Michael C. Hillman, Ph.D.

Principal Scientist, Karagozian and Case Inc.

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Education

2013 **Ph.D.**, Civil Engineering, University of California, Los Angeles
Topic: An Arbitrary Order Variationally Consistent Integration Method for Galerkin Meshfree Methods
Advisor: J. S. Chen
Focus: Computational Mechanics

2009 **M.S.**, Civil Engineering, University of California, Los Angeles
Focus: Structural and geotechnical earthquake engineering

2008 **B.S.**, Civil Engineering, California State University, Fullerton

Appointments

2022–present **Principal Scientist I**, Karagozian and Case, Inc.

2022 **Kimball Associate Professor (with tenure)**, The Pennsylvania State University
Department of Civil and Environmental Engineering

2016–2022 **Kimball Assistant Professor**, The Pennsylvania State University
Department of Civil and Environmental Engineering

2014–2016 **Postdoctoral Scholar, Instructor**, University of California, San Diego
Department of Structural Engineering (Advisor: J. S. Chen)

2013 **Postdoctoral Scholar, Instructor**, University of California, Los Angeles
Department of Civil and Environmental Engineering (Advisor: J. S. Chen)

2009–2013 **Graduate Student Researcher**, University of California, Los Angeles
Department of Civil and Environmental Engineering

Research Interests

Development of Advanced Computational Methods

- Meshfree formulations for predictive simulation of problems challenging for conventional methods (e.g. commercial software): impact, fragmentation, blast, and geomechanics
- Variationally consistent domain integration for arbitrary-order accuracy and convergence
- Accelerated stabilized nodal integration for linear, large deformation, and coupled problems
- Physics-based shock enrichment in meshfree methods
- Stabilized meshfree methods for convection-dominated problems
- Unified and high-order local and non-local meshfree methods

Application of Computational Mechanics to Material Failure and Extreme Deformations

- Stabilized meshfree methods for numerical investigation and validated simulations of
  - Tillage and earth-moving operations, shear band formation in landslides
  - Three-dimensional deposition printing (concrete, thermoplastics)
  - Image-based micro-structural failure and toughening mechanisms of high-strength concrete
  - Shock propagation in reinforced concrete members subjected to blast and bullet penetration (see below)
- Numerical investigation of damage processes and failure mechanisms of concrete walls and steel panels subject to blast and bullet penetration using advanced Galerkin meshfree methods
  - Varying wall thickness and penetration impact velocities, standoff blast distance
  - Validation with entrance and exit hole size, crater size, velocity reduction
  - Reproduction of phenomenology of shear-cone formation, radial, lateral, and circumferential cracking

Select Honors and Awards

1. CAREER Award, The National Science Foundation, 2020
2. L. Robert and Mary L. Kimball Early Career Development Endowed Professorship, The Pennsylvania State University, 2016, 2019

Technology Adapted in the Field

2022 **Thermo-mechanical Meshfree Method for Explicit Dynamics**
Karagozian & Case, Inc.
Research adapted in the FEMFRE enabling coupled thermo-mechanical analysis in hypervelocity impact with fluid-structure interaction

2020 **Naturally Stabilized Nodal Integration for Softening Materials**
Karagozian & Case, Inc.
Research adapted in the FEMFRE enabling natural stabilization in impact and blast problems with material softening

2019 **Naturally Stabilized Nodal Integration**
Case New Holland Industrial LLC
Research adapted in the MEGA code for providing stable and efficient advanced simulations of agricultural problems

2019 **Naturally Stabilized Conforming Nodal Integration**
Karagozian & Case, Inc.
Research adapted in the FEMFRE code for providing accurate, stable and efficient advanced simulations of impact and blast problems

2017 **Naturally Stabilized Nodal Integration**
Livermore Software Technology Corp.
Research adapted in the LS-DYNA code for providing stable and efficient advanced extreme event simulations

2015 **Variationally Consistent Naturally Stabilized Nodal Integration**
Sandia National Laboratories
Research adapted in the SIERRA/SolidMechanics code for providing stabilized and efficient advanced high-order accurate extreme event simulations

