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S G INTELLECTUAL
4-D (Upper Floor), DDA Pocket-2
Sector-6, Dwarka,
New Delhi-110075, India
Mob: +91 9213764385
E-mail: info@sgintellectual.com

Invoice No.: SGI/ANU/START-UP/ AI REFRIGERATOR -PATENT-03/2026

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Our Ref.: **ANU/AI REFRIGERATOR -PATENT-03/2026**

To
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AVINAB BIDANASI, CUTTACK- 753014

Description	**Fee. (INR)**
1. Professional fee towards providing general advisory on different intellectual property rights to start ups, providing information on protecting and promoting IPR to start ups in other countries, drafting Complete Specification and preparing and filing other documents such as Form-1, Form-2, Form-3, Form-9 and Form 18A, reporting to client the filing of the Patent Application No. **202631018813** dated **19th FEBRUARY 2026.**	NIL
2. Government Fee for filing the Patent Application.	INR 19,140/-
3. Miscellaneous expenses including charges for typing, phone, Print outs, photocopy, stamp fee, postal charges, conveyance etc.	INR 1000/-
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1	202631018813	TEMP/E-1/21774/2026-KOL	8640	2343	FORM 1	Full	ARTIFICIAL SUPER-INTELLIGENCE (ASI) BASED NEUROMORPHIC SMART REFRIGERATOR
2	E-106/1022/2026/KOL	202631018813	0	-1	FORM28	Full	

TransactionID	Payment Mode	Challan Identification Number	Amount Paid	Head of A/C No
N-0001871737	Online Bank Transfer	1902260041752	8640.00	1475001020000001

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Web Site: www.ipindia.gov.in

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1	E-12/432/2026/KOL	202631018813	2500	2416	FORM 9	Full	

TransactionID	Payment Mode	Challan Identification Number	Amount Paid	Head of A/C No
N-0001872368	Online Bank Transfer	1902260082628	2500.00	1475001020000001

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1	E20263011233	202631018813	8000	2420	FORM 18A	

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(71)**Name of Applicant :**
1)SRJX RESEARCH AND INNOVATION LAB LLP
Address of Applicant :PLOT NO.-3E/474 SECTOR-9, CDA POST- MARKAT NAGAR, CUTTACK, ODISHA, INDIA Orissa India
(72)**Name of Inventor :**
1)JENA, Soumya Ranjan
2)PANIGRAHI, Rakhee
3)PATJOSHI, Rajesh Kumar

(57) Abstract :
The present invention discloses an Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100) and its method. The system (100) comprises an insulated refrigeration cabinet (102), a multi sensor array (104), a processing subsystem (106), a memory unit (108), and a control layer (110). The insulated refrigeration cabinet (102) is configured to include at least one refrigeration compartment and at least one freezer compartment, and a refrigeration cycle comprising a compressor, condenser, evaporator, expansion device, and at least one circulation fan. The multi-sensor array (104) is configured to monitor internal environmental and operational parameters. The processing subsystem (106) comprises one of a microcontroller (112) and system-on-chip (MCU/SoC), and a neuromorphic processing unit (NPU) (114). The memory unit (108) is configured to store sensor data, learned behavioral models, inventory records, freshness data, and maintenance logs. The neuromorphic processing unit is configured to perform event-driven multi-sensor fusion and edge inference.

No. of Pages : 64 No. of Claims : 15

FORM 2

THE PATENTS ACT, 1970

[39 of 1970]

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THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(Section 10; Rule 13)

ARTIFICIAL SUPER-INTELLIGENCE (ASI) BASED NEUROMORPHIC SMART REFRIGERATOR

SRJX RESEARCH AND INNOVATION LAB LLP

PLOT NO-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR,

CUTTACK- 753014, ODISHA, INDIA

An Indian Company

The following Specification particularly describes the invention and the manner in which it is to be performed.

FIELD OF INVENTION

The present invention relates to Refrigerator systems, more particularly relates to Artificial Super-Intelligence (ASI) based neuromorphic refrigerator system.

BACKGROUND

Refrigerators are among the most essential household and commercial appliances used to preserve perishable food items by maintaining controlled low-temperature environments. Modern refrigerators are no longer limited to basic cooling; they increasingly incorporate electronics, sensors, and connectivity to improve user convenience, energy efficiency, and food management. In today's lifestyle, where families often purchase groceries in bulk and store items for extended periods, the need for smarter refrigeration systems that can reduce spoilage, minimize waste, and support healthier consumption habits has become more important than ever.

Conventional refrigerators operate using predefined thermostat logic and fixed control algorithms. Although these approaches are reliable, they are not intelligent enough to adapt to changing user behaviors, variable loading patterns, frequent door openings, seasonal temperature changes, and diverse food storage requirements. A typical refrigerator cannot "understand" what is stored inside, cannot automatically track food freshness, and cannot proactively optimize cooling cycles based on predicted demand. As a result, users often experience problems such as forgotten items, unnoticed expiry, uneven cooling in different compartments, odor buildup, or unnecessary energy consumption due to overcooling and repetitive compressor cycling.

In recent years, so-called "smart refrigerators" have been introduced with features such as internal cameras, mobile app connectivity, barcode/RFID-based tracking, voice assistants, and cloud-enabled inventory lists. Some advanced models attempt to recognize food items using image processing and machine learning, recommend recipes, and provide shopping reminders. While these developments are helpful, many existing systems remain limited because they rely heavily on cloud computation, require large datasets, have high power requirements, and may suffer latency or failure when the internet is unavailable. Additionally, privacy concerns arise when images and household consumption data are continuously uploaded to external servers.

Another significant challenge in AI-enabled appliances is energy efficiency. Traditional AI inference on GPUs/CPUs can be computationally expensive, generating heat and consuming substantial power—especially if continuous monitoring is required. For refrigerators, which run 24×7, even small inefficiencies translate into meaningful long-term electricity costs. Furthermore, continuous high-power computation inside a cooling appliance can conflict with thermal management goals. This creates a strong need for intelligence that can operate at extremely low power while still delivering reliable real-time decision-making.

Neuromorphic computing has emerged as a promising approach to address these limitations. Neuromorphic systems aim to mimic brain-like information processing using event-driven architectures, spiking neural networks, and specialized chips that can perform inference at very low energy compared to conventional deep learning hardware. Such architectures are particularly suitable for always-on sensing, anomaly detection, and adaptive control tasks where input data changes over time.

Current smart refrigerator and food-management technologies (prior art) provide useful automation, but they still leave several practical and technical problems unsolved. The present invention targets these gaps by introducing neuromorphic, always-on edge intelligence with multi-sensor fusion and adaptive control. The key problems in earlier inventions are explained below, paragraph wise.

A major limitation of conventional refrigerators is that they operate mainly on fixed thermostat logic and pre-set control rules. These systems are not designed to understand changing user behavior, variable food loads, or dynamic ambient conditions. When the door is opened repeatedly, when warm food is placed inside, or when seasonal temperature changes occur, traditional control loops often respond slowly or inefficiently. This results in temperature fluctuations, uneven cooling across compartments, unnecessary compressor cycling, and higher energy consumption.

Many AI-enabled refrigerators rely heavily on cloud connectivity for computation, updates, and intelligence features. In such prior systems, cameras and sensors capture data, which may be processed remotely for recognition or recommendations. This approach creates latency, dependence on stable internet, and reduced reliability when connectivity is weak. In practical household conditions, this means that "smart" features may stop working offline, while core intelligence becomes inconsistent and unpredictable.

Prior smart refrigerator solutions also raise significant privacy concerns. Continuous collection of images, household consumption patterns, and behavioral data may be uploaded to external servers for analysis. This can expose sensitive information about daily routines, diet, health preferences, and purchasing habits. Many users hesitate to adopt such appliances due to lack of control over data storage and sharing, and prior inventions often do not provide strong privacy-preserving local processing by default.

Another important problem is that existing smart inventory systems are often inaccurate or inconvenient for users. RFID/barcode-based methods require manual tagging or scanning, which is time-consuming and not realistic for daily use. Camera-based recognition systems may struggle with occlusion (items blocking each other), poor lighting, packaging variations, and mixed storage conditions. As a result, inventory lists frequently become outdated, which reduces user trust and makes the feature less useful over time.

Freshness detection and spoilage prediction in prior art are also limited in real-world performance. Many systems rely mainly on expiry dates, manual entry, or basic time tracking, which does not reflect true freshness because real spoilage depends on temperature history, humidity, cross-contamination risk, and storage conditions. Even inventions using cameras may detect an item but cannot reliably estimate internal spoilage. Similarly, systems using single-sensor approaches (only odor sensors or only images) may create false alarms or miss early spoilage indicators.

Energy efficiency is another major gap in earlier AI-based appliances. Conventional AI inference on CPUs/GPUs is computationally heavy and power-consuming, which is not ideal for an appliance that runs 24×7. Continuous monitoring for recognition, prediction, and alerts can increase electricity consumption and may add thermal load inside the device. Prior inventions often do not provide a dedicated ultra-low-power intelligence mechanism that remains active continuously without significantly impacting energy usage.

Earlier inventions also struggle with adaptive personalization and learning. Many smart refrigerators provide generic suggestions such as recipe recommendations or shopping lists but do not learn continuously from household routines. They often fail to adapt to patterns such as typical door-opening times, weekly grocery cycles, preferred storage habits, or special dietary needs. As a result, recommendations can feel irrelevant, and control decisions remain static rather than improving over time.

A further issue is limited integration between food intelligence and refrigeration control. In many prior systems, “smart features” operate as separate add-ons (camera inventory, app notifications) while the core refrigeration system continues to function using conventional control methods. This separation prevents the appliance from using food-context information to actively optimize cooling, humidity, airflow, and compartment settings. For example, the refrigerator may know an item is stored, yet it does not adjust humidity or airflow to preserve it better.

Lastly, predictive maintenance and fault detection in prior art are often minimal or reactive. Many appliances fail only after performance degrades significantly, leading to food spoilage, service costs, and downtime. Earlier inventions may not continuously monitor compressor vibration patterns, refrigerant performance indicators, or thermal response behavior to detect early signs of failure. Consequently, users are not warned early enough, and minor issues become major faults.

Therefore, the background of this invention lies in the limitations of conventional and current smart refrigeration technologies—namely lack of adaptive intelligence, dependence on internet/cloud processing, higher energy costs of continuous AI computation, limited freshness tracking, and privacy risks. Integrating neuromorphic intelligence within the refrigeration control architecture offers a pathway toward an always-on, low-power, privacy-preserving, and highly adaptive smart refrigerator that improves food safety, reduces waste, and enhances user convenience in both domestic and commercial environments.

Therefore, there is a need for an Artificial Superintelligence (ASI) based neuromorphic refrigerator system to overcome the above mentioned drawbacks.

OBJECTS OF THE INVENTION

The present invention targets the shortcomings of prior arts by enabling neuromorphic, event-driven edge intelligence for always-on low-power processing, robust multi-sensor fusion for more accurate inventory and freshness estimation, adaptive personalization for better decision-making, strong offline functionality, privacy-preserving local computation, tighter coupling between food intelligence and refrigeration control, and predictive maintenance for early fault detection. This combination directly addresses the practical limitations that remain unresolved in earlier refrigerator inventions.

The present invention is a next-generation refrigeration system that can deliver intelligent perception, prediction, and control at the edge with minimal power consumption. The refrigeration system is configured to continuously learn from sensor events, such as door movements, temperature fluctuations, humidity variations, gas/odor indications, vibration signatures, and user interaction patterns, and potentially optimizes compressor operation, airflow distribution, and defrost cycles more effectively than static logic controllers. The refrigeration system is configured to provide more accurate freshness estimation, early warning of spoilage risk, dynamic compartment-level cooling, and adaptive energy scheduling based on usage patterns and grid conditions.

The present invention discloses an “Artificial Superintelligence based Neuromorphic Smart Refrigerator System” that provides an advanced intelligence framework that is not merely rule-based or cloud-dependent, but capable of adaptive, context-aware decision-making. In this context, “superintelligence” is treated as a high-level system capability—meaning superior performance in prediction, optimization, and anomaly detection—achieved through a combination of multi-sensor fusion, neuromorphic edge inference, continual learning, and self-optimizing control strategies. The objective is to create a refrigerator that behaves as an autonomous, learning system: monitoring conditions, anticipating user needs, preventing wastage, and optimizing energy use without requiring constant manual input or high-cost computational resources.

According to embodiments of the present invention, the key objectives are given below:

1. To provide an Artificial Superintelligence (ASI) based smart refrigerator capable of autonomous decision-making for food preservation and appliance optimization.
2. To integrate neuromorphic (brain-inspired) computing for ultra-low-power, always-on intelligence within the refrigerator.
3. To enable multi-sensor fusion using temperature, humidity, gas/odor, camera, weight/load, door, airflow, and vibration sensors to understand real-time internal conditions.
4. To automatically detect, identify, and track stored food items and maintain a dynamic digital inventory without manual entry.
5. To estimate freshness and spoilage risk using combined inputs such as time–temperature exposure, visual cues, and gas/odor indicators.
6. To reduce food wastage by generating early alerts for expiry, spoilage risk, and recommended consumption priority ("consume soon" notifications).
7. To optimize energy consumption by adaptively controlling compressor operation, fan speed, airflow distribution, and defrost cycles based on learned usage patterns.
8. To provide adaptive cooling and humidity control at compartment level for different food categories (vegetables, dairy, meat, fruits, frozen items).
9. To detect abnormal operating conditions such as door left open, temperature drift, sensor failures, cooling inefficiency, and unusual power draw.
10. To support predictive maintenance by monitoring compressor health, vibration patterns, thermal performance, and system degradation trends.
11. To ensure privacy-preserving edge intelligence by performing primary processing locally and minimizing or avoiding cloud dependency.
12. To provide intelligent user assistance through a display/mobile app/voice interface including inventory view, expiry reminders, shopping suggestions, and recipe recommendations.

13. To operate reliably even without internet connectivity**,** ensuring core intelligence functions remain active offline.
14. To improve overall food safety and quality by maintaining stable storage conditions and providing real-time compliance tracking if required.
15. To make the invention scalable and applicable for domestic use, commercial kitchens, hospitals, hostels, and cold-chain storage environments.

