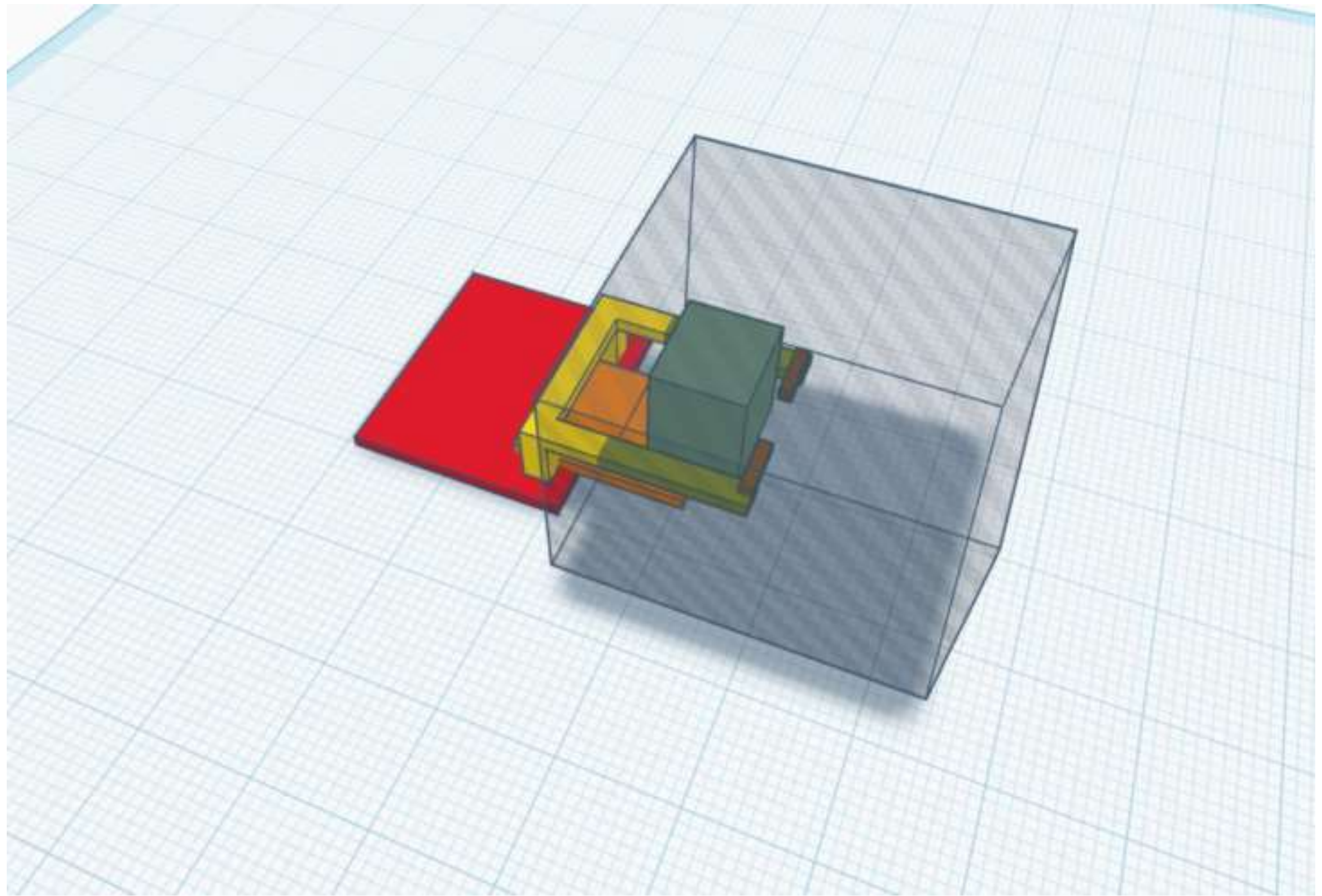
DS3001

DESIGN AND FABRICATION PROJECT



Presented by DFP-38

Topic:
Design and Development of an IoT-Enabled Smart Warehouse Automation System for Real-Time Inventory and Material Handling

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Abstract

This project presents IVEN-TRON, an autonomous smart warehouse system designed to automate product handling and optimize inventory control. The system integrates a conveyor-based material flow, a robotic storage mechanism, and a machine learning model for demand forecasting. The robot autonomously picks and places products into predefined rack positions while continuously updating inventory levels.

