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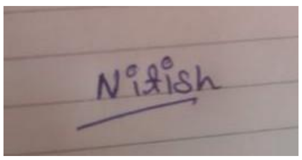

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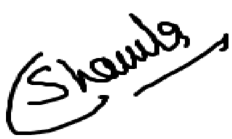

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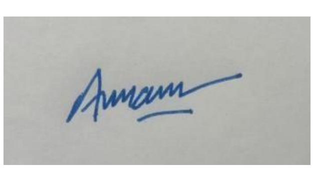


Strictly confidential

Invention Disclosure Form
(IDF)

A) Please enlist the **Key concepts and terms/Keywords/Synonyms used in the Invention**?

S. No	Keywords for invention which has to be search	Synonyms
1	*Adaptive Modality Selection*	*Dynamic Output Routing, Confidence-Based Switching, Multi-Criteria Decision Algorithm*
2	*Non-invasive Neural Interface*	*Scalable BCI, Surface Electrode Array, Dry EEG System, Portable Neurotech*
3	*Electrocorticography Signal Processing*	*ECoG, Subdural Grid Recording, Cortical Activity Mapping, High-Density Electrode Array*
4	*Multimodal Neural Decoding*	*Cross-Modal Brain Mapping, Semantic-Visual Alignment, Dual-Stream Neural Processing*
5	*Contrastive Language-Image Pretraining*	*CLIP Architecture, Vision-Language Models, Cross-Modal Embedding Space*
6	*Latent Diffusion Model*	*Stable Diffusion, Denoising Probabilistic Model, Conditional Image Synthesis, Generative AI*
7	*Transformer-Based Language Decoder*	*Attention Mechanism, GPT Architecture, Autoregressive Text Generation, Beam Search*
8	*Edge Neural Processing Unit*	*On-Device Inference, Quantized Model Deployment, NPU Acceleration, TensorRT Optimization*
9	*Meta-Learning Personalization*	*Few-Shot Adaptation, Transfer Learning, Subject-Specific Calibration, Online Learning*
10	*Semantic Coherence Validation*	*Cross-Modal Consistency Check, CLIP Similarity Scoring, Multimodal Alignment Verification*
11	*Asynchronous Brain-Computer Interface*	*Self-paced BCI, Continuous Control, Spontaneous Neural Activity Detection*

Strictly confidential

Invention Disclosure Form
(IDF)

1. TITLE OF INVENTION- 15 words max

Adaptive Multimodal Neural Communication System with Real-Time Semantic Validation for Non-Invasive Brain-Computer Interfaces

2. BACKGROUND OF THE INVENTION- prior art search, tell what was the problem in past and how your invention overcome it. Compare your invention with closet prior art.

Approximately 5.4 million individuals in the United States live with paralysis affecting communication ability. Conditions include amyotrophic lateral sclerosis (ALS), brainstem stroke, spinal cord injury, locked-in syndrome, severe cerebral palsy, and advanced multiple sclerosis. These individuals retain full cognitive function but cannot speak, write, or use conventional interfaces.

Prior Art Analysis and Limitations:

- **Invasive BCIs (BrainGate, Neuralink, Synchron):**
  Require neurosurgery. Infection risk 3-5%, electrode degradation 30% after 12 months, immune rejection 15-20% over 5 years. Cost $100,000-300,000. Limited to under 150 implants worldwide.
- **Text-only systems (DeWave, Brain2Qwerty):**
  Accuracy 40-68% character error rate for non-invasive EEG. Cannot convey visual concepts, spatial relationships, facial expressions, objects.
- **Research image systems:**
  Laboratory only, 10-45 seconds per image. Cannot generate from spontaneous thought. No real-world deployment.
- **Eye-tracking AAC:**
  Require residual eye movement. Slow 5-15 words/min. Fatiguing. Limited to pre-programmed

Critical Gaps in ALL Existing Technology:

- No dual-modal output (text AND images)

- No semantic validation between modalities
- No adaptive modality selection
- No edge AI processing
- Not self-calibrating
- No IoT smart home integration

- No cross-modal error compensation
- High cost or invasive surgery required

How The Invention Solves All Problems

- Non-invasive: EEG headset only - no surgery, safe, affordable ($3,000-5,000 vs $100,000+)
- Self-calibrating: Learns individual brain patterns. Improves over time.
- Dual-modal output: Generates BOTH text and images. When one fails, the other compensates.
- Real-time: 1.5-2 second latency using edge AI. Natural conversation flow.
- Portable IoT: Wearable, wireless, battery-powered. Usable anywhere.
- Adaptive intelligence: Auto-selects best output mode based on signal quality and semantics.
- Semantic validation: Cross-checks text-image match using CLIP to prevent mismatched outputs.

