PES UNIVERSITY

Capstone Project Phase-1

Project Title: Using Digital Twinning to enhance Human-Robot Collaboration with augmented reality

Project ID: PW23_AKP_02

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Outline

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Problem Statement

To increase the effectiveness and efficiency of robotic systems, an AR/VR tool for industrial robotics must be created. Limitations in real-time monitoring, control, predictive remote maintenance, optimization, and programming of processes result from the absence of such a tool. Additionally hampered are virtual prototyping and robotic system training. A digital counterpart of the robot must be built and replicated on an AR/VR interface to overcome these constraints.
The goal is to create an AR/VR tool that will improve industrial robotics through real-time monitoring and control, predictive remote maintenance, operation optimization and programming, and virtual prototyping and training of robotic systems.

Abstract & Scope

Developing an AR/VR tool which can be used to enhance industrial robotics.
A digital twin of the robot is made and simulated to run on an AR/VR interface.

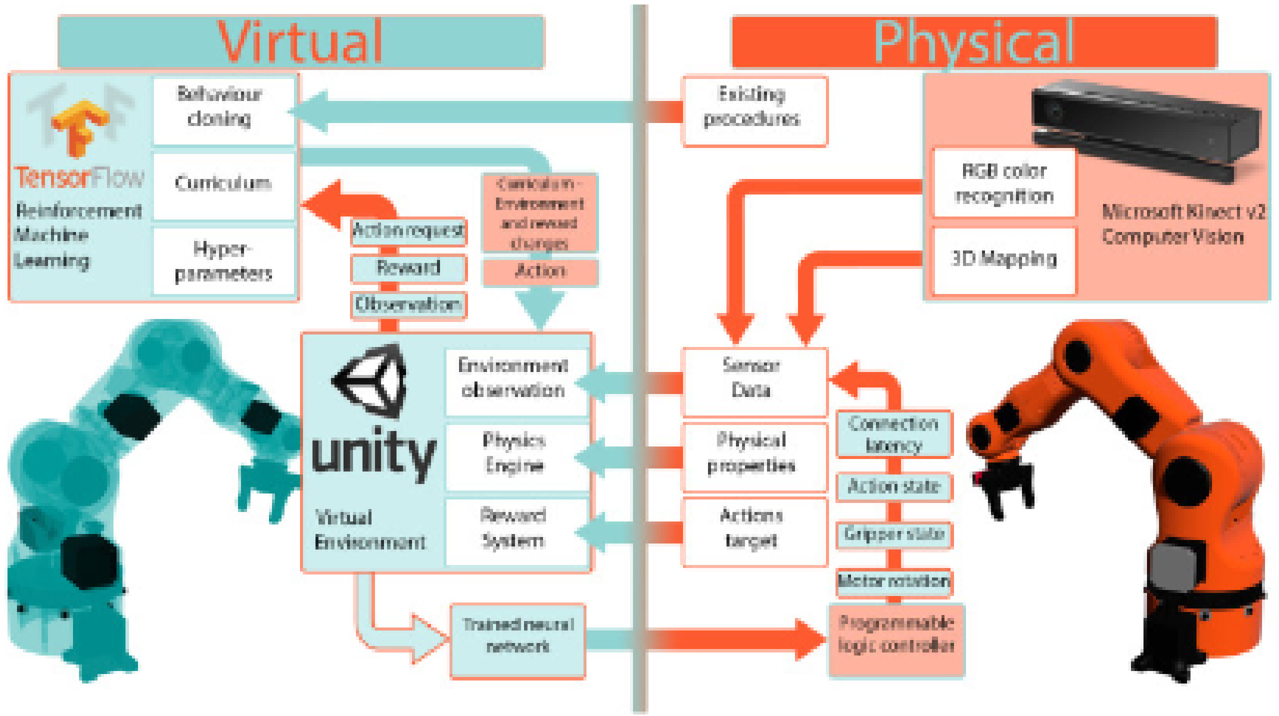
Scope:

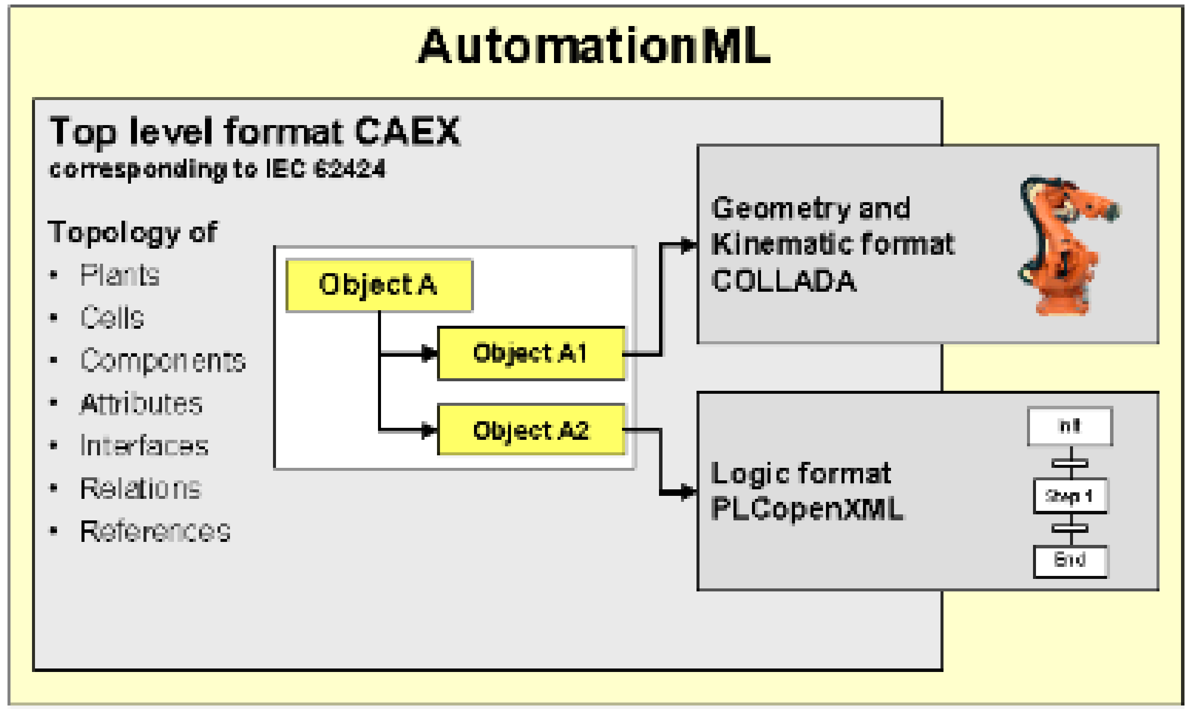
- Real-time monitoring and control of robotic systems
- Predictive Remote maintenance, optimization and programming of operations
- Virtual prototyping and training of robotic systems