SUMMARY OF THE INVENTION

An embodiment of the present invention describes an Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100). The Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100) comprises an insulated refrigeration cabinet (102) including at least one refrigeration compartment and at least one freezer compartment, and a refrigeration cycle comprising a compressor, condenser, evaporator, expansion device, and at least one circulation fan, a multi-sensor array (104) disposed within the cabinet and configured to monitor internal environmental and operational parameters, a processing subsystem (106) comprising one of a microcontroller (112) and system-on-chip (MCU/SoC), and a neuromorphic processing unit (NPU) (114), a memory unit (108) configured to store sensor data, learned behavioral models, inventory records, freshness data, and maintenance logs; and a control layer (110) operatively coupled to refrigeration actuators including the compressor, fan, airflow dampers, and defrost system, wherein the neuromorphic processing unit is configured to perform event-driven multi-sensor fusion and edge inference to: identify and track stored food items and quantity changes, compute a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration data, detect operational anomalies including temperature drift and abnormal vibration patterns, and generate adaptive control recommendations, wherein the control layer converts the adaptive control recommendations into actuation commands to modulate compressor operation, airflow distribution, compartment micro-climate, and defrost scheduling in a closed-loop sensing–inference–actuation cycle.

According an embodiment of the present invention, the multi-sensor array comprises a plurality of temperature sensors, at least one humidity sensor, at least one gas or odor sensor, at least one weight or load sensor, at least one door sensor, at least one airflow sensor, at least one vibration and/or electrical current sensor associated with the compressor or fan, and at least one internal camera.

According another embodiment of the present invention, the neuromorphic processing unit executes event-driven models that process sensor inputs only upon detection of predefined state-change events.

According to yet another embodiment of the present invention, the predefined state-change events comprise at least one of door opening, rapid temperature deviation, humidity threshold crossing, gas concentration increase, measurable load change, and abnormal vibration signature.

According to yet another embodiment of the present invention, the internal camera and weight sensor operate cooperatively to generate confidence-scored inventory updates by correlating image recognition results with load variations and door-event timestamps.

According to yet another embodiment of the present invention, the control layer performs compartment-level adaptive airflow control by selectively modulating fan speed and airflow dampers to maintain distinct micro-climate zones.

According to yet another embodiment of the present invention, the compressor is controlled through an inverter driver configured to modulate compressor speed based on predicted load events derived from learned door-opening patterns.

According to yet another embodiment of the present invention, predictive maintenance is performed by analyzing combined vibration patterns, electrical current signatures, and thermal response curves to classify early-stage mechanical degradation.

According to yet another embodiment of the present invention, defrost operation is initiated conditionally based on airflow reduction indicators and compressor runtime deviation from expected performance.

According to yet another embodiment of the present invention, primary multi-sensor fusion, inference, and freshness computation are executed locally within the refrigerator and only metadata comprising alerts or summarized inventory information is transmitted externally.

Another embodiment of the present invention describes a computer-implemented method for intelligent refrigeration control in a neuromorphic refrigerator system. The method comprises continuously monitoring internal environmental and operational parameters using a multi-sensor array including temperature, humidity, gas concentration, airflow, door position, load variation, vibration, and image data, detecting an event comprising a door event or periodic trigger event, in response to the detected event, capturing time-stamped sensor data and camera data representing current storage conditions, performing event-driven multi-sensor fusion using a neuromorphic processing unit to generate contextual state information including stored item identification and environmental status, computing a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration trends, detecting operational anomalies, generating adaptive actuation commands, and controlling refrigeration actuators including compressor operation, airflow distribution, compartment micro-climate, and defrost scheduling based on the adaptive actuation commands in a closed-loop cycle.

According to another embodiment of the present invention, the method of performing multi-sensor fusion comprises executing a spiking neural network (SNN) model that processes sensor inputs only upon detection of meaningful state changes.

According to yet another embodiment of the present invention, the method of identifying stored items comprises correlating image-based object recognition results with weight sensor measurements to generate confidence-scored inventory updates.

According to yet another embodiment of the present invention, the method of generating adaptive actuation commands comprises predicting future thermal load events based on learned user behavior patterns and pre-stabilizing compartment temperature prior to anticipated access.

According to yet another embodiment of the present invention, the method of detecting operational anomalies comprises analyzing vibration signatures and compressor current profiles to generate predictive maintenance alerts.

According to yet another embodiment of the present invention, the method of performing primary inference and freshness computation locally within the refrigerator while enabling optional transmission of alert metadata to an external device.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

This invention is described by way of example with reference to the following drawings. These drawings being referred herein are for the purpose of illustrating preferred embodiments of the invention only, and not for the purpose of limiting the same.

Figure 1 illustrates a block diagram of an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to an embodiment of the present invention.

Figure 2 illustrates a flowchart of an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to another embodiment of the present invention.

Figure 3 illustrates an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to an exemplary embodiment of the present invention.

Figure 4 illustractes a Neuromorphic Intelligence Layer, according to an embodiment of the present invention.

Figure 5 illustractes internal components of an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to an embodiment of the present invention.

Figure 6 illustractes a computer-implemented method for intelligent refrigeration control in a neuromorphic refrigerator system, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The present invention is described hereinafter by various embodiments with reference to the accompanying drawings, wherein reference numerals used in the accompanying drawings correspond to the like elements throughout the description. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, the embodiments are provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those skilled in the art.

It will be understood by those skilled in the art that the foregoing general description and the following detailed description are exemplary and explanatory of the invention and are not intended to be restrictive thereof. The terms "comprises", "comprising", or any other variations thereof, are intended to cover a non-exclusive inclusion, Appearances of the phrase "in an embodiment", "in another embodiment" and similar language throughout this specification may, but not necessarily do, all refer to the same embodiment.

Further, the words "a" or "an" mean "at least one” and the word “plurality” means “one or more” unless otherwise mentioned. Furthermore, the terminology and phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. The systems, methods, and examples provided herein are only illustrative and not intended to be limiting.

The present invention introduces an Artificial Superintelligence (ASI) based Neuromorphic Smart Refrigerator System that is fundamentally different from conventional and existing “AI refrigerators” because it is designed as an always-on, learning, self-optimizing refrigeration system rather than a refrigerator with a few smart add-on features. The unique feature of the invention lies in combining neuromorphic, event-driven intelligence with multi-sensor fusion and closed-loop adaptive refrigeration control, enabling the appliance to perceive, reason, and act locally with minimal power while continuously improving performance over time.

A primary unique aspect is the use of a neuromorphic processing architecture inside the refrigerator to perform continuous intelligence tasks at ultra-low energy. Unlike typical designs that depend on CPU/GPU or cloud computation, the invention uses event-driven inference (e.g., spiking neural networks or neuromorphic models) that processes changes in sensor signals only when meaningful events occur (door openings, rapid temperature drift, abnormal humidity rise, detected spoilage gases, unusual compressor vibration). This reduces computational overhead and supports true 24×7 intelligence without increasing energy consumption significantly, which is particularly important for appliances that operate continuously.

Another unique aspect is the invention's multi-sensor contextual intelligence, where the refrigerator does not rely on one data source (only camera or only RFID), but instead fuses information from temperature, humidity, airflow, door-angle/time sensors, weight/load sensing, gas/odor indicators, internal cameras, and compressor health sensors to build a real-time "digital twin" of the storage environment. The system correlates these inputs to derive high-confidence conclusions such as: what items are present, where they are stored, how frequently compartments are accessed, and what freshness risk is developing under specific micro-climate conditions. This fusion-based approach improves robustness in real kitchens where occlusion, packaging variation, and mixed storage are common.

A further unique aspect lies in freshness and spoilage risk prediction based on multi-factor exposure history, rather than simple expiry dates. The invention calculates freshness risk using a combination of time–temperature–humidity profiles, visual cues (when available), and gas/odor sensor signatures associated with decomposition or ripening. By learning typical deterioration patterns for different food classes under the refrigerator's actual operating conditions, the system can produce more accurate "consume soon" prioritization and early spoilage alerts, thereby reducing food waste and improving safety.

The invention is also unique in its tight coupling between food intelligence and refrigeration actuation. In prior systems, inventory tracking and recipe recommendations are typically separate from cooling control. In the present invention, intelligence outputs directly influence control decisions, including compartment-level cooling intensity, fan/airflow distribution, humidity regulation, and defrost scheduling. For example, if high-spoilage-risk items are detected in a specific compartment, the system can proactively adjust local airflow or humidity to extend freshness, while still optimizing energy use overall.

Another unique element is the ASI-inspired self-optimizing control framework, which continuously learns user routines and operating context to improve performance. The system builds long-term behavioral models such as grocery replenishment cycles, door-opening frequency patterns, preferred storage habits, and time-of-day access trends. Using these learned patterns, it predicts future load events and proactively pre-stabilizes temperatures or schedules energy-intensive tasks (like defrost) during low-impact periods. This creates a refrigerator that becomes smarter with time rather than remaining static after installation.

Finally, the invention introduces a privacy-preserving edge intelligence design. Most sensing, recognition, and decision-making are performed locally within the appliance, enabling offline functionality and reducing dependence on external servers. Where connectivity is used, the system can share only minimal metadata (alerts, summary inventory status) instead of raw images or sensitive household behavior logs. This refrigerator system is unique in balancing advanced intelligence with privacy, reliability, and practical real-world adoption. In combination, these features—neuromorphic always-on processing, multi-sensor fusion digital context modeling, multi-factor freshness prediction, closed-loop adaptive refrigeration control, self-learning optimization, and privacy-preserving edge operation—form the core novel aspects of the present invention.

Figure 1 illustrates a block diagram of an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to an embodiment of the present invention. The Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100), comprises an insulated refrigeration cabinet (102), a multi sensor array (104), a processing subsystem (106), a memory unit (108), and a control layer (110). The insulated refrigeration cabinet (102) is configured to include at least one refrigeration compartment and at least one freezer compartment, and a refrigeration cycle comprising a compressor, condenser, evaporator, expansion device, and at least one circulation fan. The multi-sensor array (104) is disposed within the cabinet and configured to monitor internal environmental and operational parameters. The processing subsystem (106) comprises one of a microcontroller (112) and system-on-chip (MCU/SoC), and a neuromorphic processing unit (NPU) (114). The memory unit (108) is configured to store sensor data, learned behavioral models, inventory records, freshness data, and maintenance logs. The control layer (110) is operatively coupled to refrigeration actuators including the compressor, fan, airflow dampers, and defrost system. The neuromorphic processing unit (114) is configured to perform event-driven multi-sensor fusion and edge inference to: identify and track stored food items and quantity changes, compute a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration data, detect operational anomalies including temperature drift and abnormal vibration patterns, and generate adaptive control recommendations. The control layer is configured to convert the adaptive control recommendations into actuation commands to modulate compressor operation, airflow distribution, compartment micro-climate, and defrost scheduling in a closed-loop sensing–inference–actuation cycle.

According to one embodiment, the multi-sensor array comprises a plurality of temperature sensors, at least one humidity sensor, at least one gas or odor sensor, at least one weight or load sensor, at least one door sensor, at least one airflow sensor, at least one vibration and/or electrical current sensor associated with the compressor or fan, and at least one internal camera.

According to one embodiment, the neuromorphic processing unit executes event-driven models that process sensor inputs only upon detection of predefined state-change events.

According to one embodiment, the predefined state-change events comprise at least one of door opening, rapid temperature deviation, humidity threshold crossing, gas concentration increase, measurable load change, and abnormal vibration signature.

According to one embodiment, the freshness or spoilage risk score is computed using a multi-factor exposure model integrating cumulative time–temperature data and humidity history with gas concentration trends.

According to one embodiment, the internal camera and weight sensor operate cooperatively to generate confidence-scored inventory updates by correlating image recognition results with load variations and door-event timestamps.

According to one embodiment, the control layer performs compartment-level adaptive airflow control by selectively modulating fan speed and airflow dampers to maintain distinct micro-climate zones.

According to one embodiment, the compressor is controlled through an inverter driver configured to modulate compressor speed based on predicted load events derived from learned door-opening patterns.

According to one embodiment, predictive maintenance is performed by analyzing combined vibration patterns, electrical current signatures, and thermal response curves to classify early-stage mechanical degradation.

According to one embodiment, defrost operation is initiated conditionally based on airflow reduction indicators and compressor runtime deviation from expected performance.

According to one embodiment, primary multi-sensor fusion, inference, and freshness computation are executed locally within the refrigerator and only metadata comprising alerts or summarized inventory information is transmitted externally.

Event Detection within the Multi-Sensor Array (104)

In the Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100), the multi-sensor array (104) continuously monitors internal environmental and operational parameters including temperature, humidity, gas concentration, airflow, door position, load variation, vibration, electrical current, and image data.

The processing subsystem (106), comprises the MCU/SoC and the neuromorphic processing unit (NPU) (114), implements predefined state-change detection logic.

The MCU/SoC performs low-power sampling of outputs from the multi-sensor array (104) and stores at least one of: Current sensor values, Previous sensor values, Baseline or reference values, and Threshold parameters stored, in the memory unit (108).

A predefined state-change event is detected when at least one of the following conditions occurs:

- Door opening detected by the door sensor;
- Rapid temperature deviation beyond a stored threshold;
- Humidity threshold crossing;
- Gas concentration increase relative to baseline;
- Measurable load change detected by the weight or load sensor;
- Abnormal vibration signature or compressor current deviation; and
- Airflow reduction below expected performance range;

The threshold parameters are stored in the memory unit (108) and may be factory-calibrated or adaptively updated during system operation.

When none of the predefined state-change events are detected, the neuromorphic processing unit (NPU) (114) remains in a low-power standby state.

Event-Driven Invocation of the Neuromorphic Processing Unit (NPU) (114)

Upon detection of a predefined state-change event according to an embodiment of the present invention, the processing subsystem (106) captures time-stamped sensor data and, where applicable, camera data representing current storage conditions.

The MCU/SoC aggregates at least one of:

- A sensor data vector from the multi-sensor array (104);
- Historical sensor samples from a sliding buffer stored in the memory unit (108);
- Door event indicators; and
- Compartment identification.

This information is transmitted to the neuromorphic processing unit (NPU) (114) through an internal communication interface.

The neuromorphic processing unit (NPU) (114) executes event-driven multi-sensor fusion and edge inference only in response to the detected predefined state-change event.

Execution of Event-Driven Multi-Sensor Fusion and Edge Inference

According to an embodiment of the present invention, the neuromorphic processing unit (NPU) (114) executes event-driven models including a spiking neural network (SNN) model.

Sensor inputs from the multi-sensor array (104) are encoded into event signals representing magnitude and rate-of-change of the detected parameters.

The neuromorphic processing unit (NPU) (114) processes sensor inputs only upon detection of predefined state-change events and performs at least one of:

- Multi-sensor fusion;

- Identification and tracking of stored food items and quantity changes;
- Computation of a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration data;
- Detection of operational anomalies including temperature drift and abnormal vibration patterns; and
- Generation of adaptive control recommendations.

