PROJECT BASED LEARNING (PBL-1) LAB (CSP390)

SMART ARMORED NEXUS INTEGRATION (SANI)

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Project Title

Smart Armored Nexus Integration (SANI)

Team / Group Formation:

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3	**Naveen Kr. Jha**	**2201010459**	**2022518370**	**AI & ML, Object detection and Conversational Chat**

Background knowledge

1. **Defense Technology & Tactical Gear**
   Research was done on existing military-grade suits such as exoskeletons, bulletproof vests, and smart combat wear to identify current capabilities and gaps. This included understanding the role of tactical gear in improving a soldier's situational awareness, protection, and communication.

2. **Embedded Systems & IoT**
   Knowledge of microcontrollers like the Raspberry Pi, sensor integration, and real-time data handling was crucial. Understanding how IoT works in wearable tech helped us design a networked system for monitoring vital signs, motion, and environmental factors.

3. **Artificial Intelligence & Data Analysis**
   Basics of AI, including pattern recognition and decision-making algorithms, were explored to process the data collected from the suit and respond with smart outputs, such as alerts or visual signals.

4. **Human Factors & Ergonomics**
   Since the suit is wearable, user comfort, weight distribution, and ease of movement had to be studied to avoid fatigue and ensure practicality during operations.

5. **Communication Systems**
   Understanding Bluetooth, Wi-Fi, and potential use of RF modules was necessary for developing the suit's remote communication and control features.

Tool

Pyttsx3, Speech recognition, tensorflow, cv2, pywhatkit, tkinter, pygames

Problem Statement

Modern-day soldiers face extreme conditions on the battlefield, including unpredictable threats, lack of real-time monitoring, and limited protective intelligence. There is a growing need for a smart armored system that not only offers physical protection but also integrates advanced monitoring, communication, and AI-based decision support. **Project SANI-AI Operated Suit for Safety and Support** aims to address this gap by developing a wearable suit that combines smart sensors, real-time data analysis, and communication modules to enhance a soldier's safety, efficiency, and situational awareness during operations.

Literature Survey

Paper / Patent	**Findings / Contributions**	**Identified Gaps**	**Relevance to SANI**
*Advances in Exoskeletons for Military Use*Franklin Mendoza et al., 2023	Systematic review of exoskeletons to reduce musculoskeletal disorders and enhance performance during strenuous tasks.	Focus on lower body; lacks AI integration and real-time adaptability; no communication systems.	SANI addresses full-body coverage, AI-based adaptability, and embedded communication tools.
*Assistive Exoskeletons in Defense and Security*D.J. Farris et al., 2023	Promising support in load carriage and manual tasks; emphasizes need for user-centered design.	Mismatch between performance and field use; lacks dynamic AI, power efficiency, and modular maintenance features.	SANI includes modular hardware, efficient power use (Arc Reactor style), and real-time AI features.
*Challenges Relevant to Exoskeletons*Harrison P. Crowell et al., 2019	Highlights evaluation gaps in design, integration, and adaptability in military scenarios over 26 years.	Difficulty adapting to diverse environments; lack of responsive AI and flexible interfaces.	SANI integrates AI-based UI, environmental adaptability, and situational reconfiguration.
*Exoskeletons for Manual Handling Tasks*J.K. Proud et al., 2022	Shows potential for reducing injury and fatigue during heavy lifting in military settings.	May restrict movement and lack adaptability for different missions.	SANI enhances mobility and flexibility using lightweight components and modularity.
*Need for Paradigm Shift in Exoskeleton Development*K. Mudie et al., 2022	Emphasizes practical deployment and user feedback as critical for real-world applications.	Current systems are not user-informed or field-adaptive.	SANI's workflow includes real-time user interaction and learning from operations.
Patent: US5597335A – Marine Rescue System	Fixed deployment rescue systems with mechanical functionality.	No real-time environment sensing; lacks adaptability to changing conditions and limited integration with smart systems.	SANI adds multi-sensor AI perception and dynamic environment adjustment.
Patent: US20200031438A1 – UAV Search & Rescue	Aerial surveillance for rescue missions.	Doesn't unify ground and aerial data; lacks autonomous decision-making; weak connectivity.	SANI offers UAV and ground robot integration with AI-led coordination and remote operability.
Patent: US7719222B2 – Extraction Assist Robot	Mechanized assistance for removing casualties.	Lacks real-time sensory feedback and autonomy; no adaptive decision-making capabilities.	SANI is designed for predictive response using CV, thermal, and audio sensors along with conversational AI.

