Graduate Council Document 06-19a-e
Approved by the Graduate Council on 10/19/06

Graduate Certificate Program Proposals

Graduate Council Document 06-19a, Database and Data Mining

Graduate Council Document 06-19b, Computing Security

Graduate Council Document 06-19c, Software Engineering

Graduate Council Document 06-19d, Biocomputing

Graduate Council Document 06-19e, Biometric Computing

Submitted by the
Department of Computer and Information Science
School of Science, IUPUI
August 22, 2006

Dr. Phillip E. Pope
Purdue University Graduate School
Ernest C. Young Hall 170
302 Wood Street
West Lafayette, IN 47907-2108
(765) 494-0136

Dear Phil;

Enclosed are revised proposals for five graduate certificates in Computer and Information Science to be offered at IUPUI for consideration by the Purdue Graduate School. Dr. Mathew Palakal has revised the proposals in response to your suggestions and questions. Please contact us if you need additional information.

Best regards,

Pamela L. Crowell, Ph.D.
Associate Dean for Research and Graduate Education
Associate Professor of Biology
(317) 278-1144
crowell@iupui.edu

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August 15, 2006

Pamela Crowell, PhD
Associate Dean
1000 Waterway, Suite 1
Indianapolis, IN 46202

Dear Pam,

It is with great excitement that we submit proposals for five new Graduate Certificate programs, to be offered by the Department of Computer and Information Science. Enclosed you will find an executive summary and each proposal, complete with alterations that were suggested by Dean Pope at the Purdue University, West Lafayette campus. The Department also received letters of support, which are included as Appendix B.

We have made every effort to adjust these proposals to meet the needs of potential students and the requirements of Purdue University West Lafayette.

Thank you for your continued support of the Department and its efforts in this regard.

Sincerely,

Mathew Palakal, PhD
Chairman, Computer and Information Science
Purdue School of Science, IUPUI
IUPUI Department of Computer and Information Science
Graduate Certificate Program

Overview: A graduate certificate will be issued when a student has completed 12 graduate credit hours in one of the specialization areas. After finishing the requirements for the graduate certificate, the student may opt to finish the remaining requirements towards a M.S. degree. All 12 credit hours of each certificate program are applicable to the M.S. degree.

Admission Criteria: The admission criteria are the same as those for the MS degree program. For students who do not have a degree in Computer Science or related field, CSCI 362 (Data Structures) or an equivalent course is required with a grade of B+ or better.

Specializations: Five specialization areas are offered: (1) Databases and Data Mining; (2) Computer Security; (3) Software Engineering; (4) Biocomputing; and (5) Biometrics.

Course Requirements: 12 graduate credit hours are required. These include:
- One core course (3 credits), as defined in the MS program.
- Three specialization courses (9 credits).

Specific requirements for the specialization areas are as follows:

- **Databases and Data Mining**
  1) Core: CSCI 503 (Operating Systems) or CSCI 580 (Algorithms)
  2) CSCI 541 (Databases)
  3) CSCI 590 (Data Mining)
  4) CSCI 590 (Distributed Databases)

- **Computer Security**
  1) Core: CSCI 580 (Algorithms)
  2) CSCI 590 (Network Security)
  3) CSCI 590 (Information Assurance)
  4) CSCI 536 (Networks)

- **Software Engineering**
  1) Core: CSCI 565 (Programming Languages)
  2) CSCI 506 (Management of Software Development Process)
  3) CSCI 507 (Object Oriented Design and Programming)
  4) CSCI 537 (Distributed Computing) or 536 (Networks)

- **Biocomputing**
  1) Core: BIOL 507 (Molecular Biology) or CSCI 580 (Algorithms)
  2) CSCI 548 (Introduction to Bioinformatics)
  3) CSCI 549 (Intelligent Systems) or CSCI 590 (Data Mining)
  4) CSCI 541 (Database Systems) or CSCI 552 (Visualization)

- **Biometrics**
  1) Core: STAT 511 (Statistics) or CSCI 590 (Pattern Recognition)
  2) CSCI 590 (Biometrics Computing)
  3) CSCI 549 (Intelligent Systems) or CSCI 590 (Data Mining)
  4) CSCI 590 (Image Processing and Computer Vision) or CSCI 550 (Computer Graphics)

Admission information is at www.cs.iupui.edu.
Request for a New Graduate Certificate Program  
Department of Computer and Information Science  
School of Science, IUPUI  

Database and Data Mining Certificate  

To be offered as a Purdue Certificate at IUPUI  
Revised: May 16, 2005  
Further Revised: October 16, 2006  

Purpose of the Program  

Data Mining is an analytic process designed to explore data (usually large amounts of data - typically business or market related) in search of consistent patterns and/or systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. The ultimate goal of data mining is prediction - and predictive data mining is the most common type of data mining and one that has the most direct business applications. The process of data mining consists of three stages: (1) the initial exploration, (2) model building or pattern identification with validation/verification, and (3) deployment (i.e., the application of the model to new data in order to generate predictions).  

The program will introduce students to the core concepts necessary for the design, implementation, and application of database systems. It stresses the fundamental principles in database modeling and design. The aim is to address the continuing need for engineering databases for complex and ever changing applications requiring security, performance, and reliability. The teaching approach will be both instructional and researching. The course emphasizes fundamentals for the logical design of database systems, the entity-relationship model, semantic model, hierarchical model, network model implementations of the models, design theory for relational database, design of query languages and the use of semantics for query optimization, design and verification of integrity assertions and security, and introduction to intelligent query processing and database machines.  

Students will be able to …  

- List and explain the fundamental concepts of a relational database system.  
- Utilize a wide range of features available in a DBMS package.  
- Analyze database requirements and determine the entities involved in the system and their relationship to one another.  
- Develop the logical design of the database using data modeling concepts such as entity-relationship diagrams.  
- Create a relational database using a relational database package.  
- Manipulate a database using SQL.  
- Assess the quality and ease of use of data modeling and diagramming tools.
Objectives: Gain an understanding of distributed database system architecture, distributed database design, query processing issues, optimizing distributed queries, transaction management; elements and concepts of database design, goals and working of a modern DBMS, the SQL language for the creation of a database and applications and basic concepts and practical aspects of integrity, security, concurrency, and recovery.

Relation to existing certificate programs
This program has no relation to existing certificate programs. However, the program is a complement to our existing undergraduate and M.S. programs.

The target audience
The location of the IUPUI campus is unique within the state and the need for targeted computer science certificate programs is unique to the population and companies within the metropolitan area. Our current research activities involve local community affiliation and collaboration. The community includes the local industries such as Eli Lilly & Co., Raytheon, and the IU Medical School. All of these entities in the local community have application domains which have the need for high quality fundamental research. This program will allow employees of these local industries to establish collaborations with our research faculty while at the same time providing them with the skills necessary to introduce these initiatives within their companies. In support of these efforts, we have received several letters of support from local organizations.

Plan for sustaining steady-state enrollment
In the first year (Fall 2007), five students will likely participate in the program. It is anticipated that this number will rise rapidly to ten per year in the next two to three years, as the awareness of the program increases. The potential exists for much greater growth beyond this subsequently. Below is a table which lists the courses of the Certificate and enrollment figures for the last several terms. An asterisk (*) identifies a term in which the relevant course was not offered.

<table>
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<td>CSCI 590 (Data Mining)</td>
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<td>9</td>
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<td>51</td>
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<tr>
<td>CSCI 590 (Distributed Databases)**</td>
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<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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</tr>
</tbody>
</table>

** This is a new variable title course and has not yet been offered.
New resources
No new resources are needed. All courses are currently taught at IUPUI by existing faculty.

Proposed date of the initiation of the certificate program
Proposed date of implementation is Fall 2007, assuming all necessary approvals have been met.

Persons designated as the certificate program head
Dr. Pamela Crowell, Associate Dean for Research and Graduate Programs, School of Science, will provide the school administrative oversight.
Dr. Shiaofen Fang, Associate Professor and Chair, Department of Computer and Information Science will provide the department administrative oversight.
Dr. Xukai Zou, Assistant Professor, Department of Computer and Information Science will advise students.

Faculty initially involved in the program and their credentials

Omran Bukhres  X3801
Ph.D., North Dakota State University, 1990
Email address: bukhes@cs.iupui.edu  317-274-8674
Personal Web Page: http://www.cs.iupui.edu/~bukhes
Dr. Bukhres is the co-principal investigator of the Large Scale Distributed Computing and Multimedia Laboratory. Research focuses: (1) database management systems for multimedia data, and (2) seamless integration of the distributed multimedia databases. Other research interests include: Transaction and Workflow Management, Multimedia Databases, Interoperability and Recovery in Heterogeneous Distributed Database Systems, Knowledge Base and Expert Systems, Mobile and Client Server Computing.

Yuanshun Dai  X0458
Ph.D. in Computer Science, National University of Singapore, September 2003
Email address: ydai@cs.iupui.edu  317-274-3473
Personal Web Page: http://www.cs.iupui.edu/~ydai

Shiaofen Fang  X0329
Ph.D., University of Utah, 1992
Email address: sfang@cs.iupui.edu  317-274-9731
Personal Web Page: http://www.cs.iupui.edu/~sfang
Computer graphics, scientific visualization and geometric modeling are Dr. Fang's research specialties. Currently he is collaborating with biomedical researchers to apply computer graphics and visualization techniques, in particular volumetric modeling and visualization, for medical imaging applications.
Jeffrey Huang  X0375
Ph.D., George Mason University, 1998
Email address: huang@cs.iupui.edu  317-274-9746
Personal Web Page: http://www.cs.iupui.edu/~huang
Jeffrey Huang's specialties and research interests include image processing, pattern recognition, computer vision, machine learning, and Evolutionary Computation (EC) on the applications of face recognition, Human Computer Interaction (HCI) and the interpretations of human activities, multimedia, computer visualization, medical imagery, and Automated Target/Object Recognition (ATR) and detection.