In absence of a predefined state-change event, no inference cycle is executed, thereby reducing computational power consumption.

Computation of Freshness or Spoilage Risk Score

According to an embodiment of the present invention, the freshness or spoilage risk score is computed using a multi-factor exposure model integrating at least one of:

- Cumulative time–temperature data;
- Humidity history; and
- Gas concentration trends.

The memory unit (108) stores exposure history for identified food items and compartments.

The neuromorphic processing unit (NPU) (114) correlates the exposure history with real-time sensor data to generate a numerical or graded freshness or spoilage risk score.

Detection of Operational Anomalies

According to an embodiment of the present invention, operational anomalies are detected by analyzing at least one of:

- Rapid temperature deviation;
- Abnormal vibration signature;

- Electrical current variation associated with the compressor or fan;
- Extended compressor runtime; and
- Airflow reduction.

The neuromorphic processing unit (NPU) (114) classifies anomalies and generates corresponding adaptive control recommendations or predictive maintenance alerts.

Generation of Adaptive Control Recommendations and Actuation Commands

According to an embodiment of the present invention, the neuromorphic processing unit (NPU) (114) transmits adaptive control recommendations to the control layer (110).

The control layer (110) converts the adaptive control recommendations into actuation commands to at least one of:

- Modulate compressor operation;
- Adjust fan speed;
- Regulate airflow dampers;
- Control compartment micro-climate; and
- Initiate defrost scheduling.

The system thereby operates in a closed-loop sensing–inference–actuation cycle.

Local Execution and Power Management

According to an embodiment of the present invention, primary multi-sensor fusion, inference, and freshness computation are executed locally within the refrigerator system (100).

The neuromorphic processing unit (NPU) configured to at least one of:

- Remains in standby mode during absence of predefined state-change events;
- Is activated only when triggered by the processing subsystem (106); and

- Returns to low-power state after completion of inference.

Only metadata comprising alerts or summarized inventory information may be transmitted externally, consistent with the claims.

Safety and Deterministic Control

According to an embodiment of the present invention, the processing subsystem (106) validates outputs from the neuromorphic processing unit (NPU) before implementation.

If the neuromorphic processing unit (NPU) does not respond within a predefined time window, the control layer (110) reverts to conventional control logic to ensure safe compressor operation and temperature maintenance.

Hardware-enforced safety thresholds remain independent of adaptive control recommendations.

Spiking Neural Network Architecture within the Neuromorphic Processing Unit (NPU)

In one embodiment of the Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100), the neuromorphic processing unit (NPU) of the processing subsystem (106) executes a spiking neural network (SNN) model for performing event-driven multi-sensor fusion and edge inference.

The spiking neural network model comprises at least one of:

- an input neuron layer;
- at least one intermediate neuron layer configured for multi-sensor fusion;
- an output neuron layer configured to generate classification and control signals; and

- synaptic weight storage stored in or accessible through the memory unit (108).

The SNN model operates using discrete spike events rather than continuous numerical computation.

Input Encoding from Multi-Sensor Array (104)

Outputs from the multi-sensor array (104), including at least one of: Temperature sensors, Humidity sensor, Gas or odor sensor, Weight or load sensor, Door sensor, Airflow sensor, Vibration and/or electrical current sensor, and Internal camera-derived feature vectors, are encoded into spike representations before processing by the neuromorphic processing unit (NPU).

In one embodiment:

- A spike is generated when a predefined state-change event is detected.
- Spike frequency corresponds to magnitude of deviation.
- Spike timing corresponds to rate of change of the parameter.

For example:

- Rapid temperature deviation generates higher-frequency spikes in temperature input neurons.
- Gas concentration increase generates spike bursts in spoilage detection neurons.
- Measurable load change generates spike activation in inventory neurons.
- Abnormal vibration signature generates spikes in mechanical health neurons.

In absence of predefined state-change events, no spike signals are generated and the spiking neural network remains inactive.

Multi-Sensor Fusion through Spiking Dynamics

The intermediate neuron layer performs temporal and cross-sensor correlation by integrating incoming spike trains.

Each neuron accumulates weighted spike inputs over time. A neuron fires only when its membrane potential exceeds a predefined firing threshold.

This architecture enables:

- Correlation of door opening and rapid temperature deviation,
- Correlation of humidity threshold crossing and gas concentration increase,
- Correlation of vibration signatures and compressor current variation,
- Correlation of image-derived object recognition features and weight/load variation.

Because neurons fire only when sufficient spike activity occurs, continuous computation is avoided.

Output Layer and Functional Mapping

The output neuron layer generates discrete inference outputs including at least one of:

- Stored food item identification signals,
- Quantity change confirmation,
- Freshness or spoilage risk score levels,
- Operational anomaly classification, and
- Adaptive control recommendation signals.

The output spikes are decoded into structured digital signals by the processing subsystem (106) and transmitted to the control layer (110).

Event-Driven Processing Behavior

The spiking neural network model processes sensor inputs only upon detection of predefined state-change events, particularly:

1. The processing subsystem (106) detects a predefined state-change event.
2. The event triggers activation of the neuromorphic processing unit (NPU).
3. Encoded spike inputs are delivered to the SNN.

4. Inference is executed.
5. Adaptive control recommendations are generated.
6. The NPU returns to standby state after completion.

Thus, in absence of meaningful state changes, no neural firing activity occurs and no inference cycle is executed.

Storage and Update of Synaptic Weights

Synaptic weights associated with the spiking neural network model are stored in the memory unit (108).

In one embodiment:

- Weight parameters are pre-trained and stored at manufacturing.
- Behavioral adaptation may occur based on logged sensor data and inferred outcomes.
- Weight updates occur within bounded ranges to maintain stability.
- Safety-critical control thresholds remain hardware enforced and independent of adaptive weight updates.

Power-Efficient Operation

The system disclosed in the present invention discloses power-efficient operation because the spiking model:

- activates neurons only upon spike events,
- avoids continuous floating-point computation,
- executes inference only after predefined state-change events.

Therefore, the neuromorphic processing unit (NPU) consumes significantly lower computational power compared to continuously operating AI processors.

Strengthened Exposure Model Computation

Multi-Factor Freshness or Spoilage Risk Score

Exposure History Storage in Memory Unit (108)

In one embodiment of the Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100), the memory unit (108) stores time-stamped environmental exposure records for each refrigeration compartment and, where applicable, for identified stored food items.

For each compartment or identified food item, the memory unit (108) maintains at least one of:

- Cumulative time–temperature exposure history,
- Humidity exposure history,
- Gas concentration trend history, and
- Door-opening frequency affecting that compartment.

The exposure history is maintained using rolling time windows and cumulative aggregation logic.

Cumulative Time–Temperature Integration

The processing subsystem (106) continuously integrates temperature deviation from a predefined optimal storage range.

For example:

- If temperature remains within optimal range, exposure contribution is minimal.
- If temperature exceeds upper or lower limits for a sustained duration, exposure accumulation increases proportionally to:
  - Magnitude of deviation
  - Duration of deviation

This cumulative exposure value is stored in the memory unit (108) and updated after each predefined state-change event.

Humidity Exposure Integration

Humidity values from the multi-sensor array (104) are monitored relative to recommended storage ranges for different food categories.

If humidity exceeds or falls below target bands:

- A humidity deviation counter is incremented.
- Duration and magnitude of deviation are stored.

This allows differentiation between short transient fluctuations and prolonged humidity imbalance.

Gas Concentration Trend Analysis

Gas or odor sensor readings are compared against baseline levels established during stable storage conditions.

The processing subsystem (106):

- Maintains a baseline gas concentration profile.
- Detects increasing trends across consecutive time intervals.
- Identifies rate-of-increase exceeding predefined thresholds.

Gas concentration trends are correlated with time–temperature–humidity exposure history to reduce false positives.

Multi-Factor Risk Computation

The neuromorphic processing unit (NPU) performs event-driven multi-sensor fusion and computes a freshness or spoilage risk score based on:

- Accumulated time–temperature exposure
- Humidity deviation duration
- Gas concentration trend magnitude
- Door-opening frequency affecting thermal stability

The freshness or spoilage risk score may be represented as:

- A numerical index within a bounded range, or
- A graded category such as Low, Moderate, High risk.

The risk score is updated only upon detection of predefined state-change events to preserve computational efficiency.

Strengthened Confidence-Scored Inventory Logic

Cooperative Camera and Weight-Based Verification

In one embodiment, identification and tracking of stored food items and quantity changes are performed using correlated outputs from:

- Internal camera,
- Weight or load sensor,
- Door sensor timestamps.

Inventory Update Sequence

Upon a door opening event:

1. The internal camera captures image data.
2. The weight or load sensor measures compartment load variation.
3. Door event timestamp is recorded.

The neuromorphic processing unit (NPU) processes image recognition results and compares them with measured load variation.

Confidence Score Generation

A confidence score is generated based on:

- Consistency between detected visual object and weight change magnitude,
- Consistency between object location and compartment sensor data,
- Presence or absence of conflicting sensor inputs.

For example:

- If image recognition detects a milk container and weight increases correspondingly, confidence is high.
- If image recognition detects an object but no measurable load change occurs, confidence is reduced.

- If weight changes without visual detection (due to occlusion), inference is supported by door event timing.

The confidence score is stored in the memory unit (108) and used to determine whether automatic inventory update is confirmed or flagged for user verification.

This multi-sensor verification differentiates the invention from camera-only smart refrigerator systems.

Strengthened Predictive Load Anticipation Mechanism

Learned Door-Opening Pattern Modeling

In one embodiment, the memory unit (108) stores historical door-opening timestamps and duration values.

The processing subsystem (106) analyzes:

- Time-of-day access frequency,
- Daily and weekly repetition patterns,
- Average temperature deviation following access events.

Pattern Recognition

If a recurring access pattern is detected within a defined statistical confidence threshold:

- A predicted load event window is generated.

For example:

- Frequent door openings between 7:00–8:00 AM.
- Repeated evening access pattern between 8:00–9:00 PM.

Pre-Stabilization Control Logic

Prior to a predicted load event window:

- The control layer (110) may modulate compressor operation through an inverter driver.
- Compartment temperature may be stabilized slightly below nominal target to compensate for anticipated warm air intrusion.
- Airflow distribution may be temporarily adjusted.

After the predicted event window:

- Control parameters return to nominal energy-efficient settings.

This predictive anticipatory control reduces temperature oscillation and improves energy optimization compared to purely reactive systems.

Strengthened Condition-Based Defrost Logic

Airflow Reduction and Runtime Deviation Monitoring

In one embodiment, the multi-sensor array (104) includes at least one airflow sensor.

The processing subsystem (106) monitors:

- Airflow rate relative to stored baseline airflow performance.
- Compressor runtime duration required to achieve target temperature.
- Temperature recovery rate after compressor activation.

Frost Accumulation Indicators

If:

- Airflow rate decreases progressively without mechanical obstruction, and
- Compressor runtime increases beyond expected performance range, and
- Temperature recovery rate slows,

the system infers potential frost accumulation on evaporator surfaces.

Conditional Defrost Trigger

The control layer (110) initiates defrost operation only when:

- Frost indicators exceed predefined thresholds,
- Compartment conditions allow safe temporary heating,
- Energy optimization schedule permits.

This differs from fixed-timer defrost systems and reduces unnecessary energy consumption.

Additional Details for Freshness or Spoilage Risk Computation

Item-Level and Compartment-Level Risk Mapping

In one embodiment of the Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100), the freshness or spoilage risk score is computed at two hierarchical levels:

1. **Compartment-Level Risk Score**, and
2. **Item-Level Risk Score** for identified stored food items.

Compartment-Level Risk Score

The processing subsystem (106) maintains environmental exposure history for each refrigeration compartment using data obtained from the multi-sensor array (104).

The compartment-level freshness or spoilage risk score is computed based on:

- Cumulative time–temperature exposure within the compartment,
- Humidity deviation duration within the compartment,
- Gas concentration trends measured in proximity to that compartment,
- Door-opening frequency affecting thermal stability of that compartment.

This score reflects the overall storage condition of the compartment.

Item-Level Risk Score

Where stored food items are identified using the internal camera and correlated weight or load sensor data, the memory unit (108) associates each identified item with:

- Its storage compartment,
- Its placement timestamp,
- Its exposure history since placement.

The processing subsystem (106) maps compartment exposure data to individual identified items based on:

- Duration of item presence within the compartment,
- Localized sensor readings near the item's storage zone,
- Detected gas concentration trends associated with the item's region.

Accordingly, the neuromorphic processing unit (NPU) computes an item-level freshness or spoilage risk score reflecting cumulative environmental stress experienced by that specific item.

This mapping enables differentiation between:

- Newly placed items, and
- Items stored for extended duration under fluctuating conditions.

Risk Score Normalization and Bounded Representation

In one embodiment, the freshness or spoilage risk score is represented within a bounded range stored in the memory unit (108).

The score may be:

- A normalized numerical index within a predefined scale (e.g., minimum-to-maximum bounded value), or
- A graded categorical level such as:
    - Low Risk
    - Moderate Risk

- Elevated Risk
- High Risk

Threshold bands for each level are predefined and stored in the memory unit (108). The use of bounded representation ensures:

- Deterministic system behavior,
- Predictable control decisions,
- Compliance with safety constraints.

Risk-Triggered Adaptive Control and Notification Logic

The neuromorphic processing unit (NPU) transmits the computed freshness or spoilage risk score to the control layer (110).

Based on predefined threshold bands:

- If the risk score exceeds a moderate threshold, the control layer (110) may adjust compartment micro-climate by modulating airflow dampers or fan speed.
- If the risk score exceeds a higher threshold, adaptive control recommendations may include compressor modulation to stabilize temperature more tightly.
- If the risk score exceeds a critical threshold, the system generates user alerts through the interface and logs the event in the memory unit (108).

For item-level high-risk conditions, the system may:

- Generate “consume soon” notification,
- Suggest relocation to a colder compartment,
- Prioritize the item in the dynamic inventory list.

This direct linkage between risk score and actuation commands forms part of the closed-loop sensing–inference–actuation cycle.

Continuous Updating Mechanism

The freshness or spoilage risk score is updated only upon detection of predefined state-change events or periodic trigger events, thereby ensuring:

- Event-driven computational efficiency,
- Accurate reflection of environmental changes,
- Reduced unnecessary inference cycles.

Exposure counters and risk indices are stored persistently in the memory unit (108) and are reset or recalibrated upon item removal, confirmed consumption, or user override.

