Dr. Sathyanarayan Rao

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Research Software Engineer - Digital Twin Developer - Computational Scientist

Professional Summary

Research software engineer with expertise in computational modeling, machine learning, and digital twin development for agricultural and environmental systems. Proven experience in model coupling, full-stack web development, and deploying scientific software solutions. Strong background in Python, C++, FORTRAN, and modern ML frameworks. Experience leading technical projects and developing production-ready software in research environments.

Technical Skills

Programming: Python, C++, FORTRAN, MATLAB, JavaScript (Vue.js), HTML/CSS
ML Frameworks: TensorFlow, PyTorch, Scikit-learn, Keras
Software Engineering: Docker, Git, CI/CD, WebSockets, API Development, Hugo
Computing: MPI, OpenMP, HPC clusters, Linux systems, Parallel computing
Modeling: FEM, PIC simulations, LSTM networks, Digital twins, Model coupling
Data Science: Time series analysis, Random Forest, Cross-correlation, Anomaly detection
Instrumentation: AFM, ERT, Satellite remote sensing, Lock-in amplifiers

Professional Experience

Research Associate, Indian Institute of Science   April 2025 – Present

- Develop interactive dashboards for visualization and analysis of high-resolution hydrological and agricultural datasets

- Apply advanced time series analysis techniques including cross-correlation, LSTM neural networks, seasonal decomposition, and anomaly detection

- Investigate crop-wise variability in Leaf Area Index (LAI) using random forest regression to model satellite backscatter-soil moisture relationships

- Supervise undergraduate student research and design scientific exercises

- Prepare comprehensive dataset paper combining multidisciplinary approaches in hydrology and agriculture

Research Software Engineer, Phenorob Project, Forschungszentrum Jülich   2023 – 2025

- Developed interfaces to enable coupling between C++ crop models and Fortran Functional-Structural Plant Models, implementing loose coupling techniques and addressing time synchronization challenges

- Authored comprehensive review paper on crop model coupling methods for agricultural digital twin applications

- Independently developed project website www.phenorobdaa.de from scratch using Hugo, HTML, and CSS

- Deployed large-scale simulations on high-performance computing clusters using models like TSMP and Terrsys-MP

- Created scientific animations to visualize complex soil-plant interface processes for research communication

- Led monthly project coordination meetings and contributed to book chapters on Large Language Models and UAV drones in agriculture

Research Associate, Indian Institute of Science   2022 – 2023

- Developed machine learning models, particularly LSTM networks, for soil moisture estimation using satellite backscatter data

- Coordinated bi-weekly field campaigns to local watershed sites, synchronizing measurements with satellite overpasses for ground-truth data collection

- Trained research team members in field protocols and instrumentation for data quality and consistency

- Co-presented poster on ML-based soil moisture retrieval at national soil moisture workshop at IIT Bombay

- Developed interactive data visualization dashboards using Vue.js for real-time analysis of field measurements

- Pursued formal certifications in remote sensing, transitioning expertise from electromagnetics to geospatial science

Independent Research & Development Consultant   2020 – 2022

- Transitioned back to India during COVID-19 pandemic while pursuing postdoctoral opportunities and preparing academic grant proposals

- Developed Python-based analytical tools for financial market analysis and algorithmic trading strategies using WebSocket APIs

- Created machine learning pipelines for healthcare datasets and designed user interfaces using frameworks like Gradio

- Applied time-series modeling and signal extraction techniques across diverse domains, expanding expertise in data-driven decision-making

FNRS Research Fellow, eRoot Project, UCLouvain, Belgium   2016 – 2020

- Developed computational models for soil-root electrical interactions with unprecedented anatomical fidelity under FNRS grant T.1088.15

- Generated detailed finite element meshes representing realistic maize root architectures containing up to 500,000 tetrahedral elements

- Extended modeling framework to field-scale scenarios, investigating electrical anisotropy as non-invasive proxy for root phenotyping

- Developed Python-based automation pipelines to process thousands of root system geometries for statistical validation

