A Privacy-preserving Video Processing Pipeline

Gábor Gulyás
joint work with Gergely Erdődi

VITAREX

VeriDome

National Research, development and Innovation Office
Hungary

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The VeriDome project

- Development of a CCTV analytic and security enhancing system with privacy-by-design principles
- Key features:
  - Privacy-preserving face tracking
  - CCTV-based spatial/customer analytics
- Use cases:
  - Retail · Restaurants · Offices · Logistics · Security
- More
  - Get in touch via vitarex@vitarex.hu
  - Web: vitarex.hu/gdpr_arcfelismeres (for now 🇭🇺 only)
  - More will come here: *veridome.eu*

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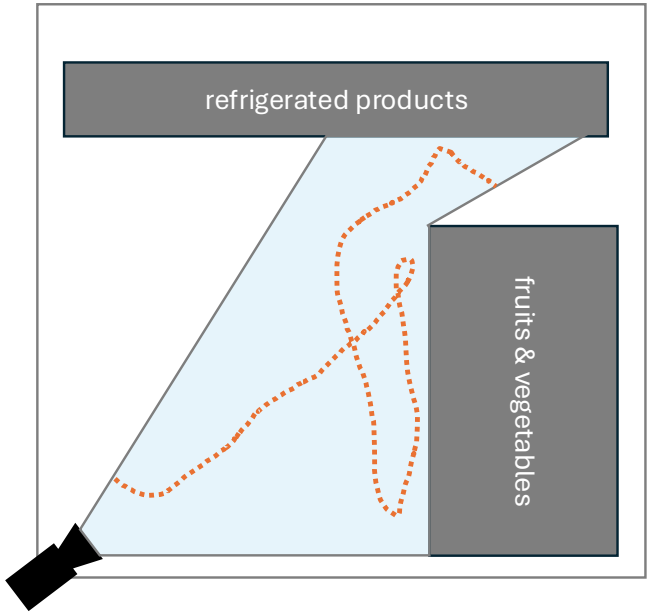
Motivation & Context

- We have data-driven insights almost in every aspects of our businesses
  - … but CCTV data remains underutilized. Analytics?



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Challenges & Goals

Challenges

- Legacy hardware
- Limited bandwidth
- Diverse use cases
- Strict regulations (GDPR, EU AI Act)

Goals

- Modular, scalable, and cost-efficient pipeline
- On-premise + cloud-native deployment
- Multi-task analytics: detection, recognition, tracking

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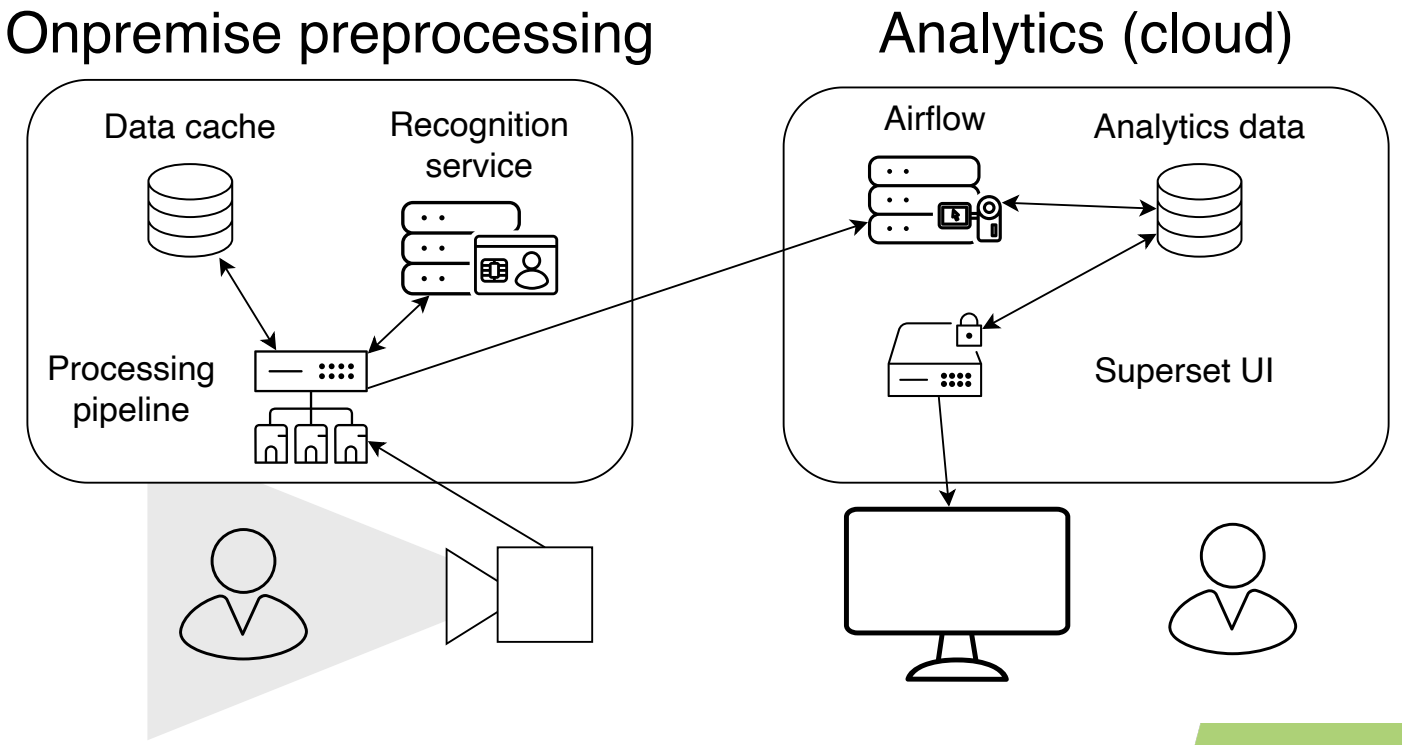
Architecture Overview

