Design and Development of a Detection and Tracking System for Moving Objects

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Research Area

Design a System that Detects and Tracks Objects, specifically pedestrians, in Various Contexts.

The Problem

Traditional Security Systems are *Not* Ideal for All Users

The Problem(s) with Traditional Systems

Very long term storage unfeasible

Single Point of Access

Not extensible without $$$ (hardware or software)

Often not accessible off-premises

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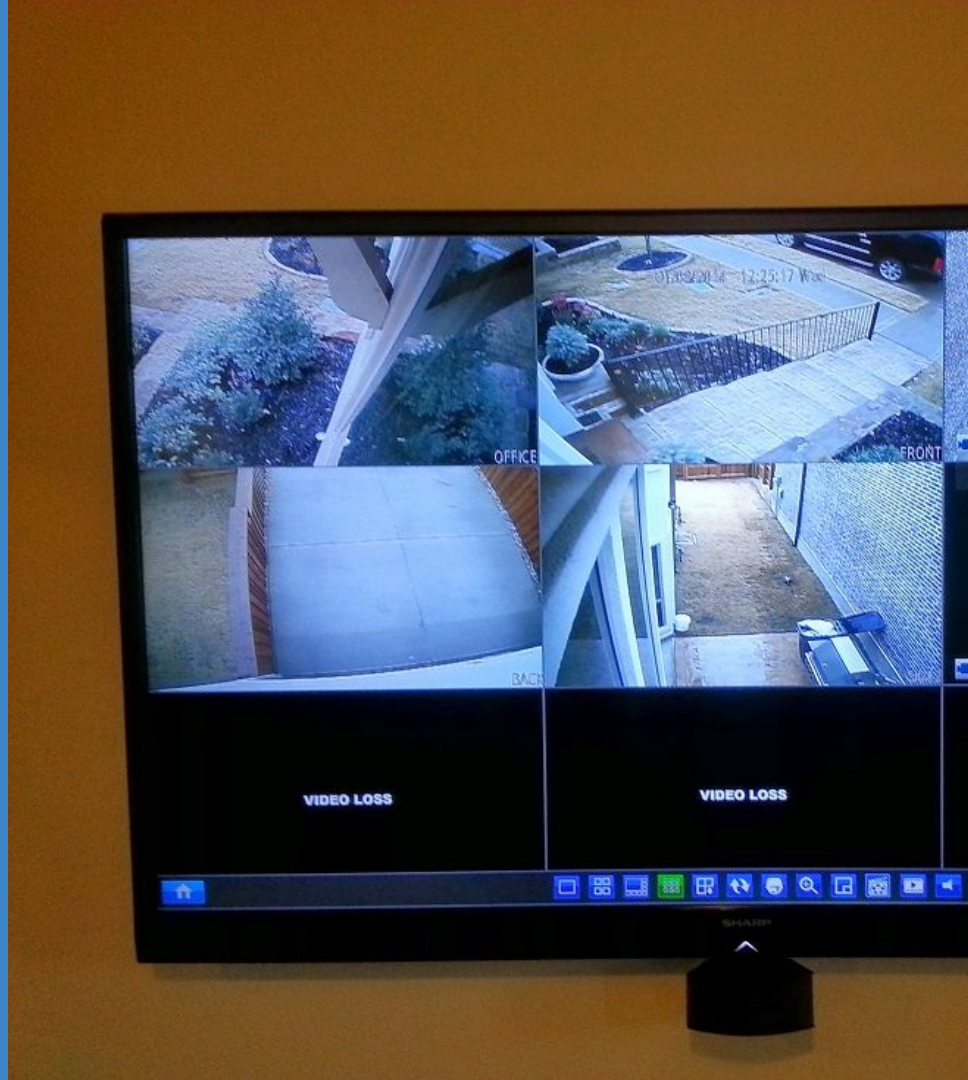
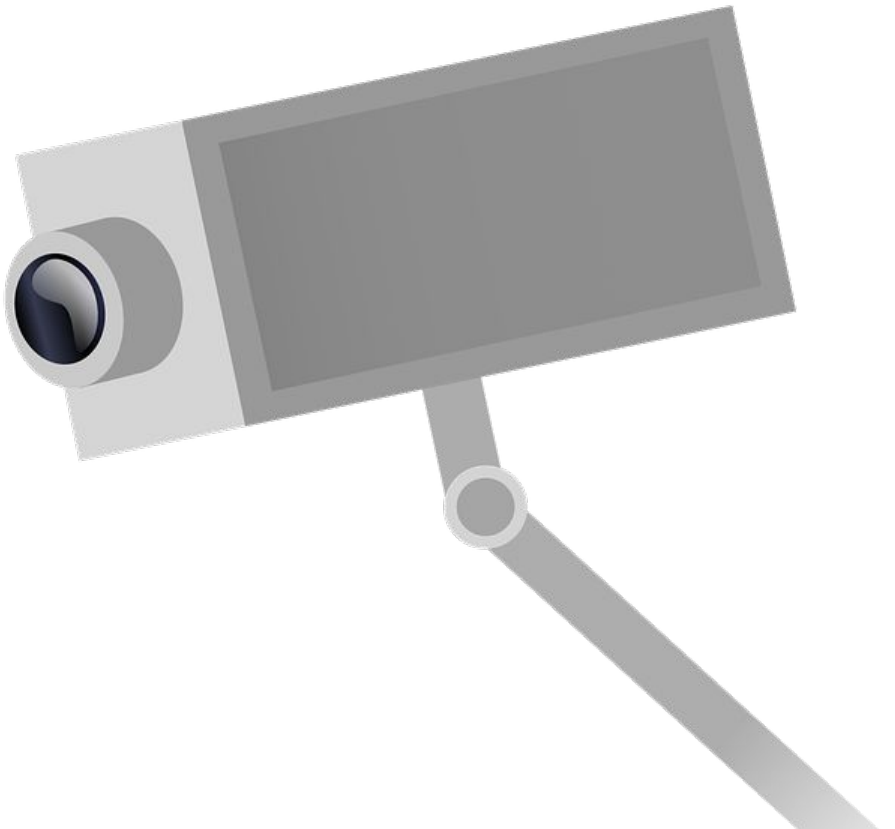
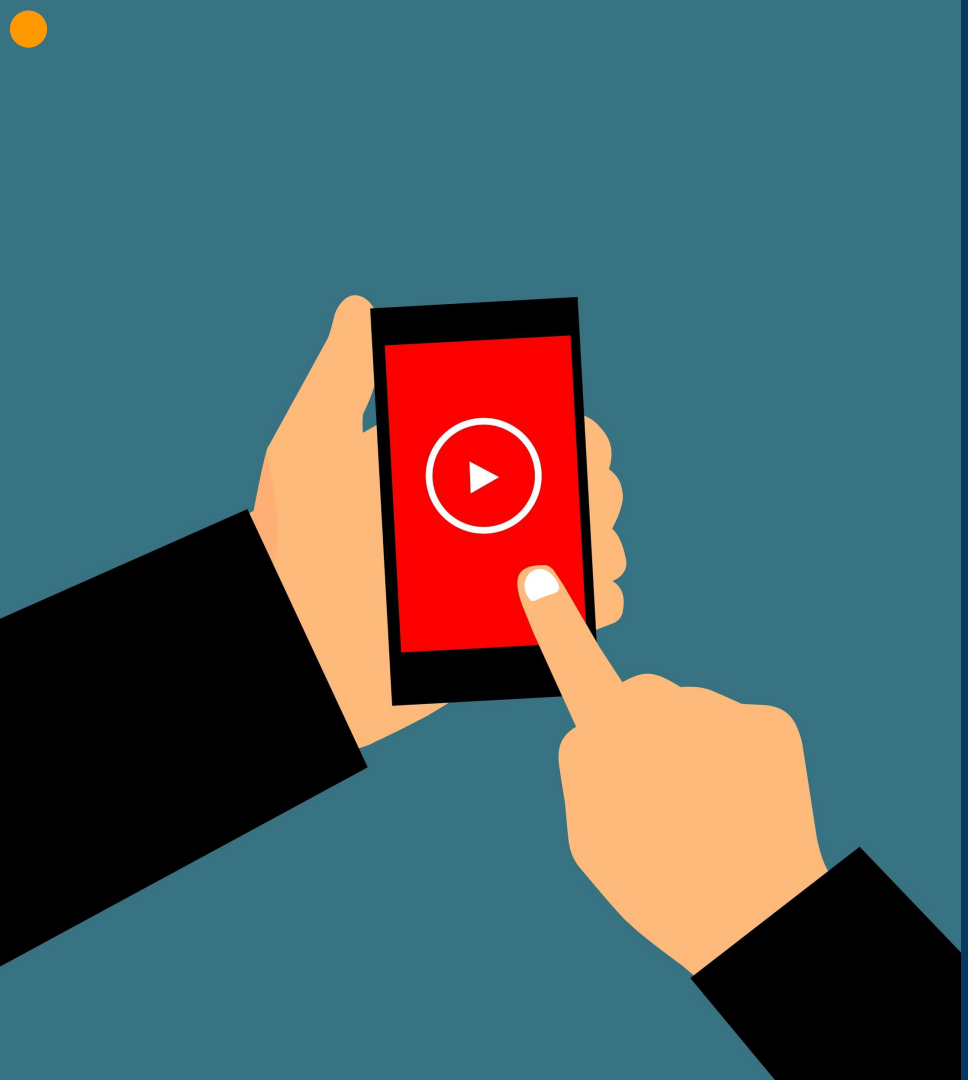


