WEB PORTAL FOR SCIENTIFIC COMPUTING LIBRARY

UMI NADIA BINTI ABDUL BASITT

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ABSTRACT

Scientific computing or computational science is a collection of tools, techniques and theories required to develop and solve mathematical models in science and engineering on a computer. There are many systems of scientific computing libraries developed nowadays, regardless of whether they are web-based or web application. However, the libraries are complex and not complete. In addition, most science teams collaborate across multiple geographically distributed institutions, therefore, it becomes more difficult to store, share and analyze the scientific data among the team members. By developing this Web Portal for Scientific Computing Library, good criteria of scientific computing library are identified. This project aims to provide sophisticated web portal to store codes, share results, and share knowledge on scientific computing. Furthermore, the scientific computing library focuses on multi-domain applications. The technologies used for this web portal development are ASP.Net as the scripting language with use of Microsoft Visual Studio 2008 and Microsoft SQL Server 2005 as the database application development software. The data set used is sequential algorithm in C and C++ programming language based on numerical simulation of partial differential equation. It is hoped that this project will give benefits to the scientists who utilize the scientific computing for their researches.

ABSTRAK

Komputeran saintifik atau komputasi sains ialah suatu koleksi alat-alat, teknik, dan teori yang diperlukan untuk membangunkan dan menyelesaikan model matematik dalam sains dan kejuruteraan menggunakan computer. Terdapat banyak sistem untuk perpustakaan komputeran saintifik yang dibangunkan hari ini, sama ada dalam bentuk web atau aplikasi web. Walau bagaimanapun, perpustakaan tersebut didapati complex dan tidak lengkap. Kebanyakan kumpulan sains berkolaborasi dengan institusi sehingga merentas sempadan geografi. Oleh itu, ia menjadi sukar untuk menyimpan, berkongsi, dan menganalisa data saintifik antara ahli kumpulan. Dengan membangunkan Portal Web untuk Perpustakaan Komputeran Saintifik ini, kriteria yang bagus untuk perpustakaan komputeran saintifik dikenalpasti. Projek ini menyasarkan untuk menyediakan portal web yang sofistikated untuk menyimpan kod, berkongsi hasil keputusan, dan berkongsi pengetahuan mengenai komputeran saintifik. Tambahan pula, perpustakaan komputeran saintifik ini memfokus kepada pelbagai bidang aplikasi. Teknologi yang digunakan untuk membangunkan portal web ini adalah *ASP.Net* sebagai bahasa pengaturcaraan dengan penggunaan *Microsoft Visual Studio 2008* dan *Microsoft SQL Server 2005* sebagai perisian pembangunan aplikasi pangkalan data. Set data yang digunakan adalah algoritma turutan dalam bahasa pengaturcaraan C dan C++ berdasarkan simulasi numerik persamaan pembezaan separa. Projek ini diharap dapat memberi faedah kepada saintis yang menggunakan komputeran saintifik untuk kajian.

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CHAPTER I

INTRODUCTION

1.8 Introduction

People nowadays are unquestionably dependent on computers and the Internet that connect them. The emergence of Internet has affected the way people live. The growth of Internet exceeds according to recent statistics reported in Internet World Stats for year 2008 on world Internet users, there is more than 1.596 billion people use Internet. From that number, Asia region users rank highest with 650.4 million of Internet users (refer to Figure 1.1). Malaysian Communications and Multimedia Commission (MCMC) published statistics on Malaysia's internet penetration in their report on year 2008 that 14.9 million people which are equivalent to 59% of the Malaysia population are Internet users.