A reinforcement learning model is used to predict future demand and determine optimal production quantities, preventing stockout and overstock conditions. Additionally, the system monitors raw material availability and triggers alerts for replenishment when required.

IVEN-TRON demonstrates how robotics and artificial intelligence can be combined to create a scalable and efficient smart warehouse solution aligned with Industry 4.0 principles.

Introduction

Warehousing plays a crucial role in modern production and supply chain systems, where efficient storage, handling, and movement of finished products determine delivery speed, operational cost, and customer satisfaction. Traditional warehouses still rely heavily on manual operations, including sorting, placing, and retrieving items, which often leads to delays, human errors, poor

With advancements in automation and Industry 4.0, there is an increasing demand for intelligent warehouse systems capable of self-operating, learning from data, and making predictive decisions.

IVEN-TRON addresses this need by integrating robotics and machine learning to automate product storage and optimize inventory planning.

Problem

- Conventional warehouse operations depend heavily on manual handling for storing, retrieving, and tracking inventory.
- This results in slow processing, human errors, poor inventory visibility, and inefficient utilization of storage space.
- Due to unpredictable or fluctuating demand, warehouses often face overstocking, which increases storage cost, or stockout, which disrupts supply and reduces customer fulfillment rate.
- Current small and medium-scale warehouses lack an integrated system combining automation with intelligent decision-making.

Objective

- To automate product handling using a conveyor-based autonomous robot.
- To store products accurately in predefined rack locations without human intervention.
- To predict future product demand using a machine learning model.
- To dynamically regulate daily production and prevent overstock or stockout conditions.
- To monitor raw material availability and trigger alerts or automated reorder requests.
- To integrate hardware automation and intelligent software for improved warehouse efficiency.

Research

1. "AI-driven warehouse automation: A comprehensive review of systems," GSC Advanced Research and Reviews, 2024.

Main Idea / Findings

A broad review of how AI (including ML, computer vision, robotics) transforms warehouse operations. Describes how AI-driven automation improves speed, accuracy, and adaptability.

Relevance

Provides a strong theoretical basis for using AI + robotics in warehousing — supports your choice of combining a robot with ML forecasting.

Research

2.“Machine Learning in Warehouse Management: A Survey,” 2024.

Main Idea / Findings

Management: A Survey (2024)

Surveys applications of ML in Warehouse Management Systems (WMS), demand forecasting, stock management, order scheduling, inventory optimization

Relevance

Supports our ML-based inventory forecasting + production planning approach; shows that ML is already a recognized solution in research.

Research

3.“Automation and Robotics in Warehousing: Improving Productivity and Accuracy in Logistics,” IJMRSET, 2024.

Main Idea / Findings

Shows that integrating automation and robotics significantly boosts throughput, reduces errors, speeds up picking/packing/shipping, and lowers labor cost.

Relevance

Validates the hardware automation part of IVEN-TRON: using conveyors, robots, lifting mechanism — as a real benefit to warehouse logistics.

Research

4.The Impact of Automated Systems on Inventory Management and Fulfillment Speed — Seothan, 2025.

Main Idea / Findings

Monitoring stock levels continuously allows predictive replenishment of raw materials and systematic shelf utilization. Automated triggers reduce the risk of production stoppage or overflow.

Relevance

In Our Solution, raw material availability is tracked, and alerts are generated when material drops below a threshold — demonstrating a real-time autonomous decision framework.

