

# 4-Year Report (Since 2005) for SHASHI SHEKHAR

April 9, 2009

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# 1 Brief Biography

Shashi Shekhar is currently a McKnight Distinguished University Professor of Computer Science at the University of Minnesota, Minneapolis, MN, USA. He was elected and AAAS<sup>1</sup> Fellow and IEEE<sup>2</sup> Fellow and received the IEEE Computer Society Technical Achievement Award for contributions to spatial database, spatial data mining, and geographic information systems (GIS). He is serving as a *co-Editor-in-Chief* of the *Geo-Informatica: An International Journal on Advances in Computer Science for GIS* (ISSN 1384-6175), a top-tier<sup>3</sup> journal in the interdisciplinary area of GIS. He is a member of the mapping science committee of the National Research Council National Academy of Sciences. He has served as a member of the Board of Directors of University Consortium on GIS (2003-2004), the editorial boards of IEEE Transactions on Knowledge and Data Engineering, and the IEEE-CS Computer Science & Engineering Practice Board. He contributed via major service roles in many conferences and workshops including the ACM SIG-Spatial Intl. Conference on GIS, IEEE Intl. Conf. on Data Mining (ICDM), IEEE ICDM Intl. Workshop on Spatial and Spatio-temporal Data Mining, SIAM Intl. Conf. on Data Mining, etc. He served as a technical advisor to United Nations Development Program (UNDP), Environmental Systems Research Institute (ESRI), and other organizations. His research projects have been sponsored by the NSF, NGA, NASA, Army Research Laboratories, USDOT, FHWA, MN/DoT etc. He co-edited an Encyclopedia of GIS (Springer, 2008, isbn 038730858X) and co-authored a textbook on Spatial Databases (Prentice Hall, 2003, ISBN 0-13-017480-7), which has been translated into two foreign languages. He has co-authored over 225 research papers in peer-reviewed journals, books, and conferences, and workshops. He received a Ph.D. degree in Computer Science and M.S. degrees in Business Administration as well as Computer Science from the University of California (Berkeley, CA).

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<sup>1</sup>American Association for Advancement of Science

<sup>2</sup>Institution of Electrical and Electronics Engineers

<sup>3</sup>C. Caron et al, GIScience Journals Ranking and Evaluation: An International Delphi Study, Transactions in GIS, 12(3), 2008, Blackwell Publishing Ltd. (Table 5, pp. 308 provide a summary).

## 2 BASIC INFORMATION

### CONTACT INFORMATION

Address: 4-192, EE/CS Bldg., 200 Union St. SE, Minneapolis, MN 55455.  
Phone: (612) 624-8307 :: Fax: (612) 625-0572 :: Cell: (651) 238-9223  
Electronic: shekhar@cs.umn.edu, <http://www.cs.umn.edu/~shekhar>

### RESEARCH INTERESTS

Spatial databases, spatial data mining, geographic information systems, mining spatial datasets.

### EDUCATION

- 1989 , Ph.D., Computer Science, University of California, Berkeley. (Thesis: Cooperating Expert Systems.)
- 1989 , M.S., Business Administration, University of California, Berkeley. (Thesis: A Stochastic Learning Algorithm for Neural Networks.)
- 1987 , M.S., Computer Science, University of California, Berkeley. (Thesis: Intelli-Genesis: Software Engineering Environment for AI Programs)
- 1985 , B.S., Computer Science, Indian Inst. of Tech. (IIT), Kanpur (India). (Thesis: Implementation of a Programming Environment for 'C'.)

### APPOINTMENTS

- 2005 – present, McKnight Distinguished University Professor, University of Minnesota, Minneapolis, Minnesota.
- 2005 – 07, Director, Army High Performance Computing Research Center, University of Minnesota, Minneapolis, Minnesota.
- 2001– present, Professor, University of Minnesota, Minneapolis, Minnesota.
- 1995– 01, Associate Professor, University of Minnesota, Minneapolis, Minnesota.
- 1989–95 , Assistant Professor, University of Minnesota, Minneapolis, Minnesota.
- 1985–99 , Research Asst. / Post graduate researcher, University of California, Berkeley, California. Worked on cooperating expert systems, reasoning under uncertainty, and neural networks.
- 1985 (summer) , Instructor, Regional Institute of Technology, Jamshedpur, India. Developed courses on programming paradigms.
- 1984 (summer) , Software Engineer, Taj Services Ltd., New Delhi, India. Designed and implemented a Report Generator Package for a Hotel Management System.

### PROFESSIONAL MEMBERSHIPS

- IEEE Computer Society (Fellow)
- American Association for Advancement of Science (Fellow)
- Association for Computing Machinery
- University Consortium on Geographic Information Systems (Delegate).

## 2.1 AWARDS AND HONORS (Since 2005)

- Fellow, American Association for Advancement of Science (2008 onwards). A Fellow is defined as "a Member whose efforts on behalf of the advancement of science or its applications are scientifically or socially distinguished." Examples of areas in which nominees may have made significant contributions are research; teaching; technology; services to professional societies; administration in academe, industry, and government; and communicating and interpreting science to the public. Fellows are elected annually by the AAAS Council.
- Technical Achievement Award, Institution of Electrical and Electronics Engineers (Computer Society), 2006. It recognizes outstanding and innovative contributions to the fields of computer and information science and engineering or computer technology, usually within the past ten, and not more than fifteen years.
- McKnight Distinguished University Professorship, University of Minnesota, 2005 onwards. It honors and rewards highest-achieving faculty, whose work has brought great renown and prestige to the University of Minnesota. Selectivity is less than one sixth of one percent.
- Fellow, Institution of Electrical and Electronics Engineers (Computer Society), 2003 onwards. the IEEE Grade of Fellow is conferred by the Board of Directors upon a person with an extraordinary record of accomplishments in any of the IEEE fields of interest. The total number selected in any one year does not exceed one-tenth percent of the total voting Institute membership.
- Fellow, Minnesota Supercomputing Institute, University of Minnesota, 2005 onwards.
- The Center for Transportation Studies (CTS) **2006 Research Partnership Award**, which recognizes research projects within the CTS program that have **resulted in significant impacts on transportation**, and rewards teams of individuals who have drawn on the strengths of their diverse partnerships to achieve those results.
- Member, Dean's ad-hoc Committee, Division of Engineering and Applied Sciences, Harvard University, January, 2007.
- Member, DARPA IXO Panel on "Model the Planet" for the very large spatial database program, 2006.
- Member, Mapping Science Committee, National Research Council of national academies, 2004-9.
- Member, Rand Committee to review Geo-knowledgebase prototype (GKB-p) project at the National Geo-spatial Intelligence Agency, July 2005.
- Member, Review and Advisory Committee, Strategic Research Cluster in Advanced Geotechnologies, Science Foundation Ireland (ICT Division), Dublin, Ireland, 2007.
- Member, FY 2008 Director's R&D Fund Review Committee, Laboratory Directed Research and Development (LDRD), Ultrascale Computing Initiative Oak Ridge National Laboratory, U.S. Department of Energy, 2007.
- Member, Review Committee, Pennsylvania Department of Health Final Performance Review, Oak Ridge Associated Universities (ORAU), 2008.
- Member, Review Committee, Florida Centers of Excellence proposals, Oak Ridge Associated Universities (ORAU), 2008.
- Member, Advisory Board, NSF IGERT in Geographic Information Science, SUNY Buffalo, 2004-9.
- One of 4 best papers, ACM SIGKDD Workshop on Sensor Data Mining, 2007.
- One of 4 best papers, CoMoGIS 2006 - 3rd International Workshop on Conceptual Modeling for Geographic Information Systems.
- One of 4 best papers, IEEE Workshop on Spatial and Spatio-temporal Data Mining, 2006.
- Research results reported in major media including FoxTV (2006), the Star Tribune (2006, 1999), the Pioneer Press (2006, 1996) and on public radio (1992). These were also highlighted by the Office of Vice President of Research (2006), University of Minnesota Foundation (2007), Office of Vice President of Public Engagement (2006), and Center of Transportation Studies (2005) within the University of Minnesota.