Literature Survey

Digital Twin Data Modeling with AutomationML and a Communication Methodology for Data Exchange. (Communication)

- Paper proposes use of AutomationML for data modeling and communication methodologies for data exchange which can facilitate the creation and management of digital twin systems. Further research is needed to explore the effectiveness of these approaches in real-world applications and to address potential challenges such as scalability and interoperability.

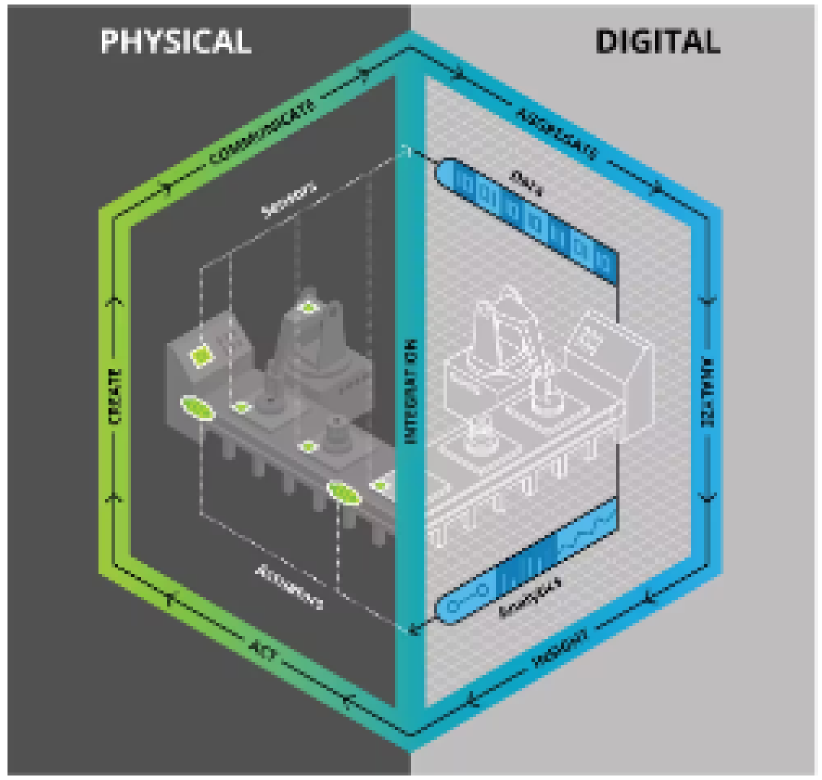




Literature Survey

The Digital Twin: Realizing the Cyber-Physical Production System for Industry 4.0. (Digitalizing)

- The article discusses the importance of digital twins in Industry 4.0, where cyber-physical systems and the Internet of Things are increasingly prevalent. Digital twins can be used to simulate and test physical systems before they are built, allowing for more efficient and cost-effective development processes. They can also be used to monitor and optimize the performance of existing systems in real-time.