Hardware

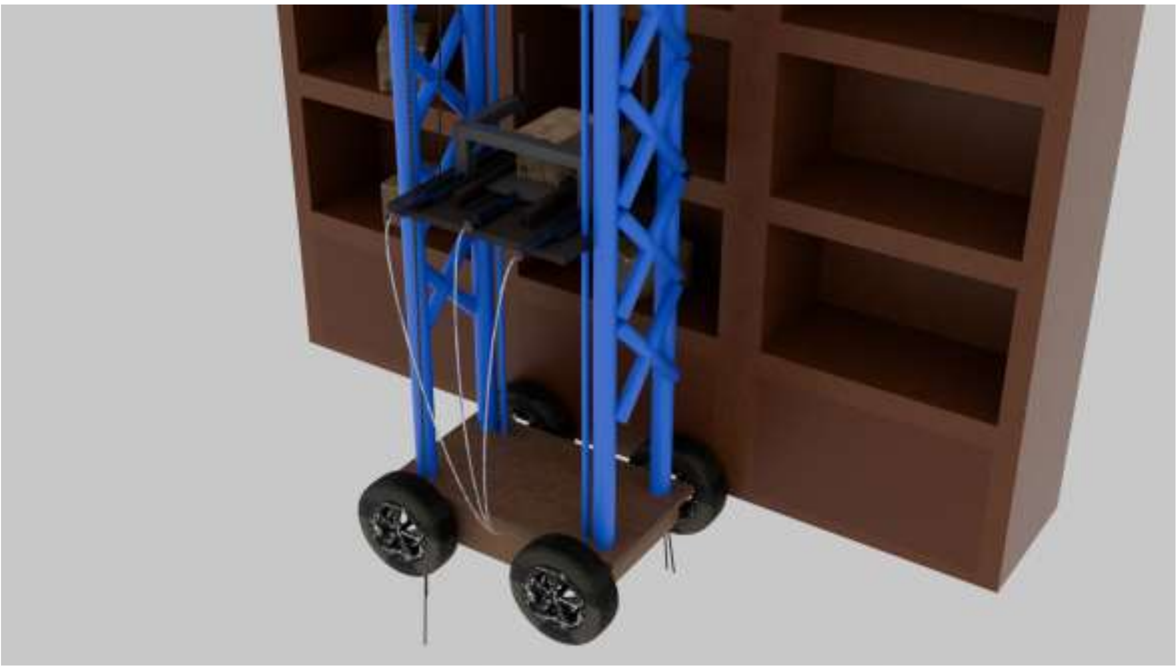
1. **Mechanical Components**

- Base frame: Aluminum extrusion / steel chassis
- Wheels: Differential or Mecanum drive
- Driven motors: 2–4 DC geared motors with encoders
- Lift system: Pulley + steel cable OR lead screw system
- Platform slide mechanism: Linear guides, rack and pinion or belt drive
- U-shaped gripper: Servo-powered joints
- Gap-filling slide plate: electric linear actuator or hydraulic micro-cylinder
- Safety bumpers / covers

2. **Electrical & Control Components**

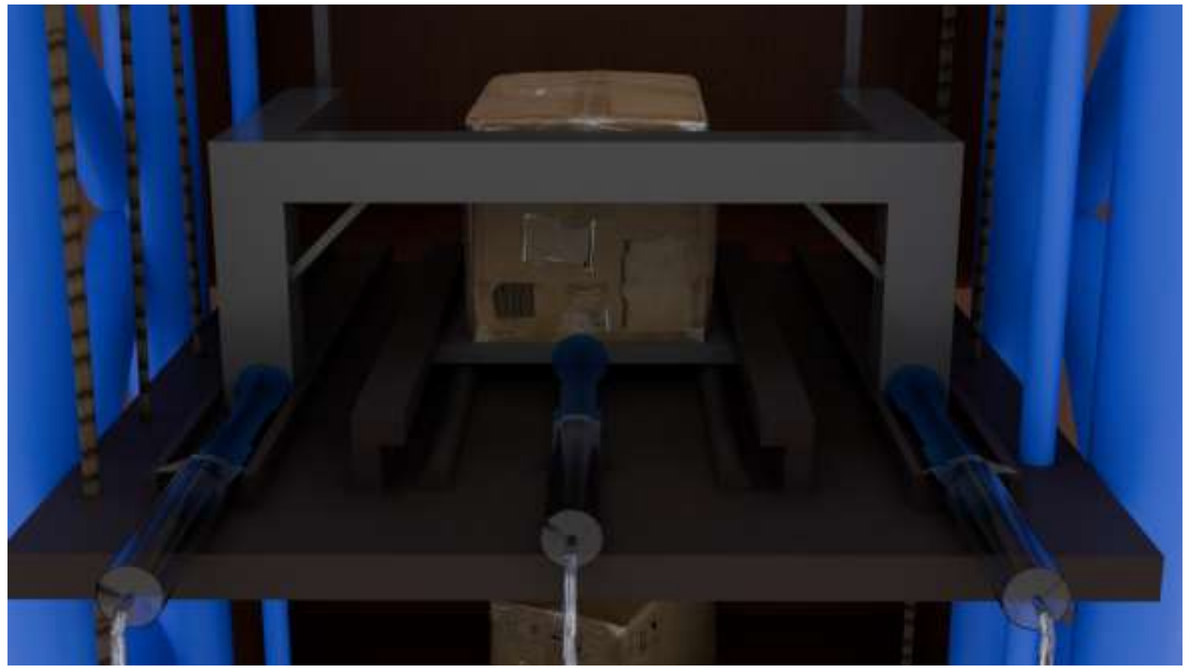
- Microcontroller: Arduino Mega
- Motor drivers: BTS7960 / L298N / Stepper drivers (TMC/A4988)
- Power system:
  - Battery pack: 12–24 V Li-ion/LiPo
  - DC-DC buck converters (12V→5V and 6V for servos)
- Actuators:
  - DC motors / stepper motors for lift & drive
  - Micro servos for claw hooks
- Sensors:
  - Wheel encoders
  - Ultrasonic/ToF distance sensors
  - Limit switches on all moving axes

