AN OBJECT-ORIENTED DESIGN PATTERN FOR MODELING CONTINUOUS PROCESS APPLICATIONS*

JONAS A. MONTILVA C.[1]

EDGAR A. CHACÓN R.[2]

University of Los Andes
Faculty of Engineering
Computer Science Department
[1] Data & Knowledge Engineering Research Group (GIDyC)
[2] LaSDAI and CESIMO
Mérida, Mérida, 5101, Venezuela

Abstract

In this paper, we propose an object-oriented design pattern that can be used for modeling continuous process applications. The pattern is based on the notion of organizational systems which considers a production system from a holistic perspective. The pattern integrates the decision making processes of the hierarchical structure of an organization with the control and physical processes that characterize a continuous production industry. It provides the essential object classes that are required in most continuous process applications, such as real-time information systems for manufacturing and continuous process industries.

Keywords: Continuous process modeling, OO design patterns, enterprise integration modeling, real time information systems.

1. INTRODUCTION

Continuous process applications are a special kind of business applications that deal with the problem of supplying information for decision taking, control and automation purposes in industrial organizations. The domain or wider system of a continuous process application is an *organizational system*, that is a human-made activity system that performs a set of processes (activities), in order to achieve a set of ends that have been previously defined. An organizational system is a purposeful system. Its processes are carried out by actors (people and/or machines) in order to reach the pre-defined ends. Actors require information for performing processes. The information required by an actor depends on the level on which the actor operates into the decision making hierarchy of the organizational system. The role of a continuous process application is, therefore, to provide the information that actors

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requires, at the different levels of the hierarchy, for executing the planning, control and physical processes that conform a continuous production process.

This paper introduces an object-oriented design pattern that can be used for designing applications in manufacturing, batch and continuous production organizations. The purpose of our design pattern is to serve as a reference model for understanding and representing the organizational system during the process of developing a continuous process application, such as a real-time information system in a continuous production industry.

By design pattern we mean an abstraction that captures the essential structure of a proven solution to a recurring problem within a certain context [1]. An object-oriented design pattern provides an object scheme for refining the components of a software application that are recurring within a given context [2]. We use here the OMT notation [3] for documenting the pattern. Other object-oriented notations, such as [4,5,6,7] could also be applied for describing the pattern.

In most of business applications, including continuous process applications, the business process is a central component to be considered when modeling the application. In fact, the process is the central type of entity to be represented in the integrated automation of continuous processes in industrial organizations [8,9,10].

A good understanding of the different business processes of an organizational system is crucial for designing continuous process applications. We believe that a design pattern that provides a generic reference model of all the processes along the decision making hierarchy of an organizational system could be very useful for modeling and integrating continuous process applications. This design pattern could be applied, for instance, as a reuse mechanism for designing the object model of a particular a real-time information system for a continuous production process.

The paper is organized as follows. Section 2 introduces the notion of organizational system as a context, environment or wider system of a continuous process application. The model of an organizational system is described in this section based on its main components: ends, processes, actors, entities rules, technologies, events, and job structure. The notion of continuous production process is presented in section 3. Its characteristics and the architecture of the decision taking process are given in this section. The object-oriented design pattern is described in section 4. How the design pattern can be used in designing business applications for continuous processes industries is explained in section 5. Finally, the concluding remarks are discussed in section 6.

2. ORGANIZATIONAL SYSTEMS

An organizational system may be seen as an organized set of activities or *processes* that are designed and performed by a group of *actors* with the purpose of achieving a set of predefined *ends*. Actors could be humans, machines or a set of both.

Human actors are organized into a *job structure* (e.g. departments, divisions or production units) which defines the responsibilities for performing the processes. The job structure also defines a typical three level hierarchy of decision making. These levels are normally referred to as strategic planning, management control and operational control.

Each process requires, uses or involves a set of *entities* (e.g. personnel, clients, raw materials, products and clients) and one or more *technologies* (e.g., methods, techniques or devices).

A process is triggered by an *event* that represents a new operation conditions (e.g., the arrival of raw material or a service order) or a failure in the process (e.g., failures in a device, goals not achieved in a predetermined time). An event may modify the *state* of the entities involved in the process.

A process is regulated by *business rules* (e.g., laws, policies, norms, procedures and regulation or control algorithms).

These components of an organizational system and their inter-relationships are partly shown in Fig.1.

