The Development of an Integrated Process Operation Management System

A thesis submitted for the degree of

Doctor of Philosophy

by

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I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

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Yvonne Power

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To my Grandfather

Jure Tabain (January 25, 1921 – November 3. 2003)

For his Wisdom & Guidance

SUMMARY

This project details the development of a new framework known as the Coordinated Knowledge Management method to enable complete task integration of all low and mid-level tasks for process industries. The framework overcomes past problems of task integration, which made it impossible to have a fully integrated system and with integration being limited to data acquisition, regulatory control and occasionally supervisory control. The main component of the project includes the use of hierarchically structured timed place Petri nets, which have not previously been used for integrating tasks in intelligent process operations management. Tasks which have been integrated include all low-level tasks such as data acquisition, regulatory control and data reconciliation, and all mid-level tasks including supervisory control and most significantly the integration of process monitoring / fault detection and diagnosis.

The Coordinated Knowledge Management method makes use of hierarchical timed place Petri nets to (i) coordinate tasks, (ii) monitor the system, (iii) activate tasks, (iv) send requests for data updates and (iv) receive notice when tasks are complete. Visualization of the state of the system is achieved through the moving tokens in the Petri net. The integration Petri nets are generic enough to be applied to any plant for integration using existing modules thus allowing the integration of different tasks, which use different problem solving methodologies.

Integrating tasks into an intelligent architecture has been difficult to achieve in the past since the developed framework must be able to take into account information flow and timing in a continuously changing environment. In this thesis Petri nets have been applied to continuous process operations rather than to batch processes as in the past. In a continuous process, raw materials are fed and products are delivered continuously at known flow-rates and the plant is generally operated at steady state (Gu and Bahri, 2002).

However, even in a continuous process, data is received from the distributed control system (DCS) at discrete time intervals. By transforming this data into process events, a Petri net can be used for overseeing process operations.

The use of hierarchical Petri nets as the coordination mechanism introduces inherent hierarchy without the rigidity of previous methods. Petri nets are used to model the conditions and events occurring within the system and modules. This enables the development of a self-monitoring system, which takes into account information flow and timing in a continuously changing environment. Another major obstacle to integration of tasks in the past has been the presence of faults in the process. The project included the integration of fault detection and diagnosis a component not integrated into current systems but which is necessary to prevent abnormal plant operation. A novel two-step supervisory fault detection and diagnosis framework was developed and tested for the detection and diagnosis of faults in large-scale systems, using condition-event nets for fault detection and Radial Basis Function neural networks for fault diagnosis. This fault detection and diagnosis methodology detects and diagnoses faults in the early stages of fault occurrence, before fault symptoms propagate throughout the plant.

The Coordinated Knowledge Management method and the newly developed fault diagnosis module were developed in G2[1] and applied and tested on the Separation and Heating sections of the Pilot plant for the Bayer process at the School of Engineering Science, Murdoch University. Testing indicated that the use of an intelligent system comprising of Petri nets for integration of tasks results in improved plant performance and makes the plant easier to monitor increasing profits. The fault detection and diagnosis module was found to be useful in detecting faults very early on and diagnosing the exact location of faults, which would otherwise prove to be difficult to detect. This would also increase plant safety, reduce wastage and improve environmental considerations of the plant.

[1] G2 is a commercial programming environment for creating and deploying intelligent real-time applications (Gensym, 1999).

References

Gensym Corporation (1999). *G2 Reference Manual (Version 5.0)*, Cambridge, MA.

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