Snehasis Mukhopadhyay  X0313
Ph.D., Yale University, 1994
Email address: smukhopa@cs.iupui.edu  317-274-9732
Current research interests are adaptation and learning in multi-level and distributed systems; information filtering and retrieval; modeling, simulation analysis and adaptive control of complex nonlinear systems using neural networks; design and analysis of intelligent controllers. Dr. Mukhopadhyay received a National Science Foundation Career Award.

Mathew Palakal   X0199
Ph.D., Concordia University, 1987
Email address: mpalakal@cs.iupui.edu
The development of Artificial Neural Network (ANN) models as learning and decision-making systems for various AI-related problems are of primary interest. He is involved in projects that include modeling Biosonar systems, neural network models to predict damages in materials and structures, and distributed information filtering.

Rajeev Raje    X0328
Ph.D., Syracuse University, 1994
Email address: rraje@cs.iupui.edu
Dr. Raje is interested in the system and application aspects of the distributed-object model of computing. His current projects include the development of a seamless environment for net-centric applications, distributed information filtering, collaborative software engineering and visualization environments, and enhancement of different distributed-object models.

Mihran Tuceryan   X0336
Ph.D., University of Illinois-Urbana Champaign, 1986
Email address: tuceryan@acm.org
Dr. Tuceryan's research interests include augmented reality, model-based video coding, 3D computer graphics, 3D computer vision, and pattern recognition. Augmented Reality combines technologies from 3D computer graphics, visualization, advanced user interfaces, and 3D computer vision.
Jiang Yu Zheng    X0384
Ph.D., Osaka University, 1990
Email address: jzheng@cs.iupui.edu
Web Page: http://www.cs.iupui.edu/~jzheng    317-274-9742
Dr. Zheng’s research interests include Computer Vision, 3D Modeling, Dynamic Image Processing, Multimedia, Internet, Scene Representation Graphics, Virtual Reality, Digital Museum Sensor Information Processing, Robotics

Xukai Zou    X0422
Ph.D., Dec., 2000, Computer Science, University of Nebraska-Lincoln
Email address: xkzou@cs.iupui.edu
Applied cryptography and network security, Secure group communication: dynamic key, management, key agreement and distribution, Access control in distributed systems, Authentication and digital signature, data integrity and hash functions, Communication networks and wireless/mobile networks, Software engineering and Web/Internet technologies, Design and analysis of computer algorithms, Data/image processing compression.

Admissions requirements and procedures
Admission requirements
Admission requirements and procedures are the same as those established for the Computer Science Master of Science program as outlined in the IUPUI bulletin and can be reviewed at http://bulletin.iupui.edu/2004-html/science/cis.html#master.

Students admitted directly to the Computer Science Master of Science graduate program may earn this certificate in conjunction with their M.S. degree provided that all the requirements of the certificate program are satisfied and by formally applying to the Certificate Program.

Completion requirements and audit and certification procedures
Course Requirements: 12 graduate credit hours are required. These include:

- One core course (3 credits),
- Three specialization courses (9 credits).

Specific Requirements
1. Core: 503 (Operating Systems) or 580 (Algorithms)
2. 541 (Databases)
3. 590 (Data Mining)
4. 590 (Distributed Databases)

Minimum overall GPA
Successful completion of the certificate requires at least a B average over all courses counting towards the certificate. Courses with a grade of C- or less must be taken again to count towards the certificate. The minimum grade that will be accepted in any single course is C.
Maximum number of credits that can be transferred from another institution
Applicants who have already earned credit for one or more of the equivalent courses from other institutions and other certificate programs may request to apply up to a maximum of three credits of these courses toward this certificate. Any waivers or substitutions have to be approved by the committee that oversees the program.

Maximum number of undergraduate courses that can be applied
No undergraduate courses can be applied to this certificate program.

Maximum time for completion
All requirements for the certificate must be completed within three years. Most students enrolled in this program will be part-time students, employed full time. Thus two years may be needed for the completion of all courses if students take one course per semester.

Number of credit hours taken prior to admission to the certificate program that may be counted to completion of the degree
Up to 6 equivalent credit hours taken prior to admission to the certificate program, including 3 hours taken from another institution, will be counted towards the certificate. The rest of the courses must be completed at IUPUI within a three-year period from the time of admission.

Course lists for the program including course descriptions

503 Operating Systems (3 cr.) P: 403. Spring. Basic principles of operating systems: addressing modes, indexing, relative addressing, indirect addressing, stack maintenance; implementation of multitask systems; control and coordination of tasks, deadlocks, synchronization, mutual exclusion; storage management, segmentation, paging, virtual memory, protection, sharing, access control; file systems; resource management; evaluation and prediction of performance.

580 Algorithm Design, Analysis, and Implementation (3 cr.) P: 463 and 470. Basic techniques for designing and analyzing algorithms: dynamic programming, divide-and-conquer, balancing, upper and lower bounds on time and space costs, worst case and expected cost measures. A selection of applications such as disjoint set union/find, graph algorithms, search trees, pattern matching. The polynomial complexity classes P, NP, and co-NP; intractable problems.

590 Data Mining (3 cr.) *Data Mining* is an analytic process designed to explore data (usually large amounts of data - typically business or market related) in search of consistent patterns and/or systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. The ultimate goal of data mining is prediction - and predictive data mining is the most common type of data mining and one that has the most direct business applications. The process of data mining consists of three stages: (1) the initial exploration, (2) model building or pattern identification with validation/verification, and (3) deployment (i.e., the application of the model to new data in order to generate predictions).

590 Distributed Databases (3 cr.) This course covers fundamental concepts and issues of distributed database systems. Topics discussed in this course include distributed database design, query processing and optimization in distributed databases, concurrency control and reliability, transaction processing in distributed databases, data replication and data integration, and cutting-edge products and technologies in distributed data management.

Procedures for governing the program including construction of committees that will provide oversight
A committee comprised of Dr. Shiaofen Fang, Dr. Xukai Zou and Dr. Yuanshun Dai will jointly oversee the program. All advising will be done by these faculty members. The Department of Computer and Information Science and Ms. Myla Langford, the graduate coordinator, will take responsibility for all record keeping and tracking of students.

Procedures for program evaluation including the criteria for success
Upon completion of the program, exit interviews will be conducted for all students to determine the effectiveness of the program in meeting their needs and to identify how they are using the skills and tools learned in the program in their professions. Follow-up interviews will be conducted after three and five years. Given the projected enrollment of this program, and the fact many of the graduates will remain employed locally, it is anticipated that most students will be tracked this way.

Success of the program will be defined in terms of demand (enrollment) and the responses of the students surveyed upon completion of their degree and in the follow-up interviews.
Request for a New Graduate Certificate Program
Department of Computer and Information Science
School of Science, IUPUI

Computing Security Certificate

To be offered as a Purdue Certificate at IUPUI
Revised: May 16, 2005
Further Revised: October 16, 2006

Purpose of the program
The program will explore concepts and principles of cryptography and network security, including classical and modern cryptography, cryptanalysis, secret key cryptosystems, public key cryptosystems, digital signature and authentication, hash functions and message digest, key distribution and key management, network security protocols. The focus of this class is on practical aspects and application of cryptosystems and security protocols in network systems such as the Internet. The goal of this program is for the participant to acquire an understanding of the concepts and principles of cryptography and network security, and to have a hands-on experience in the practice and application of cryptosystems, security protocols and current network security standards. By the end of the course, the successful participant will know: what are network security threats and attacks, what are security requirements of computer and network systems, what are techniques enforcing security requirements and how to implement these techniques/protocols.

Relation to existing certificate programs
This program has no relation to existing certificate programs. However, the program is a complement to our existing undergraduate and M.S. programs.

The target audience
The location of the IUPUI campus is unique within the state and the need for targeted computer science certificate programs is unique to the population and companies within the metropolitan area. Our current research activities involve local community affiliation and collaboration. The community includes the local industries such as Eli Lilly & Co., Raytheon, and the IU Medical School. All of these entities in the local community have application domains which have the need for high quality fundamental research. This program will allow employees of these local industries to establish collaborations with our research faculty while at the same time providing them with the skills necessary to introduce these initiatives within their companies. In support of these efforts, we have received several letters of support from local organizations.
Plan for sustaining steady-state enrollment
In the first year (Fall 2007), five students will likely participate in the program. It is anticipated that this number will rise rapidly to ten per year in the next two to three years, as the awareness of the program increases. The potential exists for much greater growth beyond this subsequently. The table below lists the courses included in the Certificate and the enrollment for each in the last several semesters. An asterisk (*) indicates a term in which the course was not offered.

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<tr>
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<td>*</td>
<td>16</td>
<td>*</td>
<td>4</td>
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</tbody>
</table>

**This course has not yet been offered.

New resources
No new resources are needed. All courses are currently taught at IUPUI by existing faculty.

Proposed date of the initiation of the certificate program
Proposed date of implementation is Fall 2007, assuming all necessary approvals have been met.

