Burak Aksoylu, PhD

Curriculum Vitae

TOBB University of Economics and Technology
Department of Mathematics
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Academic Career Highlights

1. **Assistant Professor** at TOBB University of Economics and Technology, Department of Mathematics, adjunct Assistant Professor at Louisiana State University (LSU), Department of Mathematics, and adjunct Assistant Professor at University of New Mexico, Department of Mathematics and Statistics.
2. **Collaborative interdisciplinary research**. Led research projects in broad application areas such as **biophysics, computer graphics, geosciences, numerical relativity, and structural mechanics**.
3. **Effective team leader and player**. Led and worked with groups in prestigious research institutions such as CalTech, UCSD, UCI, UT-Austin, and LSU. Has had an active role in the development phase of CCT as chair and member of committees.
4. **High quality, in-depth research portfolio**. Produced lengthy research articles with comprehensive treatment of technically intensive, highly active research areas, and published these in prestigious journals.
5. **Developed rigorous mathematical analysis and novel algorithms** in areas ranging from finite element approximation theory, multilevel preconditioning theory, singular perturbation analysis, partial differential equation theory, and numerical linear algebra.
6. **Constructed the first nonlocal domain decomposition.** Nonlocal models are effective where classical (local) models cease to be predictive. Examples include fracture of solids, peridynamics modeling of cracks, wavelength behavior of elastic waves.
7. **Contributor to software tools and frameworks**. Developer of extension libraries for Finite Element ToolKit (FETK) and Implicit Parallel Accurate Reservoir Simulator (IPARS). Produced optimal complexity solver codes that are in high demand in a wide array of applications due to their computational superiority.
8. **Effective teaching and communication skills**. Attracted a great number of students to scientific computing courses that have been previously failing due to lack of attendance. Interacted and worked with students and groups from diverse backgrounds in science, engineering, and education.
9. **Successful mentoring of undergraduate research**. His undergraduate student presented in Louisiana Academy of Science as well as Sandia National Laboratories, and has been selected as the top ranking student by the LSU Department of Mathematics.
10. **Ability to tailor individually focused teaching strategies** for undergraduate students ranging from high profile to average and poor. Especially developed learning and teaching strategies for averagely to poorly achieving students.
11. **Teaches Mathematics Education Capstone Course** continuously.
12. **Successful recruitment of high profile graduate students**. All his students have had high honors and passed their qualifying exams on their arrival. Chaired both undergraduate and graduate recruitment committees.

Academic Experience

Assistant Professor Department of Mathematics	TOBB University of Economics and Technology 2010–present
Adjunct Assistant Professor Department of Mathematics	Louisiana State University 2010–present
Adjunct Assistant Professor Department of Mathematics and Statistics	University of New Mexico 2010–present
Assistant Professor Department of Mathematics Center for Computation and Technology	Louisiana State University 2005–2010 2005–2010
Postdoctoral Fellow Institute for Computational Engineering and Sciences	The University of Texas at Austin 2003–2005
Postdoctoral Scholar Department of Computer Science	California Institute of Technology 2001–2003
Postdoctoral Scholar Department of Biochemistry	University of California, San Diego 2001–2001 (3 months)

Education

Ph.D. in Mathematics
University of California, San Diego, 1996–2001. Advisor: Michael Holst.

M.S. in Mathematics
University of California, Irvine, 1994–1996.

B.S. in Mathematics (Double major)
Middle East Technical University (METU), Ankara, Turkey, 1991–1993.

B.S. in Science Education, Mathematics Teaching
METU, Ankara, Turkey, 1989–1993.

Major Areas of Research Interest

Numerical analysis, scientific computing.

Focus: Numerical solutions to partial differential equations, preconditioning, iterative solvers, multilevel hierarchical preconditioning, robust preconditioning for high-contrast media, scalable solvers for fracture mechanics and peridynamics, numerical linear algebra, Krylov subspace methods.

Research Accomplishment Highlights

1. **First nonlocal domain decomposition construction**. Generalized iterative substructuring methods to nonlocal settings and characterized the *impact of nonlocality upon the scalability*. Established spectral

equivalences to characterize conditioning of the underlying stiffness matrix and the Schur complement by proving a *nonlocal Poincaré inequality*.

