行政院國家科學委員會專題研究計畫　成果報告

配對合成網路的錯誤診斷研究

計畫類別：個別型計畫
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計畫主持人：譚建民

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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：■個別型計畫　　□整合型計畫

計畫編號：NSC93－2213－E－009－091－

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P.-L. Lai, J.J.M. Tan, C.-H. Tsai, and L.-H. Hsu "The Diagnosability of the Matching Composition Network under the Comparison Diagnosis Model," IEEE Trans. on Computers, vol. 53, no. 8, pp.1064-1069 Aug. 2004.

計畫主持人：譚建民

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□出席國際學術會議心得報告及發表之論文各一份

□國際合作研究計畫國外研究報告書一份

執行單位：國立交通大學資訊科學學系

中　華　民　國　　94 年　　7 月　　31 日

配對合成網路的錯誤診斷研究

The diagnosability of the matching composition network

計劃編號：NSC93-2213-E-009-091-

計劃期限：93/8/1～94/7/31

主持人：譚建民　國立交通大學資訊科學學系　教授

一、中英文摘要

在這個計劃中，我們研究 multiprocessor system 的錯誤診斷問題(fault diagnosis problem)，關於多處理機系統的 錯誤自我診斷問題，在文獻中已有幾個不同的模式被提出。Preparata, Metze and Chien 三人最早提出一種構想及模式。現在稱為 PMC-Model。在此模式下，兩個相連接的 processor 可以互相偵測是否 faulty。Maeng and Malek 在之後提出一種 comparison model 稱為 MM-model。他們對錯誤診斷的基本構想是由一個 processor 向相鄰的兩個 processors，送出信號，然後由回收的訊號，比較並判斷是否有 fault。為了要收集到最多的資料以供錯誤診斷，在 MM*-model 下，規定任一個 processor 都對其所有相鄰的兩個 processors 作偵測及比較。

錯誤診斷在 IEEE Trans. on Computers 及 IEEE Trans. on Parallel and Distributed Computing 已有很多文獻研究。我們近年也在這個領域作了一些研究，並投稿至 IEEE Trans. on Computers，已有一篇在做最後 revision。

在這個計畫中，我們研究一種配對合成網路 matching composition network (MCN) 的診斷能力 (diagnosability)，在 MM*-comparison model 下，配對合成網路的診斷能力 (diagnosability)，與它的組成成分之間的 diagnosability and connectivity 有一定關係，我們研究其間的關係，可將文獻中有關各種 cube 如 hypercube, crossed cube, twisted cube and Mobius cube 的 diagnosability 研究結果有一個統一的解釋。我們已有一些研究成果，撰文投稿 。

對 PMC- model 下的錯誤診斷也有所研究。我們定義出一種”strongly t-diagnosable systems ” 及 ” conditional diagnosability”的觀念。目前正在探究，期能繼續進行成果收集。

關鍵詞：錯誤診斷(fault diagnosis)，Comparison-model, MM*-model, PMC-model 診斷能力 (diagnosability).

英文摘要

We propose to study the diagnosis problem of multiprocessor system. For the purpose of
self-diagnosis of a given system, several different models have been proposed in literature. Preparata, Metze, and Chien first introduced a model, so called PMC-model, for system level diagnosis in multiprocessor systems. In this model, it is assumed that a processor can test the faulty or fault-free status of another processor.

The comparison model, called MM model, proposed by Maeng and Malek, is considered to be another practical approach for fault diagnosis in multiprocessor systems. In this approach, the diagnosis is carried out by sending the same testing task to a pair {u, v} of processors and comparing their responses. The comparison is performed by a third processor w that has direct communication links to both processors u and v. The third processor w is called a comparator of u and v.

If the comparator is fault-free, a disagreement between the two responses is an indication of the existence of a faulty processor. To gain as much knowledge as possible about the faulty status of the system, it was assumed that a comparison is performed by each processor for each pair of distinct neighbors with which it can communicate directly. This special case of MM-model is referred to as the MM*-model. Sengupta and Dahbura studied the MM-model and the MM*-model, gave a characterization of diagnosable systems under the comparison approach, and proposed a polynomial time algorithm to determine faulty processors under MM*-model.

In this proposal, we consider the diagnosability of a family of networks, called the Matching Composition Network (MCN); two components are connected by a perfect matching. The diagnosability of MCN under the comparison model is shown to be one larger than that of the component, provided some connectivity constraints are satisfied. Applying our result, the diagnosability of the Hypercube Qn, the Crossed cube CQn, the Twisted cube TQn, and the Möbius cube MQn can all be proved to be n, for $n \geq 4$.

We shall also study the diagnosis problem under PMC-model. We define some new concepts called "strongly t-diagnosable system" and "conditional diagnosability", we are currently working on this subject.

Keywords: fault diagnosis, comparison model, MM*-model, PMC-model, diagnosability.

