VŠB TECHNICKÁ UNIVERZITA OSTRAVA | IT4INNOVATIONS NÁRODNÍ SUPERPOČÍTAČOVÉ CENTRUM

TIMOTEC

T A
Č R

Program TREND

# Multi-Camera Vision System for Operator Monitoring and Scene Understanding in Isolator

## REAL-TIME 3D MONITORING FOR ASEPTIC MANUFACTURING OF GENE THERAPY PRODUCTS

Petra Svobodová

**Isolator**
(manipulation inside isolator)

MOTIVATION

# Why is monitoring inside isolators important?

- Gene therapy manufacturing requires strict **aseptic conditions**
- Human operators introduce **contamination risk**
- Traditional monitoring is **limited**
  - manual documentation
  - standard 2D video surveillance
- Reliable tracking of actions and **object manipulation** remains challenging

**Operator**
(human factor)

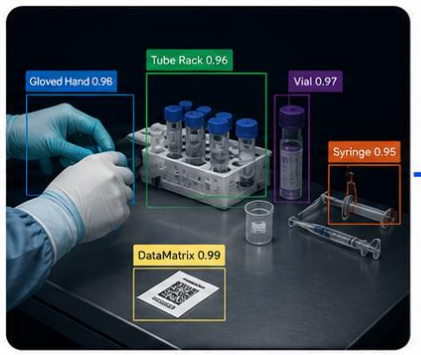
PROJECT GOAL

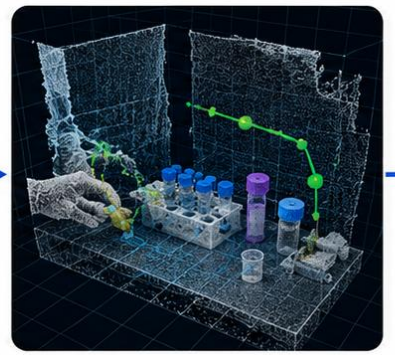
# What we aim to achieve

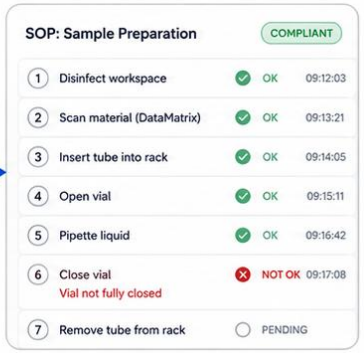
- **Propose** a **multi-camera system** inside an isolator
- **Identification** of operator
- Real-time monitoring of aseptic manufacturing, operator activity analysis, and scene understanding inside isolator
- **Reading of 2D codes** (QR code, DataMatrix)
- Detection of **laboratory equipment**
- **Hand pose estimation**

---

1 Operator → 2 Cameras → 3 AI Processing → 4 3D Reconstruction → 5 Workflow Validation





MULTI-CAMERA SETUP

# Selected camera system

Stereo vision cameras by Stereolabs (ZED X Series)

ZED X One

Stereo ZED X One
on compact base


ZED X Mini 4 mm
(stereo)


ZED X Mini 2.2 mm
(stereo)

## Selected Camera Platform

**Stereolabs ZED X Series**

- High-performance stereo vision cameras
- Designed for real-time AI detection
- Integration with NVIDIA Jetson
- Suitable for multi-camera synchronization

## Evaluated Camera Models

- ZED X One
- ZED X Mini 4 mm
- ZED X Mini 2.2 mm

## Key Requirements

- Real-time processing capability
- Accurate depth estimation
- Wide field of view and full workspace coverage

