

# Reactive Processes

Monika Solanki\* and Craig Chapman  
Knowledge Based Engineering Lab  
Birmingham City University, UK  
{monika.solanki, craig.chapman}@bcu.ac.uk

**Abstract.** In this paper we present the *Reactor Pattern* to enable the modelling of processes that consume inputs and produce outputs under specific environmental conditions and on being triggered by certain events. Reactor pattern is a content ontology design pattern and is especially targeted towards modelling reactive processes with a “black box” view of the process.

## 1 Introduction

Many scenarios in the engineering, manufacturing and biotechnologies sectors employ “reactive” processes, usually carried out in a closed system, e.g., a bioreactor in which a chemical process is carried out, which involves organisms or biochemically active substances derived from such organisms. Such processes consume inputs and produce outputs in a controlled environment and on being triggered by certain events. The purpose of the reactor pattern is to enable the ontological modelling of such reactive processes in a generic way across multiple domains. The reactor pattern is a content design pattern and provides ontological placeholders for input and output parameters, environmental conditions and events. The pattern exploits other CPs for the definition of certain entities.

## 2 Reactor Pattern

### 2.1 Intent

The remit of the reactor pattern is to enable the modelling of processes that are reactive, consume inputs and produce outputs under specific environmental conditions a.k.a. constraints and on being triggered by certain events. Reactive processes are parametric where the governing parameters are process inputs and outputs. The pattern can be instantiated to provide a knowledge level solution to the problem of capturing parametric process related information in a domain independent way.

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\* Principal and corresponding author

## 2.2 Competency Questions:

- What are the “types” of inputs consumed by a certain process?
- What are the “types” of outputs produced by a certain process?
- What are the values of parameters for a certain process?
- What is the measurement criteria for a specific parameter?
- What environmental conditions need to hold for the process to get activated?
- Which event triggers a specific process?

## 2.3 Some Conceptual Elements

- **Process**: placeholder for a process. The concept covers the definition of a generic process.
- **ParametricProcess**: placeholder for a process governed by parameters.
- **ReactiveProcess**: a process specialising from **ParametricProcess**. Note that in our abstraction, a reactive process needs to explicitly define at least one input and output.
- **ProcessParameter**: an overarching entity representing parameters consumed and produced by the process. The concept extends from **Parameter** defined in the Parameter<sup>1</sup> CP.
- **InputParameter**: a specialisation of the **ProcessParameter** representing the input parameter. A process can consume several inputs.
- **OutputParameter**: a specialisation of the **ProcessParameter** representing the output parameter. A process can produce several outputs.
- **EnvironmentalCondition**: an entity representing environmental conditions governing the activation of the process. The condition may be specified as a SWRL rule<sup>2</sup>. There can be several environmental conditions for a process.
- **Event**: an event that triggers the process.
- **hasEnvironmentalCondition**: a relation between the environmental condition and the process.
- **triggeredBy**: a relation between the process and the environment.
- **definesCondition**: a relation between, **EnvironmentalCondition** and one or more conditions it enforces.

It is worth noting that we explicitly abstract from providing further details on how the environmental conditions are represented or how the parameter measurements are defined. These are not part of the pattern definition. Well defined existing vocabularies such as the LOD ontology<sup>3</sup> for modelling events and the QUDT vocabulary<sup>4</sup> for measurement units should be exploited to provide definitions for these concepts.