The Solution



Objectives

- Easily Scalable
- Multiple Access Points
- Secure
- Available Off-Premises
- Little Latency



Objectives

- Observe Paths taken by Objects
- Live Video Streams with Identified and Tracked Objects
- Secure Access
  - Secure Login
- Administrator Ability to Add and Remove Cameras

The Solution

VERIFEYE

A security system that is:

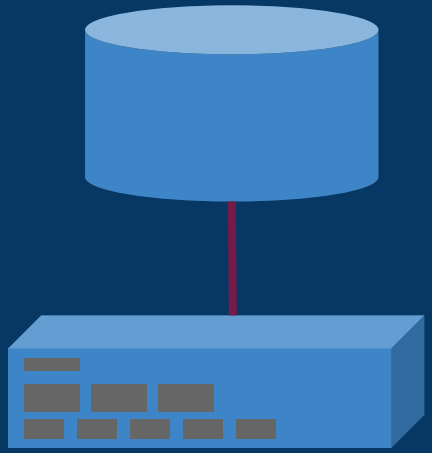
- Distributed tracking-based security system
- Multi-platform
- Portable
- Extensible in hardware
  - Supports the addition of any number of cameras
- Extensible in software

How VERIFEYE Works

Client Devices
Display Footage

Available on IOS, Web and Android

Server and DB
Heavy Lifting



With non-proprietary, modifiable protocols

Cameras
Put the Eye in VerifEye

Of any shape, size and number

How VERIFEYE Compression Works


1.jpg


1.mp4


1_path.jpg


2.jpg


2.mp4


2_path.jpg


3.jpg


3.mp4


3_path.jpg


7.jpg


7.mp4


7_path.jpg


10.jpg


10.mp4


10_path.jpg

Modes of Tracking - Past Footage

VerifEye can handle security in the following configurable ways

Requirement	Method Used	Storage Implications
High-traffic, low area-of-coverage	Traditional - Record the entire scene, overlays bounding boxes	Matches today's storage rates
Low traffic, high area-of-coverage. Non-safety critical	Minimized - Record only the actors and their movements. Not whole video.	Vastly improves storage rate.

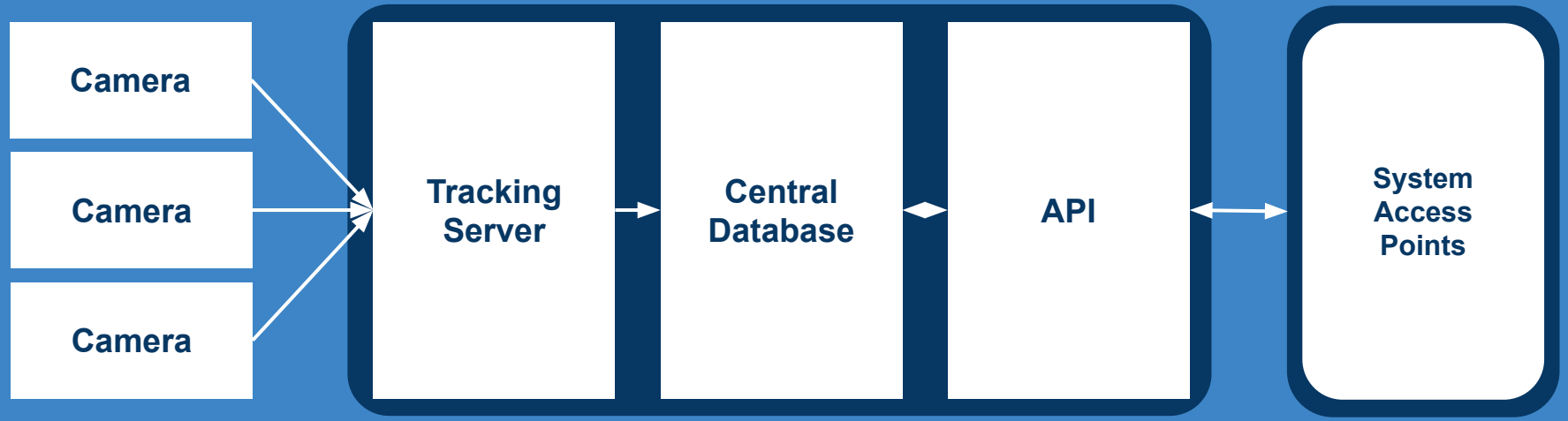
The Design

A thorough overview

Requirements

- Mobile Application + Web Application
- Security
- Multiple Cameras
- View footage from server
  - Live
  - Past
- Track Objects in Footage

