Automated Process Design Using Web-Service based Parameterised Constructors

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Abstract

This paper introduces a web-service based approach in conceptual process design, parameterised constructors, which are able to construct process and initial data for control system configuration. Constructors use unit process or larger sub-process templates readily available in a plant model library. The templates consist of upper level process structures, control descriptions and detailed process structures. Thus, the preliminary process design can be defined in a more general level and as the design process proceeds, more accurate models (e.g. PI and automation diagrams, simulation models) are composed and used. Definitions of a common data model are also discussed.

Keywords: Conceptual process design, parameterised constructor, web-service framework, plant model, process life-cycle

1. Introduction

Open extensibility for value-added services is becoming an essential issue in information management during all phases of process life cycle, from process design to demolition. The progress in information technologies offers possibilities for new kind of integration of process design systems, simulation tools and different value-added services such as dimensioning tools and intelligent constructors. The new value-added services are implemented as web services. A common data model, manipulated through web service interfaces, links and reflects the different requirements of the process and automation design, delivery project and plant operation and maintenance.

The objective of this paper is to introduce a value-added service applicable to construct a process and a control system configuration. In practice, the processes consists of almost alike structures. However, template based reuse does not solve the whole design problem because the modifications may be laborious. Thus more intelligent software components, parameterised constructors, are needed.

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2. Design support systems for conceptual process design

In recent years, numerous approaches have been developed to support the activities in chemical process design. In this chapter, a few new methods are presented.

Rodriguez-Martinez et al. (2004) have represented a proposal of a multi-model knowledge representation to be used within a retrofit methodology for chemical processes. The retrofit methodology consists of four steps: data extraction, analysis, modification and evaluation. The use of structural, behavioural, functional and teleological models of process equipment/devices allows the designer to work with a combination of detailed and abstract information depending on the retrofit step.

Marquardt and Nagl (2004) have studied the early phases of the chemical process design lifecycle, the conceptual design and front-end engineering. The research issues were development of an integrated information model of the design process, a number of innovative functionalities to support collaborative design, and a-posterior integration of existing software tools to an integrated design support environment.

Efficient networking emphasises the need to have a common data model. In different process design phases of the process life cycle, several interest groups interact and need to exchange information between each other. Global CAPE-OPEN is a project for standardising communication between components in process engineering, leading to the availability of software components offered by leading vendors, research institutes and specialised suppliers. This will enable the process industries to reach new quality and productivity levels in designing and operating their plants (CO-LaN, 2005).

Open issues of information modelling are also discussed by Schneider and Marquardt (2002) and Bayer and Marquardt (2004). They have developed a conceptual model framework CliP, which holds solution approaches for the integrated representation of information and work processes, the description of documents as carriers of data, and the integration of existing data models. CliP can also serve as an integration basis for existing information models.

Because design processes are highly creative, many design alternatives are explored, and both unexpected and planned feedback occurs frequently. Therefore, it is difficult to manage the workflows in design processes. One approach to manage design processes is the web-service framework, which also supports the progress of a new kind of design practice (Kondelin et. al., 2004).

3. Web-service framework

In order to achieve tool integration for the whole process plant life cycle, a domain specific framework specification is needed. The specification takes into account the software architectural aspects and the variety of existing production related information systems that end users have.

Compared to the use of separate systems, the proposed service framework provides

- a common user interface and knowledge presentation
- a common way to extend the existing systems with new value-added services

The framework also enables discovering and binding of the services by service requestors. It thus makes it viable to construct, compose and consume software component based web services, which will add domain specific value.

Life cycle information management is a common concern in research and development activities today. The issue is addressed from different viewpoints in several national and international projects. All these activities support the need of a generic framework for information management.

The framework can be divided into core services, framework services and value added services. The interfaces of core services and framework services are defined in the framework specification while the interfaces of value added services are not fixed beforehand. Core services represent legacy systems in the architecture such as process design systems, simulators or control systems. The most important core service from the viewpoint of the case of this paper is the plant model core service. The plant model service contains information that is accumulated in design time, updated and specified in operational phase, and used by various services of the framework during various life cycle phases (Kondelin et. al., 2004).

