博　士　学　位　論　文

Doctoral Thesis

内容の要旨

及び

審査結果の要旨

Thesis Abstracts

and

Summaries of the Thesis Review Results

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博士の学位を授与したので、学位規則（昭和28年4月1日文部省令第9号）第8条の規定に基づき、その論文の内容の要旨及び論文審査の結果の要旨をここに公表する。

学位記番号に付した「甲」は学位規則第4条第1項（いわゆる課程博士）によるものであることを示す。

Preface

On granting the Doctoral Degree to the individuals mentioned below, abstracts of their theses and the theses review results are herewith publicly announced, in according to the provisions provided for in Article 8 of the Ruling of Degrees (Ministry Of Education Ordinance No.9, enacted on April 1, 1953)

The Chinese character, “甲”, at the beginning of the diploma number represents that an individual has been granted the degree in accordance with the provisions provided for in Paragraph 4-1 of the Ruling Of Degrees (what in called “Katei Hakase,” or the Doctoral Degree granted by the University at which the grantee was enrolled.)

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The relevant degree 学位の種類	Doctoral degree (in Computer Science and Engineering) 博士(コンピュータ理工学)
Number of the diploma of the Doctoral Degree 学位記番号	甲 CI 博第 1 号
The Date of Conferment 学位授与日	September 26, 2008 平成 20 年 9 月 26 日
Requirements for Degree Conferment 学位授与の要件	Please refer to the article five of “University Regulation on University Degrees” 会津大学学位規程　第5条該当
Thesis Title 論文題目	Design and Evaluation of Data-Parallel Algorithms on a Matrix Processor マトリクス型プロセッサにおけるデータ並列計算手続きの設計と評価
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Design and Evaluation of Data-Parallel Algorithms on a Matrix Processor

Thesis Abstract

As increasing clock frequency approaches its physical limits, a good strategy to enhance performance of general-purpose microprocessors is to increase parallelism by integrating more cores to accelerate the different workloads in scientific, engineering, and signal/image processing applications. This thesis proposed a many-core matrix processor model consisting of a scalar unit augmented with a matrix unit of $N \times N$ simple cores tightly connected in a 2-D torus to accelerate the GEneral Matrix Multiply-add (GEMM), an important and pervasive operation in the above mentioned applications. The basic idea behind the matrix unit is merging computing and local communication of data and/or partial results into one indivisible 'multiply-add-roll' operation. Then applying software pipelining and loop unrolling techniques to hide the communication latency so that the theoretical peak performance of the processor can be attained.

By applying time-space mappings, we introduced optimal and efficient data allocations to execute the $N \times N$ matrix multiply-add (MMA) operation, $C \leftarrow C + A \times B$ where A, B, and C are $n \times n$ dense matrices, on the matrix unit in the minimal computing time. Using these optimal allocations, four versions of the GEMM operation based on the initial data layout inside the matrix unit are presented. Each GEMM version describes how the four variants $C \leftarrow C + A \times B$, $C \leftarrow C + A^T \times B$, $C \leftarrow C + A \times B^T$, and $C \leftarrow C + A^T \times B^T$ are performed on the matrix unit. On each version, three variants required the matrix transpose operation. We avoided transposition in two of these variants, however, to deal with the remaining variant we proposed matrix transpose algorithms formulated as MMAs and executed on the same matrix unit. Using a decoupled Load/Store unit tightly connected to the torus matrix unit, the data alignment overhead including the matrix transposition is overlapped with the load/store operations and consequently the performance enhanced.

The basic linear algebra subroutines (BLAS) are standard operations used to achieve portability, modularity, and efficiency of solving linear algebra problems on high performance and parallel computer systems. The BLAS have been very successful and have been used in a wide range of software packages such as LINPACK and LAPACK. We designed algorithms for some important operations from Level-1, Level-2, and Level-3 of the BLAS, and we evaluated their performance analytically on the proposed matrix processor. We showed that the performance of the Level-3 BLAS represented by the $n \times n$ MMA operation, $n \rangle\rangle N$, approaches the theoretical peak of the matrix processor as n increases while the performance of Level-1 and Level-2 BLAS is lower. Fortunately, many dense linear algebra applications are based on intensive use of Level-3 BLAS with small percentage of Level-1 and Level-2 BLAS.