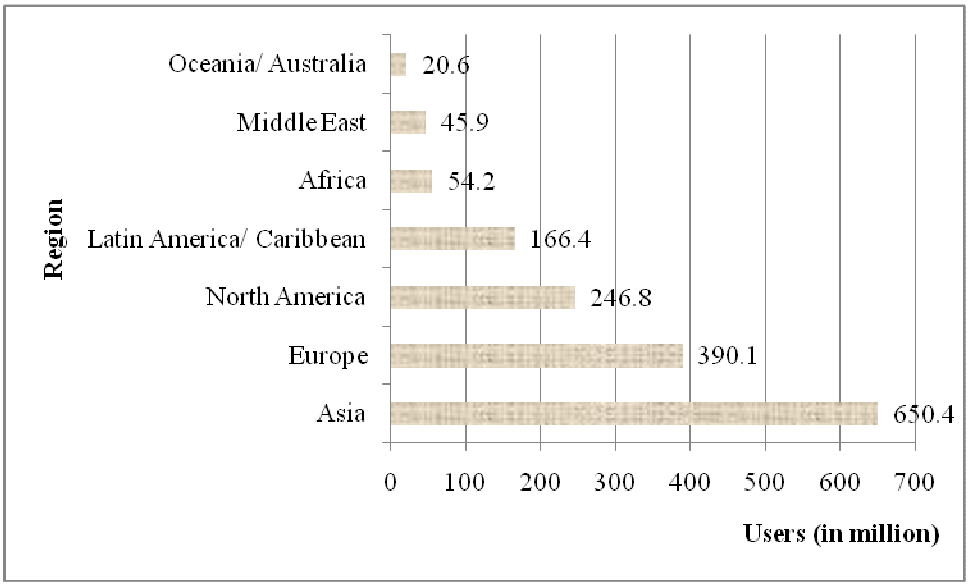

Figure 1.1 World Internet users by world region (Internet World Stats, 2009)

Advances in new information technologies and development of the Internet and World Wide Web (WWW) in the 1990s have changed the computing environment for both individuals and businesses. Since its birth in the 1990s, people have been witnessed to widespread use of the WWW for commercial purposes (Li and Dasgupta, 2005). Variety of web applications are also includes scientific applications.

According to Borgman *et al.* (2004), few repositories offer the tools and services that scientists appear to desire, such as the ability to store data for personal analysis and use, and tools to monitor and interpret data in the field so that changes can be made to experiments in progress. The majority of scientific researchers save all of their data and they reuse those data when applicable to future research. However, their available tools support analysis of data much better than they do preservation and sharing. As a result, scientists often store data with minimal documentation and do little toward preservation other than to back up files. These approaches are largely local and do not adequately support future access and use. Therefore, an approach of Web Portal for Scientific Computing Library (PSCL) will be developed to overcome the current problem.

A few studies have investigated and surveyed web-based scientific computing library research in the recent past. These studies include proposing collaboration tool to support and facilitate data sharing (Chin and Lansing, 2004; Drummond and Marques, 2005), discuss on management of computing services and resources, and also building

and executing complex application (Dozsa *et al*., 2006; Suzumura *et al*., 2001), aims on repository concept for scientific computing (Lazar *et al*., 2007; Brezany and Winslett, 1999; Mitra *et al*., 2007), discuss of sharing scientific data (Chin and Lansing, 2004; Mitra *et al*., 2007), and discuss on user environment for problem solving (Akzhalova and Aizhulov, 2007; Vazhkudai *et al*., 2007).

1.9 Problem Background

Scientific computing library is a collection of tools, techniques and theories required to develop and solve mathematical models in science and engineering on a computer (Steeb *et al*., 2004). Usually, it is used as predictive analysis tools. Among organizations or people that use or need this scientific computing are programmers at corporations, research laboratories and academic institutions. The core of scientific computing is designing, writing, testing, debugging and modifying numerical software for application to a vast range of areas, from graphics, meteorology and chemistry to engineering, biology and finance (Oliveira and Stewart, 2006).

From the observation that has been done on existing scientific computing libraries, it is found that the libraries are quite complex to use for the beginners and the libraries content is not complete (refer to subtopic 2.5.3). Knowledge resources are not centralized and the amount of distributed knowledge sources available can constitute an obstacle for finding and retrieving the relevant knowledge. Moreover, this critical mass of scientific computing is also a factor which contributes to the storage problem. As a result, the users waste time searching for the necessary scientific computing to perform work task efficiently (Razmerita, 2004).

According to Vazhkudai (2007), traditionally, scientists have conducted their experiments or raw data collection at various facilities, and then leave their data sets in

hand for analysis back at their home institutions. Most science teams collaborate across multiple geographically distributed institutions. Therefore, it becomes difficult for each user to store and analyze a given experiment's data storage and management infrastructure is imperative for the full production scale of experiments to ensure flexible and efficient accessibility and the proper integrity of metadata management and tracking. Even the majority of users, especially at academic institutions are given an integrated software analysis infrastructure; they would often be confined to run analyses just on local desktop computers. Therefore, access to computational resources is required to properly conduct more sophisticated data analyses, or any associated simulation / modeling of experimental samples.

1.10 Problem Statement

This research focuses on developing a PSCL based on four domains which are chemistry, biology, mathematics, and computer science. Comparison of existing system on scientific computing library in market and comparison of previous studies on scientific computing library were done.

The following research question is addressed to solve the problem: Could PSCL stores and manages data in multiple formats and multi-domain applications?.