3.1 Common data model of the web-service framework

A common data model (a plant model) offers possibility for transformations between different application software attached to the framework. For example different management, design and simulation tools are used at different stages of the process life cycle and many of them are incompatible.

The plant model is actually a domain specific meta-model that describes how object types are defined. Object types are created by defining plant object types, property types, and relation types according to the meta-model. In addition, relation rules that restrict relations between objects and properties are defined. Object types describe the common taxonomy for plant object instances. In the framework, instances are represented and transferred as XML fragments that conform to the plant data model, which is defined by utilizing XML Schema type definitions (Kondelin et. al., 2004).

In the case described in this paper, there are four different object types depicted in Figure 1. The Conceptual function type represents upper level functions of some kind, such as pressure change. The Constructional function type represents more specific functions analogous with objects in a PI-chart. Conceptual functions may contain several constructional functions.

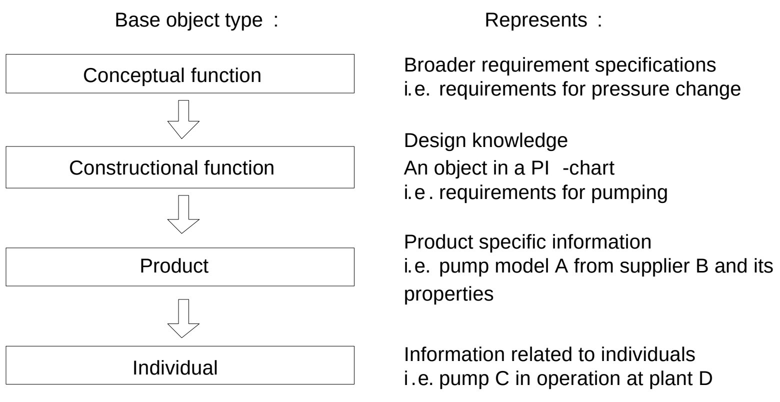

Figure 1. Base object types

The Product type realizes the functionality of the Constructional function type i.e. an equipment type. The Individual type represent equipment individual (e.g. pump A in plant X).

3.2 Parameterised constructors

Parameterised constructors can be applied to construct process and produce initial data for configuration. They use unit process templates and larger sub-process readily available in a plant model library. The templates consist of upper level process structures, control descriptions and detailed process structures. Parameterised constructors are used to:

- Generate process structures and/or parts of the processes.
- Intensify routine process design tasks.
- Generate operational descriptions. Based on the loop type descriptions detailed initial data is generated for control engineers for design purposes, operation information for operators is also given.
- Integrate operability and flexibility considerations into the process synthesis procedures.

The benefit of using constructors is that the preliminary process design can be at first defined in a more general level. As the design proceeds, more accurate models (e.g. PI and automation diagrams, simulation models) are used. Unit processes and equipment models are defined to the plant model library and based on the user selections the plant model is dynamically created. The constructors also generate control scheme according to the user's selections and include it into the plant model. As a result, detailed operational descriptions are generated and are readily available to the control system supplier for configuration.

3.3 Process templates

Similar process structures are often used in the design of processes. Existing design knowledge, like upper level process structures, automation diagrams and detailed process structures, is stored in the templates. They are defined to whole plant models, unit process models and equipment models, and stored in the plant model library. Different templates can be defined for the same process structure. Templates can also be differently equipped depending on the purpose of the design task. The templates in the plant library are updated when new design concepts, like new and better technical solutions or process improvements, are developed.

