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論文内容要旨

Computer communication systems which range from worldwide data and voice communications networks to local area networks or recent multiprocessor computer systems are dramatically increasing their variety and complexity. To enable the increasing variety and comlexity of computer networks, faster production of more complex, higher quality, and more efficient communication software has being overwhelming demanded. Communication protocols are an important part of communication software. They are procedures or rules for exchange of information or cooperation between computers. Two important conditions must hold in a developed protocol: no logical errors and satisfaction to the functions asked by the protocol designer. This dissertation discusses the protocol design and development problems with the point of view of no logical errors. Consisting of 6 Chapters, this dissertation focuses the discussions on the efficient design and development methods of communication protocols and the support systems for developing protocols without logical errors.

Chapter 1 is a introduction of this ersearch. The background and purpose are introduced in this Chapter.

In Chpter 2 , the problems of traditional protocol design methods are discussed with the view of increasing productivity and reducing cost. Until now, communication protocols have been designed and developed in life cycle model by which the design and development process has been broken down into some manageable subtasks which are independently and sequentially developed. However, though the life cycle development model reduced the development complexity of the communication protocols, it created some problems such as long development time, lack of traceability. Moreover, the life cycle model is deeply dependent on the level of experience of the protocol designer which is a common problem in software designs and development s. These problems and the status of protocol designs and developments are descussed in detail in Chapter 2 .

Chapter 3 focuses on software tools for communication protocol designs and developments. A new software tool, called interactive protocol synthesis method, for developing protocol in a shorter development time without logical errors is proposed and discussed. A protocol development process from an informal description of a protocol to be designed, to its Finite State Machines representation is defined as synthesis in this dissertation.

Many communication systems can be considered as two coordinating concurrent independent computing processes or entities. The protocol development tool is proposed for this set of communication systems. Several specification models such as temporal logical or algebra have been proposed and developed, except of FSM's model. Because the specification languages SDL and Estelle, which are the two standard specification languages proposed by CCITT (International Telegraph and Telephone Consultative Committee) and ISO (International Organization for Standardization), are based on FSM's, and a protocol described in FSM's is easy to be understood and implemented, We use FMS's as specification model.

With a set of production rules for producing FSM's and a set of rules for avoiding logical errors, the proposed interactive synthesis method can be used to synthesize a protocol without logical errors; unspecified specifications, deadlocks, overspecifications and buffer overflows. Here, unspecified specifications, deadlocks and overspecifications are prevented or avoided by the synthesis algorithm, and the buffer overflows are detected by the synthesis algorithm. Validation of these properties of the proposed synthesis method is given in three theorems in Chapter 3 .

The progress of AI techniques in recent years makes it possible to apply AI techniques to the protocol design and development fields. However, few of these applications has been reported. Chapter 4 discusses a new paradigm for protocol design and development, called knowledge based protocol design model, using knowledge based systems to assist the protocol designer to design a protocol smartly. Ideally, this protocol design and development model only needs the nature language descriptions or simple graphical descriptions of a protocol (informal descriptions) as the input of a support system for protocol design and development. So then, the support system performs syntax analysis and semantics analysis of the given nature languages or the understanding of the given graph to convert them into the forms which can be accepted by the algorithms or rules for producing formal descriptions of a protocol. The logical errors, incomplete description or ambiguous are removed through the interactions of the system and the protocol designer or automatically removed by the algorithms or rules stored in the system. The produced formal specifications will be further implemented and tested by the system, so that the codes of a deliverable protocol can be automatically generated. Based on this proposed paradigm, Chapter 4 further proposes a knowledge based system for protocol design and development to support the process of designing and developing a protocol described in a specification model based on Finite State Machines (FSM's).

There are so many problems such as process of nature languages, knowledge acquisitions, developments of tools for producing FSM's and for eliminating logical errors and etc., to be solved to consturct such a knowledge based system for protocol design and development. Chapter 4 outlines all these problems and focuses its discussion on the problems of how to construct a Knowledge based System for Protocol Synthesis (KSPS), and how to abstract and acquire the knowledge for eliminating logical errors and for consturcting FSM's, from experts of protocol design and development. Since the knowledge abstraction from experts of protocol design and development is a very complex process, this Chapter points out that obtainig the corresponding knowledge is most important for constructing a knowledge based system for protocol design and development. The rules for constructing FSM's and the rules for eliminating logical errors proposed in Chapter 3 are used as a part of the knowledge stored in the knowledge base of KSPS. Other part of the knowledge stored in the knowledge base of KSPS includes some expericnce of the author. Using these kinds of knowledge, KSPS which can be considered as a prototype of the knowledge based system for protocol design and development, interactively produces a protocol modeled in FSM's without logical errors. In the process of interaction, KSPS provides some kinds of advice for the protocol designer. They are: how to specify messages to be sent from one process to another one, and how to assign the process state when a message has been sent or received at the process. These kinds of advice are very useful because the protocol designer always assigns the process states based on his experience, but no any help from anywhere. The advises will consequently help the protocol designer to find and remove the errors embedded in the informal descriptions of a protocol, and prevent the protocol designer from creating FSM's with logical errors.