- Orchestration via Apache Airflow
- Docker/Kubernetes for scalability



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Architectural Setup

- Airflow DAGs manage analytics tasks in parallel
  - Tasks: heatmaps, tracking, counting, geofencing, face analysis
  - Video decoding via OpenCV + NVIDIA codec
  - PostgreSQL for data storage & orchestration
- ISAPI-enabled NVR integration

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Model Selection

- **Object Detection**: YOLOX preferred (fast, accurate, Apache 2.0)
- **Face Detection**: YuNet (fast, lightweight, CUDA support)
- **Face Recognition**: FaceNet (MIT license, good accuracy)
- **Tracking**: ByteTrack (robust in crowded scenes)
- **Optimization**: TensorRT for inference speed-up

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System Evaluation

- Hardware: RTX 4060 GPU, i5 CPU, 16 GB RAM
  - 1 hour Full HD video → 100 sec (GPU) vs 3.8 h (CPU)
- Scales to 72 camera streams/day with GPU
- Compared with Kerberos.io, ZoneMinder → broader functionality

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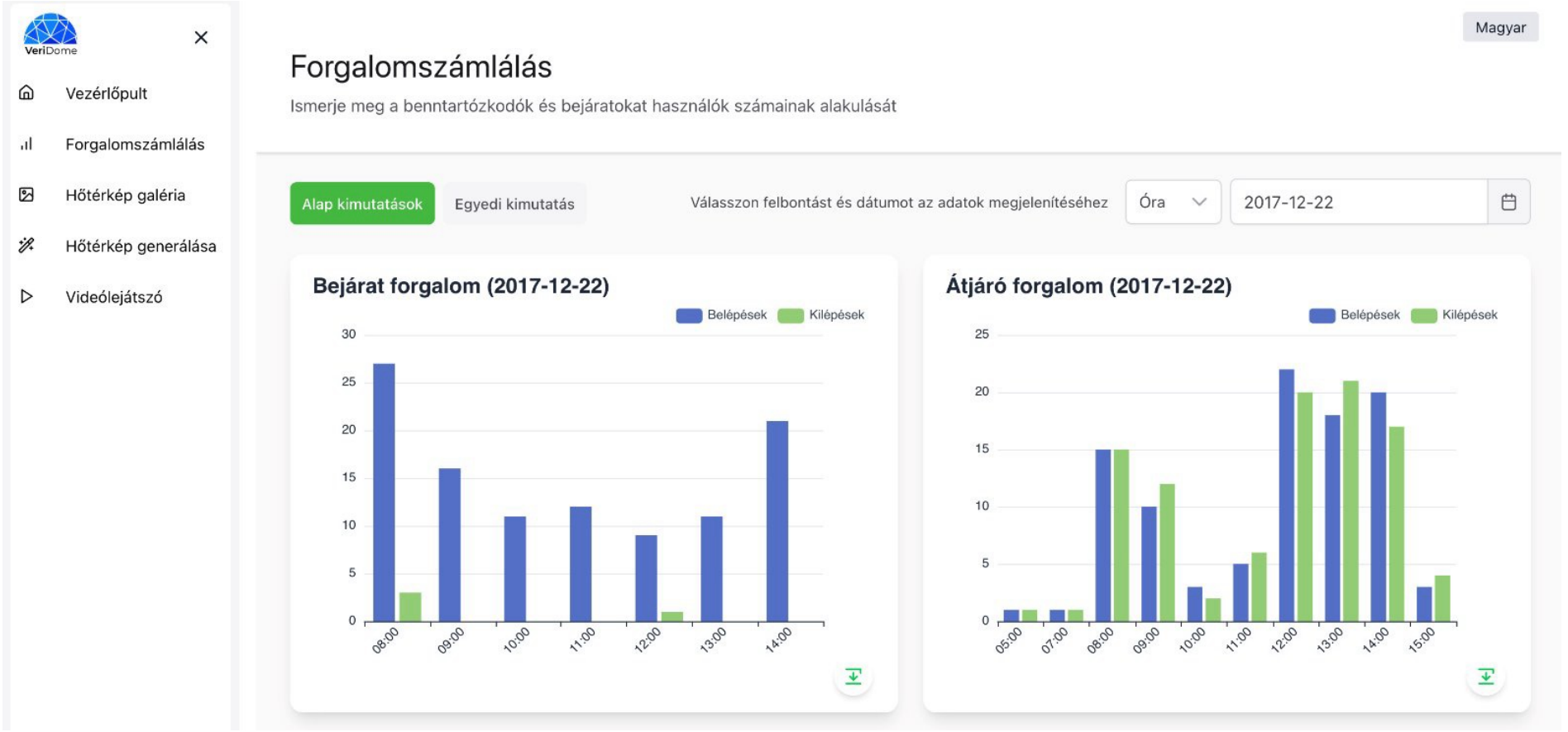
Analytics & Visualization

