Digital Twin Calibration Using An Industrial Vision System

Nithish SALLUSTRE

Sébastien HENRY   Vincent CHEUTET

Laboratoire Décision et Information Pour les Systèmes de Production

INSA Institut National des Sciences Appliquées Lyon · Université Claude Bernard Lyon 1 · Université Lumière Lyon 2 · Université Jean Monnet Saint-Étienne · Université de Lyon

Laboratoire
Décision et Information
Pour les Systèmes de Production

Outline

- Research Context
- Research Questions
  - Introduction
  - Methodology
  - Result
- Use Case
- Conclusion
- Future Research

Research Context

Current Strategy

Observable States:
Utilizing states observable via the control system.

Industrial IoT Augmentation:
Enhancing observation through extensive instrumentation, leading to cost and reliability issues

Problem Statement

Calibration

This project aims to solve the issue of updating the digital twin to ensure it accurately reflects its physical counterpart.

Proposed Strategy

The proposed strategy aims to leverage industrial vision systems to enhance the calibration of Digital Twins with their physical counterparts.

Benefits

- **Cost-Effective**

  Reduces the need for extensive physical instrumentation, thereby lowering overall costs and complexity.

- **Improved Accuracy**

  High-fidelity visual data enhances the accuracy of the Digital Twin, ensuring it reflects the physical system precisely.

Research Questions

- Can industrial vision systems be utilized to monitor the behaviour of physical System (in context of Digital Twin)?

  - How to find the behavioural pattern for the system using industrial vision system data?

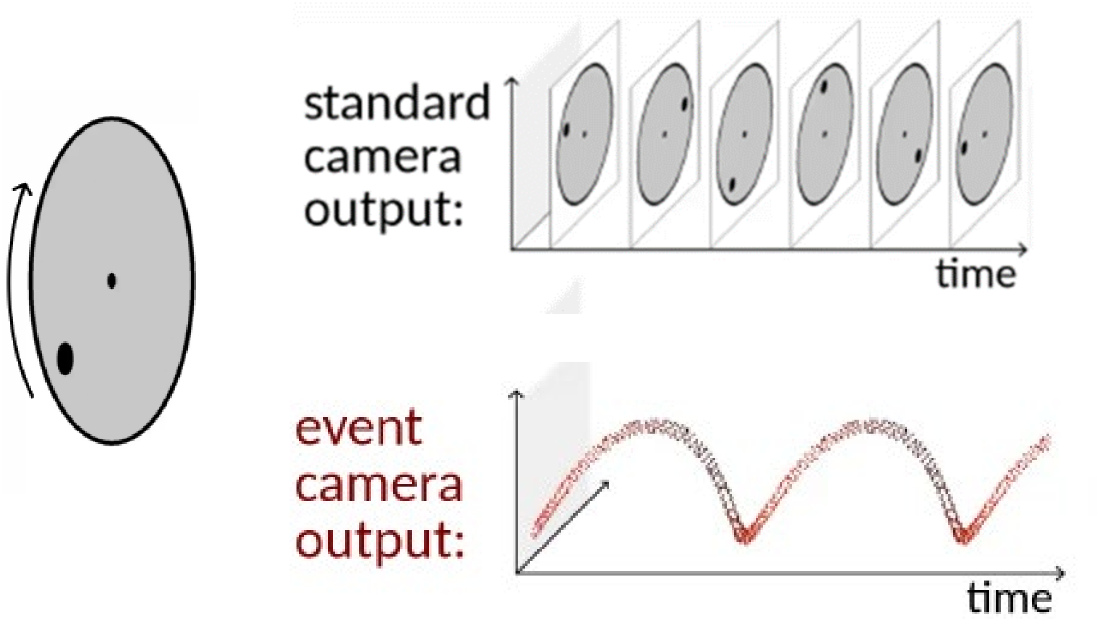
  - How to find the signature behavioural pattern for the states of physical system that can be used for model calibration?

Event-Based Vision System

Due to the inherent drawbacks of classical frame-based vision systems, we propose the adoption of **event-based vision systems** for our physical system.

- **High Temporal Resolution**
- **Reduced Data Redundancy**

These advantages make event-based vision systems ideal for high-speed, dynamic environments where real-time data processing is crucial.



Neuromorphic Vision System

Neuromorphic vision systems, inspired by the human visual system, offer significant advantages over other event-based technologies, making them the optimal choice for our applications.