MULTI-CAMERA SETUP

# Camera placement

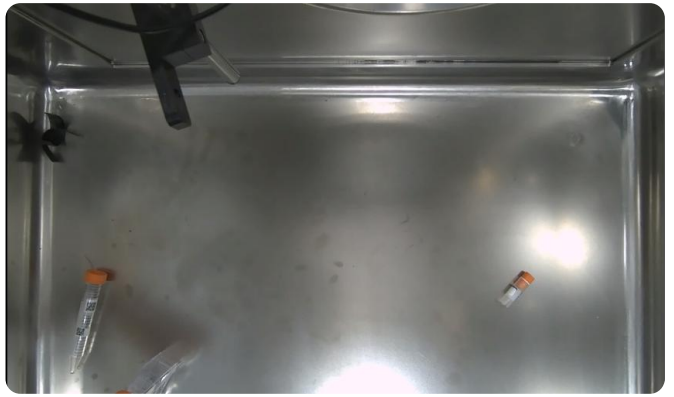
Three synchronized viewpoints inside isolator


## 1 Top View

- ZED X Mini 2.2 mm
- Wide overview of the entire workspace

## 2 Front View

- ZED X Mini 4 mm
- Main view of the operator area and working zone



## 3 Side View

- ZED X One
- Side perspective focused on manipulation area and tools

OPERATOR IDENTIFICATION

# Contactless identification in sterile environments

## PROBLEM

**Standard biometrics cannot be used:**

- protective suit
- mask
- gloves

## SOLUTION

- Bluetooth Low Energy (BLE)

## FUNCTIONALITY

- Contactless worker identification
- Presence tracking
- Approximate localization


## BLUE LITE ID BEACON


- Lightweight and wearable
- Unique ID for each operator
- Battery life (>1 year)

## CASSIA X2000 GATEWAY


- Recieves BLE signals from beacons
- High accuracy and reliability
- PoE powered

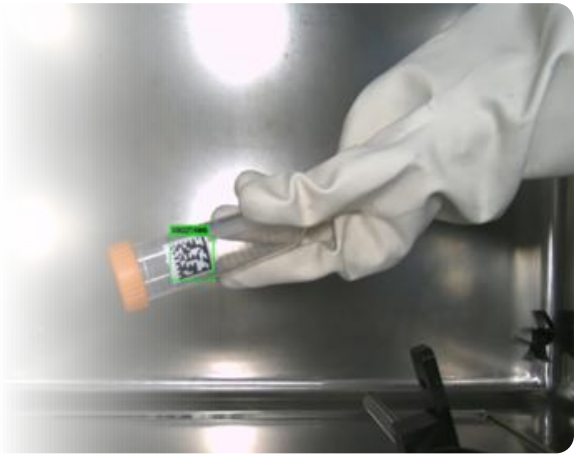
CODE IDENTIFICATION

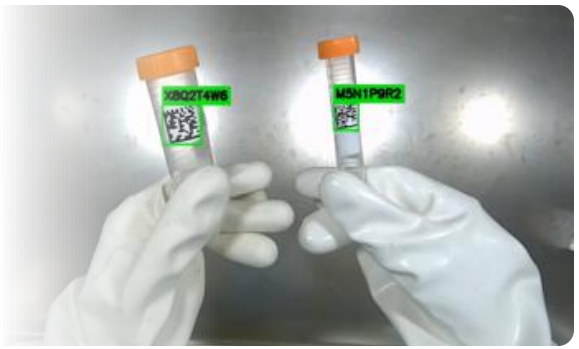
# Detection and decoding of 2D codes

QR code

DataMatrix

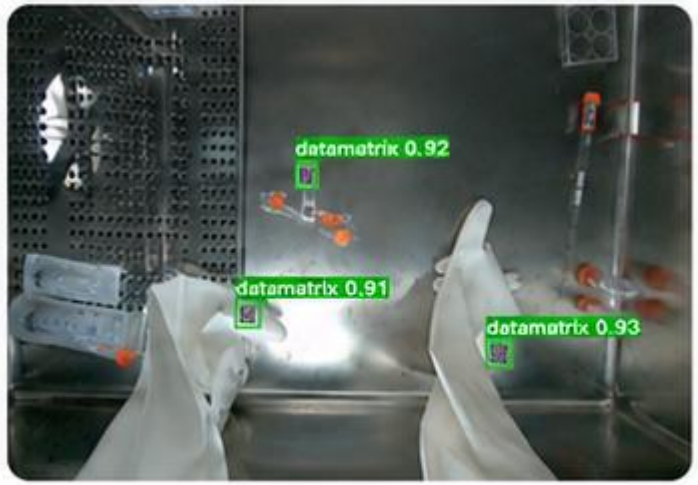
- How reliably can each camera detect and decode?
- What is the optimal printed code size?
- How does surface curvature affect decoding?