- Utilized high-performance computing resources at Forschungszentrum Jülich supercomputing facility for large-scale simulations

- Published multiple peer-reviewed journal articles advancing knowledge in root system biophysics and soil geoelectrics

Research Assistant, University of Paderborn, Germany   2015 – 2016

- Developed FORTRAN code to simulate excitonic resonances in two-level systems for optical pulse delay applications
- Implemented Maxwell-Bloch equations using advanced numerical methods including high-order Runge-Kutta schemes and finite difference methods
- Conducted numerical simulations to model photon-matter interactions in engineered two-level systems under DFG funding

Research Assistant, Alabama A&M University, USA   2013 – 2014

- Conducted experimental and theoretical research on photodegradation mechanisms using various dye molecules including Rhodamine 6G
- Performed photo-patterning and photo-deposition of biosensing molecules on polymer thin films using clean room facilities
- Operated and maintained laser systems ($5,000-$100,000) including UV lasers, lock-in amplifiers, and optical test benches
- Characterized biomolecule deposition patterns using Atomic Force Microscopy (AFM) with nanometer-scale precision
- Served as Teaching Assistant for Physics 101, supporting undergraduate laboratory instruction

Research Assistant, University of Alabama in Huntsville, USA   2010 – 2013

- Extended existing 2D electrostatic Particle-in-Cell (PIC) simulation code into 3D electromagnetic framework under NSF grant ATM0647157
- Developed custom modules to simulate magnetic field configurations, implementing Helmholtz coil field generation for plasma thruster digital modeling
- Created high-fidelity digital twin of plasma thruster capturing wave-particle interactions and plasma instabilities
- Implemented parallel computing strategies using MPI and optimized code components with OpenMP for scaling on supercomputing infrastructure
- Contributed to peer-reviewed publications in Physics of Plasmas through code development and high-performance computing implementations

Education

PhD in Engineering Sciences, UCLouvain, Belgium   2016 – 2020
Thesis: Computational Modeling of Electrical Signatures of Plant Roots
Advisor: Prof. Mathieu Javaux

MS in Optical Physics, Alabama A&M University, USA   2013 – 2014
GPA: 4.0/4.0

MS in Electrical Engineering, University of Alabama in Huntsville, USA   2010 – 2012
GPA: 3.9/4.0, Advisor: Prof. Nagendra Singh

B.Eng in Electronics and Communication, VTU, India   2006 – 2010
First Class with Distinction

Key Projects

Agricultural Digital Twin Platform - Developed model coupling interfaces between C++ and Fortran applications for crop simulations, deployed on HPC clusters
Scientific Website Development - Created phenorobdaa.de using Hugo framework with scientific animations and documentation
ML-Based Soil Moisture Prediction - Built LSTM networks for satellite data analysis with ground-truth validation from field campaigns
Real-time Data Processing - Implemented algorithmic trading systems using Python and WebSocket APIs for financial market analysis

Selected Publications

- **Rao, S.**, et al. (2020). Sensing the electrical properties of roots: A review. *Vadose Zone Journal*, 19(1).

- **Rao, S.**, et al. (2020). Imaging plant responses to water deficit using electrical resistivity tomography. *Plant and Soil*.

- **Rao, S.**, et al. (2019). Impact of maize roots on soil-root electrical conductivity: A simulation study. *Vadose Zone Journal*, 18(1).

- **Rao, S.**, Singh, N. (2012). Numerical simulation of current-free double layers created in a helicon plasma device. *Physics of Plasmas*, 19(9).

Fellowships & Achievements

- FNRS Research Fellowship, UCLouvain (2016-2020)

- DFG Research Fellowship, University of Paderborn (2015-2016)

- NSF Fellowship, University of Alabama in Huntsville (2011-2012)

- Published 8 peer-reviewed articles in computational physics and agricultural modeling

- Created scientific content and video documentation for agricultural research community

Professional Development

- Land in Focus - Basics of Remote Sensing, EO College   November 2022
- Advanced HPC training workshops and computational modeling courses