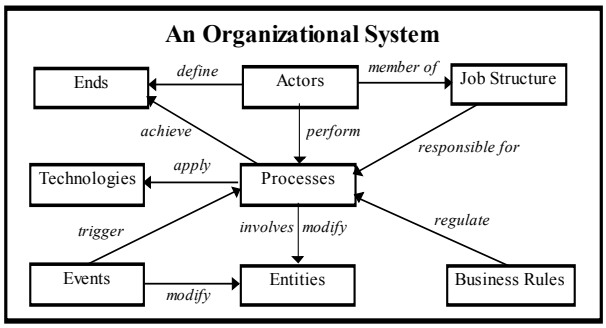

FIGURE 1. COMPONENTS OF AN ORGANIZATIONAL SYSTEM

3. CONTINUOUS PRODUCTION PROCESSES

A continuous production process involves many production units that are physically interconnected. Each production unit has predefined ends, which are established by actors in an upper decision making level. Each production unit have actors that perform processes that are of different nature, such as : optimization tasks that improve the performance of the material transformation or generation of the process; control tasks that perform monitoring, regulation and actuation activities (control process) ; and the transformation activities. Each production unit can be considered autonomous but it must ensure that its outputs are compatible with other units, as shown in Figure 2.

The control activities are performed in a cyclic manner that involve the detection and measurement of the process, the evaluation of its state, the generation of new set points and the delivery of information to the *effectors* (units).

Several decision making levels are found in a factory or plant and the difference of their components are related to the kinds of activities performed at each level. For a unit, the ends determine the actions that the unit must perform. For its supervisor, the unit ends are the set points that the unit (effector) must accomplish. This way of working is general or common for each level found at the plant.

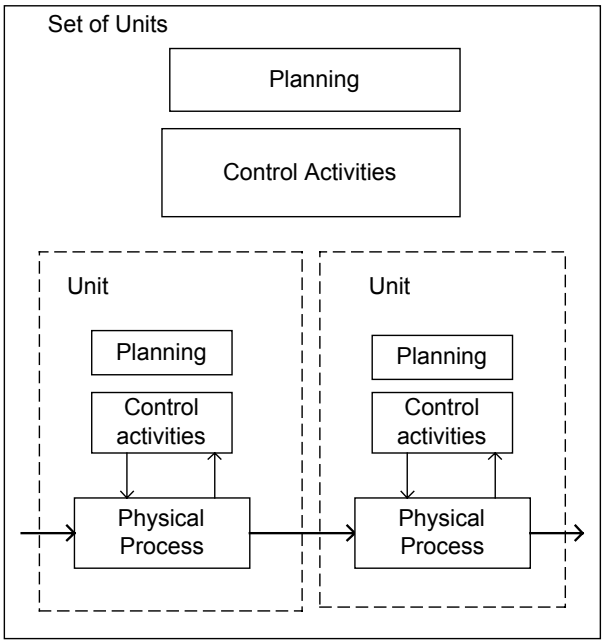

FIGURE 2. A CONTINUOUS PRODUCTION PROCESS STRUCTURE

The development of the control activities is similar at each level, and the information required (i.e., the knowledge about the state of the supervised process) is recovered from the data bases located at the supervised level. Data is updated by the transformation process in a real-time mode. Sensors for the decision processes measures changes in the lower level processes by reading their data bases. An evaluation of the supervised unit (determined from the measured conditions of its process) establishes the achieving of the goals in order to fix new production goals, as shown in Figure 3.

An effector modifies ends at the data base of the supervised level, and updates the information in the data base associated with its current level. Ends and performance are the principal means of communication among the supervisors and the processes. One of the most important element here is the information process. This process is the interface between adjacent levels with different ends and technology. The information process informs to the supervisors, in real-time and synchronously at the physical regulatory systems interface, about the state of the process and signals by events transmission when changes in the supervised process appear.