## Detection & decoding pipeline

### Detection by YOLO
Locate 2D codes in the image




### Crop / ROI extraction
Extract detected regions

### Decoding by ZXing
Read and validate code

**ID: M20274MG**
Type: DataMatrix
Status: OK

**ID: MSN1P0R2**
Type: DataMatrix
Status: OK

**ID: S00007H0**
Type: DataMatrix
Status: OK

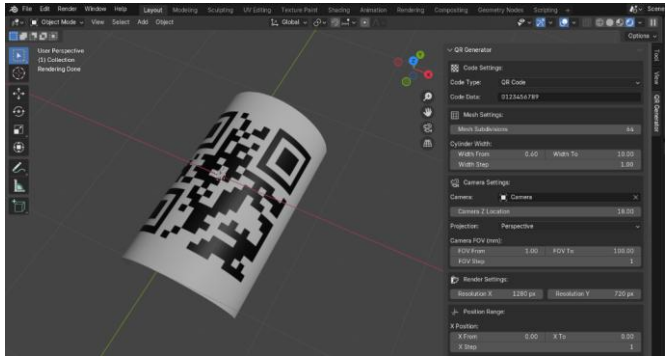
CODE IDENTIFICATION

# Experimental evaluation of 2D code reading

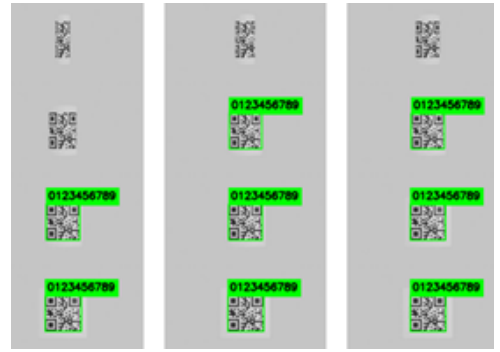
## Experiment 1
### Influence of surface curvature

Evaluate how curvature of the surface affect detection and decoding performance.

3D model of curved surface (Blender simulation)



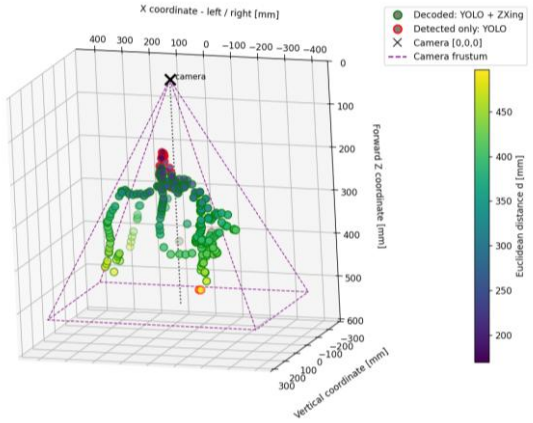
Detection examples at different curvatures



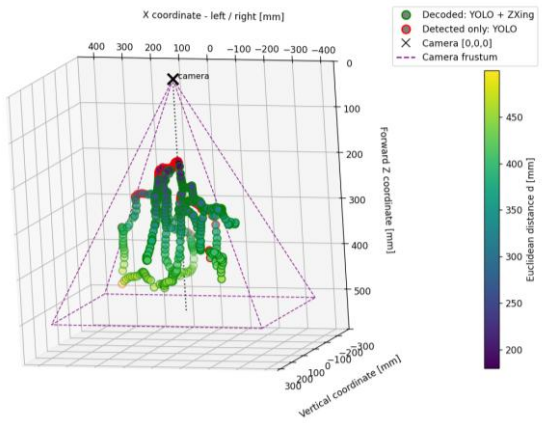

## Experiment 2
### Influence of code size and camera distance

Determine the maximum distance at which different DataMatrix code sizes can be reliably detected and decoded.