## 2.2 LIST OF INVITED PRESENTATIONS (Since 2005)

- **Annual Dangermond Distinguished Lecture**, University of California, Santa Barbara, May 28th, 2009.
- Geospatial Technology Working Group, Mapping and Analysis for Public Safety, National Institute of Justice, U.S. Department of Justice, Annapolis, MD, April 16th, 2009.
- Innovision, National Geospatial Intelligence Agency (Reston, VA), Washington D.C., March 18th, 2009.
- Panel on GIScience and Computational Transportation Science, University Consortium on GIS, Winter Assembly, Jefferson Building (Library of Congress), Washington D.C., February 5th, 2009.
- **Keynote Speech**, Geospatial Science Forum ([www.mapworldforum.org/2009/conference/gf.htm](http://www.mapworldforum.org/2009/conference/gf.htm)), Mapworld Forum, HICC Hyderabad, India February 12th-13th, 2009.
- National Science Foundation Workshop on GeoSpatial and GeoTemporal Informatics, Washington D.C., January 8-9, 2009.
- Board on Earth Sciences and Resources, National Research Council, National Academy of Sciences Beckman Center, Irvine, CA, December 9-10, 2008.
- NATO Network of Experts Workshop "Visualizing Network Dynamics, NATO Research Task Group "Visualisation Technologies for Network Analysis", QinetiQ Malvern Technology Centre, United Kingdom, 4th-6th Nov. 2008.
- GIScience Journal Editors Panel, Biannual, Intl. Conference on Geographic Information Science, Salt Lake City, Utah, Sept. 2008
- Plenary Session on What have we learned? Suggestions for future IWCTS workshops? Intl. Workshop on Computational Transportation Science (IWCTS), Trinity College, Dublin, Ireland, July 2008.
- Education Plenary Session on Teaching GIScience: A Computational Perspective, University Consortium on GIS, Summer Assembly, Minneapolis, MN, June 2008.
- Informatics Workshop, Summer Institute and Science Advisory Meeting, NSF IGERT on Sensor Science, Engineering and Informatics, University of Maine, Orono, June 2008.
- Panel on Cyberinfrastructure and Geographic Information Sciences at the "Annual Meeting of the American Association of Geographers", Boston, MA, April 2008.
- Minnesota Population Center, University of Minnesota, MN, February, 2007.
- **Keynote Speech** on "GIS in 2015" at the "Research & New Venture Showcase: Geospatial Sciences", University of Texas, Dallas, TX, January 2008.
- Electrical Engineering and Computer Science Department, University of Tennessee, Knoxville, TN, December, 2007.
- National Geospatial Intelligence Agency, Workshop on Complicated Features, Airlie Conference Center, Virginia, November, 2007.
- NSF Workshop on Next Generation Data Mining (NGDM), Baltimore, October, 2007.
- National Geospatial Intelligence Agency PI Workshop, National Academies, Washington D.C., September, 2007.
- Transportation Research Board / Federal Highway Authority Workshop on Advanced Research in Geospatial Information Technologies for Transportation, National Academy of Science, Washington DC, September, 2007.
- China National Laboratory on Machine Perception, Center for Information Sciences, Peking/Beijing University, Beijing, China, August, 2007.
- China State Key Laboratory of Software Engineering, Wuhan University, Wuhan, China, August, 2007.
- China State Key Lab of Information Engineering in Surveying Mapping and Remote Sensing, (LIEMARS), Wuhan University, Wuhan, China, August, 2007.
- Computer Science Department, Fudan University, Shanghai, China, July, 2007.
- Spatial Database Group, Oracle Corporation, Nashua, NH, July, 2007.

- Volpe National Transportation Systems Center, USDOT Research and Innovative Technology Administration, MIT Campus, Cambridge, MA, July 2007.
- IEEE Computer Society President's Awards Banquet, Los Angeles, CA, May, 2007.
- **Keynote Speech**, NSF Workshop on Discrete Mathematical Problems in Computational Biomedicine, DIMACS Center, Rutgers University April, 2007.
- Computer Science Department, University of Houston, February, 2007.
- Workshop on Ubiquitous and Mobile Computing, Workshop on Ubiquitous and Mobile Computing, National Center on Geographic Information and Analysis, January, 2007, Portland, Maine.
- **Keynote Speech** at the IEEE ICDM Workshop on Spatial and Spatiotemporal Data Mining (SSTDM), Dec. 18th, 2006, Hong Kong.
- Computer Science Department, Hong Kong University, Hong Kong, December, 2006.
- Microsoft Virtual Earth Workshop (11/3012/1, 2006), Seattle, USA.
- Panel on Model the Planet, Defense Advanced Research Projects Agency, Summer, 2006.
- Defense Advanced Research Projects Agency, Information Exploitation Office, May, 2006.
- Army Research Laboratory, Computational Science Workshop on Future Directions, June, 2006, Aberdeen, MD.
- 38th Symposium on the interfaces of statistics, computing science, and applications (Interfaces 2006: Massive Data Sets and Streams), Pasadena, CA, May, 2006.
- 2nd Intl. Statistical Challenges in ECommerce Research Symposium, Carlson School of Management, University of Minnesota, May 2223, 2006 (<http://www.misrc.umn.edu/symposia/20060522/>)
- IBM T. J. Watson Research Center, NY, March, 2006.
- Panel on Evacuation Planning for Twincities Metropolitan, Minnesota Intelligent Transportation Systems Conference, March, 2006.
- Computational Research Institute, Purdue University, January, 2006.
- Oakridge National Laboratory, TN, February, 2006.
- National Research Council, National Academy of Science, Committee on Confidentiality Issues in linking GeographicallyExplicit and SelfIdentifying Data, Washington DC, December, 2005.
- **Keynote Speech**, ISPRS International Workshop on Spatial Data Mining, Middle Eastern Technical University, Ankara, Turkey, November 2005.
- **Keynote Speech**, Brazilian National GeoInformation Conference, Campos dos Jordao, Brazil, November 2005.
- Topographic Engineering Center (an Army ERDC), Alexandria, VA, October 2005.
- IEEE Fellows Local Conference, University of Minnesota, October 2005.
- **Keynote Speech**, Ninth International Symposium on Spatial and Temporal Database, Angora dos Rias, Brazil, August 2005.
- PI Workshop on Sensor Networks for Homeland Defense, Oakridge National Laboratory and Office of Naval Research, Washington D.C., July 2005.
- **Keynote Speech**, NSF Workshop on National Phenology Network, University of Nebraska, Lincoln, May 2005.
- Workshop on Voter Registration Databases for Election Assistance Commission, Computer Science and Telecommunication Boards, National Research Council, National Academies, May 2005.
- Remote Sensing Center, Boston University, Boston, March 2005.
- Topographic Engineering Center, Army Core of Engineers, Alexandria, VA, Feb. 2005.