Design: The System



Records Video

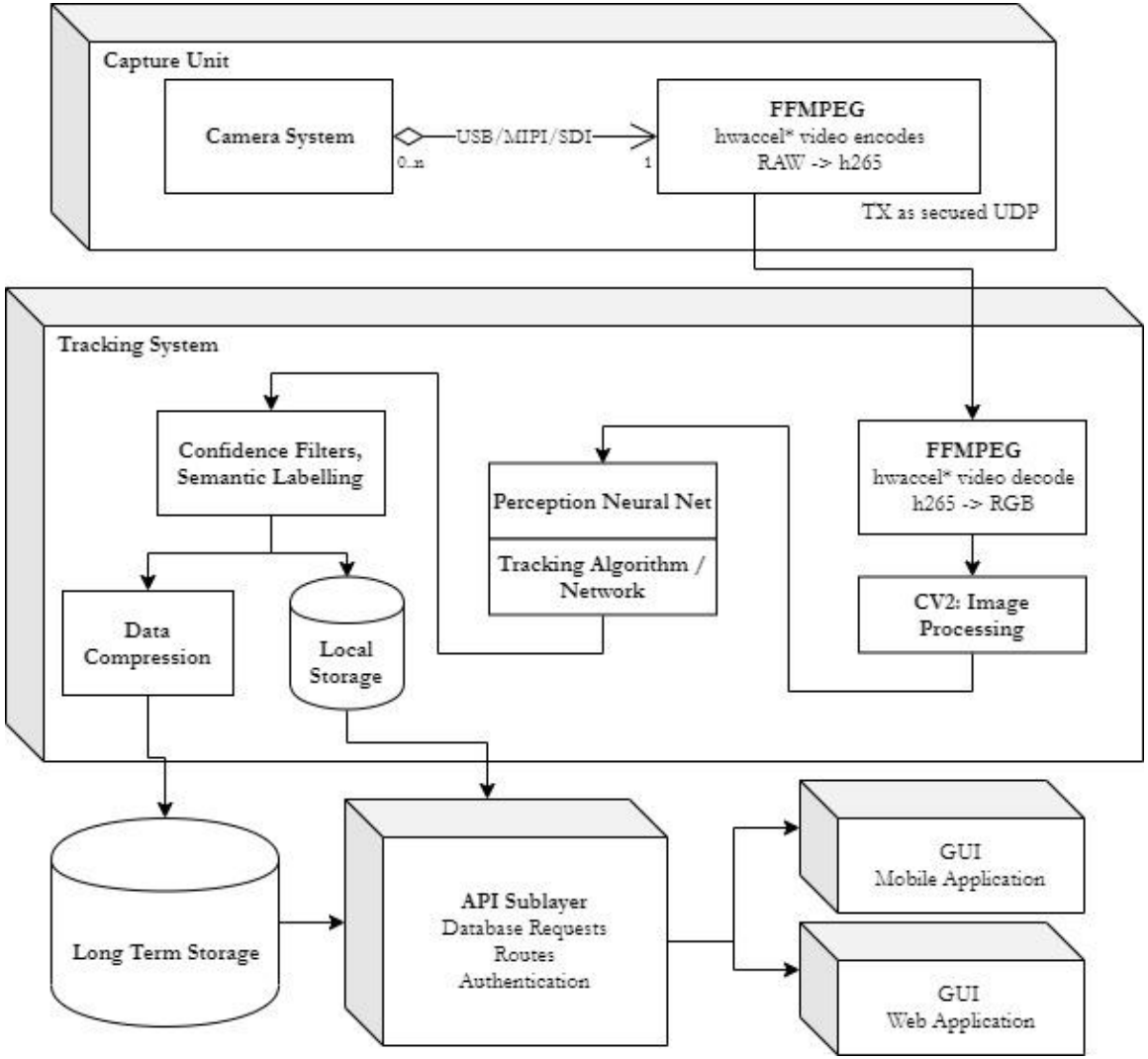
Detects and Tracks Objects

Save User and Video Data

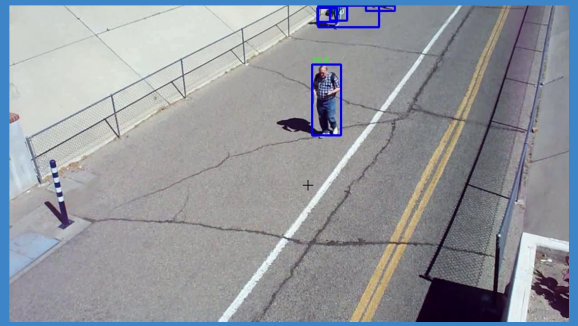
Link Between Access Point and Database

User Interacts with System

Design: System Architecture



Design: Server



Goal of server: Track objects of interest

How it works:

- Custom trained Neural Network for tracking
- SORT - a Kalman Filter based Multiple Object Tracking model
- Additional logic for occlusion and re-entry
- FFmpeg and OpenCV for decoding, processing and encoding

Design: Database & NFS

- User Information
  - Login credentials
  - User Preferences
  - User Information
- Camera Information by organization
- Video Data
- Tracked Objects as video streams

Design: API Endpoints

- Asynchronous, distributed event bus
- Scalable architecture
- Video data is chunked and sent asynchronously as a byte stream
  - Vert.x is able to stream video very efficiently by bypassing userland

Design: UI Endpoints

- Mobile application built with Flutter
  - View Cameras, add Favorites, Profile Settings
- Web application built with Angular
  - Feature parity with mobile application + admin portal