2015 **Variationally Consistent Naturally Stabilized Nodal Integration**
U.S. Army Engineer Research and Development Center
Research adapted in the NMAP code for providing stabilized and efficient high-order accurate advanced simulations of bullet penetration/perforation, blast, explosive welding, and geotechnical problems

Project Experience

Research, Development, and Implementation of Novel Meshfree Methods for Explicit Dynamics

- Specialized in numerical algorithms to improve the accuracy (e.g. by 10x-1000x), stability, efficiency (e.g. 10x-20x speedup), and robustness of large-scale parallel explicit dynamic codes
- Developing novel methods to simulate engineering applications such as natural and man-made disasters (e.g. landslides, impact/penetration, blast), three dimensional printing (fused deposition modeling, printing concrete), geotechnical problems (e.g. bulldozing, tillage), and damage evolution of complex composite microstructures based on CT-scans.
- Implementing and overseeing verification and validation.
- Research, development, implementation, and calibration of advanced damage-plasticity material models—ranging from isotropic to orthotropic—for application to geomaterials, ceramic composites, and timber.

Obtaining and Administering Grants and Contracts

Hillman obtained $1.8M in external funding for his research program at Penn State and continues to help obtain funding at Karagozian and Case. At Penn State, he was the lead investigator on nine research projects. Sources include

- The National Science Foundation
- The US Army Engineer Research and Development Center
- The Missile Defense Agency
- Karagozian and Case, Inc.
- Case New Holland Industrial, LLC
- The Johns Hopkins Applied Physics Laboratory LLC
- Penn State Internal Seed Grants

Projects as a Developer/Researcher

2022–present **The K&C Finite Element and MeshFree (KC-FEMFRE) analysis code**

Role: Developer

Funding Source: K&C, external sponsors

Summary: FEMFRE is an explicit meshfree nonlinear solver for extreme deformations. Since joining K&C, Hillman is spearheading the development of this software for the planned v1.0 release in 2024. The code extends engineers' capability to solve problem difficult or impossible to solve via the finite element analysis, including blast, penetration, bio-mechanics, etc.

- Oversaw implementation, verification, and validation of semi-Lagrangian RKPM, enabling extreme-deformation analysis not previously possible; a key code enhancement for the success of several externally-funded projects. Implemented many supporting features.
- Implemented various elastic and elastic-plastic-damage material models such as hyperelasticity, anisotropic damage-plasticity, and Drucker-Prager plasticity
- Oversaw and implemented regression testing suite for quality control
- Wrote python scripts to automate (process data, plot data, output tables) post-processing of results to compare FEMFRE output to analytical, experimental or other reference solutions, to assure QA/QC
- Spearheading new coupled fluid-structure interaction code including theory, implementation guidance, and running regular meetings

2016–2022 **The Meshfree Explicit Galerkin Analysis (MEGA) code**
Role: Developer, Principal investigator
Funding Source: Kimball Endowment
Summary: Starting at Penn State, Hillman used his previous seven years of experience working on large-scale meshfree codes to write his own parallel meshfree code from scratch using OpenMP and FORTRAN90, making it possible to solve problems which are difficult or impossible for conventional finite element methods (e.g., commercial software) such as three-dimensional printing, bullet penetration, earth-moving, and landslides

- Developed and implemented stabilized VC integration methods to ensure numerical stability and optimal convergence
- Wrote read subroutines for user-friendly input control
- Compatible with standard geometric input files for mechanical analysis (LS-DYNA type)
- Wrote output code for VTK visualization
- Wrote user manual [Download] with set of example input and output files, as well as a technical manual [Download]
- Served as basis for two other major research codes
- Used by a private company for numerical simulations of industrial applications
- Documented in a peer-reviewed conference paper [Download]

2020–2021 **RKPM2D: an open-source implementation of nodally integrated reproducing kernel particle method for solving partial differential equations**
Role: Developer
Funding Source: N/A
Summary: Worked with a team at UC San Diego to implement novel meshfree numerical methods for two-dimensional solving partial differential equations in an open-source MATLAB code [Link]

- Provided input and advice to UC San Diego on implementation of meshfree algorithms
- Helped to document use in a user manual [Download], and performance in a peer-reviewed paper [Download].