Persons designated as the certificate program head
Dr. Pamala Crowell, Associate Dean for Research and Graduate Programs, School of Science, will provide the school administrative oversight.
Dr. Shiaofen Fang, Associate Professor and Chair, Department of Computer and Information Science will provide the department administrative oversight.
Dr. Xukai Zou, Assistant Professor, Department of Computer and Information Science will advise students.

Faculty initially involved in the program and their credentials

Omran Bukhres X3801
Ph.D., North Dakota State University, 1990
Email address: bukhres@cs.iupui.edu 317-274-8674
Personal Web Page: http://www.cs.iupui.edu/~bukhres
Dr. Bukhres is the co-principal investigator of the Large Scale Distributed Computing and Multimedia Laboratory. Research focuses: (1) database management systems for multimedia data, and (2) seamless integration of the distributed multimedia databases.

**Yuanshun Dai**

Ph.D. in Computer Science, National University of Singapore, September 2003
Email address: ydai@cs.iupui.edu 317-274-3473
*Personal Web Page*: http://www.cs.iupui.edu/~ydai

**Shiaofen Fang**

Ph.D., University of Utah, 1992
Email address: sfang@cs.iupui.edu 317-274-9731
*Personal Web Page*: http://www.cs.iupui.edu/~sfang
Computer graphics, scientific visualization and geometric modeling are Dr. Fang’s research specialties. Currently he is collaborating with biomedical researchers to apply computer graphics and visualization techniques, in particular volumetric modeling and visualization, for medical imaging applications.

**Jeffrey Huang**

Ph.D., George Mason University, 1998
Email address: huang@cs.iupui.edu 317-274-9746
*Personal Web Page*: http://www.cs.iupui.edu/~huang
Jeffrey Huang's specialties and research interests include image processing, pattern recognition, computer vision, machine learning, and Evolutionary Computation (EC) on the applications of face recognition, Human Computer Interaction (HCI) and the interpretations of human activities, multimedia, computer visualization, medical imagery, and Automated Target/Object Recognition (ATR) and detection.

**Snehasis Mukhopadhyay**

Ph.D., Yale University, 1994
Email address: smukhopa@cs.iupui.edu 317-274-9732
Current research interests are adaptation and learning in multi-level and distributed systems; information filtering and retrieval; modeling, simulation analysis and adaptive control of complex nonlinear systems using neural networks; design and analysis of intelligent controllers. Dr. Mukhopadhyay received a National Science Foundation Career Award.

**Mathew Palakal**

Ph.D., Concordia University, 1987
Email address: mpalakal@cs.iupui.edu
The development of Artificial Neural Network (ANN) models as learning and decision-making systems for various AI-related problems are of primary interest. He is involved in
projects that include modeling Biosonar systems, neural network models to predict damages in materials and structures, and distributed information filtering.

**Rajeev Raje**  
Ph.D., Syracuse University, 1994  
Email address: rraje@cs.iupui.edu  
317-274-5174  
Dr. Raje is interested in the system and application aspects of the distributed-object model of computing. His current projects include the development of a seamless environment for net-centric applications, distributed information filtering, collaborative software engineering and visualization environments, and enhancement of different distributed-object models.

**Mihran Tuceryan**  
Ph.D., University of Illinois-Urbana Champaign, 1986  
Email address: tuceryan@acm.org  
317-274-9736  
Dr. Tuceryan's research interests include augmented reality, model-based video coding, 3D computer graphics, 3D computer vision, and pattern recognition. Augmented Reality combines technologies from 3D computer graphics, visualization, advanced user interfaces, and 3D computer vision.

**Jiang Yu Zheng**  
Ph.D., Osaka University, 1990  
Email address: jzheng@cs.iupui.edu  
317-274-9742  

**Xukai Zou**  
Ph.D., Dec., 2000, Computer Science, University of Nebraska-Lincoln  
Email address: xkzou@cs.iupui.edu  
317-278-8576  
Applied cryptography and network security, Secure group communication: dynamic key, management, key agreement and distribution, Access control in distributed systems, Authentication and digital signature, data integrity and hash functions, Communication networks and wireless/mobile networks, Software engineering and Web/Internet technologies, Design and analysis of computer algorithms, Data/image processing compression.

**Admissions requirements and procedures**

**Admission requirements**

Admission requirements and procedures are the same as those established for the Computer Science Master of Science program as outlined in the IUPUI bulletin and can be reviewed at [http://bulletin.iupui.edu/2004-html/science/cis.html#master](http://bulletin.iupui.edu/2004-html/science/cis.html#master).
Students admitted directly to the Computer Science Master of Science graduate program may earn this certificate in conjunction with their M.S. degree provided that all the requirements of the certificate program are satisfied and by formally applying to the Certificate Program.

Completion requirements and audit and certification procedures

Course Requirements: 12 graduate credit hours are required. These include:
- One core course (3 credits),
- Three specialization courses (9 credits).

Specific Requirements
- Core: 580 (Algorithms)
- 590 (Network Security)
- 590 (Information Assurance)
- 536 (Networks)

Minimum overall GPA
Successful completion of the certificate requires at least a B average over all courses counting towards the certificate. Courses with a grade of C- or less must be taken again to count towards the certificate. The minimum grade that will be accepted in any single course is C.

Maximum number of credits that can be transferred from another institution
Applicants who have already earned credit for one or more of the equivalent courses from other institutions and other certificate programs may request to apply up to a maximum of three credits of these courses toward this certificate. Any waivers or substitutions have to be approved by the committee that oversees the program.

Maximum number of undergraduate courses that can be applied
No undergraduate courses can be applied to this certificate program.

Maximum time for completion
All requirements for the certificate must be completed within three years. Most students enrolled in this program will be part-time students, employed full time. Thus two years may be needed for the completion of all courses if students take one course per semester.

Number of credit hours taken prior to admission to the certificate program that may be counted to completion of the degree
Up to 6 equivalent credit hours taken prior to admission to the certificate program, including 3 hours taken from another institution, will be counted towards the certificate. The rest of the courses must be completed at IUPUI within a three-year period from the time of admission.

Course lists for the program including course descriptions

580 Algorithm Design, Analysis, and Implementation (3 cr.) P: 463 and 470. Basic techniques for designing and analyzing algorithms: dynamic programming, divide-and-
conquer, balancing, upper and lower bounds on time and space costs, worst case and expected cost measures. A selection of applications such as disjoint set union/find, graph algorithms, search trees, pattern matching. The polynomial complexity classes P, NP, and co-NP; intractable problems.

536 Data Communication and Computer Networks (3 cr.) P: 402. Data communications: communication hardware technologies including local area and long-haul network hardware, circuit and packet switching, interfaces between computer and network hardware, and performance issues. Network architecture: protocol software and conceptual layering, reliable delivery over an unreliable channel, transport protocols, virtual circuits, datagrams, Internet working as a fundamental design concept, the client-server paradigm, naming and name binding, name servers, addressing and address resolution, routing and routing algorithms, congestion and flow control techniques, network file systems, distribution of computation, DARPA Internet protocols (TCP/IP) as examples of protocol organization.

590 Network Security (3 cr.) This is an introductory level course on the concepts and principles of cryptography and network security, including classical and modern cryptography, cryptanalysis, secret key cryptosystems, public key cryptosystems, digital signature and authentication, hash functions and message digest, key distribution and key management, network security protocols. The focus of this class is on practical aspects and application of cryptosystems and security protocols in network systems such as the Internet.

590 Information Assurance (3 cr.) P: 362, N421. The course aims to give students a thorough understanding of what information assurance means. different security models and techniques, non-technical issues related to security. Topics covered include Basic notions of confidentiality, integrity, authentication, and availability; Introduction to secret-key and public key cryptosystems; Virus, worms, Trojan horses, security kernels and secure programming; Intrusion detection and response; Access controls; Firewall technologies; and Legal, social and managerial issues and security policies.

Procedures for governing the program including construction of committees that will provide oversight
A committee comprised of Dr. Shiaofen Fang, Dr. Xukai Zou and Dr. Yuanshun Dai will jointly oversee the program. All advising will be done by these faculty members. The Department of Computer and Information Science and Ms. Myla Langford, the graduate coordinator, will take responsibility for all record keeping and tracking of students.

Procedures for program evaluation including the criteria for success
Upon completion of the program, exit interviews will be conducted for all students to determine the effectiveness of the program in meeting their needs and to identify how they are using the skills and tools learned in the program in their professions. Follow-up interviews will be conducted after three and five years. Given the projected enrollment of this program, and the fact many of the graduates will remain employed locally, it is anticipated that most students will be tracked this way.
Success of the program will be defined in terms of demand (enrollment) and the responses of the students surveyed upon completion of their degree and in the follow-up interviews.
Request for a New Graduate Certificate Program
Department of Computer and Information Science
School of Science, IUPUI

Software Engineering Certificate

To be offered as a Purdue Certificate at IUPUI
Revised: May 16, 2005
Further Revised: October 16, 2006

Purpose of the program
A central problem of today’s economical development and competitiveness in industry, society, science and engineering is the mastering of complex, large, heterogeneous, software-intensive products and the processes of their construction, application and adaptation. The success of software products and services as well as of enterprises and organizations is increasingly determined by the availability of such adequate software solutions.

Software engineering is the establishment and use of engineering principles to manage the human and technical components involved in creating software so that is satisfies the client’s functional requirements and constraints. This course is intended as an introduction to the principles and practice of software engineering. It will cover tools and techniques used in software development to evaluate and control software quality and project progress.