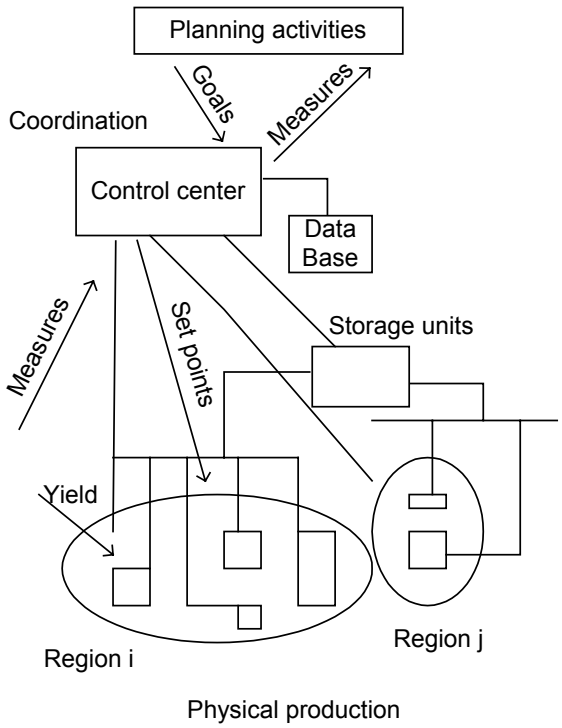

FIGURE 3. AN INTEGRATED PRODUCTION INDUSTRY

4. THE O-O DESIGN PATTERN

The central component of our design pattern is the process associated with a production unit. A continuous production process is a composite object whose components are other processes which, in turn, are made of sub-processes at a lower level. A transformation process, for instance, is a composite process that can be decomposed into a hierarchy of processes at several levels of depth.

The processes of a production unit are of three different types or classes : decision making processes, transformation processes and information processes. A unit has a decision making process (DMP) that supervises a transformation process by means of the information managed and provided by the information process. A DMP regulates a transformation process by setting production constraints. An information process is updated by a transformation process.

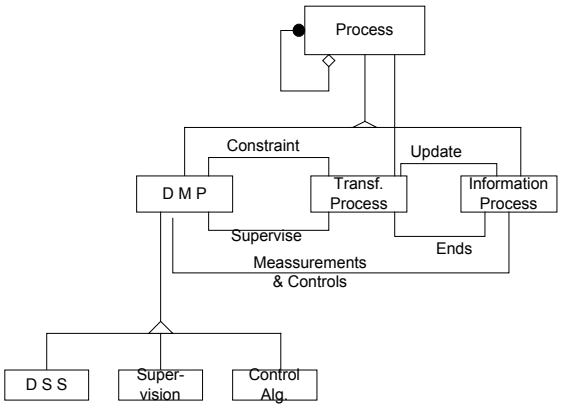

FIGURE 4. THE OO PATTERN FOR CONTINUOUS PROCESS APPLICATIONS

A decision making process can be classified into three different categories of processes : decision support systems, supervision processes, and control algorithms.

The transformation process can be a physical process, a coordination process, an optimization process, etc. Each one of them uses methods, techniques, and technology in order to measure, recognize the state and establish new goals.

Finally, an information process may be classified into three categories : data acquisition process, data administration process, and information generation process.

As shown by Figure 4, the control process is an activity that can be generalized and a design pattern can therefore be derived. Independently of the kind of process, the cycle of decision is the same for continuous production processes.

5. USING THE OO DESIGN PATTERN

An oil production process involves many production units that must be coordinated. Production units have ends and goals to accomplish for time units. Those goals are established looking for an optimal production that takes into account the equipment restrictions and fails, and the conditions of the production yields. The goals are established for a production region that have several yields. In a production region the main constraints are the capacity of the storage tanks, the energy used, and the capabilities of equipment. The conditions change continuously, and the

decision systems must work according to those changes. The information system must provide updated information to the decision support systems and must transmit the decisions to the actors that drive the process by using the channels of the information system.

6. CONCLUSIONS

The object-oriented design pattern introduced in this paper uses the notion of organizational system as a vehicle for obtaining a better comprehension of a continuous process application domain. It provides a framework for representing the application domain from a systemic point of view. The pattern is a reusable set of generic classes that can be specialized or used as templates for accommodating the specific requirements of particular application in the domain of continuous production industries.

Using our design pattern has the following benefits:

- A better understanding of the ends, process, actors, rules, job structure, events and entities of a continuous process system is achieved.
- The role of a continuous process application is understood from a major and wider business perspective.
- It reduces the cost and time needed for developing a continuous process application.

Although the pattern is oriented to continuous process applications in industrial organizations, it could be adapted to be used as a reference framework for a) organizational modeling in Business Process Reengineering [11]; b) designing information systems architectures [12]; and c) designing enterprise integration models [13].

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