A Knowledge-based Strategy for the Automated Support to Network Management Functions (ネットワーク管理業務の能動的支援における知識処理の研究)

氏名（本籍地）	ABAR SAMEERA（アバー サミーラ）
学位の種類	博士（情報科学）
学位記番号	情博第450号
学位授与年月日	平成21年3月25日
学位授与の要件	学位規則第4条第1項該当
研究科、専攻	東北大学大学院情報科学研究科（博士課程）応用情報科学専攻
学位論文題目	A Knowledge-based Strategy for the Automated Support to Network Management Functions （ネットワーク管理業務の能動的支援における知識処理の研究）
論文審査委員	（主査）東北大学教授 木下 哲男 東北大学教授 加藤 寧　東北大学教授 曽根 秀昭

論文内容の要旨

A Knowledge-based Strategy for the Automated Support to Network Management Functions

Abstract: This research project proposes a reuse-based knowledge representation and acquisition strategy, for the automatic provision of just-in-time and just-enough, context-dependent resource knowledge, for actively managing the communication network systems. In the proposed knowledge model, the static domain content of a network system has been represented as the domain knowledge ontology, and the experiential management knowledge is encoded as the production-rule type representations of distributed multi-agent middleware architecture. For the proof of concept, an experimental network system has been set-up in the laboratory. A couple of test-cases have been designed for experimenting with the implemented prototype system. Experimental results confirm a marked reduction in the management-overhead as compared to the manual network management techniques, in terms of the time-taken and effort-done during a particular fault-diagnosis session. Validation of the reusability/modifiability aspects of our system, illustrates the flexible manipulation of the knowledge fragments within diverse application contexts.

1: Research Overview

The growing complexity of the distributed communication network systems, and the associated voluminous information overhead has made the network management an increasingly troublesome task. For managing these huge distributed network systems, the manual procedures have become quite tedious. The effective management of huge and complex networks is possible only with the intelligent and automated network management tools. The key to the automation of network management functions is the detailed interpretation of the network-related knowledge resources. The proposed knowledge model has been constructed in-line with the CommonKADS [1], which is a comprehensive methodology for structuring the application intensive knowledge of expert systems.

2: Proposed Knowledge Model

Our knowledge modeling approach categorizes the network-related knowledge as the domain knowledge (static domain content, and dynamic status information), and the experiential management knowledge (inference strategy, and task structures).

The hierarchy of concepts within our experimental network system, and their crucial properties are specified through the attribute-value mechanism, or more specifically, the domain knowledge ontology, which has been designed in Protégé-3.4 [2]. The fault-symptom taxonomy contains the knowledge of nearly all the possible failures which could be encountered by the user in the prototype network management system. The management expertise prescribes the execution of various task relevant goals in the operational network system, and is incorporated as the fault-case reasoning models in the system. This experiential management knowledge is explicitly encoded as the production-rule type representations of the DASH-agents [3], which actualize the automated reasoning tasks in conjunction with the static domain-specific content. Moreover, the cooperative problem-solving is initiated when the agents invoke the underlying base-processes, which interact with the run-time dynamic status information during the diagnostic sessions. Task Knowledge or problem solving task structures are designed as the generic hierarchy of tasks which prescribe the activities to be performed in a domain of interest. The diagnosis is defined as the task of identifying the cause of a fault that is manifested by some observed behavior. Fault diagnosis process incorporates the following steps: observe the symptoms, develop a hypothesis about

the cause of a symptom, test the hypothesis, and if the hypothesis fails, iterate these steps until a conclusion is reached.

3. Multi-agent Middleware System

The intelligence layer consists of multi-agents for handling the empirical task relevant knowledge to relieve the network operators from the tedious monitoring and control of the network system. The proposed system architecture is supported by the Agent-based Distributed Information Processing System (ADIPS) framework [4], which is a flexible computing environment for the implementation of multi-agent systems. This framework employs a repository-based system development methodology which allows autonomous adaptive actions on each designed distributed system. For each initial fault-symptom detected, various run-time checks are performed for all possible occurrences of the fault-symptom, and the information obtained (about the root causes of the obstacle), is compared with the pre-defined one, and then the problem-solving findings are forwarded to the management console.