Code size: 8 mm




Code size: 9 mm



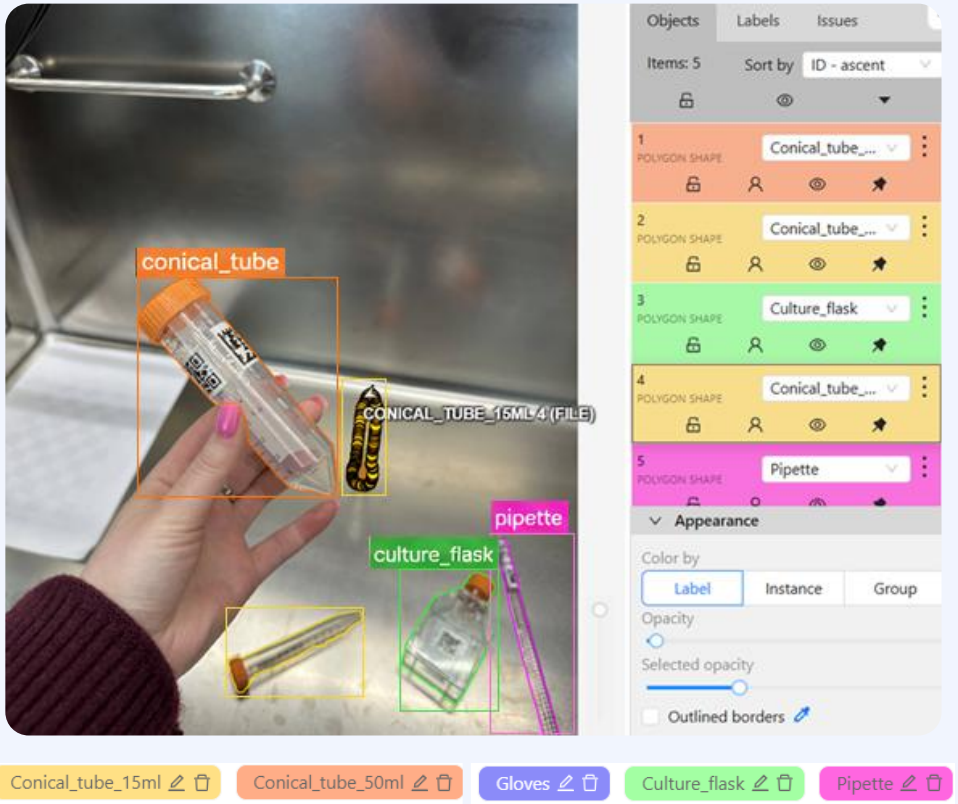
OBJECT DETECTION

# Detection of hands & lab equipment

AI-based detection and segmentation inside isolator.