According to an embodiment of the present invention, an Artificial Superintelligence (ASI) based Neuromorphic Smart Refrigerator performs intelligent food monitoring, freshness prediction, and adaptive refrigeration control using neuromorphic edge computing and multi-sensor fusion. The invention is described as a complete system comprising a refrigeration unit, sensing modules, an intelligent neuromorphic processing unit, a control and actuation subsystem, and a user interaction layer, all working together to improve food preservation, reduce spoilage, and optimize energy consumption.

In one embodiment, the refrigerator comprises a conventional insulated cabinet having at least one refrigeration compartment and one freezing compartment, each fitted with shelves, drawers, and airflow channels. The cabinet includes a compressor-based refrigeration cycle (or any equivalent cooling mechanism), evaporator, condenser, expansion device, and one or more circulation fans. The invention does not replace the basic refrigeration cycle; rather, it enhances operation by adding an intelligent control architecture that dynamically manages cooling power, airflow distribution, humidity control, and defrost scheduling based on learned usage patterns and real-time storage conditions.

In another embodiment, the refrigerator includes a multi-sensor array positioned at strategic locations within compartments and air channels. The sensor set may include temperature sensors distributed across compartments, humidity sensors for moisture tracking, door sensors for detecting door-open/close events and door angle, airflow sensors to monitor ventilation effectiveness, load/weight sensors integrated under shelves or drawers for measuring food mass changes, internal cameras for food recognition, gas/odor sensors for detecting spoilage-related volatile compounds, and vibration/current sensors for monitoring compressor and fan health. Each sensor produces time-stamped readings, and the arrangement is designed so that local micro-climate variations inside the refrigerator can be detected rather than assuming uniform temperature and humidity.

In a key embodiment, the system integrates a neuromorphic processing unit (NPU) or neuromorphic co-processor that executes event-driven learning and inference. The NPU receives sensor data either continuously or in event-triggered form. For example, when a door opens, when temperature changes rapidly, when humidity spikes, or when odor signals cross a threshold, an event is generated and fed to the neuromorphic intelligence layer. This layer uses neuromorphic models (such as spiking neural networks) to perform low-power classification, anomaly detection, and prediction tasks. Unlike conventional AI chips that may require high energy for constant computation, the event-driven nature enables the refrigerator to maintain always-on intelligence with minimal power overhead.

In one embodiment, the invention provides a food recognition and inventory subsystem. When the door is opened, internal cameras capture images of shelves and compartments. The system optionally uses lighting control to improve capture quality. The images are processed locally through the intelligence layer to detect and classify food items and packaging types. Weight sensors may corroborate quantity changes, and door-event timestamps help associate inventory updates with user actions. The refrigerator maintains a dynamic digital inventory list that stores item identity, storage location, estimated quantity, and time history. If the user prefers, the system can allow manual corrections through the interface, and the learning module updates its recognition accuracy over time for the household's specific brands and packaging.

In another embodiment, the invention provides freshness estimation and spoilage risk prediction. For each identified item or food category, the system maintains exposure history such as temperature duration, humidity exposure, and door-opening frequency in that compartment. Gas/odor sensor signatures can indicate ripening or decomposition processes, and visual cues may indicate color change, mold risk, or texture changes for certain foods. By fusing these multi-modal indicators, the system computes a spoilage risk score and generates prioritization such as "consume soon," "store in colder zone," or "check for spoilage." This approach is more accurate than relying solely on printed expiry dates because it uses real storage conditions and continuously updates as conditions change.

In a further embodiment, the invention includes an ASI-based adaptive control framework that directly controls refrigeration actuators. Based on predicted load events and real-time conditions, the control system modulates compressor duty cycle, fan speed, damper position, and optionally compartment-level humidity regulation. For example, if the system detects frequent door openings at a certain time each day, it may pre-stabilize temperature slightly before that period to reduce temperature swings. If the vegetable drawer humidity drops below a desired level, airflow can be adjusted to maintain freshness. Defrost operations may be scheduled during low-usage periods while ensuring energy efficiency and minimizing food temperature disturbance.

In an additional embodiment, the invention performs predictive maintenance and fault detection. Vibration sensors, temperature response curves, compressor current patterns, and airflow performance are analyzed by the neuromorphic intelligence layer to identify early signs of compressor wear, fan imbalance, blocked vents, sensor drift, or refrigerant performance degradation. When abnormal patterns are detected, the system provides warnings such as “service recommended” or “check door seal,” preventing sudden failure and reducing food loss.

Finally, the invention includes a user interaction and communication layer through a touchscreen display on the door and/or a mobile application. The interface can show inventory lists, freshness alerts, recommended storage actions, shopping suggestions, and energy optimization tips. The system may operate fully offline with local intelligence, while optional connectivity enables remote notifications, periodic secure updates, and integration with recipe services. Overall, the invention provides a neuromorphic, adaptive, privacy-aware smart refrigerator that continuously learns, predicts, and optimizes, thereby delivering superior food preservation and energy efficiency compared to prior systems.

Figure 2 illustrates a flowchart of an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to another embodiment of the present invention

The above Working Flowchart shows the complete operating cycle of the Neuromorphic Smart Refrigerator from the moment the system runs, detects an event, analyzes data, takes control actions, updates the user, learns, and repeats. Here is a clear step-by-step explanation of how it works:

The process starts at “Start”, meaning the refrigerator is powered ON and the control software is running continuously in the background. The system remains in a monitoring mode so that it can react immediately when something important happens inside the refrigerator.

Next comes the decision block: “Door Event or Periodic Event?” This is a trigger step. A Door Event means the door was opened/closed or remained open too long (detected by the door sensor). A Periodic Event means a scheduled check occurs at fixed intervals (for example every 5 minutes or every 30 minutes) even if the door is not used. If the answer is No, the system does not run the heavy processing cycle and simply stays in monitoring mode to save energy. If the answer is Yes, it proceeds to the next step.

When an event occurs, the system moves to “Capture Sensor and Camera Data.” In this step, all real-time readings are collected together, such as temperature, humidity, gas/odor signals, weight/load changes, airflow status, and camera snapshots. This step gathers the current state of the refrigerator environment and food storage conditions. The goal is to obtain a complete “current condition data package” for analysis. After data capture, the system performs “Multi-Sensor Fusion and Edge Inference.” This is the intelligence step where the neuromorphic processing (NPU) combines multiple sensor readings into one accurate understanding. For example, if the camera sees a milk bottle and the weight sensor shows a decrease, the system infers milk consumption. If temperature rises and door sensor indicates the door is open, the system infers warm air intrusion. If gas sensor increases near the crisper and humidity is high, it may infer spoilage risk. This fusion reduces errors that can occur if only one sensor is used.

Next is “Compute Freshness Risk Score.” Here the refrigerator calculates a numeric or graded score indicating how likely food items are nearing spoilage. This score is based on exposure history (time–temperature–humidity), current sensor conditions, and any detected spoilage indicators (like odor/gas changes or visual cues). The system may compute freshness for compartments (zone-level freshness) and/or for individual items (item-level freshness). If the risk score crosses a threshold, it prepares alerts like “consume soon” or “check item for spoilage.”

Then the system proceeds to “Decide Adaptive Actuation Commands.” This is where the refrigerator decides what physical actions to take. Depending on the computed results, the control module may:

- increase or decrease compressor duty cycle,
- adjust fan speed / airflow vents,
- modify humidity handling (by airflow tuning),
- schedule or trigger defrost if efficiency is dropping,
- activate door-open alarms or warnings,
- apply localized cooling strategies to maintain stability. So, in this step, intelligence is converted into actual control commands that regulate the internal environment.

After executing these actions, the flowchart moves to “Update User Interface / Log Events.” Here the system updates the touchscreen/mobile app with information such as: updated inventory list, freshness warnings, energy status, or fault alerts. In addition, the refrigerator stores logs of sensor readings, actions taken, and outcomes. This logging is important for traceability (useful in commercial use), and it also supports learning.

Next is “Continue Learning and Energy Optimization.” This step represents continual learning and improvement. The refrigerator analyzes past events and outcomes to improve future decisions. For example, it learns the household’s typical door-opening times, which shelves get warmer, which foods spoil quickly in certain zones, and how the compressor behaves when aging. It then updates its internal models so that next time it can restore temperature faster with less energy or provide earlier freshness warnings with higher accuracy.

Finally, the process reaches “End”, but in practical operation, this does not mean the refrigerator stops permanently. It means the current cycle ends, and the system loops back to monitoring again, waiting for the next-door event or periodic event to repeat the full workflow. In short, the diagram shows a closed-loop intelligent cycle:

Event Trigger → Data Capture → Fusion & Inference → Freshness Scoring → Control Actions → UI Updates → Learning & Optimization → Repeat.

Figure 3 illustrates an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to an exemplary embodiment of the present invention.

Neuromorphic Smart Refrigerator works as an integrated system where sensors collect real-time information, the Neuromorphic Processing Unit (NPU) + control logic analyze it, and the cooling/airflow/defrost hardware takes actions to maintain freshness, safety, and energy efficiency. Below is a detailed component-wise working explanation in paragraph form.

The Temperature Sensors are placed at multiple zones (upper shelf area, mid-zone, vegetable crisper, and near the freezer/evaporator region). Their job is to continuously measure the actual temperature at different locations, because a refrigerator does not cool uniformly everywhere. When the door opens, warm air enters and the temperature rises quickly near the front; these sensors detect that rise instantly. The control system uses this information to decide how much cooling is needed, where to direct cold air, and whether the compressor should run longer or shorter. This multi-point sensing prevents overcooling in one area and undercooling in another, improving food preservation.

The Humidity Sensors work mainly to manage moisture-sensitive foods, especially in the vegetable crisper. Fruits and vegetables stay fresh longer when humidity is maintained in a controlled range; too low humidity causes dehydration and wilting, while too high humidity increases condensation and mold risk. The refrigerator continuously reads humidity values and adjusts airflow, fan speed, or damper positions to maintain an appropriate micro-climate. If humidity becomes abnormal due to frequent door openings or warm food placement, the system compensates by changing ventilation patterns instead of running the compressor unnecessarily.

The Internal Cameras capture images of shelves and compartments during key events—typically when the door is opened, at the moment of maximum opening, or just before closing. The camera stream supports food recognition and inventory tracking. The system identifies items (milk bottle, vegetables, packaged foods) and compares new images with previous images to detect what was added or removed. If the camera view is partially blocked, the system can combine camera data with weight sensors and door timing to make a more reliable decision about inventory change. This avoids the need for manual input and helps maintain an automatic food list.

The Weight Sensors (load sensors) are fitted under shelves or drawers to detect changes in stored load. When you place a new item, the shelf weight increases; when you remove something, it decreases. Weight sensors are very useful when camera visibility is limited (packets behind other packets). The controller correlates weight changes with door-open events and camera snapshots to infer which compartment's inventory changed. Over time, the system can estimate consumption patterns (how quickly milk reduces, how often vegetables are replenished) and use this to generate intelligent alerts and shopping recommendations.

The Door Sensor detects when the door opens, closes, and how long it remains open. Door events are critical because they are the most common cause of temperature fluctuation and energy loss. If the door remains open beyond a safe duration, the system can trigger a buzzer or notification. More advanced operation includes predicting the thermal impact: if the door is opened repeatedly in a short time, the controller might temporarily increase airflow circulation to restore uniform temperature quickly, instead of forcing aggressive compressor cycling.

The Cooling Fan and Airflow Vents control how cold air is distributed inside the compartments. The compressor and evaporator create the cooling effect, but the fan and vents determine where that cold air goes. The smart system adjusts fan speed and vent/damper positions based on sensor readings. For example, if the top shelf warms faster due to frequent access, the controller can increase airflow to that region. If the crisper needs humidity retention, the system reduces airflow there to avoid drying out vegetables. This targeted airflow control is a major reason why the refrigerator can maintain freshness efficiently.

The Compressor is the main cooling engine of the refrigerator. It compresses refrigerant and drives the refrigeration cycle to remove heat from inside. Traditional refrigerators run the compressor using basic thermostat thresholds. In this invention, compressor operation becomes adaptive: the controller decides when to start, stop, or modulate compressor activity based on multi-sensor conditions, predicted usage, and stability requirements. The goal is to maintain temperature within tight bounds with minimum energy. If the system predicts that the user will open the door soon (based on learned patterns), it can pre-stabilize temperature slightly to reduce post-opening recovery load.

The Vibration Sensors monitor the compressor and fan for abnormal vibration patterns that indicate mechanical wear, imbalance, loose mounting, or early failure symptoms. Over time, a compressor that is deteriorating often shows measurable vibration changes, unusual noise signatures, and inefficient cooling response. The system analyzes vibration signals together with cooling performance data (how quickly temperature drops after compressor ON) to estimate health. If it finds early warning signs, it generates a predictive maintenance alert, helping prevent sudden breakdown and food spoilage.

The Defrost System removes ice buildup on the evaporator coils (especially in frost-free models). Ice accumulation reduces heat exchange, lowers efficiency, and increases power consumption. In normal refrigerators, defrost runs on a fixed schedule. In this smart design, defrost is optimized: the controller triggers defrost when sensors indicate efficiency is dropping (e.g., airflow reduction, coil temperature behavior, longer compressor runtime to achieve cooling). It can also schedule defrost during low-usage hours to minimize disturbance. This improves efficiency and ensures stable cooling.

The Neuromorphic Processing Unit (NPU) is the intelligence core. It receives sensor data (temperature, humidity, gas, weight, door events, vibration, camera features) and processes it using event-driven models. Instead of running heavy computation continuously, the NPU reacts mainly when meaningful changes occur (door opens, temperature rises abnormally, gas increases, vibration shifts). It performs tasks like anomaly detection, pattern learning, freshness estimation, inventory inference, energy optimization decisions, and predictive maintenance signals. Because neuromorphic processing is event-driven and efficient, it can keep monitoring continuously without adding significant power load.

The Microphone and Voice Assistant Speaker enable voice interaction. Users can ask "What items are inside?", "Which items will expire soon?", or "Add milk to shopping list." The system can also give alerts through voice such as "Door open" or "Vegetables may spoil soon." Voice input is especially helpful for hands-free kitchen use. The system combines voice commands with inventory data and freshness scores to provide meaningful responses.

The Touchscreen Display / Mobile App Interface provides the user with real-time information such as current compartment temperatures, inventory list, freshness alerts, and suggested actions. The user can confirm or correct recognized items, set dietary preferences, set notification rules, and view energy reports. The app can also send remote alerts when spoilage risk is detected or when the door is left open. This interface layer converts complex sensor intelligence into simple, actionable user guidance.

Overall, the refrigerator works by continuously following a closed-loop cycle: Sense → Understand → Decide → Act → Learn. Sensors capture the environment, the NPU and control module interpret the data, the compressor/fan/vents/defrost act to maintain ideal conditions, and the system learns patterns to become more accurate and energy-efficient over time.