2012–2016 **Development and implementation of RKPM into SIERRA**
Role: Postdoctoral Scholar
Funding Source: Sandia National Laboratories
Summary: Implemented meshfree capabilities in Sandia's parallel SIERRA code framework, making it possible to solve mechanical problems which are difficult or impossible for conventional methods (e.g. using government/lab or commercial codes)

- Developed and implemented VC integration to ensure optimal convergence
- Developed and implemented stabilized nodal integration for nonlinear large deformation problems to ensure numerical stability
- Documented in a peer-reviewed conference paper [Download].

2010–2016 **A multiscale meshfree approach for modeling fragment penetration into ultra high-strength concrete**
Role: Postdoctoral Scholar, Graduate Research Assistant
Funding Source: U.S. Army Engineer Research and Development Center
Summary: A primary researcher and developer for a large MPI parallel FORTRAN90 meshfree simulation code (NMAP) capable of modeling complex mechanical problems such as bullet penetration, landslides, blast, and explosive welding, to name a few

- Developed and implemented VC integration for nonlinear large deformation problems to ensure optimal convergence
- Developed and implemented stabilized nodal integration for nonlinear large deformation problems to ensure numerical stability
- Developed and implemented a stabilized nodal integration with enhanced efficiency (an order of magnitude) over previously implemented stabilization method
- Implemented adaptively coupled FEM-RKPM formulation improving the efficiency of the code several times over
- Implemented efficient parallel node-search algorithms reducing the cost of node search from $\mathcal{O}(n^2)$ to $\mathcal{O}(n \log n)$
- Performed large scale simulations for validation of meshfree implementation for fragment-impact problems

2010–2011 **Parallelized meshfree modeling of earth-moving problems**
Role: Graduate Research Assistant
Funding Source: Caterpillar Inc.

- Developed and implemented stabilized nodal integration for nonlinear large deformation problems to ensure numerical stability
- Implemented parallel contact algorithms making large-scale simulations tractable
- Performed large-scale benchmark simulations of dozing and ripping for validation of meshfree implementation for earth-moving simulations

2009–2011 **Development and implementation of meshfree technologies in computational mechanics**
Role: Graduate Research Assistant
Funding Source: Weidlinger Associates Inc.

- Implemented meshfree capabilities for fragment-impact simulations into the commercial finite element code NLFlex, which were previously extremely difficult or impossible with existing code
- Implemented an FEM-RKPM coupled formulation for optimal coupling with existing finite element code

Publications

Hillman has authored 36 publications including one book, 25 journal articles, three book chapters, one encyclopedia entry, three articles, and four conference papers

