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Domain Analysis Report – Week 5

**Objective:** Document the study of the application context and identify representative applications and workload requirements for low-cost AI-enabled mobile phones, focusing on biometric security and intelligent connectivity.

1. **Introduction and Context**

1.1 Project Background  
The project focuses on designing and simulating a custom RISC-V-based processor for low-cost AI-enabled mobile phones. In Africa, mobile devices are pivotal for communication, financial inclusion, and access to digital services. Integrating AI into these devices enables innovative features like voice-controlled assistants and context-aware security systems, which can overcome language barriers and improve accessibility for users with limited English proficiency. **This initiative is a direct response to the challenges and opportunities of the Fourth Industrial Revolution (4IR) in emerging markets, where affordable technology must deliver advanced capabilities without compromising battery life or cost.**

**1.2** Purpose of the Domain Analysis  
This report aims to study the application context to identify representative applications and their workload requirements. The goal is to understand how AI-driven features, such as voice recognition, biometric security, and intelligent connectivity, will influence the design and simulation of a low-cost processor for mobile devices. **The findings from this analysis will directly inform the processor's Instruction Set Architecture (ISA) extensions and microarchitectural features, ensuring it is optimized for the target workloads.**

1. **Mobile AI Telephony Context Study**

2.1 Domain Overview  
Mobile AI telephony devices are essential in enabling communication, financial transactions, and access to services in areas with limited infrastructure. Features like voice commands and context-aware security improve usability for diverse populations, particularly in multilingual regions such as Lesotho.

**Key constraints in this domain include:**

* **Cost Sensitivity:** The processor and device must remain affordable for the target market.
* **Power Efficiency:** Limited access to consistent electricity makes long battery life a critical design goal.
* **Network Connectivity:** Intermittent or low-bandwidth connections necessitate on-device AI processing rather than reliance on the cloud.
* **User Diversity:** Applications must be accessible to users with varying levels of literacy and in local languages (e.g., Sesotho).

2.2 Role of AI  
AI enables devices to interpret user input intelligently, such as recognizing voice commands, authenticating users through biometrics, and dynamically adjusting security based on nearby trusted devices. These capabilities require processing workloads that balance low power consumption with real-time responsiveness. **Specifically, AI moves the computational burden from the network (cloud) to the device (edge), reducing latency, preserving user privacy, and ensuring functionality offline.**This shift is fundamental to the processor's design philosophy.

1. **Identification of Representative Applications**

3.1 Criteria for Selection  
Applications were selected based on their relevance to everyday mobile use, their demand on processing resources, and their potential to demonstrate the capabilities of the custom RISC-V processor. Selection criteria included:

* Direct impact on user accessibility and security. The application must solve a real-world problem for the target audience.
* Representativeness of typical AI workloads on low-cost mobile devices: It should embody common operations like signal processing, pattern matching, and classification.
* Feasibility of simulating the application with simple programs for workload analysis.

3.2 Identified Applications

* Voice Recognition: Allows users to issue commands in Sesotho (e.g., wake word, call contact, send money). Requires real-time speech-to-text processing and keyword matching.
* Biometric Security: Combines voice recognition and optional PIN entry for authentication. Provides context-sensitive access control based on user location or nearby trusted devices.
* Intelligent Connectivity AI: Detects nearby trusted devices (via Bluetooth/Wi-Fi) and adapts the security policy accordingly, reducing friction in familiar environments while maintaining security in untrusted contexts.

1. **Workload Requirements Analysis**

4.1 Workload Characterization

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| Application | Workload Characteristics |
| Voice Recognition | High compute intensity (matrix multiplications for neural network inference). Strict, low-latency requirements for user experience (<100ms response). Real-time speech capture and processing; Keyword detection and matching; Low latency required for responsive user experience. |
| Biometric Security | Moderate latency tolerance (1-2 seconds for authentication is acceptable). Voice-based authentication plus optional PIN verification; Decision logic based on environment and trust level; **Random memory access**for fetching authentication data and policy rules. |
| Intelligent Connectivity AI | Scanning for nearby devices/networks; Context-aware rule-based decisions; Low compute, mostly conditional logic |

4.2 Mapping Requirements to Processor Design

* Latency: Voice recognition requires low-latency instruction execution to provide immediate feedback.
* Throughput: Simultaneous audio capture and text processing demand sufficient throughput for real-time recognition.
* Memory Access Patterns: Keyword models and PIN verification data require efficient memory access.
* Compute Intensity: Voice recognition is the most compute-intensive, while connectivity logic is lightweight.
* Implications for ISA & Microarchitecture: Custom instructions may accelerate keyword matching, conditional checks, and data movement, optimizing the processor for mobile AI workloads.

1. **Conclusion**  
   This analysis identifies voice recognition, biometric security, and intelligent connectivity as representative applications for low-cost AI-enabled mobile phones. Each application introduces distinct workload requirements, from real-time audio processing to lightweight context-aware decision-making. These findings inform the design of a custom RISC-V processor and guide the creation of high-level application prototypes in C++ to simulate these workloads.