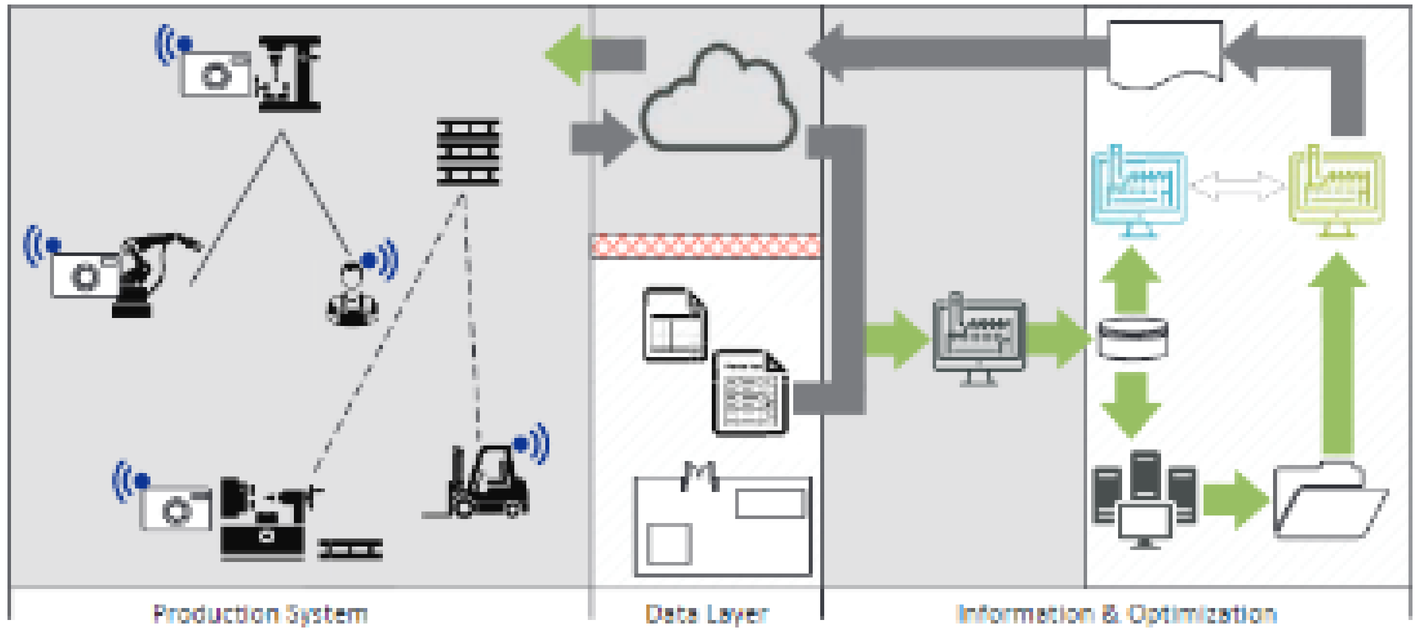
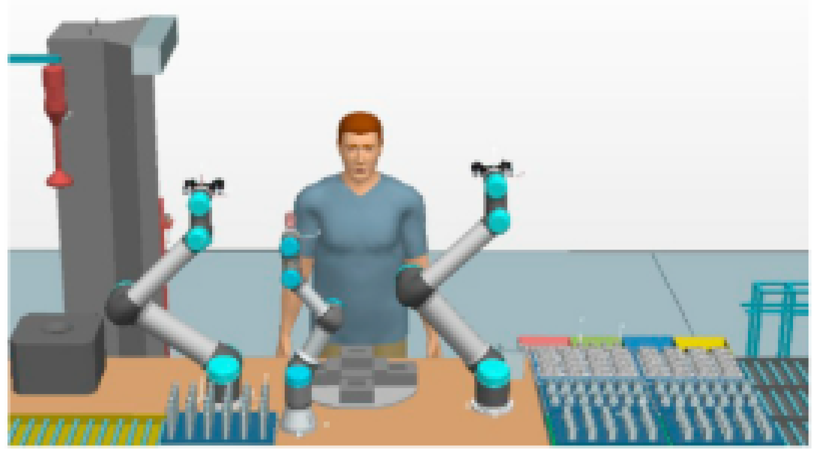


Fig. 3: Concept for the realization of the CPPS through the Digital Twin in SME

Literature Survey

Digital twins of human robot collaboration in a production setting (Application)

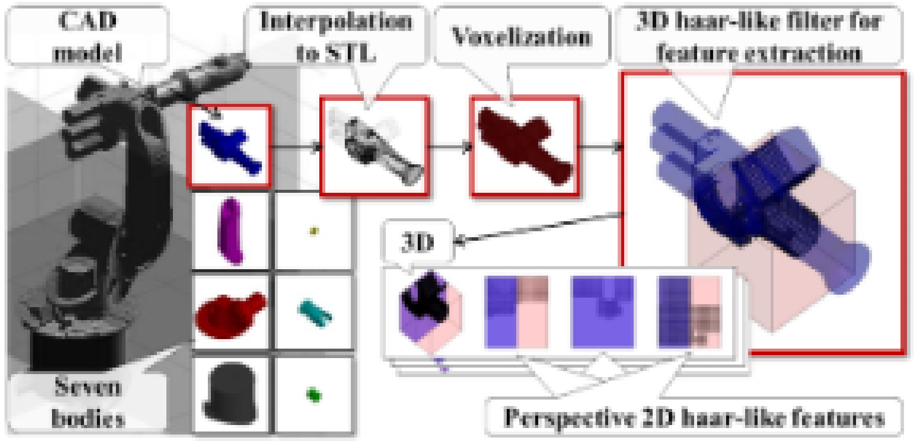
- The methodology for creating the digital twin involves collecting data from sensors and other sources, and using this data to create a virtual representation of the collaboration process. The digital twin is then used to simulate different scenarios and optimize the collaboration process for efficiency and safety.
- The paper concludes that digital twinning has the potential to significantly improve human-robot collaboration in production environments by enabling real-time monitoring and optimization of the collaboration process.
- However, the author notes that there are still challenges that need to be addressed, such as data privacy and security concerns, in order to fully realize the potential of digital twinning in this context.

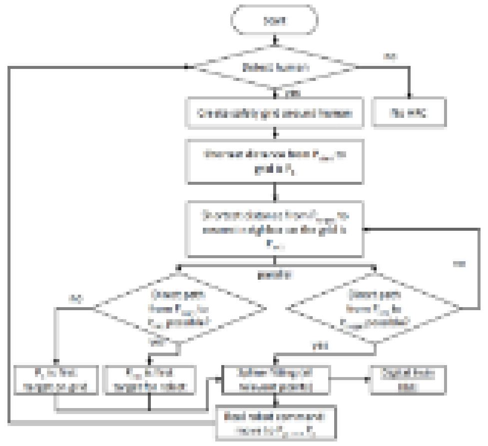


Literature Survey

A Machine Learning-Enhanced Digital Twin Approach for Human-Robot-Collaboration (Machine Learning)

- The proposed approach is applied to a case study involving a human-robot collaboration system in a manufacturing environment. The authors demonstrate that their machine learning-enhanced digital twin approach can improve the efficiency and safety of the system by optimizing the robotic movements based on the worker's behavior and position.
- The study shows promising results, suggesting that machine learning-enhanced digital twin technology has the potential to enhance the performance of human-robot collaboration systems in real-world scenarios. The authors conclude that their approach could be extended to other domains beyond manufacturing, including healthcare, agriculture, and construction.