The Implementation

Behind the Scenes

Cameras

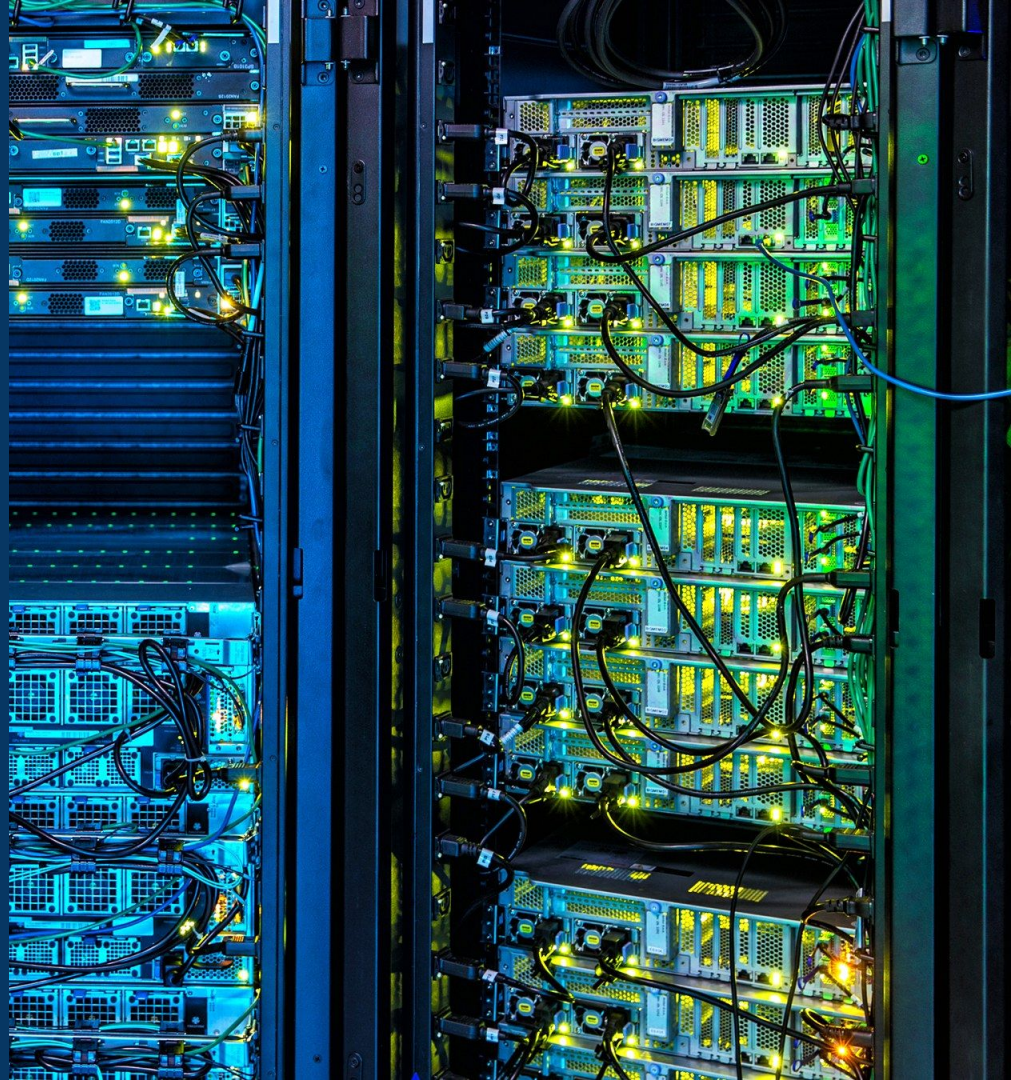
Any camera that uses a non-proprietary interface

- USB
- MIPI
- SDI

Also supporting IP Cameras for low-cost, low-energy solutions

Server: Python

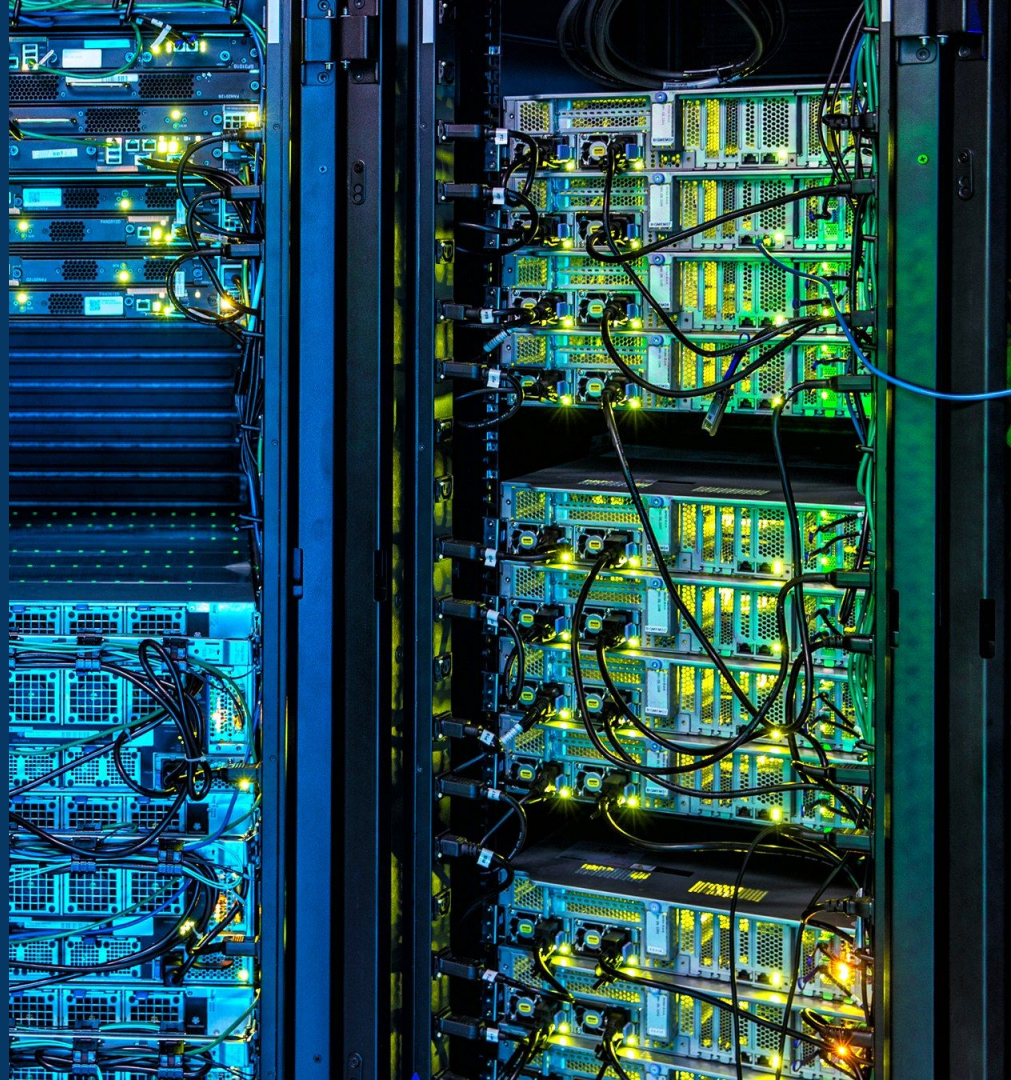
- Runs on windows, linux or EC2 instance
- An Dell Precision 3520 can handle 2 720p streams at 30fps
- Deep neural network + Multiple object tracker
- Inference -> Track