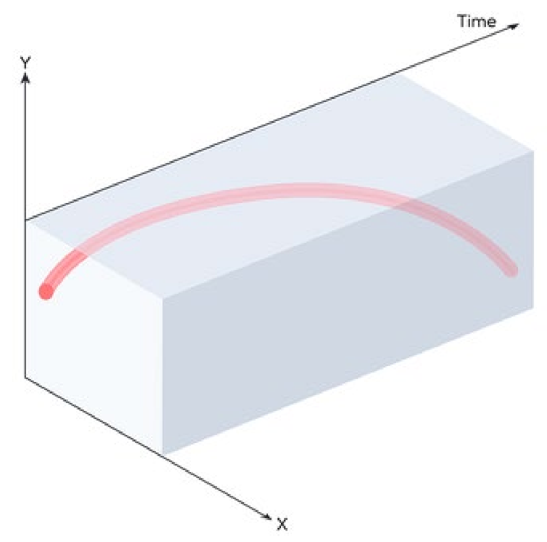
High Temporal Resolution

- Neuromorphic vision systems can operate with **microsecond precision.** This capability is crucial for applications that require rapid detection and response to dynamic changes

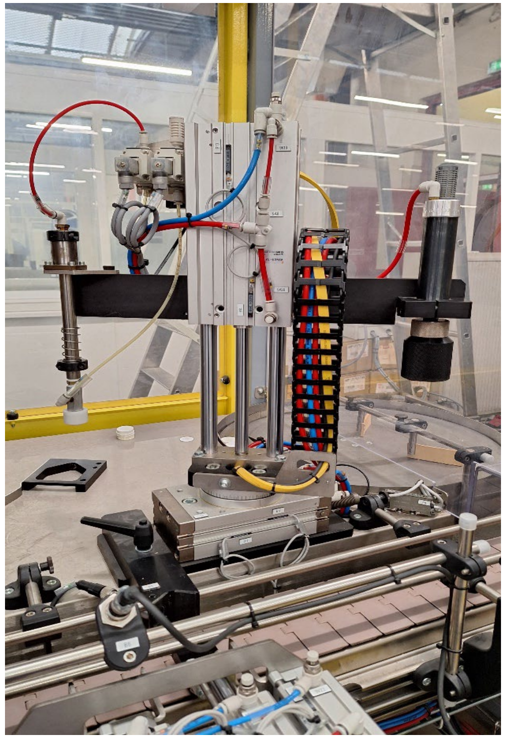
Low Latency

- These systems process events as they occur, resulting in near-instantaneous data output.

EVENT-BASED VISION

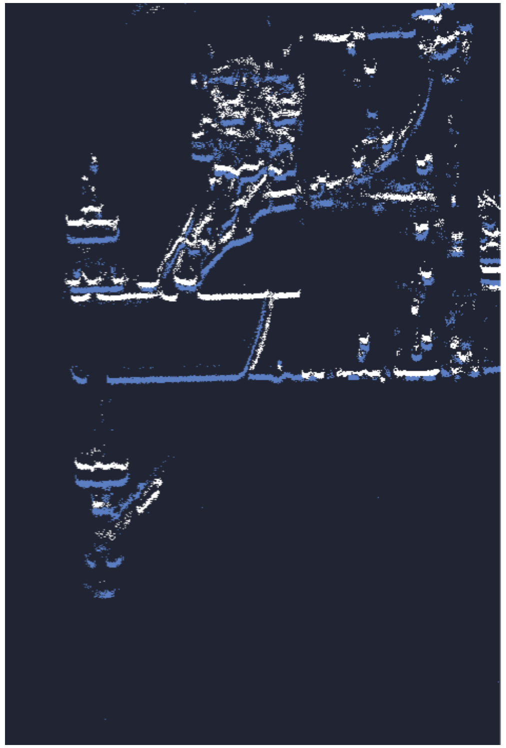


Use Case



Physical System

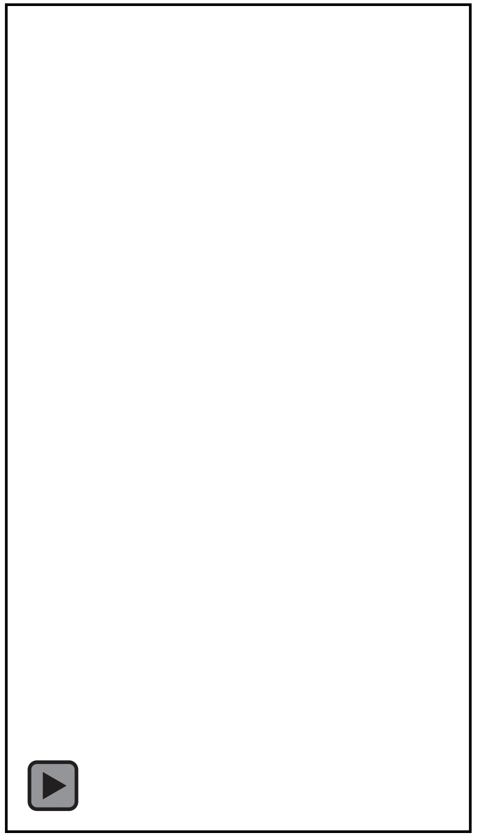
Vision System (Static)



