Applied Category Theory 2019 School

Applicant: Santiago Núñez-Corrales, Informatics PhD candidate, University of Illinois at Urbana-Champaign (nunezco2@illinois.edu) - LinkedIn

Advisor: Eric Jakobsson, School of Molecular and Cellular Biology, University of Illinois at Urbana-Champaign (jake@illinois.edu)

1. An explanation of any relevant background you have in category theory or any of the specific projects' areas

- ***Category theory:*** during the last six months, I have learned the basics of category theory using Steve Awodey's textbook (Category Theory 2nd edition, Oxford University Press) as well as several online resources and articles, but I would greatly benefit from attending a school on applications of category theory.
- ***Quantum computing:*** courses at graduate level, ongoing work with advisor towards biomedical applications in the context of personalized medicine, Mayo Clinic
- ***Financial risk:*** no prior background or interest.
- ***Complexity and Computability:*** courses and undergraduate and graduate levels, some experience with statistical physics aspects of computational complexity
- ***Optics and profuctors:*** no prior background or interest.
- ***Distributional semantics:*** no prior background or interest.
- ***Autopoiesis:*** courses at graduate level on systems biology, some experience with self-regulating and self-assembling complex systems, ongoing research on abiotic-to-biotic transitions using stochastic automata.

2. Completion of PhD

- ***Expected:*** May 2020
- ***Summary subject matter:*** construction of a generalized theory of interactions and development of simulation cyberinfrastructure to describe complex multiscale stochastic systems and obtain accurate phenomenological descriptions

3. Order of project preference (from highest to lowest):

- Toward a mathematical foundation for autopoiesis
- Quantum computing
- Simplifying quantum circuits using the ZX-calculus
- Complexity classes, computation, and Turing categories
- Traversal optics and profunctors
- Partial evaluations, the bar construction, and second-order stochastic dominance
- Formal and experimental methods to reason about dialogue and discourse using categorical models of vector spaces

4. To what extent can you commit to coming to Oxford

At present, I can commit to going to Oxford contingent on finding funding at University of Illinois. The travel funding sources at the university are triaged by the Informatics PhD program and has February 15 as its internal deadline, since only two students are selected (contact person for verification: Karen Readel, program manager, kereadel@illinois.edu). Otherwise, if selected, I would commit to finding funding with the local Provost office.

5. Statement of interest

The present stage of my research involves developing a unifying formalism capable of describing complex multiscale stochastic systems (CMSS), a category of systems that include entities composed of multiple scales of action and structure subject to irreducible and non-negligible fluctuations. Our core hypothesis is that such description can be found regardless of particular details if the focus shifts from trajectories or frequencies into interactions as the fundamental construct behind phenomena. The theory should be general enough to capture facts about many physical, biological, social and economic systems, and at the same time remain simple enough to explain concrete instances in statistical terms.

In the course of this project, two mathematical formalisms have acquired increased relevance: discrete external forms as a means to capture systems without relying on continuous mathematics, and category theory, which is needed as a consequence of systematizing interactions as exchanges of degrees of freedom between two systems, both subject to irreversible thermodynamics, for which future uncertainty can be defined. Interactions modulate, fix or constrain other interactions (the INT category), interactions may be mapped to systems of stochastic differential equations if a suitable correspondence is found (the MAP category), and interactions may be similarly mapped to laws whose character is geometrical if suitable statistical limits exist (the LAW category). At present, our preliminary work suggests that categories allow such ambitious theory to remain compact and usable, specially when facing degeneracies. Improving my current knowledge on the subject would greatly help me better understand application aspects in category theory and acquire experience which I lack of at present.

Two recent examples of CMSS have come to attention recently into my work. One of them is the abiotic origin of life, for which I am in the process of building formalisms based on probabilistic automata and stochastic games. This makes autopoiesis a natural project of interest for me. The second example is the use of quantum computing in personalized medicine problems, in particular GWAS, which will require constructing new abstractions capable of simplifying the translation from hard combinatorial searches and multiple hypothesis testing into computational renditions in available quantum hardware. This justifies my interest in the project related to simplification of quantum circuits.

SANTIAGO NÚÑEZ-CORRALES

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SUMMARY. Full-time PhD Candidate (4th year, graduation expected May 2020) at the Informatics Ph.D. program, University of Illinois at Urbana-Champaign (UIUC). Experienced in science, technology and innovation public policy making and foresight exercises. Research and technology consultant in computing and related fields.