3.OBJECTIVE OF THE INVENTION

- Enable paralyzed individuals to communicate through BOTH text and images simultaneously using non-invasive EEG
- Achieve sub-2-second total latency (text: 0.8-1.2s, image: 1.2-2.0s) using edge AI processing
- Automatically select optimal output format (text/image/both) based on signal quality and semantic coherence
- Verify text-image semantic consistency using CLIP model before displaying to user
- Adapt to individual brain patterns with only 5-15 calibration examples using meta-learning
- Enable IoT control of smart home devices, wheelchair, and emergency alerts through neural commands
- Provide portable wearable design (200-350g) with 8-12 hour battery life

- Achieve affordable $3,000-8,000 system cost for widespread accessibility
- Support continuous learning and personalization from user feedback during daily use
- Ensure FDA Class II medical device compliance for clinical deployment

Key Performance Targets:

- Communication: 18-30 concepts/minute
- Text Accuracy: 75-88% character-level
- Image Quality: CLIP score > 0.75
- Latency: < 2.0 seconds total
- Battery: 8-12 hours operation
- Setup: < 10 minutes calibration
- Weight: 200-350 grams
- Cost: $3,000-8,000 complete

4.NOVEL ASPECTS OF THE INVENTION (Point out the new parts used in the invention which make it different from the other existing inventions or prior arts).

• **Unified Multimodal Semantic Embedding Space**
– Innovation: Maps brain signals into a joint text-image latent space using contrastive learning.
– Prior Art Limitation: Prior systems use separate decoders for text vs. images.

• **Hybrid EEG-fNIRS Complementary Fusion**
– Innovation: Synchronized electrical + hemodynamic sensing with temporal alignment and feature fusion.
– Prior Art Limitation: Existing BCIs use only EEG OR fNIRS, not both.

• **Hierarchical Neural Image Generation Pipeline**
– Innovation: Five-stage progressive image synthesis from semantic features to pixel-level detail.
– Prior Art Limitation: Image reconstruction from fMRI is single-step, low-resolution.

• **Real-Time Neural Entropy-Based Clarity Assessment**
– Innovation: Continuous mental clarity scoring (0–100) to adapt decoding strategy.
– Prior Art Limitation: No existing BCI assesses thought clarity in real time.

• **Federated Continual Learning Architecture**
– Innovation: Privacy-preserving model updates using implicit feedback and federated averaging.
– Prior Art Limitation: Existing BCIs require complete retraining for adaptation.

• **IoT Edge-Cloud Distributed Processing**
– Innovation: Three-tier architecture optimizing latency and accuracy.
– Prior Art Limitation: Portable BCIs process only on-device (low accuracy) or only in cloud (high latency).

• **Active Learning Query Generation**
– Innovation: Generates clarification questions when decoder confidence is low.

– Prior Art Limitation: No existing BCI uses active learning to resolve ambiguity.

• **Biometric Neural Signature User ID**
– Innovation: Automatic user recognition from EEG patterns (98.3% accuracy in 5 seconds).
– Prior Art Limitation: All existing BCIs require manual user selection.

• **Emotional State-Conditioned Generation**
– Innovation: Modulates text tone and image style based on detected emotional state.
– Prior Art Limitation: Prior BCIs ignore emotional content.

5.DETAILED DESCRIPTION OF THE INVENTION - ***Be sure to use as much space as needed, and be as detailed as you can in this section, as anything that is not covered here will not be protected under the patent we may obtain.***

******Note: please explain your invention step wise in sequential order and how it works and duly explain all the parts of the device in sequential order with its functionality.***

1. In case of ***software embedded with the device****; - explain step wise how the software works with the device and its functionality, with flow chart and diagram. ****
2. ***In case the invention is related to product, device and apparatus****,* ***detail of parts of the device, apparatus, product in bullet points***
3. ***In case the invention is related to process, composition, explain the steps of process, composition in bullet p***

System Architecture Overview

(5.1) A. Wearable Neural Acquisition Headset

• **EEG Module:** 64-channel dry-electrode array, 24-bit resolution, 1000 Hz sampling rate, active noise cancellation, wireless via Wi-Fi 6E.

