241a Smart Enterprises: Integrated Environment for Hybrid Data-Driven/Model-Centric Support of Manufacturing Operations

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Throughout the 1990s, the computer-aided process engineering (CAPE) community made considerable progress in two strategic areas: the technical development and commercialisation of general-purpose modelling environments, and the standardisation and validation of open interface specifications for component-based modelling and simulation. Not only did these advances motivate the widespread use of rigorous process models to solve conventional process-engineering problems of interest to both the academy and industry, but they also inspired a genuine interest in model-centric technologies.

The potential of model-centric technologies as support systems of industrial manufacturing operations has long been recognised within the CAPE community. However, in order to succeed in their insertion in the industrial environment, model-based software tools must overcome a series of challenges limiting their ability to meet the needs of the Smart Enterprise. First, a series of software components aiming at assisting the definition of hybrid data-driven/model-based problems must be created so that realistic process-engineering problems can be defined and solved. Second, these software components must be integrated seamlessly into a single environment so that points-of-synergy between complementarity model-based technologies can be unravelled and exploited.

In this work we present a software environment for integrated simulation, estimation/reconciliation and optimisation of large-scale/plant-wide industrial process systems based on mechanistic process models. This environment is inspired on a framework that eases the definition of rigorous model-based activities and promotes the transfer of knowledge between complementary model-based software tools.

The framework proposed in this work redefines the architecture for software development and identifies the scope of a novel software tool, the Problem Definition Component (PDC). The PDC manages the definition of advanced hybrid data-driven/model-based problems by a series of mechanisms which entail the manipulation of the so-called Data Model Templates (DMTs) and Data Model Definitions (DMDs).

The DMT/DMD mechanism creates an innovative means to capture both in-house knowledge on the process system and expertise on the use of model-centric tools and combine these with experimental process data with the aim to support process operations. DMTs/DMDs also provide increased opportunities for language-neutral documentation and re-use of case-studies that further promote the continuity of corporate memory. Overall, the introduction of these data models redefines the way hybrid data-driven/model-based problems are defined by users of model-centric technologies and it creates a paradigm that brings model-based software tools closer to users in the industrial workplace.

In this work, we present an environment which has been tailored to support the operation of the continuous pulping system of a state-of-the-art industrial pulp and paper mill. The results of the several case-studies provide excellent feedback to both the Pulp and Paper and Process Industries.

First, the process model is validated as a suitable representation of the process system according to the statistical analysis of results. The economic incentive for accurate inventory analysis and production accounting is highlighted in this first case-study. In the second case-study, historical operating conditions of the continuous pulping system are explored in a hybrid dynamic simulation activity for extended inferential monitoring and troubleshooting. The case-study for improvement of the nominal operating conditions of the continuous pulping system at a given production level shows the chances for millionaire profit increases through a less intensive use of cooking chemicals and a more effective distribution of the available liquor. In the last case-study, a transient operating procedure which reduces

the variability of quality control indicators of the continuous cooking digester during scheduled transitions is determined. These results provide further insight into the optimal transition management of production rate changes which are a regular operating practice in modern pulp and paper mills.

Overall, the environment for integrated model-centric support offers an unparalleled chance to assimilate recent advances in modelling and solution engines, open-software architectures and information technology within the industrial environment. This software tool facilitates the execution of a series of model-based process-engineering activities in a progression that reshapes raw plant data into useful process knowledge. This opportunity for unprecedented process analysis and improvement gives the Smart Enterprise of the new millennium a genuine competitive advantage for continuous optimisation of manufacturing operations.