Topics include life cycle concepts, applied to program specification, development and maintenance, the use of a specific methodology in developing large programs, program verification, and techniques for testing and quality control. The goal is to acquire an understanding of the principles of, and skills in current practice for, carrying out a team sized software engineering project. Students completing this certificate will be familiar with esthetic issues in software design, ethical practices in the software industry, a current process for developing software, current process for managing software engineering projects, measures of software quality, measures of project progress, tools that support software engineering projects.

Relation to existing certificate programs
This program has no relation to existing certificate programs. However, the program is a complement to our existing undergraduate and M.S. programs.

The target audience
The location of the IUPUI campus is unique within the state and the need for targeted computer science certificate programs is unique to the population and companies within the metropolitan area. Our current research activities involve local community affiliation and collaboration. The community includes the local industries such as Eli Lilly & Co., Raytheon, and the IU Medical School. All of these entities in the local community have application domains which have the need for high quality fundamental research. This program will allow employees of these local industries to
establish collaborations with our research faculty while at the same time providing
them with the skills necessary to introduce these initiatives within their companies.
In support of these efforts, we have received several letters of support from local
organizations.

**Plan for sustaining steady-state enrollment**
In the first year (Fall 2007), five students will likely participate in the program. It is
anticipated that this number will rise rapidly to ten per year in the next two to three
years, as the awareness of the program increases. The potential exists for much
greater growth beyond this subsequently. The table below includes information on
courses in the Certificate and enrollment figures for the last several terms. An
asterisk denotes a term in which the relevant course was not offered.

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</tr>
</tbody>
</table>

**CSCI 507 has been approved but has not been offered yet.**

**New resources**
No new resources are needed. All courses are currently taught at IUPUI by existing
faculty.

**Proposed date of the initiation of the certificate program**
Proposed date of implementation is Fall 2007, assuming all necessary approvals have
been met.

**Persons designated as the certificate program head**
Dr. Pamela Crowell, Associate Dean for Research and Graduate Programs, School of
Science, will provide the school administrative oversight.
Dr. Shiaofen Fang, Associate Professor and Chair, Department of Computer and
Information Science will provide the department administrative oversight.
Dr. Rajeev Raje, Associate Professor, Department of Computer and Information
Science will advise students.
Faculty initially involved in the program and their credentials

Omran Bukhres X3801
Ph.D., North Dakota State University, 1990
Email address: bukhres@cs.iupui.edu 317-274-8674
Personal Web Page: http://www.cs.iupui.edu/~bukhres
Dr. Bukhres is the co-principal investigator of the Large Scale Distributed Computing and Multimedia Laboratory. Research focuses: (1) database management systems for multimedia data, and (2) seamless integration of the distributed multimedia databases. Other research interests include: Transaction and Workflow Management, Multimedia Databases, Interoperability and Recovery in Heterogeneous Distributed Database Systems, Knowledge Base and Expert Systems, Mobile and Client Server Computing.

Yuanshun Dai X0458
Ph.D. in Computer Science, National University of Singapore, September 2003
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Shiaofen Fang X0329
Ph.D., University of Utah, 1992
Email address: sfang@cs.iupui.edu 317-274-9731
Personal Web Page: http://www.cs.iupui.edu/~sfang
Computer graphics, scientific visualization and geometric modeling are Dr. Fang's research specialties. Currently he is collaborating with biomedical researchers to apply computer graphics and visualization techniques, in particular volumetric modeling and visualization, for medical imaging applications.

Jeffrey Huang X0375
Ph.D., George Mason University, 1998
Email address: huang@cs.iupui.edu 317-274-9746
Personal Web Page: http://www.cs.iupui.edu/~huang
Jeffrey Huang's specialties and research interests include image processing, pattern recognition, computer vision, machine learning, and Evolutionary Computation (EC) on the applications of face recognition, Human Computer Interaction (HCI) and the interpretations of human activities, multimedia, computer visualization, medical imagery, and Automated Target/Object Recognition (ATR) and detection.

Snehasis Mukhopadhyay X0313
Ph.D., Yale University, 1994
Email address: smukhopa@cs.iupui.edu 317-274-9732
Current research interests are adaptation and learning in multi-level and distributed systems; information filtering and retrieval; modeling, simulation analysis and adaptive control of
complex nonlinear systems using neural networks; design and analysis of intelligent controllers. Dr. Mukhopadhyay received a National Science Foundation Career Award.

Mathew Palakal X0199
Ph.D., Concordia University, 1987
Email address: mpalakal@cs.iupui.edu
The development of Artificial Neural Network (ANN) models as learning and decision-making systems for various AI-related problems are of primary interest. He is involved in projects that include modeling Biosonar systems, neural network models to predict damages in materials and structures, and distributed information filtering.

Rajeev Raje X0328
Ph.D., Syracuse University, 1994
Email address: rraje@cs.iupui.edu
Dr. Raje is interested in the system and application aspects of the distributed-object model of computing. His current projects include the development of a seamless environment for net-centric applications, distributed information filtering, collaborative software engineering and visualization environments, and enhancement of different distributed-object models.

Mihran Tuceryan X0336
Ph.D., University of Illinois-Urbana Champaign, 1986
Email address: tuceryan@acm.org
Dr. Tuceryan's research interests include augmented reality, model-based video coding, 3D computer graphics, 3D computer vision, and pattern recognition. Augmented Reality combines technologies from 3D computer graphics, visualization, advanced user interfaces, and 3D computer vision.

Jiang Yu Zheng X0384
Ph.D., Osaka University, 1990
Email address: jzheng@cs.iupui.edu
Web Page: http://www.cs.iupui.edu/~jzheng 317-274-9742
Dr. Zheng’s research interests include Computer Vision, 3D Modeling, Dynamic Image Processing Image Processing, Multimedia, Internet, Scene Representation Graphics, Virtual Reality, Digital Museum Sensor Information Processing, Robotics

Xukai Zou X0422
Ph.D., Dec., 2000, Computer Science, University of Nebraska-Lincoln
Email address: xkzou@cs.iupui.edu
Applied cryptography and network security, Secure group communication: dynamic key, management, key agreement and distribution, Access control in distributed systems, Authentication and digital signature, data integrity and hash functions, Communication
networks and wireless/mobile networks, Software engineering and Web/Internet technologies, Design and analysis of computer algorithms, Data/image processing compression.

Admissions requirements and procedures

Admission requirements

Admission requirements and procedures are the same as those established for the Computer Science Master of Science program as outlined in the IUPUI bulletin and can be reviewed at http://bulletin.iupui.edu/2004-html/science/cis.html#master.

Students admitted directly to the Computer Science Master of Science graduate program may earn this certificate in conjunction with their M.S. degree provided that all the requirements of the certificate program are satisfied and by formally applying to the Certificate Program and by formally applying to the Certificate Program.

Completion requirements and audit and certification procedures

Course Requirements: 12 graduate credit hours are required. These include:

- One core course (3 credits),
- Three specialization courses (9 credits).

Specific Requirements

1. Core: 565 (Programming Languages)
2. 506 (Management of Software Development Process)
3. 507 (Object Oriented Design and Programming)
4. 537 (Distributed Computing) or 536 (Networks)

Minimum overall GPA

Successful completion of the certificate requires at least a B average over all courses counting towards the certificate. Courses with a grade of C- or less must be taken again to count towards the certificate. The minimum grade that will be accepted in any single course is C.

Maximum number of credits that can be transferred from another institution

Applicants who have already earned credit for one or more of the equivalent courses from other institutions and other certificate programs may request to apply up to a maximum of three credits of these courses toward this certificate. Any waivers or substitutions have to be approved by the committee that oversees the program.

Maximum number of undergraduate courses that can be applied

No undergraduate courses can be applied to this certificate program.

Maximum time for completion

All requirements for the certificate must be completed within three years. Most students enrolled in this program will be part-time students, employed full time. Thus two years may be needed for the completion of all courses if students take one course per semester.
Number of credit hours taken prior to admission to the certificate program that may be counted to completion of the degree
Up to 6 equivalent credit hours taken prior to admission to the certificate program, including 3 hours taken from another institution, will be counted towards the certificate. The rest of the courses must be completed at IUPUI within a three-year period from the time of admission.

Course lists for the program including course descriptions

506 Management of the Software Development Process (3 cr.) A survey of the fundamental principles and concepts of managing a software project. Topics include life cycle models, standards and goals, cost estimation, risk analysis, tool use, component reuse, traceability, metrics, and process control and improvement. Students are required to apply management concepts using a project-based approach.

507 Object-Oriented Design and Programming (3 cr.) An advanced exploration of the object-oriented model and programming. Topics range from a review of the object model to advanced concepts such as abstraction mechanisms, standard library/packages, OO design using an OO language, the syntax and the semantics of constructs.

536 Data Communication and Computer Networks (3 cr.) P: 402. Data communications: communication hardware technologies including local area and long-haul network hardware, circuit and packet switching, interfaces between computer and network hardware, and performance issues. Network architecture: protocol software and conceptual layering, reliable delivery over an unreliable channel, transport protocols, virtual circuits, datagrams, Internet working as a fundamental design concept, the client-server paradigm, naming and name binding, name servers, addressing and address resolution, routing and routing algorithms, congestion and flow control techniques, network file systems, distribution of computation, DARPA Internet protocols (TCP/IP) as examples of protocol organization.

537 Introduction to Distributed Computing (3 cr.) P: 503 and 536. Introduction to the principles and methods in the design of distributed computing systems. It covers the fundamentals of distributed computing from four perspectives: underlying communication media, protocols and their implications; operating system issues; high-level language constructs; and distributed algorithms.