Project Description

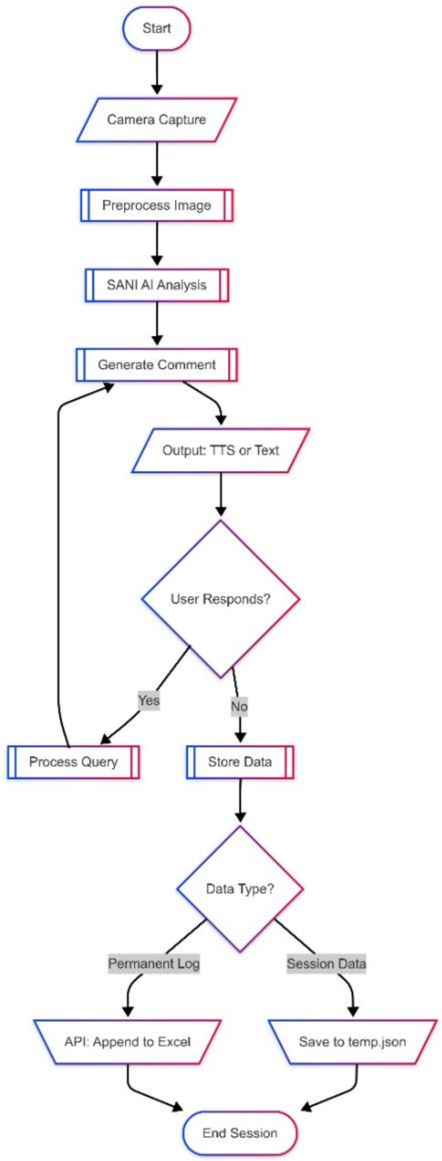
The SANI suit is designed to be easy to wear and quick to upgrade or repair. It can detect objects and assess threats, working both onsite and remotely. Using speech recognition and tools like pywhatkit, users can train the AI to perform tasks based on spoken instructions. It supports instant messaging, web searches, data storage, and sharing.

In areas with weak or no connectivity, a one-time handshake (OTH) technology helps the AI stay connected to nearby teammates. Long-distance control is possible using VNC server-client, which allows an instructor to access and control the suit remotely. Python is used to code the AI (named SANI), especially for Suit Functioning and Conversational tasks.

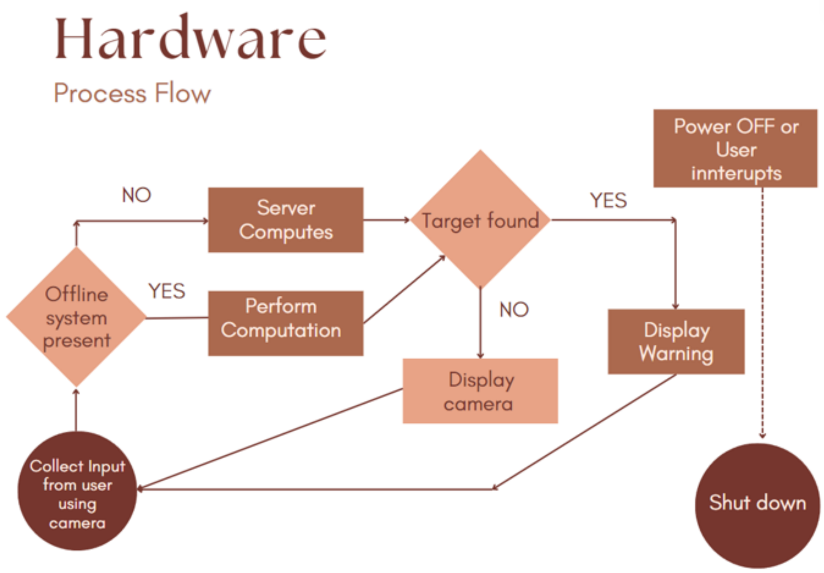
Suit can easily work with only 3 components namely; Arc reactor, Raspberry Pi and A Screen (even that can be absent)

