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Thesis Title: *Federated AI on a Network of Dynamically Reconfigurable Wireless Smart Cameras*

With the proliferation of intelligent visual sensors, wireless camera networks are becoming a key research area for many applications, such as surveillance, object recognition, and real-time scene analysis. However, optimizing data processing and transmission remains a major challenge due to constraints on bandwidth, energy consumption, and the computational capacity of embedded sensors. In a frugality-driven approach, this thesis explores efficient resource management mechanisms and proposes a distributed architecture based on blockchain and federated artificial intelligence to optimize information exchange within the network. To ensure confidentiality and preserve individuals' privacy, the cameras used are very low-resolution (32x32 pixels), thus reducing the risk of identification while still collecting relevant information for targeted applications. These cameras already exist and consist of a low-resolution sensor, an analog PIR sensor, a small FPGA (Max10 – low-cost and low-power), and an ESP32-C6 to handle network communication via Bluetooth.

Problem Statement

The use of wireless cameras in dynamic environments imposes conflicting requirements. On one hand, it is necessary to capture and analyze data to ensure optimal accuracy. On the other hand, energy consumption and transmission latency must be minimized. The adoption of very low-resolution cameras helps reduce processing load and improves data transmission while ensuring the privacy of filmed individuals. The existing hardware architecture, relying on a small FPGA (Max10 – low-cost and low-power) and an ESP32 for Bluetooth communication, imposes additional constraints in terms of optimizing embedded processing and the efficiency of information exchange protocols.

By adopting a frugal and decentralized approach, we propose to explore how dynamic reallocation of hardware and software resources, combined with blockchain-based data governance and federated artificial intelligence, can enhance system efficiency. Federated AI will allow for training of processing models without the need to centralize data, thereby ensuring greater confidentiality while improving overall network performance.

Research Objectives

The main objective of this thesis is to design a wireless camera network system capable of optimizing data processing using reconfigurable circuits that dynamically adjust their architecture to reduce computational load and energy consumption. By integrating a private blockchain infrastructure and a federated AI approach, this system will allow for more secure and decentralized management of captured data. Federated AI will enable collaborative learning among cameras while preserving the privacy of raw data. Information transmission over the Bluetooth network will be optimized based on bandwidth constraints, ensuring increased authentication and data integrity through the use of blockchain. The use of low-resolution cameras, combined with a dedicated blockchain and a distributed AI approach, will ensure the collection of relevant data while reducing computational load and enhancing the confidentiality of video streams.

Methodological Approach

The research will follow a hybrid approach combining theoretical modeling, simulations, and practical implementations. The design and simulation of reconfigurable circuits will be conducted to optimize the processing of data captured by the cameras. A prototype integrating a flexible processing architecture will be implemented and tested on a wireless camera network using Bluetooth as the communication protocol. A dedicated blockchain will be deployed for the validation and management of information exchanges. Federated AI will be implemented to enable cameras to learn collectively from their own observations, without directly sharing raw data. System performance will be evaluated based on energy consumption, transmission latency, AI processing accuracy, and the quality of exchanged data.

Expected Impact and Contributions

This thesis will contribute to the advancement of intelligent visual sensor networks by proposing an adaptive, energy-efficient, and decentralized solution. The integration of blockchain will enhance data security and traceability while enabling a distributed communication mode. The addition of federated artificial intelligence will optimize local processing while avoiding data centralization, thus addressing concerns related to privacy and energy consumption. The use of very low-resolution cameras will provide an added advantage by enabling more responsible management of visual data and reducing privacy risks. Optimizing the Bluetooth protocol for information exchange between the cameras and the blockchain infrastructure will also be a key advancement. This approach will pave the way for various applications, ranging from surveillance to autonomous object recognition, in a context of frugality and reduced hardware and energy costs.

Conclusion

The integration of reconfigurable architectures into wireless camera networks, combined with dedicated blockchain technology and federated AI, represents a major step forward in optimizing data processing and transmission. The use of very low-resolution cameras enables a balance between performance and privacy, while reducing the system's energy footprint. By leveraging a Bluetooth network for data exchange and integrating a secure blockchain and distributed AI system, this thesis will provide an innovative and efficient solution to address the challenges posed by such systems, while opening new perspectives for embedded technologies.