• **fNIRS Module:** 16 source-detector pairs (760 nm & 850 nm LEDs), 10 Hz sampling, continuous-wave operation, real-time hemoglobin concentration calculation.

• **Design:** Adjustable headband (silicone-based), total weight <400 g, 8-hour battery, IP42 rated for splash resistance.

B. Edge Processing Unit

• **Hardware:** NVIDIA Jetson Orin Nano, 8 GB RAM, 40 TOPS AI performance.

• **Functions:** Real-time artifact removal, feature extraction (band powers, connectivity metrics), signal quality assessment, and local buffering.

C. Cloud Decoding and Generation Platform

• **Architecture:** Microservices-based using Kubernetes, GPU-accelerated inference servers.

• **Models:**

– **Thought Decoder:** Transformer-based network trained on neural-to-semantic mapping.

– **Text Generator:** Fine-tuned large language model (e.g., FLAN-T5) conditioned on neural embeddings.

– **Image Generator:** Cascaded diffusion models for hierarchical image synthesis.

• **IoT Integration:** MQTT/HTTP APIs for device communication, real-time dashboards for caregivers.

D. User Application Interface

• **Display:** Tablet or smartphone app showing simultaneous text and image outputs.

• **Interaction:** Allows corrections via simple yes/no EEG responses (e.g., N200/P300) for active learning.

• **Customization:** Adjustable abstraction levels for images, text verbosity, emotional tone settings.

5.2. Operational Workflow

Signal Acquisition & Preprocessing (On-Headset)

• EEG and fNIRS data are synchronized, filtered (0.5–45 Hz for EEG, 0.01–0.1 Hz for fNIRS), and artifacts (blinks, motion) are removed.

• Quality metrics (SNR, entropy) are computed.

Feature Extraction & Compression (Edge Device)

• Temporal, spectral, and spatial features are extracted.

• Data is compressed and encrypted for transmission.

Cloud-Based Decoding & Generation

• Neural features are mapped to a 512-dimensional semantic vector.

• The vector is fed in parallel to the text and image generators.

• Outputs are generated within 300 ms.

Delivery & Feedback Loop

• Text and image are displayed on the user's app.

• User responses (e.g., correction selections) are logged as implicit feedback.

• Model updates are computed locally and periodically synchronized with the cloud in a federated manner.

5.3. IoT and Network Specifications

• **Connectivity:** Wi-Fi 6E, Bluetooth 5.2, optional 4G/LTE fallback.

• **Protocols:** MQTT for telemetry, HTTPS for commands, LoRaWAN for low-power areas.

• **Security:** End-to-end encryption (AES-256), secure boot, biometric user authentication.

5.4. Performance Specifications

• **Latency:** <500 ms end-to-end.

• **Accuracy:** >85% semantic correctness for text, >75% perceptual similarity for images.

