

Harish Narayanan

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Born: October 198x—Madras, India

Nationality: Indian

Areas of Specialisation

Classical and modern field theories of mechanics • Modelling multi-physics phenomena

Mathematics of growth and remodelling of biological tissues

Analysis and implementation of numerical methods • Error-controlled finite element methods

Appointments Held

- 2008 – Postdoctoral fellow, *Center for Biomedical Computing, Simula Research Laboratory, Norway*
2002 – 2008 Research assistant, *Department of Mechanical Engineering, University of Michigan, Ann Arbor*

Education

- 2007 Ph.D. in Mechanical Engineering and Scientific Computing, *University of Michigan, Ann Arbor*
DISSERTATION: *“A continuum theory of multiphase mixtures for modelling biological growth”*
ADVISOR: *Prof. Krishna Garikipati*
- 2006 M.S. in Mathematics, *University of Michigan, Ann Arbor*
- 2003 M.S.E. in Mechanical Engineering, *University of Michigan, Ann Arbor*
- 2002 B.E. in Mechanical Engineering, *University of Madras, India* (First class with distinction)

Academic Honours

- 2001 – 2002 Received the *Sir C. P. Ramaswamy Aiyar Endowment Scholarship* from the University of Madras for excellent academic performance at the undergraduate level.
- 1998 Received a *Certificate of Merit* in high school for outstanding academic work throughout 12th grade, including securing the first rank in physics, AISSCE (CBSE 12th).

Publications & Communications

JOURNAL ARTICLES

H. Narayanan, M. M. Maleckar, W. R. Giles, “The role of K⁺ channels in human articular chondrocyte electrophysiology: a computational perspective,” Under preparation in 2012.

K. Selim, A. Logg, H. Narayanan, M. G. Larson, “An adaptive finite element method for fluid-structure interaction,” Submitted in 2011. [\[PDF\]](#)

H. Narayanan, S. N. Verner, K. L. Mills, R. Kemkemmer, K. Garikipati, “In silico estimates of the free energy changes in growing, avascular, tumor spheroids,” *Journal of Physics: Condensed Matter*, vol. 22(19), 2010. [\[DOI\]](#) [\[PDF\]](#)

H. Narayanan, E. M. Arruda, K. Grosh, K. Garikipati, “The micromechanics of fluid-solid interactions during growth in porous soft biological tissue,” *Biomechanics and Modeling in Mechanobiology*, vol. 8(3), pp. 167–181, 2009. [\[DOI\]](#) [\[PDF\]](#)

K. Garikipati, M. Falk, M. Bouville, B. Puchala, H. Narayanan, “The continuum elastic and atomistic viewpoints on the formation volume and strain energy of a point defect,” *Journal of the Mechanics and Physics of Solids*, vol. 54(9), pp. 1929–1951, 2006. [\[DOI\]](#) [\[PDF\]](#)

K. Garikipati, J. Olberding, H. Narayanan, E. M. Arruda, K. Grosh, S. Calve, “Biological remodelling: Stationary energy, configurational change, internal variables and dissipation,” *Journal of the Mechanics and Physics of Solids*, vol. 54(7), pp. 1493–1515, 2006. [\[DOI\]](#) [\[PDF\]](#)

K. Garikipati, E. M. Arruda, K. Grosh, H. Narayanan, S. Calve, “A continuum treatment of growth in biological tissue: The coupling of mass transport and mechanics,” *Journal of the Mechanics and Physics of Solids*, vol. 52(7), pp. 1595–1625, 2004. [\[DOI\]](#) [\[PDF\]](#)

CHAPTERS IN BOOKS

H. Narayanan, “A computational framework for nonlinear elasticity,” in A. Logg, K-A. Mardal, G. N. Wells (Eds.), *Automated Solution of Differential Equations by the Finite Element Method*, chap. 27, pp. 527–544, 2012. [\[DOI\]](#) [\[PDF\]](#)