## 3 RESEARCH GRANTS (Since 2005)

### 3.1 External Grants From Federal/State Agencies & Companies

- P.I., USDOD Army Corps of Engineers (Topographic Engineering Center W9132V-09-C-0009), Case-case Models for Multi-Scale Spatio-temporal Pattern Discovery, \$150,000, 02/03/09 - 01/31/12.
- P.I., IGERT: Non-equilibrium Dynamics Across Space and Time: A Common Approach for Engineers, Earth Scientists and Ecologists, \$2,269,282 (approx), National Science Foundation (**NSF**), DGE-0504195, Aug. 2005 - July 2010. (w/ C. Neuhauser, C. Paola, M. Hondzo, R. Hozalski, S. Sugita). Grant transferred to Computer Science Department in Summer 2008 with a balance of over \$1.2 M.
- P.I., Dynamic Purpose-Aware Graph Models for Composite Networks, \$750,000, US Department of Defense (HM1582-08-1-0017), Aug. 14th, 2008 - Aug. 13th, 2013.
- P.I., III-CXT: Spatio-temporal Graph Databases for Transportation Science, \$449,993 (approx), National Science Foundation (**NSF**), IIS-0713214, Aug. 2007 - July 2010. (w/ H. Liu)
- P.I., Spatio-Temporal Pattern Mining for Multi-Jurisdiction Multi-Temporal Activity Datasets, \$750,000, US Department of Defense (HM1582-07-1-2035), Aug. 14, 2007 - July 31st, 2012. (w/ L. Khan, U. T. Dallas).
- Co-P.I., CRI:IAD Infrastructure for Research in Spatio-Temporal and Context-Aware Systems and Applications, \$140,403, National Science Foundation (**NSF**), CNS-0708604, July 2007 - June 2010. (w/ A. Tripathi, M. Mokbel).
- P.I., Spatial Database Research for Mapping and Analysis for Public Safety, \$100,000 (unrestricted gift), Ned Levine & Associates, 2006-2009.
- P.I., Modeling and Mining Spatio-temporal Data, USDOD Army Corps of Engineers, \$111,000, 03/15/06 - 09/30/08.
- P.I., Army High Performance Computing Research Center (AHPCRC), \$5,000,000 (approx.), Army Research Lab. and Network Computing Services, Jan. 2006 - Jan. 2007.
- P.I., Discovering personal gazetteers from travel histories (GPS tracks), \$40,000 (unrestricted gift), Microsoft Mappoint Research Program, 2005-2006.
- P.I., Spatio-temporal data analysis techniques for behavioural ecology, \$576,395, National Science Foundation (**NSF**), September 2004 - August 2007. (w/ J. Srivastava, A. Pusey).
- P.I., Spatio-temporal data mining for sensor networks, \$200,000, Oakridge National Laboratory, Department of Energy (DOE), June 2005 - June 2008.
- P.I., High Performance Spatial Data Mining, \$100,000, Army Research Lab. (AHPCRC), Jan. 2005 - Jan 2006.
- P.I., Evacuation Planning Software for Twin Cities Metro Area Scenario, \$53,011, Minnesota Department of Transportation, February 4th, 2005 to November 30th, 2005.
- co-P.I., Planning for full-scale CLEANER: Options for field facilities and cyberinfrastructure in America's heartland, \$69,960, National Science Foundation (**NSF**), August 2004 - July 2006. (w. M. Hondzo et al).
- P.I., Decision Support System for Evacuation Planning, \$60,000, Federal Highway Authority (FHWA), August 2004 - November 2005.
- Co-P.I., Complexity of Spatial and Categorical Scale in Land Use Classification, \$535,914, National Science Foundation (**NSF**), July 2003 - June 2006. (w/ S. Gopal, Boston U).

### 3.2 Internal Grants

- \$25,000, Minnesota Futures (Phase I: Symposium Grant), Office of Vice President of Research 2008-2009.
- \$100,000, McKnight Distinguished University Professorship, 2005-2010.
- P.I., Indoor navigation system for visually impaired, \$29,000, Digital Technology Center, July 2005 - June 2006.

## 4 GRADUATE STUDENTS, VISITORS, etc. (Since 2005)

### 4.1 Faculty, Postgraduate and Graduate Visitors

1. Pronab Mohanty, a Humphrey Fellow (U S Dept. of State), is visited our group in Spring 2009 to collaborate on spatial data mining for public safety and security. He is with the Indian Police Service (Banglore, India).
2. Prof. Prabhat Ranjan visted our group for a month in summer 2008 to explore collaboration on india center initiative at the University of Minnesota. He heads the Embedded Systems and Sensor Networks research group at the D. Ambani Institute of Information & Communication Technology (intranet.daiict.ac.in), India. His projects include detection of water on the Moon (a part of indian lunar mission, Chandrayaan-2), tracking and preserving wildlife, detection of forest fires, etc.
3. Prof. Sungwon Jung spent a large part of his sabbatical with our group in Fall 2007 and Spring 2008 to collaborate on spatio-temporal databases and query processing. He is with Department of Computer Science, Sogang University, Seoul, Republic of Korea.
4. Prof. Christopher Eick visted our group for a month in two summers (2008, 2006) to explore collaboration on spatial data mining. He is affiliated with the Computer Science faculty at the University of Houston.
5. Dr. (Ms.) Vania Bogorny visited our group during the 2004-5 academic year. She was supported by a government fellowship for the federal government of **Brazil**. She is currently a research fellow (PRODOC/CAPES) at Instituto de Informatica da UFRGS/Brazil.
6. Hosted colloquium and workshop speakers included
  - Prof. Michael Goodchild (U. C. Santa Barbara and a NAS member),
  - Prof. May Yuan (Assoc. Dean, U. Oklahoma),
  - Dr. Kentaro Toyama (Microsoft Research),
  - Prof. Michael Worboys (University of Maine, NCGIA),
  - Jack Dangermond (President, ESRI),
  - Prof. Hanan Samet (University of Maryland),
  - Prof. Benjamin Wah (Univ. of Illinois, Urbana-Champaign),
  - Prof. K. Y. Whang (KAIST, Korea), etc.
  - Dr. Eric Hoel (ESRI Geodatabase lead),
  - Dr. Budhendra Bhaduri (OakRidge National Lab., GIS lead),
  - Dr. Tim McGrath (Microsoft Mappoint lead),
  - Dr. Bhavani Thuraisingham (NSF, UT Dallas),
  - Dr. Jim Shine (Topographic Engineering Center, Engineering Research and Development Center, Army Core of Engineers) etc.

### 4.2 List of Ph. D. Students (9 graduated, 6 current)

1. Dr. Pusheng Zhang GRADUATED with a Ph.D. in Summer 2005 and joined Microsoft Mappoint group. His thesis focussed on the problem of efficient indexing methods and query processing strategies for correlation based selection and join over spatial time-series datasets in context of climate modelling applications with Earth Science researchers from NASA. He was awarded a doctoral dissertation fellowship from the University of Minnesota in a university wide competition. He was co-advised by Prof. V. Kumar.
2. Prof. Hui Xiong GRADUATED with a Ph.D. in summer 2005 and joined the faculty of Rutgers University. His thesis explored the problem of identifying correlated item pairs from a large collection of items and transactions. He was co-advised by Prof. V. Kumar. He is a tenured Management Science and Information Systems faculty member with the Rutgers University.
3. Dr. Baris Kazar GRADUATED with a Ph.D. in summer 2005 and joined the Spatial Database group at Oracle corporation. His thesis explores computationally-efficient parameter-estimation methods for the spatial autoregression model. He joined Oracle corporation (Spatial group).

