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Selecting Minimal Inspection Items in Zero-Defect Quality Control Using an Ant Colony Optimization Approach

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In contemporary manufacturing environments, inspection is essential to guaranteeing product quality. However, examining every component with every available inspection tool can be time-consuming and resource-intensive. In order to overcome this difficulty, this research suggests an effective optimization method to determine the minimal number of inspection items needed to find every defective part in a specific production batch. Inspection items are represented by columns and parts by rows in a binary matrix formulation of the problem. If an inspection item's value is 1, it can identify a flaw in a particular part. The proposed approach is based on Ant Colony Optimization (ACO), which has been modified to prioritize inspection items that cover more parts of the product. It focuses on items that have not yet been found while ensuring that the chosen items collectively cover every part. Learning from previous choices is accomplished through adaptive score updates. At first, every inspection item is given an equal score. Inspection items are selected one at a time during each trial until every faulty part is found. Scores are updated by rewarding successful items and slightly lowering unsuccessful ones. Then, the solutions are assessed after each trial to promote exploration. After the process is repeated for a predefined number of trials, the final solution is the optimal set of inspection items. That is, the smallest set that ensures complete defect detection. Three datasets of varying sizes and complexity were used to test the algorithm. They are a small dataset with five parts and four inspection items, a medium dataset with ten parts and eight inspection items, and a large realistic scenario with five hundred parts and fifty inspection items. The algorithm was able to identify a minimal set of inspection items in every case, ensuring complete defect detection. The capacity of the method to minimize inspection effort while preserving complete coverage has been established. This is demonstrated by the fact that the number of selected items was considerably less than the total available in each case.

Keywords: Ant Colony Optimization, Minimal Inspection Items, Zero-Defect Quality Control