565 Programming Languages (3 cr.) P: 300. R: 470. Fall. An exploration of modern or unconventional concepts of programming languages, their semantics, and their implementations; abstract data types; axiomatic semantics using Hoare's logic and Dijkstra's predicate transformers; denotational semantics; functional, object-oriented, and logic programming; concurrency and Owicki-Gries theory. Example languages include ML, Ada, Oberon, LISP, PROLOG, and CSP.

Procedures for governing the program including construction of committees that will provide oversight
A committee comprised of Dr. Shiaofen Fang, Dr. Rajeev Raje and Dr. Yuanshun Dai will jointly oversee the program. All advising will be done by these faculty members. The
Department of Computer and Information Science and Ms. Myla Langford, the graduate coordinator, will take responsibility for all record keeping and tracking of students.

**Procedures for program evaluation including the criteria for success**

Upon completion of the program, exit interviews will be conducted for all students to determine the effectiveness of the program in meeting their needs and to identify how they are using the skills and tools learned in the program in their professions. Follow-up interviews will be conducted after three and five years. Given the projected enrollment of this program, and the fact many of the graduates will remain employed locally, it is anticipated that most students will be tracked this way.

Success of the program will be defined in terms of demand (enrollment) and the responses of the students surveyed upon completion of their degree and in the follow-up interviews.
Purpose of the program

The popularity and the growth of the Internet and associated networking technologies are allowing a rapidly increasing number of users, representing diverse segments of the society to access an enormous amount of geographically dispersed information available in different electronic form and media. With the successful completion of prominent efforts, such as the Digital Library Initiative, this volume of information will grow at a phenomenal rate. Without effective automated support systems to access and filter such information, an average user runs the risk of being overwhelmed by the sheer volume of irrelevant and possibly unwanted information. Providing a personalized, efficient, adaptive and intelligent access to this plethora of information, without creating an “information overload” on the users, is a major challenge right now, and will become increasingly urgent as we head into the next millennium.

Recent developments in science produce a wealth of experimental data of sequences and three dimensional structures of biological macromolecules. With the advances of computer and information science, this data is available to the public from the variety of databases on the internet. Analysis of this data with various computational methods to obtain useful information is an emerging interdisciplinary area of study. Students completing this certificate will understand structures, functions and evolution of proteins and nucleic acids, retrieve and interpret bioinformation from the internet, learn principles, algorithms and software for sequence alignment, similarity search of sequence databases, estimation of phylogenetic trees, structural prediction and functional interference.

The explosive growth of biological genetic information sources, available over the Internet, has given rise to both opportunities and challenges for biological and medical researchers. The opportunities they provide are both scientific (e.g., understanding the information encoded in elementary biological structures) as well as technological (e.g., new drug discovery for specific diseases). The challenges, on the other hand, lie in how to discover, among the vast volume of data, the items that are relevant or interesting to a given researcher, without an undesirable amount of effort and work load.

The complete information system development is based on an agent-society framework where the elementary information services such as resource discovery and information retrieval, representation, classification, and user interaction are carried out
autonomously by independent software units (called agents), and the large-scale information activity is accomplished by means of collaboration between these elementary agents. Such a conceptual agent-based information system is innovative and has the potential to scale up to a broad range of complex information services.

Relation to existing certificate programs
This program has no relation to existing certificate programs. However, the program is a complement to our existing undergraduate and M.S. programs.

The target audience
The location of the IUPUI campus is unique within the state and the need for targeted computer science certificate programs is unique to the population and companies within the metropolitan area. Our current research activities involve local community affiliation and collaboration. The community includes the local industries such as Eli Lilly & Co., Raytheon, and the IU Medical School. All of these entities in the local community have application domains which have the need for high quality fundamental research. This program will allow employees of these local industries to establish collaborations with our research faculty while at the same time providing them with the skills necessary to introduce these initiatives within their companies. In support of these efforts, we have received several letters of support from local organizations.

Plan for sustaining steady-state enrollment
In the first year (Fall 2007), five students will likely participate in the program. It is anticipated that this number will rise rapidly to ten per year in the next two to three years, as the awareness of the program increases. The potential exists for much greater growth beyond this subsequently. The table below lists the relevant courses and their enrollments over the last several semesters. An asterisk (*) denotes a term in which the course was not offered.

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New resources
No new resources are needed. All courses are currently taught at IUPUI by existing faculty.

Proposed date of the initiation of the certificate program
Proposed date of implementation is Fall 2007, assuming all necessary approvals have been met.

Persons designated as the certificate program head
Dr. Pamela Crowell, Associate Dean for Research and Graduate Programs, School of Science, will provide the school administrative oversight.
Dr. Shiaofen Fang, Associate Professor and Chair, Department of Computer and Information Science will provide the department administrative oversight.
Dr. Snehasis Mukhopadhyay, Associate Professor, Department of Computer and Information Science will advise students.

Faculty initially involved in the program and their credentials

Omran Bukhres   X3801
Ph.D., North Dakota State University, 1990
Email address: buhres@cs.iupui.edu   317-274-8674
Personal Web Page: http://www.cs.iupui.edu/~bukhres
Dr. Bukhres is the co-principal investigator of the Large Scale Distributed Computing and Multimedia Laboratory. Research focuses: (1) database management systems for multimedia data, and (2) seamless integration of the distributed multimedia databases. Other research interests include: Transaction and Workflow Management, Multimedia Databases, Interoperability and Recovery in Heterogeneous Distributed Database Systems, Knowledge Base and Expert Systems, Mobile and Client Server Computing.

Yuanshun Dai    X0458
Ph.D. in Computer Science, National University of Singapore, September 2003
Email address: ydai@cs.iupui.edu   317-274-3473
Personal Web Page: http://www.cs.iupui.edu/~ydai

Shiaofen Fang    X0329
Ph.D., University of Utah, 1992
Email address: sfang@cs.iupui.edu   317-274-9731
Personal Web Page: http://www.cs.iupui.edu/~sfang
Computer graphics, scientific visualization and geometric modeling are Dr. Fang's research specialties. Currently he is collaborating with biomedical researchers to apply computer graphics and visualization techniques, in particular volumetric modeling and visualization, for medical imaging applications.
Jeffrey Huang  
X0375
Ph.D., George Mason University, 1998
Email address: huang@cs.iupui.edu  
317-274-9746
Personal Web Page: http://www.cs.iupui.edu/~huang
Jeffrey Huang's specialties and research interests include image processing, pattern recognition, computer vision, machine learning, and Evolutionary Computation (EC) on the applications of face recognition, Human Computer Interaction (HCI) and the interpretations of human activities, multimedia, computer visualization, medical imagery, and Automated Target/Object Recognition (ATR) and detection.

Snehasis Mukhopadhyay  
X0313
Ph.D., Yale University, 1994
Email address: smukhopa@cs.iupui.edu  
317-274-9732
Current research interests are adaptation and learning in multi-level and distributed systems; information filtering and retrieval; modeling, simulation analysis and adaptive control of complex nonlinear systems using neural networks; design and analysis of intelligent controllers. Dr. Mukhopadhyay received a National Science Foundation Career Award.

Mathew Palakal  
X0199
Ph.D., Concordia University, 1987
Email address: mpalakal@cs.iupui.edu
Personal Web Page: http://www.cs.iupui.edu/~mpalakal  
317-274-9735
The development of Artificial Neural Network (ANN) models as learning and decision-making systems for various AI-related problems are of primary interest. He is involved in projects that include modeling Biosonar systems, neural network models to predict damages in materials and structures, and distributed information filtering.

Rajeev Raje  
X0328
Ph.D., Syracuse University, 1994
Email address: rraje@cs.iupui.edu
Personal Web Page: http://www.cs.iupui.edu/~rraje  
317-274-5174
Dr. Raje is interested in the system and application aspects of the distributed-object model of computing. His current projects include the development of a seamless environment for net-centric applications, distributed information filtering, collaborative software engineering and visualization environments, and enhancement of different distributed-object models.

Mihran Tuceryan  
X0336
Ph.D., University of Illinois-Urbana Champaign, 1986
Email address: tuceryan@acm.org
Web Page: http://www.cs.iupui.edu/~tuceryan  
317-274-9736
Dr. Tuceryan's research interests include augmented reality, model-based video coding, 3D computer graphics, 3D computer vision, and pattern recognition. Augmented Reality combines technologies from 3D computer graphics, visualization, advanced user interfaces, and 3D computer vision.
Jiang Yu Zheng    X0384
Ph.D., Osaka University, 1990
Email address: jzheng@cs.iupui.edu
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Dr. Zheng’s research interests include Computer Vision, 3D Modeling, Dynamic Image Processing, Image Processing, Multimedia, Internet, Scene Representation Graphics, Virtual Reality, Digital Museum Sensor Information Processing, Robotics

Xukai Zou    X0422
Ph.D., Dec., 2000, Computer Science, University of Nebraska-Lincoln
Email address: xkzou@cs.iupui.edu
Applied cryptography and network security, Secure group communication: dynamic key, management, key agreement and distribution, Access control in distributed systems, Authentication and digital signature, data integrity and hash functions, Communication networks and wireless/mobile networks, Software engineering and Web/Internet technologies, Design and analysis of computer algorithms, Data/image processing compression.

Admissions requirements and procedures
Admission requirements

Admission requirements and procedures are the same as those established for the Computer Science Master of Science program as outlined in the IUPUI bulletin and can be reviewed at http://bulletin.iupui.edu/2004-html/science/cis.html#master.

