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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計畫編號：NSC 89-2213-E-004-012-

執行期間：89 年 08 月 01 日至 90 年 07 月 31 日

計畫主持人：趙玉 **國立政治大學，資管系**

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□國際合作研究計畫國外研究報告書一份

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

最小吸虹之合成

計畫編號：NSC 90-2213-E-004-004-

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主持人：趙玉 國立政治大學資訊管理學系

一、中文摘要

關鍵詞：派萃網路(Petri nets)、彈性製造系統(FMS)、達成度(or 延展性 reachability)、活的(Live)、死結、控制、合成、分析、同步選擇、TP 和 PT 世代。

Abstract: Lautenbach's marking condition for liveness [7] (where all minimal siphons are invariant-controlled) has been successfully applied to FMS. However, there are two exceptions with no solutions in literatures. We have uncovered these mysteries and extends the above models to all types of resource-sharing based on the concept of synthesis of minimal siphons. Different structures in the synthesis result in different classes of nets. Each class is maximal in the sense that it covers various classes of nets in the literature. Lautenbach's marking condition for liveness (MCL) is extended to more general cases and we are able to offer a more intuitive insight as to the structural cause for the above exceptions. It also helps to discover new TP-PT generation rules for our proprietary Knitting technique [2-3]. We have studeid each of the above maximal classes and derive its marking condition for liveness. We also propose a procedure to find the S-invariant that controls a minimal siphon.

Keywords：Petri Nets, Marking, Live, Deadlock, Control, FMS, Synthesis, Minimal siphons, Synchronized-Choice, TP- and PT generations.

二、緣由與目的

Ezpeleta et al proposed a class of PN called Systems of Simple Sequential Processes with Resources (S^3PR), which generalizes that in [4] by allowing choices. However, such a class cannot model iteration statements (loop) in each sequential process (SP) and the relationships of synchronization and communication among SP.

The model by [5] has some constraints and at any state of a process, it cannot use multi-sets of resources. As a result, their model cannot apply to concurrent systems other than FMS such as database systems, operating systems, and parallel processing. Their idea is to compute all bad siphons of the given model and find the maximum number of tokens at each idle state followed by a control policy of adding arcs and nodes with tokens. However, the number of bad siphons grows exponentially with the size of PN. Because each WP is limited to a SM, bad siphons are solely due to resource-sharing between WPs. Ezpeleta, however, did not take advantage of this. Instead, they analyze bad siphons in a global manner; i.e., digging them out in the whole net. We, however, locate bad siphons in a local and incremental fashion.

Jeng [6] proposed a synthesis technique that merges resource control nets (RCN) through common transitions and transition subnets. It allows more general usage of a resource such as robot: Robots used at a state of a WP does not have to be released at the next state. They proved the merged nets are conservative and hence bounded. Structural liveness can be checked for two sufficient conditions. Instead of searching for all bad siphons, they calculated deadlock structures. The proposed algorithm holds valid only for special structures where any common transition can have at most one input operation place. Also, there are restrictions on the RCN to be merged that is for each common transition, there can only be at most one input place that is an operation (not a resource) place. As a result, they cannot model cases where an assembly operation is performed on several different parts coming from separate preceding processes.

We allow any WP to be a well-behaved SNC (a new class [1]) that covers well-behaved and various classes of FC and is not included in AC. A SNC allows internal choices and concurrency. It therefore can model assembly operations with multiple parts. Hence it is more general and powerful than S^3PR and Jeng's model. Next, we propose an efficient technique to find all bad siphons. Note that Jeng's deadlock-structure search technique no longer holds here. The new technique is general in the sense that not only does it apply to S3PR (systems of simple sequential processes with resources), Jeng's model and the proposed technique; but also it bodes well for newer classes of nets to be explored in the future.

None of them dealt with the marking condition for liveness. Either no theory was given or the MC derived was incorrect. We apply Lautenbach's Marking condition for liveness [7] to produce remarkable results. However, it is only a sufficient, and not a necessary condition. Lautenbach proposed a class of nets where it is also necessary. But the class is too limited in the sense that to return to an initial marking,all transitions must be fired. He cited one example where the condition is not necessary. However, neither intuitive insight nor structural cause was given. We have found the maximal class of nets where it is both sufficient and necessary based on the concept of synthesis of minimal siphons. In the mean time, we offer its structural origin.

A PME models a resource shared by independent processes and an SME models sequentialization (synchronization) of PMEs. In a PME, any independent process may monopolize the use of a resource, thus creating an unfair situation. The SME eliminates this unfairness problem by sequentializing or synchronizing these independent processes. Incorporation of SME enhances our SNC-based approach to PME. As a result, we create ESNC (Extended SNC) as a new class of PN that extends SNC.

Zhou et al [8] presented the deadlock-free condition (DFC) of a PN containing Sequential Mutual Exclusion (SME). However, Zhou's DFC holds only simple cases and it is unclear how to apply to more general cases. Chao [3] presented an alternative approach to explain SME and Parallel Mutual Exclusion (PME) in the context of the knitting technique and structural relationship, illustrated the application of S-Matrix to detect deadlocks in SMEs, generalized the DFC for more complicated SMEs than the example in [8], and discoverd new DFCs.

In general, two SME may be connected in a sequential, parallel, or exclusive manner. Multiple SME do so in a combinatorial fashion. It is unclear what the liveness conditions would be. However, both Zhou and Chao [3] did not consider this. Zhou [8] considered only a single SME and Chao [3] considered only interactions between SME.

Our proposed method generalizes the (MCL) for al the above cases.

三、結果與討論

We have extended Lautenbach's marking condition to more general cases and we are able to offer a more intuitive insight. It also helps to discover new TP-PT generation rules for our proprietary Knitting technique. We have uncovered mysteries and extended the above models to all types of resource-sharing based on the concept of synthesis of minimal siphons. Different structures in the synthesis result in different classes of nets. Each class is maximal in the sense that it covers various classes of nets in the literature. This theory of synthesis of minimal siphons can unify different theories on different classes of nets and offer a single theory to explain all.

Proof of liveness for various new classes of nets such as S^3PR—Non-Self controlling are not intuitive and too complicated to understand. Based on the theory of synthesis of minimal siphons, we can find the exact structure that causes a net to be deadlock-free but not live. In other words, we can find the maximal class of PN such that if no minimal siphon ever gets empty, then the net is live. This is convenient because if a new class of PN lies within the maximal class, we don't have to prove its liveness in a hard and non-intuitive way and it is live if every minimal siphon is marked.

If all transitions a net are dead, then the set of marked places forms a siphon, i.e., there exits an empty siphon. This implies that if all siphons are not empty, then at least one transition is live, i.e., the net is deadlock free. There, however, exist classes of nets that for the above situation not only one but all transitions are live. For these classes of nets, the following property is always true. *A net is live iff all siphons are nonempty.* Proof of liveness becomes relatively easy compared to that for general nets by showing all minimal siphons are marked. Such a net is live if all siphons are nonempty.

四、計畫成果自評

We have successfully completed the project and derive new theoretical results. We have yet to complete the paper to be ready to submit to journals.

五、參考文獻

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