4. Test Network

Our experimental network system, comprises of the

100BASE-TX Ethernet, firewall configured as NAT (Network Address Translation), routers, bridges, various personal computers arranged in three sub-networks, and Fedora-Core-ver: 2.0 has been installed on all the network nodes.

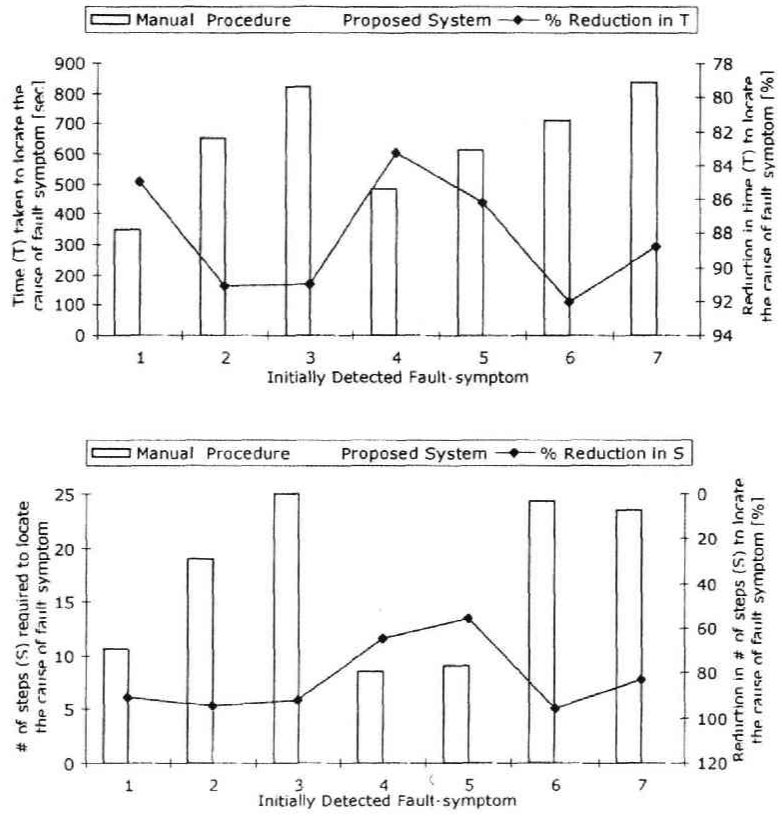

Figure-1 Quantitative performance evaluation

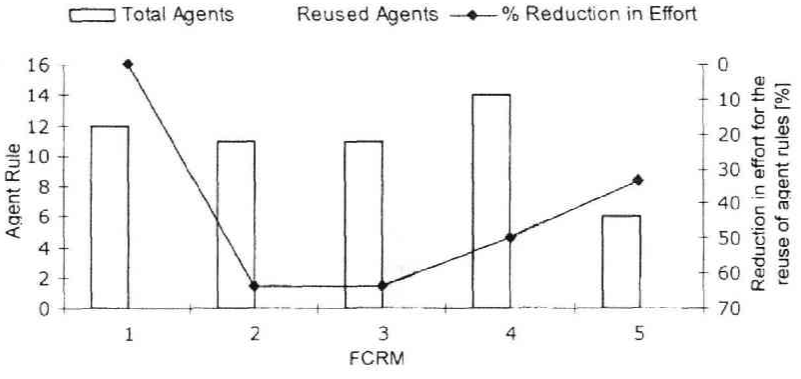

Figure-2 Reuse of fault-case reasoning knowledge

5. Prototype System's Evaluation

The performance of the proposed knowledge-model method is determined in comparison to the OS-default network management tools. The time elapsed between the notification of the failure to its root-cause determination has been measured, plus the number of procedures executed. Figure-1 results determine an average reduction of 88.16% in time, and 82.35% in the number of steps performed, in comparison to the manual method, while resolving a particular fault-case. Figure-2 illustrates a considerable reduction in the effort required while designing the agent-based fault-case reasoning models, for various failure scenarios. Similarly, the network domain ontology can also be modified efficiently on the centralized management console. More specifically, it concludes that some alteration of the network do not reflect the changes in