This research is conducted to address the issues by utilizing content management system using web portal technology. The system proposed allows solving different scientific problems at any time through the internet technologies. It offers an attractive alternative to expensive supercomputers and parallel computer systems for high-performance computing.

1.11 Objectives

This project aims to achieve the following objectives:

a) To investigate scientific computing library as a content management system and the way it can be managed online.
b) To study the criteria of existing scientific computing library in market.
c) To gather and analyze scientific computing material for the repository.
d) To design and develop a prototype web-based application to support scientific computing library that can manage scientific algorithm.

1.12 Scope

The scopes of this project are:

a) The study focuses on scientific computing for real case problem in Institute of Ibnu Sina (IIS), Universiti Teknologi Malaysia (UTM).
b) The data set focuses on sequential algorithm in C and C++ programming language which is based on numerical simulation of Partial Differential Equation (PDE) for any physical problem statement.
c) The prototype is done for UTM and focuses on the proposed model.
d) The project develops a prototype web-based application for managing scientific algorithm with three modules which are users, scientific algorithm providers, and scientific librarian.

The shaded area in Figure 1.2 shows scope of research that is done in this project. This research framework acts as a guideline for the author to do the research. This scope will be discussed in detail for the later chapters.

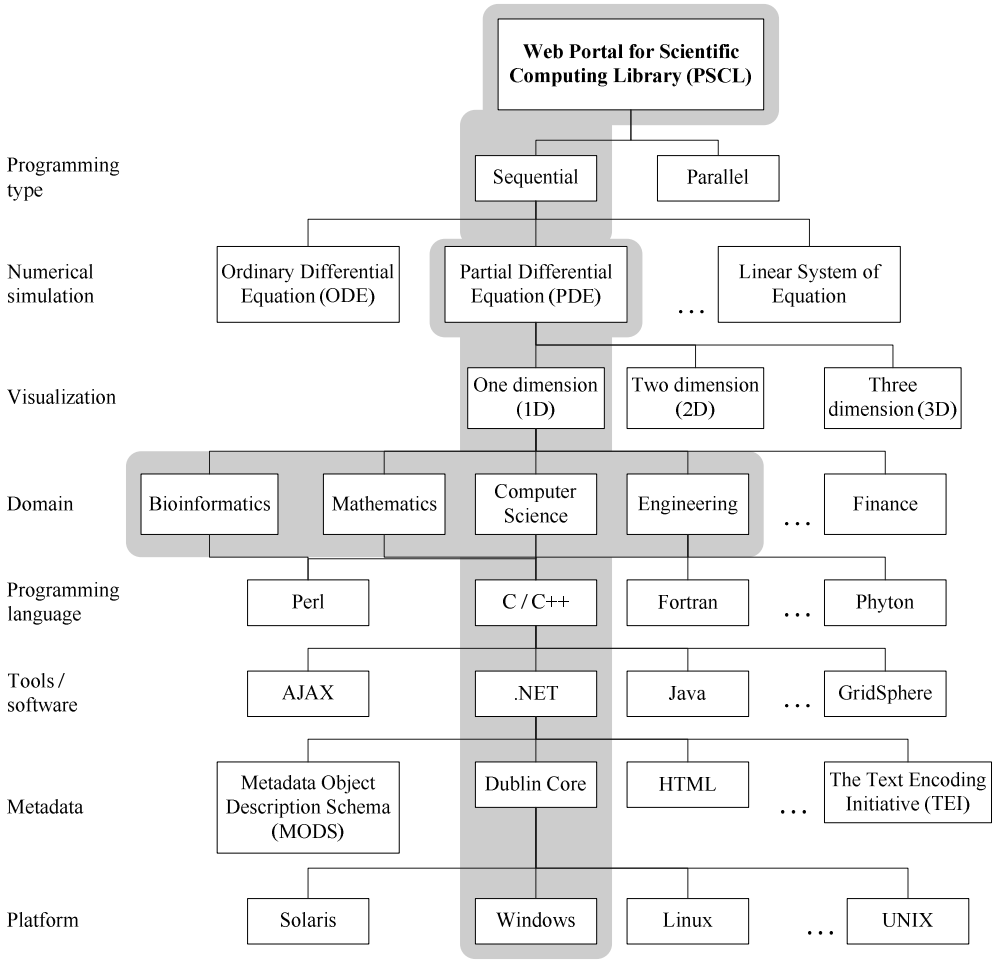

Figure 1.2 Research framework

1.13 Project Importance

Ideally, users would like all resources to be virtualized and not to have to deal with storage or transfer components and issues. Therefore, the importance of the PSCL is to enable widely accessible scientific computing, anytime and anywhere, without worrying about the physical storage or data transfer. It is hope to shorten time for researchers to search a huge amount of scientific computing and thus, can improve their experiments. PSCL also enables:

a) Scientists to easily store, archive, and publish data to the community.
b) Data and basic knowledge sharing among scientists.
c) Scientists to search and retrieve information that they require.
d) Scientists to share their insights with others without geographically constrained.
e) Utilization of mathematical simulation to support the target market and target user.

