行政院國家科學委員會補助專題研究計畫成果報告

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計畫類別：x **個別型計畫**　　□**整合型計畫**

計畫編號：NSC 89-2213-E-004-009-

執行期間：89 **年** 08 **月** 01 **日至** 90 **年** 07 **月** 31 **日**

計畫主持人：趙玉

共同主持人：

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執行單位：國立政治大學資訊管理學系

中　華　民　國 90 **年** 9 **月** 28 **日**

行政院國家科學委員會專題研究計畫成果報告

協同派翠網路之工具及擴充

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一、中文摘要

吾人進一步發展出新 DCOM 元件可建構結構矩陣及最大發展協同派翠網路之成分可用於分析。

關鍵詞：Petri 網路、同步選擇網路、工具、活的、死結、合成、分析

Abstract

We develop a **DCOM component** to construct S-Matrix and maximal SNC component for analysis. We have developed an efficient technique to find all bad siphons in an incremental fashion and applied to FMS deadlock-prevention with resource-sharing.

Keywords: Petri Nets, Synchronized Choice Nets, Tools, Deadlock, Liveness, Synthesis, Verification

二、緣由與目的

We have developed a very powerful CAD tool for designing protocols and Petri nets. Currently, the tool is able to draw Petri nets, state diagrams, data flow graphs, (extended) finite state machines, and general graphical objects. Once the graph is drawn, the tool can analyze, simulate, reduce, animate, and synthesize them. Few existing tools are capable of such integration.

It enhances our current powerful CAD tool [2-3] for the modeling, analysis, reduction, synthesis, code embedding and generation, performance analysis, and scheduling of Petri nets. This tool has been ported partly (modeling, analysis, and simulation) to Win95 environment using Visual C++. However, its analysis relies on reachability analysis; hence it can only analyze small size OPN.

It has been an important research to apply Petri net to analyze the integrity of workflow process. So far, little (including both theory and implementation) has been done. **資策會** has developed a Petri-nets based workflow (WF) system with DCOM component implementation. This tool provides user-interface for designer to construct and execute workflow process. However it lacks the ability to check the syntactic and logical properties. The resulting tool will be able to analyze and simulate various properties of Petri net workflow. As indicated in the final report, "It is promising to play a leading role if in future, we can port our tool for reduction, synthesis, code embedding and generation, performance analysis, and scheduling of Petri nets to generate DCOM components." However, the analysis was also based on reachability analysis. All other PN tools also rely on reachability analysis (See Appendix).

Thus the completion of the proposed NSC project will not only enhance our current CAD, but also benefit III's WorkFlow CAD tools. Our NSC proposal is important, because III has delivered its product to 鼎新 which is currently very active in advertising its WorkFlow products to the business community for them to perform business reengineering. The success of this project will allow them to compete more favorably in the international arena, since *no current WorkFlow tool is able to handle efficient analysis for large WF.* In addition, since PN has many applications, the enhanced tool can apply to efficient analysis of communication protocols, data flows, Flexible Manufacturing System, etc.

The efficient algorithm can be extended to more complicated classes of nets in future projects. T**he NSC project will produce efficient tools will be produced for dealing analysis for complicated classes of nets such as for resource sharing.** And this future tool will be very useful for both academic and industrial community.

We proposed a new class of PN called SNC which covers well-behaved FC and yet is not included in AC (assymetric choice). We discovered that local structures play a role not only in the classification but also in the characterization of deadlocks and irreversibility of SNC nets. **Since the liveness condition is simple, the time complexity for verifying liveness is therefore much reduced and is polynomial.** We propose to integrate the algorithms for detecting SNCs and TP- and PT- inconsistent pair of places into our CAD tool for analysis. We have extended SNC to ESNC (extended ESNC) where TP- and PT-handles are allowed. It now allows asymmetric first order structures (FOS). To make analysis tractable, we have limited the nets with pure FOS where the intersection between any two FOS contains at most one node. Such a net can be converted to a General Petri net (GPN) and existing theory can be applied to study its liveness and boundedness properties. We then enhance it in three aspects and apply to an FMS with resource sharing.

We identified its bad siphons and derived the marking condition for liveness. We propose to develop algorithms for detection, analysis, and synthesis for ESNC.

The implementation will be the world's first in its kind and is important because it (1) finds SNC backbone components [1] to construct classes of nets for FMS resource sharing more complicated than any existing class of nets, (2) avoids reachability analysis and can analyze arbitrarily large SNC nets, (3) supports **資策會 which has developed a Petrinets based workflow (WF) system with DCOM component implementation. This tool lacks the ability to check the syntactic and logical properties. We have delivered three DCOM (Distributed Common Object Model) components for workflow analysis and simulation based on PN. But it suffers state explosion problem. Since most WF can be modelled by SNC, the implementation will render 資策會 the leading player in the WF business. (4) is the basis to develop efficient techniques for dealing analysis for complicated classes of nets such as for resource sharing.**

We propose to improve current practice on FMS control based on Petri nets. Another motivation of this proposal is to continue and advance our NSC87&88 research on Synchronized- Choice nets into new research frontier. Also, the proposal helps to discover new TP-PT generation rules for our proprietary Knitting technique. This research proposes (1) to create a more powerful model or class of Petri nets to deal with deadlock prevention and study its properties of conservation, boundedness, liveness, reversibility, reachability, …etc. (2) to develop an efficient technique to find all bad siphons. A set of new bad siphons can be obtained by the union of a common existing bad siphon with another and the deletion of a common set of places. (3) to obtain more general marking conditions for liveness (4) to improve current control practice by removing redundant control arcs and nodes.

三、研究成果

We have developed algorithms for detection, analysis, and synthesis for ESNC. We have developed a **DCOM component** to construct S-Matrix and the maximal SNC component. We have developed an efficient technique to find all bad siphons in an incremental fashion and applied to FMS with resource-sharing.

四、計畫成果自評

We have successfully completed the project and been able to define new projects and derive new results such as marking conditions for liveness. We have completed the paper to be ready to submit to journals.

To prevent an FMS from entering deadlocks, control places and arcs are added to avoid bad siphons from being emptied. However, this may create new bad siphons. Since we are able to find bad siphons incrementally, we are able to detect the generation of new bad siphons and hence to add new places and arcs, if necessary, to guarantee deadlock-free operation. While using Ezpeleta's [4] technique, we need to perform global analysis upon the completion of adding new control places and arcs, which is quite time-consuming.

Thus, our research is very useful!

五、參考文獻

[1] D. Y. Chao and Jose A. Nicdao, "Liveness for Synchronized Choice Petri Nets," in Computer Journal (British Computer Society), Vol. 44, No. 2, 2001, pp. 124-136.

[2] D.Y. Chao, "A Computer Aided Design Technique for Flexible Manufacturing Systems Synthesis Utilizing Petri Nets," *Computer-Aided Design, Engineering, and Manufacturing: Techniques and Applications,* Volume III, *Operational Methods in Computer Aided Design*, CRC Press, 2001, pp. 8.1-8.64.

[3] D.Y. Chao, "Application of A Synthesis Algorithm to Flexible Manufacturing System," *Journal of Information Science and Engineering,* Vol. 14, No. 2, June 1998, pp. 409-447.

[4] J. Ezpeleta, J.M. Colom, and J. Martinez, "A Petri Net Based Deadlock Prevention Policy for Flexible Manufacturing Systems," *IEEE Transactions on Robotics and Automation,* Vol. 11, No. 2 April 1995, pp. 173-184.