CURRENT RESEARCH. Understanding complex multiscale stochastic systems -systems with irreducible noise that can be described at multiple scales and are thermodynamically irreversible- by focusing on interactions as the topmost category of action rather than dynamics or trajectories, through novel mathematical physics and cyberinfrastructure developments embodying principles derived from this view towards tackling grand challenges such as finding new pharmacological targets against pancreatic adenocarcinoma and constructing feasible experimental instruments to test quantum gravity theories. The use of quantum computing is under exploration as new type of hardware accelerator for problems of high combinatorial complexity derived from CMSS instances, such as multiomics inferences.

BROADER INTERESTS AND EXPERIENCE. Theoretical and applied quantum computing, Exascale computing and HPC, stochastic simulation of non-linear systems, self-organized criticality, probability and information theory, category theory, discrete differential geometry, philosophy of science, public policy making, science and technology foresight, redesign of economic systems.

PERSONAL INFORMATION

Citizenship	Costa Rican
Date of birth	April 16th, 1984
Language proficiency	Spanish: native, English: full, French: intermediate

EDUCATION

2016-2020 (expected) — **University of Illinois at Urbana Champaign, Urbana IL – United States**
PhD. Candidate (September 5, 2018) in Informatics, minor in Global Studies. Advisor: Eric Jakobsson, Ph.D. *Dissertation topic: Towards a unified view of complex multiscale stochastic systems: a generalized theory of interactions and related cyberinfrastructure as means for their universal and efficient investigation.*

2002 – 2006 — **Costa Rica Institute of Technology, Cartago – Costa Rica**
Bachelor of Science in Computer Science and Engineering. Professional internship: *Deployment of Beowulf clusters and applications for the first National eScience Grid Infrastructure*. Advisor: José Castro Mora, Ph.D.

PROFESSIONAL EXPERIENCE

- University of Illinois at Urbana-Champaign
  - *(August 2018 – present)* Outreach Coordinator for the Open Storage Network, Midwest Big Data Hub, National Center for Supercomputing Applications
    - *Local project administrative coordination with team members*
    - *Project communication strategies and*
    - *Coordination of use cases and technical teams to gather and devise functional specifications*
  - *(May 2018 – July 2018)* Intern for the Whole Tale Project, School of Information Science
    - *Research on software reproducibility aspects in ecological niche modeling*
    - *Reproduction of the seminal MaxEnt paper in ecological niche modeling*
    - *Design of a Python software library for MaxEnt modeling using introspection*
  - (Jan 2016 – May 2018) Graduate Research Assistant for Social Simulation at Scale, National Center for Supercomputing Applications
    - *Converging research on multi-agent systems, social theory and Exascale computing*
    - *Development of a scalable multi-agent platform for Exascale environments.*
    - *Design of two programming languages for agent-based simulation.*
- Ministry of Science, Technology and Telecommunications, Republic of Costa Rica
  - *(January 2014 – November 2015)* Director General, Directorate of Research and Technology Development
    - *Founding director, technical liaison with the CSTP in the context of accession to the OECD.*
    - *Edition and writing of several plans and foresight exercises at national, regional and international levels.*

        - *Coordination with national and international academic, governmental and industrial organizations across multiple coordinating bodies.*
    - *(August 2011 – December 2013)* Director General, Directorate of Digital Technology
        - *Reactivation and officialization of the governmental Cybersecurity Incident Response Team, coordination of technical missions with South Korea on Cybersecurity, early technical support towards the officialization process of the Budapest Convention on Cybersecurity.*
        - *Coordination of multiple initiatives on digital technologies including improved strategic support to the CECI project, mapping of needs of the national ICT sector and joint governmental representation of Costa Rica on ICANN and the Information Society.*
        - *Strategic IT management advisor for the Central Government and the Ministry.*
- Costa Rica Institute of Technology
    - *(January 2011 – January 2012)* Founding coordinator, e-Science Research Program
        - *Strategic program management and development*
        - *Procurement of funding for the e-Science laboratory*
        - *Coordination with the public university system on advanced research data networks*
    - *(January 2010 – July 2011)* Instructor, School of Computer Engineering
        - *Computer Architecture, Operating Systems*
        - *Principles of Programming Languages*
        - *Computing for Engineers*
- RidgeRun, LLC
    - *(April 2009 – July 2010)* Senior Embedded Systems Engineer
        - *Android application programming*
        - *Implementation of digital video drivers in Texas Instruments*
        - *Systems programming in C and ARM assembly language*
- National Center for Advanced Technology Studies, Costa Rica
    - *(January 2006 – April 2009)* Junior Research Staff
        - *Participated in the deployment of the first national computing grid across the public university system*
        - *Support to research scientists on scientific computing in computational volcanology, computational nanotechnology and remote sensor image processing*
        - *Initiated and supported the process to reconnect the public university system to RedCLARA*