Vision System
(In Movement)

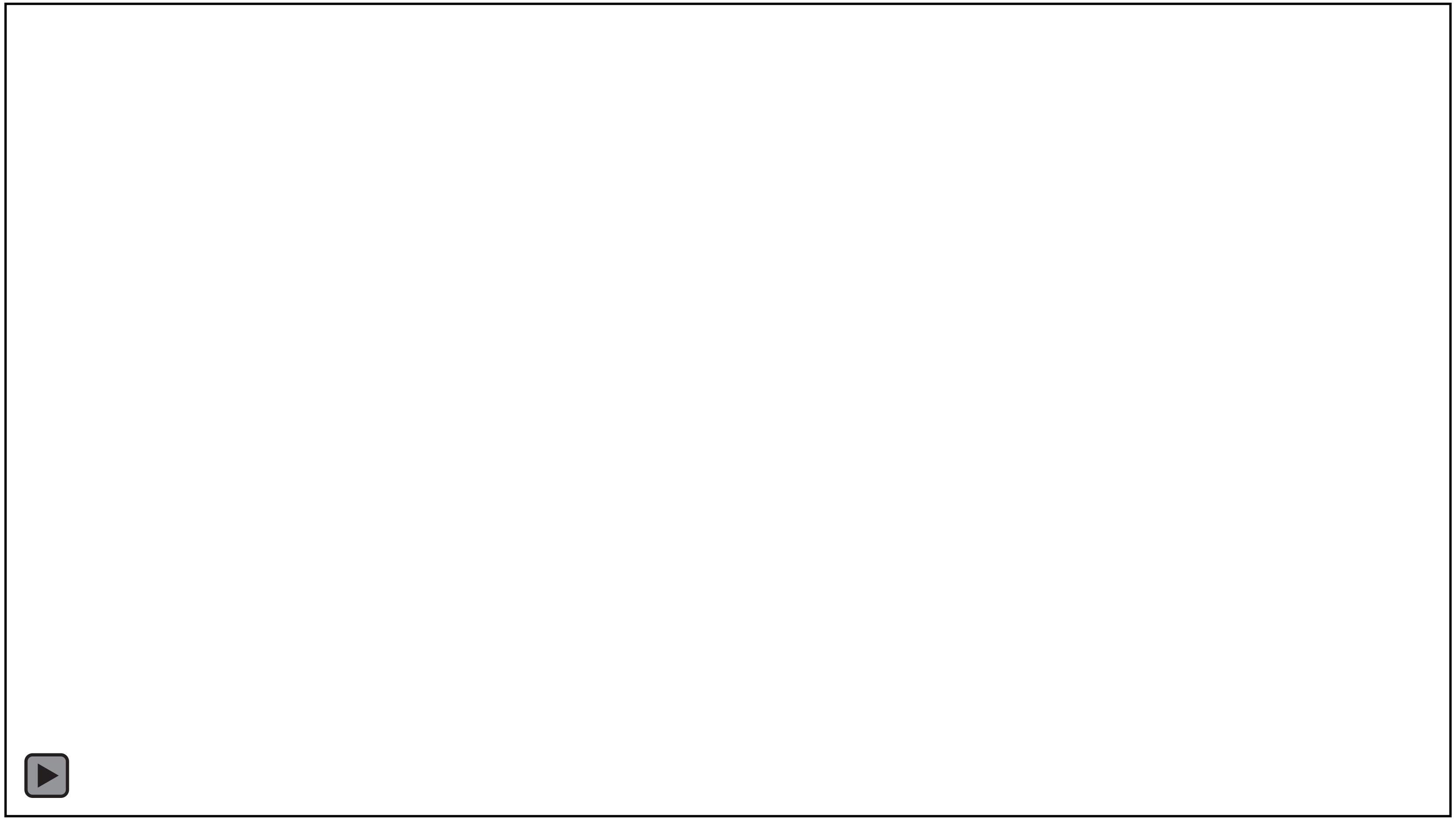
Use Case

Physical System



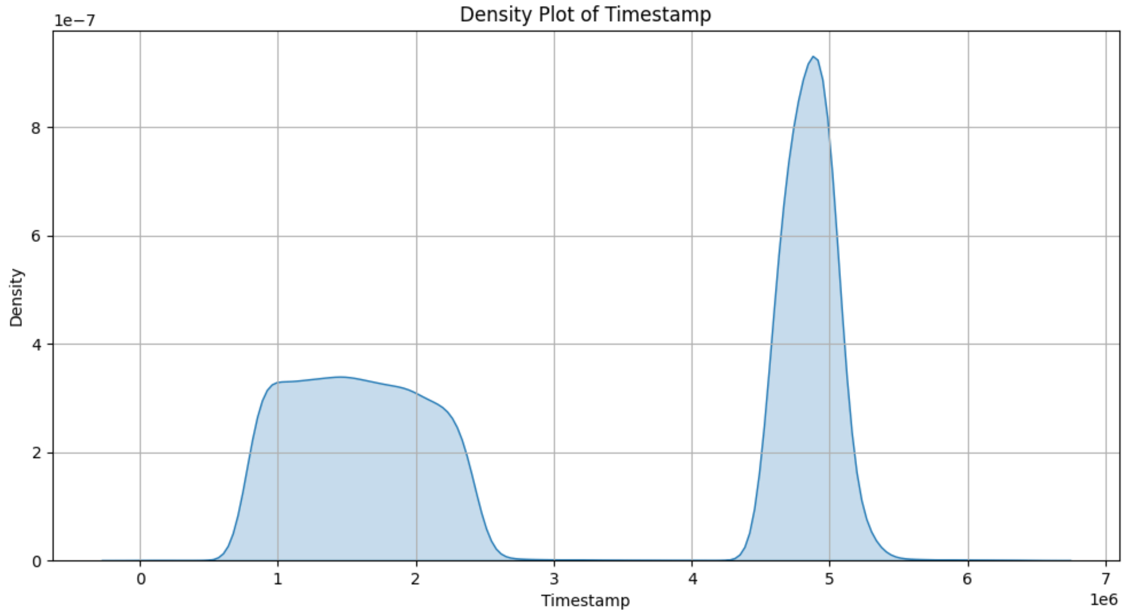
Use Case

Neuromorphic Vision System



Research Question 1

How to find the behavioural pattern for the system using industrial vision system data?