2. **Novel algorithmic development with desirable features.** Developed *algebraic* preconditioners that are robust with respect to high-contrast physical properties such as composite materials, rock properties, and plate bending parameters. The contrasts create *smallest eigenvalues* that hinder the performance of iterative solvers. Developed algorithms are *purely algebraic* making them very attractive for *complicated geometry*.

3. **Robustness with respect to rough PDE coefficients and mesh size.** Extended robustness of the above preconditioners with respect to contrast size to *robustness with respect to both contrast and mesh size*. *Singular perturbation analysis* is a critical tool that reveals that the limiting behavior of the Schur complement and the resulting low-rank perturbations.

4. **Achieved a desirable preconditioning design goal.** The same family of robust preconditioners can be used for different elliptic PDEs with varying discretizations. For diffusion equation, linear finite element and finite volume discretizations and for biharmonic plate equation, HCT and Morley discretizations are used. Can even be extended to PDEs of order $2k,\ k > 2$.

5. **Rigorous solver technology.** Performance of the above preconditioners is identical to that of Ruge-Stüben algebraic multigrid (AMG) methods. While a proof of the AMG robustness with respect to contrast is missing, our preconditioners come with *rigorous estimates*.

6. **Krylov subspace methods.** Devised *deflation* strategies to be used in implementations to guarantee *robustness with respect to smallest eigenvalues* in the spectrum of the linear systems.

7. **Superconvergence.** Developed *superconvergent* finite element methods for generating initial data for general relativity applications. Generating initial data for nonlinear relativistic simulations calls for the solution of Einstein constraint equations. Obtained superconvergence using quadratic elements with order $3 + \sigma$ $(0 \leq \sigma \leq 1)$ due to local symmetry at the mesh vertices.

8. **PDE theory for rough coefficients.** Constructed rigorous treatment of second-order self-adjoint PDE with L^∞ coefficients and the corresponding first-order formulation. The *first-order formulation* is very desirable because it *eliminates the dependence of the operator domain on the PDE coefficients*, thereby, guarantees continuity of solutions as a function of the PDE coefficients. First-order formulations such FOSLS are popular in least squares finite element framework.

9. **Application problems of significance.** Developed multilevel preconditioners for the *adaptive FEM solution of Poisson-Boltzmann equation (PBE)* where adaptive mesh refinement is driven by goal-oriented error estimation based on the free energy functional. The PBE (a nonlinear elliptic PDE) is one of the most popular coarse-graining methods that approximates the solvent (e.g., water) interactions by a dielectric continuum.

10. **Realistic 3D FEM approximation theory.** Gave the first optimality proof of the additive variant of multigrid method, Bramble-Pasciak-Xu (BPX) preconditioner for a *realistic 3D refinement procedure*. This optimality is the fundamental assumption for the hierarchical basis (HB) methods and lays the foundations of various results for function spaces under adaptive refinement.

11. **Comprehensive technical treatment.** Developed *unified framework supporting HB and BPX preconditioners* under adaptive mesh refinement. Through this framework, gave the *first optimality proof* of the additive wavelet-modified hierarchical basis method with 3D and 2D adaptive mesh refinement routines.

12. **Mathematical technology transfer to computer graphics.** Developed *novel mesh coarsening* hierarchies in conjunction with *multilevel optimal solvers for parameterization of surface meshes for computer graphics applications*. Parameterization is of fundamental importance in many applications of *digital geometry processing* such as *remeshing and texture mapping*.

13. **Optimal solver implementations.** Developed software tools that are instrumental in the implementation of *optimal complexity* multilevel preconditioner under *adaptive mesh refinement*. Contributed these tools as extension libraries to various software frameworks Finite Element ToolKit (FETK) and Implicit Parallel Accurate Reservoir Simulator (IPARS) related software.

Publications

Refereed journal articles submitted (in review or revised)

A13. B. Aksoylu, S. Bond, E. Cyr, and M. Holst, *Goal-oriented error estimation and multilevel preconditioning for the Poisson-Boltzmann equation*, Journal of Scientific Computing (2011), revised.

