DEVELOPMENT OF A DELTA ROBOT FOR SORTING ITEMS IN INDUSTRIAL CONDITIONS

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Abstract. *This article was created as part of a Problem Based Learning (PBL) project in which we investigated delta robots, CNC machines and embedded systems. In response to the imperatives of Industry 4.0, this research introduces "DeltaSort", a delta robot system poised to revolutionize agricultural sorting processes. Through the integration of advanced gripping mechanisms and artificial intelligence-driven object recognition, DeltaSort meticulously assesses and categorizes harvested fruits and vegetables, ensuring judicious force application for gentle handling and precise sorting. Beyond the confines of agriculture, the system presents a plethora of advantages, encompassing heightened productivity, superior precision, elevated safety standards, increased production speeds, and non-stop operational capability, rendering it an instrumental solution in contemporary automated processes.*

Key words: *delta robot, industry 4.0, agricultural sorting, advanced gripping mechanisms.*

Introduction

In the rapidly advancing landscape of modern technology, the creation of machines capable of mimicking human movements has become a hallmark of innovation. Defined by the Oxford English Dictionary as "machinery resembling a human being and able to replicate certain human movements and functions automatically," robots, particularly those with parallel kinematics, have garnered significant attention from various industries and researchers [1]. The inherent advantages of parallel kinematic mechanisms, such as higher precision, rigidity, dynamic performance, and loading capabilities compared to serial robots, have positioned them as transformative elements in the realm of automation.

A prominent representative of parallel kinematics is the Delta robot, renowned for its versatility in mimicking human arm movements and executing tasks requiring precision. However, it is crucial to acknowledge that Delta robots are not universally applicable; they excel in high-speed pick-and-place applications involving lightweight parts with simple geometries. Notwithstanding, limitations arise in scenarios where products cannot withstand such high speeds and accelerations.

This article delves into the nuanced landscape of Delta robots, exploring their applications across diverse industries. While their proficiency in pick-and-place operations is well-acknowledged, Delta robots exhibit capabilities beyond this realm, encompassing assembly, material handling, palletizing/packaging, and other specialized functions.

The subsequent sections elaborate on the vision-based material classification, the robotic system's components, and the crucial role played by the vacuum gripper. Additionally, the article discusses the benefits of incorporating robotics and automation in CNC machining operations, emphasizing increased productivity, enhanced precision, improved safety, higher production speeds, flexibility, and 24/7 operation. While acknowledging the advantages, the article also addresses the potential challenges associated with the implementation of robotics in CNC machining.

The integration of Delta robots and advancements in CNC machining, coupled with the infusion of technologies like Big Data, AI, IoT, and 3D printing, marks a paradigm shift in manufacturing and automation [2]. The subsequent sections of this article delve into specific applications, technical details, and implications of these advancements, offering a comprehensive exploration of their impact on industrial processes and efficiency.

Use Cases

Delta robots are highly demanded nowadays in industries, due to the fact that there are many functionalities that they can execute. Further, some of the applications of delta robots will be listed, along with the percentage of the robots used specifically for each purpose [3]:

- Assembly (10%)
- Pick and place (32%)
- Material handling (14%)
- Palletizing/packaging (32%)
- Others (12%)

Functionalities stated above, make delta robots an indispensable tool in various industries. We will discuss the primary use cases for our project - using delta robots in agriculture: Delta robots, known for their speed and precision in manufacturing, have found innovative applications in the realm of farming and agriculture. These robots are increasingly being utilized to enhance efficiency and productivity in various agricultural processes. In precision agriculture, delta robots are employed for tasks such as planting, seeding, and harvesting with unmatched accuracy, minimizing waste and optimizing crop yields. Their rapid and precise movements make them well-suited for delicate operations like fruit picking and sorting. Additionally, delta robots can be integrated into automated systems for packaging and handling of agricultural products, streamlining post-harvest processes. The deployment of delta robots in agriculture not only improves operational efficiency but also contributes to sustainable practices by reducing resource usage and increasing overall crop quality [4].

DeltaSort

In the realm of robotic applications, our project, aptly named "DeltaSort", stands as a pioneering endeavor to harness the capabilities of Delta robots for transformative purposes. While Delta robots have traditionally been associated with high-speed pick-and-place operations, "DeltaSort" extends their utility into the critical domain of agricultural sorting. Leveraging advanced gripping mechanisms, computer vision technology, and sophisticated algorithms, our project seeks to revolutionize the sorting processes for fruits and vegetables, ensuring precision and efficiency.

Key Components of DeltaSort

- Object Recognition. Central to the success of DeltaSort is its utilization of cutting-edge AI algorithms trained on extensive datasets. This enables the system to recognize various types of fruits and vegetables based on their size, shape, and color, laying the foundation for efficient and accurate sorting.
- Sorting Criteria. DeltaSort categorizes produce according to user-defined parameters such as size and color. This intelligent sorting ensures that each item is directed to the appropriate destination, whether for packaging or further processing.
- Gentle Handling. Recognizing the delicate nature of fruits and vegetables, DeltaSort's movements are meticulously programmed to be gentle, preventing any damage during the sorting process.