Due to the growing complexity of the web, portals have become essential to the Internet users. Portals allow easy access to information by integrating heterogeneous applications or data sources in consistent way. It gives users a personalized and restricted view of domain information (Rovan, 2008).

This scientific computing library will be developed in order to:

a) Achieve accuracy, reliability, and stability towards the exact solution in multi-discipline industry.
b) Help the target market.
c) Minimize the absolute error between approximation solution and exact solution.
d) Solve actual problem in industry.

The PSCL will be developed with hope to give better understanding about sharing of scientific data among users. It also hopes to give general knowledge on simulation of the scientific data in order to get the result.

1.14 Chapter Summary

This chapter gives general idea on the project of PSCL based on research of repository of scientific data. Problem background describes current problem in managing scientific computing. Problem statement is the main question that needs to be addressed. Objectives are elements that need to be achieved at the end of this project, while scope is the project boundary that has been identified. Project importance explains on the benefits gained by the parties involved in this project. It is hoped that this project will be very beneficial to everyone and can contributes to the future of research and development.

REFERENCES

Aihara, K., Yamada, T., Kando, N., Fujisawa, S., Uehara, Y., Baba, T., Nagata, S., Tojo, T., Awaji, T., and Adachi, J. (2006). Owlery: A Flexible Content Management System for Growing Metadata of Cultural Heritage Objects and Its Educational Use in the CEAX Project. In Sugimoto, S. *Digital Libraries: Achievements, Challenges and Opportunities*. Berlin: Springer Berlin / Heidelberg. 22-31.

Akzhalova, A. Z. and Aizhulov, D. Y. (2007). Web Portal to Make Large-Scale Scientific Computations Based on Grid Computing and MPI. In Wyrzykowski, R. *Parallel Processing and Applied Mathematics*. Berlin: Springer Berlin / Heidelberg.

Alexander, W. and Yang, W. (2006). Scientific Visualization Today. *Journal of Computing Sciences in College (JCSC)*. 21 (5): 189-190.

Antoch, J. (2008). Environment for statistical computing. *Computer Science Review*. 2 (2): 113-122.

Bader, M. (2003). *Introduction to Scientific Computing.* (2009, February, 5).

Balay, S., Buschelman, K., Dalcin, S., Eijkhout, V., Gropp, W., Karpeev, D., Kaushik, D., Knepley, M., McInnes, L. C., Smith, B., and Hong, Z. (2008). *Portable, Extensible Toolkit for Scientific Computation (PETSc).* http://www.mcs.anl.gov/petsc/petsc-as (2009, February, 23).

Bancroft, G. V., Merritt, F. J., Plessel, T. C., Kelaita, P.G., McCabe, R. K., and Globus, A. (1990) FAST: A multi-processed environment for visualization of computational fluid dynamics. *Proceedings of IEEE Visualization 1990*. October 23-26. U.S.A.: IEEE Computer Society Press. 14-27, 461-462.

Bennett, S., McRobb, S., and Farmer, R. (2006). *Object-Oriented Systems Analysis and Design Using UML.* 3rd ed. U.S.A.: McGraw-Hill Companies, Inc.

Boiko, B. (2001). *Content Management Bible*. 2nd ed. U.S.A.: Wiley Publishing, Inc.

Boisvert, R. F., Cools, R. and Einarsson, B. (2005). Assessment of Accuracy and Reliability. In Einarsson, B. *Accuracy and Reliability in Scientific Computing*. United States of America: Society for Industrial and Applied Mathematics (SIAM). 14.

Bollig, E. F., Jensen, P. A., Lyness, M. D., Nacar, M. A., da Silveira, R. C., Kigelman, D., Erlebacher, G., Pierce, M., Yuen, D. A., da Silva, R. S. (2007). VLAB: Web services, portlets, and workflows for enabling cyber-infrastructure in computational mineral physics. *Physics of the Earth and Planetary Interiors*. 163 (1-4): 333-346.

Borgman, C. L., Wallis, J. C., Mayernik, M. S., and Pepe, A. (2007). Drowning in Data: Digital Library Architecture to Support Scientific Use of Embedded Sensor Networks. *Joint Conference on Digital Libraries (JCDL) 2007*. June 18–23. U.S.A: Association for Computing Machinery (ACM). 269-277.