Literature Survey

Digital Twin in Industry: State-of-the-Art

- SMART manufacturing is one of the strategic priorities shared by all the major manufacturing initiatives such as Industry 4.0 and Industrial Internet.
- DT in areas such as product design, production planning, assembly, man-machine interaction is increasing. It can trigger simulation waves which are specific to device based special tools, or a generic device based on standard tools or even the multilevel multidisciplinary simulation.
- Concept of DT: Since 2003 but the technology boomed when NASA defined the DT as a multiphysics, multiscale, probabilistic, ultra fidelity simulation that reflects, in a timely manner, the state of a corresponding twin based on the historical data, real-time sensor data, and physical model.
- Current Development of DT in industry: 3 types of interactions where DT interact with each other that is physical-physical (used for performing complex task), virtual-virtual interaction (used to form network for information sharing), and virtual-physical (interaction for optimised synchronization).

Literature Survey

Industrial application of DT:
1. Product Design: for better responsive, efficient products. Most of the design decisions were made with least amount of interaction.
2. Production: DT makes production more reliable,flexible and predictable since visualisation and updation happens in real time which is essential for Production.
3. Prognostic health management of aircrafts: Essential for predicting the structural life of aircraft through multiphysics modeling, multiscale damage modeling and integration.

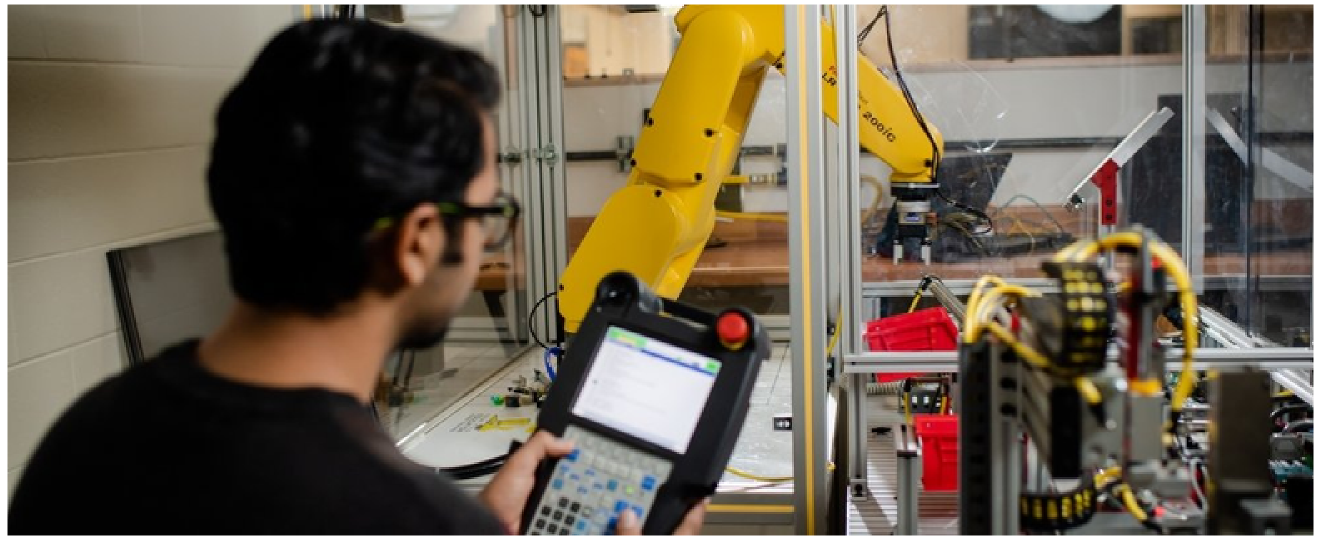
The paper outlines the key enabling technologies for DT modeling, simulation and vv&A, data fusion, interacting and collaboration, and service and much more. It also throws light on the surge of DT booming in the recent times in a diverse industries. While DT is still in buzz, dispatching optimization and operational control are the 2 areas which are underexplored.