K. Valen-Sendstad, A. Logg, K-A. Mardal, H. Narayanan, M. Mortensen, “A comparison of some finite element schemes for the incompressible Navier-Stokes equations,” in A. Logg, K-A. Mardal, G. N. Wells (Eds.), *Automated Solution of Differential Equations by the Finite Element Method*, chap. 21, pp. 395–417, 2012. [\[DOI\]](#) [\[PDF\]](#)

E. M. Arruda, S. Calve, K. Garikipati, K. Grosh, H. Narayanan, “Characterization and modeling of growth and remodeling in tendon and soft tissue constructs,” in G. A. Holzapfel, R. W. Ogden (Eds.), *Mechanics of Biological Tissue*, chap. 5, pp. 63–75, 2006. [\[DOI\]](#) [\[PDF\]](#)

K. Garikipati, H. Narayanan, E. M. Arruda, K. Grosh, S. Calve, “Material forces in the context of biotissue remodelling,” in P. Steinmann, G. A. Maugin (Eds.), *Mechanics of Material Forces*, chap. 8, pp. 77–84, 2005. [\[DOI\]](#) [\[PDF\]](#)

CONFERENCE PROCEEDINGS

J. Ma, H. Narayanan, K. Garikipati, K. Grosh, E. M. Arruda, “Experimental and computational investigation of viscoelasticity of native and engineered ligament and tendon,” in K. Garikipati, E. M. Arruda (Eds.), *Cellular, Molecular and Tissue Mechanics*, IUTAM Symposium Bookseries, vol. 16, pp. 3–17, 2010. [\[DOI\]](#) [\[PDF\]](#)

H. Narayanan, K. Garikipati, A. Logg, “Collaborative computational frameworks and the growth problem,” in D. Ambrosi, K. Garikipati, E. Kuhl (Eds.), *The Mathematics of Growth and Remodelling of Soft Biological Tissues*, Mathematisches Forschungsinstitut Oberwolfach Reports, vol. 5, no. 3, pp. 2247–2249, 2008. [DOI] [PDF]

K. Garikipati, H. Narayanan, K. Grosh, E. M. Arruda, “Mathematical modelling of solid tumor growth,” in D. Ambrosi, K. Garikipati, E. Kuhl (Eds.), *The Mathematics of Growth and Remodelling of Soft Biological Tissues*, Mathematisches Forschungsinstitut Oberwolfach Reports, vol. 5, no. 3, pp. 2235–2238, 2008. [DOI] [PDF]

OTHER ACADEMIC WRITING

H. Narayanan, “A continuum theory of multiphase mixtures for modelling biological growth,” *Doctoral Dissertation*, University of Michigan, 2007. [DOI] [PDF]

H. Narayanan, “Variational level sets in shape reconstruction from unorganised data sets,” *Project Report*, University of Michigan, 2005. [PDF]

SELECTED TALKS

“The role of K⁺ channels in human articular chondrocyte electrophysiology,” *Cardiac Modelling Seminar at Simula Research Laboratory*, Oslo, Norway, July 2011. [SLIDES]

“An automated computational framework for hyperelasticity,” *Fourth European Conference on Computational Mechanics*, Paris, France, May 2010. [SLIDES]

“A goal-oriented error-controlled solver for biomedical flows,” *Fifth M.I.T. Conference on Computational Fluid and Solid Mechanics*, Cambridge, MA, June 2009. [SLIDES]

“Collaborative computational frameworks and the growth problem,” *Workshop on the Mathematics of Growth and Remodelling of Soft Biological Tissues*, Mathematisches Forschungsinstitut Oberwolfach, Germany, September 2008. [SLIDES]

“Reshaping tumour growth,” *University of Michigan Engineering Graduate Student Symposium*, Ann Arbor, MI, November 2007. [SLIDES]

“The numerical implications of multiphase mechanics assumptions underlying growth models,” *Ninth U.S. National Congress on Computational Mechanics*, San Francisco, CA, July 2007. [SLIDES]

“Finite element methods in general relativity,” *University of Michigan Engineering Graduate Student Symposium*, Ann Arbor, MI, November 2006. [SLIDES]

“Viscoelastic and growth mechanics in engineered and native tendons,” *43rd Annual Technical Meeting of the Society of Engineering Science*, University Park, PA, August 2006. [SLIDES]