Figure 4 illustractes a Neuromorphic Intelligence Layer, according to an embodiment of the present invention.

The Software/firmware & Logic Layer Diagram represents how intelligence in the neuromorphic smart refrigerator is organized from the user-facing functions down to the sensing, inference, and actuator control. The layers work in a top-to-bottom flow for monitoring and decision-making, and then bottom-to-top for feedback and user updates. Below is a clear paragraph-wise explanation of each layer and how they work together.

The Application Layer is the topmost layer that the user directly interacts with. It includes the Touchscreen & Voice Interface, Dynamic Inventory Management, and Personalized Recommendations modules. Through the touchscreen or mobile/voice interface, the user can view current food items, see freshness alerts, receive expiry reminders, and control settings such as temperature modes (eco mode, vacation mode, quick-cool, etc.). The inventory module displays what items are inside and their status, while recommendation functions suggest recipes, shopping reminders, and “consume soon” priority notifications. This layer does not directly control cooling hardware;

instead, it communicates user commands and preferences downward to the Control Layer and receives processed results back from lower layers for display.

The Control Layer is the decision and execution management layer that converts high-level goals into actual refrigerator actions. It has three main blocks: Adaptive Scheduling & Actuation, Freshness Monitoring & Spoilage Risk Prediction, and Predictive Maintenance & Fault Alerts. Adaptive scheduling decides when to run the compressor, how much to run it, how to distribute airflow, and when to trigger defrost, based on both real-time sensor conditions and predicted future behavior. Freshness monitoring converts sensor-derived food condition signals into a measurable freshness score or spoilage risk score, which drives alerts and actions like adjusting humidity or airflow in specific zones. Predictive maintenance continuously checks for abnormal operational patterns (like unusual compressor vibration, longer cooling times, airflow blockage) and generates fault alerts before breakdown occurs. In short, the Control Layer is responsible for converting intelligence outputs into safe, optimized control commands for the refrigerator.

The Neuromorphic Intelligence Layer is the core intelligence engine that makes the invention different from typical “AI refrigerators.” It performs Multi-Sensor Fusion, Event-Driven Processing and Edge Inference, and Continual Learning & Fault/Condition Learning. Multi-sensor fusion means the system does not trust any single sensor alone; it combines temperature, humidity, gas/odor, weight, camera features, and vibration signals into one unified understanding. Event-driven processing means it performs heavy inference mainly when something meaningful happens (door opens, temperature rises quickly, gas spikes, weight changes, vibration pattern shifts), which reduces power usage while still keeping the system always-on. Continual learning allows the refrigerator to improve accuracy over time—for example, learning how a particular household stores items, learning the typical door-opening schedule, or learning the normal vibration signature of a healthy compressor so that deviations can be detected early. This intelligence layer sends its conclusions upward as structured outputs: inventory updates, freshness risk, anomaly alerts, and predicted control recommendations.

The Edge Interfaces section represents the boundary where real-world data enters and where control actions leave. It includes sensor inputs such as Temperature/Humidity, Gas Sensors, Weight/Load Sensors, and Camera Feed, and it also connects to system-level inputs like compressor/vibration sensing and operational state signals. These interfaces perform basic functions like sensor calibration, noise filtering, timestamping, and formatting the data so that the neuromorphic layer can process it reliably. Essentially, this block ensures "clean and usable" sensor data reaches the intelligence modules, and ensures that actuator commands coming back down are delivered correctly to the hardware controllers.

The Data Flow (Upward Path) works as follows: raw signals from sensors and camera feed move into the Edge Interfaces, then flow into the Neuromorphic Intelligence Layer for fusion and inference, then go to the Control Layer where decisions are finalized, and finally reach the Application Layer for user display and interaction. This upward path transforms raw sensor readings into meaningful outcomes such as "Milk quantity reduced," "Vegetables at risk of spoilage," "Door left open," or "Compressor efficiency dropping," which the user can understand and act upon.

The Decision Output (Downward Path) is the execution pathway. After the Control Layer determines the best action, it sends commands downward to the refrigeration hardware control system—such as compressor ON/OFF or modulation level, fan speed, airflow damper positions, defrost activation timing, and alarm/notification triggers. These actions change the internal environment (temperature stability, humidity level, airflow distribution), and then sensors immediately measure the new conditions. This creates a continuous closed-loop cycle: Sense → Infer → Decide → Act → Verify, which is the foundation of intelligent appliance control. The diagram shows a structured architecture where the Application Layer focuses on user services, the Control Layer focuses on decision execution and safety, the Neuromorphic Intelligence Layer focuses on low-power event-driven learning and inference, and the Edge Interfaces ensure robust real-world sensing and actuation connectivity.

Figure 5 illustractes internal components of an Artificial Superintelligence (ASI) based neuromorphic refrigerator system, according to an embodiment of the present invention.

The Power Supply converts mains AC power into regulated DC rails required by the electronic system. It typically generates multiple voltages (for example, 12V/5V/3.3V) to separately power the MCU/SoC, neuromorphic co-processor, sensors, camera module, communication module, and driver circuits. It includes protection features such as over-voltage, over-current, surge suppression, and thermal shutdown. Stable and noise-free power is essential because sensor readings, camera capture, and neuromorphic inference can be affected by power fluctuations.

The MCU/SoC (Microcontroller / System-on-Chip) is the main control brain for real-time operations. It collects sensor readings via the sensor interfaces, handles door-event triggers, manages timing (periodic sampling, defrost schedules), and executes the core control logic to generate commands for compressor, fan, airflow dampers (if present), and defrost heater. The MCU/SoC also manages communications with the display/mobile app and coordinates with the neuromorphic co-processor for higher-level inference tasks. In short, it is responsible for system orchestration, safety interlocks, and deterministic control.

The Neuromorphic Co-Processor performs low-power event-driven intelligence tasks. It receives either raw sensor features or pre-processed sensor packets from the

MCU/SoC and executes neuromorphic inference such as multi-sensor fusion, anomaly detection (temperature drift, gas spikes, abnormal vibration), freshness estimation, behavior pattern learning, and predictive maintenance scoring. Because it is event-driven, it runs inference only when required (door open, major sensor change, scheduled snapshot), which reduces power consumption compared to continuously running CPU/GPU inference. The co-processor returns decision signals and confidence values back to the MCU/SoC to support adaptive control actions.

The Memory (System Memory / Storage) stores firmware, configuration parameters, sensor calibration tables, AI/neuromorphic model parameters, and event logs. It may include both volatile memory (RAM) for running processes and non-volatile storage (Flash/eMMC) for persistent data such as learned user patterns, inventory records, and maintenance history. Logging and storage enable the system to compare past and current states (for example, learning typical door opening patterns and compressor behavior) and support diagnostics.

The Sensor Interfaces (Front-End / Signal Conditioning) form the electrical and logical bridge between physical sensors and the MCU/SoC. This block may include ADCs (analog-to-digital converters), I²C/SPI/UART buses, filtering circuits, and sensor drivers. It handles sensor sampling, noise reduction, timestamping, and normalization so that temperature, humidity, gas, and weight data are accurate and consistent. Proper interfacing ensures reliable readings even in electrically noisy environments near motors, compressors, and switching power supplies.

The Temperature / Humidity Sensors provide continuous or periodic measurements of internal conditions in multiple compartments. The MCU/SoC uses these readings to maintain setpoints, detect abnormal rises (such as door open or cooling failure), and compute exposure history for freshness estimation. These sensors also support compartment-level optimization by enabling the system to adjust airflow or compressor duty cycle to stabilize temperature and manage moisture for different food categories. Their data is also used by the neuromorphic co-processor for pattern recognition and prediction.

The Gas Sensors (Odor / Spoilage Sensors) detect volatile compounds associated with ripening and food spoilage. They provide early-warning signals before visible spoilage becomes obvious. The readings are fused with temperature/humidity history and, when available, camera observations to compute a freshness risk score. When gas signatures exceed thresholds or show abnormal trends, the system can trigger alerts ("check items") and optionally adjust ventilation/airflow to reduce odor accumulation or improve freshness conditions.

The Weight / Load Sensors measure changes in mass on shelves/drawers to infer placement or removal of items. When the door event occurs, weight changes are correlated with camera snapshots and timestamps to update the inventory list and estimate consumption rates. Weight sensing increases accuracy where camera visibility is limited (occlusion/packaging). Over time, the system learns typical depletion patterns and can generate shopping reminders or "low quantity" notifications.

The Camera Interface connects internal cameras to the processing system through a suitable data link (such as MIPI CSI, USB, or SPI depending on design). It manages image capture timing, exposure/lighting control (if integrated), and frame delivery to the MCU/SoC or directly to the neuromorphic co-processor for local inference. Camera data supports item recognition, shelf occupancy detection, and visual cues related to freshness. Images may be processed locally for privacy, with only results (labels/alerts) stored or shared.

The Communication Interface (Wi-Fi / Bluetooth) enables connectivity for mobile app integration, remote alerts, optional cloud synchronization, and firmware/model updates. Wi-Fi may be used for remote notifications, recipe services, and diagnostics, while Bluetooth may support quick pairing and local control. Importantly, the system can operate offline; the communication interface is primarily for convenience and enhancement. The MCU/SoC controls what data is shared, and in privacy-preserving modes it shares only metadata (inventory text, alerts) rather than raw images.

The Motor Drivers provide the electrical drive stage between the low-power MCU/SoC control signals and higher-power loads such as DC/BLDC fans, airflow damper motors, and other actuators. Motor drivers handle PWM control, speed regulation, current limiting, and fault detection. By modulating fan speed and damper positions, this block helps distribute cooling to specific zones, stabilize temperature rapidly after door openings, and support humidity optimization in drawers like the vegetable crisper.

The Fan circulates cold air from the evaporator region into the refrigerator compartments and across shelves. The control system adjusts fan speed based on sensor readings to maintain uniform temperature and correct micro-climate conditions. Higher fan speed can quickly restore temperature after door openings, while lower fan speed can preserve humidity in certain compartments. Fan speed control also contributes to energy savings and noise optimization.

The Light provides interior illumination and can also support the camera subsystem by ensuring consistent lighting for image capture. In some embodiments, the light is activated briefly during camera snapshots even if the door is opened in a low-light environment. Controlled lighting improves recognition accuracy and reduces false detections in inventory tracking. The MCU/SoC manages lighting patterns to balance visibility and power use.

The Defrost Heater removes frost buildup on the evaporator coils in frost-free refrigeration systems. Frost accumulation reduces heat exchange efficiency and increases compressor runtime. The system triggers the defrost heater either on an optimized schedule or based on performance indicators such as airflow reduction and cooling response patterns. During defrost, the system coordinates fan operation and temperature monitoring to prevent overheating and ensure the refrigerator returns to stable operating conditions quickly.

The Compressor Relay / Inverter Driver is the actuator interface that controls the compressor. In a basic model, a relay switches the compressor ON/OFF. In an advanced inverter-based system, the driver modulates compressor speed for smoother control and better efficiency. The MCU/SoC uses sensor feedback and neuromorphic recommendations to choose appropriate compressor operation, reducing temperature swings and saving energy. Fault detection is also implemented to protect the compressor from abnormal conditions.

The Compressor is the core refrigeration component that compresses refrigerant and drives the cooling cycle. When activated, it removes heat from the evaporator inside the refrigerator and rejects it to the environment through the condenser. In this invention, compressor operation is not purely thermostat-based; it is adaptively controlled based on predicted load events, compartment-specific conditions, and efficiency optimization. Compressor performance is also monitored through temperature response and vibration patterns to detect early degradation.

Figure 6 illustractes computer-implemented method for intelligent refrigeration control in a neuromorphic refrigerator system, according to an embodiment of the present invention. At step 602, the method comprises continuously monitoring internal environmental and operational parameters using a multi-sensor array including temperature, humidity, gas concentration, airflow, door position, load variation, vibration, and image data.

At step 604, the method comprises detecting an event comprising a door event or periodic trigger event.

At step 606, the method comprises in response to the detected event, capturing time-stamped sensor data and camera data representing current storage conditions.

At step 608, the method comprises performing event-driven multi-sensor fusion using a neuromorphic processing unit to generate contextual state information including stored item identification and environmental status.

At step 610, the method comprises computing a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration trends.

At step 612, the method comprises detecting operational anomalies.

At step 614, the method comprises generating adaptive actuation commands.

At step 616, the method comprises controlling refrigeration actuators including compressor operation, airflow distribution, compartment micro-climate, and defrost scheduling based on the adaptive actuation commands in a closed-loop cycle.

The foregoing description describes embodiments of the present invention. It should be appreciated that these embodiments are described for the purpose of illustration only, and that numerous alterations and modifications may be practiced by those skilled in the art without departing from the scope of the invention. It is intended that all such modifications and alterations be included in so far as they come within the scope of the invention as claimed or the equivalents thereof.

We claim:

1. An Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100), comprising:

    an insulated refrigeration cabinet (102) including at least one refrigeration compartment and at least one freezer compartment, and a refrigeration cycle comprising a compressor, condenser, evaporator, expansion device, and at least one circulation fan;

    a multi-sensor array (104) disposed within the cabinet and configured to monitor internal environmental and operational parameters,

    a processing subsystem (106) comprising one of a microcontroller (112) and system-on-chip (MCU/SoC), and a neuromorphic processing unit (NPU) (114);

    a memory unit (108) configured to store sensor data, learned behavioral models, inventory records, freshness data, and maintenance logs; and

    a control layer (110) operatively coupled to refrigeration actuators including the compressor, fan, airflow dampers, and defrost system;

    wherein the neuromorphic processing unit is configured to perform event-driven multi-sensor fusion and edge inference to:

        identify and track stored food items and quantity changes,

        compute a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration data,

        detect operational anomalies including temperature drift and abnormal vibration patterns, and

        generate adaptive control recommendations,

        wherein the control layer converts the adaptive control recommendations into actuation commands to modulate compressor operation, airflow distribution, compartment micro-climate, and defrost scheduling in a closed-loop sensing–inference–actuation cycle.

2. The system as claimed in Claim 1, wherein the multi-sensor array comprising:

        a plurality of temperature sensors,

at least one humidity sensor,

at least one gas or odor sensor,

at least one weight or load sensor,

at least one door sensor,

at least one airflow sensor,

at least one vibration and/or electrical current sensor associated with the compressor or fan, and

at least one internal camera.