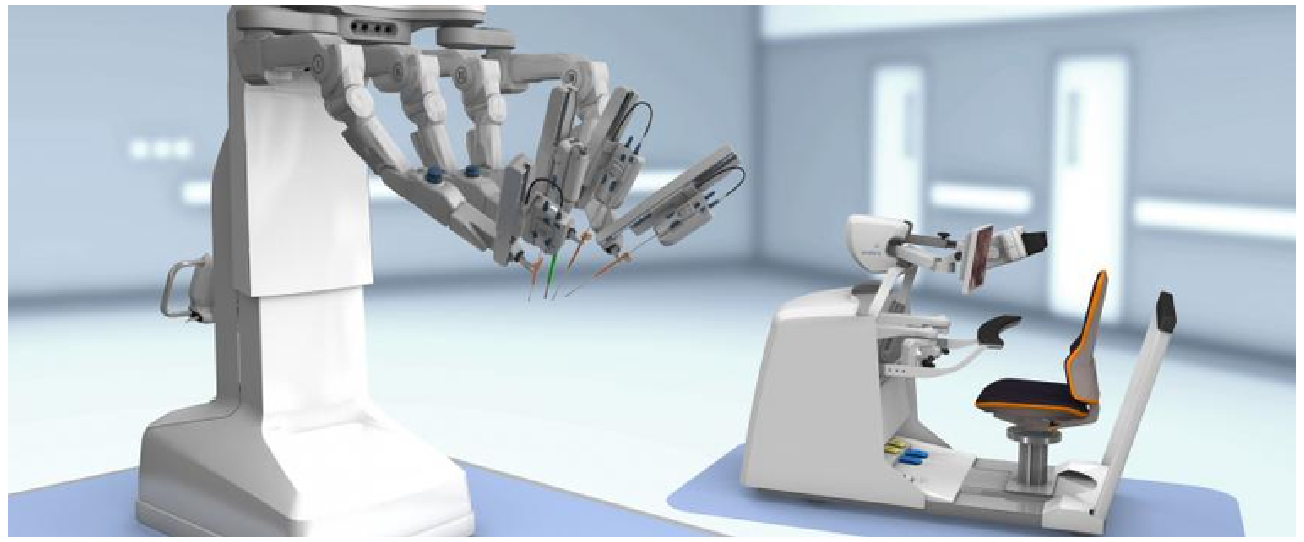
Design Approach

- Data-driven modelling
  - Involves collecting data from the physical robot and using it to build a digital twin.
- Physical modelling
  - Involves creating a digital replica of the physical components and their interactions within the robot.
- Model-based controller
  - Involves using the digital twin to control the physical robot.

Design Constraints

- Constraints:
  - Availability of data and information about the physical robot, including its specifications, component details, and performance data.
  - Computing power and storage capacity required to run the simulation and store the data.
  - Network bandwidth and latency requirements for real-time communication between the physical robot and its digital twin.



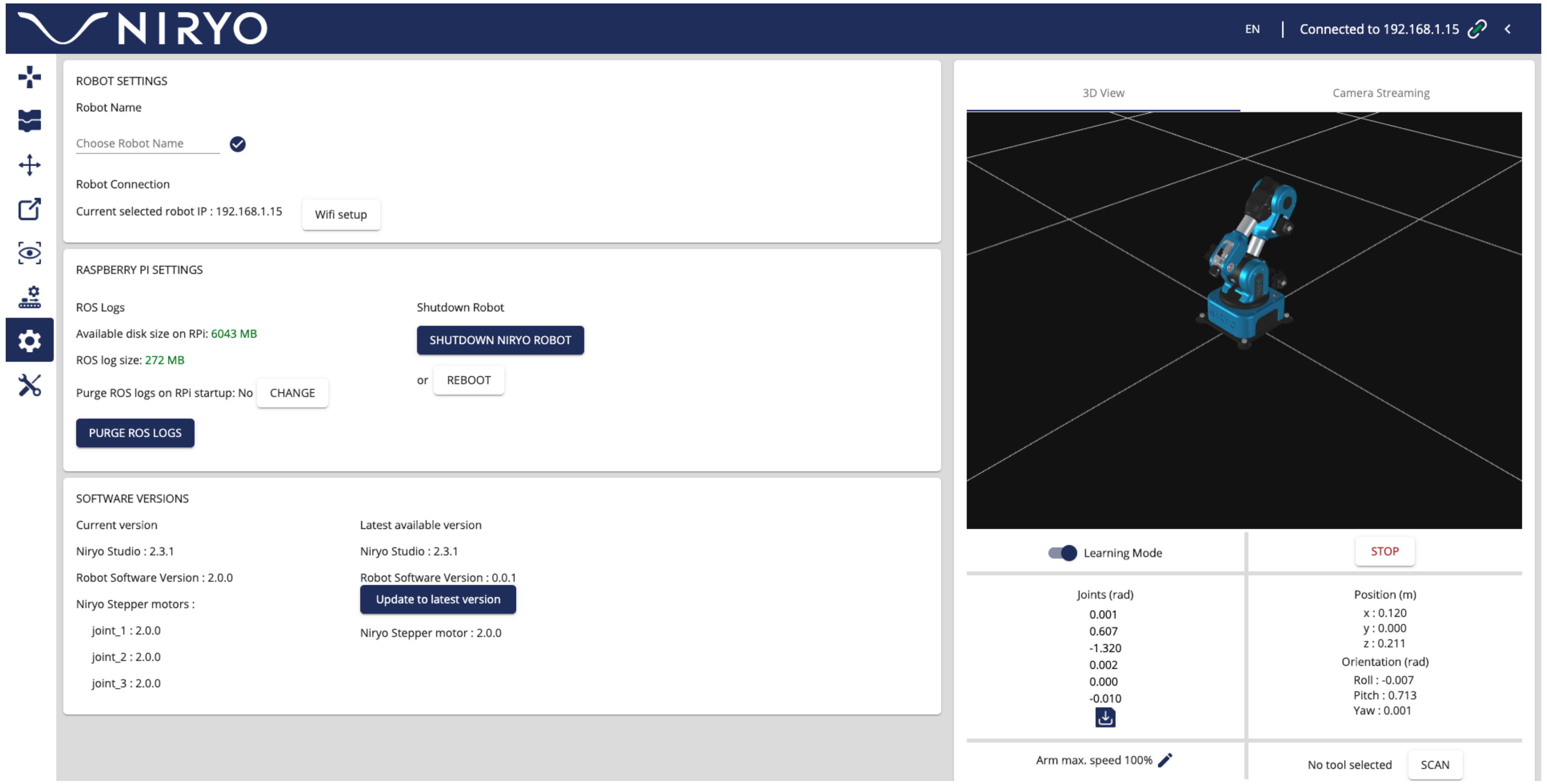


Assumptions

- Assumptions:
  - The accuracy and completeness of the data and information about the physical robot.
  - The reliability and stability of the hardware and software components used to run the simulation.
  - The consistency and accuracy of the mathematical models used to represent the physical robot and its behavior.