4. Case study: Fibre Refining Process

The fibre refining process is a part of a stock preparation department in the paper plant. Typically, stock preparation consists of several refining lines, which produce different stock to the paper machine. Refining is one of the most important stages in raw material affecting the running of paper machine and especially the paper properties. Typically, there are two or three refiners in a series in a production line supplying one paper machine. Possible process design tasks are the following:

1. Utilize existing similar design concepts (old design documents)
2. Create new design concept
3. Equipment delivery

4. Control system delivery
5. Define service and maintenance routines

4.1 Definition of plant object types

Before an engineering project, a set of object types is defined. In many cases, previous, well-established types can be re-used. The object types of the plant model are described in Section 3.1. The initial data and parameters for the conceptual model are derived from basis of design i.e. requirement specifications (raw materials, products, capacity, consistency, power demand, etc.). Conceptual models of processes or sub-processes are also generalised in three sections: pre-treatment (raw material purification, initial feed), primary treatment (reaction, refining) and post treatment (product separation, recycle, discharge). Application-wide conceptual functions are derived from those generalized functions. An example of conceptual object type, Short Fibre Line, in which the essential properties (e.g. capacity, furnish, consistency) of the fibre line are defined, is presented in Table 1. The Short Fibre Line object type also includes information about unit processes it is composed of. The constructional, product and individual object types are defined in the similar way depending of accuracy of design.

Table 1. Short Fibre Line object type.

Short Fibre Line	property	type	property set	description
(conceptual	Raw materials	enum	design	list of raw materials
function	Products	enum	design	list of products
type)	Capacity	double	design	admt/d, bdkg/min.
	Consistency	double	design	percentage of solids
	Initial Feed	boolean	design	feed from pulper
	Feed	boolean	design	pre-processing
	Refining	boolean	design	primary processing
	Recycling	boolean	design	post processing
	Discharge	boolean	design	feed blending chest

4.2 Use case: Design a new process concept

The fibre line design process begins with definition of functions in the conceptual level. First, the initial data of the refining process is defined. The initial data includes definition of stock to be produced, capacity of the refining line, specific refining energy, number of refiners, and connections of refiners (parallel/series). At this stage the upper level templates, from which the refining line is composed, are chosen. The upper level templates are e.g. Feed, Refining and Recycle. Depending on user’s input and selections, the conceptual model is further composed by the constructor. The user can define what type of control loops (e.g. liquid level control, flow rate control) these functions are equipped with. When the conceptual plant model is sufficiently defined, the constructor begins to compose the constructional plant model based on user’s selections. Constructional and control system hierarchies and their component type instances are dynamically composed and the suitable unit process templates are chosen from the plant model library. Unit process templates contain PI- and automation diagrams in SVG graphic-format. The constructional model can be disaggregated in very detailed level, e.g. every single pipeline component can be modelled.

Operational description definitions i.e. loop type description of commonly used control systems are readily defined in the plant model library. The user selects and checks initial information for control system design, e.g. which kind of control structures is used. The constructor ensures that the operational description e.g. of liquid level control of the pulp tower is transformed to an automation schema, which is used by the automation system supplier. When the constructional plant model is defined, the user can transform the plant model to simulation service. Equipment selections and dimensioning, different operation value studies and mass and energy balance calculations are made in the simulator. After simulation the plant model is updated.

4.3 Hierarchies of the plant model

During an engineering project, object types are instantiated and the plant model is constructed in different hierarchies. From web-service framework viewpoint, each hierarchy is a different view to the plant model. The constructors ensure that hierarchies, objects and their relations remain consistent. The fibre line upper level conceptual model hierarchy is formed based on the user selections when defining the requirement specifications for the process. After the conceptual modelling is finished, i.e. the process designer continues to the next design step, the constructional model hierarchy is derived by the constructor. The structure of the constructional hierarchy is based on the user's selections in the conceptual design phase. Product hierarchy is formed based on equipment models. Individual hierarchy consists of e.g. equipment operating in the plant.

Conclusion

In practice, processes are often designed based on previous solutions and using almost similar unit process structures. Routine process and control system design can be intensified using process templates readily defined in a plant model library and parameterised constructors. This approach also supports chance of design practice so that one designer will be responsible for all the design tasks of a certain sub-process.

The web-service framework, which is able to manage all the information during process life cycle, and the common plant model give an opportunity for the integration of process and control system design, simulation, operation and maintenance and plant concept modelling. This means that any plant-modelling task is not a separate duty but an integrated part of information management in a plant delivery project.

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