MOST RELEVANT SOFTWARE DEVELOPMENT EXPERIENCE

- University of Illinois at Urbana-Champaign
    - (Ongoing, dissertation related) Development of a generalized stochastic differential equations code.
    - (Ongoing, dissertation related) Development of an agent-based simulation software package.
    - (Ongoing, dissertation related) Development of a spectral organization analysis library.
    - Development of a library to perform spectral analysis of protein structures to screen for lithium sensitivity.
    - Development of a library to perform maximum entropy ecological niche models using introspection.
- Costa Rica Institute of Technology
    - Development of a portal to manage and execute high performance computing tasks in a given cluster.
    - Development of a code to simulate high-intensity electric fields for a Sterallator nuclear fusion device.
- Industry – Embedded systems
    - Development of a device driver for analog-to-digital video converter TVP7002 in the Linux kernel mainline.
- National Center for Advanced Technology Studies, Costa Rica (codes are proprietary)
    - Development of an extension for PNNL's NWChem to support simulation of nanotube growth using voltaic arcs.
    - Development of a code for analysis of combinatorial properties of DNA sequences from the human genome.
    - Development of a code to orthorectify and stitch multispectral and hyperspectral remote sensor data.

HONORS AND AWARDS

2018	**Whole-Tale/RDA - Student and Early Career Fellowship** Recipient - link
2018	**Clinton Foundation – Clinton Global Initiative University** UIUC nominee and participant.
2017	**ACM SIGHPC/Intel Computational and Data Science Fellowship** Recipient - link
2015	**International Symposium on Grids and Clouds 2015, Academia Sinica, Taipei, Taiwan** Keynote speaker: Costa Rica towards 2050: rethinking world development through evidence-based, data driven decision-making
2013, 2015	**Chamber of Information and Telecommunication Technologies, Costa Rica**

Expert Jury for the National Price on Information and Communications Technology

2012-2015 **Ministry of Science, Technology and Telecommunications, Costa Rica**
President of the Expert Jury for the National Prize in Technology Awarding Committee

2013 **PASI 2013: Methods in Computation Based-Discovery, Guatemala City, Guatemala**
Keynote speaker. "Science and Technology, the 21st Century and the Americas: Towards Regional Multidisciplinary Envisioning"

2005 **Global Grid Forum 15 – Boston MA, USA**
Recipient of the GGF Student Scholarship Award

PUBLICATIONS

Book chapter Núñez-Corrales, S. (publication pending) Some considerations towards a predictive theory of life. Book chapter to appear in *Understanding Molecular Biodiversity*, Gustavo Caetano-Anollés (Ed.), expected October 2019.

Conference paper Núñez-Corrales, S., Ludäscher, B. (submitted). Repeatability, Replicability, and Reproducibility: Capturing Scales of Scientific Intentionality within the PRIMAD Model. *ACM/IEEE Joint Conference on Digital Libraries 2019*. Urbana-Champaign, IL. June 02-06, 2019.

Journal article Castillo, G. B., Nuñez-Corrales, S., & Malavassi, E. (2018). Ash fallout hazard from Irazú volcano, Costa Rica. *Revista Geográfica de Chile Terra Australis*, *54*(1), 13-25.

Poster presentation Núñez-Corrales, S., Ludäscher, B. (2018), Franz, N. Reproducibility in Ecological Niche Models: the case of Phillips et al (2006). *Whole Tale Workshop on Tools and Approaches for Publishing Reproducible Research*. Chicago, IL. September 12-14.

Poster presentation Jakobsson, E., Kindratenko, V., Lipka, A., Núñez-Corrales, S. **(**2018**)** Accelerating multiple hypothesis testing through GPU/FPGA hardware accelerators and quantum computing infrastructure: Application to genome-wide association studies. *CCBGM Biannual Meeting*. Mayo Civic Center, Rochester MN.

Journal article Porras-Gómez, M., Vega-Baudrit, J., Núñez-Corrales, S. (2018) Ampicillin-Loaded Chitosan Nanoparticles for In Vitro Antimicrobial Screening on Escherichia coli. In *Chitin-Chitosan-Myriad Functionalities in Science and Technology*. IntechOpen.