4. Dr. Qing Song Lu GRADUATED with a Ph.D. in Winter 2006 and joined the Microsoft Mappoint group. His thesis developed novel capacity constrained routing algorithms for identifying evacuation routes to minimize evacuation time for homeland security applications. The societal impact of his work was recognized by the CTS partnership award (2006). He joined Microsoft (Virtual Earth group).
5. Dr. Vatsai Ranga Raju GRADUATED with a Ph.D. in Summer 2006. His thesis explored semi-supervised methods for producing land-use classification maps from satellite imagery with very limited ground truth information. He is currently with Oakridge National Laboratory (ORNL) and earlier worked with IBM India.
6. Prof. Ms. Jin Soung Yoo GRADUATED with a Ph.D. in Spring 2007. Her thesis explored spatio-temporal data mining problems. Earlier she explored the nearest neighbor problem in context of open location based services. The pioneering nature of her work was recognized by peer scholars via a best paper award. She joined faculty of Computer Science at Indiana University - Purdue University.
7. Dr. Sangho Kim GRADUATED with a Ph.D. in Spring 2007. His thesis explored large scale flow network algorithms for contra-flow aware evacuation route planning. The societal impact of his work was recognized by the CTS partnership award (2006). He joined the Geo-database group at the Environment Systems Research Institute.
8. Prof. Mete Celik GRADUATED with a Ph.D. in Spring 2008. His thesis investigated scalable methods to quantify and discover the mixed-drove co-occurrence patterns to identify subsets of vehicle-types which often move together given a spatio-temporal datasets describing vehicle trajectories. He also worked closely with Jane Goodall Institute. He joined the Computer Engineering faculty of the Erciyes University, Turkey.
9. Dr. Ms. Betsy George GRADUATED with a Ph.D. in Spring 2008. Her thesis noted that well-known shortest-path algorithms (e.g. A\*, Dijkstra's) assumed stationary ranking of alternative routes. This assumption is not true due to change in travel time due to rush hours, HOV/Toll lanes, congestions, intersection-control traffic-signals, etc. She proposed new data structures (e.g. time-aggregated graphs) and algorithms to address these challenges. The path-breaking nature of her work was recognized by peer scholars via multiple best paper awards.
10. Mr. James Kang passed the oral thesis examination in Spring 2008. His thesis is exploring spatio-temporal data mining problems in context of environmental science application such as water quality monitoring. He is an active member of an NSF IGERT program. Earlier he worked on reverse nearest neighbor queries, as well other computational problems related to Ecology and Environmental Sciences.
11. Mr. Xiaobin Ma passed the oral thesis examination in Spring 2008. His thesis is exploring scalable algorithms for multi-type nearest neighbor problem.
12. Mr. Pradeep Mohan joined spatial database research group in Fall 2007. He is exploring computational problems related to spatial statistical models in hot-spot analysis in context of mapping and analysis for public safety.
13. Mr. Michael Robert Evans joined spatial database research group in Fall 2008 on an NSF IGERT fellowship. He will be exploring computational problems related to Ecology and Environmental Sciences.
14. Mr. Xun Zhou will be joining the spatial database research group in Fall 2009. He will be exploring computational problems related to Spatial Databases and Spatial Data Mining.
15. Mr. Jeffery Wolffe completed a M.S. degree recently and is joined the Ph.D. program in Fall 2007. His interests include computational problems related to evacuation route planning.
16. Mr. Stuart Ness will be joining spatial database research group in Fall 2006 on an NSF IGERT fellowship. He is on leave currently. His interests include computational problems related to Ecology and Environmental Sciences.
17. Mr. ChangQing Zhou passed the major written preliminary examination in Spring 2003. He is working on map compression, caching and pre-fetching issues in context of wireless mobile geographic information systems.

### 4.3 List of M.S. Students (8 graduated, 3 current)

Two students graduated with Plan A option as indicated in bold font.

1. Ms. Roshmi Bhoumik GRADUATED with a M.S. (plan B) in Spring 2005. Her M.S. project evaluated indoor location estimation using wireless local area network infra-structure.
2. Ms. Jin Soung Yoo completed a M.S. (plan B) in Fall 2005 and continued work towards a Ph.D. degree. Her M.S. project explored spatial data mining problem of designing faster joinless algorithms for discovering colocation patterns
3. Mr. Xiobin Ma GRADUATED with a M.S. (plan B) in early 2006. He worked on location based services to address the problem of identifying optimal routes to visit spatial instances of a collection of service types. He joined NCR Corporation (Terradata group).
4. Ms. Xiaojia M Li GRADUATED with a M.S. (plan B) in Spring 2006. She worked on data modeling and database design for the Gombe chimpanzee dataset in the Jane Goddall Institute.
5. Mr. Jeffrey Wolff GRADUATED with a M.S. (plan B) in Summer 2006. He worked on visualization of evacuation routes and schedules. Part of his work was included in a Fox TV news on the evacuation planning project on May 11th, 2006. He joined BAE corporation.
6. Mr. Abhinaya Sinha GRADUATED with a M.S. (plan B) in Fall 2006. He worked on efficient implementation of spatial database queries for a natural resource software system and mapserver, a public domain software for creating web-sites for distributing geo-spatial information. He joined CNET corporation.
7. Mr. Vijay Gandhi GRADUATED with a M.S. (plan B) in Summer 2007. He worked on computational structure of statistical computations in context of classification of remote sensing imagery using multi-scale models. He joined Oracle corporation.
8. Mr. Chetan Shivarudrappa GRADUATED with a M.S. (plan B) in Fall 2008. His project compared alternative data-structures to support novel routing algorithms for applications where ranking of candidate routes can change over time. He also worked on modularizing CrimeStat, a popular spatial statistical software for mapping and analysis for public safety. He joined amazon.com.
9. Mr. Mark Dietz joined spatial database group in Spring 2008. He is exploring a project on modelling and computing (e.g. routing) with multi-modal transportation systems. He works with Honeywell Corp.
10. Mr. Chintan Patel joined spatial database group in Spring 2009. He is investigating development of a library for the time-aggregated graph data-structure to help researchers using graph representation in exploring temporal questions.
11. Mr. Santosh joined spatial database group in Spring 2009. With Chintan Patel, he is investigating development of a library for the time-aggregated graph data-structure to help researchers using graph representation in exploring temporal questions.

## 5 EDITORSHIPS, CONFERENCE AND WORKSHOP ORGANIZATION (Since 2005)

- Co-Editor-in-chief, *Geo-Informatica: An Intl. Journal on Advances in Computer Science for Geographic Information Systems*, 2002-present.
- General-Chair, Intl. Workshop on Computational Transportation Science, (colocated with ACM SIG-Spatial Intl. Conf. on GIS), 2009.
- Vice-Chair (Spatial Data Mining), IEEE Intl. Conf. on Data Mining, 2009.
- Vice-Chair (Spatial Data Mining), SIAM Intl. Conf. on Data Mining, 2009.
- Co-Chair, Workshop on Spatial and Spatio-Temporal Data Mining, IEEE Intl. Conf. on Data Mining, 2007, 2008, 2009. (<http://csdl2.computer.org/comp/proceedings/icdmw/2007/3033/00/3019v.pdf>)
- Steering Committee, *ACM Intl. Workshop on Geographic Information Systems*, 2003-present.
- Co-Chair, 2nd Statistical Challenges in E-Commerce Research Symposium, Carlson School of Management, University of Minnesota, May 22-23, 2006 (<http://www.misrc.umn.edu/symposia/2006-05-22/>).
- Served on numerous program committee, including ACM Intl. Conf. on Geographic Info. Systems (1995-present), Symposium on Spatial (and Temporal) Databases, World wide web and Geographic Info. Systems, IEEE International Conference on Data Mining, SIAM International Conference on Data Mining, IEEE International Conference on Data Eng., IEEE Intl. Conf. on Tools with AI, Int'l Conf. on Software Engineering and Knowledge.
- Refereed for numerous journals, including Intl. Jr. on GIS, IEEE Trans. on Knowledge and Data Engineering, IEEE Trans. on Computers, IEEE Trans. on Software Eng., ACM Trans. on Database Systems, VLDB Journal, IEEE Computer, IEEE Expert, Artificial Intelligence Journal, Journal on Parallel and Distributed Computing, Journal on Intelligent Information Systems, Journal of Software Engineering and Knowledge Engineering, Journal of Computer and Software Engineering, Intl. Jr. on Artificial Intelligence Tools, and Information and Software Technology.
- Refereed for numerous conferences, including IEEE Intl. Conf. on Data Engineering, ACM SIGMOD Natl. Conf. on Management of Data, IEEE Tools with AI, AAAI National Conf. on Artificial Intelligence, IEEE Intl. Conf. on Computer and Software Applications (COMPSAC), Intl. Conf. on Parallel Processing (ICPP), and Scalable High Performance Computing Conference.
- Refereed for several textbook publishers including Addison Wesley (*Software Engineering* by Sommerville) McGraw Hill (*Database System Concepts* by Korth and Silberschatz) and Richard D. Irwin Inc. (Software Engineering by Schach).
- Refereed for the following national and international agencies: National Science Foundation, National Aeronautical and Space Agency, Federal Highway Authority, Center for Transportation Studies and Chinese University of Hong Kong.