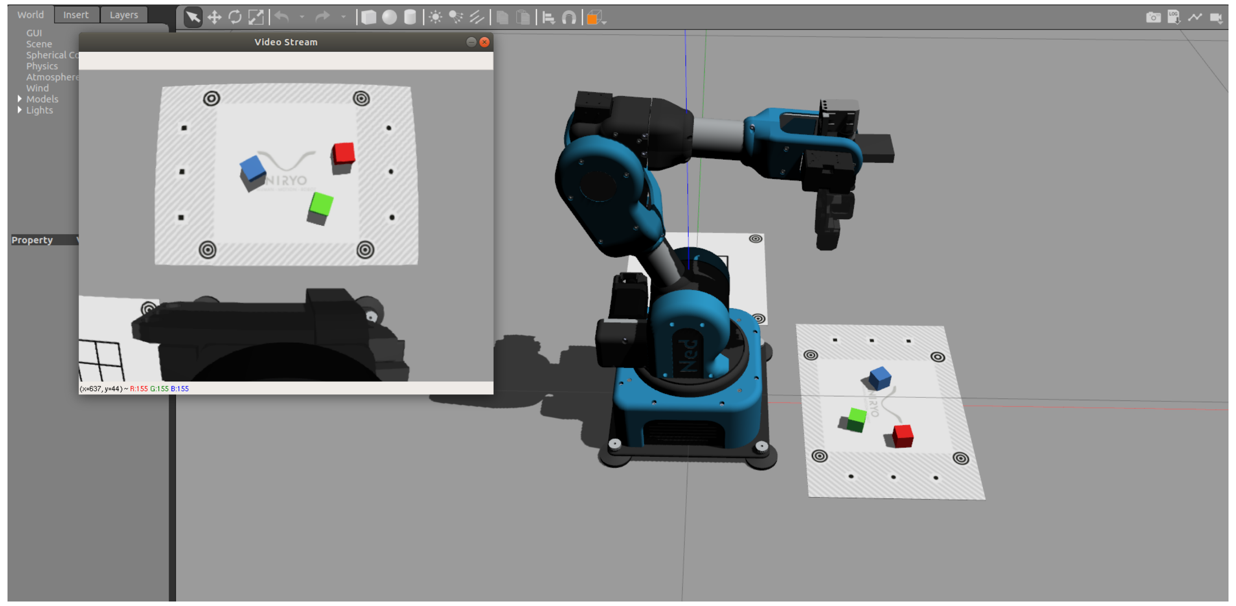
Dependencies

- Dependencies:
  - The availability of software tools and libraries for building and running simulations.
  - The ability to integrate the digital twin with other systems and software, such as control systems, data analytics tools, and visualization software.



Proposed methodology

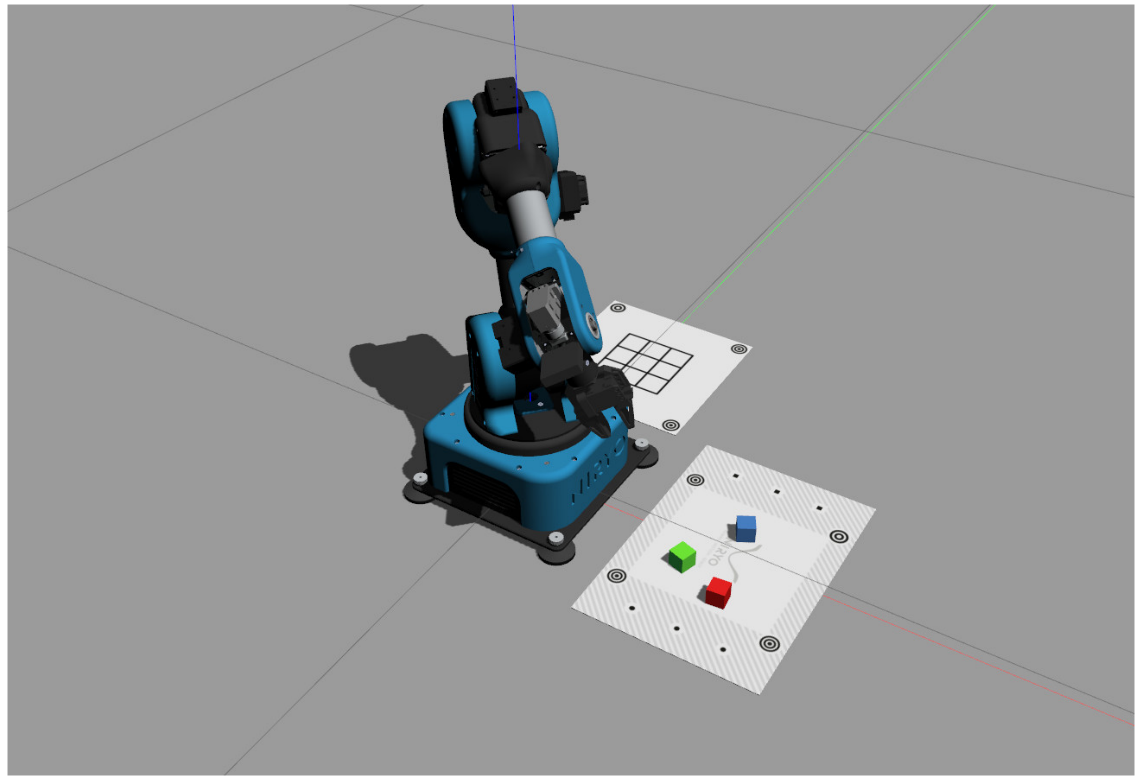
- Model-Based Design:
  - This approach involves creating a mathematical model of the robot's physical components and behavior, which can be used to simulate its operation and predict its performance. The model-based design methodology typically involves the following steps:
  - Gathering data and information about the physical robot, including its specifications, component details, and performance data.
  - Developing mathematical models to represent the physical components and behavior of the robot.
  - Validating the models against real-world data to ensure their accuracy and reliability.
  - Using the validated models to run simulations and predict the behavior and performance of the robot.