- Feed Streaming and Distant Control. The project incorporates a user-friendly web interface for feed streaming, allowing real-time monitoring of the sorting process from any location. Additionally, DeltaSort offers distant control, enabling users to modify sorting processes, define product placement, or halt operations with a simple tap.
- On-Screen Display. Real-time updates and statistics are displayed on the web interface, offering a comprehensive view of the progress in sorting, assembly, or packaging tasks.

Feedback Forms

To ensure the delta robot operates smoothly and sorts correctly, implement a feedback system for user alerts when issues arise. This system can take various forms:

- - Visual Feedback:

The main visual feedback will be obtained by real-time updates and stats on a monitor or touchscreen

- - Remote Monitoring and Alerts:

Remote Access is provided with a monitor and receives alerts from anywhere with internet access.

- - User Interface Feedback:

Intuitive Interfaces are user-friendly design for error reduction. Error Messages guide operators in resolving issues effectively.

Benefits of using system

The incorporation of delta robot systems into sorting, assembling, and packaging tasks yields significant advantages across diverse industries and applications:

- Enhanced Productivity: Employing delta robots diminishes downtime and enhances productivity compared to human labor. Robots operate continuously without breaks or fatigue, resulting in heightened output and improved operational efficiency.
- Augmented Precision and Accuracy: Delta robots exhibit exceptional precision and repeatability, ensuring consistent and accurate machining processes. They achieve stringent tolerances and mitigate human errors, thereby enhancing part quality and minimizing scrap or rework.
- Elevated Safety Standards: Automation eliminates manual intervention in hazardous or physically demanding tasks, mitigating the risk of accidents, injuries, and exposure to harmful environments. This fosters a safer working environment for operators.
- Accelerated Production Rates: Delta robots execute machining operations at significantly faster speeds than human operators. Their capacity for swift execution of complex movements and tool changes translates into reduced cycle times and heightened production rates.
- Flexibility and Adaptability: Robotic systems possess the capability to be programmed for a wide spectrum of tasks, facilitating enhanced flexibility. They seamlessly transition between diverse machining operations or workpieces, facilitating efficient batch production and swift product changeovers.
- Continuous Operation: Automated systems operate round-the-clock, including beyond regular working hours, without necessitating human supervision. This maximizes machine utilization and enables uninterrupted production, thereby bolstering overall production capacity.

System requirements

Functional Requirements:

- Interface for Setup and Configuration: This requirement entails providing a user-friendly interface through which operators can configure and set up the delta robot system according to specific sorting requirements. The interface should offer intuitive controls and options for adjusting parameters such as sorting criteria, sensitivity levels, and sorting algorithms. A well-designed setup interface ensures efficient deployment of the system and facilitates customization to suit varying sorting needs across different batches of produce.

- Error Detection and Correction Mechanisms: The system must incorporate robust error detection and correction mechanisms to minimize sorting errors and maintain high accuracy levels. This involves implementing algorithms and sensors capable of identifying discrepancies between the expected and actual sorting outcomes. Upon detecting errors or anomalies, the system should promptly initiate corrective actions, which may include recalibration, repositioning of objects, or triggering alarms for manual intervention. Reliable error detection and correction mechanisms are crucial for ensuring consistent sorting quality and reducing the need for manual oversight.
- Operational Data Logging and Analysis: Operational data logging is essential for capturing relevant performance metrics and operational parameters during sorting tasks. The system should log data such as sorting speed, accuracy rates, error occurrences, and equipment utilization. This accumulated data serves as a valuable resource for conducting in-depth analysis to identify trends, patterns, and areas for improvement. By analyzing operational data, operators can gain insights into system efficiency, optimize sorting processes, and make informed decisions to enhance overall performance and productivity. Effective data logging and analysis contribute to continuous refinement and optimization of the delta robot system for achieving optimal sorting outcomes.

Non-functional Requirements:

- Compliance with Safety Standards and Regulations: Ensuring compliance with relevant safety standards and regulations is paramount to safeguarding operators and maintaining a secure working environment. This requirement involves adhering to established guidelines governing the design, operation, and deployment of robotic systems in agricultural and waste management settings. Safety measures may include incorporating protective barriers, emergency stop mechanisms, and safety interlocks to prevent accidents or injuries during system operation. Compliance with safety standards demonstrates a commitment to workplace safety and minimizes the risk of legal liabilities associated with non-compliance.
- Compatibility with Standard Communication Protocols: The system should be compatible with widely adopted communication protocols to facilitate seamless integration with existing infrastructure and third-party systems. Compatibility with standard protocols such as Ethernet/IP, Modbus TCP, or OPC UA enables interoperability with other equipment, control systems, and data management platforms commonly used in industrial environments. This interoperability enhances the system's flexibility, scalability, and interoperability, allowing for streamlined data exchange, centralized monitoring, and coordinated control across interconnected systems. Compatibility with standard communication protocols fosters an ecosystem of interconnected technologies, enabling efficient collaboration and data sharing for enhanced operational efficiency and decision-making.
- Energy Efficiency and Environmental Impact: Designing the system with energy-efficient components and operational modes is essential to minimize power consumption and reduce its environmental footprint. This requirement involves optimizing the selection of motors, actuators, and control systems to maximize energy efficiency without compromising performance. Additionally, implementing power-saving features such as sleep modes, variable speed drives, and intelligent power management strategies helps minimize energy waste during system operation. By prioritizing energy efficiency, the system not only reduces operational costs but also contributes to sustainability goals by conserving resources and mitigating