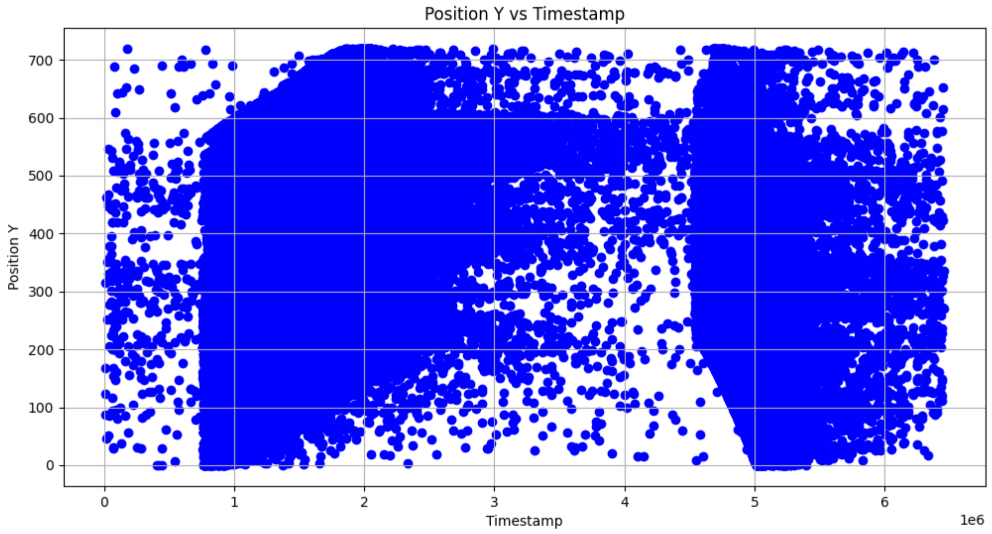
Introduction

Identifying behavioural patterns is essential for ensuring that the digital twin accurately reflects the physical system's state and behaviour.

Methodology

- Analysed spatiotemporal data to identify recurring patterns and states.