## 6 SERVICE TO UNIVERSITY OF MINNESOTA (Since 2005)

### 6.1 Service to College and University

- Member, Committee to review President's Award for Outstanding Service nominations, University Honors and Awards, University of Minnesota, 2008-2009.
- Faculty Representative, All-University Honors Committee, University of Minnesota Senate, 2007-8. Participated in review of nomination for various awards. Helped reformulate honorary degree categories and definitions.
- Member, Geo-spatial Steering Committee, University of Minnesota, 2007-2009. Assisted in creation of GIS undergraduate minor, organizing visit of Jack Dangermond (President and founder, ESRI) to receive a honorary doctorate. Led a successful proposal to Minnesota Futures program (Office of Vice President of Research) and organized a workshop (Jan. 30th-31st, 2009) to bring together the GeoInformatics community across a dozen departments from half a dozen colleges to facilitate. A major goal of the Minnesota Futures initiative is to promote more in-depth work to convert ideas into viable research questions to enable faculty members to respond collaboratively and boldly to emerging opportunities in interdisciplinary research and scholarship.
- Member, Committee exploring India Center, University of Minnesota, 2007-2009. Assisted Vice President McQuaid with strategy formulation towards exploring creation of India Center as requested by Rep. Eric Paulsen and State of Minnesota. Hosted Dr. Mitra, Director of Indo-US Joint Science and Technology Forum (Fall 2008) and Dr. Kentaro Toyama (Microsoft Research). Visited MapForum conference (Feb. 2009) to meet with Secretary of Science & Technology (Government of India), Dr. R Siva Kumar (CEO, National Spatial Data Infrastructure, Govt. of India), Dr. N. L. Sarda (IIT Bombay), to explore possible collaboration opportunities. Also met with Dr. Krishna Kant (NSF, Intel) and Prof. R. Sangal (Director, IIIT-Hyderabad) as well as talked to US leadership of IUSJT to explore opportunities.
- Director, Army High Performance Computing Research Center, Fall 2005-March 2007. Defined strategic focus of the center, helped form a new research cluster around network sciences, interfaced with 5 partner universities, and sponsors.
- Member of the Graduate Research Advisory Committee (GRAC), Graduate School, University of Minnesota, Fall 2000 - Spring 2006. Reviewed faculty research proposals to the grant-in-aid program.
- Recruiting Committee, Distinguished ADC Chair, Digital Technology Center, University of Minnesota, 2003-5.

### 6.2 Service to Computer Science Department

- Chair, Awards Committee, 2007-2009. Facilitated preparation of nomination for a variety of faculty award by working closely with nominees, sponsoring faculty members, award committee members, etc. Working on institutionalizing a process for improving awards nomination process.
- Chair, Mentoring Committee for Prof. Mohamed Mokbel, 2007-2009. Organized mentoring committee meeting, advice and feedback on a variety of issues ranging from annual review, summer trip to Microsoft, NSF proposal preparation and revisions in response to reviews, etc.

## 7 SOFTWARE DEVELOPED

### Evacuation Route Planning Software

In recent years, my research group developed a web-based software system to help transportation professionals and first responders to develop *evacuation route* for many scenarios as mandated by the Department of Homeland Security. It was used by Emergency Management professionals to prepare evacuation plan for Twincities metropolitan area. It is receiving wide publicity in local media including newspaper (March 8th, 2006 Pioneer Press) and TV (FoxTV news, summer 2006). It was also highlighted by the University of Minnesota Vice President of Research in the 2007 annual report (Research magazine) as well as University of Minnesota foundation magazine.

The software uses databases to get transportation network (e.g. road maps), census (e.g. night time population) maps and employment statistics by location. The software tool has a web-based interface to display a map showing evacuation routes (and schedules) to minimize evacuation time after taking critical evacuation parameters including the geographic location and size of evacuation area, destinations, time of evacuation (e.g. day or night) to estimate population, transportation modes (e.g. driving vs. pedestrian). These options help first responders to compare possible alternatives of scenarios and evaluate their impacts. For example, they compared the overall efficiency of evacuation scenarios around the Mall of America when the affected people move out either with vehicles or by walking.

The software system was built on a Web server with mapping technology, thereby, reducing the cost of installation and maintenance and increasing the accessibility and availability. The graphic user interface of the software was improved after feedback given at two major evacuation workshops and a number of user meetings. At the second workshop, we installed a small booth for potential users to play the software. The testing and calibrating tasks were carried out using the five predefined evacuation scenarios. The resulting routes from this software were delivered to the parent project, Metro Evacuation Planning. The software and users manual were finalized in 2005 based on suggestions received from workshop participants including Mn/DOT, State and Local Emergency Management and Public Safety Officials, Transit Providers, and private sector personnel.

### Computer Science Contributions

Mass evacuations are among the most difficult challenges faced by transportation professionals, but planning for a complete evacuation of a specific city is particularly difficult because such evacuations are only rarely necessary. As a result, developing evacuation plans has been carried out largely on the basis of engineering judgment and educated guesses about how to best make use of the road system.

Previously, computational techniques for solving evacuation problems often relied on the mathematical programming (MP) approach, which is widely used in optimization problems involving flow within transportation networks. Mathematical programming techniques are proven to produce optimal solutions to network flow problems and are known to work well for computing evacuation plans for smaller networks such as a single building. However, the high computational cost associated with current MP methods makes it difficult to scale MP methods up to problems involving extensive urban transportation networks with large numbers of evacuees.

Our research team focused its efforts on developing a novel and more practical form of heuristic algorithm for evacuation planning one that would take into account the capacity constraints built into transportation networks but also determine a good solution to any large-scale evacuation problem in much less time than a mathematical programming approach would require. After development of two preliminary algorithms, this effort culminated in the Capacity Constrained Route Planner (CCRP) algorithm. Experiments with synthetic and real evacuation datasets showed that CCRP took significantly less computational time and resources to identify evacuation routes. In addition, the evacuation routes produced by CCRP were comparable to those produced by mathematical programming techniques in terms of total evacuation time.

This is a significant scientific breakthrough in terms of the design of the evacuation planning algorithm, which is not only novel but also improved. It is also significant from a transportation perspective, since the reduced computational cost of CCRP helps emergency planners at two different stages. During planning and preparedness, emergency planners can evaluate many more scenarios using CCRP given specific computa-

tional resources relative to mathematical programming techniques. During operation, they have the option of revising evacuation routes using CCRP in response to major events (e.g. bridge failure in New Orleans) which were not anticipated during planning and preparedness.