Students admitted directly to the Computer Science Master of Science graduate program may earn this certificate in conjunction with their M.S. degree provided that all the requirements of the certificate program are satisfied and by formally applying to the Certificate Program.

Completion requirements and audit and certification procedures
Course Requirements: 12 graduate credit hours are required. These include:
  - One core course (3 credits),
  - Three specialization courses (9 credits).
Specific Requirements
  1. Core: BIO 507 (Molecular Biology) or CSCI 580 (Algorithms)
  2. 548 (Introduction to Bioinformatics)
  3. 549 (Intelligent Systems) or 590 (Data Mining)
  4. 541 (Database Systems) or 552 (Visualization)

Minimum overall GPA
Successful completion of the certificate requires at least a B average over all courses counting towards the certificate. Courses with a grade of C- or less must be taken again to
count towards the certificate. The minimum grade that will be accepted in any single course is C.

**Maximum number of credits that can be transferred from another institution**
Applicants who have already earned credit for one or more of the equivalent courses from other institutions and other certificate programs may request to apply up to a maximum of three credits of these courses toward this certificate. Any waivers or substitutions have to be approved by the committee that oversees the program.

**Maximum number of undergraduate courses that can be applied**
No undergraduate courses can be applied to this certificate program.

**Maximum time for completion**
All requirements for the certificate must be completed within three years. Most students enrolled in this program will be part-time students, employed full time. Thus two years may be needed for the completion of all courses if students take one course per semester.

**Number of credit hours taken prior to admission to the certificate program that may be counted to completion of the degree**
Up to 6 equivalent credit hours taken prior to admission to the certificate program, including 3 hours taken from another institution, will be counted towards the certificate. The rest of the courses must be completed at IUPUI within a three-year period from the time of admission.

**Course lists for the program including course descriptions**

**BIOL K322 Genetics and Molecular Biology (3 cr.)** P: K103 and CHEM C106. Fall, day. Spring of even-numbered years. The course covers the principles of classical and molecular genetics including Mendelian inheritance, linkage, nucleic acids, gene expression, recombinant DNA, genomics, immunogenetics, and regulation.

**BIOL 507 Principles of Molecular Biology (3 cr.)** P: K322, CHEM C342, or consent of instructor. Fall, night. Molecular aspects of structure and function of nucleic acids and proteins, including recombinant DNA research. Prokaryotic and eukaryotic molecular biology are given equal weight.

**CSCI 548 Introduction to Bioinformatics (3 cr.)** P: 340, BIOL K483, CHEM C483, or MATH 511. Analysis of biological data employing various computational methods to obtain useful information in the emerging area of bioinformatics. Topics include: structures, functions and evolution of proteins and nucleic acids, retrieval and interpretation of bioinformation from the Internet, learning principles, algorithms and software for sequence alignment, similarity search of sequence databases, estimation of phylogenetic trees, structural prediction, and functional inference.

552 Advanced Graphics and Visualization (3 cr.) P: 550. An introduction to data visualization methods and tools, and related graphics techniques. Students will explore a variety of data representation and modeling techniques, their corresponding visualization algorithms, and practical visualization applications in scientific, engineering, and biomedical fields.

CSCI 580 Algorithm Design, Analysis, and Implementation (3 cr.) P: 463 and 470. Basic techniques for designing and analyzing algorithms: dynamic programming, divide-and-conquer, balancing, upper and lower bounds on time and space costs, worst case and expected cost measures. A selection of applications such as disjoint set union/find, graph algorithms, search trees, pattern matching. The polynomial complexity classes P, NP, and co-NP; intractable problems.

CSCI 590 Intelligent Systems (3 cr.) This course will discuss problems in the area of intelligent systems. Topics include the formalisms within which these problems are studied, the computational methods that have been proposed for their solution, and the real-world technological systems to which these methods have been applied.

CSCI 590 Data Mining (3 cr.) This course introduces the core concepts necessary for the design, implementation, and application of database systems. It stresses the fundamental principles in database modeling and design. The aim is to address the continuing need for engineering databases for complex and ever changing applications requiring security, performance, and reliability. The teaching approach will be both instructional and researching. The course emphasizes fundamentals for the logical design of database systems, the entity-relationship model, semantic model, hierarchical model, network model implementations of the models, design theory for relational database, design of query languages and the use of semantics for query optimization, design and verification of integrity assertions and security, and introduction to intelligent query processing and database machines.

Procedures for governing the program including construction of committees that will provide oversight
A committee comprised of Dr. Shiaofeng Fang, Dr. Snehasis Mukhopadhyay and Dr. Jeffrey Huang will jointly oversee the program. All advising will be done by these faculty members. The Department of Computer and Information Science and Ms. Myla Langford, the graduate coordinator, will take responsibility for all record keeping and tracking of students.
Procedures for program evaluation including the criteria for success

Upon completion of the program, exit interviews will be conducted for all students to determine the effectiveness of the program in meeting their needs and to identify how they are using the skills and tools learned in the program in their professions. Follow-up interviews will be conducted after three and five years. Given the projected enrollment of this program, and the fact many of the graduates will remain employed locally, it is anticipated that most students will be tracked this way.

Success of the program will be defined in terms of demand (enrollment) and the responses of the students surveyed upon completion of their degree and in the follow-up interviews.
Request for a New Graduate Certificate Program
Department of Computer and Information Science
School of Science, IUPUI

Biometric Computing Certificate

To be offered as a Purdue Certificate at IUPUI
Revised: December 21, 2005
Further Revised: October 16, 2006

Purpose of the program
Biometrics is defined as the capture of the physiological and behavioral characteristics for personal identification and/or individual verification purposes. Since it uses individual personal characteristics to verify or recover identity, it is set to become a successor to the personal identification token. The technique of using biometric methods for identification can be widely applied to forensics, ATM banking, communication security, time and attendance, and access control. And it also plays an important role in enhancing homeland security. In this course we will introduce the principle of various biometric technology including face recognition, fingerprint identification, iris identification, voice recognition, DNA matching and the fundamental computational methods for implementation. Some of the topics include: authentication technologies, biometric systems, sensor and signal processing, face recognition, eye biometrics, fingerprint identification, and DNA matching.

Biometrics refers to the automatic identification of a person based on his/her physiological or behavioral characteristics. This method of identification is preferred over traditional methods involving passwords and PIN numbers for various reasons: (i) the person to be identified is required to be physically present at the point-of-identification; (ii) identification based on biometric techniques obviates the need to remember a password or carry a token. With the increased use of computers as vehicles of information technology, it is necessary to restrict access to sensitive/personal data. By replacing PINs, biometric techniques can potentially prevent unauthorized access to or fraudulent use of ATMs, cellular phones, smart cards, desktop PCs, workstations, and computer networks. PINs and passwords may be forgotten, and token based methods of identification like passports and driver's licenses may be forged, stolen, or lost. Thus biometric based systems of identification are receiving considerable interest. Various types of biometric systems are being used for real-time identification, the most popular are based on face, iris and fingerprint matching. However, there are other biometric systems that utilize retinal scan, speech, signatures and hand geometry.

A biometric system is essentially a pattern recognition system which makes a personal identification by determining the authenticity of a specific physiological or behavioral characteristic possessed by the user. An important issue in designing a practical system is
to determine how an individual is identified. Depending on the context, a biometric system can be either a verification (authentication) system or an identification system.

With an increasing reliance on online technology and other shared resources, the information age is quickly revolutionizing the way transactions are initiated and completed. Business transactions of all types are increasingly being handled online; this unprecedented growth in electronic transactions has underlined the need for a faster, more secure, and more convenient method of user verification than passwords can provide. Using biometric identifiers offers several advantages over traditional and current methods. This is because only biometric authentication is based on the identification of an intrinsic part of a human being. Tokens such as smart cards, magnetic stripe cards, and physical keys, can be lost, stolen, duplicated, or left at home; passwords can be forgotten, shared, or unintentionally observed by a third party. By eliminating all of these potential trouble spots, only biometric technology can provide the security and convenience needed for today’s complex electronic landscape.

**Relation to existing certificate programs**
This program has no relation to existing certificate programs. However, the program is a complement to our existing undergraduate and M.S. programs.

**The target audience**
The location of the IUPUI campus is unique within the state and the need for targeted computer science certificate programs is unique to the population and companies within the metropolitan area. Our current research activities involve local community affiliation and collaboration. The community includes the local industries such as Eli Lilly & Co., Raytheon, and the IU Medical School. All of these entities in the local community have application domains which have the need for high quality fundamental research. This program will allow employees of these local industries to establish collaborations with our research faculty while at the same time providing them with the skills necessary to introduce these initiatives within their companies. In support of these efforts, we have received several letters of support from local organizations.

**Plan for sustaining steady-state enrollment**
In the first year (Fall 2007), five students will likely participate in the program. It is anticipated that this number will rise rapidly to ten per year in the next two to three years, as the awareness of the program increases. The potential exists for much greater growth beyond this subsequently. The table below indicates the courses involved in the Certificate and the enrollments of each for the last several terms. An asterisk denotes a term in which the course listed was not offered.
New resources
No new resources are needed. All courses are currently taught at IUPUI by existing faculty.

Proposed date of the initiation of the certificate program
Proposed date of implementation is Fall 2007, assuming all necessary approvals have been met.

Persons designated as the certificate program head
Dr. Pamala Crowell, Associate Dean for Research and Graduate Programs, School of Science, will provide the school administrative oversight.
Dr. Shiaofen Fang, Associate Professor and Chair, Department of Computer and Information Science will provide the department administrative oversight.
Dr. Jeffrey Huang, Assistant Professor, Department of Computer and Information Science will advise students.

