Towards a semantic-based process supervision

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Process supervision deals with the detection and isolation of abnormal events. It consists of determining the current state of the real process from sensor readings and process knowledge. In Chemical industry, this task is of crucial importance in terms of safety and also of economics, because of the influence of abnormal situations in yield and quality of products.

Although several advanced supervision approaches have been proposed from academia, in industry the management of abnormal situation usually rely on skilled operators who monitor the process variable over a distributed control system (DCS). The problem with several advanced supervision methods is that they are "black box" solutions based on monolithic strategies that require the analysis of a huge amount of data for each implementation, thus resulting in an intensive task in terms of time, effort and money. In order to develop more generalized and transparent solutions, the interest on knowledge-based supervision system arise. However, most of them adopt a rule-based approach which has some drawbacks due to the limited expressiveness and the difficulty to share the knowledge. Consistency maintenance is also a problem because when the rules are modified, the semantic impact in the rest of the system can not be easily controlled. In addition, modern industries present a challenge in integrating the information needed for process supervision since they are big and complex environments involving multiples sources of technology, software and instruments.

In this context, we propose the use of semantic web technologies to develop a knowledge-based framework for process supervision. The semantic web technologies leverages knowledge integration and exploitation in distributed environments. They propose knowledge to be modeled using ontologies and formalized by means of description logic-based languages such as OWL. These languages have a good trade-off between expressiveness and computational tractability. On account of these features, ontology-based modeling has attracted the attention in process systems engineering (PSE) domain as a convenient mean of knowledge representation [1], but less attention has been paid to the associated reasoning mechanisms.

This thesis attempts to exploit the deductive capabilities of the semantic reasoners to automate the supervision task through a knowledge-driven approach. With that aim, we have explored the characteristics of DL-based modeling and reasoning to support qualitative supervision methods. The emphasis have been placed in multivariate data analysis. Through them, failures are detected and diagnosed using patterns of qualitative symptoms (i.e. Fault Signatures) that involve several process variables.

We first applied multivariate analysis with timeless patterns [2, 3]. In this approach, fault signatures are composed by a set of parameters deviations included into the knowledge base as OWL axioms. By mean of these axioms any off-the-shelf DL-based reasoner can detect hazard situations from the process measurements. Useful information associated to these events, such as the involved equipments, instruments and control systems are easily accessed as all data are linked in a consistent way. An incremental reasoning scheme has also proposed in order to achieve supervision tasks be performed on-line. However this supervision method do not consider the process dynamics for it analysis since the fault signatures are searched in snapshot views of the process.

In order to support the monitoring of process dynamics a novel ontology-based framework that manage temporal abstraction (TA) has been introduced [4]. It is a more general and powerful solution that is able to reason over temporal patterns by mean of time intervals-based operators [5]. The framework provides a valuable tool for intelligent data analysis (IDA) since diverse qualitative representations of one or more dynamic properties can be combined to discover complex temporal patterns.

These supervision strategies lie on a set of novel ontologies. Industrial standards were employed to build conceptualization of Equipments, Control Systems, HAZOP analysis and Fault Conditions. Additionally, heavyweight ontologies has also been employed whit a focus on integrability: DOLCE, SSN, SWRL Temporal Ontology.

Our experiments have showed promising results on detecting and diagnosing failures, and characterizing hazard situation on several chemical industrial benchmarks. DL reasoners was able to manage the knowledge consistency and formally justify the obtained results. The latter is an appreciated feature in this kind of hazardous environment since it enables to audit the supervision decisions, making the system more dependable.

Future work will be in the direction of multi-scale qualitative supervision. This involves new challenges on modeling processes at several resolution levels. Reasoning must be also improved to support more complex pattern composed by qualitative episodes at different scales.

References

1. Morbach, J., Wiesner, A., Marquardt, W.: Onto cape-a (re-) usable ontology for computer-aided process engineering. Computers & Chemical Engineering **33** (2009) 1546–1556
2. Musulin, E., Roda, F., Basualdo, M.: A knowledge-driven approach for process supervision in chemical plants. Computers & Chemical Engineering **59** (2013) 164–177
3. Roda, F., Musulin, E., Basualdo, M.: Ontology-based representation schemes for data integration in plant information systems. Iberoamerican Journal of Industrial Engineering **5**(9) (2013) 171–185
4. Roda, F., M.E.: An ontology-based framework to support multivariate qualitative data analysis. In: Computer Aided Chemical Engineering. Elsevier (2014)
5. Allen, J.F.: Maintaining knowledge about temporal intervals. Communications of the ACM **26**(11) (1983) 832–843