Design Model

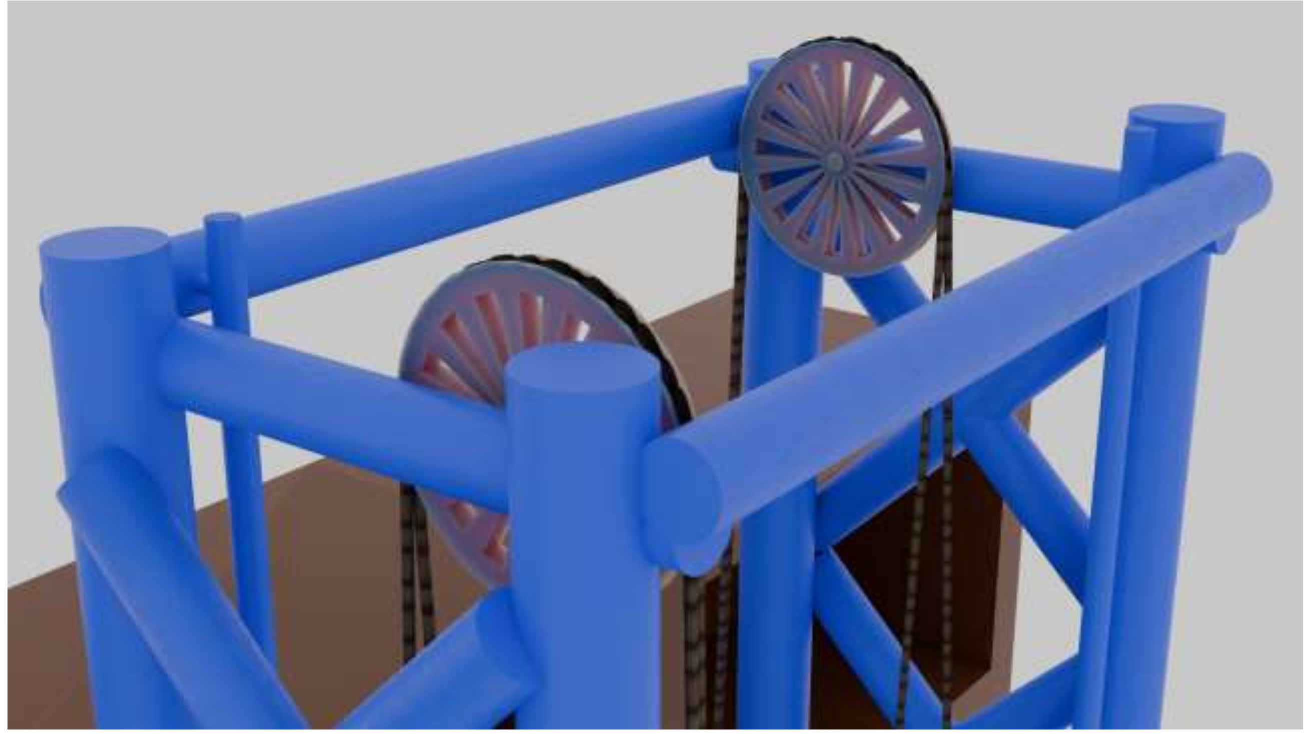


Top View

Front View



Design Model



Vertical Motion of Base

Horizontal Motion for Base

Software

Machine Learning Model Description

Our system uses a Reinforcement Learning (RL)–based prediction and decision model to automatically determine how many units should be produced each day to avoid both overstocking and stockout situations.

The ML model is trained using a custom inventory simulation environment, where an autonomous agent learns by interacting with data and receiving feedback (rewards and penalties). Over time, the model discovers the most efficient production policies to match fluctuating demand patterns.

Algorithms Used:

- Two reinforcement learning algorithms are implemented:
- Deep Q-Network (DQN)
- Proximal Policy Optimization (PPO)

Software

Model Workflow:

- The model observes the current inventory level, day index, and day of the week as input.
- It then predicts the optimal production quantity from a set of possible discrete actions.
- After one simulated day, the system receives a reward:
- +1 if there is neither shortage nor excessive storage
- –1 if there is stockout or overstock
- By repeating this process across thousands of episodes, the model learns the best long-term strategy for balanced inventory.

Process Flow

1. **Product Input**
   - Finished products arrive at the pickup zone via the conveyor system.
2. **Product Detection**
   - Sensors confirm product presence and trigger the robot to begin operation.
3. **Robot Positioning**
   - The robot navigates to the pickup location and aligns itself with the conveyor.
4. **Height Adjustment**
   - The lifting mechanism raises the platform to match the rack shelf level.
5. **Pickup Operation**
   - The gap-cover plate extends and the U-shaped arm grips and retrieves the product onto the platform.
6. **Storage Movement**
   - The robot moves to the assigned storage cell based on inventory availability.

Process Flow

7. **Placement Operation**
   - The lift and alignment system position the product at the correct shelf slot and deposit it securely.
8. **Digital Update**
   - The inventory database updates the stored item location and current stock levels.
9. **ML-Based Optimization**
   - Reinforcement learning predicts next-day production quantity and raw material needs based on patterns and stock status.