Conference paper Núñez-Corrales, S., Gasser, L. (2018) Scalable social simulation: an evaluation of modeling frameworks as cyberinfrastructures and the design-test of a new approach. *SPR-BRiMS 2018*. George Washington University, Washington DC, USA, July.

Book Núñez-Corrales, S. (2018). Oportunidades globales hacia emprendimientos de alto valor en Costa Rica Fronteras, Tecnologías, Referentes y Estrategias. Programa Nacional para la aceleración de Proyectos de Innovación Tecnológica. Editor: Luis Alonso Jiménez-Silva. *Joint oficial publication by Universidad de Costa Rica, Ministerio de Ciencia, Tecnología y Telecomunicaciones and Consejo Nacional de Investigaciones Científicas y Tecnológicas.* February 2018.

Journal Article Katz, D. S., Niemeyer, K. E., Gesing, S., Hwang, L., Bangerth, W., Hettrick, S., Idaszak, R., Salac, J., Hong, N.C., Núñez-Corrales, S., Allen, A. (2018). Fourth Workshop on Sustainable Software for Science: Practice and Experiences (WSSSPE4). *Journal of Open Research Software*, *6*(1).

Journal Article Porras-Gómez, M., Vega-Baudrit, J., García, F., Núñez-Corrales, S., & Madrigal-Carballo, S. (2017). Evaluation of the Synergistic Effect of EDTA-Functionalized Chitosan Nanoparticles on Imipenem Delivery in Pseudomonas aeruginosa Carbapenem-Resistant Strain AG1. *Journal of Biomaterials and Nanobiotechnology*, *9*(01), 64.

Journal Article Jakobsson, E., Argüello-Miranda, O., Chiu, S. W., Fazal, Z., Kruczek, J., Nunez-Corrales, S., Pandit, S. and Pritchet, L. (2017). Towards a Unified Understanding of Lithium Action in Basic Biology and its Significance for Applied Biology. *The Journal of membrane biology*, *250*(6), 587-604.

Oral presentation Núñez-Corrales, S., Jakobsson, E. (2016). Some requirements of formal languages for the scientific description of nature. IV Latin American Congress on Analytic Philosophy. San José, Costa Rica. May 25-27.

Journal article Núñez-Corrales, S. (2016). A preliminary model for the impact of research and development in health care expenditure: the case of Costa Rica. *Revista Hispanoamericana de Ciencias de la Salud*, 2(1), 52-61.

Poster presentation Núñez-Corrales, S., Caesar J., MacCalla T. (2015). ICIMSware 2.0: Community Informatics for Collaborative Competitiveness. Collective Intelligence 2015. Santa Clara CA, USA. May 31-June 2.