1. An Arc Reactor: It is a power source which provides electricity which can be measured using clamp meter in it. Materials required:
    a) Wires
    b) 9V batteries
    c) USB-B port
2. A Graphic User Interface for AI:
    a) It is user friendly interface which help user to get across functions
    b) It will be made using python
    c) By using AI, we can create a chatbot which can help us in finding and analyzing objects through camera input
3. A Screen:
    a) It will display the real-time environment information along with GUI and commands from a distance
    b) It is connected with the motherboard (Raspberry pi) and a camera to show the output.

Project Modules: Design/Algorithm



Methodology



Hardware Process Flow (SANI System)

The hardware of SANI, boots up with the incorporated AI [Based on Large Language Models (LLMS)], it then starts collecting visual input from the real world through a camera which is connected to the raspberry pi and mounted to the helmet. This serves as a primary source for threat detection and situational analysis.

Once the image input is captured, the system determines whether it is operating in **online** or **offline** mode. If an internet connection is available, the input is processed via the **remote server/computer on which AI is trained**, this helps in efficient computational resources to analyze the data. If there is no Internet, the system switches to **offline computation**, where all analysis is handled locally on the device (Raspberry Pi 3B+ model (our case) or equivalent).

After processing, the system evaluates whether a **target (threat)** has been identified:

a) If **no threat** is found, the camera feed continues to be displayed, looping back to collect further input.

b) If a **target is detected**, the system transitions into an alert mode.

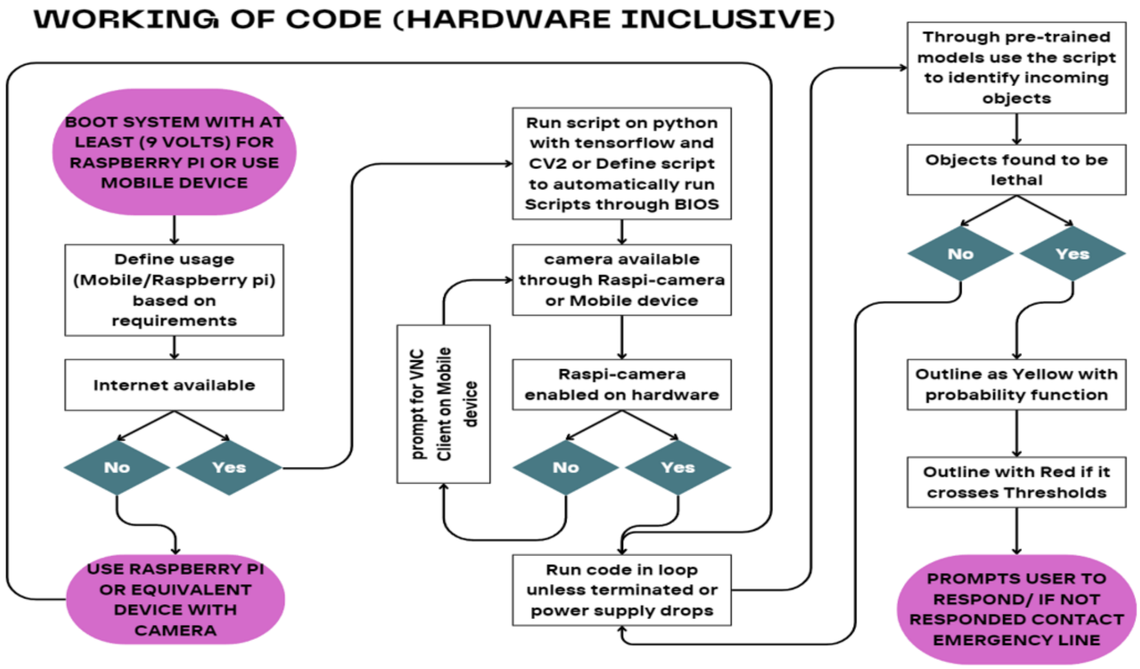
Upon identifying a threat, SANI generates a **warning**, displaying the alert to the user along with the processed video feed. SANI also provides assistance through conversational means (Text-To-Speech), this conversational chat will provide insights of the object detected as lethal if trained else will learn from the internet if user prompts. The system will remain in this alert loop until:

a) The **user manually interrupts** the process (e.g., acknowledging or dismissing the threat), or

b) There is a **loss of power**, prompting an automatic shutdown.

In either of these cases, the session is cleanly **terminated**, ensuring that logs are updated and processes are safely stopped.

This flow ensures that SANI remains responsive, intelligent, and secure, whether operating with full server access or autonomously in isolated environments.



The workflow begins with system initialization. When the suit is powered on using a minimum 9V power supply, SANI (trained as LLMs) first performs a device check, for internet to determine whether it is running on a Raspberry Pi or another mobile-based platform. Following this, it verifies the user authenticity by prompting for password or a guest account. When an internet connection is available, SANI establishes a link with the remote AI server (trained modules can be on PCs as well) to enable cloud-based operations. In the absence of connectivity, it switches to offline mode and logs all session data locally on .json file, which can be synced once the connect ion is restored. The data which seems to be of permanent and crucial data will automatically be added to the Spreadsheet through Google API, making SANI learn important information in long term memory.

Updated Workflow of SANI System (Hardware Inclusive)

The SANI (Smart Armored Nexus Integration) system begins its operation when powered with at least a **9V supply**, necessary to initiate the Raspberry Pi or a compatible mobile device. On boot, the system determines whether it's running on a **Raspberry Pi or a mobile device**, adapting its workflow accordingly based on the defined usage mode and available hardware.

Next, the system checks for **internet availability**:

a) If internet is available, it enables remote features like **AI model updates**, **data syncing**, and **VNC client access** for mobile control.

b) If no internet is detected, SANI switches to **offline mode**, using **locally stored models and scripts** for continued autonomous functioning.

Once the environment is verified, the system **initializes the camera interface** either a **Raspi-camera** or a **mobile camera**, depending on the device in use. A Python script, built using **TensorFlow** and **OpenCV (CV2)**, is launched manually or auto-started via BIOS. This script handles continuous video capture and real-time object detection.

The core AI engine uses **pre-trained models** to identify and classify objects in the video feed. Upon detecting an object, the system determines its threat level:

a) If the object is **non-lethal**, the system ignores it and continues scanning.

b) If a **potentially lethal object** is detected:

   i. It is **outlined in yellow** when the model predicts it with moderate certainty (using a probability function).

   ii. If the confidence level **exceeds a critical threshold**, the object is **outlined in red**.

In either threat scenario, SANI **immediately prompts the user to respond**. If the user fails to reply, the system **automatically contacts a predefined emergency line** to ensure safety.

The entire process is designed to run in a **loop**, only stopping if terminated manually or due to power failure. All data is categorized and stored as:

a) **Permanent logs**, appended via API to a Google Sheet or Excel file when connectivity allows.

b) **Session data**, temporarily saved in a local .json file for later synchronization.

This robust system enables **real-time threat detection**, **hands-free emergency response**, **offline resilience**, and **remote operability**, making SANI a powerful solution for field use in military, disaster relief, and tactical environments.

Result & Conclusion

The result and conclusion of a project focused on developing a military-grade suit would depend on the specific goals and objectives of the project.