Brezany, P. and Winslett, M. (1999). Advanced Data Repository Support for Java Scientific Programming. *Proceedings of the 7th International Conference on High-Performance Computing and Networking*. April 12–14. U.K.: Springer-Verlag. 1127 – 1136.

Butler, G. F., Kramer, W. T. C., Shoshani, A., Agarwal, D. A., Draney, B. R., Jin, G., and Hules, J. A. (2003). Deep Scientific Computing Requires Deep Data. *IBM Journal of Research and Development.* 48 (2): 209-232.

Caro, A., Calero, C., Caballero, I., and Piattini, M. (2006). Defining a Quality Model for Portal Data. *Proceedings of the 6th International Conference on Web Engineering (ICWE) 2006*. July 11-14. U.S.A.: Association for Computing Machinery (ACM). 115-116.

Chin, G. and Lansing C. S. (2004). Capturing and Supporting Contexts for Scientific Data Sharing via the Biological Sciences Collaboratory. *Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work (CSCW) 2004*. November 6-10. U.S.A.: Association for Computing Machinery (ACM).

Chu, H., Chen, M., and Chen, Yn. (2007). A Semantic-based Approach to Content Abstraction and Annotation for Content Management. *Expert Systems with Applications.* 36 (2009): 2360-2376.

Chu, W. C., Hong-Xin, L., and Juei-Nan, C. (2005). Context-Sensitive Content Representation for Mobile Learning. In Xing-Yi, Lin. *Advances in Web-Based Learning – ICWL 2005*. Berlin: Springer Berlin / Heidelberg. 349-354.

CM3 Content Manager (1997). *Key Benefits of Content Management*. http://www.cm3cms.com/company/articles/key_benefits.html (2009, February 7).

Daigle, S. L. and Cuocco, P. M. (2002). Portal Technology Opportunities, Obstacles, and Options: A View from the California State University. In Katz, R. N. *Web Portals and Higher Education Technologies to Make IT Personal*. U.S.A.: Jossey-Bass, A Wiley Company. 109-123.

Delannoy, O. and Emad, N. (2006). YML / LAKeWeb Portal: Web based research portal for linear algebra application. *High Performance Computing Symposium (HPC 2006)*. April 2-6. France: Versailles University.

Dennis, A., Wixom, B. H., and Tegarden, D. (2005). *Systems Analysis and Design with UML Version 2.0.: An Object-Oriented Approach.* 2nd ed. U.S.A.: John Wiley & Sons, Inc.

DeRose, P., Warren, S., Fei, C., AnHai, D., and Raghu Ramakrishnan. (2007). Building Structured Web Community Portals: A Top Down, Compositional, and Incremental Approach. *International Conference on Very Large Data Bases (VLDB) 2007*. September 23-28. U.S.A.: VLDB Endowment. 399-410.

Dewitz, S. D. (1996). *Systems Analysis and Design and the Transition to Objects*. U.S.A.: McGraw-Hill Companies, Inc.

Donoho, D. and Grimes, C. (2001). A New Paradigm for Scientific Computing. http://www.ima.umn.edu/talks/workshops/4-9-13.2001/grimes/slides0413.pdf (2009, March 14).

Dozsa, G., Kacsuk, P., Nemeth, C. (2006). Grid Application Development on the Basis of Web Portal Technology. In Dongarra, J., Madsen, K., Wasniewski, J. *Applied Parallel Computing*. Berlin: Springer Berlin / Heidelberg. 472-480.

Drummond, L. A. and Marques, O. A. (2005). An Overview of the Advanced Computational Software (ACTS) Collection. *Transactions on Mathematical Software (TOMS)*. 31 (3): 282–301.

Dublin Core Metadata Initiative (2009). *Dublin Core Metadata Element Set, Version 1.1*. http://www.dublincore.org/documents/dces/ (2009, March 18).

Foddy, W. (1993). *Constructing Questions for Interviews and Questionnaires: Theory and Practice in Social Research.* Cambridge: Cambridge University Press.

Ford, B. and Sayers D. K. (1976). Developing a Single Numerical Algorithms Library for Different Machine Ranges. *Transactions on Mathematical Software (TOMS).* 2 (2): 115-131.

Fraternali, P. and Paolini, P. (2000). Model-driven Development of Web Applications: the AutoWeb system. *ACM Transactions on Information Systems (TOIS).* 18 (4): 323 - 382 .