Books

1. Belystchko, T., Chen, J.S., Hillman, M. Meshfree and Particle Methods, Wiley: Hoboken, NJ, 2024. Amazon link.

Journal Publications

1. Jafarzadeh, S.‡, Hillman, M. An ultra-high-speed reproducing kernel particle method. Computational Mechanics, https://doi.org/10.1007/s00466-025-02599-0, 2025.
2. Wang, J.‡, Hillman, M., Wilmes, D., Magallanes, J., Bazilevs, Y. Smoothed naturally stabilized RKPM for non-linear explicit dynamics with novel stress gradient update. Computational Mechanics, Vol 75, pp. 137-158, 2025.
3. Tang, Y., Wang, Y., Hillman, M., Chen, J. S., Du, J. Fracture experiments of coated and non-coated epoxy-alumina composites coupled with micro-CT. Composites Part A: Applied Science and Manufacturing, Vol 192, p. 108762, 2025.
4. Groeneveld, A.†, Hillman, M. A new meshfree variational multiscale (VMS) method for essential boundary conditions, Computer Methods in Applied Mechanics and Engineering, Vol 427 p. 117081, 2024.
5. Wang, Y., Baek, J., Tang, Y., Du, J., Hillman, M., Chen, J. S. Support vector machine guided reproducing kernel particle method for image-based modeling of microstructures. *Computational Mechanics*, Vol. 73(4), pp. 907-942, 2024. Download.
6. Cheng, H.†, Radlinska, A., Hillman, M., Li, F.† , Wang, J.‡ Modeling concrete deposition via 3D printing concrete using RKPM. Cement and Concrete Research, Vol 181 p. 107526, 2024.
7. Wang, J.‡, Hillman, M. Upwind reproducing kernel collocation method for convection-dominated problems. Computer Methods in Applied Mechanics and Engineering, Vol 420 p. 116711, 2024. Download.
8. Li, W., Moutsanidis, G., Behzadinasab, M., Hillman, M., Bazilevs, Y. Reduced quadrature for Finite Element and Isogeometric methods in nonlinear solids. Computer Methods in Applied Mechanics and Engineering, Vol 399, p. 115389, 2022. Download.
9. Wang, J.‡, Hillman, M., Temporal stability of collocation, Petrov-Galerkin, and other Non-symmetric methods in elastodynamics and an energy conserving time integration. Computer Methods in Applied Mechanics and Engineering, Vol 393, p. 114738, 2021. Download.
10. Williams, B., Madra, A.‡ Heard, W., Graham, S., Grotke, M., Hillman, M., & Nie, X. Characterizing damage modes and size effects in high-strength concrete under hydrostatic and triaxial stress states using X-ray microtomography. Construction and Building Materials, Vol. 311, p. 125338, 2021. Download.
11. Behzadinasab, M., Hillman, M. & Bazilevs, Y. IGA-PD penalty-based coupling for immersed air-blast fluid-structure interaction: a simple and effective solution for fracture and fragmentation. *Journal of Mechanics*, Vol. 37, pp. 680-692, 2021. Download.
12. Wang, J.†, Zhou, G.‡, Hillman, M., Madra, A.‡, Bazilevs, Y., Du, J., Su, K. Consistent immersed volumetric Nitsche methods for composite analysis, *Computer Methods in Applied Mechanics and Engineering*, Vol 385, p.114042, 2021. Download.
13. Hillman, M., Lin, K. C.†, Nodally integrated thermomechanical RKPM: Part II — Generalized thermoelasticity and hyperbolic finite-strain thermoplasticity, *Computational Mechanics*, Vol. 68, pp. 821-844, 2021. Download.
14. Hillman, M., Lin, K. C.†, Nodally integrated thermomechanical RKPM: Part I — Thermoelasticity, *Computational Mechanics*, Vol 68, pp. 795-820, 2021. Download.
15. Tang, Y., Su, K., Man, R., Hillman, M., Du, J., Investigation of internal cracks in epoxy-alumina using in situ mechanical testing coupled with micro-CT, *JOM*, Vol. 73, pp. 2452–2459, 2021 Download.
16. Baek, J., Chen, J. S., Zhou, G.‡, Arnett, K. P., Hillman, M., Hegemier, G., Hardesty, S., A semi-Lagrangian RKPM with node-based shock algorithm for explosive welding simulation, *Computa-*

tional Mechanics, Vol. 67, pp. 1601–1627, 2021. Download.