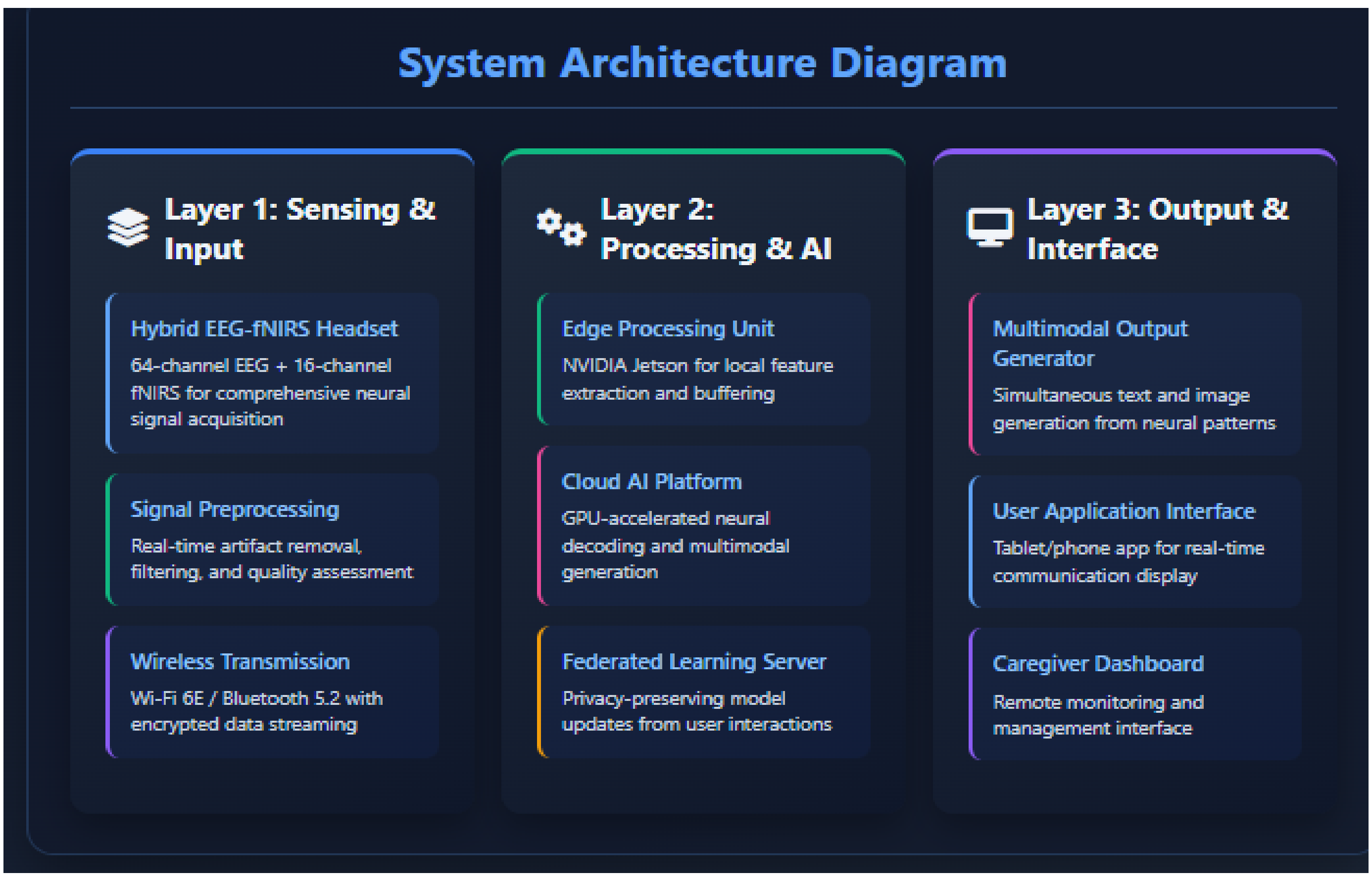
• **Battery Life:** 8 hours continuous use, 2-hour fast charging.

• **Cost:** Target <$3,000 complete system.

6.DRAWINGS OR SUPPORT MATERIAL

1. System Architecture Diagram

- **Three-layer structure** (Sensing → Processing → Output)
- **Color-coded components** for each layer
- **Technical specifications** for each subsystem