Refereed journal articles

A12. B. Aksoylu and M. L. Parks, *Variational theory and domain decomposition for nonlocal problems*, Applied Mathematics and Computation, 217 (2011), pp. 6498–6515, doi:10.1016/j.amc.2011.01.027.

A11. B. Aksoylu and Z. Yeter, *Robust multigrid preconditioners for the high-contrast biharmonic plate equation*, Numerical Linear Algebra with Applications, 18 (2011), pp.733–750, doi:10.1002/nla.761.

A10. B. Aksoylu and T. Mengesha, *Results on nonlocal boundary value problems*, Numerical Functional Analysis and Optimization, 31 (2010), pp. 1301–1317.

A09. B. Aksoylu and Z. Yeter, *Robust multigrid preconditioners for cell-centered finite volume discretization of the high-contrast diffusion equation*, Computing and Visualization in Science, 13 (2010), pp. 229–245.

A08. B. Aksoylu and H. R. Beyer, *Results on the diffusion equation with rough coefficients*, SIAM Journal on Mathematical Analysis, 42 (2010), pp. 406–426.

A07. B. Aksoylu and H. R. Beyer, *On the characterization of asymptotic cases of the diffusion equation with rough coefficients and applications to preconditioning*, Numerical Functional Analysis and Optimization, 30 (2009), pp. 405–420.

A06. O. Korobkin, B. Aksoylu, M. Holst, E. Pazos, and M. Tiglio, *Solving the Einstein constraint equations on multi-block triangulations using finite element methods*, Classical Quantum Gravity, 26 (2009) p.145007(28 pp.).

A05. B. Aksoylu and H. Klie, *A family of physics-based preconditioners for solving elliptic equations on highly heterogeneous media*, Applied Numerical Mathematics, 59 (2009), pp. 1159–1186.

A04. B. Aksoylu, I. G. Graham, H. Klie, and R. Scheichl, *Towards a rigorously justified algebraic preconditioner for high-contrast diffusion problems*, Computing and Visualization in Science, 11 (2008) pp. 319–331.

A03. B. Aksoylu and M. Holst, *Optimality of multilevel preconditioners for local mesh refinement in three dimensions*, SIAM Journal on Numerical Analysis, 44 (2006), pp. 1005–1025.

A02. B. Aksoylu, A. Khodakovsky, and P. Schröder, *Multilevel solvers for unstructured surface meshes*, SIAM Journal on Scientific Computing, 26 (2005), pp. 1146–1165.

A01. B. Aksoylu, S. Bond, and M. Holst, *An odyssey into local refinement and multilevel preconditioning III: Implementation and numerical experiments*, SIAM Journal on Scientific Computing, 25 (2003), pp. 478–498.

Conference proceedings

B02. B. Aksoylu, I. G. Graham, H. Klie, and R. Scheichl, *A rigorously justified robust algebraic preconditioner for high-contrast diffusion problems*, Extended Abstract for the 8th World Congress on Computational Mechanics (WCCM8) and the 5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008).

B01. B. Aksoylu and H. Klie, *Physics-based preconditioners for solving PDEs on highly heterogeneous media*, In proceedings of ICIAM 2007, Proc. Appl. Math. Mech. 7 (2007), pp. 1020703-1020704.

Technical reports and miscellanea

C10. B. Aksoylu and Z. Yeter, *Robust multigrid preconditioners for the high-contrast biharmonic plate equation*, tech. rep., LSU CCT-TR-2009-15, (2009), arXiv 0910.0487.

C09. B. Aksoylu and Z. Yeter, *Robust multigrid preconditioners for cell-centered finite volume discretization of the high-contrast diffusion equation*, tech. rep., LSU CCT-TR-2009-7, (2009), arXiv 0904.1885.

C08. B. Aksoylu, D. Bernstein, S.D. Bond, and M. Holst, *Generating Initial Data in General Relativity Using Adaptive Finite Element Methods*, tech. rep., LSU CCT-TR-2008-9, (2008), arXiv 0801.3142.

C07. B. Aksoylu, I. G. Graham, H. Klie, and R. Scheichl, *Towards a rigorously justified algebraic preconditioner for high-contrast diffusion problems*, tech. rep., UT-Austin ICES Report 07-35, (2007).

