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Knowledge Representation and Planning Strategies for Batch Plant Operating Procedure Synthesis

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Extended Abstract

Synthesis of operating procedures for batch plants involves systematic generation of step by step instructions which the operator can implement to manage the batch plant safely and optimally. This is a labor and knowledge-intensive task. It often takes weeks of effort by experts to prepare a clear and error free set of instructions even for a moderately complex plant. If this process is automated, it would be possible to develop operating procedures and control sequences more efficiently and accurately. This paper proposes a knowledge-based framework for this problem

The operating procedures are to be developed from information about the plant setup, process chemistry and recipe, and product requirements. The plant configuration information would consist of process equipments, their capabilities, constraints and their connectivities. The process chemistry and recipe information would comprise of the various steps, such as reaction and unit operations like filtration, centrifugation and drying, that were carried out in the laboratory in order to generate the desired product. The plant

setup and process chemistry constitute process specific knowledge; that is, they give details about a particular process that has to be carried out in a certain plant. In addition, we have process general knowledge. These are models that tell us how to perform a certain type of operation in a particular kind of equipment. An example would be a model representing the sequence of tasks that need to be performed to heat the contents of a reactor. Here the operation type is heating and the equipment type is reactor. Making use of the process specific and process generic knowledge the sequence of operating procedures are to be developed.

The key issues towards solving the automation problem are knowledge representation and planning. The knowledge representation strategy should be able to handle both the process specific and process generic knowledge in a flexible manner that can facilitate easy modification, and also address the discrete event character of batch processes. We solve these needs by adopting object oriented techniques to model process specific knowledge and a framework called Grafcets for representing the process generic knowledge. Grafcets is a discrete event modeling framework based on Petri nets concepts. Grafcets is ideal for representing task sequences that are encountered in batch plant operations.

Planning provides the control strategy that utilizes the process specific and process general knowledge to generate the exact sequence of tasks that need to be performed by the operator to produce the required product in a certain batch plant facility. We use hierarchical planning for the problem of sequence generation. This approach tackles the problem of sequencing the operations first at the level of operations like reaction and unit operations such as centrifugation, filtration etc. These can be called higher-level operations. Once the details of performing these operations are worked out, then the control strategy becomes more fine grained. It takes apart these higher level operations and sequences the tasks that make up these operations. For example, a reaction operation could consist of charging the inputs, heating the mixture of inputs. So the planning strategy would determine in what order and in which pieces of equipment the two charging subtasks and the heat subtask need to be performed. The nature of the planning strategy helps it exploit the structured modeling framework of Grafcets to come up with a feasible set of operating procedures.

The proposed framework has been implemented in Gensym's object-oriented expert system environment called G2. The salient features of the framework have been tested on a real-life pharmaceutical case study and the results are found to compare favorably with the operating procedures that were developed by the experts.