Testing the Server

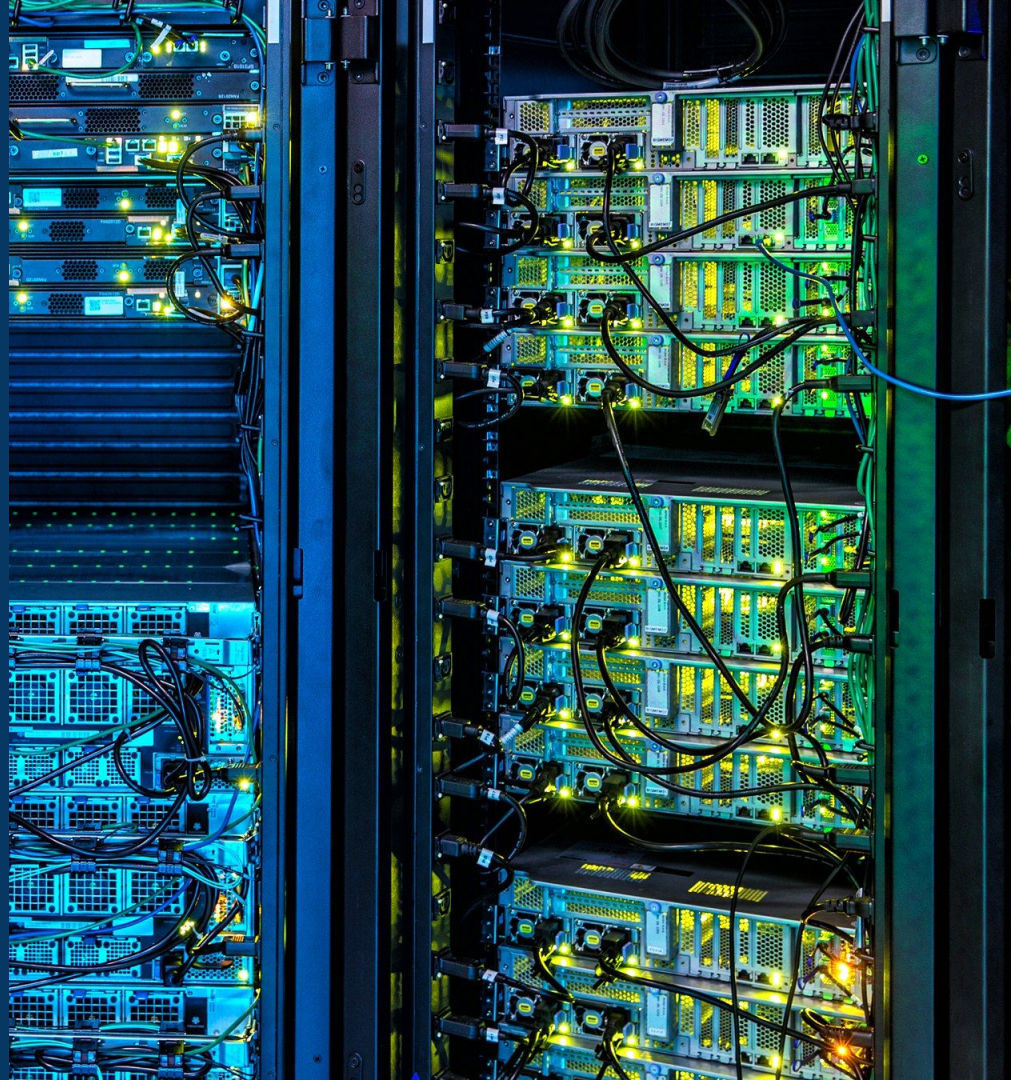
- Checked the mAP of the detections
  - 78-96%
- Visually checked the following*:
  - False positive crossovers
    - 5 (on exit & re-entry)
  - Lost actors
    - 1
  - False positive switches
    - 41

*over 20 minutes of concatenated video



Engineering Tradeoffs

- Latency vs Extensibility
  - Is low latency really important?
  - Solution: Enable both (HLS + option for UDP)
- Tracking accuracy vs privacy
  - Reduce number of false positive switches by re-identifying actors?
  - Not worth it



API and API Testing:

- REST
- Java-based (vert.x)
- “Glue” for other services making up the application
- Postman API design suite
  - Scriptable interface