knowledge models embedded in the system. This makes the knowledge acquisition activity less complex.

6. Concluding Remarks

We have presented a knowledge representation, acquisition, and utilization approach for the automated management support to communication network systems. Validation of the reusability aspects of the system, as well as its performance measurements has been done. The ontology design and implementation in this project, in the practical network management domain, is the most novel concept which has never been reported in literature.

References

1) G. Schreiber etal., CommonKADS: A Comprehensive Methodology for KBS Development, IEEE Expert, Vol. 9, pp. 28-37, (1994).

2) Protégé — An ontology editing tool:
http://protege.stanford.edu/

3) DASH — Distributed Agent System based on Hybrid Architecture:
http://www.agent-town.com/dash/index.html

4) T. Kinoshita, and K. Sugawara, ADIPS Framework for Flexible Distributed Systems, Lecture Notes in AI, Springer-Verlag, Vol. 1599, pp. 18-32, (1999).

論文審査結果の要旨

ネットワークシステムは多種多様な機能や機器によって構成される複雑・大規模なシステムである。その運用管理業務では様々な知識が要請されることから、知識や経験の乏しい担当者の作業負担は増大傾向にあり、その効果的な支援が求められている。そこで、著者は、ネットワーク管理に関わる情報や知識を集積・管理し、これをネットワーク管理業務の場面で効果的に活用するための支援手法について詳細に検討した。本論文は、その成果をまとめたもので、全編6章から成る。

第1章は序論である。

第2章では、ネットワーク管理に関する従来手法や現行システムの調査と分析を行い、知識工学的観点から、ネットワーク管理支援における領域知識の利活用に関する技術課題を整理している。

第3章では、ネットワーク管理支援に対する第一のアプローチとして、能動的情報資源を適用したネットワーク管理支援の手法を提案し、エージェント技術に基づいて、ネットワーク管理向き能動的情報資源の設計、及び、これらを組み合わせて構成されるネットワーク管理支援システムの試作を行い、ネットワーク稼働状況の監視と情報管理の業務を対象とした評価実験を通して、管理者の作業負担の軽減が可能となることを実証した。この成果は、能動的情報資源の自律性を活用したネットワーク管理支援の有効性を示したものとして高く評価できる。

第4章では、ネットワーク管理支援に対する第二のアプローチとして、知識モデリングに基づく支援手法を提案している。本手法は、ネットワークシステムに関する種々の知識を記述したオントロジ（概念知識・語彙の体系）と知識モデルを利用して管理者を支援するもので、ネットワーク障害対策を具体例として、オントロジ構築と知識モデル設計を行ない、エージェント技術を利用した実現手法を与えている。これは、ネットワーク管理支援における知識モデリング手法の適用事例として興味深い成果である。

第5章では、前章で与えた知識モデリングに基づく支援手法の実装と評価実験、及び、第3章で述べた能動的情報資源に基づく支援手法との比較と評価を行なった。これにより、ネットワーク管理業務の支援における領域知識活用の効果と有用性を実証している。

第6章は結論である。

以上要するに本論文は、ネットワーク管理支援において種々の領域知識を系統的に活用するための新しい手法を提案し、エージェント技術に基づくプロトタイプシステムの試作と実験を通してその有効性を実証したもので、エージェント指向知識工学ならびに応用情報科学の発展に寄与するところが少なくない。

よって、本論文は、博士（情報科学）の学位論文として合格と認める。