3. The system as claimed in Claim 1, wherein the neuromorphic processing unit executes event-driven models that process sensor inputs only upon detection of predefined state-change events.
4. The system as claimed in Claim 1, wherein the predefined state-change events comprise at least one of door opening, rapid temperature deviation, humidity threshold crossing, gas concentration increase, measurable load change, and abnormal vibration signature.
5. The system as claimed in Claim 1, wherein the freshness or spoilage risk score is computed using a multi-factor exposure model integrating cumulative time–temperature data and humidity history with gas concentration trends.
6. The system as claimed in Claim 1, wherein the internal camera and weight sensor operate cooperatively to generate confidence-scored inventory updates by correlating image recognition results with load variations and door-event timestamps.
7. The system as claimed in Claim 1, wherein the control layer performs compartment-level adaptive airflow control by selectively modulating fan speed and airflow dampers to maintain distinct micro-climate zones.
8. The system as claimed in Claim 1, wherein the compressor is controlled through an inverter driver configured to modulate compressor speed based on predicted load events derived from learned door-opening patterns.

9. The system as claimed in Claim 1, wherein predictive maintenance is performed by analyzing combined vibration patterns, electrical current signatures, and thermal response curves to classify early-stage mechanical degradation.

10. The system as claimed in Claim 1, wherein defrost operation is initiated conditionally based on airflow reduction indicators and compressor runtime deviation from expected performance.

11. The system as claimed in Claim 1, wherein primary multi-sensor fusion, inference, and freshness computation are executed locally within the refrigerator and only metadata comprising alerts or summarized inventory information is transmitted externally.

12. A computer-implemented method for intelligent refrigeration control in a neuromorphic refrigerator system, the method comprising:

continuously monitoring internal environmental and operational parameters using a multi-sensor array including temperature, humidity, gas concentration, airflow, door position, load variation, vibration, and image data;

detecting an event comprising a door event or periodic trigger event;

in response to the detected event, capturing time-stamped sensor data and camera data representing current storage conditions;

performing event-driven multi-sensor fusion using a neuromorphic processing unit to generate contextual state information including stored item identification and environmental status;

computing a freshness or spoilage risk score based on time–temperature–humidity exposure history and gas concentration trends;

detecting operational anomalies;

generating adaptive actuation commands; and

controlling refrigeration actuators including compressor operation, airflow distribution, compartment micro-climate, and defrost scheduling based on the adaptive actuation commands in a closed-loop cycle.

13. The method as claimed in Claim 12, wherein performing multi-sensor fusion comprises executing a spiking neural network model that processes sensor inputs only upon detection of meaningful state changes.
14. The method as claimed in Claim 12, wherein identifying stored items comprises correlating image-based object recognition results with weight sensor measurements to generate confidence-scored inventory updates.
15. The method as claimed in Claim 12, further comprising performing primary inference and freshness computation locally within the refrigerator while enabling optional transmission of alert metadata to an external device.

Dated this 19th day of February 2026

Signature

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Anuradha Gupta
Patent Agent (IN/PA-1514)
Agent for the Applicant

ABSTRACT

ARTIFICIAL SUPER-INTELLIGENCE (ASI) BASED NEUROMORPHIC SMART REFRIGERATOR

The present invention discloses an Artificial Superintelligence (ASI) based neuromorphic refrigerator system (100) and its method. The system (100) comprises an insulated refrigeration cabinet (102), a multi sensor array (104), a processing subsystem (106), a memory unit (108), and a control layer (110). The insulated refrigeration cabinet (102) is configured to include at least one refrigeration compartment and at least one freezer compartment, and a refrigeration cycle comprising a compressor, condenser, evaporator, expansion device, and at least one circulation fan. The multi-sensor array (104) is configured to monitor internal environmental and operational parameters. The processing subsystem (106) comprises one of a microcontroller (112) and system-on-chip (MCU/SoC), and a neuromorphic processing unit (NPU) (114). The memory unit (108) is configured to store sensor data, learned behavioral models, inventory records, freshness data, and maintenance logs. The neuromorphic processing unit is configured to perform event-driven multi-sensor fusion and edge inference.

Figure 1

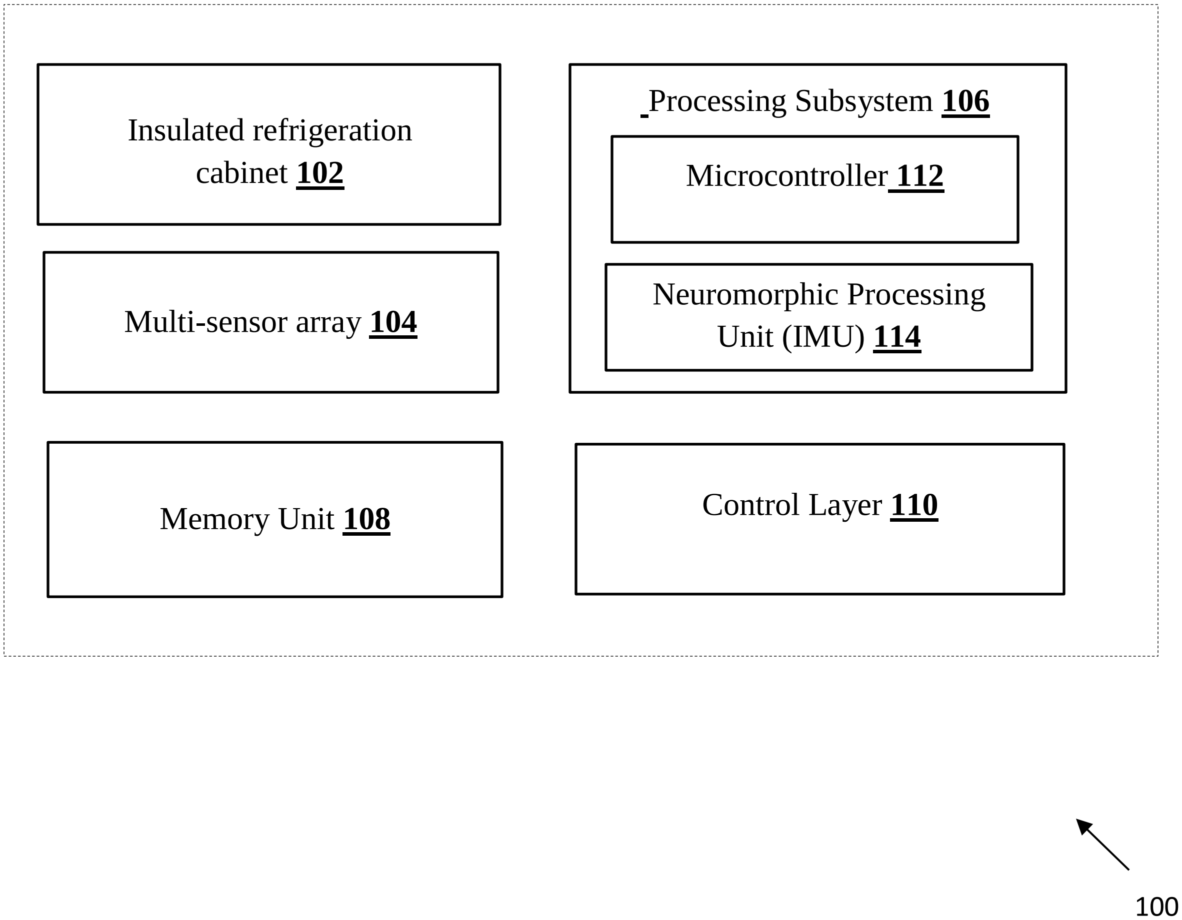

Figure 1

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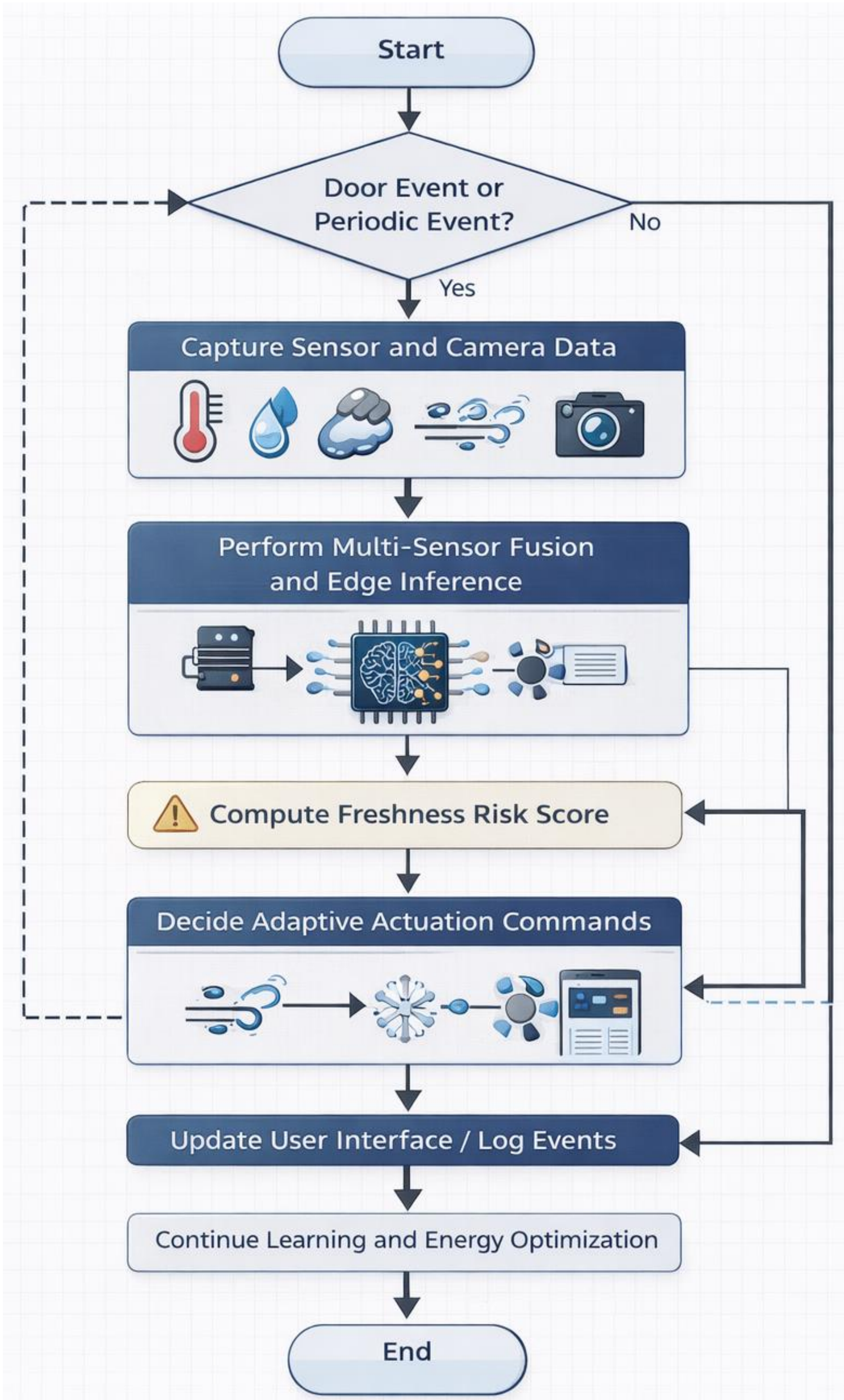

Figure 2

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Figure 3

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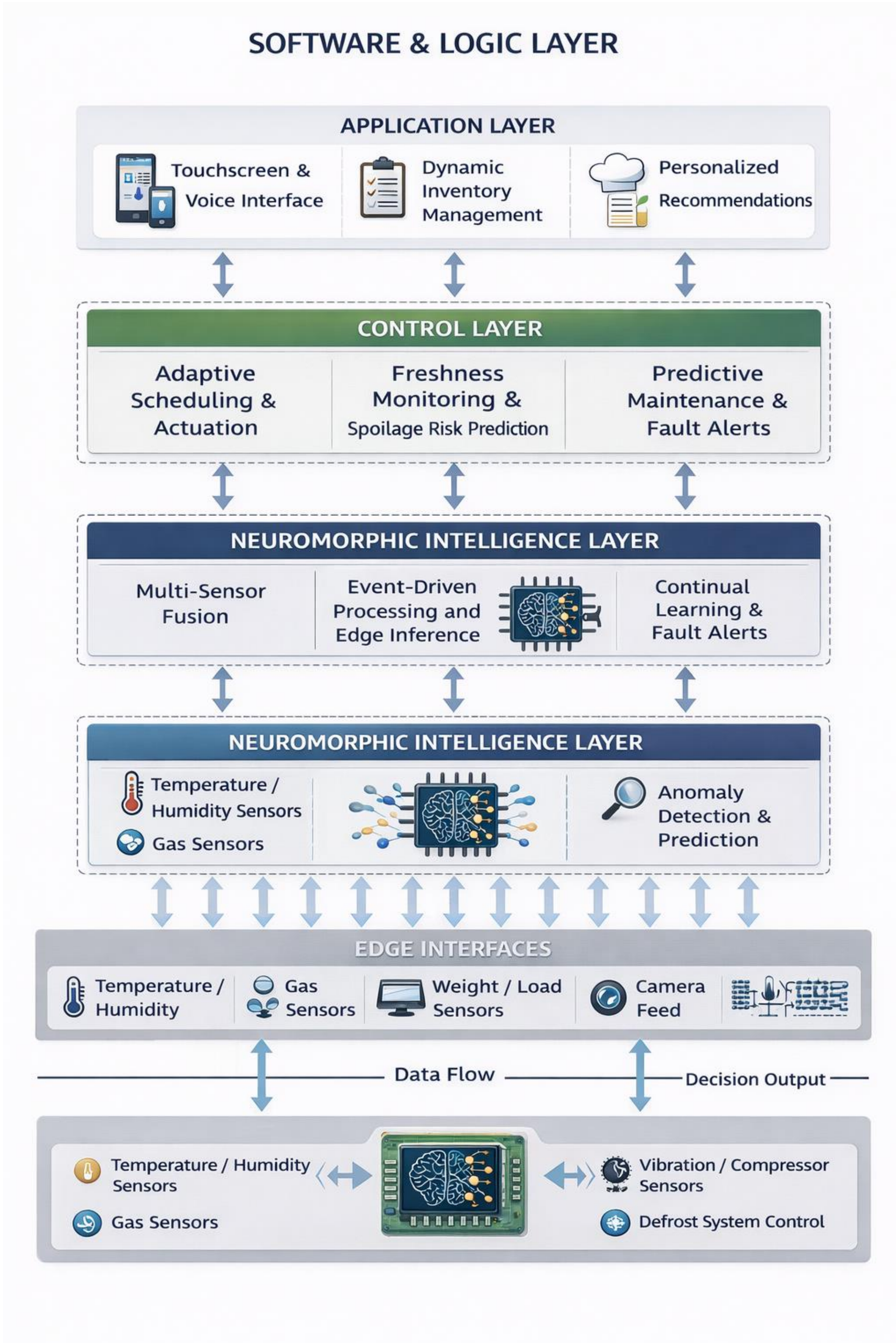