System Access Points

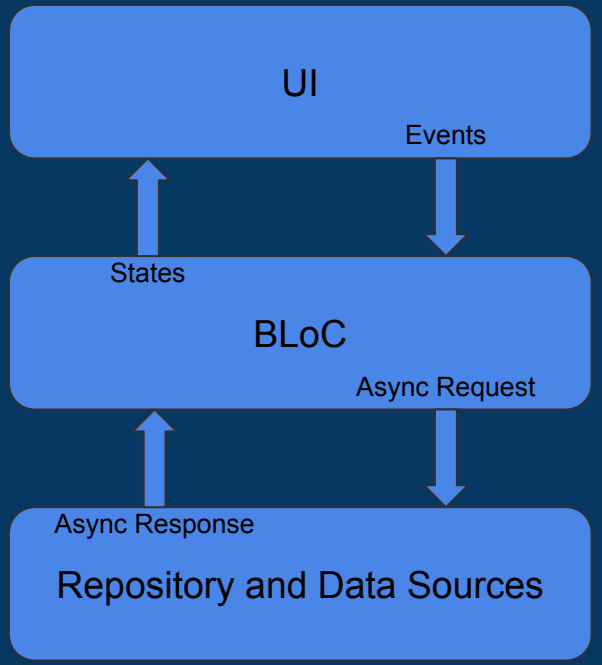
- Mobile Application
- Web Application

- Interact with REST API for data, video and security

Mobile Application - Built With Flutter

Using the BLoC architecture

- Streams of Events -> Streams of States
- Allows better separation
- Powerful state management
- Rich Debugging
- Hierarchy of BLoCs



Design: Web Application

- Angular
  - Extensible, Secure
  - Open Source, built on TypeScript
- Material Design

