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AI-BASED OPTIMIZATION OF PACKING PROBLEMS FOR ENHANCING MEDICAL SAFETY SYSTEMS

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Abstract. In the context of enhancing medical safety systems, AI-based optimization of packing solutions is crucial, particularly in the secure and sanitary storage of hazardous materials within healthcare environments. Ensuring that toxic, radioactive, or infectious substances are stored according to strict sanitary guidelines is vital for protecting public health and preventing contamination. This study introduces an AI-driven mathematical model to address packing problems, with a focus on meeting both technological and hygiene standards. By modeling the optimal placement of containers in a deployment area and incorporating key safety and sanitary restrictions, the problem is reduced to a nonlinear programming framework. The phi-function technique is utilized to capture geometric relationships effectively, enabling the development of AI-optimized, sanitary-compliant storage solutions. Numerical examples are provided to demonstrate the approach's efficacy.

In an era of rapid technological advancement, the development and deployment of safety systems are critical to ensuring the secure and efficient operation of various systems, particularly in healthcare environments [1]. These systems are essential for safeguarding both human life and infrastructure, playing a pivotal role in mitigating risks and preventing potentially catastrophic outcomes. Nowhere is this more evident than in medical institutions, where the failure of safety systems can have severe consequences, including the spread of infectious agents or exposure to toxic and radioactive materials [2].

In healthcare settings, safety systems must be meticulously designed not only to prevent accidents but also to mitigate the impact of any incidents. Modern systems, leveraging continuous monitoring and advanced AI-driven analytics, are capable of identifying potential risks in real time and triggering prompt response mechanisms. However, a critical aspect of medical safety often overlooked is the proper storage of hazardous substances, such as toxic, radioactive, or infectious materials, where both technological and sanitary compliance are necessary to prevent contamination and ensure swift response in emergencies [3].

Previous studies have highlighted the risks associated with incorrect placement and storage of hazardous materials in healthcare environments [4]. This paper seeks to address these challenges through an AI-based approach, offering optimization techniques that enhance medical safety by ensuring the strategic and sanitary-compliant placement of hazardous materials in healthcare facilities.

The primary aim of optimization packing problem can be described as follows: to search for a spatial arrangement of a given set of geometric objects within a deployment area that satisfies safety clearance, while maximizing or minimizing a specific optimization goal.

Key elements of the system are shape and boundaries of the deployment area, geometry of the objects to be placed in this area, technological and safety constraints governing the arrangement of these objects within the designated space, optimization objective.

The area may have a complex shape, with certain regions being off-limits for container placement due to safety factors.

$$D = cl(D_0 \setminus \bigcup_{l=1}^{\sigma} P_l) .$$

To formalize the problem, the outer boundary of the region is presented as a combination of segments and circular arcs.

Problem Statement. Find the vector that optimizes the placement of the maximum number of circles items from the set within the deployment area D while ensuring safety clearance.

This study formulates the problem of optimally arranging containers for hazardous materials, considering specified sanitary constraints, as an optimization placement problem. A mathematical model is developed for packing congruent circles into a deployment area. This model is framed as a nonlinear optimization problem.

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