17. Hillman, M., Lin, K. C.†, Consistent weak forms for meshfree methods: Full realization of h-refinement, p-refinement, and a-refinement in strong-type essential boundary condition enforcement, *Computer Methods in Applied Mechanics and Engineering*, Vol. 373, p. 113448, 2021. Download.
18. Hillman, M., Pasetto, M., Zhou, G.‡, Generalized reproducing kernel peridynamics: Unification of local and non-local meshfree methods, non-local derivative operations, and an arbitrary-order state-based peridynamic formulation, *Computational Particle Mechanics*, Vol. 7, pp. 435–469, 2020. Download.
19. Zhou, G.‡, Hillman, M., A Non-ordinary state-based Godunov peridynamics formulation for strong shocks in solids, *Computational Particle Mechanics*, Vol. 7, pp. 365–375, 2020. Download.
20. Chen, J. S., Huang, T. H., Wei, H., Hillman, M., RKPM2D: An open-source implementation of nodally integrated reproducing kernel particle method for solving partial differential equations, *Computational Particle Mechanics*, Vol. 7, pp. 393–433, 2020. Download.
21. Khaghani, M., Rajabipour, F., Gholizadeh-Vayghan, A., Hillman, M., Characterization of viscoelastic behavior of synthetic alkali–silica reaction gels, *Cement and Concrete Composites*, Vol. 104, p. 103359, 2019. Download.
22. Liang, S., Chen, J. S., Li, J., Lin, S. P., Chi, S. W., Hillman, M., Roth, M. J., Heard, W., Numerical investigation of statistical variation of concrete damage between scales, *International Journal of Fracture*, Vol 208(1), pp. 97–113, 2017. Download.
23. Bazilevs, Y., Moutsanidis, G., Bueno, J., Kamran, K., Kamensky, D., Hillman, M., Gomez, H., Chen, J.S., A new formulation for air-blast fluid structure interaction using an immersed approach. Part II — Coupling of IGA and meshfree discretizations, *Computational Mechanics*, Vol. 60, pp. 101–116, 2017. Download.
24. Chen, J. S., Hillman, M., Chi, S. W., Meshfree methods: progress made after 20 years, *Journal of Engineering Mechanics*, Vol. 143(4), p. 04017001, 2017. Download.
25. Hillman, M., Chen, J. S., An accelerated, convergent and stable nodal integration in Galerkin meshfree methods for linear and nonlinear mechanics, *International Journal for Numerical Methods in Engineering*, Vol. 107, pp. 603–630, 2016. Download.
26. Hillman, M., Chen, J. S., Nodally integrated implicit gradient reproducing kernel particle method for convection dominated problems, *Computer Methods in Applied Mechanics and Engineering*, Vol. 299, pp. 381–400, 2016. Download.
27. Wei, H., Chen, J. S., Hillman, M. A stabilized nodally integrated meshfree formulation for fully coupled hydro-mechanical analysis of fluid-saturated porous media. *Computers and Fluids*, Vol. 141, pp. 105–115, 2016. Download.
28. Sherburn, J., Roth, M. J., Chen, J. S., Hillman, M., Meshfree modeling of concrete slab perforation using a reproducing kernel particle impact and penetration formulation, *International Journal of Impact Engineering*, Vol. 86, pp. 96–110, 2015. Download.
29. Hillman, M., Chen, J. S., Bazilevs, Y., Variationally consistent domain integration for isogeometric analysis, *Computer Methods in Applied Mechanics and Engineering*, Vol. 284, pp. 521–540, 2015. Download.
30. Hillman, M., Chen, J. S., Stabilized and variationally consistent nodal integration for meshfree modeling of impact problems, *Computational Particle Mechanics*, Vol. 1, pp. 245–256, 2014. Download.
31. Chen, J. S., Hillman, M., Rüter, M., An arbitrary order variationally consistent method for Galerkin meshfree methods, *International Journal for Numerical Methods in Engineering*, Vol. 95, pp. 387–418, 2013. Download.

Presentations

- Author/co-author of over 100 talks at national and international conferences

- Ten invited talks, including three keynotes
- Two short courses on meshfree methods for advanced numerical simulations

Mentoring Students and Postdoctoral Scholars

- Advised to completion three PhD students and one MS student
- Advised four postdoctoral scholars
- Six student awards and fellowships, one postdoctoral award

Teaching Experience

[§]New course developed

Graduate: Meshfree Methods for Linear and Nonlinear Solid Mechanics[§], The Finite Element Method (linear static and dynamic analysis using solid elements)
Undergraduate: Structural Analysis, Design of Reinforced Concrete Structures, Introduction to Computing for Civil Engineers, Algorithms and Programming for Structural Engineering

Service to the Computational Mechanics Community

Professional Committees

Was elected Chair of the Computational Mechanics Committee of the *American Society of Engineers' Engineering Mechanics Institute*, and currently elected Member of the *US Association for Computational Mechanics* Technical Thrust Area on Novel Methods in Computational Engineering & Sciences. Host for 2022 EMI Career Path Panel, and panel member for 2023 EMI Career Path Panel.

Editorial Service

Guest editor for a thematic issue in *Computational Particle Mechanics* (Impact factor 2.7).

Organizing Computational Mechanics Conferences

Co-organized 30 minisymposia/topics at national and international conferences, including seven invited sessions. Invited to serve on more than ten conference organizing committees.

Peer Review of Manuscripts and Grants

27 manuscripts for journals including *Computational Mechanics*, *Computer Methods in Applied Mechanics and Engineering*, and *International Journal for Numerical Methods in Engineering*. Reviewed grant proposals for the National Science Foundation, and the Research Grants Council of Hong Kong.