Faculty initially involved in the program and their credentials

**Omran Bukhres**
X3801
Ph.D., North Dakota State University, 1990
Email address: bukhres@cs.iupui.edu 317-274-8674
*Personal Web Page*: http://www.cs.iupui.edu/~bukhres
Dr. Bukhres is the co-principal investigator of the Large Scale Distributed Computing and Multimedia Laboratory. Research focuses: (1) database management systems for multimedia data, and (2) seamless integration of the distributed multimedia databases. Other research interests include: Transaction and Workflow Management, Multimedia Databases, Interoperability and Recovery in Heterogeneous Distributed Database
Yuanshun Dai
Ph.D. in Computer Science, National University of Singapore, September 2003
Email address: ydai@cs.iupui.edu  317-274-3473
Personal Web Page: http://www.cs.iupui.edu/~ydai
Computing Systems Reliability, Software/Hardware Reliability, Grid Computing,
Parallel/Distributed Computing, Fault Tolerant Computing, System Modeling are Dr. Dai's specialties.

Shiaofen Fang
Ph.D., University of Utah, 1992
Email address: sfang@cs.iupui.edu  317-274-9731
Personal Web Page: http://www.cs.iupui.edu/~sfang
Computer graphics, scientific visualization and geometric modeling are Dr. Fang's research specialties. Currently he is collaborating with biomedical researchers to apply computer graphics and visualization techniques, in particular volumetric modeling and visualization, for medical imaging applications.

Jeffrey Huang
Ph.D., George Mason University, 1998
Email address: huang@cs.iupui.edu  317-274-9746
Personal Web Page: http://www.cs.iupui.edu/~huang
Jeffrey Huang's specialties and research interests include image processing, pattern recognition, computer vision, machine learning, and Evolutionary Computation (EC) on the applications of face recognition, Human Computer Interaction (HCI) and the interpretations of human activities, multimedia, computer visualization, medical imagery, and Automated Target/Object Recognition (ATR) and detection.

Snehasis Mukhopadhyay
Ph.D., Yale University, 1994
Email address: smukhopa@cs.iupui.edu  317-274-9732
Current research interests are adaptation and learning in multi-level and distributed systems; information filtering and retrieval; modeling, simulation analysis and adaptive control of complex nonlinear systems using neural networks; design and analysis of intelligent controllers. Dr. Mukhopadhyay received a National Science Foundation Career Award.

Mathew Palakal
Ph.D., Concordia University, 1987
Email address: mpalakal@cs.iupui.edu
The development of Artificial Neural Network (ANN) models as learning and decision-making systems for various AI-related problems are of primary interest. He is involved in projects that include modeling Biosonar systems, neural network models to predict damages in materials and structures, and distributed information filtering.
Rajeev Raje    X0328
Ph.D., Syracuse University, 1994
Email address: rraje@cs.iupui.edu
Dr. Raje is interested in the system and application aspects of the distributed-object model of computing. His current projects include the development of a seamless environment for net-centric applications, distributed information filtering, collaborative software engineering and visualization environments, and enhancement of different distributed-object models.

Mihran Tuceryan   X0336
Ph.D., University of Illinois-Urbana Champaign, 1986
Email address: tuceryan@acm.org
Dr. Tuceryan's research interests include augmented reality, model-based video coding, 3D computer graphics, 3D computer vision, and pattern recognition. Augmented Reality combines technologies from 3D computer graphics, visualization, advanced user interfaces, and 3D computer vision.

Jiang Yu Zheng    X0384
Ph.D., Osaka University, 1990
Email address: jzheng@cs.iupui.edu
Web Page: http://www.cs.iupui.edu/~jzheng  317-274-9742
Dr. Zheng’s research interests include Computer Vision, 3D Modeling, Dynamic Image Processing Image Processing, Multimedia, Internet, Scene Representation Graphics, Virtual Reality, Digital Museum Sensor Information Processing, Robotics

Xukai Zou    X0422
Ph.D., Dec., 2000, Computer Science, University of Nebraska-Lincoln
Email address: xkzou@cs.iupui.edu
Applied cryptography and network security, Secure group communication: dynamic key, management, key agreement and distribution, Access control in distributed systems, Authentication and digital signature, data integrity and hash functions, Communication networks and wireless/mobile networks, Software engineering and Web/Internet technologies, Design and analysis of computer algorithms, Data/image processing compression.

Admissions requirements and procedures
Admission requirements
Admission requirements and procedures are the same as those established for the Computer Science Master of Science program as outlined in the IUPUI bulletin and can be reviewed at http://bulletin.iupui.edu/2004-html/science/cis.html#master.
Students admitted directly to the Computer Science Master of Science graduate program may earn this certificate in conjunction with their M.S. degree provided that all the requirements of the certificate program are satisfied and by formally applying to the Certificate Program.

**Completion requirements and audit and certification procedures**

**Course Requirements:** 12 graduate credit hours are required. These include:
- One core course (3 credits),
- Three specialization courses (9 credits).

**Biometrics**
1. Core: STAT 511 (Statistics) or 590 (Pattern Recognition)
2. 590 (Biometrics Computing)
3. 590 (Intelligent Systems) or 590 (Data Mining)
4. 590 (Image Processing and Computer Vision) or 550 (Computer Graphics)

**Minimum overall GPA**
Successful completion of the certificate requires at least a B average over all courses counting towards the certificate. Courses with a grade of C- or less must be taken again to count towards the certificate. The minimum grade that will be accepted in any single course is C.

**Maximum number of credits that can be transferred from another institution**
Applicants who have already earned credit for one or more of the equivalent courses from other institutions and other certificate programs may request to apply up to a maximum of three credits of these courses toward this certificate. Any waivers or substitutions have to be approved by the committee that oversees the program.

**Maximum number of undergraduate courses that can be applied**
No undergraduate courses can be applied to this certificate program.

**Maximum time for completion**
All requirements for the certificate must be completed within three years. Most students enrolled in this program will be part-time students, employed full time. Thus two years may be needed for the completion of all courses if students take one course per semester.

**Number of credit hours taken prior to admission to the certificate program that may be counted to completion of the degree**
Up to 6 equivalent credit hours taken prior to admission to the certificate program, including 3 hours taken from another institution, will be counted towards the certificate. The rest of the courses must be completed at IUPUI within a three-year period from the time of admission.

**Course lists for the program including course descriptions**

STAT 511 Statistical Methods I (3 cr.) P: MATH 164. Descriptive statistics; elementary probability; random variables and their distributions; expectation; normal, binomial, Poisson,
and hypergeometric distributions; sampling distributions; estimation and testing of hypotheses; one-way analysis of variance; correlation and regression.

**CSCI 590 Intelligent Systems (3 cr.)** This course will discuss problems in the area of intelligent systems. Topics include the formalisms within which these problems are studied, the computational methods that have been proposed for their solution, and the real-world technological systems to which these methods have been applied.

**590 Pattern Recognition (3 cr.)** This course covers the fundamental techniques of statistical pattern recognition and clustering analysis. It looks at traditional applications of pattern recognition techniques as well as newer applications such as data mining. This is not a primarily or exclusively data mining course. Its main focus is pattern recognition, with data mining as one of the application domains.

**550 Computer Graphics (3 cr.)** An introduction to computer graphics. Topics include the concepts, principles, algorithms, and programming techniques in 3D interactive computer graphics. Emphasis is on the development and applications of 3D graphic algorithms and methods.

**590 Data Mining (3 cr.)** *Data Mining* is an analytic process designed to explore data (usually large amounts of data - typically business or market related) in search of consistent patterns and/or systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. The ultimate goal of data mining is prediction - and *predictive data mining* is the most common type of data mining and one that has the most direct business applications. The process of data mining consists of three stages: (1) the initial exploration, (2) model building or pattern identification with validation/verification, and (3) deployment (i.e., the application of the model to new data in order to generate predictions).

**590 Image Processing and Computer Vision (3 cr.)** Computer images are everywhere, occupying a dominant part of the computer culture. Three mail fields of computer imagery are computer graphics, image processing and computer vision. Computer vision techniques are used in computer graphics to collect and model complex scenes; computer graphics techniques are used constrain the recognition of 3D objects by computer; image processing techniques are routinely used by graphic designers to manipulate photographs. This course emphasizes image processing and computer vision, and their merging with many other applications. We will discuss image transform, feature detection and recognition in 2D image processing, and stereo, dynamic images, and 3D measure in computer vision.

**590 Biometrics Computing (3 cr.)** Biometrics is defined as the capture of the physiological and behavioral characteristics for personal identification and / or individual verification purposes. Since it uses individual personal characteristics to verify or recover identity, it is set to become a successor to the personal identification token. The technique of using biometric methods for identification can be widely applied to forensics, ATM banking, communication security, time and attendance, and access control. And it also plays an important role in enhancing homeland security. In this course we will introduce the principle
of various biometric technology including face recognition, fingerprint identification, iris identification, voice recognition, DNA matching and the fundamental computational methods for implementation. Some of the topics include: authentication technologies, biometric systems, sensor and signal processing, face recognition, eye biometrics, fingerprint identification, and DNA matching.

**Procedures for governing the program including construction of committees that will provide oversight**
A committee comprised of Dr. Shiaofen Fang and Dr. Jeffrey Huang will jointly oversee the program. All advising will be done by these faculty members. The Department of Computer and Information Science and Ms. Myla Langford, the graduate coordinator, will take responsibility for all record keeping and tracking of students.