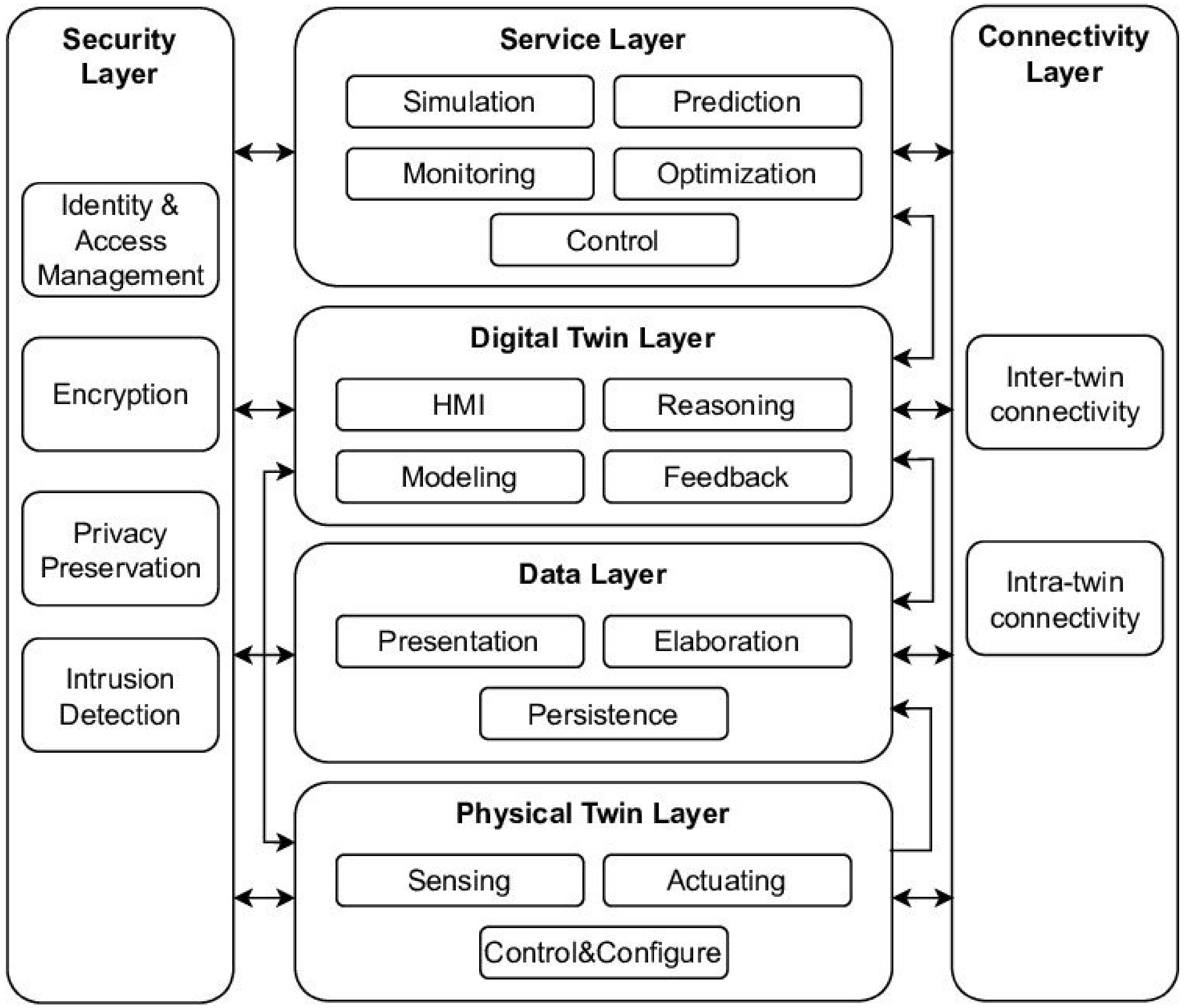
Benefits of Proposed methodology

Benefits of Model-Based Design:

- Improved accuracy: By creating mathematical models of the physical components and behavior of the robot, it is possible to accurately simulate its operation and predict its performance. This can help to identify potential problems and optimize the design of the robot.
- Faster development: By using simulations to test and validate the design of the robot, it is possible to speed up the development process and reduce the need for physical prototypes.
- Better understanding of the system: By visualizing the behavior of the robot in a simulation, it is possible to gain a deeper understanding of its operation and how it responds to different inputs and conditions.



Architecture



Design Descriptions

```
+------------------+          +--------------------+
|  PhysicalRobot   | <--------|   SimulationModel  |
+------------------+          +--------------------+
|  - specifications |         |-mathematical models|
|-component details|          |  -simulation data  |
|-performance data |          +--------------------+
+------------------+                    |
                                        |
+---------------+             +-------------------+
| UserInterface | <-----------|  SimulationEngine |
+---------------+             +-------------------+
|-visualizations|             | -simulation logic |
|  -user inputs  |            |-simulation results|
+---------------+             +-------------------+

+----------------+             +------------------------+
| DataManagement | <-----------| CommunicationInterface |
+----------------+             +------------------------+
|  -sensor data  |             |      -data exchange    |
|-simulation data|             |   -command exchange    |
+----------------+             +------------------------+
```

Design Descriptions

- **Logical User Groups:**
  - Operators: Responsible for controlling and monitoring the physical robot.
  - Engineers: Responsible for designing, developing, and maintaining the digital twin.
  - Management: Responsible for making decisions about the deployment and use of the digital twin.