The user interface of a knowledge based system for protocol design and development is also very important with the view of increasing the productivity and reducing the cost. A human interface module of KSPS is also discussed in Chapter 4. The human interface module is designed from the points of view of easy to be understood and easy to input.

In Chapter 5, the experience of constructing KSPS is discussed and the examples of synthesizing real world protocols by using KSOS are given.

KSPS has been consturcted on SUN 3 workstation. In KSPS, a hybrid programming language OPS 83 which has been developed for constructing expert systems by Dr. C. L. Forgy, and a programming language C are used to construct the knowledge base and the human interface. The knowledge currently stored in the knowkedge base is the set of rules for constructing FSM's, the set of rules for eliminating logical errors, the set of rules for assisting protocol designers as described above. Approximate 200 rules written in OPS 83 and 500 lines of programs written in C are used for constructing this knowledge base.

The human interface of KSPS is constructed in C, consisting of approximate 1500 lines of the C programs. This human interface provides the functions for the protocol designer; such as interactively performing protocol synthesis, dynamically expressing the current synthesizing status and advises for helping the protocol designer to design a protocol wihtout logical errors, properly showing the ptoducts of the synthesis and the information for teaching the protocol designer how to use this system. Multiwindow mechanisms, text and color utilities, graphical expressions are used in the human interface to provide the above functions. Consequently, the protocol design activities are facilitated and the dependence to the protocol designer is reduced by using this human interface, which have been proved by synthesizing some real world protocols such as X.25.

Chapter 6 summarizes the conclusions and open questions.

審査結果の要旨

通信システムにおいて，プロトコル開発法は，信頼性が高く且つ効率的な情報通信システムを構成する上で極めて重要であり，同時に通信ソフトウェアの生産性の向上にも大きな影響を与えている。このため，信頼性の高いプロトコルを効率的に開発する設計法の確立及びその設計支援システムの構成が課題となっているが，プロトコル合成支援などについては現在十分な成果は得られていない。著者はプロトコルの効率的な開発法について理論と実験の両面から研究し，本論文はその成果をまとめたものであり，全編6章より成る。

第1章は序論である。第2章では，従来のプロトコルの開発における問題点を考察し，プロトコルのライフサイクルにおいて各ステップの相互依存関係など生産性を向上させる観点から詳細に論じている。

第3章では，プロトコル設計者との対話を通して，プロトコルの素案から論理的な不完全さ，曖昧さ，デッドロックなどのエラーがないようなＦＳＭを構成するプロトコル合成のためのアルゴリズムを提案している。本合成アルゴリズムを用いれば，構成されたプロトコルには従来のパータベーション解析により検出されるデッドロックなどの論理誤りが存在しないこと，プロトコルに曖昧さを含まないことなど本アルゴリズムの重要な性質が理論的に証明されている。これらは重要な成果である。

第4章では，知識処理技術の研究成果を用い，プロトコルの素案から対応するソフトウェアを計算機に実現するまでのプロトコル開発の全過程を支援する知識型設計支援システムについて論じている。まず，知識型設計支援システムの枠組について考察し，設計者の持っている知識の抽出が重要であることを指摘している。次に，具体的な知識として，主にデッドロック回避アルゴリズムなどを組み込み，ユーザフレンドリィなインタフェースを通して，設計者に助言し論理エラーがないようにＦＳＭを構成する知識型支援システムを構成している。これは，知識処理の手法をプロトコル合成に応用した試みであり，興味深い成果である。

第5章では，人工知能システム開発用言語ＯＰＳ83を用いて第4章で提案した設計支援システムのプロトタイプを開発している。これにより，実際のX.25の呼設定フェーズなどいくつかのプロトコルを具体的に合成することによって，開発したシステムの有効性を確認している。

第6章は結論である。

以上要するに本論文は，情報通信システムの設計の基本問題であるプロトコルの開発法について詳細な研究を行い，高度な情報通信システム構成のための基礎を与えたもので，情報通信工学，計算機工学の発展に寄与するところが少なくない。

よって，本論文は工学博士の学位論文として合格と認める。