Figure 4

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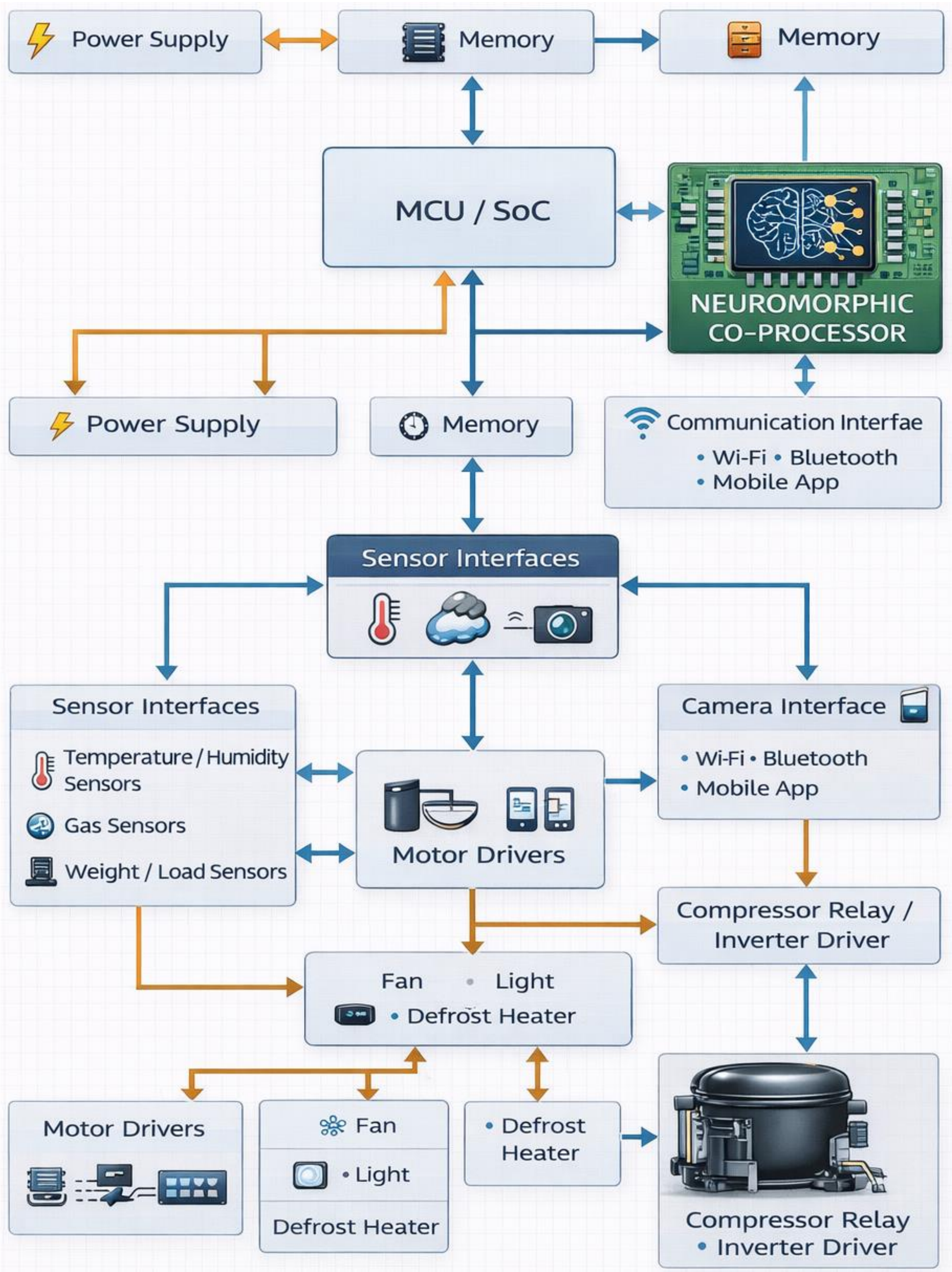

Figure 5

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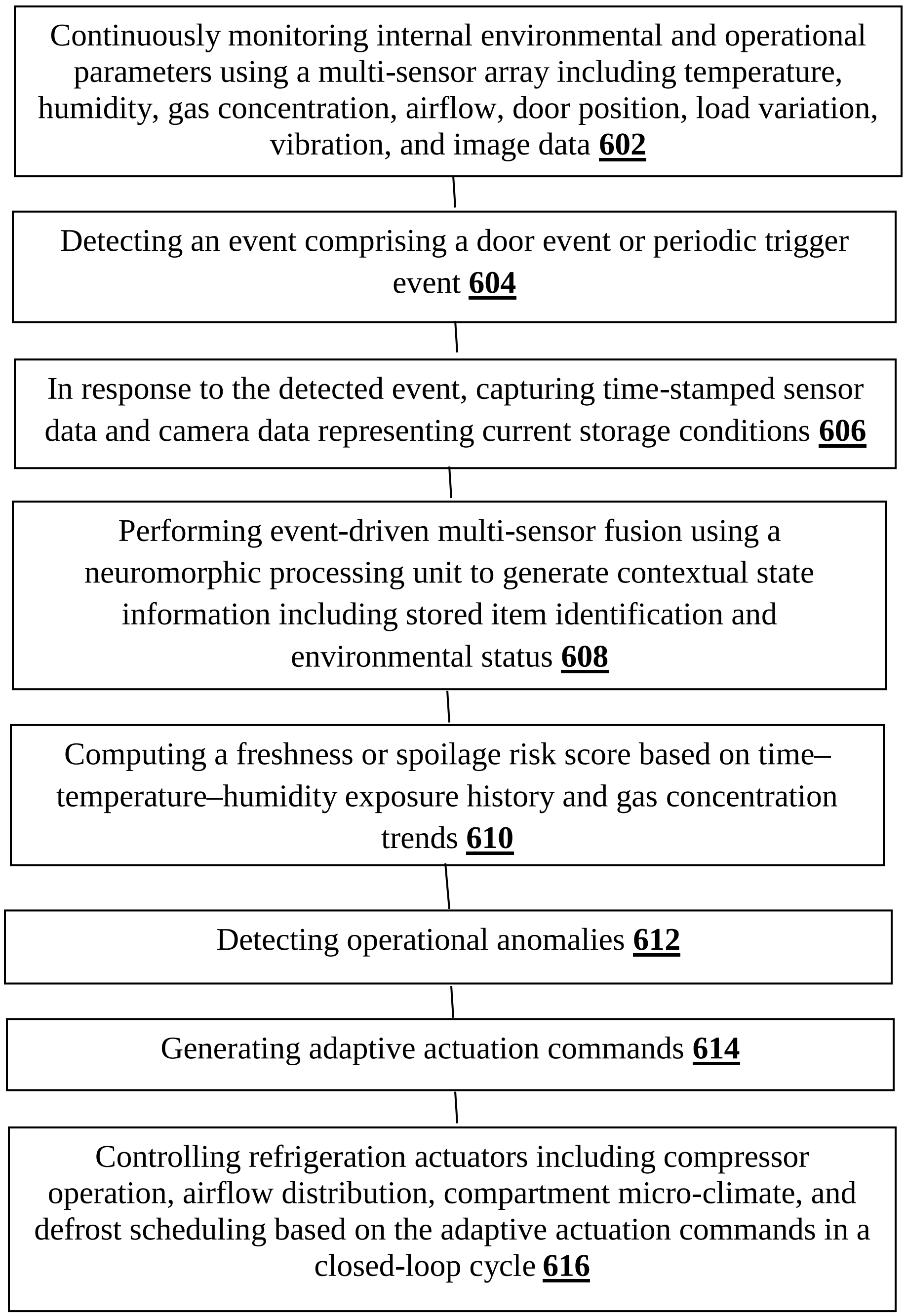

Figure 6

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FORM 3
THE PATENT ACT, 1970
(39 of 1970)
and
THE PATENTS RULES, 2003
STATEMENT AND UNDERTAKING UNDER SECTION 3
(See Section 8; Rule 12)

1. Name of Applicant	I/We, **SRJX RESEARCH AND INNOVATION LAB LLP** established at PLOT No-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK- 753014, ODISHA, INDIA, Hereby Declare:
	(i) That I/We who have made the application for Patent number **202631018813** in India, dated 19th February 2026 alone (ii) that I/We have not made any application for the same/substantially the same invention outside India Or (ii) ~~that I/We have made for the same/substantially same invention, application(s) for patent in the other countries, the particular of which are given below:~~

Name of the Country	**Date of application**	**Application No.**	**Status of the application**	**Date of publication**	**Date of grant**
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2. Name and address of the assignee	~~(i) that the rights in the application(s) filed in India has/have been assigned to……………………….~~ (ii) that I/We undertake that upto the date of grant of the patent by the Controller, I/We would keep him informed in writing regarding the details of corresponding applications for patents filed outside India in accordance with the provisions contained in section 8 and rule 12. Dated this 21st day of February 2026.
3. To be signed by the applicant or his authorized registered patent agent	Signature
4. Name of the Natural person who has signed	(**Anuradha Gupta)** Patent Agent (IN/PA-1514) Agent for the Applicant
	To The Controller of Patents, The Patent Office At Kolkata

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FORM 26

THE PATENTS ACT, 1970

(39 of 1970)

&

THE PATENTS RULES, 2003

Form of authorization of a patent agent/or any person in a matter or proceeding under the Act

(See sections 127 and 132 and rule 135)

We,

SRJX RESEARCH AND INNOVATION LAB LLP, a company registered in India, having office at **PLOT NO.-3E/474, SECTOR-9, CDA, POST-MARKAT NAGAR, CUTTACK- 753014, ODISHA, INDIA**

do hereby authorize **S. N. Sav and Anuradha Gupta**, Patent Agent of **S G Intellectual**, 4-D (UPPER FLOOR) DDA Pocket-2, Sector-6, Dwarka, New Delhi--110075, **Delhi** , and also at A-108, Block -A, MBR Shangri La, Mysore Road, Kengeri, **Bangalore**-560059, India and/or all or any Associates/ Partners of the firm, to act on our behalf in connection with filing any and all Patent Application for any and all the inventions with the Controller of Patents, appearing on our behalf before the Controller, processing our application in respect of the same, filing provisional and/or complete specifications, and other necessary request and documents in connection with the grant of Patent for the patent application, obtaining certified copies/extracts from the Patent Office, Certificate/s of Registration, filing request for renewal of the Patent and generally to do all acts, deeds and things that may be necessary in connection with the above application, including appointment of any substitute or substitutes.

We request that all notices, requisitions and communication relating thereto may be sent to such person at the above address unless otherwise specified.

We hereby revoke all our previous authorization, if any made, in respect of same matter or proceeding.

We hereby assent to the action already taken by the above said person in the matter.

Dated this 7th day of **February 2026**

Soumya Ranjan Jena

(Dr. Soumya Ranjan Jena)
Designation: Director
SRJX RESEARCH AND INNOVATION LAB LLP

To,
The Controller of Patents
Patent Office, Kolkata

SRJX Research and Innovation Lab LLP
LLPIN: ACO-1435

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FORM 5
THE PATENTS ACT, 1970
(39 of 1970)
&
The Patents Rules, 2003
DECLARATION AS TO INVENTORSHIP
[See section 10(6) and Rule 13 (6)]

1. **NAME OF THE APPLICANTS: SRJX RESEARCH AND INNOVATION LAB LLP** established at PLOT No-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK-753014, ODISHA, INDIA,

hereby declare that the true and first inventor(s) of the invention disclosed in the Complete specification filed in pursuance of our application Numbered 202631018813 dated 19th February 2026 are:

2. INVENTORS:

(i) (a) NAME : JENA, Soumya Ranjan
(b) NATIONALITY: INDIAN
(c) ADDRESS : PLOT NO-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK- 753014, ODISHA, INDIA

(ii) (a) NAME : PANIGRAHI, Rakhee
(b) NATIONALITY: INDIAN
(c) Address : PARALA MAHARAJA ENGINEERING COLLEGE, SITALAPALLI, BERHAMPUR, GANJAM-761003, ODISHA, INDIA

(iii) **(a) NAME : PATJOSHI, Rajesh Kumar**
(b) NATIONALITY: INDIAN
(c) Address : PATJOSHI COMPLEX, MAIN ROAD BEHERAMAL, JHARSUGUDA-768234, ODISHA, INDIA

3. DECLARATION TO BE GIVEN WHEN THE APPLICATION IN INDIA IS FILED BY THE APPLICANT(S) IN THE CONVENTION COUNTRY :- N/A
~~We the applicant in the convention country hereby declares that our right to apply for a Patent in India is by way of assignment from the true and first inventors.~~

Dated this 21st day of February 2026 Name of the signatory **Anuradha Gupta**
Patent agent - IN/PA-1514

4. STATEMENT (to be signed by the additional inventor(s) not mentioned in the application **F**orm : **N/A**

~~/We assent to the invention referred to in the above declaration, being included in the Complete specification filed in pursuance of the stated application.~~

Dated this day of 20……..