Existing Solutions

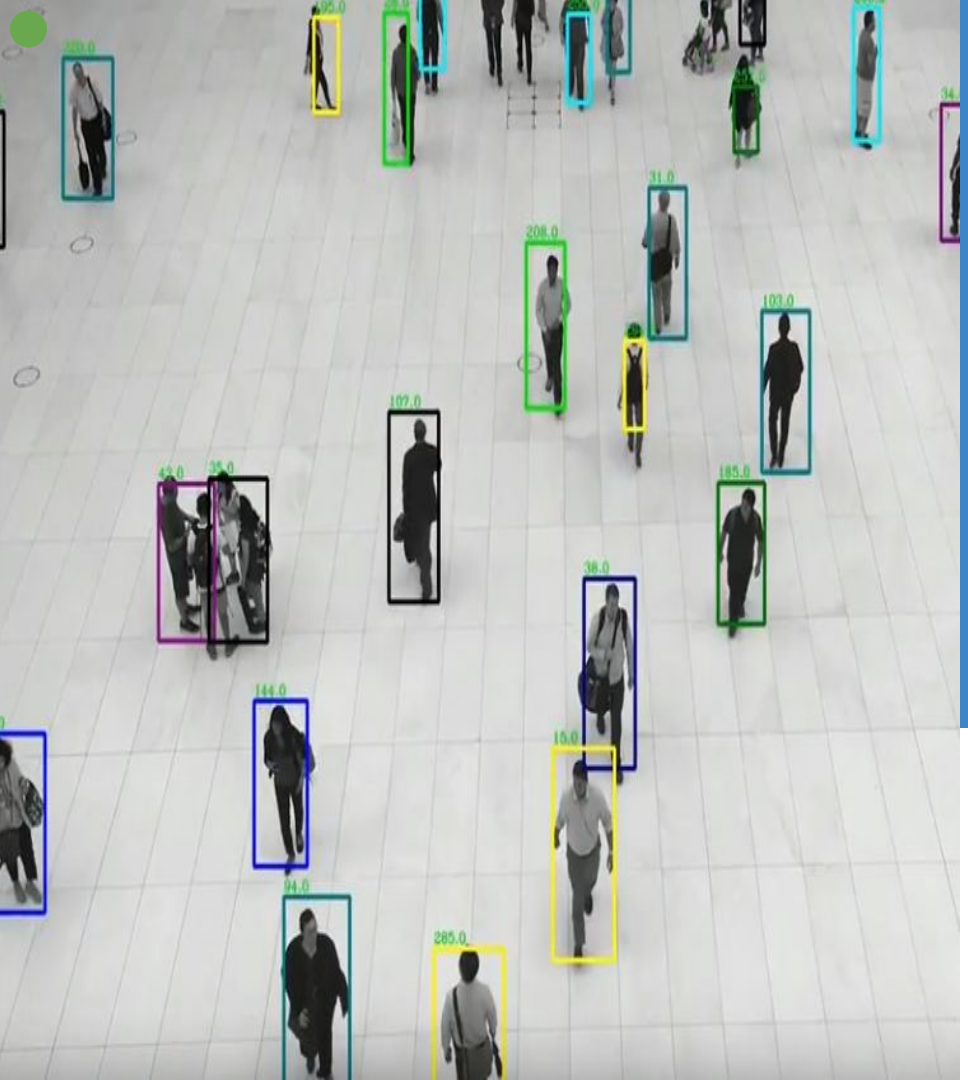


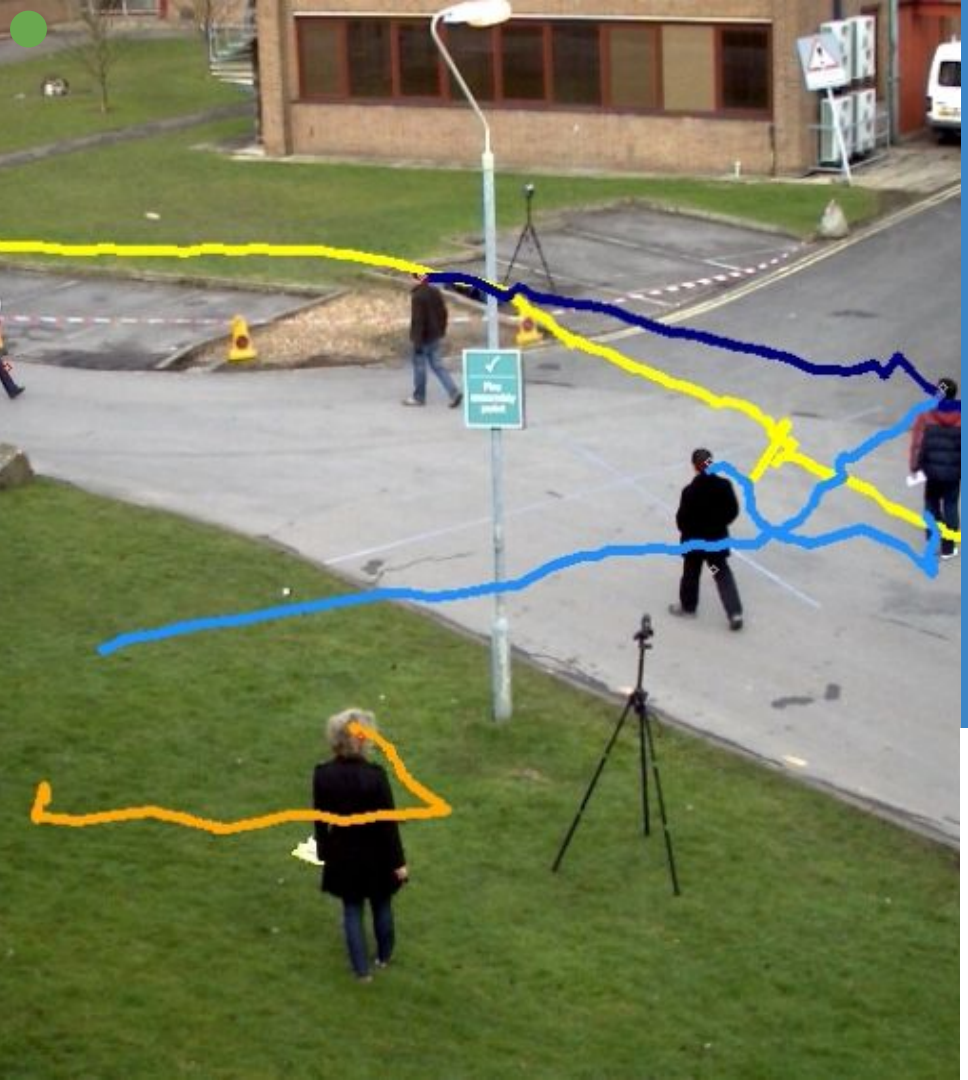
Image Recognition

- Microsoft Computer Vision API
- Amazon Rekognition
- Google Cloud Vision API
- Open CV
- Clarifi
- Torch

We use

YOLO

Deep Neural Convolutional Net



Object Tracking

- Tracker by Vicon
- Qualisys
- Kinovea
- Noraxon

We use

SORT

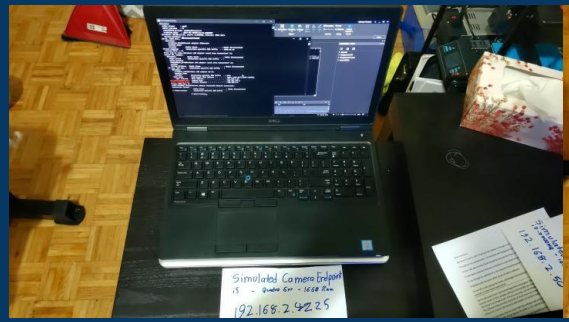
Kalman Filter Based Tracking

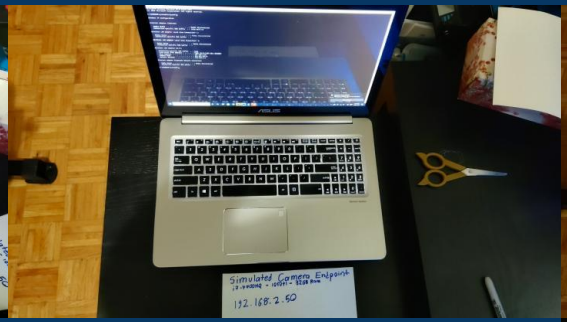
Implications of Development

VerifEye started off as an application. It is now a powerful Open Source Platform.

- **Each component of VerifEye is valuable in its own right**
  - **Multiple Object Tracking with occlusion considerations is a currently open problem**
    - **Applicable to self driving cars**
  - **Open source distributed code for serving video**
    - **Applicable to many other use cases**
    - **Internal, secure video streaming for large organizations**
  - **Extensible, flexible dual-platform code that handles live and stored video**
    - **Useful for content-sharing**

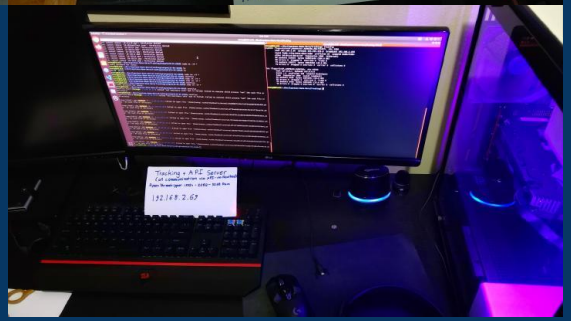
Demo and Testing Setup





Testing Setup:

4 Computers (Server, API, Observer, User)



Demonstration

Q&A