“The numerical implications of fluid incompressibility in multiphase modelling of soft tissue growth,” *Seventh World Congress on Computational Mechanics*, Los Angeles, CA, July 2006. [SLIDES]

“Tendon growth and healing: The roles of reaction, transport and mechanics,” *15th U.S. National Congress on Theoretical and Applied Mechanics*, Boulder, CO, June 2006. [SLIDES]

“Computational modelling of mechanics and transport in growing tissue,” *Eighth U.S. National Congress on Computational Mechanics*, Austin, TX, July 2005. [SLIDES]

“Simulations of coupled mechanics and transport in growing soft tissue,” *Third M.I.T. Conference on Computational Fluid and Solid Mechanics*, Cambridge, MA, June 2005. [SLIDES]

“Multi-scale simulations of the mechanics of transport and growth in soft tissue,” *41st Annual Technical Meeting of the Society of Engineering Science*, Lincoln, NE, October 2004. [SLIDES]

“Material forces in the context of biological tissue remodelling,” *Seventh U.S. National Congress on Computational Mechanics*, Albuquerque, NM, July 2003. [SLIDES]

“A continuum treatment of growth in tissue,” *Second M.I.T. Conference on Computational Fluid and Solid Mechanics*, Cambridge, MA, June 2003. [SLIDES]

Teaching Experience

- 2009 Invited Lecturer, *Simula Research Laboratory*
Conducted a lecture series on *Introductory Continuum Mechanics* for interested graduate students and researchers at the Department of Scientific Computing.
- 2008 – 2011 Ph.D. Co-Advisor, *Simula Research Laboratory*
Guided Kristoffer Selim, a Ph.D. student at the University of Oslo and Simula Research Laboratory, with his research on robust numerical methods for fluid-structure interaction problems.
- 2006 Graduate Student Instructor, *University of Michigan*
Assisted Prof. Ellen M. Arruda and Prof. J. Wayne Jones in teaching *Mechanical Behavior of Materials* [ME 382] to junior undergraduate students at the Department of Mechanical Engineering.

Professional Development & Service

- 2011 – Established *Mechanics Academy*, a website to house open-access video lectures on university-level mechanics, along with related lecture notes, practice exercises and avenues to get support. Currently planning and preparing lectures for a first course on computational biomechanics.
- 2009 – 2010 Visited the Department of Engineering at the University of Cambridge for three months to collaborate with Dr. Garth N. Wells on error-controlled methods for multiphase flow through porous media.
- 2009 Participated and successfully completed the requirements of the course *Communicating Scientific Research* offered by Prof. Michael Alley from Pennsylvania State University.
- 2008 Attended a short course on *Nonlinear Finite Element Analysis* taught by Prof. Thomas J.R. Hughes and Prof. Ted Belytschko in Paris, France.
- 2007 – 2008 Served as a reviewer for articles on biological tissue growth for the *ASME Journal of Biomechanical Engineering* and *Philosophical Transactions of the Royal Society*.
- 2005 Recognised as an *Engineering Academic Scholar* by the office of the Associate Dean for Graduate Education, University of Michigan, after successfully completing the *Academic Careers in Engineering and Sciences* program.
- 2003 – 2008 Served as system administrator and webmaster for the *Computational Physics Group*, University of Michigan.
- 2003 – Associate member of the *Free Software Foundation*, and contributor to different free software projects. These include, currently, *The FEniCS Project* (patches, build system, website, applications) and *WordPress* (patches), and, historically, *The GIMP* (website, documentation).

Programming & IT Skills

Programming languages:

C++, Python, FORTRAN

Numerical programming environments:

COMSOL, MATLAB/Octave, R

Symbolic computation:

Mathematica, GiNaC, SymPy, Maple

Research finite element method codes:

FEniCS, FEAP

Scripting languages:

Shell script (Bash), AppleScript

Web programming:

PHP, SQL, XHTML, CSS, XML, JavaScript

Typesetting, graphics and illustration:

L^AT_EX, Photoshop, Inkscape, matplotlib

Operating environments:

Mac OS X, Linux, Windows

References

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