### **Accrued, quantifiable benefits**

In 2005, the software implementing the novel CCRP evacuation planning algorithm was used to identify evacuation routes for five selected scenarios in the Twin-Cities for the Metro Evacuation Traffic Management Plan, which is now serving as the baseline for the entire mass evacuation plan that the US Department of Homeland Security is requiring every state to submit by March 2006. Discussions are underway with Metro Emergency Management Officials regarding the adoption and use of these tools in their emergency management plans as well.

The CCRP algorithm aims at identifying the most efficient routes among all possible route combinations. Thus, it can identify some critical routes which might be missing in the handcrafted plans typically used by local and state governments. One example is the comparative results of the University of Minnesota scenario. Even though the handcrafted version made by a select group of emergency planners covered several major routes including those to I-94 or I-35, our system was able to find additional routes to reduce evacuation time by using routes through Riverside Avenue or another way to I35 through Como Avenue. In an earlier evaluation, the CCRP algorithm identified ways to reduce evacuation time for the Montecillo Nuclear Power Plan evacuation zone by identifying potential congestion near the destination and adding additional routes to relieve it.

### **Recognitions**

The Center for Transportation Studies (CTS) honored this work via the **2006 Research Partnership Award**, which recognizes research projects within the CTS program that have **resulted in significant impacts on transportation**, and rewards teams of individuals who have drawn on the strengths of their diverse partnerships to achieve those results. This work was invited for presentation in multiple public forums including the Intelligent Transportation Systems forum (March 8th, 2006), and the Annual CTS Conference (May, 2006).

University of Minnesota venture center is evaluating this software towards potential commercialization.

## 8 PUBLICATIONS (Since 2005)

NOTE: I have not kept track of acceptance years for journal papers. Most forums interested in my C.V. do not ask for this information. Thus, papers are usually listed by actual publication year, which is often used by Google Scholar, DBLP, citeseer, etc.

### 8.1 BOOKS [1 - 2]

1. S. Shekhar and H. Xiong. Encyclopedia of Geographic Information Systems, Spring Verlag, 2008, 1377 page, isbn 038730858X.
2. K. Clark, M. Armstrong, B. Bhaduri, B. Buttenfield, M. Gahegan, M. Jackson, S. Shekhar, C. Tucker, and A. Frazier. Priorities for GEOINT Research at the National Geospatial-Intelligence Agency, The National Academies Press, 2006, isbn 0309101492.

### 8.2 BOOK CHAPTERS [3 - 14]

3. S. Shekhar and B. George. Spatial Network Databases (Field Ed.: R. Gutting), *Encyclopedia of Database Systems (EICs: T. Ozsu, L. Liu)*, Springer Publishers, 2009 (Expected), isbn 978-0387355443.
4. S. Shekhar, V. Gandhi, J. M. Kang, and M. Mokbel . Spatial Databases, *Handbook of Database Technology (Ed. Markus Schneider and Joachim Hammer)*, CRC Press, 2009 (expected).
5. S. Shekhar and J. M. Kang. Spatial Databases, *Wiley Encyclopedia of Computer Science and Engineering (Ed. Benjamin Wah)*, John Wiley and Sons Inc, 2009, isbn 978-0471383932.
6. S. Shekhar and J. Kang. Spatial Data Mining (Field Editor: D. Papadis), *Encyclopedia of Database Systems (EICs: T. Ozsu, L. Liu)*, Springer Publishers, 2009 (Expected), isbn 978-0387355443.
7. R. Vatsavai, S. Chawla, and S. Shekhar . Spatial Classification and Prediction Models for Geospatial Data Mining, *Geographic Data Mining and Knowledge Discovery (Eds. H. Miller, J. Han)* , CRC Press, 2009 (Expected), 2nd Edition, isbn 978-1420073973.
8. C. T. Lu and S. Shekhar et al,. Spatial Classification and Prediction Models for Geospatial Data Mining, *Geographic Data Mining and Knowledge Discovery (Eds. H. Miller, J. Han)* , CRC Press, 2009 (Expected), 2nd Edition, isbn 978-1420073973.
9. S. Shekhar and R. Vatsavai et al. Trends in Spatial Data Mining, *Data Mining: Next Generation Challenges and Future Directions (Ed. H. Kargupta, J. Han, P. Yu, R. Motwani, V. Kumar)* , Chapman Hall / CRC, Oct. 2008, ISBN: 1420085867, 2nd Edition.
10. B. George and S. Shekhar . Digital Road Maps, *Encyclopedia of GIS (Ed. S. Shekhar, H. Xiong)*, Springer Verlag, 2008, isbn 978-0387308586.
11. M. Celik, B. M. Kazar, S. Shekhar, D. Boley, and D. J. Lilja. Modellare la dipendenza geografica usando l'Auto-regressione spaziale (in Italian), *Geocomputation, Geosimulation, Geovisualisation: metodi innovativi a supporto della pianificazione urbana e territoriale (Editor: Beniamino Murgante)* , Collana di ingegneria della citt e del territorio, Alinea Editrice Firenze, 2008 (expected), (Italian translation, English version in First ICA Workshop on Geospatial Analysis and Modeling" 8 July 2006, Vienna, Austria.
12. S. Shekhar, V. Gandhi, and J. M. Kang. Spatial Data Mining, *Encyclopedia of Geographical Information Science (Ed. Karen Kemp)*, , Sage Publications, 2007, isbn 1412913136.
13. P. Zhang, P. Tan, M. Steinbach, V. Kumar, S. Shekhar, S. Klooster, and C. Potter. Discovery of Patterns in the Earth Science Data using Data Mining, *Next Generation of Data Mining Applications (Ed. J. Zurada and M. Kantardzic)*, IEEE Press, Feb. 2005, ISBN: 0-471-65605-4.
14. S. Shekhar, P. Zhang, and Y. Huang . An Invitation to Spatial Data Mining, *The Data Mining and Knowledge Discovery Handbook: A Complete Guide for Practitioners and Researchers (Ed. O. Maimon and L. Rokach)* , Springer, 2005, isbn 0-387-24435-2.