<sup>1</sup> <http://www.ontologydesignpatterns.org/cp/owl/parameter.owl>

<sup>2</sup> <http://www.w3.org/Submission/SWRL/>

<sup>3</sup> <http://linkedevents.org/ontology/>

<sup>4</sup> <http://qudt.org/1.1/vocab/dimensionalunit>

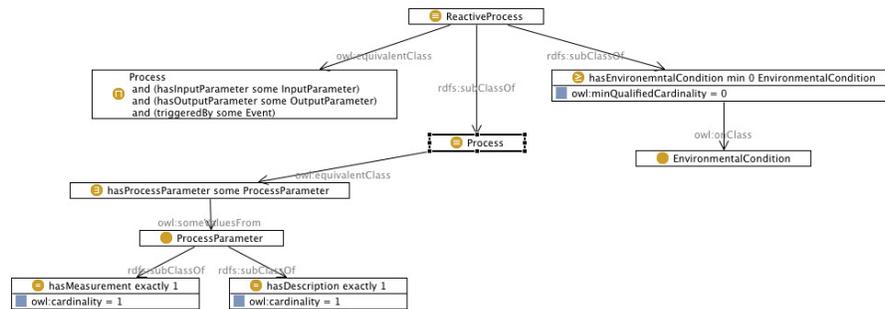
## 2.4 Pattern Representation

The core concept in the pattern is a reactive process, parameterised with inputs and outputs. A Manchester syntax rendering of the concept is illustrated below.

```

Class: ReactiveProcess
  EquivalentTo:
    ParametericProcess
    and (hasInputParameter some InputParameter)
    and (hasOutputParameter some OutputParameter)
    and (triggeredBy some Event)
  SubClassOf:
    hasEnvironemntalCondition min 0 EnvironmentalCondition,
    ParametericProcess
  
```

Figure 1 depicts the graphical representation of the reactor pattern <sup>5 6</sup>.



**Fig. 1.** Graphical Representation of Reactor Pattern

## 2.5 Consequences

The main advantage of this pattern is that it provides ontological modelling capabilities for the inputs, outputs and environmental conditions that govern reactive processes across several domains, independent of modelling details of the actual reactor involved. This effectively caters for exposing a black box view of the process, which is very desirable when querying the model for consumption and production logistics of the process.

<sup>5</sup> The OWL ontology for the pattern is available at <http://purl.org/biomass/ReactorPattern>

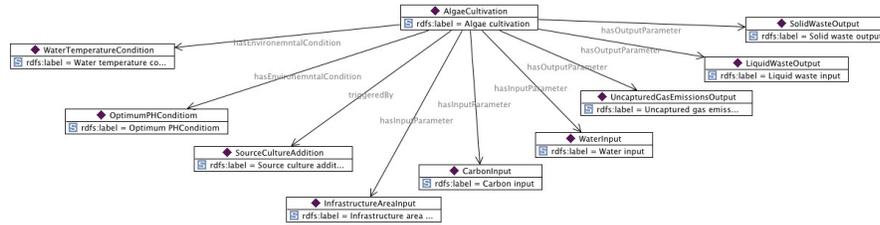
<sup>6</sup> Graphical representations of the pattern in this paper have been produced using a trial version of the Maestro edition of TopBraid Composer.

## 2.6 Example usage: Algal Biomass Domain

As an exemplifier for the reactor pattern, we present a use case from the domain of algal biomass. The set of inputs to the process of algal biomass cultivation are carbon, water, total infrastructure area, total energy, nutrients, consumables and labour. Possible outputs from the process are algal constituent products, indirect algal products, uncaptured gas emission, liquid waste output, solid waste output. Some environmental conditions that must hold for the algae to be harvested are,

- The water must be in a temperature range that will support the specific algal species being grown.
- The pH range for most cultured algal species should be between 7 and 9, with the optimum range being 8.2-8.7.

The event that triggers of the algae cultivation is the addition of the source culture to the growing containers or reactors. Figure 2 depicts the application of the reactor pattern.



**Fig. 2.** Graphical Representation of reactor pattern for modelling the algal cultivation process

## 3 Summary

The reactor pattern provides a building block for the ontological modelling of reactive processes. The pattern can be used across domains in scenarios where a reactor is used to run processes that consume inputs to produce outputs under controlled environmental conditions and when triggered by certain events. As an example, the pattern has been applied to the algal biomass domain to model the reactive process of algae cultivation.