C06. B. Aksoylu and H. Klie, *Physics-based preconditioners for solving PDEs on highly heterogeneous media*, tech. rep., LSU CCT-TR-2007-1, (2007).

C05. B. Aksoylu, H. Klie, and M. F. Wheeler, *Physics-based preconditioners for porous media flow applications*, tech. rep., UT-Austin ICES Report 07-08, (2007).

C04. B. Aksoylu and M. Holst, *An odyssey into local refinement and multilevel preconditioning II: Stabilizing hierarchical basis methods*, tech. rep., UT-Austin ICES Report 05-04, (2005).

C03. B. Aksoylu and M. Holst, *An odyssey into local refinement and multilevel preconditioning I: Optimality of the BPX preconditioner*, tech. rep., UT-Austin ICES Report 05-03, (2005).

C02. B. Aksoylu, M. Holst, and S. Bond, *Theoretical and implementation aspects of the BPX preconditioner in the three dimensional local mesh refinement setting*, tech. rep., UT-Austin ICES Report 04-50, (2004).

C01. B. Aksoylu, *Adaptive multilevel numerical methods with applications in diffusive biomolecular reactions*, Ph.D. Dissertation, Department of Mathematics, Computational and Applied Mathematics Group, University of California, San Diego, (2001).

Funded Projects

1. EU Marie Curie Career Integration Grant 293978, *Numerical methods for nonlocal problems*, 100,000Euro, 09.12.2011–09.11.2015, PI: Burak Aksoylu *(single investigator)*.

2. NSF DMS 1016190, *Numerical methods for heterogeneity and nonlocality*, $180,000, 08.15.2010–07.31.2013, PI: Burak Aksoylu (*single investigator*).

3. NSF CNS 0540374, *DDDAS–TMPR: DynaCode: A general DDDAS framework with coast and environment modeling applications*, $220,000, 01.01.2006–12.31.2006, PI: Gabrielle Allen, Co-PIs: Burak Aksoylu, Ivor van Heerden, Gregory Stone Joannes Westerink.

4. NSF LA EPSCoR, *High performance solvers for atomistic-to-continuum modeling*, $3,000, extended stay at Sandia National Laboratories, summer 2008, PI: Burak Aksoylu.

5. LSU CCT focus areas grant, *Utilizing pseudospectral tools to analyze stability of evolution equations*, $10,000, 01.01.2007–05.31.2007, PI: Manuel Tiglio, Co-PI: Burak Aksoylu.

6. LSU CCT General Development Program, *Interplay between finite element method and evolution of Einstein's equations*, $40,000, 01.01.2006–06.30.2007, PI: Burak Aksoylu, Co-PI: Manuel Tiglio.

Long Term Research Visits

1. Department of Mathematics, Louisiana State University, Baton Rouge, Louisiana, five weeks, the summer of 2011.

2. Applied Mathematics and Applications Group, Sandia National Laboratories, Albuquerque, New Mexico, one week, the summer of 2011.

3. Applied Mathematics and Applications Group, Sandia National Laboratories, Albuquerque, New Mexico, seven weeks, the summer of 2009.

4. Applied Mathematics and Applications Group, Sandia National Laboratories, Albuquerque, New Mexico, six weeks, the summer of 2008.

Invited Industry Talks

1. ExxonMobil Corporate Strategic Research, Clinton, New Jersey, 07.02.2009,

2. Object Reservoir, Research and Development Division, Austin, Texas, 01.13.2009.

Minisymposium organizer

1. 7th International Congress on Industrial and Applied Mathematics ICIAM11, Vancouver, British Columbia, 07.18-22.2011,