- **Application Components:**
  - Simulation Engine: Responsible for running the mathematical models that represent the physical robot and its behavior.
  - User Interface: Responsible for presenting information to the users and allowing them to interact with the digital twin.
  - Data Management: Responsible for collecting, storing, and analyzing data from the physical robot and the digital twin.
  - Communication Interface: Responsible for exchanging data and commands between the physical robot and the digital twin.

- **Data Components:**
  - Physical Robot Data: Information about the physical robot, including its specifications, component details, and performance data.
  - Simulation Data: Results of the simulation, including predictions of the robot's behavior and performance.
  - Sensor Data: Data collected from sensors on the physical robot, including information about its current state and environment.
  - Control Data: Commands and instructions sent to the physical robot from the digital twin.

- **Interfacing Systems:**
  - Control System: System responsible for controlling the physical robot.
  - Data Analytics Tools: Tools used to analyze and visualize the data collected from the digital twin and the physical robot.
  - Visualization Software: Software used to display the results of the simulation and the data collected from the physical robot.

Technologies Used

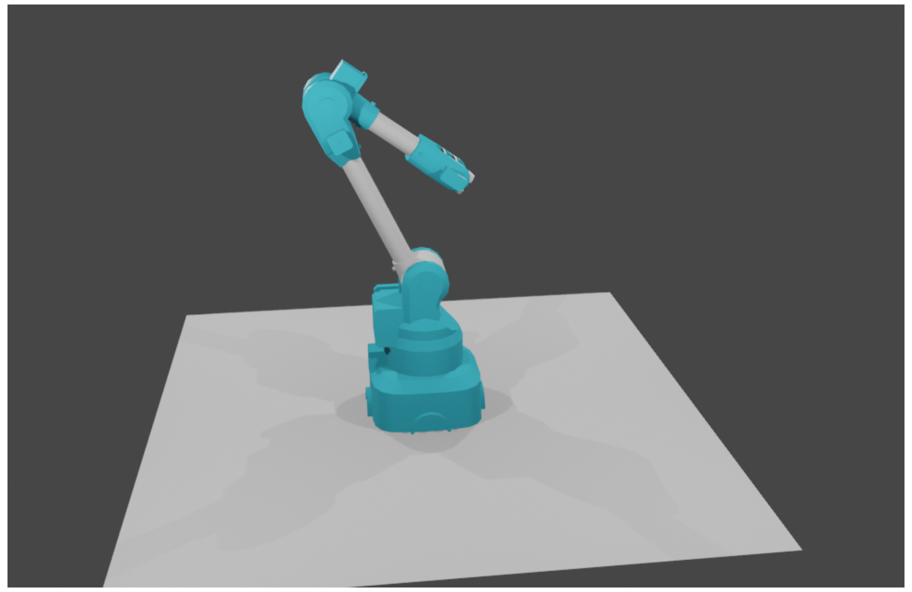
Tools and processes:

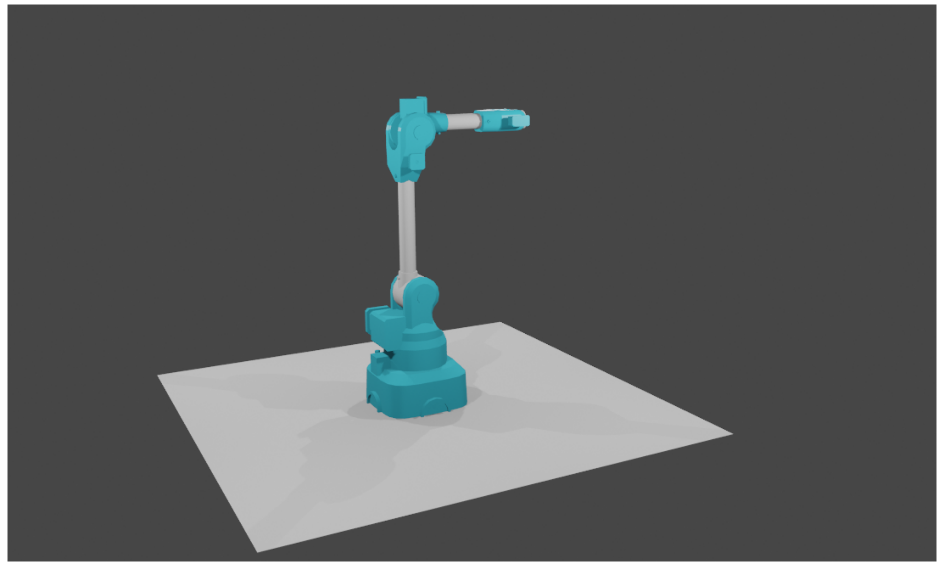
- 3D modeling - blender, Unity3D
- AR platform - Industrial AR tools
- Robotics- Raspberry pi, ArduinoIDE, ROS
- Languages- C++, C#, python.

Project Progress

Tasks completed:

1. Digital twin modeling
2. Establishment of Robot api connection
3. Moving robot from remote location





References

Research done -
https://docs.google.com/spreadsheets/d/1Uet7KWej06JfQ50rUx7eLIetOz4LF18dSRvonRCbmfc/edit#gid=0

Thank You