### 8.3 REFEREED JOURNAL PAPERS [15 - 28]

15. V. Gandhi, J. M. Kang, S. Shekhar, J. Ju, E. D. Kolaczyk, and S. Gopal. Context-Inclusive Function Evaluation: A Case Study with EM-Based Multi-Scale Multi-Granular Image Classification, *Knowledge and Information Systems (KAIS): An Intl. Journal, (issn 0219-1377)*, Springer, 2009 (Expected), (accepted, in press).
16. J. M. Kang, M. Mokbel, S. Shekhar, T. Xia, and D. Zhang. Incremental and General Evaluation of Reverse Nearest Neighbors, *Transactions on Knowledge and Data Engineering (TKDE)*, IEEE, (Accepted with minor revision in 2008).
17. Sangho Kim and Shashi Shekhar. Evacuation Route Planning: Scalable Algorithms, *Journal of Intelligent Transportation Systems*, Taylor & Francis, 2007, Under review.
18. B. George, S. Shekhar, and S. Kim. Spatio-temporal Network Databases and Routing Algorithms, *Transactions on Knowledge and Data Engineering (TKDE)*, IEEE, (Submitted in 2008, Also Tech. Report 08-039, Computer Sc., Univ. of Minnesota).
19. Sangho Kim, Shashi Shekhar, and Manki Min. Contraflow Transportation Network Reconfiguration for Evacuation Route Planning, *Transactions on Knowledge and Data Engineering (TKDE)*, IEEE, Vol. 20, No. 8, 2008, (pp. 1115-1129).
20. M. Celik, S. Shekhar, J. Rogers, and J. Shine. Mining Mixed-drove Spatio-temporal Co-occurrence Patterns, *Trans. on Knowledge and Data Engineering*, IEEE, Vol. 20, No. 10, 2008, (pp. 1322-1335).
21. Changqing Zhou, Dan Frankowski, Pamela Ludford, Shashi Shekhar, and Loren Terveen. Discovering Personally Meaningful Places: An Interactive Clustering Approach, *Transactions on (Office) Information Systems*, ACM, Vol. 25, No. 3, 2007.
22. M. Celik, B.M. Kazar, S. Shekhar, D. Boley, and D.J. Lilja. NORTHSTAR: A Parameter Estimation Method for Spatial Autoregression Model, *Transactions on Knowledge and Data engineering*, IEEE, Under review.
23. Q. Lu, B. George, and S. Shekhar. Evacuation Route Planning: A Case Study in Semantic Computing, *Intl. Journal of Semantic Computing*, World Scientific, Vol. 1, No. 2, June 2007, issn 1793-351X.
24. B. George and S. Shekhar. Time Aggregated Graphs for Modeling Spatio-temporal Networks, *LNCS Journal on Data Semantics (<http://lbdwww.epfl.ch/e/Springer/>)*, Springer, Vol. JoDS XI, December 2007, (Special Issue: Selected papers from ER 2006, Guest Editors: J.F. Roddick, S. Spaccapietra).
25. J. S. Yoo and S. Shekhar. A Join-less Approach for Mining Spatial Co-location Patterns, *Transactions on Knowledge and Data Engineering (TKDE)*, IEEE, Vol. 18, No. 10, October 2006.
26. H. Xiong, S. Shekhar, P. Tan, and V. Kumar. TAPER: A Two-Step Approach for All-strong-pairs Correlation Query in Large Databases, *Transactions on Knowledge and Data Eng. (TKDE)*, IEEE, Vol. 18, No. 4, April, 2006.
27. S. Shekhar and J. S. Yoo. Processing In-Route Nearest Neighbor Queries: A Comparison of Alternative Approaches, *Geo-Informatica: An International Journal on Advances in Computer Science for Geographic Information Sciences, (Special issue on best papers from ACM Intl. Conf. on GIS 2003)*, Springer, Vol. 9, No. 5, June 2005.
28. C. T. Lu, L. Sripada, S. Shekhar, and R. Liu. Transportation Data Visualization and mining for emergency management, *Intl. Journal of Critical Infrastructure*, Vol. 1, No. 2/3, 2005.

### 8.4 PAPERS IN HIGHLY SELECTIVE CONFERENCES [29 - 57]

29. J. Kang, S. Shekhar, C. Wennen, and P. Novak. Discovering Flow Anomalies: A SWEET Approach, *Intl. Conference on Data Mining (ICDM 08)*, IEEE, 2008, (Selection 1 out of 7).
30. Z. Zhang, W. Wu, and S. Shekhar. Optimal Placement in Ring Networks for Data Replicas in Distributed Databases with Majority Voting Protocol, *Intl. Conference on Distributed Computing Systems (ICDCS)*, IEEE, 2008, (Selection 1 out of 8, isbn 978-0-7695-3172-4).
31. Pradeep Mohan, Ronald Wilson, Shashi Shekhar, Betsy George, Ned Levine, and Mete Celik. Should SDBMS support a join index? A Case Study with CrimeStat, *Intl. Conference on Advances in Geographic Information Systems (ACMGIS 08)*, ACM SIG- Spatial, 2008, (Selection 1 out of 4).

32. R. R. Vatsavai, S. Shekhar, T. Burk, and B. Bhaduri. \*Miner: A Spatial and Spatio-temporal Data Mining System, *Intl. Conference on Advances in Geographic Information Systems (ACMGIS 08)*, ACM SIG- Spatial, 2008, (Selection 1 out of 4).
33. J. Partyka, N. Alipanah, L. Khan, B. Thuraisingham, and S. Shekhar. Content-based ontology matching for GIS datasets, *Intl. Conference on Advances in Geographic Information Systems (ACMGIS 08)*, ACM SIG- Spatial, 2008, (Selection 1 out of 4).
34. S. Shekhar and B. Bhaduri. Sub-class Recognition from Aggregate Class Labels: Preliminary Results, *Intl. Conference on Tools with Artificial Intelligence (ICTAI)*, IEEE, 2008, (Selection 1 out of 4).
35. R. R. Vatsavai, S. Shekhar, T. E. Burk, and B. L. Bhaduri. \*Miner: A Suit of Classifiers for Spatial, Temporal, Ancillary, and Remote Sensing Data Mining, *Intl. Conference on Information Technology: New Generations (ITNG 2008)*, IEEE Computer Society, 2008, (Selection 1 out of 4).
36. J. Yoo and S. Shekhar. Mining Temporal Association Patterns under a Similarity Constraint, *20th Intl. Conf. on Scientific and Statistical Database Management (SSDBM 2008)*, Springer LNCS 5069 (isbn 978-3-540-69476-2), 2008, (Selection 1 out of 4).
37. R. R. Vatsavai, S. Shekhar, and B. L. Bhaduri. A Learning Scheme for Recognizing Sub-classes from Model Trained on Aggregate Classes, *Jt. Intl. Workshop on Structural, Syntactic, and Statistical Pattern Recognition (SSPR & SPR 2008)*, International Association of Pattern Recognition (IAPR), 2008, (Selection 1 out of 4, Springer LNCS 5342, isbn 978-3-540-89688-3).
38. M. Celik, J.M. Kang, and S. Shekhar. Zonal Co-location Pattern Discovery with Dynamic Parameters, *In Proc. of 7th IEEE Intl Conf. on Data Mining (ICDM)*, 2007, Omaha, Nebraska (Selection 1 out of 5).
39. Betsy George, Sangho Kim, and Shashi Shekhar. Spatio-temporal Network Databases and Routing Algorithms: A Summary of Results, *10th International Symposium on Advances in Spatial and Temporal Databases (SSTD'07)*, 2007, Boston, MA (Selection 1 out of 4).
40. J. M. Kang, M. Mokbel, S. Shekhar, T. Xia, and D. Zhang. Continuous Evaluation of Monochromatic and Bichromatic Reverse Nearest Neighbors, *23rd International Conference on Data Engineering (ICDE 07)*, IEEE, April 16-20, 2007, Istanbul, Turkey (Selection 1 out of 7).
41. Mallikarjun Shankar, Alexandre Sorokine, Budhendra L. Bhaduri, David Resseguie, Shashi Shekhar, and Jin Soung Yoo. Spatio-temporal Conceptual Schema Development for Wide-Area Sensor Networks, *Second International Conference on. Geospatial Semantics (GeoS 2007)*, 2007, Centro de Investigacion en Computacion. Mexico City, Mexico (Selection 1 out of 3).
42. Betsy George and Shashi Shekhar. Modeling Spatio-temporal Network Computations: A Summary of Results, *Second International Conference on. Geospatial Semantics (GeoS 2007)*, 2007, Centro de Investigacion en Computacion. Mexico City, Mexico (Selection 1 out of 3).
43. Sangho Kim, Betsy George, and Shashi Shekhar. Evacuation Route Planning: Scalable Heuristics, *15th ACM International Symposium on Advances in Geographic Information Systems (ACMGIS'07)*, 2007, Seattle, WA (Selection 1 out of 4).
44. Jin Soung Yoo, Shashi Shekhar, Sangho Kim, and Mete Celik. Discovery of Co-evolving Spatial Event Sets, *Proceedings of the International Conference on Data Mining (SDM)*, SIAM, 2006, (acceptance ratio 1 out of 7).
45. M. Celik, S. Shekhar, J. Rogers, J. Shine, and J.S. Yoo. Mining Mixed-drove Spatio-temporal Co-occurrence Patterns: A Summary of Results, *Proc. of Int'l Conference on Data Mining (ICDM)*, IEEE, December 2006, Hong Kong (Selection 1 out of 10).
46. Ranga Raju Vatsavai, Shashi Shekhar, Thomas E. Burk, and Stephen Lime. UMN-MapServer: A High-Performance, Interoperable, and Open Source Web Mapping and Geo-spatial Analysis System, *Bi-annual Intl. Conference on Geographic Information Science*, 2006, (Selection 1 out of 4).
47. Xiaobin Ma, Shashi Shekhar, Hui Xiong, and Pusheng Zhang. Exploiting Page-Level Upper Bound for Multi-Type Nearest Neighbor Queries, *International Symposium on Advances in Geographic Information Systems (ACM GIS 2006)*, 2006, (Selection 1 out of 3).
48. M. Celik, S. Shekhar, J. Rogers, and J. Shine. Sustained Emerging Spatio-temporal Co-occurrence Pattern Mining: A Summary of Results, *In Proc. of Int'l Conference on Tools on Artificial Intelligence (ICTAI)*, November 2006., (Selection 1 out of 3).