Results:

1. Design and Prototype: The project can lead to a successful design and prototype of a military grade suit. This can include the choice of materials, the creation of a functional prototype, and the integration of various components such as ballistic protection, environmental management, and communication systems.
2. Performance Testing: The suit will likely undergo rigorous performance testing to ensure it meets the required standards. This may include ballistic testing, exposure to chemical and biological agents, thermal testing and other assessments to verify its protective properties.

Conclusion:

3. Suit Viability: Determining whether a military-grade suit is usable for its intended purpose. This would include an assessment of its effectiveness in protecting the user against various threats and harsh environmental conditions.

4. Safety and Reliability: Assess the safety and reliability of the suit in use scenarios. This includes the suit and its ability to consistently perform and protect the wearer as expected.

5. User Acceptance: Feedback from potential users can influence the conclusion. If a suit is well received and meets the needs of the military, it is more likely to be considered a success.

Future Scope and further enhancement of the Project

Future developments in technology, changing military requirements, and the desire to provide soldiers with better protection, mobility, and situational awareness could greatly expand the use of military-grade suits.

6. Advanced Armour and Materials: The study and creation of materials that are lightweight and extremely protective, such as metamaterials, graphene, and advanced ceramics. The use of self-healing materials to increase robustness and lower maintenance needs. The creation of materials that can defend against newly emerging dangers like directed energy weapons.
7. Biomechanical Enhancement: Exoskeleton technology should be developed further to improve soldiers' physical prowess, including strength, endurance, and agility. Studies on brain-computer interfaces (BCIs) and neurotechnology for smooth control and feedback systems in exosuits.
8. Integration of Sensors and Situational Awareness: Integration of cutting-edge sensors for threat detection, environmental monitoring, and health monitoring in real time for soldiers. Improved information-sharing and data fusion capabilities to offer all-encompassing situational awareness. Heads-up displays (HUDs) and augmented reality (AR) displays for better data visualization and communication.
9. Power and Energy Efficiency: The creation of cutting-edge, durable power sources, like energy-harvesting systems or large-capacity batteries. Investigate energy-saving technologies to increase the amount of time between recharges or replacements.
10. Personalization and Flexibility: Easily adjustable modular designs to accommodate specific military needs, mission profiles, and environmental circumstances. Systems that are adaptive and capable of independently reconfiguring to maximize performance under various conditions.
11. AI and Machine Learning Integration: Using AI to help with decision-making, threat detection, and pattern identification. Machine learning techniques to maximize suit performance according to mission goals and user preferences
12. More Flexibility and Mobility: Studies into flexible, lightweight materials that permit more mobility without sacrificing protection. Reduced suit weight and enhanced joint support to reduce weariness after prolonged use.

Advantages of this Project

Here are some of the key advantages:

1. Enhanced Protection:
   - Ballistic Protection: Military-grade suits provide protection against bullets, shrapnel, and other ballistic threats, reducing the risk of injury to soldiers in combat.
   - Chemical and Biological Protection: Many military suits are designed to protect against chemical and biological agents, safeguarding soldiers from hazardous substances.
   - Environmental Protection: These suits offer protection against extreme weather conditions, including cold, heat, and radiation.
2. Augmented Strength and Endurance:
   - Exoskeletons and powered components in military-grade suits can significantly increase a soldier's physical capabilities, allowing them to carry heavier loads and reduce fatigue during extended missions.
   - These enhancements enable soldiers to perform physically demanding tasks more efficiently, such as lifting heavy equipment, climbing, and running.
3. Improved Mobility and Agility:
   - Military-grade suits are designed to maintain or even improve the wearer's mobility and agility while providing protection.
   - Joint support and ergonomic design allow soldiers to move freely, enhancing their operational effectiveness.
4. Situational Awareness:
   - Integration of advanced sensors, heads-up displays (HUDs), and augmented reality (AR) technology provides real-time information and enhances situational awareness.
   - Data fusion and communication systems enable soldiers to make informed decisions in the field.
5. Communication and Networking:
   - Military-grade suits often come equipped with advanced communication systems that facilitate seamless connectivity within a squad and across military networks.
   - This ensures coordinated efforts and information-sharing among soldiers.

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