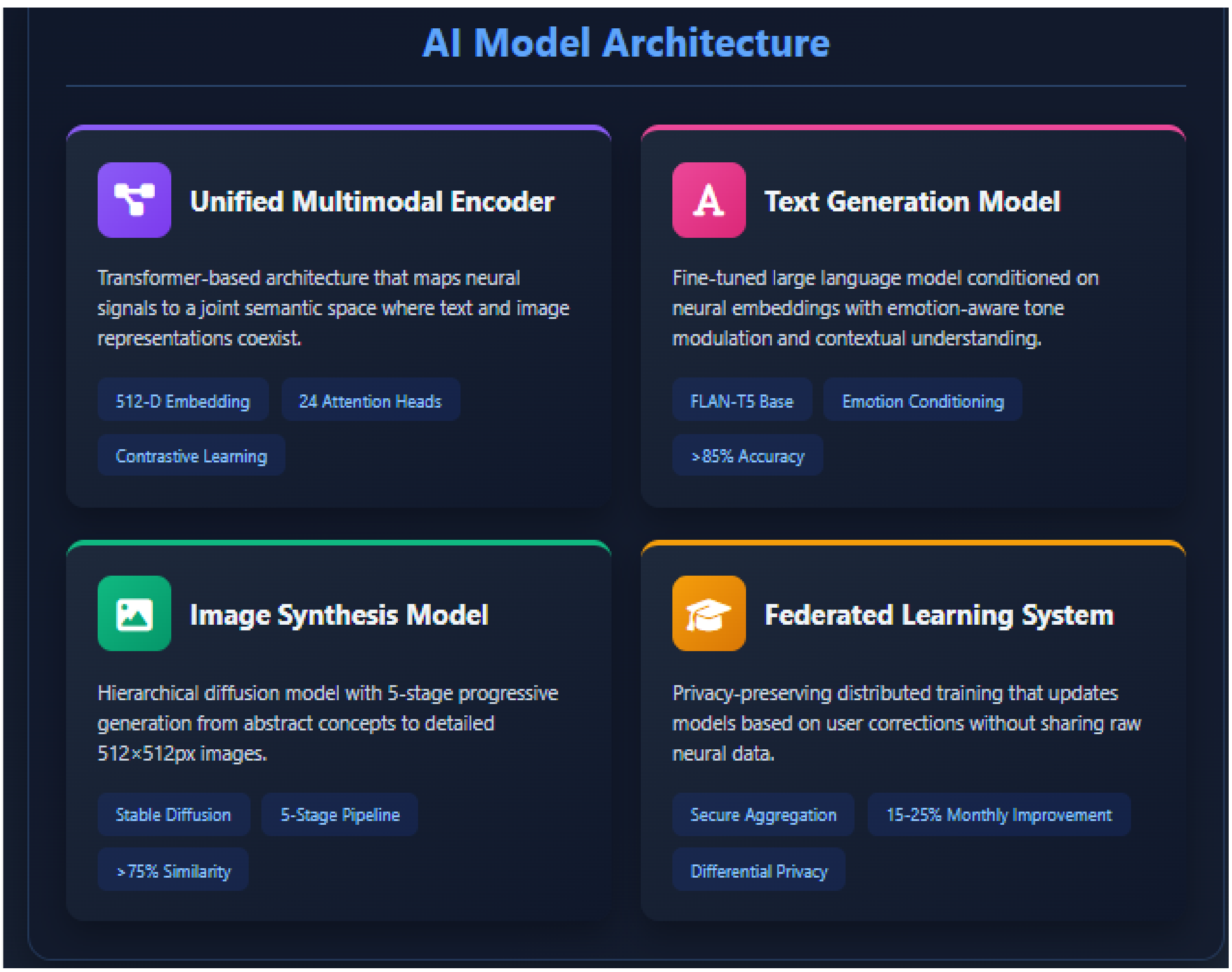


2. Neural Processing Pipeline

- **5-step sequential flow** from signal acquisition to semantic decoding
- **Icon-based visualization** of each processing stage
- **Detailed technical descriptions** of each step