Solving dense systems of linear equations is one of the most important computations in scientific computing. The most compute-intensive part of the solution process is the factorization phase. Based on storing the coefficient matrix as square $N \times N$ blocks, we designed two fine-grained blocked algorithms for the LU factorization with partial pivoting to

evaluate the performance of the proposed matrix processor. We scheduled the primitives of the algorithms regarding the possibility of overlapping execution between both the scalar and matrix units. Our analytical results showed the speed of computing of the matrix processor for relatively large matrix size ranges from around 50-90% of the peak. We also showed that the execution overlap between the two processing units enhanced the performance.

2-D separable transforms play a fundamental role in the field of digital signal and image processing. The 2-D separable transforms DCT, DFT, and DHT and their inverses can be described as two consecutive matrix products. Therefore, they are candidates to get high performance on the proposed matrix processor. The 2-D DCT and its inverse IDCT are computationally intensive kernels in standard image and video codecs. Using our proposed matrix transpose algorithm, we designed algorithms to implement the 2-D DCT/IDCT and evaluated their performance on the proposed matrix processor. We showed that the matrix processor can support real-time processing for the 640×480 frames at sampling rate of 30 frames per cycle. The designed algorithms are general and can be applicable to any 2-D separable transform. Only the transform coefficient matrix or its transpose is calculated and input to the matrix unit to compute the required transforms.

Summaries of the Thesis Review Results

This dissertation is organized within 8 chapters. In Chapter 1, an introduction, motivation and related works are presented. In Chapter 2, we introduced new scheduling of the matrix multiply-add (MMA) operation. We determined all optimal scheduling functions that resulted in optimal data allocations to perform the MMA operation on $n \times n$ mesh array processors (APs) with torus interconnection. In Chapter 3, we formulated the basic data alignment including the complex matrix transpose operation as MMAs performed on the same torus AP. In Chapter 4, a matrix processor model based on integrating the torus AP (as a SIMD matrix unit) with a general-purpose microprocessor for enhancing many data-parallel kernels in scientific, engineering, and image/signal processing applications is described together with an analytical time model. In Chapters 5-7, the merits of the matrix unit have been shown by designing efficient algorithms for: the basic linear algebra library BLAS, solving dense linear system of equations, and performing 2-D separable transforms. Our analytical evaluation of the algorithms showed a high performance of the proposed matrix processor. In Chapter 8, conclusions and future works based on the thesis work are presented.

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Thesis Title 論文題目	Statistical Modeling of Time-Varying Electricity Market: A Study on Power Supply Risk Reduction after Liberalization - 電力市場の時変統計モデリングに関する研究:自由化後の電力供給リスク低減の検討
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Statistical Modeling of Time-Varying Electricity Market: A Study on Power Supply Risk Reduction after Liberalization

Thesis Abstract

This research is about statistical modeling that contributes to reducing social risk that arises from the deregulated electric power industry.

Electric power industry is in the midst of deregulation, or liberalization, across the world. The aim is to promote social welfare, by providing the public with reliable and uninterruptible electricity supply at lowered rates. However, experiences in foreign countries show that poorly designed deregulation can *increase* social risk, in such forms as more expensive electricity rates and large-scale blackouts. Meanwhile, global warming, to which electric power industry carries a significant impact, has become one of the hottest issues in the world's politics. The society now faces a social risk in the age of electric power liberalization and environmental conservation.