2. SIAM Conference on Mathematical Aspects of Materials Science, Philadelphia, Pennsylvania, 05.23-26.2010,

3. SIAM Conference of Mathematical and Computational Issues in the Geosciences, Avignon, France, 06.09.2005.

Selected Scientific Presentations

1. Minisymposium presentation, 11th US National Congress on Computational Mechanics, Minneapolis, Minnesota, 07.26.2011,
2. Minisymposium presentation, 7th International Congress on Industrial and Applied Mathematics ICIAM11, Vancouver, British Columbia, 07.20.2011,
3. Contributed presentation, 7th International Congress on Industrial and Applied Mathematics ICIAM11, Vancouver, British Columbia, 07.18.2011,
4. Invited colloquium talk, Department of Mathematics and Statistics, University of New Mexico, Albuquerque, 07.14.2011,
5. Applied dynamics research group seminar talk, Department of Mathematics, Middle East Technical University, Ankara, Turkey, 05.06.2011,
6. Invited seminar talk, Department of Mathematics, Middle East Technical University, Ankara, Turkey, 03.03.2011,
7. Seminar talk, Department of Mathematics, TOBB University of Economics and Technology, Ankara, Turkey, 10.22.2010,
8. Invited presentation, US Air Force Office of Scientific Research, Washington D.C., 06.15.2010,
9. Minisymposium presentation, SIAM Conference on Mathematical Aspects of Materials Science, Philadelphia, 05.24.2010,
10. Invited colloquium talk, Faculty of Engineering and Natural Sciences, Sabanci University, Istanbul, Turkey, 05.07.2010,
11. Invited colloquium talk, Department of Mathematics and Computer Sciences, Bahcesehir University, Istanbul, Turkey, 05.05.2010,
12. Invited colloquium talk, Department of Mathematics and Statistics, Texas Tech University, Lubbock, Texas, 02.15.2010,
13. Invited colloquium talk, Department of Mathematics, Washington State University, Pullman, 04.29.2009,
14. Invited colloquium talk, Science Programs, Washington State University, Vancouver, 04.27.2009,
15. Invited colloquium talk, Computational Science Program, The University of Texas at El Paso, 02.23.2009,
16. Invited colloquium talk, Department of Mathematics and Statistics, University of New Mexico, Albuquerque, 02.10.2009,
17. Invited colloquium talk, Department of Mathematical Sciences, Michigan Technological University, Houghton, 01.26.2009,
18. Invited colloquium talk, Department of Mathematics, Louisiana State University, Baton Rouge, 01.15.2009,
19. Invited talk, Applied Mathematics and Applications Group, Sandia National Laboratories, Albuquerque, New Mexico, 06.11.2008,

20. Invited talk, Applied Mathematics and Applications Group, Sandia National Laboratories, Albuquerque, New Mexico, 02.04.2008,

21. Invited colloquium talk, Department of Mathematical and Statistical Sciences, University of Colorado at Denver, 01.28.2008,

22. Seminar talk, Department of Mathematics, Louisiana State University, Baton Rouge, 10.01.2007,

23. Invited talk, Department of Mathematics and Computer Science, Emory University, Atlanta, Georgia, 09.25.2007,

24. Minisymposium presentation, 6th International Congress on Industrial and Applied Mathematics ICIAM07, Zurich, Switzerland, 07.17.2007,

25. Contributed presentation, Conference on Preconditioning Techniques for Large Sparse Matrix Problems in Scientific and Industrial Applications, Toulouse, France, 07.10.2007,

26. Minisymposium presentation, SIAM Conference of Mathematical and Computational Issues in the Geosciences, Santa Fe, New Mexico, 03.20.2007,

27. Plenary talk, Workshop on "Numerical Methods for Differential Equations", Izmir Institute of Technology, Izmir, Turkey, 05.12.2006,

28. Minisymposium presentation, SIAM Conference of Mathematical and Computational Issues in the Geosciences, Avignon, France, 06.09.2005,

29. Contributed talk, Industrial Affiliates Meetings, Center for Subsurface Modeling, The University of Texas at Austin, 10.26.2004,

30. Invited talk, Mathematical Sciences Institute, Australian National University, Canberra, Australia, 07.17.2003,

31. Contributed presentation, 5th International Congress on Industrial and Applied Mathematics ICIAM03, Sydney, Australia, 07.08.2003,

32. Invited talk, School of Mathematics and Statistics, University of New South Wales, Sydney, Australia, 07.03.2003,

33. Contributed paper presentation, 7th Copper Mountain Conference on Iterative Methods, Copper Mountain, Colorado, 03.29.2002.

Awards

Recipient of the University of Texas at Austin ICES postdoctoral fellowship.

