:** Employ infrared technology to detect heat signatures for tasks such as identifying overheating machinery or locating living beings in disaster zones.

    c. **Tactile Sensors:** Measure pressure, texture, and material properties for robotic arms in industrial applications or medical robots performing delicate surgeries.

    d. **Auditory Sensors:** Use advanced microphones for sound localization, such as detecting and isolating specific frequencies in noisy environments.

    e. **Environmental Sensors:** Record air quality, temperature, and humidity for applications in precision agriculture and climate monitoring.

    f. **Data Fusion Process:** The **sensor fusion model** integrates multi-modal sensor inputs into a unified data stream. For example:

i. A drone uses optical sensors to detect debris in the ocean while thermal sensors differentiate between organic and non-organic materials, enabling targeted debris collection.

ii. Data is pre-processed to remove noise, normalized for consistency, and then analyzed using AI algorithms to generate actionable insights.

21. **System Benefits:** This multi-sensor fusion enables real-time analysis, robust situational awareness, and reduced reliance on human input, ensuring seamless operation in dynamic and unpredictable environments.

22. Learning Mechanisms

23. The invention incorporates advanced machine learning models that enable autonomous systems to learn, adapt, and optimize their performance continuously.

a. **Reinforcement Learning (RL):**

i. Systems engage in trial-and-error interactions to identify the best course of action in various scenarios. For instance, a warehouse robot learns optimal navigation routes to reduce time and energy costs.

ii. The RL process is augmented by reward functions tailored to specific objectives, such as maximizing efficiency or minimizing errors.

b. **Transfer Learning:**

i. Knowledge acquired during one system's operation is shared across the network. For example, a drone mapping terrain shares its data and models with another drone tasked with similar missions, bypassing redundant training.

c. **Behavioral Training Layer:**

i. Mimics human decision-making processes by integrating multi-sensor inputs. For example, a robotic arm in an assembly line adjusts its grip based on tactile feedback, similar to how a human adapts when handling fragile items.

d. **Examples:**

i. In disaster response, RL enables drones to learn search patterns for finding survivors in different terrains.

ii. In healthcare, transfer learning allows a surgical robot to perform new procedures based on data shared by other robots in the network.

24. Global Sensor Fusion Network

25. The invention's **global network** facilitates knowledge sharing and collaborative learning among connected autonomous systems.

a. **Cloud-Based Knowledge Repository:**

i. Stores sensor data, task protocols, and optimized models. For example, a fleet of agricultural drones shares data on soil quality and crop health to improve collective efficiency.

ii. Ensures data security and accessibility through encryption and decentralized backups.

b. **Edge Computing Nodes:**

i. Perform real-time data processing locally, minimizing latency. For example, an autonomous vehicle makes immediate braking decisions using edge computing instead of waiting for cloud-based instructions.

c. **Continuous Learning Loop:**

i. New data collected by any system is analyzed, shared, and incorporated into global models. For example, a network of surveillance drones updates its algorithms based on new patterns of behavior observed in the field.

26. Real-Time Task Generalization and Execution

27. Autonomous systems equipped with this invention can dynamically adapt to new tasks without pre-programmed instructions.

a. **Dynamic Task Learning:**

i. Systems analyze real-time data to determine task requirements. For example, an industrial robot switches between assembling components and repairing faulty machinery based on detected anomalies.

b. **Task Execution Example:**

i. A drone identifies oil spills in the ocean using optical sensors and deploys an appropriate cleanup mechanism.

ii. A robotic arm in manufacturing dynamically shifts from precision welding to component assembly based on production needs.

28. Applications and Benefits

a. **Disaster Response:**

i. Drones equipped with optical and thermal sensors locate survivors in collapsed buildings. Their ability to share findings across the network reduces redundancy and accelerates rescue operations.

b. **Healthcare:**

i. Surgical robots use tactile and optical feedback to adjust precision during procedures, minimizing risk and improving patient outcomes.

c. **Environmental Conservation:**

i. Robotic systems analyze ecosystems using multi-sensor arrays and implement corrective actions like removing invasive species or planting native flora.

d. **Industrial Automation:**

i. Robots equipped with tactile sensors identify worn components in machinery and perform repairs autonomously, reducing downtime.

29. Advantages and Improvements

30. This invention offers significant improvements over prior systems:

a. **Comprehensive Understanding:** The multi-sensor array captures and processes diverse environmental data, enabling a holistic view of operations.

b. **Enhanced Collaboration:** Shared learning accelerates task execution across a network of autonomous systems.

c. **Scalability:** The modular design supports diverse configurations and applications, from agriculture to healthcare.

d. **Dynamic Flexibility:** Real-time task generalization allows systems to adapt seamlessly to changing conditions.

31. Alternative Configurations

a. The system supports numerous alternative configurations:

b. Custom sensor arrays tailored to specific industries (e.g., seismic sensors for mining operations).

c. Hybrid edge-cloud processing models for environments with intermittent connectivity.

d. Adaptable machine learning algorithms to optimize performance in domain-specific tasks.

32. Detailed Examples

a. **Use Case 1:** An autonomous drone monitors a forest using optical and thermal sensors to detect illegal logging. When suspicious activity is identified, the drone alerts nearby law enforcement drones, enabling rapid intervention.

b. **Use Case 2:** A robotic arm in a factory line identifies defective parts using tactile sensors and redirects them for repair. Simultaneously, it adjusts its processes to prevent future defects based on sensor feedback.

33. This enhanced detailed description ensures that someone skilled in the art can fully understand and replicate the invention, highlighting its adaptability, robustness, and diverse applications.

Claims

1. A global sensor fusion network for autonomous systems, comprising:

    A multi-sensor array including optical, thermal, tactile, auditory, and environmental sensors;

    A sensor fusion model integrating multi-modal data into a unified understanding of the environment.

2. The network of claim 1, wherein autonomous systems utilize reinforcement and transfer learning to dynamically adapt to new tasks and environments.
3. The network of claim 1, further comprising a cloud-based repository for sharing sensor data, task learnings, and operational models among distributed systems.
4. The network of claim 1, wherein edge computing nodes enable real-time decision-making and task execution with reduced latency.
5. The network of claim 1, wherein autonomous systems perform task generalization, allowing for dynamic execution of novel tasks based on sensor inputs.
6. The network of claim 1, applied in disaster response, healthcare, environmental conservation, and industrial automation to enhance efficiency and adaptability.

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Abstract

1. This invention presents a global sensor fusion network for autonomous systems, enabling multi-sensor learning, rapid adaptation, and collaborative knowledge sharing. The network integrates diverse sensor arrays, including optical, thermal, tactile, and environmental sensors, to provide a comprehensive understanding of the environment. Using reinforcement and transfer learning, autonomous systems dynamically adapt to new tasks and environments, sharing learnings through a centralized knowledge repository. Applications include disaster response, healthcare, environmental monitoring, and industrial automation, with continuous improvement driven by collective learning.