environmental impact. Efficient energy management aligns with environmental stewardship principles and enhances the system's overall sustainability credentials, making it an environmentally responsible choice for agricultural and waste management applications.

Architectural Design

System Components:

- Video Camera:
- Optical Sensor: Hardware component capturing visual data, utilizing CCD or CMOS technology.
- AI Processing Core: Computational unit analyzing visual data for object recognition, size estimation, and color detection, often employing CNNs.

Delta Robot:

- Microcontroller Unit (MCU): Controls robot movement and sorting logic based on grabbing sensor input and AI-processed data.
- Grabbing Sensor: Detects item presence and location, providing timing feedback for precise picking operations.
- Delta Object Picker: End-effector picking and placing items securely using suction cups, guided by MCU instructions.

UI Components:

- Dashboard Interface: Central control panel offering real-time system status and access to various functionalities.
- Camera Feed Display: Live video feed showcasing sorting process, with options for zooming and camera views.
- Parameter Configuration Panel: Allows user adjustment of sorting parameters such as size and color thresholds for tailored sorting criteria.

Below, in the Fig.1 are presented all these architectural components of the system, in a diagram:

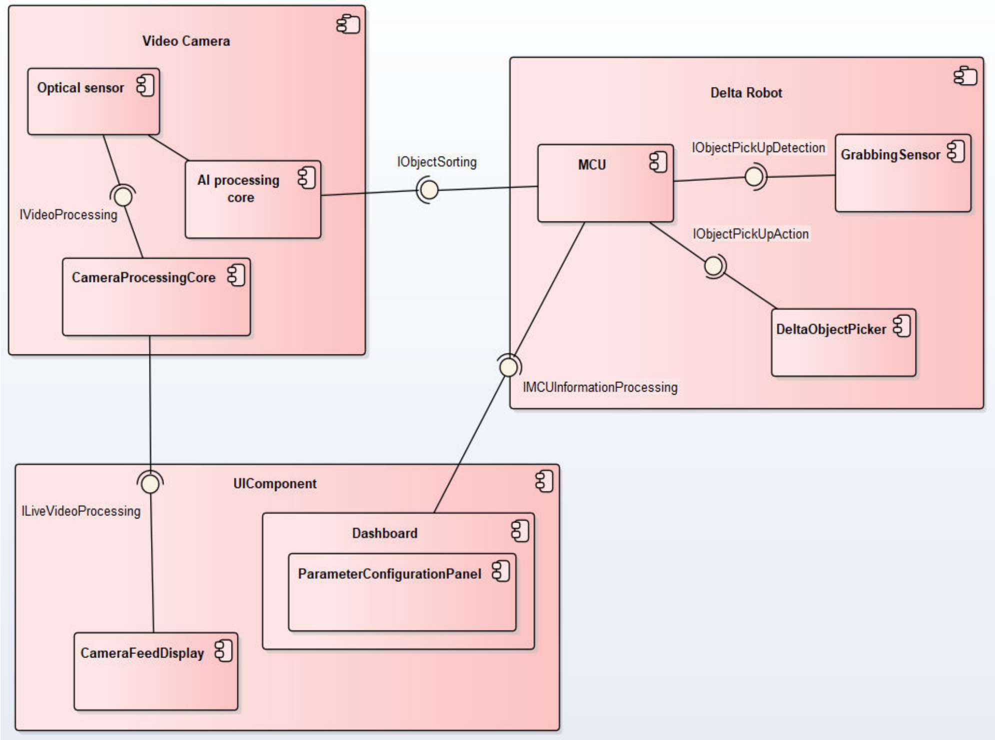

Figure 1. Architectural Design of the System

Conclusion

In summary, the development of a delta robot tailored for industrial sorting tasks marks a significant advancement in automation technology. Engineered with precision and efficiency in mind, this innovative system seamlessly integrates cutting-edge components to meet stringent industrial demands. Its versatility promises enhanced productivity and operational flexibility across various sectors. Looking ahead, further advancements in robotics technology hold the potential to elevate efficiency and versatility, reinforcing the role of automation in modern manufacturing. In essence, the delta robot exemplifies the transformative impact of automation on industrial processes, driving progress and competitiveness in the ever-evolving landscape of manufacturing.

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