To understand and reduce such social risk, this research focuses on building models that forecast and analyze i) *Price uncertainties* and ii) *Electricity supply uncertainties*. For this purpose, three statistical models will be proposed in the thesis: Time-varying Multi-Regression (TV-MR) model, Time-Varying Simultaneous Equations Model (TV-SEM), and Kalman Filter Tank Model (KF-Tank Model). All these models employ time-variability of the electricity market and generation resources, to better represent the Price and Supply uncertainties said above.

After the background and motivation statement in Chapter 1, the main achievements of this research are the following:

Chapter 2 reviewed the past history of deregulation and market liberalization in EU countries and the United States, and discussed the effectiveness of the deregulation and new challenges for power companies.

Chapter 3 introduced the TV-MR model and showed the model could forecast the next-day market price in the JEPX (Japan Electric Power eXchange) spot market, as well as decompose the price into several contributing factors such as temperature and electricity demand, and saw the time-wise changes in the magnitude of impacts from those factoer. The model will assist practitioners build their biffing strategy.

Chapter 4 introduced TV-SEM model and showed the model could estimate the slopes and intercepts of the demand and supply curves in the spot market. The model was able to capture the time-wise changes associated with random shocks to the market such as exceptional electricity demand surges and unscheduled shutdown of major power plants due to earthquakes. With this TV-SEM framework, practitioners can forecast the next-day price and quantity, then analyze and understand the underlying market dynamics.

Chapter 5 introduced KF-Tank Model, attempting to model the expected next-day output from the run-of-river type hydropower plants, one of the most important CO2-free generation technologies. The proposed model could achieve the target forecasting error of 0.05[per unit], and is now being considered for actual implementation in an existing power company.

In sum, it was implied that the above three models, all built on the physical structure of power supply and demand, have more degree of generality than conventional “black-box type models”. The proposed models will contribute to comprehensive understanding of the social risks in the era of deregulation, energy security and environmental compliance.

Summaries of the Thesis Review Results

Mr. Ofuji studied two kinds of time series analysis models to analyze time-varying electricity price behavior in liberalized electricity market of Japan which began at 2005. The results shows his model was useful to predict the electricity price accurately, and also useful to identify price variation factors in the electricity market. Also, he proposed the Kalman-filter tank model for robust forecasting of daily hydropower output. These results will contribute to reduce the power supply risk in electric companies after liberalization.

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Web User Interactions for Accessing Dynamic Contents

Thesis Abstract

Information Requirement Elicitation (IRE) is essential in Web service to elicit information requirement through interactive choice prompts. The IRE approach and its conceptual design were proposed by Sun (2003) to overcome limitations posed by user skills and many types of mobile devices. IRE is the interactive communication in which an information system helps users specify their requirements. It facilitates user information search in the web based environment. This research analyzes the designs of high-level user interfaces for IRE, in the context of geographic map database queries, and Hospital Information Systems by a Web user.

The proposed interface, the Query By Object (QBO) interface, is an object-by-object approach for locating an object of interest. The user intent is captured via objects/operations and path navigation through an option-based interface. The proposed interface aims to eliminate ambiguities in users' communication with an information system by virtue of a step-by-step procedure. Studies conducted on a prototype of the QBO interface demonstrates that the proposed interface is intuitive and easy to learn and use.

A purely menu driven query interface is good for online access. However, when the number of possible operations is very large, a menu driven approach can be cumbersome. This type of user interfaces are commonly used by store counters (7-11 stores). Similarly, web pages are routinely organized as a tree using child links from main (home) page. This type of approach is very good to help a user to focus on the information needed. This approach fails, in a case, where user needs information based on multiple attributes. More recently, large companies such as Amazon.com offer form based input for linking the user key-words with items to be searched. This approach is limited to the choice of options, for which it has been programmed. It does not work in a general purpose case of finding information based on user's need.

One of the earlier approaches to finding an easy to use interface is the query input approach using QBE (Query-by-example). On the whole, both the former approaches, using SQL or use of QBE were designed in the 1970s. These are programmer oriented approaches and require that the user must be familiar with the structure of the database. Recently, a few essential extensions to QBE have been proposed which enables it to handle spatial queries. These have been accordingly named as Spatial QBE.