Gammel (1991). *Matpack C++ Numerics and Graphics Library*. http://www.matpack.de (2009, February, 6).

Garcia, R., Gimeno, J. M., Perdrix, F., Gil1, R., Oliva, M., and Lytras, M. D. (2008). The Rhizomer Semantic Content Management System. *Proceedings of the 1st World Summit on The Knowledge Society: Emerging Technologies and Information Systems for the Knowledge Society.* Berlin: Springer Berlin / Heidelberg. 385-394.

Kathuria, G. (2006). *Web Content Management with Documentum: Set up, Design, Develop, and Deploy Documentum Applications.* Birmingham, U.K.: Packt Publishing Ltd. 7.

Gertz, M. and Ludascher, B. (2006). Scientific Data and Workflow Management. 10th International Conference on Extending Database Technology (EDBT). March 26-30.

Gilbane, F. (2000). What is Content Management? *The Gilbane Report*. 8 (8).

Gray, J., Liu, D. T., Nieto-Santisteban, M., Szalay, A. S., DeWitt, D., and Heber, G. (2005). Scientific Data Management in the Coming Decade. *ACM SIGMOD Record*. U.S.A.: Association for Computing Machinery (ACM). 34 (4): 34-41.

Greenberg, J. and Carrier, S. (2008). Metadata for Scientific Datasets (MeS) Workshop. *International Conference on Dublin Core and Metadata Applications*. September 22-26. U.K.: Emerald Group Publishing Limited. 4-5.

Gu, Y. T, Liu, G. R. (2003). A Boundary Radial Point Interpolation Method (BRPIM) for 2-D Structural Analyses. *Structural Engineering And Mechanics*. 15 (5): 535-550.

Hackos, J. T. (2002). *Content Management for Dynamic Web Delivery*. U.S.A.: John Wiley & Sons, Inc.

Han, X. and Liu, G. R. (2003). Computational Inverse Techniques For Material Characterization Of Functionally Graded Materials. *AIAA Journal*. 41 (2): 288 - 295.

Heath, M. T. (2002). *Scientific Computing an Introductory Survey*. 2nd ed. New York: McGraw-Hill.

Heroux, M., Baker, C., Bartlett, R., Bochev, P., Boggs, P., Boman, E., Chevalier, C., Coffey, T., Day, D., Devine, K., Dohrmann, C., Gay, D., Guillen, E., Hetmaniuk, U., Hoekstra, R., Hooper, R., Howle, V., Hu, J., Kolda, T., Knepper, S., Kotulski, J., Lehoucq, R., Long, K., Nusbaum, K., Pawlowski, R., Phipps, E., Riesen, L. A., Sala, M., Salinger, A., Siefert, C., Thornquist, H., Tuminaro, R., Willenbring, J., and Williams, A. (2003). *The Trilinos Project.* http://trilinos.sandia.gov (2009, February, 23).

HPCx Consortium (2008). *HPCx Service Annual Report for 2008*. http://www.hpcx.ac.uk/projects/reports/annual/HPCXAnnual2008_Summary.pdf (2009, March 18).

http://www.sapdesignguild.org/editions/edition3/portal_definition.asp (2009, February, 23).

Hultquist, J. P. and Raible, E. L. (1992). SuperGlue: A programming environment for scientific visualization. *Proceedings of IEEE Visualization 1992*. October 19-23. U.S.A.: IEEE Computer Society Press. 243-250.

Internet World Stats (2009). *World Internet Usage Statistics News and World Population Stats.* http://www.internetworldstats.com/stats.htm (2009, March 14).

Jianwei, L., Wei-keng, L., Choudhary, A., Ross, R., Thakur, R., Gropp, W., Latham, R. Siegel, A., Gallagher, B., and Zingale, M. (2003). Parallel netCDF: A High-Performance Scientific I/O Interface. *Conference on Supercomputing 2003*. November 15-21. U.S.A.: IEEE Computer Society. 39.

Kandaswamy, G., Fang, L., Huang, Y., Shirasuna, S., Marru, S., and Gannon, D. (2006). Building web services for scientific grid applications. *IBM Journal of Research and Development*. 50 (2/3): 249-260.

Kandaswamy, G., Fang, L., Huang, Y., and Shirasuna, S. (2006). Building Web Services for Scientific Grid Applications. *IBM Journal of Research and Development*. 50 (2/3): 249-260.

Kartchner, C. (1998). Content Management Systems: Getting from Concept to Reality. *Journal of Electronic Publishing.* 3 (4).