49. J. Yoo, P. Zhang, and S. Shekhar . Mining Time-Profiled Associations: An Extended Abstract, *Proc. of the Pacific-Asia Conf. on Data Mining and Knowledge Discovery (PAKDD)*, , 2005, (acceptance ratio 1 out of 6).
50. J. S. Yoo, S. Shekhar, and M. Celik. A Join-less Approach for Co-location Pattern Mining: A Summary of Results, *In Proceedings of the Intl. Conf. on Data Mining (ICDM)*, IEEE, 2005, (acceptance ratio 1 out of 10).
51. S. Mane, C. Murray, S. Shekhar, J. Srivastava, and A. Pusey,. Spatial Clustering Of Chimpanzee Locations For Neighborhood Identification, *In Proceedings of the Intl. Conf. on Data Mining (ICDM)*, IEEE, 2005, (acceptance ratio 1 out of 10).
52. H. Xiong, S. Shekhar, P. Tan, and V. Kumar. Exploiting a Support-based Upper Bound of Pearson's Correlation Coefficient for Efficiently Identifying Strongly Correlated Pairs, *in Proc. of the Tenth SIGKDD Int'l Conf. on Knowledge Discovery and Data Mining*, ACM, 2004, (acceptance ratio 1 out of 8).
53. H. Xiong, S. Shekhar, Y. Huang, V. Kumar, X. Ma, and J. Yoo . A Framework for Discovering Co-location Patterns in Data Sets with Extended Spatial Objects, *Proc. International Conf. on Data Mining (SDM)*, SIAM, 2004, (acceptance ratio 1 out of 7).
54. V. R. Raju, S. Shekhar, and T. Burk . A Semi-supervised Learning Method for Remote Sensing Data Mining, *Proc. of the Intl. Conf. on Tools with Artificial Intelligence*, IEEE, 2005, (acceptance ratio 1 out of 4).
55. Q. Lu, B. George, and S. Shekhar . Capacity Constrained Routing Algorithms for Evacuation Planning: A Summary of Results, *Proc. of 9th Intl. Symposium on Spatial and Temporal Databases (SSTD05), Angra dos Reis, Brazil*, , August 22-24, 2005, (acceptance ratio 1 out of 4).
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57. B. M. Kazar, S. Shekhar, D. J. Lilja, D. Shires, J. Rogers, and M. Celik . A Parallel Formulation of the Spatial Auto-Regression Model, *Proc. Intl. Conf. on Geographic Information (GIS PLANET)*, , May 2005 (Lisbon, Portugal), (acceptance ratio 1 out of 3).

## 8.5 PAPERS IN PEER-REVIEWED WORKSHOPS, SYMPOSIUMS [58 - 73]

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59. J. Partyka, N. Alipanah, L. Khan, B. Thuraisingham, and S. Shekhar. Ontology Alignment Using Multiple Contexts, *Proceedings of the Poster and Demo. Session at the 7th Intl. Semantic Web Conference (ISWC2008)*, Semantic Web Science Association Web (SWSA), 2008, (Selection 1 out of 2).
60. , U.S. Army Office of the Asst. Secy. of the Army for Acquisition, Logistics and Technology, 2008, (Selection 1 out of 3).
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62. Changqing Zhou, Nupur Bhatnagar, Shashi Shekhar, and Loren Terveen. Mining Personally Important Places from GPS Tracks: A Hybrid Approach, *In Proc. of Workshop on Spatio-Temporal Data Mining (STDM) with Int'l Conference on Data Engineering (ICDE)* , IEEE, April 20, 2007, (Selection 1 out of 2).
63. B. George, J. M. Kang, and S. Shekhar. Spatio-Temporal Sensor Graphs (STSG): A Sensor Model for the Discovery of Spatio-Temporal Patterns, *First SIG-KDD International Workshop on Knowledge Discovery from Sensor Data (Sensor-KDD '07)*, ACM, August 12, 2007, San Jose CA (BEST PAPER Award).

64. J. Shine, J. Rogers, M. Celik, and S. Shekhar. Temporal Extensions to Spatial Statistical Metrics, *Joint Statistical Meeting*, Americal Statistical Association, Statistical Society of Canda, 2007, (Selection 1 out of 2).
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66. Betsy George and Shashi Shekhar. Time-Aggregated Graphs for Modeling Spatio-temporal Networks, *3rd International Workshop on Conceptual Modeling for Geographic Information Systems (CoMo-GIS2006)*, 25th International Conference on Conceptual Modeling (ER2006), 2006, (Selection 1 out of 2).
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68. V. Gandhi, M. Celik, and S. Shekhar. Parallelizing Multiscale and Multigranular Spatial Data Mining Algorithms, *The Second Conference on Partitioned Global Address Space Programming Models, (PGAS)* , AHPCRC - George Washington University, October 3-4, 2006, (Selection 1 out of 2).
69. Mete Celik, Baris M. Kazar, Shashi Shekhar, Daniel Boley, and David J. Lilja . Spatial Dependency Modeling Using Spatial Auto-regression, *Workshop on Geospatial Analysis and Modeling with Geoinformation Connecting Societies (GICON)* , International Cartography Association (ICA), 2006, (Selection 1 out of 2).
70. Mete Celik, Baris M. Kazar, Shashi Shekhar, and Daniel Boley. Parameter Estimation for the Spatial Autoregression Model: A Rigorous Approach, *Second NASA Data Mining Workshop: Issues and Applications in Earth Science with the 38th Symposium on the Interface of Computing Science, Statistics and Applications* , May 2006, (Selection 1 out of 2).
71. Ranga Raju Vatsavai and Shashi Shekhar. Miner: A Suit of Classifiers for Spatial, Temporal, Ancillary, and Remote Sensing Data Mining, *Second NASA Data Mining Workshop: Issues and Applications in Earth Science with the 38th Symposium on the Interface of Computing Science, Statistics and Applications* , May 2006, (Selection 1 out of 2).
72. Jin Soung Yoo and Shashi Shekhar . A Framework for Mining Co-evolving Spatial Events, *Second NASA Data Mining Workshop: Issues and Applications in Earth Science with the 38th Symposium on the Interface of Computing Science, Statistics and Applications* , May 2006, (Selection 1 out of 2).
73. C. Zhou, L. Terveen, and S. Shekhar. Discovering Personal Paths from Sparse GPS Traces, *In Proc. of the Workshop on Data Mining (WDM '05)*, JCIS, 2005, (acceptance ratio 1 out of 2).