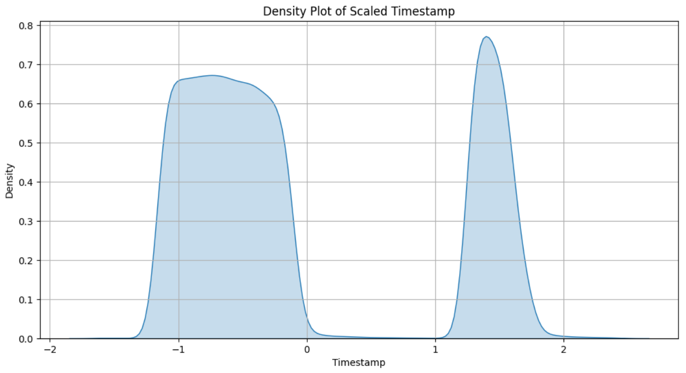
- Used machine learning techniques to classify and predict these patterns.



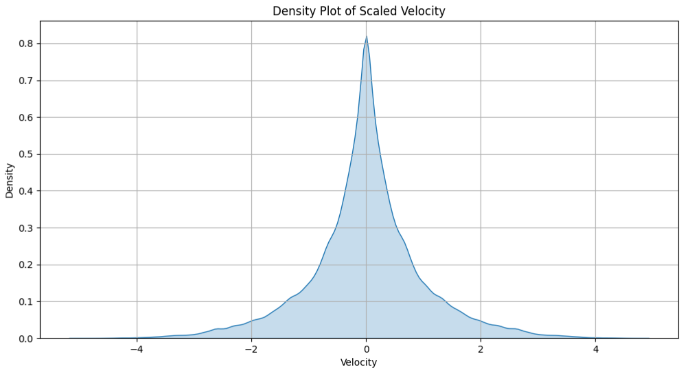
Analysis of Vision Data

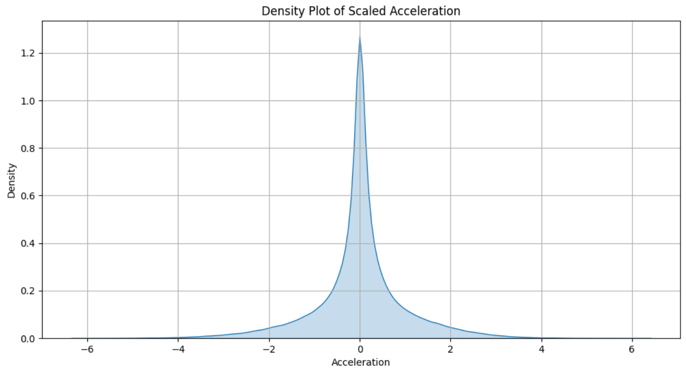
Steps involved in analysing the event-based vision data:

- **Step 1:** Feature Engineering
  - Velocity
  - Acceleration



- **Step 2:** Standardization

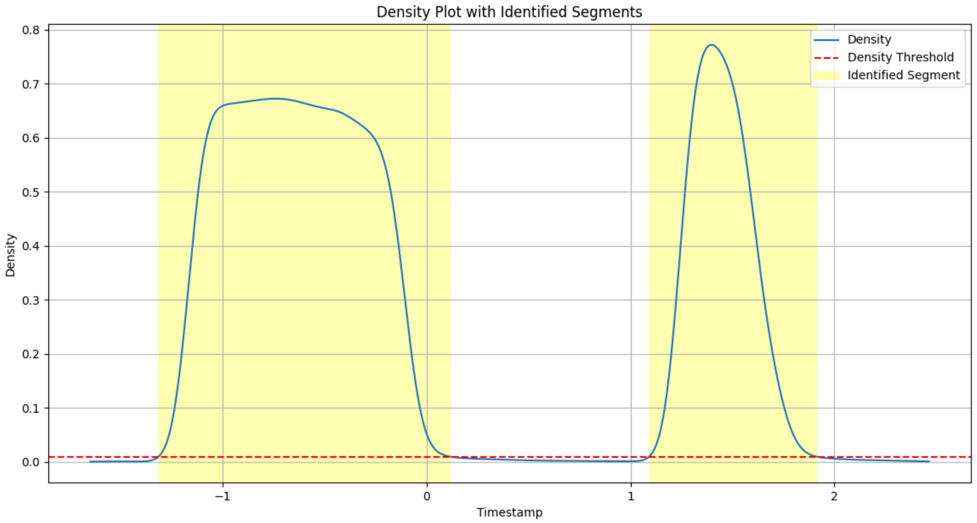




Analysis of Vision Data

Steps involved in analysing the event-based vision data:

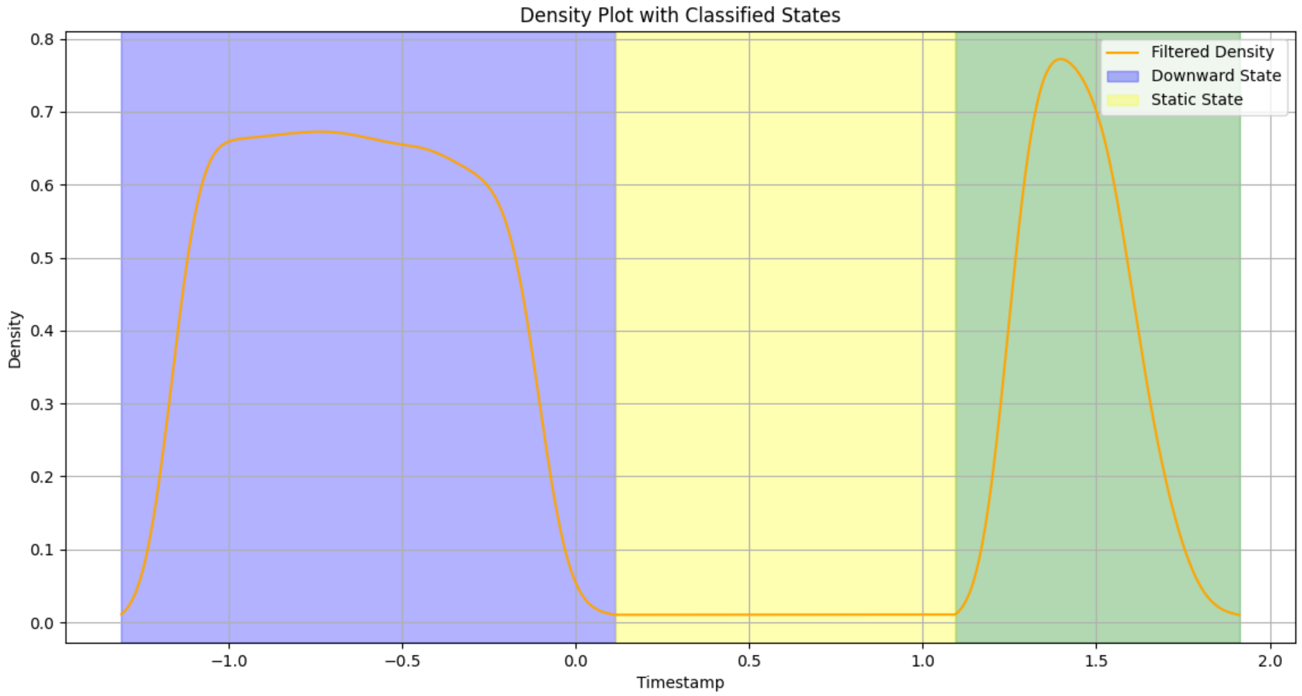
- **Step 3:** Segmentation based on states
  - Manual Segmentation
  - Automatic Segmentation using threshold Segmentation



Analysis of Vision Data

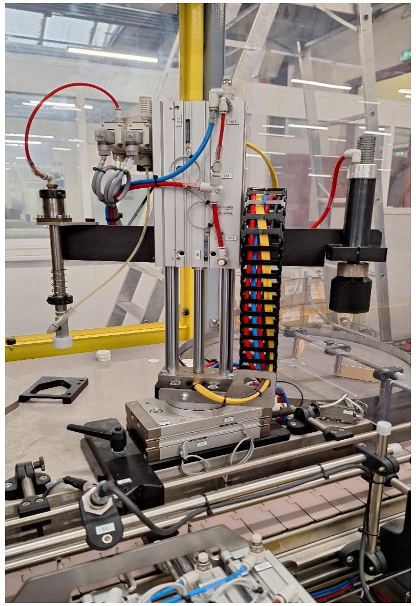
Steps involved in analysing the event-based vision data:

- **Step 4:** Segment Classification based on states

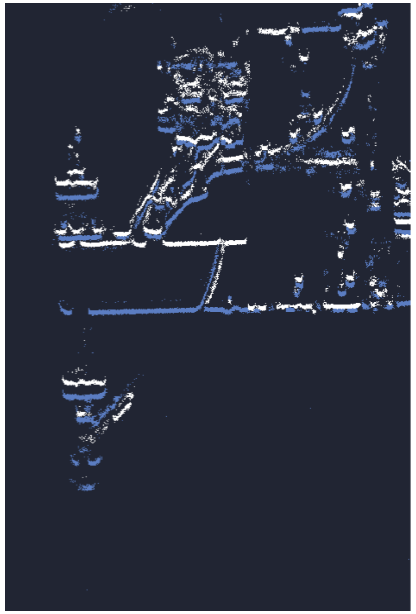


Result

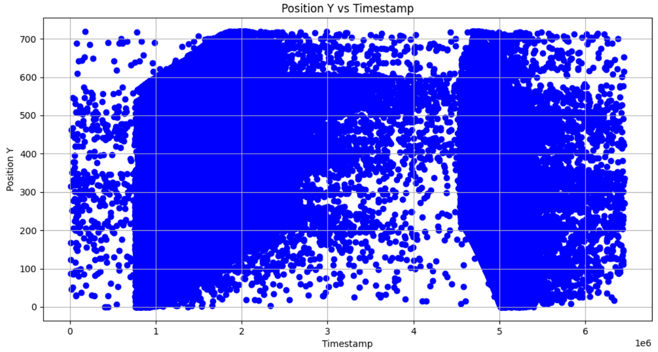
- Discovered patterns in the cylinder movements that can be used as benchmarks.
- Developed models that predict the physical system's behaviour based on these patterns.

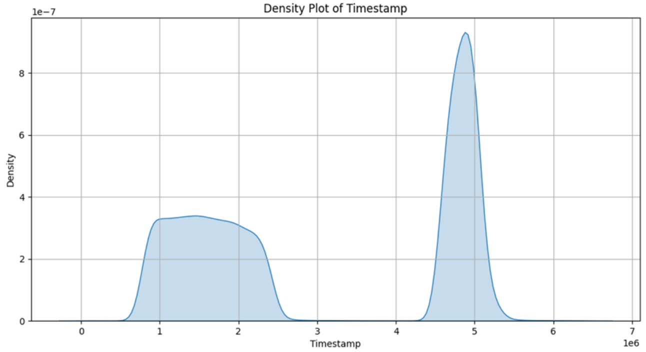


Physical System

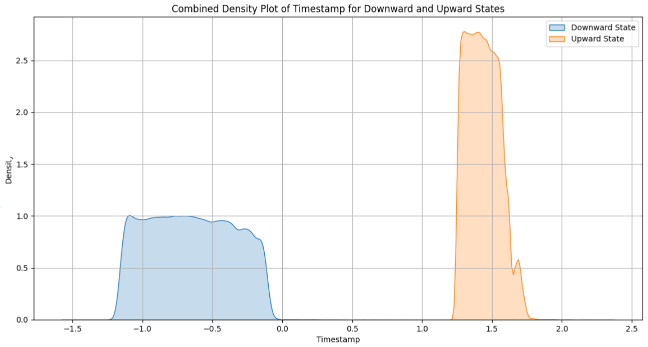


Vision System





Raw Data



Behavioural Pattern

Research Question 2

How to find the signature behavioural pattern for the states of physical system that can be used for model calibration?

Introduction:

- Identifying signature behavioural patterns is crucial for creating an accurate and reliable model of the physical system.

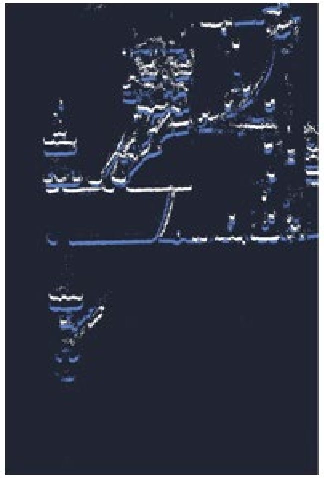
Methodology:

- Conducted detailed analysis of the dataset to extract significant patterns.
- Used statistical and machine learning methods to identify and validate these patterns.

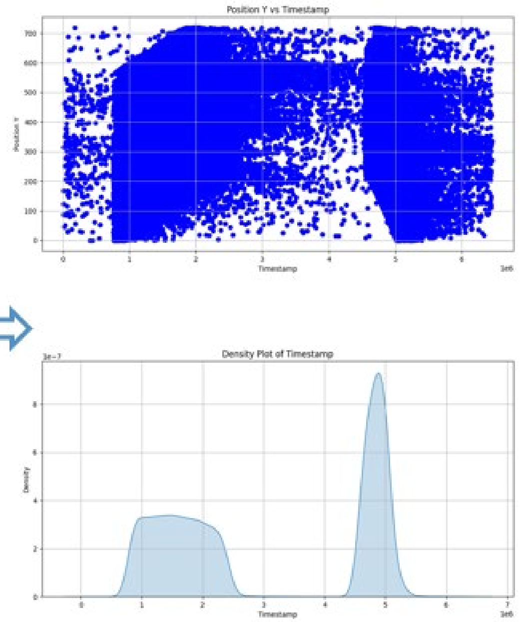
Result

- Identified specific patterns that occur consistently under certain conditions.
- Determined the most significant patterns that serve as signatures for different states of the system.