Lang, U., Lang, R., and Ruhle, R. (1991). Integration of Visualization and Scientific Calculation in a Software System. *Proceedings of the 2nd Conference on Visualization 1991*. U.S.A.: IEEE Computer Society Press. 268-274.

Lazar, Z. I., Kovacs, L. I., and Mathe, Z. (2007). COMODI: Architecture for a Component-Based Scientific Computing System. In Lazar, Z. I., Kovacs, L. I., and Mathe, Z. *Applied Parallel Computing. State of the Art in Scientific Computing*. Berlin: Springer Berlin / Heidelberg. 280-288.

Li, X. and Dasgupta, S. (2005). User Satisfaction with Web Portals: An Empirical Study. In Yuan, Gao. *Web Systems Design and Online Consumer Behavior.* U.S.A: Idea Group Publishing.

Liu, G. R. and Liu, M. B. (2003). Smoothed Particle Hydrodynamics: A Meshfree Particle Method. Singapore: World Scientific Publishing Co.

Louis, K. S., Jones, L. M., and Campbell, E. G. (2002). Sharing in Science. *American Scientist.* 90 (4): 304 -307.

Louis, K. S., Jones, L. M., and Campbell, E. G. 2002. Sharing in Science. *American Scientist*. 90 (4): 304-307.

Malaysian Communications and Multimedia Commission (2008). Report on Malaysia's Internet Penetration. http://www.skmm.gov.my/facts_figures/stats/index.asp. (2009, March 14).

Mann, B., Williams, R., Atkinson, M., Brodlie, K., Storkey, A., and Williams, C. (2002). *Scientific Data Mining, Integration, and Visualization.* UK e-Science Technical Report Series. October 24-25. Edinburgh: e-Science Institute.

McCormick, B., DeFanti, T. A., and Brown, M. D. (1987). Visualization in Scientific Computing. *Computer Graphics*. 21 (6):15-21.

Mickus-Miceli, K. D. and Domik, G. O. (1992). An Enriched Visualization Framework for Multidisciplinary Data Analysis. *Symposium on Intelligent Scientific Computation, American Association for Artificial Intelligence (AAAI).* October 23-25. U.S.A.: AAAI Press.

Mohd. Shahizan Othman (2009). *Mohd. Shahizan Othman*. http://web.utm.my/fsksm/staf/shahizan/ (2009, March 30).

National Information Standards Organization (2004). *Understanding Metadata*. U.S.A.: NISO Press.

National Library of Australia. Preservation Services Branch (2009). *Metadata.* http://www.nla.gov.au/padi/topics/30.html (2009, March 15).

Nickols, F. (2003). Prototyping Systems Development in Record Time. *Journal of Systems Management.* 44 (9).

Nielsen, J. and Landauer, T. K. (1993). A mathematical model of the finding of usability problems. Proceedings of ACM INTERCHI '93 Conference. April 24-29. 206-213.

Nonaka, I. (1994). A Dynamic Theory of Organizational Knowledge Creation. *Organization Science*. 5 (1):14–37.

Numerical Analysis Group members (2007). *HSL*. http://www.cse.scitech.ac.uk/nag/hsl (2009, February, 3).

Oakes, G. (2006). *Introduction to Content Management Systems: Spend Your Time Managing Information, Not Technology.* http://www.freesoftwaremagazine.com/articles/cms_intro (2009, February, 10).

Oliveira, S. and Stewart, D. E. (2006). *Writing Scientific Software: A Guide to Good Style*. U.K.: Cambridge University Press.

Parr, C. S., Espinosa, R., Dewey, T., Hammond, G., and Myers, P. (2005). Building a Biodiversity Content Management System for Science, Education, and Outreach. *Data Science Journal*. 4: 1-11.

Peltier, S. T., Ellisman, M. H. (2003). The Biomedical Informatics Research Network. In Foster, I. and Kesselman, C. *The Grid: Blueprint for a New Computing Infrastructure.* U.S.A.: Morgan Kaufmann.

Pinchover, Y. and Rubinstein, J. (2005). *An Introduction to Partial Differential Equations*. U.S.A.: Cambridge University Press. 1-2.

Mitra, P., Giles, C. L., Sun, B., and Ying, L. (2007). ChemXSeer: A Digital Library and Data Repository for Chemical Kinetics. *CyberInfrastructure: Information Management in eScience (CIMS) 2007*. November 9. U.S.A.: Association for Computing Machinery (ACM). 7-10/

Razmerita, L. (2004). Ontology-Based User Modeling for Knowledge Management Systems. In Angehrn, A. and Maedche, A. *User Modeling 2003*. Berlin: Springer Berlin / Heidelberg. 148.