Journal article	Castillo, G. B., Nunez-Corrales, S., Mora, J. C., Rojas, E. M., & Montoya, C. S. (2013). Irazu volcano ash fall simulation using a modification of the tephra software. *Geo Uerj*, 5-18.
Journal article	Porras-Gómez, M., Vega-Baudrit, J, Núñez-Corrales, S. (2012). Overview of multidrug-resistant Pseudomonas aeruginosa and novel therapeutic approaches. Journal of Biomaterials and Nanobiotechnology, 3(04), 519.
Journal article	Núñez-Corrales, S. (2013). El Hecho Científico y la Computación: e-Science como agente de transformación en lo científico y lo social. Trama. Revista de Ciencias Sociales y Humanidades, 3(1).
Conference paper	Núnez-Corrales, S., & Jakobsson, E. (2011). Hierarchical Modularity: The Description of Multi-Level Complex Systems as Nested Coupled Fokker-Planck Equations. Unifying Themes in Complex Systems Volume VIII: Proceedings of the Eighth International Conference on Complex Systems. Quincy MA, USA. June 26 – July 2011. Pp. 967-981.
Conference paper	Nunez-Corrales, S., Bethwaite, B., Brenes, J., Barrantes, G., Castro, J., Malavassi, E., & Abramson, D. (2010). Ng-tephra: A massively parallel, nimrod/g-enabled volcanic simulation in the grid and the cloud. In e-Science (e-Science), 2010 IEEE Sixth International Conference on (pp. 129-136). IEEE. December 7-10.
Conference paper	Núnez-Corrales, S., Barrantes, G., Malavassi, E., Brenes, J., & Castro, J. (2010). On the Structure of Parametric Sweeps in Large-Scale, Grid-Enabled Ash Deposition Simulations for the Irazu Volcano in the PRAGMA Grid. In Frontier of Computer Science and Technology (FCST), 2010 Fifth International Conference on (pp. 424-428). IEEE. August 21-25.
Poster presentation	Núñez-Corrales S., Rivera, A. (2010). Simulation of the Synthesis of SWCNTs using Computational Quantum Chemistry XII Latin American Symposium on Polymer Science. San José, Costa Rica. July 13-16.
Oral presentation	Núñez-Corrales S., Barrantes G., Malavassi E., Brenes J. (2010). NG-TEPHRA: Enabling Large-Scale Volcanic Hazard Simulations in the Pragma Grid Environment. PRAGMA Workshop 18. March 3-5.
Poster presentation	Caesar J., MacCalla T., Núñez-Corrales S., Wang S., Castro-Mora J. (2009). i-CIMSware: Community Profiling and Asset Mapping Understanding Regional Development through Algorithms and Computation. TeraGrid 09. Arlington, VA, USA. June 22-25.
Journal article	Vega-Baudrit, J., Sibaja-Ballestero, M., Vázquez, P., Nuñez-Corrales, S., Martín-Martínez, J. M., & Benavides-Rodríguez, L. (2008). Kinetics of isothermal degradation studies in adhesives by thermogravimetric data: effect of hydrophilic nanosilica fillers on the thermal properties of thermoplastic polyurethane-silica nanocomposites. Recent patents on nanotechnology, 2(3), 220-226.
Poster presentation	Araúz, M., Soto, C., Vargas, C., Arias, L., Núñez-Corrales, S. (2008). Forest Coverage and Land Use in San Ramon, Costa Rica: Analysis of Forest Patches. XXI Congress of the International Society for Photogrammetry and Remote Sensing. Beijing, China. July 3-11.
Conference paper	Franklin, K., Núñez-Corrales, S., Castro, J., Bajcsy, P., De la Ossa, A., MacCalla, T., Datta, A. (2008). GridARTCA: A collaborative technology environment utilizing Cyberinfrastructure - A preliminary report. International Computer Science and Technology Conference. San Diego, CA, USA. April 1-3.
Oral presentation	Argüello, O., Villatoro, F., Núñez-Corrales, S. (2008). An epidemiological model of dengue fever including second infection stage in human hosts. XVI International Symposium on Mathematical Methods Applied to the Science. San José, Costa Ric. Feb 19-22.
Position paper	Franklin, K. Burton, O., Appleford, S., Yahja, A., Núñez-Corrales, S. (2008). TeraGrid II: a vision toward the 21st century integrated knowledge infrastructure. The Future of the TeraGrid, Position Papers.
Conference paper	Núñez-Corrales, S., Vega J., De la Ossa, A. (2007). Simulation and Optimization of Carbon Nanotubes Growth Processes. Proceedings of the XXXIII Latin American Conference on Informatics. October 9-12.
Conference paper	Barrantes G., Garita C., Núñez-Corrales S., Castro J. (2007). Application of Geographic Information Systems in the Creation of Risk Scenarios for Tephra Fall. Proceedings of the XXXIII Latin American Conference on Informatics. October 9-12.
Conference paper	Núñez-Corrales, S. (2007). The Costa Rican Software Industry: The Research + Development + Innovation challenge: How is success fostered in innovation initiatives? Proceedings of the XXXIII Latin American Conference on Informatics. October 9-12.

Conference paper	Torres F., Fallas A., Núñez-Corrales S. (2007). Is Action Research the Path to a Solid Research Culture in IS/SE for Costa Rica? Proceedings of the XXXIII Latin American Conference on Informatics. October 9-12.

LEADERSHIP AND SERVICE ACTIVITIES

2017	Selected as national consultant to develop the next-generation high-technology innovation and entrepreneurship fund allocation strategy for Costa Rica. A total of 25 projects were selected with a disbursed investment of $250k. Link.
2013-present	*Ad honorem* board member of the Foundation for Renewable Energy in Costa Rica, an organization against climate change through economic redesign.
2015	Appointed as the principal editor for developing the National Science, Technology and Innovation Plan 2015-2021 for the Republic of Costa Rica. Organized a consultation with 2000+ participants, coordinated 54 expert contributors and established the current nation-wide priorities for research and technology development.
2013-2015	Appointed as the Costa Rican liaison officer to the Committee on Science and Technology Policy of the Organization for Economic Development and Cooperation, Paris (France). Member of the CSTP advisory committee for Inclusive Growth.
2012-2015	Appointed as member of the steering committee of the Advanced Research and Technology Collaborative for the Americas at the Organization of American States, Washington D.C. (USA).
2010-2011	First coordinator of the e-Science Research Program at the Costa Rica Institute of Technology, Cartago (Costa Rica). Secured $800k in initial HPC lab funding.
2008	Local coordinator of the SC08 Education Program Workshop on Nanotechnologies and High Performance Computing in Education and Research. EARTH, Limón, Costa Rica. June 29-July 5. First SC Education Workshop to be executed outside the US.
2007	Recipient of the International Fellows Program at the National Center for Supercomputing Applications, University of Illinois at Urbana Champaign, Urbana IL (USA).
2002-2015	*Ad honorem* music instructor, oboe and baroque recorder performer at the Vásquez de Coronado Music School, San José (Costa Rica).