Signature of the additional inventor(s):
Name--------------------

To
The Controller of Patent
The Patent Office Branch
At KOLKATA

Digitally Signed By:
ANURADHA GUPTA
Date: 21-02-2026 11:26:11

"FORM 1 THE PATENTS ACT 1970 (39 of 1970) and THE PATENTS RULES, 2003 APPLICATION FOR GRANT OF PATENT (See section 7, 54 and 135 and sub-rule (1) of rule 20)	(FOR OFFICE USE ONLY)

	Application No.	202631018813
	Filing date:	
	Amount of Fee paid:	
	CBR No:	
	Signature:	
1. APPLICANT'S REFERENCE / IDENTIFICATION NO. (AS ALLOTTED BY OFFICE)		

2. TYPE OF APPLICATION *Please tick (✓) at the appropriate category+

Ordinary (✓)		Convention ( )		PCT-NP ( )	
Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )

3A. APPLICANT(S)

Name in Full	Nationality	Country of Residence	Address of the Applicant	
SRJX RESEARCH AND INNOVATION LAB LLP	**INDIAN COMPANY**	**INDIA**	House No.	**PLOT NO.-3E/474 SECTOR-9, CDA**
			Street	**POST- MARKAT NAGAR,**
			City	**CUTTACK**
			State	**ODISHA**
			Country	**INDIA**
			Pin code	**753014**

3B. CATEGORY OF APPLICANT *Please tick (✓) at the appropriate category+

Natural Person ()	Other than Natural Person (✓)		
	Small Entity ( )	Startup (✓)	Others ()

4. INVENTOR(S) *Please tick (✓) at the appropriate category+

Are all the inventor(s) same as the applicant(s) Named above?	Yes ()	No (✓)

If "No", furnish the details of the inventor(s)

Name in Full	Nationality	Country of Residence	Address of the Inventor	
JENA, Soumya Ranjan	**INDIAN**	**INDIA**	House No.	**PLOT NO.-3E/474 SECTOR-9, CDA**
			Street	**POST- MARKAT NAGAR**
			City	**CUTTACK**
			State	**ODISHA**
			Country	**INDIA**
			Pin code	**753014**
PANIGRAHI, Rakhee	**INDIAN**	**INDIA**	House No.	PARALA MAHARAJA ENGINEERING COLLEGE, SITALAPALLI, BERHAMPUR, GANJAM-761003, ODISHA, INDIA
PATJOSHI, Rajesh Kumar	**INDIAN**	**INDIA**	House No.	PATJOSHI COMPLEX, MAIN ROAD BEHERAMAL, JHARSUGUDA-768234, ODISHA, INDIA

5. TITLE OF THE INVENTION: **ARTIFICIAL SUPER-INTELLIGENCE (ASI) BASED NEUROMORPHIC SMART REFRIGERATOR**

6. AUTHORISED REGISTERED PATENT AGENT(S)	Patent Agent No.	**1514**
	Name	**ANURADHA GUPTA**
	Mobile No.	**9213764385**
7. ADDRESS FOR SERVICE OF APPLICANT IN INDIA	Name	**S G INTELLECTUAL**
	Postal Address	**4-D (UPPER FLOOR), DDA POCKET-2 SECTOR-6, DWARKA, NEW DELHI-110075, DELHI**
	Telephone No.	**011 35586108**
	Mobile No.	**9213764385**
	E-mail ID	**sav@sgintellectual.com**

8. IN CASE OF APPLICATION CLAIMING PRIORITY OF APPLICATION FILED IN CONVENTION COUNTRY, PARTICULARS OF CONVENTION APPLICATION				
Country	Application Number	Filing date	Name of the applicant	Title of the Invention
----------	---------	----------------------	----------------	-------------------

9. IN CASE OF PCT NATIONAL PHASE APPLICATION, PARTICULARS OF INTERNATIONAL APPLICATION FILED UNDER PATENT CO-OPERATION TREATY (PCT)	
International application number	International filing date
---------------------------------------	---------------------------------

10. IN CASE OF DIVISIONAL APPLICATION FILED UNDER SECTION 16, PARTICULARS OF ORIGINAL (FIRST) APPLICATION-NA	
Original (first) application No	Date of filing of original (first) application
-------------------------------------	------------------------------

11. IN CASE OF PATENT OF ADDITION FILED UNDER SECTION 54, PARTICULARS OF MAIN APPLICATION OR PATENT-NA	
Main application/patent No.---------------	Date of filing of main application -----------------

12. DECLARATIONS

(i) Declaration by the inventor(s)-
(In case the applicant is an assignee: the inventor(s) may sign herein below or the applicant may upload the assignment or enclose the assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period).

We, the above named inventors are the true & first inventors for this Invention and declare that the applicant herein is our assignee ~~or legal representative~~.

i) (a) Date: 19-Feb-2026

(b) Signature: Soumya Ranjan Jena
(c) Name : **JENA, Soumya Ranjan**

ii) (a) Date: 19-Feb-2026

(b) Signature: Rakhee Panigrahi
(c) Name: **PANIGRAHI, Rakhee**

iii) (a) Date: 19-Feb-2026

(b) Signature: Rajesh K. patjoshi
(c) Name: **PATJOSHI, Rajesh Kumar**

ii) Declaration by the applicant(s) in the convention country ---N/A

~~(In case the applicant in India is different than the applicant in the convention country: the applicant in the convention country may sign herein below or applicant in India may upload the assignment from the applicant in the convention country or enclose the said assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period)~~

~~I/We, the applicant(s) in the convention country declare that the applicant(s) herein is/are my/our assignee or legal representative.~~

~~(a) Date~~

~~(b) Signature(s)~~

~~(c) Name(s)~~

(iii) Declaration by the applicant(s)

- ~~I/~~We the applicant(s) hereby declare(s) that: -
- ~~I am~~/We-are in possession of the above-mentioned invention.
- The Complete Specification relating to the invention is filed with this Application.
- ~~The invention as disclosed in the specification uses the biological material from India and the necessary permission from the competent authority shall be submitted by me/us before the grant of patent to me/us.~~
- There is no lawful ground of objection(s) to the grant of the Patent to me/us.
- ~~I am/we are the true & first inventor(s).~~
- ~~I am~~/we are the assignee or legal representative of true & first inventor(s).
- ~~The application or each of the applications, particulars of which are given in Paragraph-8, was the first application in convention country/countries in respect of my/our invention(s).~~
- ~~I/We claim the priority from the above-mentioned application(s) filed in convention country/countries and state that no application for protection in respect of the invention had been made in a convention country before that date by me/us or by any person from which I/We derive the title.~~
- ~~My/our application in India is based on international application under Patent Cooperation Treaty (PCT) as mentioned in Paragraph-9.~~
- ~~The application is divided out of my /our application particulars of which is given in Paragraph-10 and pray that this application may be treated as deemed to have been filed on DD/MM/YYYY under section 16 of the Act.~~

13. FOLLOWING ARE THE ATTACHMENTS WITH THE APPLICATION

(a) Form 1

Item	Details	Fee	Remarks
Complete specification	No. of Pages - 53	Rs. 8640/-	
Claim(s)	No. of Claims - 15 No. of Pages - 4	----------------	-----------------
Abstract	No. of Pages - 1		
Drawing(s)-	No. of Drawings - 6 No. of Pages - 6		

(b) Complete Specification
(d) Drawings
(c) Abstract
(d) Application Form-1
(e) DIPP Certificate.
(f) Form-28
....

We hereby declare that to the best of our knowledge, information and belief, the fact and matters stated herein are correct and We request that a patent may be granted to us for the said invention.

Dated this 19th day of February 2026

Signature Soumya Ranjan Jena

(Dr. Soumya Ranjan Jena)
Designation: Director

Name of Applicant: SRJX RESEARCH AND INNOVATION LAB LLP

SRJX Research and Innovation Lab LLP
LLPIN: ACO-1435

To
The Controller of Patents
The Patent Office, KOLKATA

Digitally Signed By:
ANURADHA GUPTA
Date: 21-02-2026 19:35:04

FORM 18 A THE PATENTS ACT,1970 and THE PATENT RULES,2003 REQUEST FOR EXPEDITED EXAMINATION OF APPLICATION FOR PATENT [See section 11B and Rule 24C]	(FOR OFFICE USE ONLY) RQ. No.: Filing Date: Amount of fee Paid: CBR no: Signature:

1. **APPLICANT:**

(A) NAME: **SRJX RESEARCH AND INNOVATION LAB LLP**

(B) NATIONALITY: **Indian Company**

(C) ADDRESS: **PLOT No.-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK- 753014, ODISHA, INDIA**

2. We, **SRJX RESEARCH AND INNOVATION LAB LLP** established at PLOT No-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK- 753014, ODISHA, INDIA, hereby request that our Application Patent No. **202631018813** filed on 19th February 2026 for invention Titled "**ARTIFICIAL SUPER-INTELLIGENCE (ASI) BASED NEUROMORPHIC SMART REFRIGERATOR"** shall be examined under sections 12 and 13 of the Act.

~~or~~

~~I/We --- hereby request that my/our application for patent no.--------------- filed on -------------------- for --- the -- invention titled --- based on Patent Cooperation Treaty (PCT) application no………………..…. dated………………….. made in country ……….. shall be examined under sections 12 and 13 of the Act, immediately without waiting for the expiry of 31 months as specified in rule 20(4)(ii). or~~

~~I/We hereby request that my/our request for examination bearing no.------------ for application for patent no.--------------- filed on -------------------- for -- the -- invention titled --- may be converted to a request for expedited examination of patent application under rule 24C and the application shall be examined under sections 12 and 13 of the Act.~~

3. The applicant(s) to indicate (by ticking the appropriate box) any of the grounds applicable for request for expedited examination:

() that India has been indicated as the competent International Searching Authority or elected as an International Preliminary Examining Authority in the corresponding international application; or

(✓) that the applicant is a startup; or

( ) that the applicant is a small entity; or

( ) that the applicant is a natural person or in the case of joint applicants, all the applicants are natural persons, then applicant or at least one of the applicants is a female; or

( ) that the applicant is a department of the Government; or

( ) that the applicant is an institution established by a Central, Provincial or state Act, which is owned or controlled by the Government; or

( ) that the applicant is a Government company as defined in clause (45) of section 2 of the Companies Act, 2013 (18 of 2013); or

( ) that the applicant is an institution wholly or substantially financed by the Government; or

( ) that the application pertains to a sector which has been notified by the Central Government, on the basis of a request from the head of department of the Central Government; or

( ) that the applicant is eligible under an arrangement for processing a patent applicant pursuant to an agreement between Indian Patent Office and a foreign Patent Office.

ADDRESS FOR SERVICE IN INDIA:

ANURADHA GUPTA
4-D (UPPER FLOOR), DDA Flat, Pocket-2, Sector-6, Dwarka, New Delhi-110075, India
Mobile No. +91 9213764385
Email: sav@sgintellectual.com ; anuradha_sgi@yahoo.in

Dated this 19th day of February, 2026

Signature
-Digitally Signed-

Name of the signatory: **Anuradha Gupta**
Agent for the Applicant
IN/PA-1514

To
The Controller of Patent
The Patent Office, at Kolkata

Digitally Signed By:
ANURADHA GUPTA
Date: 19-02-2026 21:04:05

FORMS 28
THE PATENTS ACT, 1970
(39 of 1970)
AND
THE PATENTS RULES, 2003
TO BE SUBMITTED BY A SMALL ENTITY / STARTUP
[See rules 2 (fa), 2(fb) and 7]

1.	Insert name, address and nationality	We, **SRJX RESEARCH AND INNOVATION LAB LLP**, a company registered in India, having office at PLOT NO.-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK-753014, ODISHA, INDIA Applicant in respect of the patent application No…………. Hereby declare that we are a startup in accordance with rule 2(fb) and submit the following documents(s) as proof:
2.	Documents to be submitted	
	ii. For claiming the status of a startup	
	A. For an Indian applicant: Any document as evidence of eligibility, as defined in rule 2(fb).	
	Certificate of Recognition issued by DIPP: Certificate No. DIPP203406	
3.	To be signed by the applicant(s) / patentee(s) / authorized registered patent agent.	The information provided herein is correct to the best of our knowledge and belief. Dated this 19th day of February 2026. Signature : -Digitally Signed- (Anuradha Gupta) Patent Agent (IN/PA-1514) Agent for the Applicant To The Controller of Patents, The Patent Office, At Kolkata.
4.	Name of the natural person who has signed. Designation and official seal, if any, of the person who has signed.	

Digitally Signed By:
ANURADHA GUPTA
Date: 19-02-2026 13:31:38

FORM 9
THE PATENTS ACT, 1970
(39 of 1970)
&
The Patents Rules, 2003
REQUEST FOR PUBLICATION
[See section 11A (2); Rule 24A]

1. Name, address and nationality of Applicant(s)	We, **SRJX RESEARCH AND INNOVATION LAB LLP** a Company registered in India, having office at PLOT No.-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK- 753014, ODISHA, India,
2. To be signed by the applicant or his authorized registered patent agent	hereby request for early publication of our Patent Application No. **202631018813 dated 19th February 2026** under section 11A (2) of the Patent Act.

.

Dated this 19th day of February 2026

3. Name of the natural person who has signed.	-Digitally Signed- (Anuradha Gupta) Patent Agent (IN/PA-1514) Agent for the Applicant

To
The Controller of Patents,
The Patent Office,
At KOLKATA

Digitally Signed By:
ANURADHA GUPTA
Date: 19-02-2026 19:37:26

FORMS 28
THE PATENTS ACT, 1970
(39 of 1970)
AND
THE PATENTS RULES, 2003
TO BE SUBMITTED BY A SMALL ENTITY / STARTUP
[See rules 2 (fa), 2(fb) and 7]

1.	Insert name, address and nationality	We, **SRJX RESEARCH AND INNOVATION LAB LLP**, a company registered in India, having office at PLOT NO.-3E/474, SECTOR-9, CDA, POST- MARKAT NAGAR, CUTTACK-753014, ODISHA, INDIA Applicant in respect of the patent application No. **202631018813** Hereby declare that we are a startup in accordance with rule 2(fb) and submit the following documents(s) as proof:
2.	Documents to be submitted	
	ii. For claiming the status of a startup	
	A. For an Indian applicant: Any document as evidence of eligibility, as defined in rule 2(fb).	
	Certificate of Recognition issued by DIPP: Certificate No. DIPP203406	
3.	To be signed by the applicant(s) / patentee(s) / authorized registered patent agent.	The information provided herein is correct to the best of our knowledge and belief. Dated this 19th day of February 2026. Signature : -Digitally Signed- (Anuradha Gupta) Patent Agent (IN/PA-1514) Agent for the Applicant To The Controller of Patents, The Patent Office, At Kolkata.
4.	Name of the natural person who has signed. Designation and official seal, if any, of the person who has signed.	

Digitally Signed By:
ANURADHA GUPTA
Date: 19-02-2026 21:04:05

CERTIFICATE NO:
DIPP203406

सत्यमेव जयते

Government of India
Ministry of Commerce & Industry
Department for Promotion of Industry and Internal Trade

#startupindia

CERTIFICATE OF RECOGNITION

This is to certify that ***SRJX RESEARCH AND INNOVATION LAB LLP*** *incorporated as a* ***Limited Liability Partnership*** *on* ***05-05-2025****, is recognized as a startup by the Department for Promotion of Industry and Internal Trade. The startup is working in 'Professional & Commercial Services' Industry and 'Professional Information Services' sector as self-certified by them.*

This certificate shall only be valid for the Entity up to **Ten** years from the date of its incorporation only if its turnover for any of the financial years has not extended ₹ **100 Cr.**

14-05-2025

DATE OF ISSUE

Scan to Verify

04-05-2035

VALID UPTO

Digitally Signed By:
ANURADHA GUPTA
Date: 19-02-2026 21:04:05