In Spatial QBE, each spatial relation (example relation) is displayed with an additional geometric attribute column. A spatial condition box is provided to specify the spatial condition(s) in the query, using constants, domain variables, spatial operators and functions. The objects of the algebra are domain variables of spatial attributes of the source relations and the operators of the algebra are spatial operators and functions. Spatial QBE is a user-friendly query interface suitable for desktop GIS applications. The main strengths of Spatial QBE are its simplicity to express a query and its expressive power.

To realize the aim for an alternative interface to QBO for IRE, the essential modifications have been proposed. Our design proposals are based on the observation that a calculator oriented approach is more suitable for the web users. It is a more preferred interface for users with limited knowledge of the data, and programming language skills. In addition, its suitability for limited screen displays has also been found to be a good match.

In the present study, the tests have been carried out by using a map database and a Hospital Information System. In both cases, the critical requirements help to analyze the information requirement. The proposed approach has been successfully been demonstrated as a workable solution.

Summaries of the Thesis Review Results

The research study aims to present improved query language support for Web user Interfaces. It assumes that it is possible to provide high level query language interfaces for web users and others, who are not familiar with the database programming languages. At the same time, these users have query requirements that match the database query language levels. New approaches have been presented in this study report to meet the above objectives for Relational Database systems and maps.

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Thesis Title 論文題目	Ubiquitous Learning Systems for Interactive and Personalized Education in Daily Life インタラクティブで個人化された教育サービスを提供するユビキタス学習システム
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Ubiquitous Learning Systems for Interactive and Personalized Education in Daily Life

Thesis Abstract

Computing technologies are taking huge impact on the human learning process. For example, internets enable people to learn in different places and different time. And search engines tell people that learn to find and use information becomes much more important than remember and repeat information.

In such a background, u-learning is advocated after the popularization of the term ubicomp. UbiComp is based on the fact that our surrounding environment is being populated by an increasing number of digital devices. It focuses on bridge the gap between people and environment so that people can take control of the environment in a nature way.

U-learning is based on the UbiComp. We deem that u-learning shall be able to help people to learn in the physical environment in their daily life.

From the computer sciences point of view, to reach the goal, there are two main challenges for the u-learning application development. One is HCI design for u-learning system. Second is the middleware to manage the resources and facilitate the u-learning applications development.

In this thesis, a HCI design theory based on the artifacts metaphor is presented. A middleware called u-map is proposed to manage the digital artifacts. In order to illustrate and evaluate our ideas, a number of digital devices and u-learning application were developed.

Beside the u-learning field, the ideas present in this thesis can be applied into other scenarios, like health care, marketplace, factory, military and so forth, with little effort. The result of our research may contribute to pave the way for a new wave of smart object and UbiComp applications.

Summaries of the Thesis Review Results

The applicant has investigated the smart devices and the future ubiquitous learning application systems based on the smart devices. At first, the concept of smart devices called Digital Artifact (DA) is given out and principles of DA design are discussed. Then, a middleware is presented to facilitate the u-learning application development. Moreover, three different kinds of u-learning systems are discussed in more details. The first is a physical object reminder based on one DA (a ubiquitous schoolbag). The system can know what is in the schoolbag and what

should in the schoolbag. When pupils forget something, it will remind the pupils. The second is a review system based on two DA (a digital flash card and a ubiquitous schoolbag). The system can know what the pupils have learned on a given lecture, and remind and help the pupils to review the learned contents at proper time. The third is a query and answer system based on multiple DAs. The system can know the objects locations surrounding the pupils. When pupils have any questions, they can query the system in a nature way. The system will encourage and advice the pupils to do experiment to find out the answer in their surrounding environment. The principles on the DA design are proved to be effective through a series of u-learning systems design and evaluation experiments.

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