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Optimization of Facility Layout on the Basis of Example Solutions

Abstract: Designing the layout of a manufacturing facility is a complex multi-disciplinary effort. Instead of explicitly modelling all relevant layout rules, we have investigated an alternative approach for a decision support system: We apply machine learning on examples of well-designed layouts, in order to combine implicit expert knowledge with an explicit layout optimization model. We tested the concept on artificial test data, and the initial results are promising.

Keywords: optimization, facility layout problem, machine learning, constraint programming

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1 Background

To design the layout of process components in a manufacturing facility, the designer has to consider the construction, operation and maintenance of the facility and all its subsystems, as well as relevant rules and regulations. Due to the complexity of the problem, automated optimization of facility layout has not reached the status of a practical design tool. In research literature, practical design rules have been modelled as explicit constraints, which can be laborious to specify, or left as the responsibility of expert designers in an interactive optimization approach.

2 Aims

We investigated the feasibility of machine learning of design rules from examples of expert-designed layouts. The aim is that learning-based optimization uses example layouts of old facilities to provide reasonable layout proposals for a new facility, without requiring the user to set too many input parameters.

3 Materials and methods

We have developed a probabilistic machine learning model that can be used to evaluate the similarity of a proposed layout to example layouts. We use a model of geometric similarity based on kernel density estimation, which can be derived from a small number (on the order of 10) of example layouts. We combine the probabilistic similarity model with an optimization model that minimizes connection distance (pipe length) between components. The optimization model is based on constraint programming. The connection distance and similarity measure are treated as separate objectives in a multi-objective optimization setting: by weighting the objectives we can choose a different trade-off between the objectives, and provide alternative layout proposals for the user.

To apply the method in practice, the layouts of existing facilities must be available in machine-readable form, and reduced to the most significant components and their connections. A common classification must be defined for the components in the example layouts, and the components of the new facility: e.g. large/small tanks, pumps, and other machines. For the new facility, the user must specify the required components, their dimensions and their connections, and the locations of the building walls. Once cost coefficients are given for the connection lengths, the system then automatically produces layouts that present different trade-offs between minimizing connection cost, and following layout rules similar to the example layouts.

4 Results

We have implemented the similarity model and the layout optimization model, and tested them on artificial test data. Our initial tests indicate that the concept works, and we can successfully trade off similarity to examples and the connection distance objective.

Due to the use of a relatively simple probabilistic model, there is random variation in the learning results especially when the connection structure of the example layouts differs from the new facility. Nevertheless, our combination of machine learning and optimization presents a promising alternative to traditional model-based optimization, which would require much more explicit modelling work to produce layouts similar to those designed by experts.