

ECE-21 On-Board License Plate Obfuscation System

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Current Practices

Networked surveillance cameras are widely used in traffic monitoring and public safety systems. However, many of these systems capture, stream, or store raw video before any privacy protections are applied. As a result, personally identifiable information such as vehicle license plates can be exposed before anonymization occurs.

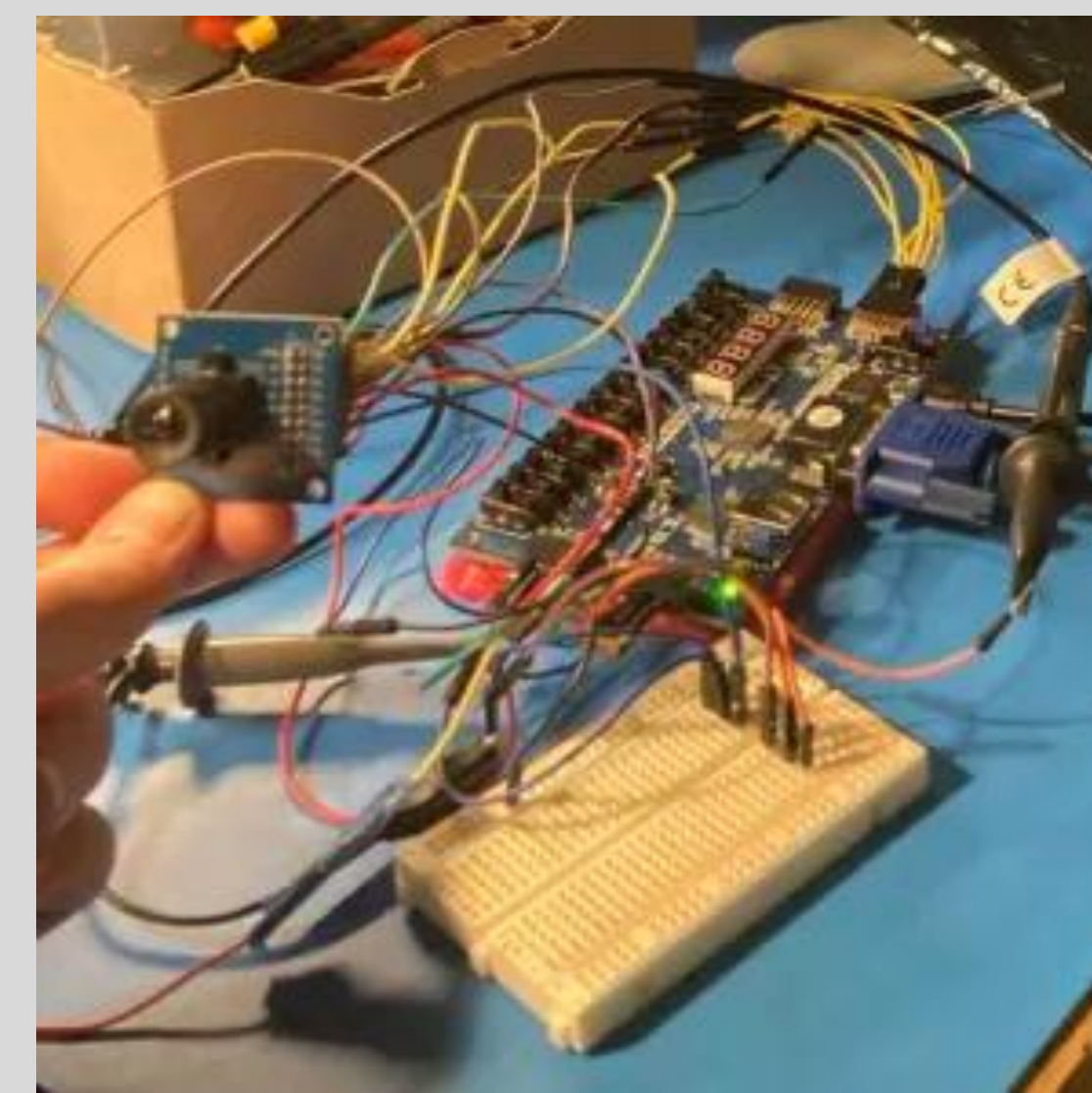
Industry Challenge

Current anonymization methods are often performed off-device, which creates a security gap between image capture and privacy protection. During this window, sensitive video data can be intercepted, misused, or stored in unsecured form. This makes it difficult to guarantee privacy compliance while still supporting real-time surveillance and public safety needs.

Our Solution

This project uses an FPGA-based edge system to anonymize license plates as soon as video is captured, so raw sensitive footage never leaves the device. Running on the ZUBoard 1CG, it uses a lightweight YOLOv5 model to detect plates and then applies either permanent masking or reversible scrambling. This creates a fast, real-time privacy solution directly on the hardware.

Results of Hardware Testing



Camera Feed

Our FPGA → Camera prototype enabled testing of

- Camera Internal Configuration
- Frame rate
- Frame storage cost
- Clock speed

	Results
Frames per second	30 FPS
Storage Cost	88% of Memory
Clock Speed	25 MHz

The results of our initial prototype prove the feasibility of our design, showing that an FPGA with few internal resources can process the camera feed with room for future processing logic

Prototype Development Methods

- Ultralytics was used to prepare and manage labeled license plate training data
- YOLOv5 was used for training and validation for bounding box detection
- The model will be pruned with Vitis AI Optimizer
- The model will be quantized with Vitis AI Quantizer
- The model will be mapped to the FPGA via Vitis AI Compiler
- Live video input provided via camera module
- I2C communication was used to configure the camera's settings
- Initial implementation on a Basys3 FPGA using Vivado
- Upgrading to ZUBoard 1CG for Obfuscation Pipeline

Obfuscation Methods



Detection\Obfuscation Process



Conclusion

- Basys3 lacks enough BRAM, so the ZUBoard 1CG is the better choice for the full obfuscation pipeline.
- Initial testing reached 30 FPS, showing real-time performance is feasible.
- Prototype results validated the live camera pipeline and support expansion to full on-board processing.
- YOLOv5 is the current model choice because it is easier to test and integrate.
- The design can later transition to NanoDet if further optimization is needed.
- The system will support multiple obfuscation methods, giving flexibility for different privacy and recovery needs.
- Overall, the project shows that edge-based license plate obfuscation is feasible.

Design Overview