## Dataset annotation (CVAT)

Manual annotation of lab equipment and hands

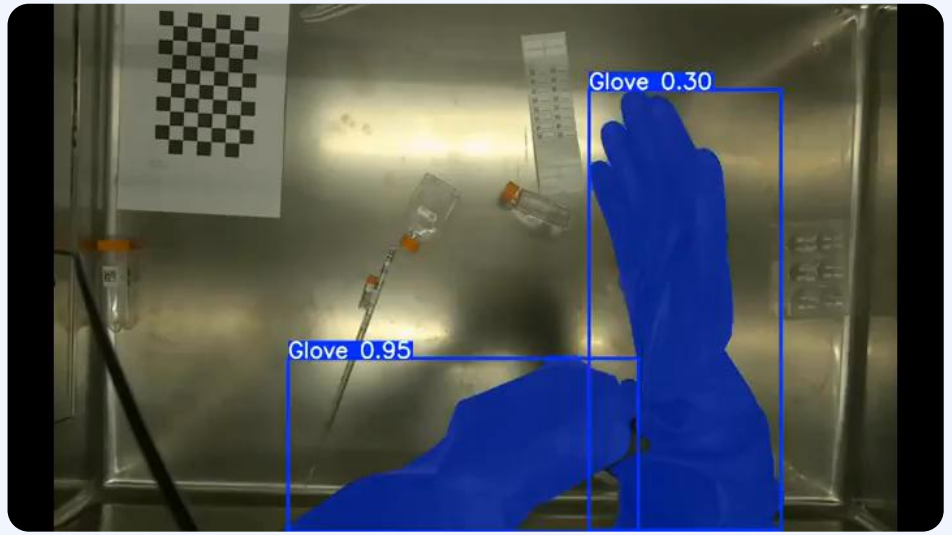



## Workflow

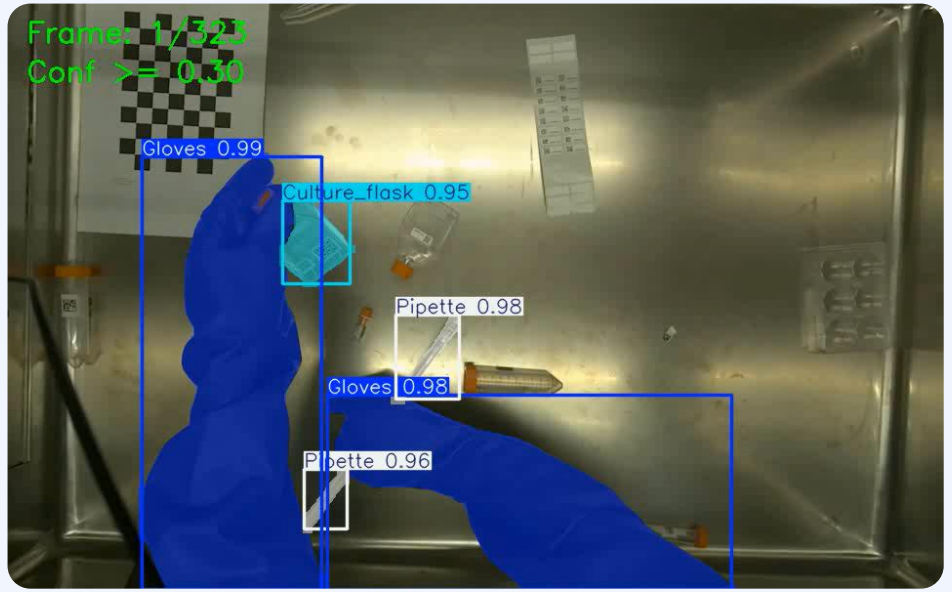
- Dataset annotation
- Model training
- Real-time detection
- Scene under-standing

## Real-time detection and segmentation

### 1. Hand segmentation




### 2. Object detection



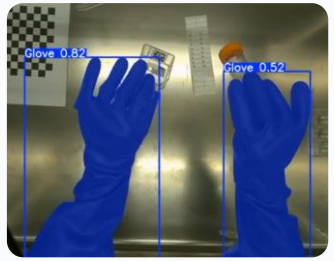
FUTURE WORK

# Conclusion & future directions

## Current tasks

### Object detection

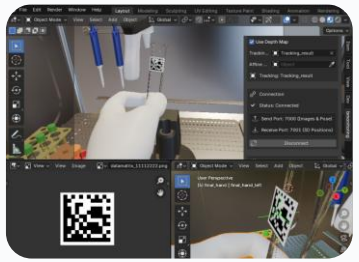

### Hand segmentation




### 2D code reading

### Operator identification

### 3D scene reconstruction



## Future tasks

- 3D hand pose estimation
- Workflow definition
- Action recognition
- Workflow integration
- Action validation

Program TREND

VŠB TECHNICKÁ UNIVERZITA OSTRAVA | IT4INNOVATIONS NÁRODNÍ SUPERPOČÍTAČOVÉ CENTRUM

TIMOTEC

# Thank you for your attention


Ing. Petra Svobodová, Ph.D.
Ing. Petr Strakoš, Ph.D.
Ing. Milan Jaroš, Ph.D.
Ing. Nikola Cudráková
Bc. David Kolář

petra.svobodova@vsb.cz

IT4Innovations