Recipient of the Burroughs Wellcome Fund interdisciplinary LJIS predoctoral fellowship.

Recipient of the Ministry of Education Overseas Higher Education Scholarship given only to 2 students nationwide by the Turkish Government to pursue doctoral studies abroad.

Technical Reviewer

National Science Foundation Computational Mathematics review panel,

SIAM Journal on Numerical Analysis,

SIAM Journal on Scientific Computing,

Multiscale Modeling and Simulation,

AMS Mathematics of Computation,

Applied Numerical Mathematics,

Computer Methods in Applied Mechanics and Engineering,

Numerical Fuctional Analysis and Optimization,

Proceedings of the Domain Decomposition Methods Conference,

Proceedings 7th IEEE International Symposium on Cluster Computing and the Grid.

Teaching Career Highlights

1. Has *extensive teaching experience* in all levels for a wide array of courses in both US and overseas institutions.
2. Holds an *additional degree in Mathematics Education*. Has been an active member of the LSU Mathematics Education program.
3. Has been teaching *Mathematics Education Capstone Course* continuously.
4. Successfully mentored *undergraduate research*. His undergraduate student, Irina Craciun, presented in Louisiana Academy of Science as well as Sandia National Laboratories, and has been selected as the top ranking student by the LSU Department of Mathematics.
5. *Ability to tailor individually focused teaching strategies* for undergraduate students ranging from high profile to average and poor. Especially developed learning and teaching strategies for averagely to poorly achieving students.
6. Has successfully *recruited high profile graduate students*. All students have had high honors and passed their qualifying exams on their arrival. Chaired both undergraduate and graduate recruitment committees in the Dept of Math and CCT.
7. *Attracted a great number of students to scientific computing courses that have been previously failing due to lack of attendance*. Interacted and worked with students and groups from diverse backgrounds in science, engineering, and education. A great number of students asked me to be in their Ph.D. committees.
8. *Coached candidates for the International Math Olympiad (IMO).* Acted in the IMO committee in the 1993 Istanbul Olympiad.

ETU Teaching History

Mat 496	Project II	S2011
Mat 395	Numerical Analysis	S2011
Mat 102	Calculus II	S2011
Mat 495	Project I	F2010
Mat 101	Calculus I	F2010

LSU Teaching History

Math 1550	Analytic Geometry and Calculus I	S2010
Math 4004	Mathematics Education Capstone Course	S2009
Math 4038	Mathematics Methods in Engineering	S2009
Math 4004	Mathematics Education Capstone Course	S2008
Math 4153	Finite Dimensional Vector Spaces	S2007
Math 4004	Mathematics Education Capstone Course	S2007
Math 7390-2	Scientific Computing	F2006
Math 4066	Numerical Analysis II	S2006
Math 4065	Numerical Analysis I	F2005

Dissertations Directed

1. Zuhal Yeter (PhD, Mathematics, advisor)
2. Irina Craciun (Undergraduate, Mathematics, advisor, graduated in S2008 receiving the top undergraduate award, Senior Mathematics Award)
3. Ernst Nils Dorband (PhD, Physics and Astronomy, committee member), *Computing and analyzing gravitational radiation in black hole simulations using a new multi-block approach to numerical relativity*, graduation date: May 2007, advisor: Manuel Tiglio.
4. Nathan Matthew Lane (PhD, Chemical Engineering, IGERT co-advisor), advisor: Karsten Thomphson

Recruitment of Students and Faculty

F2011–present, Coordinator, Graduate program, ETU Department of Mathematics.
F2007–S2008, Chair, Undergraduate and graduate competitive research program committee, CCT
F2007–S2010, Member, Undergraduate advising committee, Department of Mathematics
F2005–S2010, Member, Scientific computing and numerical analysis undergraduate concentration committee, Department of Mathematics
F2005–S2006, Member, Postdoctoral recruitment committee, CCT

Membership

Society of Industrial and Applied Mathematics.

Academic References

Prof. Michael Holst, UCSD
Prof. Randolph Bank, UCSD

Prof. Paul Saylor, UIUC
Prof. Edward Seidel, NSF
Prof. Frank Neubrander (teaching), LSU
Prof. George Cochran (teaching), LSU.