TECHNOLOGIES (ORDERED BY DEGREE OF PROFICIENCY PER TYPE)

- **Operating systems:** Linux, MacOS, Windows, BSD
- **Scripting languages:** bash, tcl, csh
- **Programming languages:** C, Python, Scala, Scheme, Java, OCaml, Haskell, C++, Prolog, Lisp, FORTRAN
- **Statistical packages:** R; Pandas, NumPy, SciPy
- **Parallel programming:** MPI, OpenMP, Charm++
- **Web development:** Django, Flask, OpenLayers
- **Blockchain:** Ethereum, Holochain
- **Data formats:** HDF4/5, NetCDF
- **Build tools:** make, automake, conda

Gmail

Applied Category Theory <act2019school@gmail.com>

recommendation for Santiago Nunez-Corrales

1 message

Jakobsson, Eric <jake@illinois.edu>
To: "act2019school@gmail.com" <act2019school@gmail.com>

Wed, Jan 30, 2019 at 8:33 AM

January 30, 2019

Eric Jakobsson, Professor Emeritus

University of Illinois at Urbana-Champaign

Email: jake@illinois.edu

Phone: 217-390-7024

Re: Application to Category Theory Course 2019

Santiago Nuñez Corrales is one of the smartest people I have met in the course of my scientific career. Rare in this day of specialization, he is a true polymath. His interests, skills, and understanding, range from deep theory to computational virtuosity to biophysics to public policy. Santiago's resume speaks for itself. I will add to that my knowledge of his current projects, and my observations on interacting with him.

At the theoretical core of Santiago's work is the idea that dynamical interactions between objects are the essential components of model building, as opposed to the properties of the objects themselves. That would seem to be well aligned with the defining concepts of category theory. A second core concept of Santiago's work is that the dynamical interactions are inherently stochastic rather than deterministic, which may not yet be embedded in category theory, but might be an interesting concept t consider within the framework of category theory.

At the core of Santiago's work is developing a general and efficient solver for stochastic differential equations. His fundamental premise is that this can be done efficiently by substituting Lebesgue integration for the traditional Riemann integration that is well suited to solving deterministic differential equations. His desire to do this comes from his judgment that stochastic methods should be more widely applied to the analysis and simulation of dynamical systems than they are, and his determination to make such simulations more efficient and accurate. He has written code embodying this approach, included a method for efficiently dealing with stiff systems, and validated the results against more conventional methods on the well-known Lorenz equations. To my knowledge this is the first specific application of Lebesgue integration for dynamic simulation, so his work is already pioneering. At this writing his benchmarks indicate efficiency comparable to existing methods for stochastic dynamics, but he is a long way from optimizing his approach, so his hypothesis that Lebesgue integration will prove a fundamental advance in stochastic simulations appears likely to be true.

His approach has potential applicability to multiple areas of science, including fluid dynamics, social systems modeling, computational neuroscience, climate and weather modeling, and biomolecular evolution. He has assembled a graduate committee with broad expertise, to inform his thesis work of the multiple application possibilities. He served as an unofficial advisor during last year's Costa Rica presidential campaign in the area of science and technology policy to the ultimate winner and now President, applying his work to economic modeling on the impact of science and technology policy on economic growth. Indeed, it was on a visit to Costa

Rica involving consultation on science policy that I first met Santiago. He spanned policy and science content, moving from one to the other seemingly effortlessly, although in fact he actually works quite hard.

I have seen Santiago interacting with graduate students. The breadth of his knowledge and quickness of his insights make him function like a second mentor more than another student.

In summary– –highest recommendation. Likely to become a star.

Best regards,

Eric Jakobsson,

Professor Emeritus, University of Illinois at Urbana-Champaign