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Technical Report

SPARtS - Small Parts Automated Retrieval and Storage

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Abstract

This report presents SPARtS, an automated storage and retrieval system designed to organize small parts in workshops and laboratories. The project addresses common challenges such as the time-consuming process of locating components, the high number of similar items, and the possibility of human error when storing parts. SPARtS integrates mechanical, hardware, and software components to automatically store and retrieve items through menu browsing, text search, or visual identification, and keep real-time stock estimates. The mechanical structure includes an XYZ movement system, a conveyor belt, a retractable platform, and 24-slot storage built with MDF, aluminum extrusions, and 3D-printed parts. The hardware architecture employs an ESP32 microcontroller, ESP32-CAM, load cell with HX711, RFID sensors, stepper motors, and custom-made circuitry. The software system combines a Vue.js frontend, a Python backend, and a YOLOv11-based computer vision model capable of identifying multiple item classes with high reliability. The system meets all functional requirements, demonstrating accurate positioning, reliable stock estimation, intuitive user interaction, and effective detection of item classes. With optimized workflow and precise automation, SPARtS proves to be a successful and efficient solution for improving organization and operational speed in workshop environments.

1 Introduction

Workshops and laboratories frequently rely on a large variety of small parts for daily operations. However, storing, locating, and managing these components can become a time-consuming and error-prone task, especially when many similar items are involved. Human mistakes in placing items in incorrect locations, combined with the difficulty of maintaining an accurate inventory, highlight the need for a more efficient organizational solution.

To address these challenges, the SPARtS project proposes an automated system capable of storing, retrieving, organizing, and tracking small parts with minimal human intervention. The system integrates mechanical automation, embedded hardware, computer vision, and a user-friendly software interface to enable fast and reliable handling items. By combining an XYZ movement structure, a conveyor-based insertion mechanism, a load-cell-based stock estimation system, and YOLOv11-powered visual identification, SPARtS significantly improves operational efficiency in workshop environments.

This work presents the design, implementation, and evaluation of SPARtS, demonstrating how automation and intelligent processing can streamline inventory management and support more organized, accurate, and productive workflows.

2 Project Specification

2.1 Requirements

This section presents the main requirements established by the SPARtS project team during the planning phase, taking into account the available resources and the intended system functionalities. The requirements were divided into functional and non-functional categories and organized according to the system's subsystems: software, mechanical, and hardware.

2.2 Mechanical Requirements

Category	Requirement ID	Description
Mechanical	FR01	The system must store up to 24 storage bins each with a maximum of 100 grams of parts, for parts with minimum individual weight of 2 grams and maximum individual dimension in any direction of 30 mm
Mechanical	FR02	The system must deliver a retrieved storage bin in a output compartment
Mechanical	FR03	The system must fetch and move bins across all storage areas and the user output area
Mechanical	FR04	The system must have a mechanism for automated storage of parts separated in buffer bins
Mechanical	FR05	The system must allow user manual access to the bins

Table 1: Mechanical Requirements

2.3 Hardware Requirements

Category	Requirement ID	Description
Hardware	FR06	The system must be able to verify the ID of a bin with an individual ID tag
Hardware	FR07	The system must capture images of items in a buffer bin
Hardware	FR08	The system must estimate stock by measuring the weight of a storage bin in the output compartment with a margin of error of +-3 grams
Hardware	FR09	The system must have a main On/Off switch

Table 2: Hardware Requirements

2.4 Software Requirements

Category	Requirement ID	Description
Software	FR010	The embedded software must retrieve an item's bin from the storage in at most 45 seconds if required by the application and the item bin is in the expected placement
Software	FR011	The embedded software must return an item's bin to the storage in at most 30 seconds if required by the application and there is no unexpected bin in its place
Software	FR012	The system must have an application for user interface
Software	FR013	The application must allow the user to select an item for retrieval
Software	FR014	The application must have an option of automatic storage
Software	FR015	The system must identify wrong storage bin placements
Software	FR016	The system must be able to reorganize storage bin placements
Software	FR017	The embedded software must check the ID of a storage bin if required by the application
Software	FR018	The system must update the stock estimation of a bin whenever it weights that storage bin

Software	FR019	The system should be able to visually identify 12 selected parts including screws, nuts, and corner supports with a minimum of 50% mAP
Software	FR020	The stock estimation must have a precision of +/-4 items

Table 3: Software Requirements

3 Project Development

3.1 Mechanical Development

3.2 Hardware Development

3.3 Software Development

4 Results

4.1 Budget

4.2 Fucntional requirements completion

5 Conclusion

References