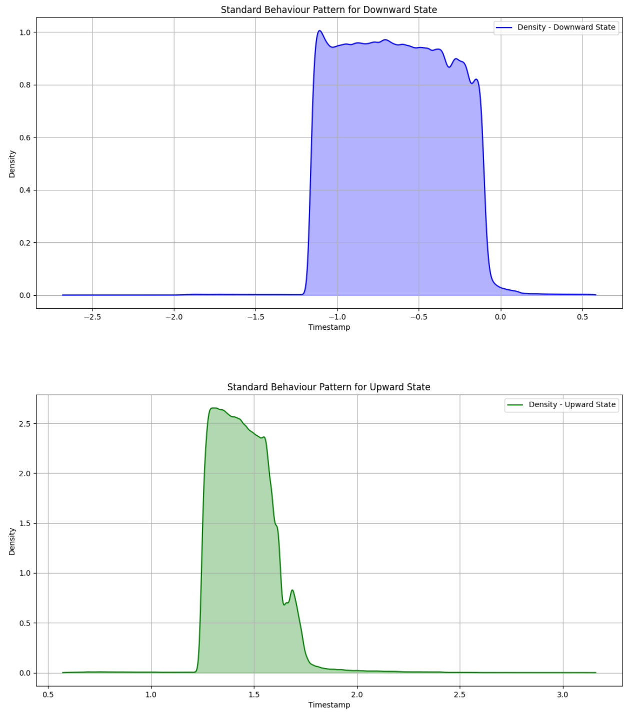
Physical System



Vision System



Raw Data



Signature Behavioural Pattern

Conclusion

- The event-based vision system was successfully utilized to monitor and analyse the behaviour of the **Vertical Pneumatic Cylinder System**. By capturing detailed **spatiotemporal data**, it revealed key dynamic patterns essential for understanding the **system's operation**.

- The analysis identified and examined behavioural patterns for the downward, static, and upward states. Furthermore, **signature behavioural patterns** were determined, serving as critical benchmarks for model calibration, enhancing the **precision and reliability of the digital twin**.

Laboratoire
Décision et Information
Pour les Systèmes de Production

Future Research

- ## Combining Systems:

Develop methods to seamlessly integrate the physical system with the industrial vision system for cohesive operation and enhanced functionality.

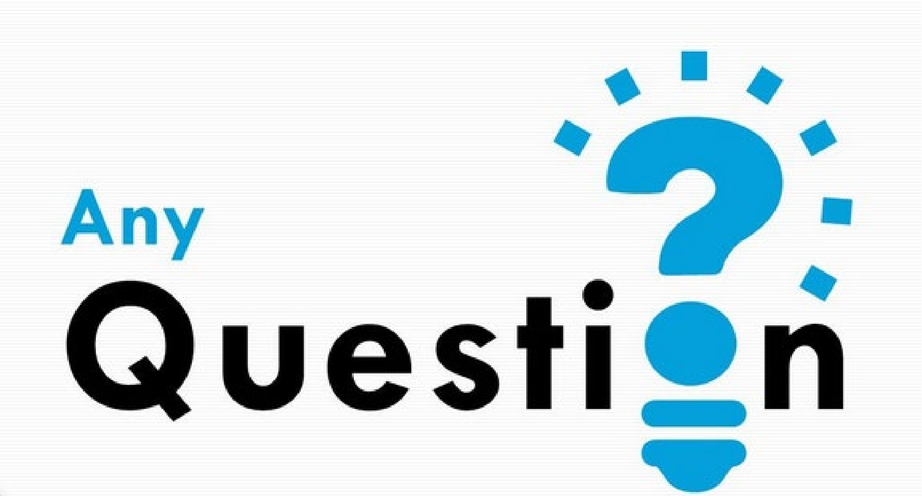
- ## Data Synchronization:

Develop a framework to address time desynchronization between the Programmable Logic Controller (PLC) and the industrial vision system, ensuring accurate and real-time data exchange and processing.

Thank You!

PERTHUS SALLUSTRE Nithish Sallustre

nithish-sallustre.perthus-sallustre@insa-lyon.fr



Digital Twin Calibration Using An Industrial Vision System

Laboratoire
Décision et Information
Pour les Systèmes de Production

Nithish SALLUSTRE

Sébastien HENRY Vincent CHEUTET

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON
Université Claude Bernard Lyon 1
université lumière lyon 2
UNIVERSITÉ JEAN MONNET SAINT-ÉTIENNE
UNIVERSITÉ DE LYON