Dashboard (was Apache superset, now Laravel)



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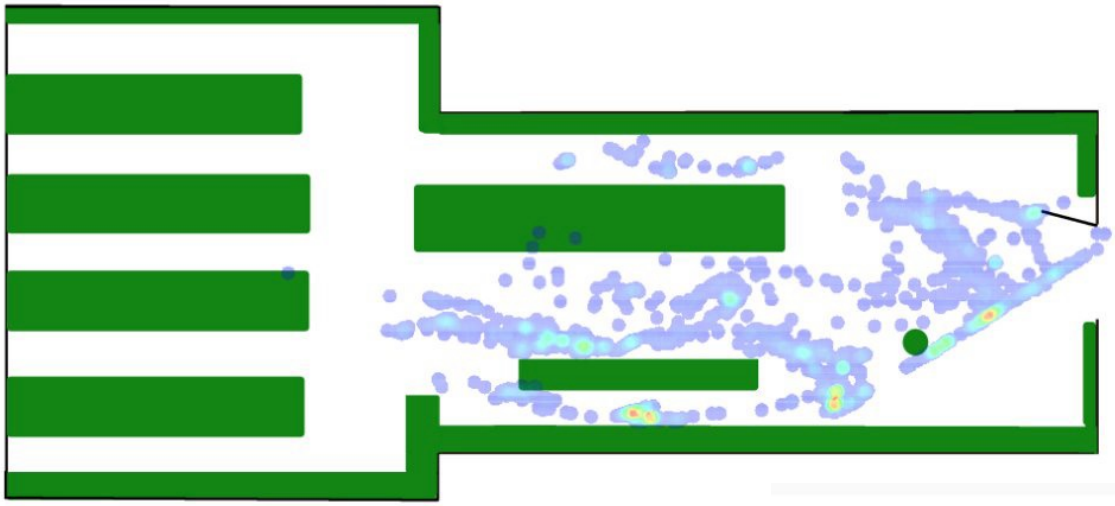
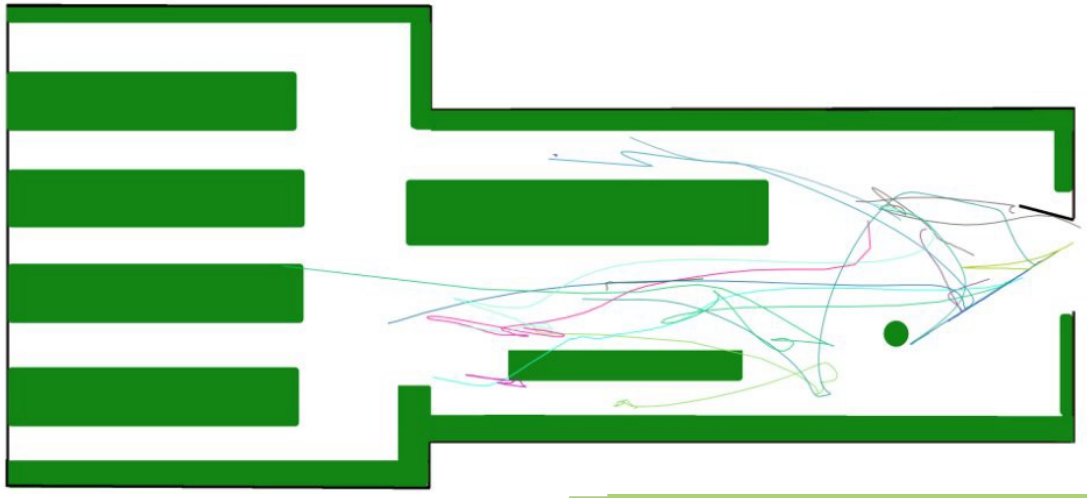
Analytics & Visualization (2)

Multi-Camera Multi-Object Tracking



Multi-camera layout mapping via homography

Constraint validation: panoptic segmentation, floor masks



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Compliance & Privacy Considerations

- Biometric data processing restrictions (GDPR & EU AI Act)
  - On-premise preprocessing ensures sensitive data control
  - Open-source models with permissive licenses preferred
  - Strong encryption and anonymization

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Future Work

- Anomaly detection (unusual patterns)
- Federated training for distributed compliance
- Wider domain applicability: retail, logistics, smart cities

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THANK YOU!
QUESTIONS?

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