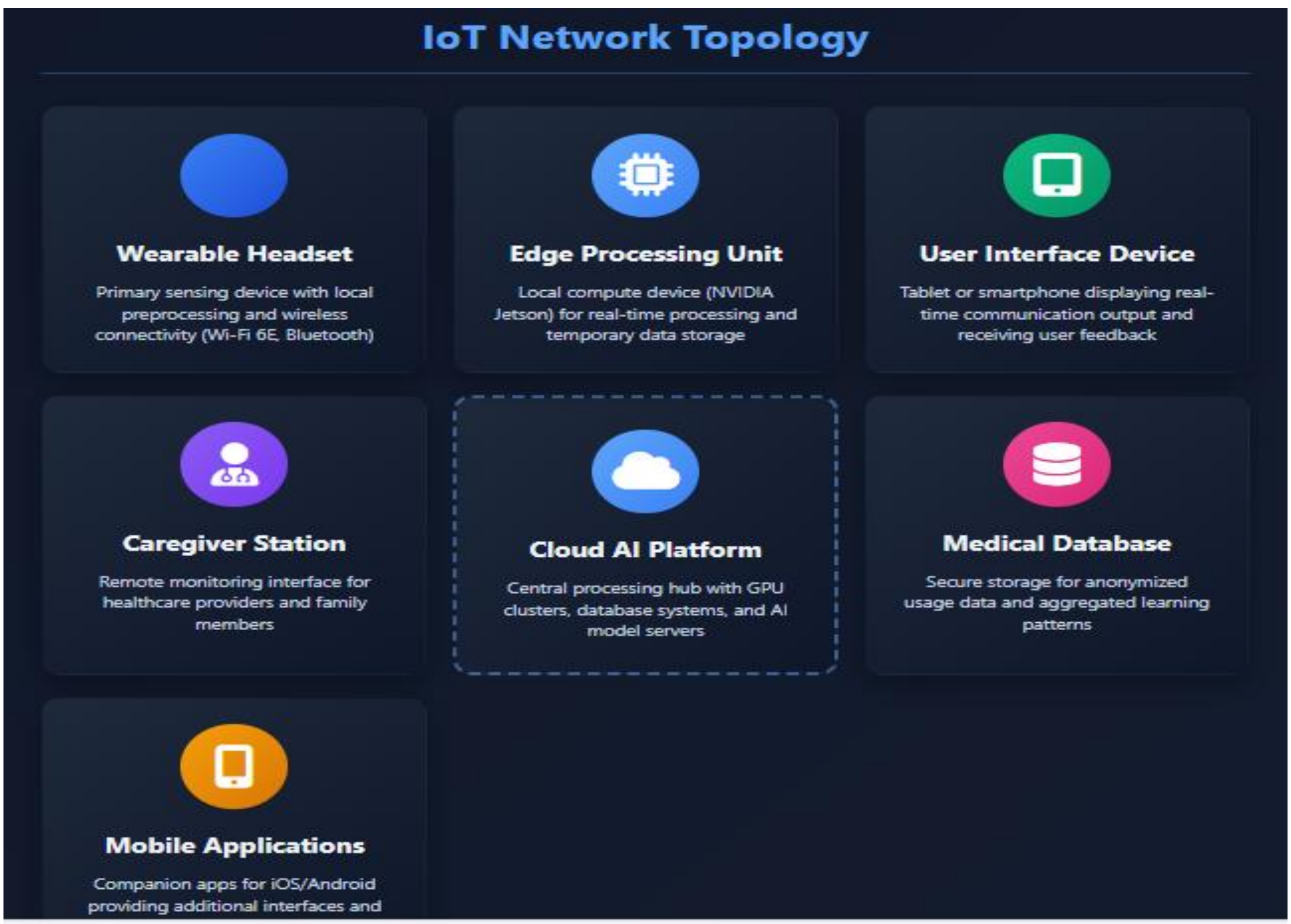
3. AI Model Architecture

- **Four key AI models** with distinct functions
- **Model specifications** and performance metrics
- **Visual representation** of each model's purpose



4. IoT Network Topology

- **Network node visualization** showing all system components
- **Central cloud architecture** with distributed nodes
- **Connection pathways** between devices and services



7.ABSTRACT (150 words)

An IoT-enabled adaptive multimodal neural communication system enables paralyzed individuals to communicate through simultaneous text and image generation from electroencephalography (EEG) signals. The non-invasive wearable device employs a dual-modal architecture where transformer-based text decoder and latent diffusion image synthesizer process identical neural features in parallel. A novel cross-modal semantic validation module using CLIP vision-language model verifies text-image coherence before display, preventing mismatched outputs. Intelligent adaptive modality selection dynamically determines optimal communication format based on decoder confidence scores, semantic alignment, and signal quality. Edge AI processing with Neural Processing Unit achieves sub-2-second latency enabling natural conversation. Self-calibrating meta-learning personalizes to individual brain patterns with minimal calibration. Comprehensive IoT integration enables smart home control, emergency alerts, and remote monitoring, providing complete communication solution for severe paralysis including ALS, locked-in syndrome, and spinal cord injury.

8.BRIEFLY EXPLAIN THE STEPS, FLOW CHART, FUNCTIONALITY OF INVENTION RELATED TO SOFTWARE, EMBEDDING WITH MACHINE, DEVICE, APPRATUS.
Note: Explain the functionality of software embedded with the device

Software System Workflow and Functionality

7.1. On-Device Embedded Software

• **Firmware:** Real-time operating system (FreeRTOS) for sensor data handling.

• **Tasks:**

– Sensor initialization and calibration.

– Continuous signal acquisition and buffering.

– Artifact detection and rejection.

– Feature extraction and data compression.

– Secure wireless transmission to edge/cloud.

7.2. Edge Processing Software

• **Modules:**

– Signal quality assessment (entropy, coherence).

– Preliminary decoding for low-latency feedback.

– Dynamic workload management between edge and cloud.

7.3. Cloud Software Architecture

• **Data Ingestion:** Apache Kafka for streaming sensor data.

• **Processing Pipeline:**

– Neural decoding service (TensorFlow Serving).

– Multimodal generation service (text + image).

– Context management service (maintains conversation history).

• **Analytics & Learning:**

– Federated learning server (PySyft).

– Real-time dashboard (Grafana) for caregivers.

– Predictive maintenance module for system health.

7.4. User Application Software

• **Frontend:** React Native app for cross-platform compatibility.

• **Features:**

– Real-time display of decoded thoughts.

– Correction interface with binary EEG response.

– Settings for output customization.