**Procedures for program evaluation including the criteria for success**
Upon completion of the program, exit interviews will be conducted for all students to determine the effectiveness of the program in meeting their needs and to identify how they are using the skills and tools learned in the program in their professions. Follow-up interviews will be conducted after three and five years. Given the projected enrollment of this program, and the fact many of the graduates will remain employed locally, it is anticipated that most students will be tracked this way.

Success of the program will be defined in terms of demand (enrollment) and the responses of the students surveyed upon completion of their degree and in the follow-up interviews.
Appendix A

Letters of Support for Proposed
Graduate Certificates in Computer Science

1. Institute for Forensic Imaging: Herbert Blitzer, Executive Director
2. Eli Lilly & Company: Vijay K. Gombar, PhD, Research Advisor
3. Indiana University School of Medicine: Feng C. Zhou, PhD, Professor of Anatomy/Cell Biology & Neurobiology
4. Network Storage, Inc.: Merrick Mossman, Director of Information Technology
5. Indiana University School of Informatics: Douglas Perry, Professor of Informatics and Associate Dean for Graduate Studies and Research (Indianapolis)
September 7, 2005

Dr. Mathew Palakal, Professor and Chair  
Dept of Computer and Information Science  
IUPUI, 723 W. Michigan St., SL 280  
Indianapolis, IN 46202

Dear Professor Palakal:

I am really happy that you are proposing to develop Graduate Certificate Programs in specialization areas such as Databases, Software Engineering, Bioinformatics, Biometrics, Networks and Network Security. Providing Central Indiana with such a contribution is a natural follow-on to the very well received M.S. Program that you currently have in place, and will address a well defined need.

Several of us are organizing the Indiana Forensic Science Initiative, and one of the branches of our interest deals with Information technology. Our organization has already created two new jobs in the State and we have only just started. As the Central Indiana business community grows, so will the need for people with better computer science related skills. Your initiative in this regard would help Central Indiana’s significant need for focused, short, graduate level programs for technically trained professionals.

Both business and government organizations will surely see this as a wonderful opportunity for their employees.

I strongly support this important initiative.

Sincerely,

Herbert Blitzer  
Executive Director

338 South Arlington Avenue, Suite 111, Indianapolis, IN 46219  
Telephone: (317) 356-0245  
Fax: (317) 356-0227  
Email: hblitzer@ifi-indy.org
2 September 2005

Dr. Mathew Palakal
Professor and Chair
Department of Computer and Information Science
IUPUI
723 W. Michigan St., SL 280
Indianapolis, IN 46202

Dear Mathew:

I am writing this letter in support of your proposal to offer Graduate Certificate Programs in highly specialized areas to meet the needs of the Indiana community. The areas that you are focusing on, especially Bioinformatics and Databases/Datamining, are very important for the pharmaceutical industry. I am sure that several Lilly employees might be interested in such short programs that would fit in their development plan.

I am also glad that the programs that you are proposing can lead to your existing M.S. Programs so that, if interested, a student can continue on to pursue a postgraduate degree.

As the business community in and around Indiana is growing, the need for specialists in Information Technology with concentration in some of the areas you are proposing is also growing. In this regard, your proposed initiative would help address focused graduate-level program needs for appropriately trained professionals.

I will be happy to promote this program in my own establishment and please let me know if I can be of any further assistance in this regard.

Sincerely,

[Signature]

Vijay K. Gombar, Ph.D.
Research Advisor
Dr. Mathew Palakal  
Chair, Department of Computer and Information Science  
IUPUI  
723 W. Michigan St., SL 280  
Indianapolis, IN 46202

Dear Dr. Palakal:

I was pleased to learn that the IUPUI Department of Computer and Information Science is pro-actively pursuing Graduate Certificates in important areas of computer science research and computing applications. The proposed graduate certificate program will provide Central Indiana the much needed IT manpower resources for both economic development and academic activities. It is a natural follow-on to the very well received M.S. Program that you currently have in place.

Biomedical research and education require increasingly more Information Technology skills. It is, therefore, essential for the biomedical community to have access to people with the required IT knowledge and skills. The proposed graduate certificate also provides an appropriate educational channel that allows some of the biomedical researchers and students to seek additional formal training in Computer Science. As you know, my lab has been collaborating with your department on several research projects. The increasing need for Computer Science skills and knowledge in our research makes this program particular timely and important to us. For example, the Biometric Computing and Bioinformatics certificate programs provide just the kind of knowledge and training that are needed in our research, as well as in biomedical industry as a whole. I strongly support the proposed graduate certificate program, and I believe I speak for many of my colleagues in the School of Medicine in this matter.

Sincerely,

[Signature]

Feng C. Zhou, Ph.D  
Professor of Anatomy/Cell Biology & Neurobiology
September 9, 2005

Dr. Mathew Palakal
Professor and Chair
Department of Computer and Information Science
IUPUI
723 W. Michigan St., SL 280
Indianapolis, IN 46202

Dear Dr. Palakal,

I am pleased to learn the Computer Science Department is considering specialized Graduate Certificate Programs in Databases, Software Engineering, Bioinformatics, Biometrics, Networks and Network Security areas. Furthermore, I endorse and support the department in these efforts to better prepare the student for central Indiana’s vocations and to better differentiate itself from other schools of higher education.

Focused accredited programs are powerful alternatives for the working professional. The IT professional in central Indiana wishing to advance has limited options. The graduate programs can be prohibitive due to time commitments and often over prepare the student for the careers available in central Indiana. I concur that the vision of these Certificate Programs is not meant to replace or diminish the established MS and PhD programs, but to complement them with focused areas matching the careers available today in central Indiana’s workplace. Higher education must adapt to meet changing requirements and I applaud your vision how to adapt it to the region’s needs.

Feel free to contact me if I can be assistance in promoting your program to the central Indiana business community.

Sincerely,

Merrick Mossman
Director of Information Technology
Network Storage, Inc.
September 22, 2005

Dr. Mathew Palakal
Chairman
Department of Computer and Information Science
School of Science, IUPUI

Dear Mathew,

I have carefully read the proposal for the Graduate Certificate Program. The program will provide a solid core in the fundamentals of computer science which will be valuable in a number of different career paths. In addition, the plan of study will be integral to your master’s and doctoral programs, allowing a vertical transition for the best of the certificate program graduates.

As with all of the other academic offerings in the Department of Computer and Information Science, this certificate program would complement the programs in the School of Informatics, not compete with them. Since the earliest planning stage, the School of Informatics has enjoyed a strong relationship with the School of Science, and this will continue.

I fully endorse your efforts to bring the certificate program into being.

Wishing you all the best,

[Signature]

Professor of Informatics
Associate Dean for Graduate Studies and Research
Appendix B

Admission Requirements for M.S. in Computer Science
Purdue School of Science, IUPUI

Submit applications for admission to the graduate program directly to the Department of Computer and Information Science. Applications should be complete by May 1 for the following fall semester and September 15 for the following spring semester. To be considered for departmental graduate assistance for the following fall semester, all application materials must be received by December 15. Financial support is generally not available for spring admissions. Apply early because it may take up to six months to complete the application process.

Students interested in advanced study or students who are required to complete preparatory courses and are waiting on application processing may take courses as graduate nondegree students. However, no more than 12 graduate credit hours earned as a nondegree student may be counted toward a graduate degree program.

See the department's Web site (www.cs.iupui.edu) for additional information on requirements and application deadlines. For guidelines and online applications, follow the link to the IUPUI Graduate Office on the department's Web site.

General Admission Requirements

The applicant to the graduate program must have a four-year bachelor's degree or equivalent.

The applicant's record should exhibit outstanding achievement as indicated by the grade point average for each degree over his or her entire academic record. An applicant is expected to have a GPA of at least a 3.0 on a scale of 4.0. The record should also demonstrate strong individual accomplishments and recommendations from independent references.

The GRE Exam is not required for admission consideration. Applicants may choose to submit their scores on the General Aptitude Test of the Graduate Record Examination (GRE), however. Those who do take the GRE General Aptitude Test are strongly encouraged to submit scores for the Computer Science subject test also.

All applicants should have a background in the following core areas of computer science:

a. software development experience in a high-level language

b. data structures and algorithms

c. systems (operating systems, compilers, and programming languages)

d. theory (discrete math and theory of computation)
e. hardware (computer architecture)

In addition, applicants should have a strong background in mathematics, including calculus, linear algebra, and in numerical computations.

All applicants whose native language is not English must submit a valid Test of English as a Foreign Language (TOEFL) score of at least 600 on the paper based or 250 on the computer based test. Students who take TOEFL iBT must have minimum scores of: Reading (19), Listening (14), Speaking (18), and Writing (18). An overall TOEFL iBT score of 77 is required for admission. As an alternative, an International English Language Testing System (IELTS) band score of at least 6.5 is required for admission.

**Conditional Admission**

Those students who do not satisfy the admission requirements may request conditional admission only to the Graduate Program if they satisfy the following requirements:

1. possess a bachelor's degree with a cumulative GPA of 3.0 on a 4.0 scale

and

2. have taken 5 semester hour credits of calculus (MATII 163 or equivalent)

and

3. CSCI 240 (C++) or equivalent experience or credit.

If conditional admission to the Graduate Program in Computer Science is granted, the student will be required to satisfy the stipulations of the admission, which may include satisfactorily completing one or more courses, before admission without conditions is granted.