10. **Autonomous Loop**
    - The system repeats this process for each product until all available inventory is stored.

Expected Results

The expected outcome of the IVEN-TRON project is a fully functional autonomous inventory management prototype that can store, organize, and track finished products with minimal human intervention. The system is anticipated to accurately transport products from the conveyor to the designated shelf location and update stock levels in real time. The machine learning model is expected to successfully predict next-day demand based on historical data and adjust production levels accordingly to prevent overproduction and stock shortages. Additionally, the system should continuously monitor raw material availability and generate early alerts or automated reorder triggers when thresholds are reached. Overall, the project is expected to demonstrate improved warehouse efficiency, accuracy, and operational automation.

Advantages of the Proposed System

The proposed system offers significant benefits over traditional warehouse management practices. Automation of product storage reduces dependence on manual labor, minimizes errors, and improves consistency and operational speed. The integration of machine learning provides intelligent decision-making, ensuring optimized production planning based on real-time demand prediction. By preventing both overstock and shortages, the system enhances storage utilization and reduces waste. Raw material tracking further supports uninterrupted production schedules and reduces downtime. Collectively, the system aligns with Industry 4.0 principles, enabling smarter, scalable, and more efficient warehouse operations.

Conclusion

- IVEN-TRON successfully demonstrates an autonomous and intelligent warehouse system integrating robotics and machine learning.
- The automated storage mechanism enables reliable product handling with minimal human intervention.
- The reinforcement learning model effectively predicts future demand and optimizes daily production levels to avoid stockout or overstock conditions.
- The system achieves real-time inventory tracking and raw-material monitoring, supporting adaptive and efficient warehouse operations.

“Overall, IVEN-TRON represents a practical step toward smart warehousing and Industry 4.0 implementation”.

THANK YOU

For your attention