Rovan, L. (2008). *Realizing Semantic Web Portal Using Available Semantic Web Technologies and Tools*. 7th International Semantic Web Conference (ISWC2008).

Schwab, M. (2000). Making scientific computations reproducible. *Computing in Science and Engineering*. U.S.A.: IEEE Computer Society. 2 (6): 61-67.

Shelly, G. B., Cashman, T. J., and Rosenblatt, H.J. (2006). *Systems Analysis and Design*. 6th ed. U.S.A.: Thomson Course Technology.

Shortliffe, E. H., Barnett, O., Cimino, J. J., Greenes, R. A., and Patel, V. L. (1996). InterMed: An Internet-Based Medical Collaboratory. *Proceedings of INET 1996, the Annual Meeting of the Internet Society*. Pennsylvania: CiteSeerX.

Siemens, G. (2003). *Content Management: Our Organized Future*. http://www.elearnspace.org/Articles/contentmanagement.htm (2009, February, 7).

Simpson, D. L. (2005). Content for One: Developing a Personal Content Management System. *SIGUCCS Conference on User Services 2005*. November 6–9. U.S.A.: Association for Computing Machinery (ACM). 338-342.

Skidmore, J. L., Sottile, M. J., Cuny, J. E., and Malony A. D. (1998). A Prototype Notebook-Based Environment for Computational Tools. *Conference on Supercomputing 1998*. November 7-13. U.S.A.: IEEE Computer Society. 1-15.

Venugopal, S., Buyya, R., and Ramamohanarao, K. (2006). A Taxonomy of Data Grids for Distributed Data Sharing, Management, and Processing. *ACM Computing Surveys*. 38 (3).

Staab, S. (2001). Knowledge Portals. *Proceedings of the workshop on Human Language Technology and Knowledge Management*. U.S.A.: Association for Computational Linguistics.

Stavroulakis, I. P. and Tersian, S. A. (2004). *Partial Differential Equations: An Introductionwith Mathematica and MAPLE*. 2nd ed. Singapore: World Scientific Publishing Co. Re. Ltd. 1.

Steeb, W. (2004). *Problems & Solutions In Scientific Computing With C++ And Java Simulations*. Singapore: World Scientific Publishing Co. Inc.

Strauss, W. A. *Partial Differential Equations: An Introduction.* U.S.A.: John Wiley & Sons, Inc. 1-2.

Suzumura, T., Matsuoka, S., and Nakada, H. (2001). A Jini-based Computing Portal System. *Conference on Supercomputing 2001*. November 10-16. U.S.A.: Association for Computing Machinery (ACM). 24.

Tanase, D., Bruce, M., Stuart-Moore, J., and Joiner, D. A. (2006). Scaffolding the Infrastructure of the Computational Science Digital Library. *Joint Conference on Digital Libraries (JCDL)*. U.S.A.: Association for Computing Machinery (ACM). 256-257.

Tveito, A. and Winther, R. (1998). *Introduction to Partial Differential Equations: A Computational Approach*. New York: Springer-Verlag. 1-2.

Unidata Program Center (1997). *Network Common Data Format (NetCDF)*. http://www.unidata.ucar.edu/software/netcdf/ (2009, March 18).

Varathan, K., Soundararajan, E., and Somasekharan, M. (2006). Content Management System: A Case Study of IGCAR Library.

Vazhkudai, S. S., Kohl, J. A., and Schwidder, J. (2007). A Java-based Science Portal for Neutron Scattering Experiments. *Principles and Practice of Programming in Java (PPPJ) 2007*. September 5–7. U.S.A.: Association for Computing Machinery (ACM). 21-30.

Visual Numerics Inc. (2009). *IMSL Numerical Libraries*. http://www.vni.com/products/imsl (2009, February 4).

Vliet, H. V. and Porskamp, P. (2000). *Methodology: An Ocean to Cross*. https://doc.freeband.nl/dsweb/Get/Document-9806/GigaCEMethodologyanOceantoCross.pdf (2009, March 9).

W3Schools (2009). *HTML Meta Tag*. http://www.w3schools.com/tags/tag_meta.asp (2009, March 31).

White, M. (2005). *The Content Management Handbook*. London: Facet Publishing. 4.

Winkler, R. (2001). *Portals the All-in-one Web Supersites: Features, Functions, Definitions,Taxonomy*.

Wulf, W. 1993. The Collaboratory Opportunity. *Science*. 261 (5123): 854-855.

LiMin, F. (2007). *Neural Networks in Computer Intelligence*. U.S.A.: McGraw-Hill Companies, Inc.