Harish Narayanan

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Born: October 198x—Madras, India
Nationality: Indian

Areas of Specialisation

Using continuum physics theory to model biological phenomena

Devising and implementing robust software for solving coupled equations

Appointments Held

2008 – 2012 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. Kemkemer, 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

"A continuum model for the active mechanical response of the myocardium," *Tenth World Congress on Computational Mechanics,* São Paulo, Brazil, July 2012. [SLIDES]

"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 multiphasic mechanics assumptions underlying growth models," *Ninth U.S. National Congress on Computational Mechanics,* San Fransisco, 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 multiphasic 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

2012 Joined a select team at the *Third Virtual Physiological Human Study Group* at the Universitat Pompeu Fabra to work on tackling some grand challenges in the field of cardiovascular research.

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, Ruby, 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:
LaTeX, Photoshop, Inkscape, Gnuplot

Operating environments:
OS X, Linux, Windows