二、計劃緣由及目的

With the rapid development of technology, the need for high-speed parallel processing systems has been continuously increasing. The reliability of the processors in parallel computing systems is therefore becoming an important issue. In order to maintain the reliability of a system, whenever a processor (node) is found faulty it should be replaced by a fault-free processor (node). The process of identifying all the faulty nodes is called the diagnosis of the system. The maximum number of faulty nodes that the system can guarantee to identify is called the diagnosability of the system.

We consider the diagnosability of the system under the comparison model, proposed by Malek and Maeng [16,17]. The diagnosability of some well-known interconnection networks under the comparison model has been investigated. For example, Wang [21,22] showed that the diagnosability of an n-dimensional hypercube Qn is n for n ≥ 5, and the diagnosability of an n-dimensional enhanced hypercube is n+1 for n ≥6. Fan [12] proved that the diagnosability of an n-dimensional crossed cube is n for n ≥ 4. Araki proposed that the k-ary r-dimensional butterfly network BF(k, r) is 2k-diagnosable for k ≥2 and r ≥ 5. Besides, the diagnosability of the Hypercubes, the Crossed cubes, and the Möbius cubes under the PMC diagnostic model were also studied in [2,10,11,14].

We study the diagnosability of a family of interconnection networks, called the Matching Composition Networks (MCN), which can be recursively constructed. MCN includes many well-known interconnection networks as special cases, such as the Hypercube Qn, the Crossed cube CQn, the Twisted cube TQn, and the Möbius cube MQn. Basically, MCN and these mentioned cubes are all constructed from two graphs G1 and G2 with the same number of nodes, by adding a perfect matching between the nodes of G1 and G2. We shall call these two graphs G1 and G2 as the components of MCN.

Our main problem is the following. Suppose that the number of nodes in each component is at least t+2, the order of each node in Gi is t, and the connectivity of Gi is also t, i=1,2. We shall prove that the diagnosability of MCN constructed from G1 and G2 is t+1 under the comparison model, for t ≥2. In other words, the diagnosability of MCN is increased by one as compared with those of the components. Using our result, it is straightforward to see that the diagnosability of the Hypercube Qn, the Crossed cube CQn, the Twisted cube TQn, and the Möbius cube MQn are n for n ≥4. Some of these particular applications are previously known results [12,22], using rather lengthy proofs. Our approach unifies these special cases and our proof is much simpler. The diagnosability of the Twisted cube TQn and the Möbius cube MQn, as far as we know, are not yet resolved.

三、研究方法與成果

近年我們的研究領域集中在連結網路上，我們對於各種著名的網路架構有深入的研究。可以將我們所知的知識應用在錯誤診斷(fault diagnosis)研究上。連結網路中的觀念如 connectivity, conditional connectivity, hypercube and cube family 都與錯誤診斷的研究息息相關。藉由這些關念，我定義出 conditional diagnosability 及 strongly t-diagnosable system 等新名詞，已有新的研究成果投稿，並還在撰寫論文繼續努力。我們的實驗室每週定時研討如下：

一、 收集文獻

我們會藉由網路、圖書館、及國內外研討會等，來收集相關的文獻。

二、 探討文獻及發現問題

將收集到的文獻作一個初步的探討後，由計畫中的成員分工合作將文獻做進一步的分析研究後，每週定期報告其文獻的內容，以及分析其文獻，進而從文獻中發現可以做進一步研究之問題，由主持人帶領成員選定研究之主題。

三、 解決問題、程式撰寫、及定理證明由老師帶領博士班學生，並由博士班學生帶領碩士班學生共同研究，並解決其問題，在研究的過程中，常常需要撰寫程式來輔

助定理的證明。我們的實驗室已自行發展出一些軟體程式供測試例子。最後將共同研究之成果整理好,完成完整的一篇論文。

四、 成果發表

近年我們已有多篇論文被國際知名期刊刊登。而本計畫結果已刊登在 2004 年 IEEE Transactions on Computers 期刊:

P.-L. Lai, J.J.M. Tan, C.-H. Tsai, and L.-H. Hsu "The Diagnosability of the Matching Composition Network under the Comparison Diagnosis Model," IEEE Trans. on Computers, vol. 53, no. 8, pp.1064-1069 Aug. 2004.

四、結論與討論

本計畫在主持人的帶領之下，每週定時討論與報告所收集的資料，並且分析和比較各種方法的優點及缺點，在多方面的不斷討論下，使我們對一些連結網路的診斷能力特性的問題與解決方式有了更清楚的了解。

由於我們對於連結網路的診斷能力相關問題，先前已經有了相當良好的基礎及經驗，所以為本計劃的執行奠定了良好的根基，且能順利完成預定的研究進度。每個參與的研究人員都能對診斷能力的特性有充分的了解，在學術上可以對連結網路發展出新的診斷能力的特性，並且可以比較分析各種不同的連結網路，它們之間診斷能力的特性。希望我們所研究的這些相關問題能提升有關這方面的領域。而我們研究所得的經驗、知識以及一些尚未解決或仍可以發揮之處，希望可做為日後更深入的研究。

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